

PREFACE

This NZ Metal Roof and Wall Cladding Code of Practice is published by the NZ Metal Roofing Manufacturers Inc., to provide prescriptive acceptable trade practice for the fixing of metal roof and wall cladding and accessories. In addition it provides prescriptive detailing for designers and sets a benchmark for the standard of detailing and workmanship required over and above that required deemed to comply with the NZBC. This does not pre-empt or preclude the use of alternative methods that would also require specific acceptance by the Building Consent Authorities.

This Industry Code of Practice is published as the current state of the art at publication date, however it is recognised that as building is a dynamic industry the Code is a living document, and that alterations to legislation, standards, improved technology and new materials will require periodic upgrading of this Code of Practice.

Version 2 of the NZMRM Code of Practice as published at April 2008 supersedes the original version published in September 2003.

Version 2 is now available in a CD version only and is protected by copyright. However, unlike version 1 the drawings and text are available to be copied and printed provided a signed license agreement is completed with the NZMRM and acknowledgment is given.

Subsequent updates and amendments will only be available to those who have completed the license agreement which was included with this CD and registered with the NZMRM and in the data base for updates.

References to 'consult or refer to the Manufacturer' or 'in accordance with standard trade practice' have been omitted. This Code of Practice has been prepared after general consensus has been obtained between suppliers, manufacturers, and members of the Roofing Association of New Zealand (RANZ).

The Code is divided into three parts:

1. The performance requirements, and the prescriptive means to comply with this Code of Practice are printed in black bold font and blue shaded. They are to be summarised in Section 17 the Appendix at a later date.

The 'What' and the 'How'.

The first part is normative, i.e. compliance is mandatory to comply with this Code of Practice and the word 'must' is used.


2. The recommended better practice options and the responsibilities of different parties to comply are printed in black - the 'Should know' and 'should do's'.

The second part is not mandatory but describes better options or alternatives. They are described by the words 'should', 'recommend', 'preferred' and 'may'.

3. The reasoning used to formulate the above is printed in blue - the 'Why'.

The third part is informative, i.e. it is for information and reference.

The provision of the third part is intended to provide the education necessary to inform designers, to complement and complete the training required to qualify as a Licenced Building Practitioner or skilled tradesperson and also to be used as a text book in such training. The Code of Practice is intended to be a stand-alone document, however users are urged to read manufacturers literature and other relevant documentation that should be used in conjunction with this Code of Practice. Although it is written in user friendly terminology some words may not be in common usage however definitions and alternative words are found in section 1.3.



Users are urged to read the complete document, as the reasoning and commentary provide a means of compliance with details and situations that may have not been previously encountered. Because metal roof and wall cladding is now regarded as a system and not a product, the interaction with, and the dependence on, other materials requires an understanding of the total Building Envelope. The implications of some subjects, such as condensation and loadings, are not always understood by designers, and therefore the roofing contractor has a responsibility to draw attention to any inadequate or incorrect detailing. No apology is offered for the complexity or any repetition included in this Code of Practice. Cross- referencing has been necessary to avoid duplication, but is available electronically by hyperlink throughout the Code, via the contents, the description, drawing details or 'find' or 'search'.

Specifiers, manufacturers, tradespeople and the public should be aware of the limitations of the material they are using, because without full understanding users can be held liable for lack of 'duty of care'. This document should be regarded as the 'state of the art' at the time of publication, however it is incumbent on all practitioners to ensure that any documentation used is the current version published by the NZMRM Inc.

This Code of Practice has been written to assist in meeting the requirements of the NZBC. partly because of the many conflicting and overlapping Standards used within the Building Industry. A current NZ, joint NZS/AS Standard or a Producer Statement can be cited as a means of specific compliance acceptable to a Building Consent Authority but which does not coincide with this Code of Practice. The information and evidence offered in support of the requirements of this Code has been obtained after wide consultation with associated industry participants resulting in a general consensus, acceptance and approval of those concerned.

The New Zealand Roof and Wall Cladding Code of Practice has been written for New Zealand conditions that recognize it as an unique island 2,000 km away from another major land mass, which is subject to high rainfall, high humidity, extremes of weather and high winds. The contents of this Code of Practice are relevant to other countries, but the information contained in this document should be moderated appropriately in accordance with local conditions. Overseas Standards and Codes of Practice are not always relevant to N.Z. conditions and should not be used in preference to this N.Z. Code of Practice.

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1.1 DISCLAIMER AND COPYRIGHT

Although the information contained in this Code has been obtained from sources believed to be reliable, New Zealand Metal Roofing Manufacturers Inc. makes no warranties or representations of any kind (express or implied) with regard to the accuracy, adequacy, currency or completeness of the information, or that it is suitable for the intended use.

Compliance with this Code does not guarantee immunity from breach of any statutory requirements, the Building Code or relevant Standards. The final responsibility for the correct design and specification rests with the designer and for its satisfactory execution with the contractor.

While most data has been compiled from case histories, trade experience and testing, small changes in environment can produce marked differences in performance. The decision to use a particular material, and in what manner, is made at your own risk. The use of a particular material and method may therefore need to be modified to its intended end use and environment.

New Zealand Metal Roofing Manufacturers Inc., its directors, officers or employees shall not be responsible for any direct, indirect or special loss or damage arising from, or as a consequence of, use of, or reliance upon, any information contained in this Code. New Zealand Metal Roofing Manufacturers Inc. expressly disclaims any liability which is based on, or arises out of, the information or any errors, omissions or misstatements.

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This V2 Code is current as at 1 April 2008. New Zealand Metal Roofing Manufacturers Inc. periodically updates the information contained in this Code. Before using this Code, please refer to the New Zealand Metal Roofing Manufacturers Inc. website (www.metalroofing.org.nz) for the most recent updates on information contained in this Code.

1.2 SCOPE

This Code of Practice provides requirements, information and guidelines, to the Building Consent Authorities, the Building Certifier, Specifier, Designer, Licensed Building Practitioner, Trade Trainee, Installer and the end user on the design, installation, performance, and transportation of all metal roof and wall cladding used in New Zealand.

The calculations and the details contained in this Code of Practice provide a means of complying with the performance provisions of the NZBC and also the requirements of the Health and Safety Act 1992.

The scope of this document includes all buildings covered by NZS 3604 and those designed and built under specific engineering design.

It has been written and compiled from proven performance and cites a standard of acceptable practice agreed between manufacturers and roofing contractors.

It is a major revision of the Profiled Metal Roofing Design and Installation Handbook printed in 1995, and supersedes it.

The drawings and requirements contained in this Code illustrate acceptable trade practice, but recommended or better trade practice is also quoted as being a preferred alternative. Because the environment and wind categories vary throughout New Zealand, acceptable trade practice must be altered accordingly, and in severe environments and high wind design load categories, the requirements of the NZBC will only be met by using specific detailing as described in this Code.

The purpose of this Code of Practice is to present both Acceptable Trade Practice and Recommended Trade Practice, in a user-friendly format in order to ensure that the roof and wall cladding, flashings, drainage accessories and fastenings:

- will comply with the requirements of B1, B2, E1 E2 and E3 of the NZBC;
- will comply with the design loading requirements of AS/NZS 1170 and NZS 3604 and with AS/NZS 1562;
- that the life of the roof sheeting and wall cladding, flashings, drainage accessories, roof lighting, and fastenings will be optimised;
- that the roof and wall cladding will be weathertight.

1.3. DEFINITIONS

Accessories:	Gutters, ridge capping, ventilators, flashings, downpipes, brackets and their fixings.
Absorption:	The ability of a material to accept within its body, quantities of vapour or liquid, such as moisture.
Acceptable solution:	A prescriptive means of compliance with the performance requirements of the NZBC, approved by the Department of Building and Housing.
Acceptable trade practice:	The minimum standard of design and workmanship to comply with the performance requirements of the NZBC.
Action effect:	A force due to a load.
Acute angle:	An angle that is less than 90°
Alloy:	A metallic substance composed of two or more chemical elements, at least one of which is a metal, combined to give enhanced strength, resistance to corrosion or lower the melting point.
Aluminium zinc coating:	A continuously hot-dipped coating used to protect steel against corrosion consisting of 45% zinc and 55% aluminium by mass. Also known as AZ, Zinalume® Galvalume, Aluzinc or Duralume generally conforming to AS/NZS 1397.
Anneal:	To soften a metal by heating, to restore or increase it's ductility.
Annular grooved nail:	A nail having a shank deformed with a series of circular grooves.
Anodic:	When two metals are connected in moist or wet conditions, galvanic corrosion can occur. The anodic metal, being the anode (-), is sacrificed to protect the more noble metal in the galvanic series, cathodic (+).
Applied finish:	A surface finish applied to metal tiles, shakes or accessories subsequent to pressing or forming. Also known as postform painting.
Approved:	Any documentation, solution or method that is accepted by a recognised authority.
Apron:	A near horizontal flashing with a vertical upstand that prevents ingress of or sheds water from a higher wall or roof onto a lower roof.
Astragal:	A metal strap used to fasten downpipes to a wall.
Asymmetrical profile:	A profile that has a different configuration on opposite sides of the horizontal centre axis. The opposite to symmetrical.
Awning:	A roof cantilevered and projecting from a building. Also known as a Canopy.
Baby Iron:	A miniature corrugated profile rolled with 6mm high ribs. Also known as sparrow iron, mini-corrugate, and mini-iron.
Backer coat:	An organic coating on the reverse side of a prepainted strip or coil, not intended for external exposure.
Backout:	The condition when a fastener works loose due to timber shrinkage, thermal movement, vibration or an incorrect thread type.
Barge flashing:	A flashing covering the edge of the roof cladding at the gable end of a roof. Also known as barge roll, cover roll, ridge roll, barge mould and square barge.

Base metal thickness:	(B.M.T.). The thickness of the bare or base metal before any subsequent coating,
Battens:	A narrow timber, steel or polystyrene member attached to a roof or wall structure, used to attach metal cladding, metal tiles, shakes, or shingles to the structure. Also known as counter-batten.
Bay:	A wide pan of fully supported roof cladding laid between standing seams or rolls.
Bead:	(a) A curled stiffening to a metal edge (b) A rounded strip of sealant. (c) A ball shaped piece of solder or brazing rod.
Bend radius:	The formed outside radius on a flashing or sheeting that is acceptable for the design end use.
B.C.A:	A Building Consent Authority which is accredited by the DBH to issue building consents.
Bossing:	The working of a malleable metal into a required shape, by the use of wooden or plastic tools. Also known as Dressing.
Boot flashing:	A proprietary EPDM prefabricated flashing used to weatherproof circular pipes.
Box gutter:	A square or rectangular internal gutter between two roof surfaces or at a parapet wall.
Brazing:	The joining of metals by the high temperature application of an alloy having a lower melting temperature than any of the metals to be joined.
Broken bond:	Tiles laid so that the side laps of any two adjacent rows of tiles down a roof do not line up and are staggered or offset.
Brittle roofing:	Flat, troughed or corrugated plastic or other sheeting, that is or can become brittle.
Buckling:	A loss of the original shape of shaped metal, by compressive bending, bearing or shear loading. Also known as a Kink, Ding, Wrinkle and Bulge.
Bullnose:	A shaped piece of roof cladding, curved near to a quarter circle on its outer end, and used predominately as verandah roof sheeting.
Building Consent Authority:	A territorial Authority or Building Certifier accredited to issue building consents, make inspections and certify Code compliance. Also known as a BCA.
Building paper:	An absorbent permeable membrane made from treated kraft paper placed under roof or wall cladding. Also known as Permeable Underlay.
Butterfly roof:	A structure having two inward sloping roofs, draining to a centre gutter.
Butt strap:	A soaker underflashing used as an expansion joint.
Camber:	(a) The deviation from a straight line of a side edge of metal cladding, flashing or unformed coil. (b) A slight convex curve of a surface, such as in a roof deck.
Canopy:	A cantilevered roof without walls over a doorway. Also known as an Awning.
Canterbury prickle:	A small shaped capping to a roof rib at a change of pitch.
Capillary:	The action that causes movement of moisture by surface tension between two surfaces in close contact. Also known as Capillary action, Capillary attraction and wicking.

Capillary groove:	An indentation formed in the edge of a metal cladding profile or flashing to prevent capillary action. Also known as a Capillary Barrier or an Anti-capillary edge. <i>(see drawing 1.4.3.)</i>
Capping:	The top flashing of a wall, parapet or balustrade. Also known as a Coping.
Catchment:	The roof, or roof and wall area above a gutter, valley or penetration that will collect rainwater.
Cathedral roof:	A roof having a pitch over 45°.
Cathodic protection:	The partial or complete protection of a metal from corrosion by becoming the cathode in a galvanic current. i.e. protection afforded to a more noble or precious metal (+) by one less so (-) (anodic)
Cat ladder:	A ladder fixed vertically to a wall, or used on a steep pitched roof as a temporary means of access.
Cavity construction:	A roof or wall that provides a drained air gap separation from the external cladding.
Chase:	A groove or recess cut into a concrete or block wall to accommodate a flashing.
Chalking:	The result of weathering on an organic paint film the degradation of which produces a chalky surface layer.
Chord:	(a) The horizontal member (bottom chord) or a pitched member (top chord) of a truss. (b) A straight line drawn across a circle with each end touching the circumference.
Cladding:	Roof sheeting fixed to the roof structure, or wall sheeting fixed to walls as the weather-resistant surface of a building.
Cleat:	A continuous concealed clip without external fixings used to fasten roof cladding or flashings.
Clerestory roof:	A roof covering of a high window used for borrowed light or ventilation.
Clip:	A small fixing used to secure roof cladding, flashings or pipes to the structure.
Closure strip:	A metal or plastic flashing, blocking open ribs or pans, to prevent the ingress of water, wind, and vermin. Also known as Bird-proofing, Filler block or Foam Seal.
Code of practice:	Prescriptive quantitative and qualitative criteria by which a product or system can comply with specified performance requirements.
Coating mass:	The weight of the metallic protection given to steel by a zinc or aluminium / zinc coating, usually described in grams per square metre (g/m ²). e.g. Z450, AZ 150. Sheet or coil is measured and described as including <i>both sides</i> . Articles Hot dipped after fabrication are measured and described as including <i>one side only</i> .
Coil- coating:	The continuous application of a metallic or organic coating to a metal coil.
Cold rolled:	A metal thickness reduction manufacturing process, using metal coil at ambient temperature.
Collar:	A round overflashing attached and sealed to a pipe to weatherproof a penetration.
Composite roof:	A factory insulated panel with metal cladding on both sides used to cover a roof or a wall. Also known as Sandwich Panel, Composite Panel, and Panel Roof.
Concealed fastening:	A method of fixing a roof by means of hidden, or secret fixing clips or brackets.

Condensation:	The process by which a vapour such as water vapour changes phase to a liquid. Also known as sweating.
Conduction:	The transmission of heat through a material by contact between the particles of matter.
Contractor:	A person or company who enters a verbal or written agreement with another party, to perform an agreed scope of work. Also called roof fixer.
Convection:	The transport of heat within a gas or a fluid by the relative movement of those parts that differ in density.
Corrosion:	The reaction of a material with its environment or incompatible materials, that causes measurable alteration, which can impair its performance.
Corrugate:	A profiled sheet formed into a series of sinusoidal or circular curves. Also known as corrugated iron.
Counterbatten:	A spacer of timber or steel fixed to a purlin or batten, which provides an air space between the cladding and any insulation or safety mesh.
Cover:	(a) The net width of sheeting less the lap. Also known as Effective Cover. (see drawing 1.4.3.) (b) The net width of a flashing that covers the sheeting.
Creep:	The metal deformation, or a change in shape that increases continuously when under constant load or stress.
Crest:	The top surface of a rib. Also known as a Crown. (see drawing 1.4.3.)
Crevice corrosion:	The rapid pitting corrosion that occurs in crevices, pockets or fissures when a patina or oxide film is prevented from forming or reforming, by the concentration or depletion of dissolved salts or oxygen in stagnant water.
Cricket:	A metal roof flashing designed and constructed to divert water around a penetration and to avoid ponding. Also known as a Raised Curb.
Crimp curving:	A method of forming a curve on profiled sheeting by discrete indentations.
Crown:	The top of a curved roof or rib.
Cupola:	A small roofed structure on a ridge to provide ventilation, or designed for aesthetic purposes.
Curb:	A gutter or apron flashing around a penetration. Also known as a kerb.
Cyclonic winds:	Strong winds rapidly spiralling clockwise into a centre of low pressure in the Southern hemisphere. Also known as a Hurricane or a Typhoon.
DBH:	A government department dealing with all legal matters pertaining to Building and Housing.
Decking:	A predominantly flat profile roof or wall cladding, also referred to as Tray.
Deck:	The substrate of a structure that supports claddings that require to be fully-supported.
Deflection:	The deviation from a straight line induced by a load or action.
Deformed shank nail:	Nails with annular, spiral or otherwise deformed shanks. Also known as Enhanced shank nails.
Depth:	The vertical height of a rib or gutter. (see drawing 1.4.3.)

De-indexing:	The releasing of interlocking profiled sheets.
Design wind load:	The site design wind pressure in kilopascals (<i>kPa</i>) on a specific part of a structure, modified by pressure coefficients.
Design wind pressure <i>p</i>:	The pressure in pascals (<i>Pa</i>) obtained by multiplying the design wind speed (<i>V_{des}</i> in <i>m/s</i>) by the formula: $p = 0.6V_{des}^2 \text{ Pa}$
Design wind speed <i>V_{des}</i>:	The wind region speed in metres per second adjusted for annual probability of exceedance, wind direction, geographic position, surrounding environment and height.
Dew point:	The temperature at which water vapour condenses, which varies with the relative humidity and the pressure.
Ding:	A permanent creasing of a rib or sheet, usually due to damage on a roof, resulting in structural depreciation, and consequent inability to comply with performance requirements.
Diverter:	(a) A penetration flashing design used to prevent the accumulation of dirt and debris, which diverts the water runoff by folding the back curb at an angle to the penetration. (b) An angle fastened to a flashing to channel water away from a penetration, obstruction or a wall.
DoL:	An acronym of the Department of Labour, formerly known as OSH.
Dog ear:	A three dimensional box like internal corner formed in metal without cutting. Also known as Pig's Lug.
Decking:	A predominantly flat profile roof or wall cladding, also referred to as Tray.
Dominant opening:	An opening in the external surface of a closed building which directly influences the internal wind pressure.
Dormer:	A roofed window structure projecting at right angles from a sloping roof surface.
Downturn:	That part of the trough of a sheet turned down into a gutter. Also known as Turndown.
Downpipe:	A pipe used to carry roof water from gutters and roof catchments to drains or storage tanks. Also known as Downspout.
Drape curving:	The use of metal cladding to cover a curved roof, using its own weight and not being pre-curved. Also known as Spring Curving.
Dressing:	The operation of flattening or beating metal into the required shape,
Drip:	(a) An outward projecting edge formed on a metal flashing, to direct water away from the building or to avoid capillary action. Also known as Birds beak, Tip, Kick, or Break. (b) A step or break in a roof or gutter, across the direction of fall.
Dropper:	A spouting or gutter outlet. Also known as a Pop.
Dry film thickness:	The thickness of a cured organic coating applied to a metal substrate.
Ductility:	The ability of metal to withstand distortion without fracture.
Duopitch:	A roof having two differing sloping pitches.

Duplex coating:	A two-coat protection system applied to a metal product whereby a metallic coating is subsequently coated with an organic coating.
Durability:	The ability of a material to withstand the action of the elements and perform the structural and functional requirements of the design performance criteria for a specified time.
Dutch gable:	A type of roof frame that is partially hipped but which terminates as a gable.
Dynamic pressure:	The potential pressure available from the kinetic energy of the effective wind speed.
E2/AS1:	An Acceptable Solution to the NZBC clause E2 External Moisture issued by the DBH.
Eaves:	The protruding edge of a roof slope. When enclosed is known as a soffit.
Eaves gutter:	An external roof gutter attached to a roof overhang or the lower edge of a roof. Also known as Spouting.
Edge protection:	A guardrail or restraint designed to prevent a person reaching over a roof edge or falling from a height.
Elastic limit:	The limit within which, when a material is stressed under load, no noticeable or measurable permanent set or deformation occurs.
Elevation:	The part of a drawing which shows the front, side or end view of the wall or structure, giving details of roof slope and openings.
Electrolysis:	The chemical change or decomposition produced in an electrolyte by an electric current.
Electrolyte:	A solution such as water that contains ions, thereby becoming electrically conductive.
Electrolytic cell:	A cell containing an electrolyte which, when an electric current passes through it, produces an electrochemical reaction.
Electrolytic corrosion:	Galvanic corrosion commonly resulting from the contact of two dissimilar metals when an electrolyte, such as water, is present.
Electrochemical series:	The order in which metals react with one another in an electrolyte, with the electronegative metal corroding in preference to the electropositive metal. Also known as Electromotive or Galvanic Series.
Emittance:	The property of a surface to reradiate infra-red heat. Polished or shiny metal surfaces are poor emitters and dull dark surfaces are good emitters.
EPDM:	A thermosetting synthetic rubber of ethylene, propylene, diene, monomer or terpolymer used as a resilient part of a sealing washer or as a roof membrane.
Erosion:	The attrition of organic or metal coatings by natural weathering.
Escarpment:	A steeply sloping face separating two relatively level plains, where the plains average slope is <5°.
Eutectic point:	The melting point of an alloy that is lower than the melting points of the elements or metals within it.
Expansion joint:	A joint in a long length of roof cladding, gutter, spouting or flashing designed to allow for thermal expansion and contraction.
Eyebrow dormer:	A roofed window structure with a curved roof projecting from a sloping roof surface.

Fall:	The slope of roof or wall cladding or gutter usually expressed in degrees, or as a ratio of vertical height to horizontal distance (e.g. 1 in 20= 3°)
Fanning:	The spreading of roof or wall cladding at the gutter or ridge that results in the sheeting being out of square with the building. Also known as Sawtoothing.
Fascia board:	A vertical board fixed to the bottom of the rafters to carry a spouting or gutter.
Fascia gutter:	(a) A square gutter formed to resemble a fascia. (b) A concealed eaves gutter system that interlocks with a vertical or near vertical metal facing.
Fasteners:	Nails, screws, clips, and bolts, which are used to fix components of a roof assembly together. Also known as Fixings.
Fatigue:	The condition that induces weakness or cracking in a metal component by continued fluctuating stress, resulting in fracture.
Filler blocks:	Shaped closed cell plastic pieces inserted into the rib ends or pans of metal cladding, to prevent the ingress of wind, water and vermin. Also known as foam seal.
Film thickness:	The thickness of a paint or other coating usually expressed in microns.(µm). Wet film thickness is the thickness of a coating as applied. Dry film thickness (DFT) is the thickness after curing.
Fixing:	The method of attachment of cladding to the frame achieved by the use of fasteners.
Flashing :	A metal covering, built in to prevent moisture movement or the ingress of water to the inner parts of a building. A component used to weatherproof, vermin-proof or seal the roof and wall cladding corner, ridge, perimeter, penetration, expansion joint, valley, gutter and other places where the roof covering is interrupted or terminated. Described variously as Apron, Barge, Back, Capping, Corner, Curb, Overcloak, Raking, Ridge, Secret, Sill, Skirt, Soaker, Soft-edge, and Stepped.
Flame retardant:	A material to which a substance has been added to reduce or retard its tendency to burn.
Flat roof:	A roof having a slope between 0° and 5°.
Flux:	A chemical liquid or substance used to clean and remove any oxide or other film from a metal, prior to soft or hard soldering or brazing.
Fillet:	A supporting infill, installed at the point where vertical and horizontal surfaces meet, to support flashings and to avoid the build-up of dirt and debris in a sharp corner.
Folding:	A manufacturing method used to permanently deform metal over a small radius to a desired angle. A similar method is known as Brake Pressing.
Free roof:	A roof without enclosing walls e.g. a carport.
Fretting:	Damage to a metal surface or coating between adjacent surfaces, caused by movement and friction, e.g. during transportation.
Fully supported cladding:	Metal cladding that requires a solid substrate to provide strength for wind or point loads. Also known as tray roofing.
Gable:	The triangular end wall surface of a building above the plate line where the rafters meet the apex at the ridge.

Gable roof:	A ridged roof having two slopes only, with a gable at each end.
Galvanising:	The process by which steel is coated by dipping it into a bath of molten zinc, measured by weight in g/m ² or thickness in microns (µm)
Galvanised steel:	Steel protected against corrosion by a hot-dipped zinc-coating described as Z.
Gambrel:	A roof that has two pitches on each side. Similar to a Mansard roof.
Gauge:	The thickness of metal described in mm or inches, previously known as a gauge non-measured number.
Geothermal hotspot:	A location that exhibits any geothermal activity such as steam, water or fumes emitting from the ground, hot water or mud pool.
Girt:	A structural horizontal wall member in a wall between columns, used to fix or support wall sheeting.
Good trade practice:	Trade habits used by members of an industry, having a history of successful usage and having a higher standard than Acceptable Trade Practice.
Grade:	The mechanical strength of a metal complying with relevant standards.
G.R.P:	Glass fibre reinforced polyester translucent or opaque sheeting, used for roof lighting and manufactured to match profiled sheeting.
Groover:	A hand tool used for seaming sheet metal. Also known as a Seamer.
Gutter:	A channel formed to collect and carry water away from a roof, variously described as internal, external, box, eaves, valley, and secret.
Half-round :	A spouting or eaves gutter having a half circle cross-section.
Head flashing:	A flashing at the top of an opening or penetration.
Hem:	A flat but open metal edge folded 180°. Also called a safety edge.
Hertz:	A metric or SI unit of frequency equal to one cycle per second used when cyclic testing metal roof and wall cladding.
Hex head:	A self-drilling or self-tapping screw with a hexagon (six sided) head.
High strength:	Unannealed metals that have a high yield strength relative to their ultimate strength.
Hip:	The external angle formed on a roof where two inclined faces meet.
Hipped roof:	A roof with a level eave and with its ends inclined as well as its sides.
Holiday:	A small pin hole or area where a liquid applied paint coating or laminate film material is missing.
Hook:	An open hem used on a hidden underflashing, to prevent water ingress.
Humidity:	The amount of water vapour suspended in the air. The state or quality of being damp.
Impermeable:	A barrier preventing the passage of a liquid or vapour. Also known as a Vapour Barrier.
Inert catchment corrosion:	The phenomenon where rainwater or condensation, flowing over inert materials such as glass, plastic, or coated metals, cause accelerated corrosion of downstream galvanised metal.

Interstitial condensation:	Condensation that occurs within an enclosed cavity of a wall or roof.
Jenny:	A hand tool used to turn an edge on a curved flashing.
Joggle:	A double offset fold used to accommodate metal thickness. Also known as a Crank.
Kilonewton (kN):	A metric or SI unit of force, used to measure point or live loads. $1000\text{N} = 1\text{ kN}$
Kilopascal (kPa):	A metric or SI square unit of pressure, used as a measure for wind loads. $1\text{ kPa} = 1\text{ kN/m}^2$
Lap:	(a) That part of a flashing or sheet that overlaps or covers any portion of the same shaped component, and variously described as overlap and underlap. (b) The total part of a flashing that laps another dissimilar component including the cover. (see drawing 1.4.3.)
Lap tape:	An adhesive strip made from UV resistant materials used as a joint sealant or part of a roof system.
Lean-to:	A monopitch or single slope roof attached to another structure but at a lesser pitch. Also known as a Shed Roof.
Leeward:	The opposite direction to that from which the wind is blowing (windward). The side sheltered from the wind.
Licensed Building Practitioner:	A person issued with a renewable licence having satisfied the Building Practitioners Board that he or she meets the minimum standard of competence for each class of licence. Also known as a LBP.
Lightweight roof:	A roof cladding which has a mass not exceeding 20kg per square metre.
Limit state:	A design method having two parts: (a) <i>Serviceability Limit State</i> - The state when a building, or any part of it, becomes unfit for its intended use due to deformation or deflection. (b) <i>Ultimate Limit State</i> - The state associated with collapse or failure or when a building, or any part of it becomes unstable or unsafe.
Load:	The value of a force resulting from an action.
Loads:	Loads or actions that the structure or roof or wall cladding must be designed to support, as required by building standards or codes. (a) <i>A dead load</i> is the weight of the permanent structure including the roof. (b) <i>A live load</i> is a superimposed load such as foot traffic on the roof. (c) <i>A wind load</i> is that load imposed on the structure by the action of the wind.
Load spreading washer:	A metal washer formed to match the ribs of profiled sheeting to provide support to the sheeting at the fastening under high wind loads. Also known as a Profiled Washer, Cyclone Washer or a Top Washer.
Local pressure coefficient:	A factor applied to the design wind load due to the dynamic increase of the wind around the periphery of walls or roofs. Also known as k_f and Local pressure factor.
Long-run:	Long length roll-formed roof and wall cladding fixed in one length without transverse laps.
Low pitched roof:	A roof having a slope between 5° and 15° .
Macro-climate:	The climate of a large geographical area.

Maintenance:	A planned set of activities regularly performed during the design working life of a structure, to enable it to fulfil durability and functional requirements. Maintenance can be divided into two types: (a) <i>Normal</i> : That which can be undertaken without special equipment e.g.washing. (b) <i>Special</i> : That which requires specialised skills or equipment
Mansard:	A roof with two pitches, having a break in the slope, the lower part being steeper than the upper.
Membrane:	A non metallic material used in conjunction with metal roof and wall cladding as gutters and penetrations, or as a fully supported roof cladding.
Metal cladding:	Formed metal commonly used in the Roofing Industry in New Zealand including, metallic coated steels, aluminium, stainless steel, copper and zinc.
Micro-climate:	The climate of a small specified area, e.g. under eaves, near the sea shore or in an enclosed cavity.
Micro-cracking:	The small cracking that occurs on external or tension bends of galvanised and aluminium/zinc coating on steel during forming, the extent of which is interdependent on coating thickness and bend radius.
Micrometre:	A millionth of a metre, used as a measure of the thickness of metallic and organic films. Also known as a Micron μm .
Monel:	An alloy of 55% copper and 45% nickel used as rivets, fasteners or clips.
Monopitch:	A roof having one constant slope with no ridge, also known as mono-slope or lean-to.
Nesting profiles:	Cladding profiles that closely stack together.
NZBC:	The New Zealand Building Code. The legal performance requirements as prescribed in the Building Act for building controls within N.Z.
Netting:	An open weave lightweight material used under roof cladding as a support for underlay
Neutral-cure silicone:	A sealant used to join metal that has a neutral pH and does not corrode metal.
Night sky radiation:	A phenomenon where a roof by radiating heat to a clear night sky, can become up to 5°C colder than the ambient temperature.
Noble metal:	A metal that is less active or likely to corrode when in contact with others.
Non-ferrous:	Metals made from elements other than iron.
Notching tool:	A hand tool used to remove a section of flashing that fits over a rib.
Obtuse angle:	An angle between 90° and 180°.
O.G. (OGee):	'Old Grecian'. A shape of convex and concave curves used in spouting. Also known as Old Gothic.
Oil canning:	Distortion in the form of waviness or centre fullness in a profiled sheet. Also known as 'Canning' or 'Panning'.
Organic coating:	The paint film of a pre-painted metal product or a laminate film of a laminated metal product.

Overflow:	An additional or alternative outlet for a gutter, spouting, rain water head or sump to harmlessly dispose of abnormal rainwater runoff, or caused by blockages of the primary outlet.
Oxide:	A chemical compound of oxygen and metal that will form as a film on the surface of metals on exposure to the atmosphere.
pH:	A unit-less logarithmic measure of acidity or alkalinity graduated from 0-14 . pH 7 is neutral, below which is more acidic, above which is more alkaline.
Patina:	A thin stable film of oxide, carbonate or other chemical reaction coating, which forms on the surface of metal on exposure to the atmosphere.
Parapet:	The part of a perimeter wall immediately adjacent to the roof, and which extends above it. A parapet higher than one metre is termed a parapet wall.
Pan:	The flat portion between the ribs of a profiled metal sheet. <i>(see drawing 1.4.3.)</i>
Pan fixing:	The fixing of cladding through the flat pan, used when fastening wall cladding, stressed skin, and composite roof cladding.
Peening:	The permanent deformation or working of metals by the use of a ball peen hammer.
Penetration:	A projection through a roof or wall e.g. vent pipe, air-conditioning unit window or doorway. Also known as a Protrusion.
Penultimate:	The next to last or the one before the last one.
Performance:	Quantitative and qualitative criteria which a product or system has to achieve, to comply with the NZBC or other relevant Standards.
Perforation:	Deterioration of metal due to corrosion or erosion that results in a hole.
Permanent ponding:	When free water is evident for more than three days in spouting, gutters or on roof or wall cladding.
Permeable membrane:	An underlay or other sheet material that permits the passage of water vapour. Also known as Breather type or Permeable Underlay.
Permeability:	The measure of the rate of a porous material to permit a gas or liquid to move through it in a unit time, area, and pressure. It is dependent on the density of both materials and the temperature.
Personal protective equipment:	(P.P.E.) Safety equipment that is personal to the employee or the person to whom it is issued. e.g. safety boots, gloves, ear plugs etc.
Pitch:	<p>The slope or rake of a roof expressed in degrees from the horizontal or as a ratio of vertical height to horizontal distance. e.g. 1 in 20 = 3° Also known as fall, and the tangent of the pitch angle. <i>(see section 15.2)</i></p> <p>A roof is described by its pitch:</p> <ul style="list-style-type: none"> (a) Less than 5° is Flat, (b) 5° to 15° is Low-pitched, (c) 15° to 30° is Pitched, (d) 30° to 60° is Steep-pitched, (e) Over 45° is known as Cathedral (f) Over 60° is defined as a Wall. <p>The distance between the centres of two ribs. <i>(see drawing 1.4.3.)</i></p>

Pitched roof:	A roof with a slope between 15° and 30° with a ridge at the highest point.
Pittsburgh lock:	A type of seam used to interlock two pieces of metal together. Also known as a Lock-Formed seam.
Plans and Specifications:	Drawings, written requirements and other related documents according to which a building is to be constructed or altered.
Point load:	A load used in a testing regime as a measure of the ability of roof or wall cladding to support a person with a bag of tools, at mid span. (1.1kN)
Polycarbonate:	A clear thermoplastic polymeric resin, formed into matching roof and wall cladding profiles or curved flat sheeting used to provide natural roof lighting.
Ponding:	Any free undrained water retained for more than three days after cessation of flow on roof cladding, flashings or a gutter due to insufficient fall, or to permanent deflection or deformation of a roof.
Pre-painted:	Base metal strip or sheet, in line painted to give protection or aesthetic appeal prior to subsequent forming, shaping or fabrication. Also known as Prefinished or pre-coated.
Pre-curved:	A metal cladding profile that is curved off-site, by progressive forming through a pyramid roll or crimp-curve machine.
Pressure coefficient:	A ratio of the pressure on the surface area of a structure to the free dynamic pressure of the wind. It is dependent on the size, shape, height and the location of the building and the number and position of its openings. Also known as Pressure Factor, and variously described as internal, external, local, positive and or negative.
Pressure equalisation:	A design of penetration flashing that relies on the complete inner seal of the penetration between it and the frame. A partial pressure equalisation design is termed pressure moderated.
Producer statement:	A detailed statement made by a manufacturer, designer or installer, about the durability, installation and performance of a product or building system, and which claims any work will be, or has been carried out in accordance with specific requirements.
Product Certificate:	A renewable certificate issued by an accredited certifier for a period of three years certifying the product when used within its scope of use and installed under specified conditions, complies with Building Code requirements.
Profile:	The cross-section of metal cladding, generically known as corrugated (sinusoidal), ribbed (trapezoidal), troughed, boxed or tray.
Profiled sheeting:	Metal sheeting produced with corrugations or ribs to increase its strength.
Pucker:	The unacceptable distortion of metal flashings due to an incorrect fit.
Pullout:	The failure of a fastener when it is pulled out of the structure. e.g. by the uplift force of the wind.
Pullover:	The failure of the sheeting when it pulls over the head of the fastener or washer. e.g. by the uplift force of the wind.
Pull-up stopend:	An end closure of the pan of profiled cladding, formed without cutting the ribs.

Purlin:	A horizontal secondary structural member supporting roof cladding.
P.V.C.:	A clear or opaque polyvinyl chloride thermoplastic resin, formed into matching cladding profiles to provide natural roof and wall lighting.
Quarter-round:	A spouting or eaves gutter with a straight back, and a cross-section of a quarter segment of a circle. Also known as Quad or 'D'.
Radiation:	The transmission and emission of infra-red energy in the form of electro-magnetic waves.
Rafter:	A sloped structural member that extends from the ridge to eave designed to support secondary members and the roof cladding.
Rain collar:	A conical flashing fitted over a pipe to weather the penetration. Also known as a Rain hat or Chinese hat.
Rainwater goods:	Any building product used for rain water disposal including downpipes, rain water heads, sumps, spreaders, eaves gutters, spouting and valleys.
Rainwater head:	An external box designed to collect rainwater from a gutter. Also known as a Rainhead
Red rust:	The formation of a reddish-brown oxide on the surface of steel or iron.
Relative humidity:	The ratio of the mass of water vapour in a volume of air, compared to the value that saturated air could contain at the same temperature and pressure.
Return period:	The average number of years within which a given wind gust or rainfall is expected to be equalled or exceeded.
Return stopend:	The end of a spouting or gutter that has the profile carried around the stopped end.
Rib:	A longitudinal up-stand produced by roll-forming, folding or crimping to strengthen or stiffen metal cladding. (<i>see drawing 1.4.3.</i>)
Ribcap:	A small metal flashing to weather a rib at a change of pitch. Also known as Prickles, Sharks Teeth, End Cap or Profile End.
Ridge:	(a) A long crest or chain of hills with sloping faces on either side. (b) The top of a ridging or profile. Also known as crest.
Ridging:	A metal flashing, roll topped, square or otherwise strengthened, which can be plain or soft-edged, used to cover the joint of the roof cladding at the ridge, apex, or hip-end.
Ridge cap:	(a) A small capping to weather the join in the ridging used at a change of pitch or direction on metal cladding. Also known as Hip-cap. (b) A formed metal tile used at a ridge.
Ridge vent:	A prefabricated ventilator used in lieu of ridging that allows the escape of warm or moist air from a building. Also known as Vent-ridge.
Rivet:	(a) A small headed hollow tubular fastener with an expandable body for joining sheet metal capable of being fastened from one side. Also known as a Blind or Pop Rivet. (b) A small headed solid fastener suitable for peening requiring access to both sides. Also known as a Timmans rivet.
Roll:	A piece of shaped timber used in fixing fully supported roof or wall cladding.

Roll curved:	A symmetrical cladding profile that is curved off-site, by progressive forming through a pyramid roll machine.
Roll formed:	A manufacturing process by which metal is progressively formed from flat sheet or coil into a profiled sheet by a series of shaped rolls.
Roof:	The surface of a structure or building designed to shelter the space below it against the elements, and to discharge rainwater outside the building.
Rofer:	A person who covers a roof.
Roofing:	The act of constructing or covering a roof.
Roof light:	Translucent profiled G.R.P., Polycarbonate or P.V.C. cladding, used in conjunction with metal roof cladding to provide natural lighting.
Saddle:	(a) A small metal support used to reinforce a damaged rib on the rib of roof or wall cladding. (b) A shaped piece of metal used to weather the junction between a horizontal and vertical surface.
Safety edge:	A small edge turned at 180° on the cut edge of a metal component in order to avoid personal or property damage. Also known as a hem.
Safety harness:	An assembly of interconnected shoulder and leg straps, used where a person could fall from a height. Also known as fall arrest harness.
Safety mesh:	A safety wire netting used to prevent workers falling through a roof. It can also function as an underlay support
Sarking:	Timber boards or plywood fastened to rafters, trusses or purlins as a roof support for metal cladding that is not itself designed to be self-supporting.
Saw tooth roof:	A trussed roof construction that is in the shape of the teeth of a saw, requiring gutters at the bottom of the near vertical face.
Screw gun:	An electric or battery driven drill, with a torque limiting or depth limiting device, used for driving self drilling, self tapping screws or other types of screw.
Scupper:	A horizontal outlet in the side-wall of a gutter or spouting to allow drainage.
Sealant:	A single- or multi-component polymeric material used to waterproof metal joints, in conjunction with mechanical fasteners.
Sealing washer:	A rubber E.P.D.M or neoprene washer, sometimes metal-backed, assembled on a fastener and which when compressed is used to prevent water from entering through a fastener hole.
Seaming:	A method of joining two separate sections of metal by mating their two interlocking parallel edges, variously described as lock-formed, grooved, lock-seam, Pittsburgh lock, single and double welt, snap-lock, or knocked-up.
Secret-fix:	A roof or wall cladding system that has no visible or exposed fixings.
Secret flashing:	A flashing hidden from view or imbedded within a wall or wall cavity.
Secret gutter:	A gutter partially or completely hidden from view, used when roof cladding is cut on a diminishing angle. At roof pitches over 12° it is termed a secret valley gutter.

Section properties:	Values assigned to specific profiles determined by their geometrical shape.
Secure footing:	The ability of a person to walk safely on a roof surface without assistance, below a 35° pitch, being dependent on the type of shoes worn and the type of surface.
Self-drilling screw:	A fastener that drills and taps its own hole.
Self-tapping screw:	A fastener that self-threads when turned into a previously drilled hole.
Shake:	An interlocking coated metal tile, impressed to resemble timber shakes.
Shank:	The original diameter of a nail, screw or bolt before heading, threading, or deformation.
Shear:	The scissor action of any tool used to cut metal.
Shear force:	A force that causes deformation by producing an opposite but parallel sliding motion.
Shed roof:	A lean-to roof having no hips or valleys and containing only one sloping plane.
Sheet:	Flat metal over .15mm and under 3mm in thickness, of exact length and over 450mm in width.
Sheeting:	Any metal, G.R.P., or plastic roof or wall cladding.
Shoe:	A downpipe angle at the discharge point. Also known as an Elbow.
Shingle:	An interlocking coated metal tile, impressed to resemble timber, composition or modified bitumen shingles.
Sidelap fixing:	The system by which one sheet is fixed to an adjacent sheet through the side of their lapping ribs, usually required at mid span for cladding with large purlin spacings.
Sill flashing:	A flashing at the bottom of a window or door opening or penetration. Also known as a Tray Flashing.
Sinusoidal:	A profile shaped with a series of arcs of a circle resembling part of a sine curve. When these are symmetrical about a centre line they are known as corrugated.
Skew:	A roof at an angle or out of square.
Skew nailing:	A method of driving nails in at an angle to the surfaces being nailed.
Skillion roof:	A pitched roof with the ceiling fastened to the rafters at the roof angle.
Skirt:	A separate overflashing used to weather penetration curb flashings.
Skylight:	A unit of plastic sheet, glass or an Acrylic dome providing natural light through a roof.
Slip joint:	An overflashing fixed to one side only, to allow for expansion.
Soaker:	An under flashing, partially hidden, that prevents water ingress by means of hooked edges.
Soffit:	The enclosed underside of any exterior eave overhang. Also known as an Eave.
Soft-edge:	A compatible soft metal edging usually lead, aluminium or composite material, seamed onto flashings to provide a closure to profiled cladding and to exclude the weather and vermin.
Sole:	The bottom surface of a gutter.

Soldering:	A method of joining of metals together by either: (a) soft soldering: using a lead/tin alloy that is melted to bond two pieces of compatible metals together at approximately 200°C (b) hard soldering: using an alloy of silver and copper to bond two pieces of compatible metals together at approximately 735°, also known as silver soldering or brazing. (c) cold soldering: using a sealant or adhesive to bond two pieces of metal together.
Snips:	A metal tool used to cut metal, having variously shaped cutting blades, variously described as straight, curved, gibbous, circular, aviation, left-hand, right-hand, or tinmans.
Snow-boards:	A timber or metal platform built over a gutter to prevent blockage by snow or hail. Also known as Hail-boards and Gutter-boards.
Span:	The centre distance between two fixing points. The clear distance between two supports is known as the clear span.
Spanbreaker:	An intermediate supporting member placed under or over roof cladding at a rooflight or a penetration to minimise deflection or traffic damage on large spans. Also known as mid-span support.
Specular gloss:	The measure of the reflective surface of an organic film at a defined angle.
Spiral shank nail:	A nail having its shank formed with helical grooves, so that it rotates when driven. Also known as twisted shank.
Spouting:	An external gutter variously known as 1/4 round, quad, D, 1/2 round, O.G., or square.
Spreader:	A downpipe tee or elbow fixed at 90° to the roof slope and used to spread the discharge of stormwater over a greater area of the roof.
Springback:	The elastic recovery of metal after deformation, which is more pronounced when forming high-strength metals.
Spring curving:	An on-site method of installing straight lengths of profiled cladding to a convex or concave substrate. Also known as Drape Curving.
Stainless steel:	A steel alloy containing a minimum of 11% chromium and up to 30% nickel, used in roof and wall cladding, accessories and fasteners.
Standing seam:	A fully supported metal roofing system that consists of an overlapping or interlocking seam that occurs at an upturned rib and is made by turning up the edges of two adjacent metal panels, then folding and interlocking them, once for a single seam and twice for a double seam.
Static line:	A rope, wire or rail secured between two points, to support any fall protection device.
Steep pitch:	A roof having a pitch between 30° and 60°.
Step flashing:	A flashing that weathers a step in the roof when the rafter length is greater than the length of sheeting that is available or advisable. Also known as a Waterfall joint.
Stepped flashing:	A short apron overflashing set into a wall chase in brick or block construction.
Stressed skin:	A term applied to roof or wall cladding that serves as a structural bracing diaphragm for a building.

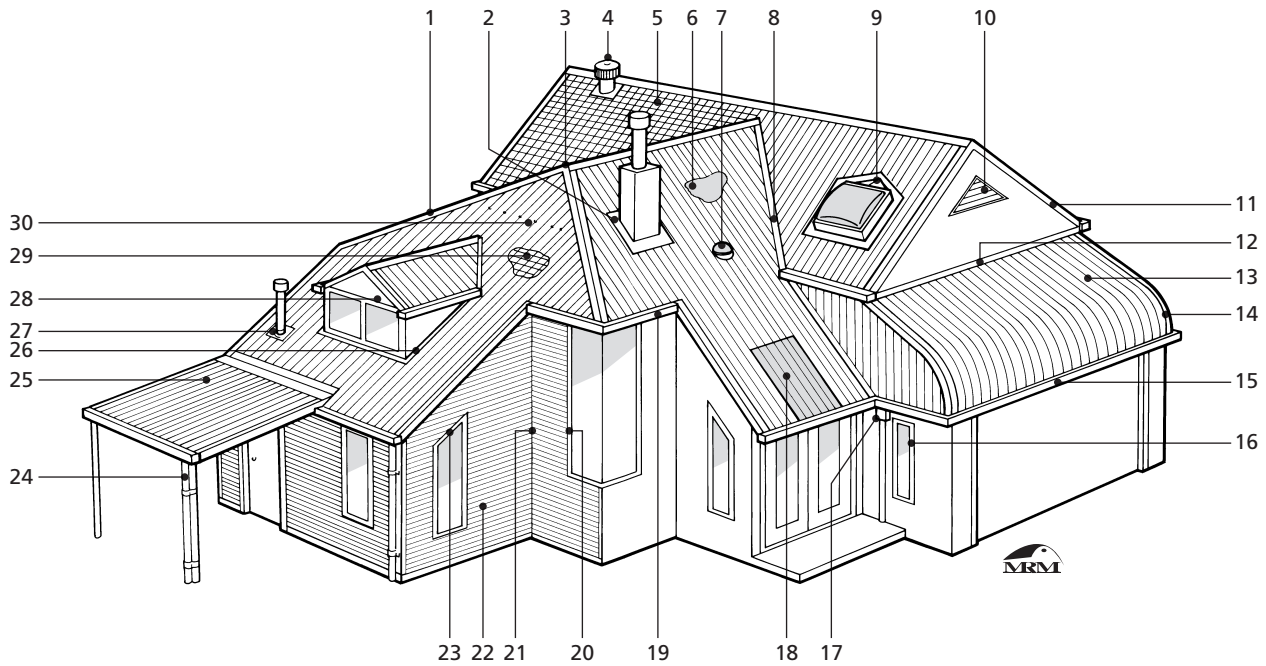
Stop end:	(a) That part of a trough of a sheet turned up at the high end of a roof or wall or the lower end of a penetration. Can be "pulled up" or "dog-eared". (b) An end closure for a gutter, spouting or flashing.
Strip:	Flat metal over 0.15mm and under 3mm, of any length and width, usually supplied in coil.
Strippable film:	A plastic film applied to surface of metal sheet or strip to give temporary protection to the finish.
Subcontractor:	A person or company who enters into a verbal or written agreement to perform specified work with the main or another contractor.
Substrate:	(a) The metallic surface to which a metal, organic or laminated film finish is applied. (b) The surface upon which the roof cladding is applied or fixed.
Sump:	An internal rain water head used to connect a gutter to downpipes.
Swage:	A small raised flat rib in a sheeting profile, used to minimise distortion, caused by centre fullness, or residual or other stress in the sheeting. Also known as a stiffener. (see drawing 1.4.3.)
Swarf:	Fine metallic filings or chips produced as debris from drilling, cutting, or grinding metal on a roof.
Sweat:	(a) Visible water droplets as condensation on a smooth surface such as metal sheeting. (b) A technique of soldering or brazing by the application of sufficient heat to fill the lap gap by capillary action with soft or hard solder.
Symmetrical profile:	A profile that has the same configuration on opposite sides of a horizontal centre axis line.
Synthetic wrap:	A polymeric building film.
Tab:	A small folded angle or projecting flap formed on a flashing to provide fixing.
Tag-line:	A rope that is used to guide a free swinging load from a crane.
T-bend:	The internal bend diameter expressed in terms of thickness used to define the external radius. i.e. $6 T \text{ bend} = 4 T \text{ radius}$.
Terrain:	The surface roughness of the ground described by its openness or by obstructions such as trees and buildings that influence wind speed.
Temper:	A hardness condition of metals, determined by a manufacturing process or subsequent annealing and described as soft, 1/4 hard, 1/2 hard, or full hard.
Tensile strength:	The tensile limit when metal breaks under load, measured by the load divided by the original cross section and expressed in MPa. (megapascals). Also known as Ultimate tensile strength. (U.T.S.)
Thermal conductivity:	(k) The rate at which heat passes through a material expressed as the amount of heat that flows per unit time, area and distance.
Tile:	An interlocking metal pressing, shaped to resemble a clay tile.
Topography:	The hills, valleys and plains that strongly influence and accelerate wind flow patterns, which alter the wind design load on a structure.

Tornado:	A violent rotating column of air attached to the base of a convective cloud, descending to the ground and often observed as a funnel.
Total coated thickness, T.C.T:	The measure of the total of the base metal thickness, plus any additional metal or organic coating.
Tradesman:	A workman or woman, having spent a prescribed period of time working at a trade, who has been qualified by the successful completion of written and practical trade examinations.
Trade practice:	Trade habits used by members of an industry, known variously as acceptable, good and bad.
Trade training:	Tuition given to a trainee or workman by a qualified tradesman.
Transverse:	A flashing or fastenings running horizontally across the sheeting.
Trapezoidal:	Profiled roof or wall cladding with longitudinal ribs angled similarly to a trapezoid.
Tray:	The pan, trough or flat draining area of a deck-type of roof .
Tray roof cladding:	A profile having a large flat area compared with the rib or seam. Also known as Deck Roofing, Trough Roofing and Fully supported roofing .
Turn-up tool:	A hand tool used to form stopends or to turn down the ends of metal cladding.
U.D.L:	A uniformly distributed load used as a measure of the wind load on metal cladding, usually expressed in kPa. (kilopascals)
Undercutting:	The corrosion of a metal substrate under a paint film, caused by a score mark, edge or hole. Also known as Edge Creep.
Underlay:	An absorbent permeable membrane that absorbs or collects condensation, or water that may penetrate the roof or wall cladding. Also known as Building Paper.
Unwashed:	Areas of roof or wall cladding protected from washing by natural rainfall at an angle of 45° by a projecting roof or overhang.
Upstand:	The vertical face of a flashing or stopend.
Valley:	A gutter at the internal intersection of two sloping planes of roof cladding where the roof pitch is 12° or greater.
Vapour barrier:	A sealed impermeable membrane designed to eliminate the passage of water or water vapour.
Vapour control layer. (V.C.L):	An impermeable membrane designed to minimise the passage of water or water vapour. Also known as a vapour check or vapour retarder.
Vented:	A cavity that provides some degree of water vapour diffusion and air movement.
Ventilated:	A cavity that has been designed to provide a significant flow of air or water vapour to the outside air, such as a ventilated ridge.
WANZ-WIS:	The Window Association of New Zealand's Window Installation System.
Walkway:	A permanent or temporary structure placed over metal roof cladding to enable access without causing damage or imposing a point load on the cladding. Also known as a cat-walk.
Watershed:	A penetration overflashing type that extends to the ridge. Also known as Back Flashing.

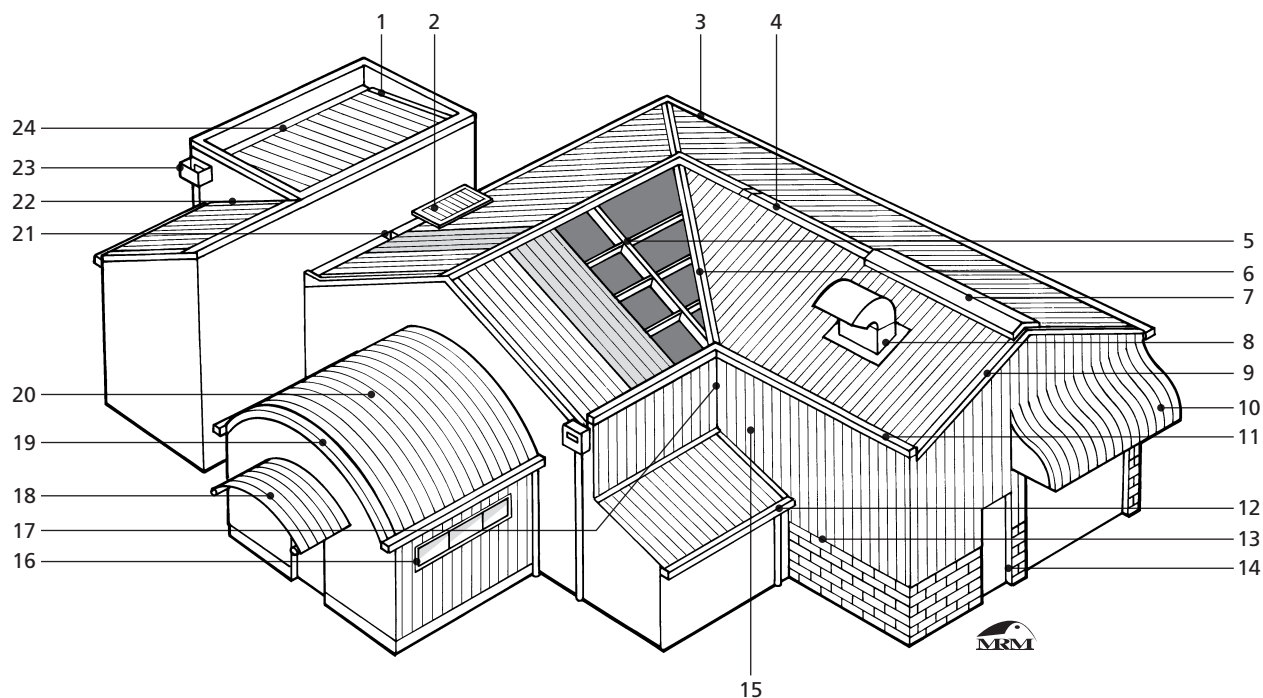
Weather:	<ol style="list-style-type: none"> 1. (noun) The state of the atmosphere at a given time and place, specified by variables including, wind velocity, humidity, temperature and pressure. 2. (verb) To cause a roof or flashing to shed water
Weathering:	(verb) To prevent deterioration, such as the oxidation of metals, or chalking of pre-coated materials due to atmospheric exposure. Also known as the intransitive verb Weathered.
Weatherproof:	<ol style="list-style-type: none"> 1. (adj) The ability to withstand exposure to weather without damage. Also known as weathertight. 2. (transitive verb) To protect a building from the elements.
Weathertightness:	The degree of protection offered from the elements.
Web:	The vertical or near vertical part of a rib.
Welt:	An interlocking metal seam used when site fabricating roof sheeting. Folds on flashings or roof cladding joining two adjacent metal sheets together at their edges without fasteners, variously described as single, double, and cross welt.
Wet storage stain:	Corrosion effects due to condensation or rain penetration of nesting profiles. Also known as White Rust for galvanised, Black Rust for Aluminium Zinc coating, and Black Stain for Aluminium.
White rust:	The visible white corrosion product found on galvanised coatings in protected, unwashed, cut edges or micro-cracked areas. Also known as bloom.
Wicking:	The movement of water through a porous material by capillary action.
Work hardening:	The reduction of metal ductility caused by cold working or movement in service.
Workman:	A man or woman employed in a trade, who is or has learned trade skills from their employer, supervisor or Technical Institute.
Wrap:	A synthetic film used as a building membrane and capable of completely enclosing walls. Also known as Synthetic or Polymeric Wrap.
Yield point:	The first stress point at which some metals will plastically and permanently deform.
Yield stress:	The recorded stress at the point of yielding.
Zinc aluminium coating:	Steel protected against corrosion by a continuously hot-dipped coating of 95% zinc and 5% aluminium by mass with the addition of Lanthanides. Known as ZA, Galfan or Galvalloy and generally conforming to EN 10214.

1.4 DESCRIPTIONS

1.4.1 DOMESTIC DRAWING DETAILS

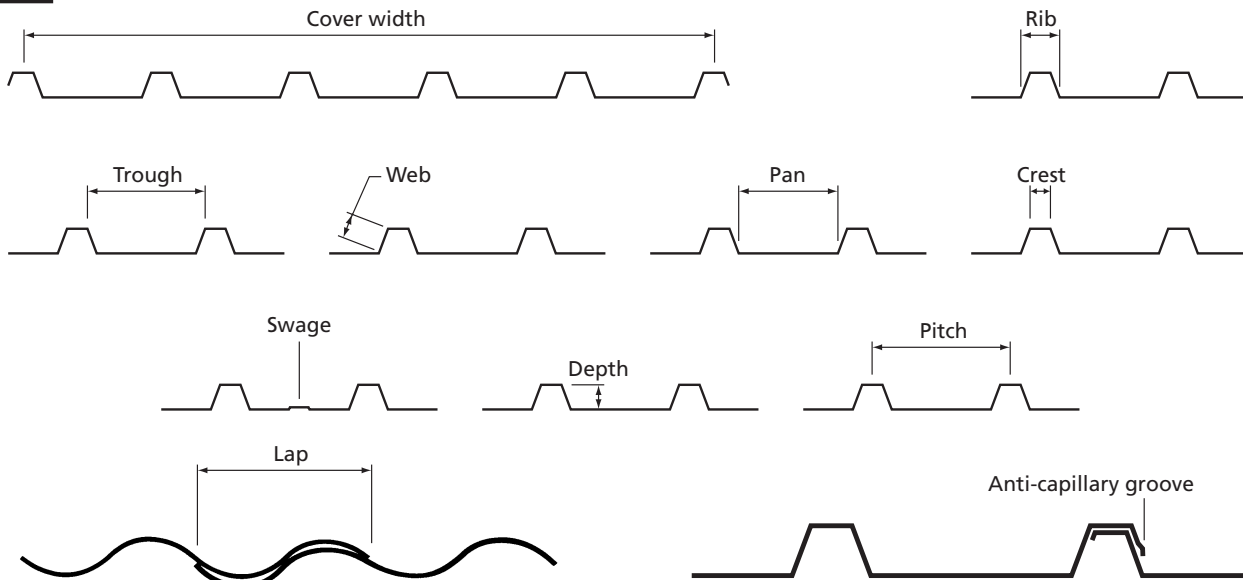


- | | | | |
|----|--------------------|----|--------------------------|
| 1 | Ridging | 16 | Recessed window |
| 2 | Penetration | 17 | Rain-water head |
| 3 | Ridge cap | 18 | Roof light |
| 4 | Ventilator | 19 | Concealed gutter |
| 5 | Pressed tiles | 20 | Butt window flashing |
| 6 | Underlay | 21 | Internal corner |
| 7 | Tubular roof light | 22 | Horizontal cladding |
| 8 | Valley | 23 | Flush window head |
| 9 | Cricket | 24 | Downpipe |
| 10 | Apex ventilation | 25 | Secret-fix roof cladding |
| 11 | Barge | 26 | Apron |
| 12 | Apron | 27 | Collar flashing |
| 13 | Roll curving | 28 | Dormer |
| 14 | Curved flashing | 29 | Safety mesh |
| 15 | Fascia gutter | 30 | Fixing patterns |

1.4.2 INDUSTRIAL DRAWING DETAILS

- | | |
|--------------------|-----------------------------|
| 1 Apron flashing | 13 Sill flashing |
| 2 Hail board | 14 Door Jamb |
| 3 External gutter | 15 Vertical cladding |
| 4 Ridging | 16 Window jamb flashing |
| 5 Purlin spacing | 17 Internal corner |
| 6 Valley | 18 Draped curve |
| 7 Ridge vent | 19 Curved flashings |
| 8 Ventilation | 20 Roll curving |
| 9 Barge flashing | 21 Internal sump |
| 10 Crimp curve | 22 Two piece apron flashing |
| 11 Parapet capping | 23 Rain water head |
| 12 Fascia gutter | 24 Internal gutter |

1.4.3 PRODUCT GEOMETRY



Drawing 1.4.3. (3.9.1 *sinosoidal*) 

1.5 ACKNOWLEDGMENTS

The author of this document is Stuart Thomson who wishes to thank the Technical Committee's of the NZMRM and RANZ and all those who have assisted in the publication of this Code of Practice.

Acknowledgment is also given to the reviewers and the trades-people who have contributed to the healthy debate within the Industry that has enabled this consensus document to be published as the NZ Roof and Wall Cladding Code of Practice.

1.6 RELATED DOCUMENTS

Reference is made in this Code of Practice to the following Documents:

NZ 2295: 2006	Pliable, permeable building underlays.
NZS 3602: 2003	Timber and wood based products for use in building.
NZS 3603: 1993 A4	Timber Structures Standard.
NZS 3604: 1999	Timber Framed Buildings. (amended 2000 & 2006)
AS/NZS 1170: 2002 A4	Structural Design Actions. Part 0. General Principles. Part 1. Permanent, imposed and other actions. Part 2. Wind Actions. Commentary to Parts 0,1 and 2.
AS/NZS 1562: 1996	Design and Installation of roof and wall cladding. Part 1 Metal. Part 3 Plastic.

AS/NZS 2728: 1997	Prefinished/painted sheet metal products. Performance requirements.
AS 3566: 2002	Self drilling screws for the Building Industry. Part 1. General requirements and mechanical properties Part 2. Corrosion resistance requirements.
AS/NZS 4256: 1996	Plastic roof and wall cladding materials. Parts 1-6.
AS/NZS 4257: 1994	Plastic roof and wall cladding materials. Parts 0-9 Methods of Test.
AS/NZS 4389 1996	Safety Mesh.
AS/NZS 4600: 2005	Cold formed Steel Structures. Supplement 1: 1998 Cold formed Steel Structures Commentary.
AS/NZS 4680: 2006	Hot-dip galvanised coatings on fabricated ferrous articles
AS 1397: 2001	Sheet steel and strip. Hot-dipped zinc coated or aluminium/zinc coated.
BS 1470: 1987	Specification for wrought aluminium and aluminium alloys for general engineering purposes.
BS 2870: 1980	Specification for rolled copper and copper alloys.
EN 988, EN1179	Specification for zinc alloy sheet and strip.
ISO 9223: 1992	Corrosion of metals and alloys. Corrosivity of atmospheres - Classification.
ISO 9224 1992	Corrosion of metals and alloys. Guiding values for the corrosion categories.

1.7. DISPUTES

Under the provisions of the Building Act and the NZBC, a contractor who undertakes to do work on a building implies that he can produce an effective and sound result which will fulfil its intended purpose. There is a customer expectation backed by consumer legislation that the finished work will leave the building weathertight, that the work done will comply with the NZBC and will be to a standard that is described as "acceptable trade practice".

"Acceptable trade practice" and "good trade practice" for the Roofing Industry are both described and contained in this Code of Practice. In addition to any contractual or verbal offer there may also be a written obligation given in the form of a warranty. (*see section 13.8. material selection*)

All contractors should ensure that materials they use comply with the requirements and specifications contained within this Code of Practice. All suppliers or manufacturers product literature should be dated and where superseding previous literature the dates should be referenced. The user must ensure that suppliers or manufacturers product literature is the latest version published.

Contractors must be satisfied that the product as described in the product literature is acceptable to the Territorial Authority and contractors must be aware of their liability under law and the contractual documents they have signed or agreed to.

Customer expectation is supported by law that states that the material and product used must be fit for its intended purpose, and the liability of each of the parties is assessed on their 'failure to warn that the product would not fulfill a perceived function.

Poor workmanship is a common cause of dispute and it is often given as the reason for non-payment between the sub-contractor, contractor or owner. This Code of Practice provides a standard of workmanship and a benchmark for arbitration.

It is in the interest of all parties to avoid the cost and delay of litigation and although there are other voluntary ways to settle disputes, they all require some compromise by those concerned.

One voluntary method is negotiation, by calling a 'site meeting' where all interested parties can air their grievances across a table and draw up a programme of rectification and reach an agreement over responsibilities and payment. Any agreement that is reached must be recorded, signed and state what is to be done, how much is to be paid, by whom, by when and how it will be accepted and checked. If no agreement can be reached then a solution may be found through mediation.

The Weathertight Homes Resolution Services Act 2002 provides for a mediation service to be available to dwellinghouse owners with eligible claims. The claiming owner and any of the other parties against whom the claim is made may agree to refer the claim to mediation, with provision for binding settlements by agreement. This service is restricted to leaky homes built within 10 years of the claim.

1.7.1 MEDIATION

Mediation is a cost-effective, confidential and voluntary process where the mediator is the facilitator who assists the parties to come to a negotiated agreement. Mediation concentrates on the parties' interests rather than on their rights, when often both parties realise that they are partly at fault and wish to resolve the dispute and accept a compromise as being preferable to litigation. Any recorded settlement in a mediation agreement can be enforced as a contract but if the parties cannot reach settlement they can refer to arbitration or the courts. A mediator acceptable to all parties is appointed and he should act independently, avoid unnecessary expense and comply with the principles of natural justice.

His task is to help the parties identify the issues and options for settlement and look for a settlement that is equitable to all concerned. He must be given all relevant documents including specifications, plans, quotations and written submissions, setting out the basis of complaint and the rebuttal by the other party. After investigation, site visits and discussion with all the parties, the mediator, using trade benchmarks such as this Code of Practice and drawing on his experience can apportion responsibilities and instruct rectification work be done. This method can provide a quick and inexpensive outcome, with costs shared by both parties but the decision is not binding and must be mutually agreed.

The downside of the informal resolution of disputes is that it does not necessarily uncover the facts and as material or installation failures are not necessarily publicly disclosed, improvement can be inhibited.

Mediation does provide the opportunity to 'move on' and does not always jeopardize business relationships as litigation invariably does.

1.7.2 ADJUDICATION

The Construction Contracts Act provides for a process of dispute resolution called adjudication, to be the first option if negotiation fails. It provides a thirty-day formal process whereby the adjudicator is appointed by the claimant and the respondent cannot opt out. The process is designed mainly for payment disputes, but it can also be used for workmanship disputes and is expected to become the normal dispute resolution method in the Construction Industry. The adjudicator's decision called a determination is binding and enforceable by the courts. Only after the determination has been complied with can it be appealed an unsatisfied party. The adjudication is subject to confidentiality, except by mutual consent or if the information is already in the public domain.

The disadvantage of both mediation and adjudication is that the faults are not made known to the Industry who should be able to learn from the mistakes of the past.

Where the amount in question is under \$7,500, or \$12,000 by agreement with the other party, an alternative method is to file the complaint with the Disputes Tribunal where no lawyers are involved and the parties usually represent themselves and a compromise outcome is sought by a referee. When this method of settlement is chosen there is no assurance that the judgment will be equitable or that the outcome will be based on technical grounds as the main purpose of this court is to seek agreement between the parties,

1.7.3 ARBITRATION AND LITIGATION

Arbitration is usually a strict and formal process similar to litigation in which the parties may be legally represented and select and pay for the arbitrator. He must comply with the Arbitration Act and his imposed decision is known as an award and it is final and binding.

The final and expensive alternative is litigation that usually involves suing for breach of contract, for non-payment, non-performance, faulty materials or non-compliance. Judgment is publicly imposed and usually made by comparison with 'state of the art' materials and practice available at the time the contract was signed.

Both arbitration and litigation can be prolonged and the parties' cost may exceed the amount in dispute.

When the roofing contractor sublets his contract he assumes the same responsibility as though he carried out the work himself.

To avoid disputes, roofing suppliers and contractors must give adequate instruction training and supervision to their staff and keep them informed of industry developments and with the contents of this New Zealand Metal Roof and Wall Cladding Code of Practice.

2.0 PERFORMANCE

2.1 NZBC

The NZ Building Code is under review at the time of publication of this revised Code of Practice.

Users of this Code of Practice must seek the latest requirements of the performance building code from the DBH website www.dbh.govt.nz

Under the Building Act 2004 there are certain changes that have been made that place greater emphasis on the consent documents. It is therefore the responsibility of the designer to design, the manufacturer to manufacture and the installer to install to the good trade practice contained in this Code of Practice.

The BCA is required to consider 'on reasonable grounds' alternative designs at time of consent. Once the consent documents have been approved no alterations must take place unless approved by the BCA.

While the Acceptable Solutions published by the DBH are accepted automatically by the BCA, this is not the case with Alternative Solutions.

Any changes must be discussed with the BCA, designers or owners before any work is commenced and this includes substitution where a nominated product is specified.

2.1.1 DURABILITY

As the requirements of the NZBC are performance based, it is necessary to make a subjective assessment specifically concerning durability of the building elements covered by this Code of Practice. While it could be assumed that roof or wall cladding can be easily accessed and therefore easily replaced, the same cannot be assumed for any flashings which may be embedded in plaster or could not be removed without the removal of monolithic claddings. Some flashings are half hidden and as this portion would not be subject to inspection or maintenance its failure could lead to structural degradation and therefore would not comply with the NZBC. Because replacement could be classified as a major reconstruction, the flashing material durability requirement is 50 years. This requirement also applies to unseen flashings and secret gutters.

The NZBC does not take into account the cost or aesthetics of replacement, so while replacement period would comply with Code, it may be not considered acceptable by the client or owner. Any pre-painted cladding will change colour over time and the replacement would be visible, and the cost of replacing one long length sheet from a distant supplier would be disproportionate to its value.

All metal roof and wall cladding and accessories should be designed and installed to comply with the durability requirements of the NZBC, but the economic and aesthetic consequences of replacement should also be considered.

2.2 METALS

Metals used in the roof and wall cladding industry in New Zealand are:

- Steel coated with zinc - Galvanised steel
- Steel coated with an alloy of aluminium and zinc,
- Metallic coated steel, plus an organic coating*
- Aluminium
- Aluminium plus an organic coating*
- Copper
- Zinc
- Stainless Steel
- Lead

*Organic coatings include acrylic, polyester, PVC and PVF.

Metals used for roof and wall cladding and accessories must be considered independently and when used in conjunction with other metals and materials must comply with the **compatibility table 2.7.2.** and the specific environment in **corrosion categories 2.5.1.**

2.2.1 THICKNESS

The performance of profiled metal roof and wall cladding is dependent on the thickness or gauge of the metal, the yield strength, and the profile. Profiled metal roof cladding is a structural member because it has to support the weight of a workman, brace the top flange of metal purlins and to resist wind uplift loads. The thickness of the metal determines the section properties of the profile, because when the thickness is doubled the section properties are doubled, but this increase in performance is not necessarily linear. *(see section properties 3.1.2.)*

Fully supported metal roof and wall cladding is not regarded as structural because it depends on the support and strength of the underlying substructure to resist downward or point loads, however the metal thickness and the number of clips / m² will determine the performance of the roof cladding under wind uplift loads.

Flashings are not regarded as structural because they also obtain their strength from the sheeting or the structure.

Cost varies with the thickness, so that the most economic design solution will be the thinnest material, consistent with performance without failure under any likely load. The thickness of the metallic coating is not considered when measuring steel cladding for performance and the material thickness is always quoted as Base Metal Thickness (B.M.T.) For the thickness of metallic coatings *(see section 2.2.4).*

2.2.2 STRENGTH

Yield strength is affected by the type, grade or temper of the metal measured in Megapascals.(Mpa).

The yield point is the point beyond which metal will permanently deform and this property is more important than the ultimate strength when designing and using metal roof and wall cladding.

The yield point of any metal will vary dependant on the temper, so if the yield point is higher, it is possible to reduce the thickness of the metal of the same profile, and to obtain equal performance.

For this reason the thickness and the grade or temper should always be quoted together.

2.2.3 METALLIC COATINGS

The primary purpose of a metallic coating on steel is to protect it from deterioration, caused by environmental conditions and thus reduce the chance of rapid oxidation that would otherwise occur. Metallic coatings of zinc, aluminium, or a combination of these accomplish this in two ways: sacrificial protection and barrier protection. (see *sacrificial protection 2.3.*)

2.2.4 GALVANISED STEEL

Galvanised steel is one of the oldest and most common metallic-coated metals. Galvanised steel has a bold crystalline pattern or 'spangle', which is a random geometric pattern that resembles frost on a window, and this pattern is designated as a 'Z' coating. The spangle size can be minimized and this product is designated as a 'ZM' coating.

The word 'galvanising' describes various methods of providing a metallic zinc coating to steel providing cathodic protection and is so termed because it provides 'galvanic protection'.

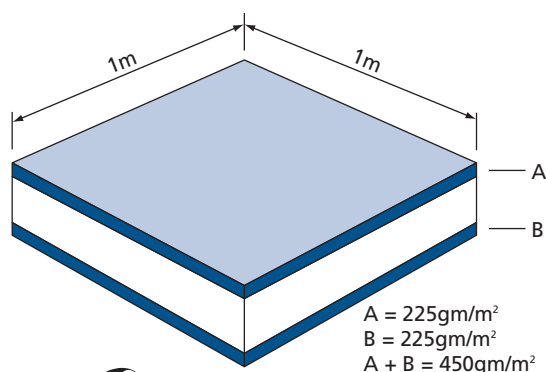
There are many processes that can be called galvanising, but only products dipped or immersed in a bath of molten zinc can be called 'hot-dipped galvanised', which is the process used for the metallic coating of steel roof and wall cladding.

During the metallic-coating process produced on a continuous coil galvanizing line, the thickness of the coating can be controlled more precisely than with other methods. The standard coating weight for plain unpainted galvanised coil and sheet used for roof and wall cladding is 450g/m^2 , however other coating weights are available. Equal coating weights of galvanised steel will oxidize at different rates depending on the environment. The more severe the conditions - the more rapid the loss of zinc. (see *corrosion 2.4.*)

The thickness of coatings in microns (μm) can be measured with a non-destructive magnetic induction meter or similar device which then can be converted into grams per square metre g/m^2 . (see *drawing 2.2.4*)

Confusion exists with the method of describing the coating thickness of sheet and strip products in g/m^2 , when compared with products hot-dipped after fabrication. The coating thickness of sheet and strip refers to the collective amount on both sides of the sheet effectively dividing the coating weight by half.

It is therefore invalid to equate the thickness or the coating weight in g/m^2 of hot-dipped zinc coatings on fabricated products or such items as nails and screws, with that of Z or AZ coatings on sheet and coil. The atmospheric corrosion performance of a hot-dipped zinc coating is directly proportional to its thickness.



Drawing 2.2.4 

A micron (μm) is one thousandth of a millimetre.

Weight of Zinc

$$7150 \text{ g/m}^2 = 1\text{mm}$$

$$\text{Z coating } 450 \text{ g/m}^2 = 450/7150 = .063\text{mm} = 63\mu = 63/2 = 32\mu \text{ each side.}$$

$$275 \text{ g/m}^2 = 275/7150 = .038\text{mm} = 38\mu = 38/2 = 19\mu \text{ each side.}$$

$$\text{AZ coating } 150\text{g/m}^2 = .038\text{mm} = 38\mu = 38/2 = 19\mu \text{ each side.}$$

Although other thickness are available, the most common used in conjunction with roof and wall cladding are as shown.

Mass of coated sheet kg/m² Standard AS 1397

Thickness (B.M.T.) mm	Z 450 g/m ²	Z 275 g/m ²
.40	3.610	3.430
.45	4.002	3.822
.50	4.395	4.215
.55	4.788	4.608
.75	6.356	6.178
.95	8.107	7.748

2.2.5 AZ COATINGS

The alloy of zinc and aluminium used mostly in New Zealand for coating steel roof and wall cladding is described as AZ, and is applied in a similar manner to a galvanised coating but with a pot temperature at about 140°C higher than a galvanized coating and rapidly cooled to provide a dual-phase microstructure. The alloy consists of 55% aluminium 43.5% zinc, and 1.5% silicon, and this percentage ratio is by mass, however by volume this percentage ratio changes to approximately 80% alum, 20% zinc. The alloy coating thickness used mostly for steel roof and wall cladding is 150 g/m² and is designated as AZ150 This coating is approximately the same thickness (.04mm) as Z275 zinc 275g/m². and for an equal thickness an AZ coating has approximately half the weight of a Z coating.

The AZ coating protects steel both as a barrier and sacrificially, as the aluminium part provides a barrier, while the zinc part of the coating will sacrifice itself to protect the base steel, The AZ coating is finer grained than zinc alone and has a silver matt hue similar to aluminium, with a lightly visible spangle which is a random geometric pattern similar to galvanizing. This finish has a relatively high level of initial reflectivity which is likely to be retained for approximately one year because in New Zealand, a thin acrylic film is applied during manufacture. This surface coating acts as a roll forming lubricant and also minimises finger marking and surface discolouration that will occur without this protective finish. Thicker clear acrylic coatings of a nominal thickness of 7µm are also available, some of which can be tinted. It is to be expected that an AZ coating will age and darken over time.

Mass of coated sheet for a coating weight of AZ 150 g/m² Standard AS 1397

Thickness (B.M.T.) mm	Weight kg/m ²
.35	2.814
.40	3.310
.45	3.702
.50	4.095
.55	4.488
.75	6.057
.95	7.627

2.2.6 ZA COATINGS

Steel, with a continuously hot-dipped coating of 95 % zinc and 5% aluminium by mass with the addition of Lanthanides is known as ZA, generally conforming to EN 10214.

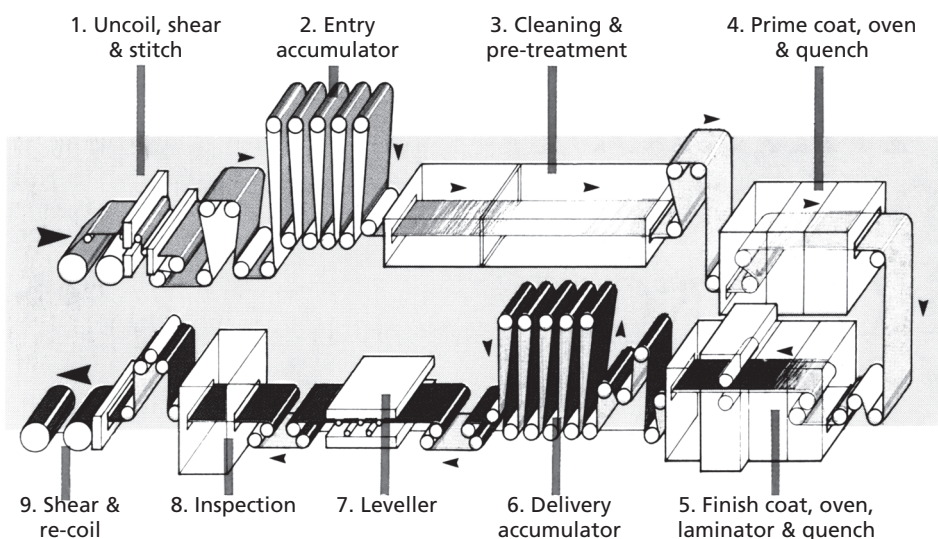
This material is produced for the same purposes as galvanised and AZ coated steels, but has a corrosion resistance with different characteristics than either of these two metallic coatings.

Aluminium as a passive barrier, corrodes more slowly than zinc but does not contribute to sacrificial protection so a ZA coating gives a better sacrificial protection than AZ coatings. The smooth surface of a corroded surface of a ZA coating is due to the lower reactivity of the eutectic micro-structure which produces less porous corrosion products than a Z coating. Whereas the corrosion rate of zinc on a galvanised surface is linear, the corrosion rate on ZA coating has been found to be parabolic.

2.2.7 ORGANIC COATINGS

Paint is used to protect metal roof and wall cladding from environmental deterioration, as well as to enhance appearance and paints can be either factory or field-applied. This section covers only factory applied systems and for information on field applied coatings (*see section 13.7.*).

Painted coatings on a steel substrate that are coated with a metallic coating and subsequently continuously paint coated and oven cured, are known as pre-painted or coil coated. Following pre-treatment, a corrosion inhibiting primer and top-coat is applied to the outer surface and a primer coat and/or a backer coat is applied to the reverse side. This process is continuous and provides for a quality of paint finish not equalled by any other process. (*see drawing 2.2.7.*)



Drawing 2.2.7 

Prepainted Zinc and Zinc/Aluminium coated steel and Aluminium are available in a range of different paint systems which have a longer life to first maintenance than post-applied coatings, but it is important that the correct type of coating is specified and used correctly for the environment and end use. All paint coatings deteriorate over time by UV degradation, which in New Zealand is very extreme.

It is to be expected that as the break down of the paint resin gradually occurs, erosion and chalking will also occur. All colours will chalk and this chalking tends to cause the appearance of fading, however on removal, some of the original colour may return. Noticeable change in colour due to chalking is much less than that which occurs when using conventional post painting or air dry painting systems.

For optimum durability and performance, a maintenance programme is required, and when fading and chalking has occurred, this time is referred to as 'time to repaint decision'. (*see section 13 maintenance*).

The specified finish coat is normally applied only to the top surface of the metal and a primer or backer or wash coat is applied to the backside, to provide some resistance to potential corrosion from the underside. The colour of this backer coat is coded and is used as a means of identification of the coating on the top side, and the backer coat also has identification marking containing the date of manufacture and the name of the coil-coater. Most New Zealand coil is marked however some imported coil may not have such marking.

Other coils that are not brand marked are double sided systems or other coatings on request and export coils.

All coating systems are different and designers and manufacturers should be aware that different substrates, combinations of paint coating thickness and combinations of primer top and backer coats are available for different environments. Factory-applied protective films can be applied to protect the paint coating but these should be removed before installation to avoid difficulty in removing the film. (*see section 2.8.5. strippable films*)

Paint systems are characterised by these criteria:

- corrosion resistance (performance in different environments.)
- exterior durability (fading and chalking resistance)
- adhesion (how well it bonds to the substrate)
- hardness (scratch resistance)
- flexibility (relating to formability of a coated metal)

The paint coating performance is very dependent on the coating underneath the surface, as the flexibility of the primer and the metallic coating can determine the performance of the topcoat during forming and in the environment. The synergy of duplex coatings that is assumed for performance enhancement by the paint coating on top of AZ or Z coatings cannot be assured, as any breaks or discontinuities in the coating at cut edges and microcracking can cause deterioration in extreme environments. (*see microcracking section 2.3.3.*) The paint coating can have an inhibiting effect on the normal cathodic protection where there is any discontinuity of the paint.

For designs not requiring the aesthetic advantage of coloured organic coatings, uncoated aluminium or a plain AZ coating may provide an economic solution provided the detailing described in this Code of Practice is followed.

2.2.8 POWDER COATING

The use of powder coating on steel roof and wall cladding and flashings is not recommended for the following reasons.

The performance of pre-painted steel coatings rely on the metal passivation pretreatment and the corrosion inhibiting primers applied before the topcoat. This topcoat is an aesthetic weathering coat for the primers underneath, and to apply a polyester powder coat without this treatment is not recommended.

Epoxy powder coatings are not recommended for exterior exposure.

Powder coating can be used over pre-primed steel roof and wall cladding and flashings to change the colour, but only if it is compatible with the existing paint coating.

Before applying any coating the surface should first be lightly abraded to provide adhesion. The powder coating is deposited on the metal by spraying with a powder from an electro-statically charged spray gun, followed by curing in a baking oven.

The application of powder coating is a post forming operation because the thickness of powder coating is much greater than that of the paint on coil coated metal, and it does not have sufficient flexibility to be folded or manipulated after coating.

2.2.9 ALUMINIUM

The aluminium alloys used in New Zealand for roof and wall cladding are included in the 3000 and the 5000 series.

3003 is an aluminium alloy containing 1.2% manganese and has good formability weldability and corrosion resistance.

5005 is an aluminium alloy containing 0.8% magnesium and has excellent workability, weldability and corrosion resistance and is specified for applications comparable to 3003.

5052 is an aluminium alloy containing 2.5% magnesium and 0.35% chromium and is a higher strength marine grade alloy with exceptional resistance to corrosion in marine or industrial environments.

5251 is an aluminium alloy containing 2.0% magnesium and is a higher strength marine grade alloy with exceptional resistance to corrosion in marine or industrial environments.

Following strain-hardening of aluminium alloys, tempering is used to increase the ductility by low temperature heating. The description of tempers given to aluminium alloys can be confusing because the magnesium alloys and the manganese alloys are strain hardened in a different manner, and their description in terms of hardness relates to the last number, i.e H12 or H32

Aluminium 3000 - 5000 series

3003	Nominal Yield MPa	5005/5052/5251
H 0 = soft	65	= H 0
H 12 = 1/4 hard	160	= H 32
H 14 = 1/2 hard	180 (Flashings, curving)	= H 34
H 16 = 3/4 hard	200 (Roll forming)	= H 36
H 18 = full hard	220	= H 38

Pure aluminium (99%) known as 'dead soft' can be used for flashings in widths between 150mm and 600mm in thicknesses of 0.30mm, 0.45mm, 0.55mm, and 0.70mm and is also used as a soft edging for ridge or apron flashings required to act as a wind barrier.

Aluminium alloys are available in three surface finishes:

- Mill finish: A smooth lustrous finish which will dull relatively quickly.
- Stucco Finish: An embossed mill finish, which reduces the specular reflectance of mill finish sheet.
- Painted Finish: A range of painted finishes are available similar to those offered for painted steel.

The high reflectance and emissivity of unpainted aluminium can considerably reduce heat transmission and the lighter mass of aluminium can provide a substantial reduction in the cost of transport to remote locations.

Aluminium Standard AS 1734

Thickness mm	Weight kg/m ²
.7	1.89
.9	2.43
1.2	3.24

Aluminium develops a thin oxide film on the surface that is impermeable to most airborne contaminants, except for strong alkalis and acids. Aluminium is subject to pitting in industrial or marine environments, which can produce a white powdered corrosion product that in turn slows down the corrosion process. Like all metals it requires to be kept clean and dry in order to perform in severe environments, and free of debris, which can cause poultice corrosion. (see corrosion section 2.6.3.)

2.2.10 STAINLESS STEEL

Most roof and wall cladding, flashings and panels in New Zealand, are made from the 300 series of austenitic non-magnetic stainless steels, which contain chromium, nickel, and manganese, with 304 and 316 being the most common grades. Type 304 stainless steel is an alloy of 18% chromium and 8% nickel, that provides high corrosion resistance and is known as an all purpose alloy.

Type 316 stainless steel, known as the marine alloy, should be specified for use in coastal or industrial areas. It contains 16% chromium, 10% nickel, with 2% molybdenum added, which increases resistance to pitting and corrosion in harsh environments. Stainless steels are resistant to most chemicals, however they are subject to crevice corrosion. (see section 2.6.1.)

Stainless steel is available in a number of different mill finishes from dull matt to highly polished and for roof cladding and sheet metal flashings the most common finishes are designated 2B and 2D. The 2B finish is a bright, cold-rolled finish that is highly reflective and 2D is a dull finish that is less reflective. BA is a bright reflective surface only suitable for decorative cladding in thicker gauges. Embossed patterns are available that reduce glare and minimise reflection, distortion and the effects of vandalism.

Stainless steel is a durable, corrosion-resistant material used in harsh environments when a non-weathering finish is desired. Chromium forms a tenacious oxide protective film on stainless steel that is transparent, self-healing as it will repair itself on exposure to the atmosphere.

Although stainless steel will not normally stain adjoining materials, the name 'stainless' does not mean stainless in all environments, and it should be cleaned regularly to obtain maximum corrosion performance. Like metallic coated steels, unwashed areas should have a maintenance schedule, or be designed to avoid the accumulation of salts and dirt which can cause staining and corrosion. Stainless steel should not be cleaned with steel wool, however stainless steel wool can be used. Stainless fixings should be used with stainless steel sheet to avoid dissimilar metal corrosion. Some minor 'tea-staining' can occur at welds or if 303 bolts are used.

There is no well defined yield point for stainless steels and so fully annealed or standard annealed tempers are used for ease of forming with 304 and 316 having an approximate yield strength of 290MPa.

Stainless steels require different forming techniques than other metals, and are known to be tougher and more difficult to form than carbon steel of the same thickness, e.g. when shearing stainless steel the equipment capacity should be increased between 30% - 50%. Because of the toughness of the metal, sharp cutting edges dull more quickly than when used with carbon steel.

Although stainless steel is not much harder than mild steel, increased power is necessary to form it because of its high ultimate strength and its higher work hardening rate. As most forming machines are rated for the heaviest gauge steel this capacity should be de-rated by 40%.

Precautions should be taken not to contaminate the surface of the metal by inclusions from roll forming or folding equipment as this can appear as rust spots on stainless steel, which is detrimental to performance. Stainless steel coil and sheet can be supplied with a stripable film to avoid this contamination.

Stainless steels have a greater spring-back, are subject to work hardening when forming, and drilling is required to be performed at a slower speed than carbon steel. Stainless steels can be welded and brazed, however heat input should be minimised. A low carbon stainless steel should be used if welding is critical and these alloys are known as 304L and 316L. Stainless steels can also be joined by soldering, using a phosphoric acid or proprietary flux.

Stainless steel roof and wall cladding is manufactured in similar thicknesses as those that are used with metallic coated steel, because although the material is tougher it is supplied in an annealed condition. The performance of the two metals is similar however a reduction in thickness is often possible, dependent on the amount of work hardening during forming.

Stainless Steel Standard AS 1449

Thickness mm	Weight kg/m ²	Nominal Yield MPa
.45	3.62	290
.5	4.25	
.55	4.43	
.75	6.05	
1.0	8.06	

2.2.11 COPPER

The copper alloys used for roof cladding are alloys 102, 110 and 122, which are very malleable and are available in various tempers, or ranges, of hardness. Soft copper is used where a high degree of formability is required and is used for architectural metal panel roof cladding that is hand folded.

These alloys are 99.9% pure copper with 102 having the addition of .02% phosphorus which increases strength.

Copper develops a patina finish over time (*see section 11.9.2.*)

Cold-rolled copper in the 1/2 to 3/4 hard temper range is used for roll forming because of its resistance to stretching and copper in the 1/4 to 1/2 hard temper range is used for sheet metal flashings

Copper Standard AS 1566 BS 2870

Thickness mm	Weight kg/m ²	MPa
.5	4.47	1/4 hard = 250
.55	5.47	1/2 hard = 280
.7	6.96	3/4 hard = 310

2.2.12 LEAD

Lead is used as a roof cladding accessory metal because of its workability. It is an extremely soft metal, can be formed by hand, and therefore is very suitable for flashing irregular shapes, junctions and vent pipes. Lead does not work harden, so it is always in an annealed state and it is a useful material where difficult shapes such as dormer eyebrow roofs, domes, turrets or where multiple curves are required.

It is no longer used as a flashing material with AZ coated steel, as it is considered incompatible.

Sheet lead has little structural strength or puncture resistance and should be installed over solid surfaces when used as a roof cladding. Single sheets of lead should not be laid exceeding 1.5m² or 1.5m in length.

Sheet lead is designated by weight, and is available from 10 kg/m² -35 kg/m².

- 10 kg/m² is suitable only for fully concealed flashings,
- 15 kg/m² can be used for flashings but is limited in length to 1.000m,
- 17.5 kg/m² is limited to lengths of 1.300m in length
- 20 kg/m² should be used for all exposed flashings
- 25 kg/m² for all roofing applications.

Premature failure under expansion stress can occur with the use of lead less than 17.5 kg/m².

Lead Standard AS2904 BS6915

Thickness mm	Weight kg/m ²		
.9	10	Green	Code 2
1.35	15	Blue	Code 3
1.8	20	Red	Code 4
2.25	25		Code 5
2.65	30		Code 6

New lead can stain plaster or other materials with a white lead carbonate, but this can be avoided by the use of patination or linseed oil wiped or painted on after installation. Some lead products are available preprimed.

Workers using lead should take safety precautions as lead is a cumulative poison. Hands should be washed in cold water before eating or smoking and any cuts should be sealed to prevent contamination.

2.2.13 ZINC

Zinc is a traditional roof cladding material and weathers to a dark gray patina in a similar manner on exposure to the environment as galvanised steel, except that the pure metal is the total thickness. Venting on the underside of a zinc panel is required to prevent pitting from condensation and high-build laquer coatings are available on the underside to protect against pitting. Zinc has a high coefficient of thermal expansion and also has application limitations, because under 7°C the metal becomes brittle and cannot be formed easily without fracturing. Zinc roof panels and flashings are commonly 0.7mm thick, although heavier gauges are used. The staining potential of zinc is less than that of copper and lead.

99.95% pure zinc is available for flashings in coils 230mm to 700mm wide in an annealed condition with limited workability. Zinc used for roof cladding generally contains very small percentages of titanium and copper, which add to the properties of pure Zinc. Zinc coil is available in pre-weathered and lacquered finishes.

Zinc Standard EN 988

Thickness mm	Weight kg/m ²	Nominal Yield MPa
.7	5.04	220
.8	5.76	
.9	6.48	
1.0	7.2	

2.3 SACRIFICIAL PROTECTION

To protect steel against corrosion, zinc is applied by various methods, including hot dipping, electroplating, and metal spraying. The protection it provides takes two forms: as a sacrificial coating and as a barrier coating.

Where the underlying steel base becomes exposed at cut edges holes or mechanically damaged areas, the zinc coating will corrode in preference to the steel. The ability of a hot-dipped zinc coating on steel to protect it against corrosion is known as sacrificial, or cathodic protection because the cathode metal is the one protected.

If it is exposed in a well washed area a heavy zinc coating will provide an effective barrier between any corrosive medium and the steel.

Not all metals have the same ability as zinc to protect steel in this manner. When steel is protected by a coating of metallic tin, as the tinplate material used for the manufacture of tin cans, the steel is anodic to tin, which means that a tin coating is not sacrificial to the steel base. While the tin coating of a tin can is completely intact, it acts as a effective barrier to corrosion, however if the coating is scratched, or is produced with any pin-hole defect, the base steel will corrode very rapidly at an accelerated rate because it is sacrificial relative to the tin. To call galvanised or AZ coated steel roof, a "tin roof" is a complete misnomer because firstly, it is not made of tin, and secondly a tin coating is not sacrificial to steel.

In the USA there is roof cladding material used that does have a tin coating - one part tin to three parts lead known as Terne plate. It is possible that this is where the misnomer started because of a similar appearance to tinplate.

2.3.1 CUT EDGES

When the cut edges of metallic coated steel cladding or accessories are in direct contact with a metal scribed apron flashing, or with another material such as a capping against a concrete slab, the edge will deteriorate because it is kept wet and impurities will collect at the drip edge. The cut edges of unpainted galvanised steel are protected from corrosion to a degree by the sacrificial protection given by the zinc of the metallic coating, and this is also provided by AZ coatings but to a lesser degree. (*see sacrificial protection 2.3*).

The cut edges of AZ coatings should not be in contact with concrete or damp plaster because the coating is not resistant to alkali.

Stainless steel fastenings do not offer the same protection as galvanised fasteners to the cut edges of drilled fastener holes in AZ coatings. Because drilling removes the metallic coating from the edge of the hole, screw and nail holes can be punched rather than drilled, but great care should be taken not to distort the metal that could affect the seal.

The cut edges of prepainted metallic coated steel roof and wall cladding do not have the same degree of sacrificial protection as unpainted, but in severe and very severe environments additional protection can be given by the application of an acrylic lacquer to the cut edges of flashings, and the cut edges of sheets when stacked.

To avoid sheets sticking together when applying the lacquer, it should be thinned 10% with water for use with a foam roller or small paint brush. In some circumstances it may be necessary to separate sheets to ensure adequate coverage and drying and to prevent the discolouration due to capillary action of the lacquer.

Cut edges of AZ coated steel and aluminium must have a minimum 3mm gap separation from concrete or cement based products.

Although non-ferrous metals do not require any edge protection, paint coated metals can benefit from a lacquer coating in very severe environments.

2.3.2 PASSIVITY

The effect known as passivity plays an important role in the corrosion resistance of some metals.

While acknowledging that the galvanic or electromotive table or series is a useful indicator of which metal is more active than others under certain conditions, the series has been established by testing metals in a laboratory in their active condition and then ranking them in order of activity. This means that the electrolyte or corrosive medium is in contact only with new metal at any time, that nothing comes between the metal and the medium, that they are free to interact without hindrance, and the metal corrodes at a steady rate.

Real world exposure conditions are very different, as the phenomenon called "passivity" can cause results to be very different from those predicted from the galvanic series.

The passive behaviour displayed by different metals and alloys under particular conditions is determined by the nature of passivity, as it plays an important role in the atmospheric corrosion resistance of metals, as well as their performance in certain specific environments. The passive layer can be electrically insulating to allow electrolytic corrosion to occur on the same piece of metal.

Some metals in contact with a corrosive medium in oxidising conditions react initially, but in doing so form a film of metal oxide on the surface, and this film then impedes further reaction by acting as a barrier between medium and metal and the metal becomes passive.

When steel is alloyed with chromium content of 12 - 13%, the resultant alloys known as "stainless steels", possess a passivity so effective that it will not react with air, water or many acids.

Stainless steels owe their corrosion resistance to a surface oxide film, which is thin, continuous, and very tenacious. Although it is not obvious or visible to the naked eye, it completely isolates the metal from the surrounding medium. "Stainless steel" is a misnomer because it can stain. It is corrosion resistant not corrosion proof and can deteriorate if used in unwashed areas and in other corrosive conditions. Normally if the oxide film is breached by some form of mechanical action, the atmosphere quickly re-passivates or reforms it, and it continues to protect the metal from attack. This "self-healing" ability is fundamental to the effectiveness of passivity. If there is no oxygen available stainless steel and aluminium can suffer from crevice corrosion. (see section 2.6.1.)

When a clip rubs against a roof cladding sheet and if the protective film is disrupted very frequently as the sheet expands and contracts, severe corrosion of the normally corrosion-resistant metal can result.

Aluminium forms a passive oxide film in normal environments that can be enhanced by a process in which a controlled oxide film is produced electrolytically known as "anodising".

Both AZ and ZA coatings form passive films when exposed to normal atmospheric conditions, and these passive films exert a major influence on their behaviour under various corrosive conditions. The passivity of the AZ coating is greater than that of zinc alone, and its atmospheric corrosion rate is much lower because of the 80% content by volume of aluminium.

Sacrificial protection and passivity can be mutually exclusive and passivity can be so well developed that sacrificial activity is suppressed.

An aluminium coating provides good corrosion protection as a barrier between the atmosphere and the steel on both an AZ coating on steel and a hot-dipped coating of aluminium on steel. Aluminised steel is described as an A type coating. Because of its strongly passive nature its corrosion rate is normally slow but any galvanic or sacrificial protection provided for the steel is negligible.

The AZ coating however does not provide as good a sacrificial protection as a pure Z or ZA coating.

The differences between Z and AZ coatings lies in the balance between passivity and sacrificial protection, and for roofing and cladding products, an AZ coating provides satisfactory sacrificial protection of cut edges but is not as effective as a zinc coating. Because of its more strongly passive nature due to its aluminium content, the AZ coating provides an enhanced degree of barrier protection and can outperform galvanised products in more severe atmospheric conditions.

Aluminium in its active condition is ranked above zinc in the electrochemical series, and in its passive state, an AZ coating is more corrosion resistant than zinc, but in its active state the reverse is true.

Where conditions work against passivity however, corrosion can be very rapid and the aluminium-rich areas in the AZ coating can corrode quite rapidly in the active state.

Where oxygen is not available in sufficient quantity to create or maintain a passive film, corrosion is likely to occur.

An AZ coating should therefore not be used where it is continually wet or where access to oxygen is inhibited.

2.3.3 MICROCRACKING

Microcracking develops due to the low ductility of metallic coatings on a steel substrate. It occurs on tension bends during forming, the extent of which is interdependent on the type of coating, coating thickness, ductility and bend radius. Although the steel is not cracked, the formability of the substrate will affect the spring-back or forming radii, which in turn will produce a greater degree of cracking of the metallic coating.

Where micro-cracking does occur and in areas that are not washed regularly, it can produce a white bloom on organic coatings and although the performance may not be greatly affected it is most visible on dark colours.

Ductile non-ferrous metals do not micro-crack, however if they are painted the paint can crack or check on sharp external bends.

Thicker and more flexible paint films have a greater tolerance to microcracking and therefore are more suited for exposure in extreme environments or unwashed areas. (*see radius section 2.3.4.*)

2.3.4 MINIMUM RADIUS

The test requirement for paint adhesion required in AS/NZS 2728: 1997 is a bend test over a nominated number of material thicknesses, (T) and is measured as the internal diameter.

The radius required to avoid microcracking on metallic coated and pre-painted steel flashings is measured externally. To obtain an equivalent external radius, two metal thicknesses are added to the internal diameter and divided by two.

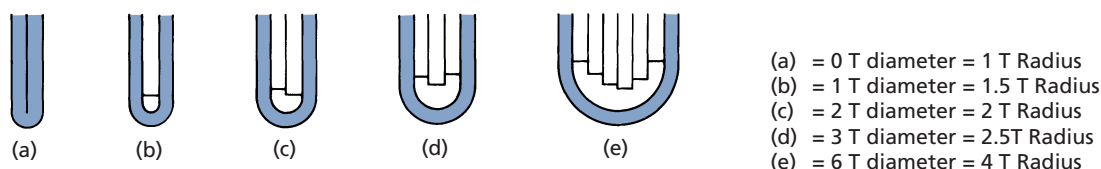


Diagram 2.3.4 

When using .55mm coated steel flashings, in order to minimise the amount of microcracking, a 6t diameter or minimum external radius of 2.3mm is required to satisfy any warranty because it will not produce visible micro-cracking.

2.3.5 OIL-CANNING

An aesthetic problem associated with the manufacture of metal roof and wall cladding and flashings is the distortion of flat metal areas. Flat pan architectural metal panels, wide flashings and profiled metal cladding with wide pan configurations without stiffening ribs, are all liable to show distortions in flat metal areas which is known as oil-canning or panning. Some paint finishes and metals are highly reflective, and the visual effects of oil-canning can be exacerbated by different light conditions when this condition can become an issue of customer acceptance. Some distortion is inevitable in light gauges and often customer expectations are unrealistically high. Flashings are limited in width to 300mm to avoid the distortion caused by expansion. (*see 5.1. materials*)

There are many causes of oil-canning and it is important to know the cause in order to remedy the problem.

- Material
- Roll tool design and setting
- Installation
- Expansion allowance

2.3.6 MATERIAL

The process of roll forming metal roof and wall cladding can cause oil canning and distortion because during forming, numerous reversals of compression and tension stresses occur both in the transverse and the longitudinal directions. It is recognised that because of variation in coils, a degree of oil canning is unavoidable.

Flashings should have straight edges to avoid distortion and an acceptable tolerance for 1200mm wide coil is 2mm deviation in a 2000mm length.

2.3.7 INSTALLATION

Oil-canning can occur if the cladding is fixed when it does not fit accurately, when fixings are spaced too far apart, or by screws or nails that are overdriven. It can also result from an uneven substrate or irregular bearing on the purlins or by the structural framing being out of line. Curved roof cladding and flashings give rise to oil-canning because the pans are in compression on concave roofs and limitations are placed on curved radii for this reason. (see section 4.9. curved roofs)

Temperature changes or movement restrictions will cause oil-canning or distortion unless provision is made for expansion at fastener or clip locations. (see section 4.1. expansion)

2.3.8 DISTORTION

Continual and extensive distortion can eventually lead to fatigue and failure but good design will minimise the effects of temperature and wind loads.

There are precautions that can be taken to reduce the visual effects of distortion or oil-canning.

- use thicker metal
- limit flashing width dimension to 300mm
- limit the length of cladding
- limit the joined length of flashings to 12 m or use expansion details
- use stiffening ribs in the pan of metal cladding
- use stiffening ribs in fascias when face dimensions are greater than 200 mm or use two pieces
- use low-gloss paints or embossed finishes
- use naturally-weathering metals that dull or fade over time
- do not fix any cladding or flashings if the structure is misaligned

If distortion is present when the cladding or flashings are laid flat before fixing, the attention of the manufacturer, contractor or owner should be drawn to this fact before any installation is started. All flat metal will distort to a degree and the degree of acceptance should be based on the thickness of the material, the ultimate visual effect and the specification. Fully supported architectural metal panels are known for their natural distortion which is acceptable, but the installation of profiled metal cladding and flashings is expected to provide finishes free of any avoidable distortion.

2.4 METAL CORROSION

It is the responsibility of the designer and the contractors concerned to comply with the requirements of B2, E2 and E3 of the NZBC.

Manufacturers specific installation requirements should be followed by the designer or roofing contractor, who should satisfy himself that the materials he is installing and the methods he is using will satisfy these requirements. The durability compliance will only be met if maintenance requirements are followed and the use of any Accreditation or appraisal also requires that the specifier or contractor follow precisely these recommendations to comply with the NZBC. The design requirements of this Code of Practice should also be followed if premature corrosion is to be avoided.

So that the designer and the tradesmen involved in installation can comply with durability requirements, it is necessary for them to have an understanding of the mechanism of the corrosion process.

The terms corrosion resistance, corrosion prevention and corrosive defect are relative, and they should always be considered together with the product performance requirements. Frequently problems of definition and communication occur, particularly between manufacturers and consumers, as the performance required by the NZBC and customer expectation often do not coincide.

The requirements of the NZBC relate to performance and do not necessarily relate to aesthetics. The roof cladding could have deteriorated but not perforated within 15 years and still comply with the NZBC, but customer expectations are unlikely to be satisfied if this occurred. The contractor has to satisfy not only the NZBC, but to fulfil any written, advertised or implied warranty given by the manufacturer and to install the products as required by this Code of Practice.

Good design, correct selection of materials and good installation practice are required because poor design and workmanship can cause premature corrosion to take place. Metals display an inherent tendency to revert to their original stable form and this is the process that is known as corrosion.

The red rusting of iron and steel is a visible common example of corrosion and other examples are provided by the weathering of copper, which darkens or develops a green patina, and silver, which turns black. In these and all other instances of corrosion, the materials affected are attacked because they react with oxygen and other substances around them.

The corrosion of metals is a complicated science and even though the relevant literature on the subject is comprehensive and the knowledge of corrosion is constantly improving, many phenomena regarding corrosion processes have not been completely clarified.

Metal corrosion is the reaction of a material with its environment that causes measurable alteration, which can lead to a corrosive defect that may impair the performance of a component or an entire system. It can be the result of direct contact with another metal or substance, or the result of run-off or fall-out. In some cases one metal alone can corrode without these conditions when either exposed to, or denied contact with oxygen.

Some metals in some environments are more prone to corrosion than others and the many permutations of material, temperature, pH, humidity, location and time of wetness all play an important part in determining the longevity of metal cladding. All metal cladding is more likely to be affected by corrosion if near the sea or in areas of high humidity.

Corrosion is a complicated subject and in reading this simplified description it may be helpful to refer to the definitions to find the terminology used.

It is important that the roofing contractor does not use flashing and fastening practices that enable water and dirt to be trapped and thus cause corrosion. It is essential that designers, manufacturers, suppliers and roofing contractors understand the nature of corrosion because they can cause it by:

- incorrect design
- incompatible or incorrectly specified materials
- unacceptable trade practice

All parties should advise the building owner of the maintenance requirements particular to the building site and the material used in order to comply with the NZBC.

2.4.1 TYPES OF CORROSION

There are many types of corrosion that affect metal claddings but they can be divided into two main types:

- atmospheric for a metal in isolation,
- electrochemical or galvanic, where the metal reacts with another metal or material.

The various manifestations of corrosion within these two types are categorised in a different way, cannot be clearly defined, almost always overlap, and frequently the different types of corrosion typical of different metals and alloys, do not develop separately, but are interdependent in a complex way.

The nature of the interaction between various metals and electrolytes, is influenced by the many permutations of environment, the degree of pollution, and the pH of the electrolyte.

It is the responsibility of both the designer and the Roofing Contractor to ensure that they do not cause corrosion by incorrect use of materials.

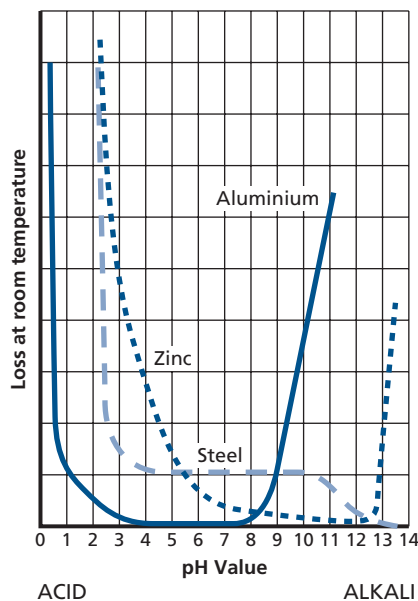
The major factors that affect metal corrosion are:

- The metal
- The atmosphere
- The rain
- Pollutants

2.4.2 METAL PERFORMANCE

To understand metal performance in any specific environment, each metal should not only be considered separately but also be considered when used in conjunction with other metals.

All metals react differently to the atmosphere and to any contaminants that contact their surface by rain, wind or condensation. pH is the logarithmic indicator of acidity or alkalinity measured from 0 – 14 and is a most important corrosion factor. pH 7 is neutral, below 7 is more acidic, above 7 is more alkaline and the performance of the three metals steel, zinc and aluminium, relative to pH is shown on **graph 2.4.2**.



Graph 2.4.2. 

It can be seen from graph 2.4.2. that uncoated steel has significant loss even in neutral atmospheres or liquids and that zinc performs better in alkali environments and aluminium performs better in acid environments. This is the reason why steel is always protected with a metallic coating and for over 150 years zinc has been used as a protective metallic coating for metal roof and wall cladding in New Zealand. In 1994 an aluminium /zinc coating known as an AZ coating, that had been successfully used elsewhere in the world was produced in New Zealand, to provide improved overall protection for steel, particularly in acid, or lower pH environments. (see section 2.2.3. *metallic coatings*)

2.4.3 THE ATMOSPHERE

The atmosphere is an important part of the corrosion environment and although there have been international attempts to define environmental categories, these divisions can only ever be taken as a general indication, as a micro-environment can often have a more significant effect on metal corrosion than the macro-environment.

The invisible gases in the atmosphere consists of 78% nitrogen, which is an inert gas, 21% of oxygen, which is highly reactive, and 1% consisting of eight other gases, of which argon is nearly .9%, and carbon dioxide is .03%. CO₂ is significant both in assisting and preventing corrosion. These percentages are for dry air, however, the major variable is water vapour, which not only varies from place to place, but varies every day and has a major influence on the corrosion of metals. Corrosion is accelerated when the relative humidity is greater than about 50% and is also temperature related. At 0°C metal corrosion is minimal, as the colder it is the slower the reaction, however with every 10° C rise in temperature the corrosion rate of some metals will double.

Other variables in the atmosphere are the many contaminates or pollutants, produced either naturally such as chlorides near the sea or geothermal hydrogen sulphide (H₂S), or man-made gases such as sulphur dioxide (SO₂).

Most metals form a metallic oxide film, which if it can be protected from corrosion, can prevent any further action on the parent metal. Unfortunately some of these 'patinas' or oxides are soluble in even mild acidic or alkali environments and so the corrosion of metal depends very much on the tenacity and reactive or volatility of the protective film.

For corrosion to occur at all there has to be moisture or an electrolyte present so the major metal corrosion factor becomes the 'time of wetness' or the % of time the reaction can occur. This in turn is affected by the humidity and also the hygroscopic nature of sea salt, which together with dirt particles provide the conditions conducive to metal corrosion.

2.4.4 THE RAIN

Rain provides the moisture that acts as the electrolyte in corrosion cells. Rain varies in pH because as it falls, it picks up a number of contaminants from the pollutants in the atmosphere. Acid rain can occur in geothermal areas due to the presence of Hydrogen Sulphide. Roof cladding is primarily a rain shield, and if rain cannot flow freely away and remains trapped, evaporation takes place, leaving behind a concentration of contaminates which can react with the metal surface.

2.4.5 POLLUTANTS

Pollutants have become the general term for a whole series of chemicals and whose effects range from minor surface discolouration to corrosion of roof and wall sheeting.

The major contributor to metal corrosion in New Zealand is chloride, and in the form of sodium chloride in particular, is a common air pollutant in coastal regions. Although water with a pH of 7 is neutral, in coastal areas rain contains salts, mostly sodium and magnesium chlorides and these salts although not regarded as either predominately acid or alkaline, do make the water electrically conductive.

Seawater contains a mixture of salts containing 2.5 to 4% sodium chloride, and small quantities of magnesium, calcium, and potassium chloride. Chlorides in airborne sea spray, dry salt particles, evaporation and infrequent rain increase salt concentrations on exterior surfaces and corrosion rates, particularly in unwashed areas. The distance airborne salt is carried varies significantly with local wind patterns and in some locations salt may be carried 30kms inland.

At a temperature of 25° C and at different humidity levels marine salts begin to absorb water and form a corrosive chloride solution.

- Sodium chloride @ 76% relative humidity (RH)
- Calcium chloride @ 41% (RH)
- Magnesium chloride @ 50% (RH)

The importance of chlorides can be recognised in the corrosion of metal roof and wall cladding, because in New Zealand the normal humidity levels are in excess of these percentages. The average RH over a period of 26 years in Auckland has been 80%.

Sulphur dioxide develops when burning fossil fuels, and it is consequently most common in urban and industrial environments, particularly in the South Island and the West Coast of the South Island. After oxidation and reaction with water, it forms sulphuric acid (H_2SO_4) that contributes considerably to the atmospheric corrosion of zinc and steel. The SO_2 content in the atmosphere increases in winter, which means that the corrosion of zinc and steel progresses more rapidly at that time of the year.

Although New Zealand does not have the severe acid rain problems of industrial Europe or USA, coastal industrial and geothermal areas create environments, which require careful consideration when choosing roof cladding material and fasteners. Chloride contents are usually lower in industrial and urban environments but they considerably encourage corrosion and play an important part in the chloride induced stress corrosion cracking of stainless steel.

The acids that attack zinc and steel, come from the air and from carbon dioxide even at 0.03 percent per volume in the natural atmosphere, which when combined with oxygen encourage the creation of protective patinas on nonferrous metals.

It has been discovered recently that organic acids can also be produced by micro-organisms that live on paint surfaces and on plastic coatings which can form spore-like formations in the cavities of coatings, particularly on the shady side of any roof. Mould and lichen retain moisture and are fed by nutrients that fall from trees or as fallout or drift from farming activities. (*see maintenance section 13*).

2.4.6 ATMOSPHERIC CORROSION

Atmospheric corrosion is chemical in action because the metal reacts with oxygen and other elements.

If there is no moisture present there is no action, however as this situation is unlikely, most metals in moderate environments form an oxide, or patina.

Zinc oxide converts to hydroxide, carbonate and basic zinc salts depending on the environment. Zinc coatings are usually stable and tenacious although in acid environments they can become water soluble, in which case deterioration is rapid. (*see inert catchment section 2.6.4.*)

In free weathering exposure in moderate environments at some distance from the sea, there is little corrosion or only very slow corrosion. Corrosion increases in humid, drizzly and foggy weather, or in places that are not exposed to direct rainfall, because moisture may turn acidic and its pH value may fall considerably below 7. The corrosion that occurs on unwashed areas can be up to 3-4 times greater than that on washed areas.

The designer should be aware that any area of metal cladding that does not receive the benefit of rain washing and drying by the sun can suffer concentration of contaminants that lead to corrosion. These areas are termed "unwashed areas", and to avoid premature deterioration, a maintenance program is required to remove the corrosive salts and dirt that cause corrosion. The designer should recognise his responsibility when drawing or specifying details where metal cladding or accessories that require maintenance are unable to be maintained.

2.4.7 GALVANIC CORROSION

Galvanic corrosion acts in a similar way to the process of electroplating, or to a battery which produces an electric current, having an anode and a cathode and an electrolyte, and is known as electrolytic action.

Corrosion is dependent on the polarity and potential difference between two metals or even an anodic or cathodic parts of the same metal.

This electrical current can be measured and the amount related to the potential driving force responsible for corrosion, which leads to the gradual dissolution of the metal. The electric current will try to minimise the potential with differences of only a few tenths of a volt and the greater the difference in potential, the greater the corrosion current and the faster the corrosion will be. The electro-potential difference is the basis of the electrical series and the electrochemical tables

2.4.8 THE ELECTROCHEMICAL OR GALVANIC SERIES

The electrochemical tables or galvanic series scales that are often quoted in technical literature as a measure of corrosion show the electro-potential between pure metals, not their oxides and so represents theory and not real world conditions. Although theoretically correct, any table can give a misleading indication as to the performance of any protective film on metal roof and wall cladding in different environments. The mechanism of corrosion is too complicated to be judged by this scale alone, as the degree and type of corrosion is greatly influenced by many other factors.

The electrochemical table should only be used in conjunction with the other corrosion factors described in this Code of Practice.

The Electrochemical series table is still a useful indicator of electrode potential, as the further apart two metals are in the electrochemical series, the greater the potential difference between them.

Moist air, absorption or thin water films or condensation all can become the electrolyte and permit electrolytic reactions to develop on the metal surface. Theoretically, in the presence of moisture, any metal can be ranked in the galvanic series. Those termed 'anodic', active, negative or less noble, will corrode in preference to any other metal that is higher in the galvanic series ranking, called 'cathodic', noble, positive or less active. The metal that is less noble becomes the anode and is subject to corrosion as it has a negative potential compared to the cathode, and the greater the potential difference, the more corrosion there will be on the less noble metal, i.e. on the anode.

This series only applies to certain conditions of metal, electrolyte type, pH and concentration, temperature, and the corrosion potential can deviate greatly from the standard potential.

Different rankings can be derived in different electrolytes and metal alloys may not display a single potential which applies to metals in their "active" state. Under certain conditions, some metals can exist in a "passive" state, which renders them less active, so that any ranking can be misleading and "Passivity" becomes an important phenomenon in controlling corrosion rates.

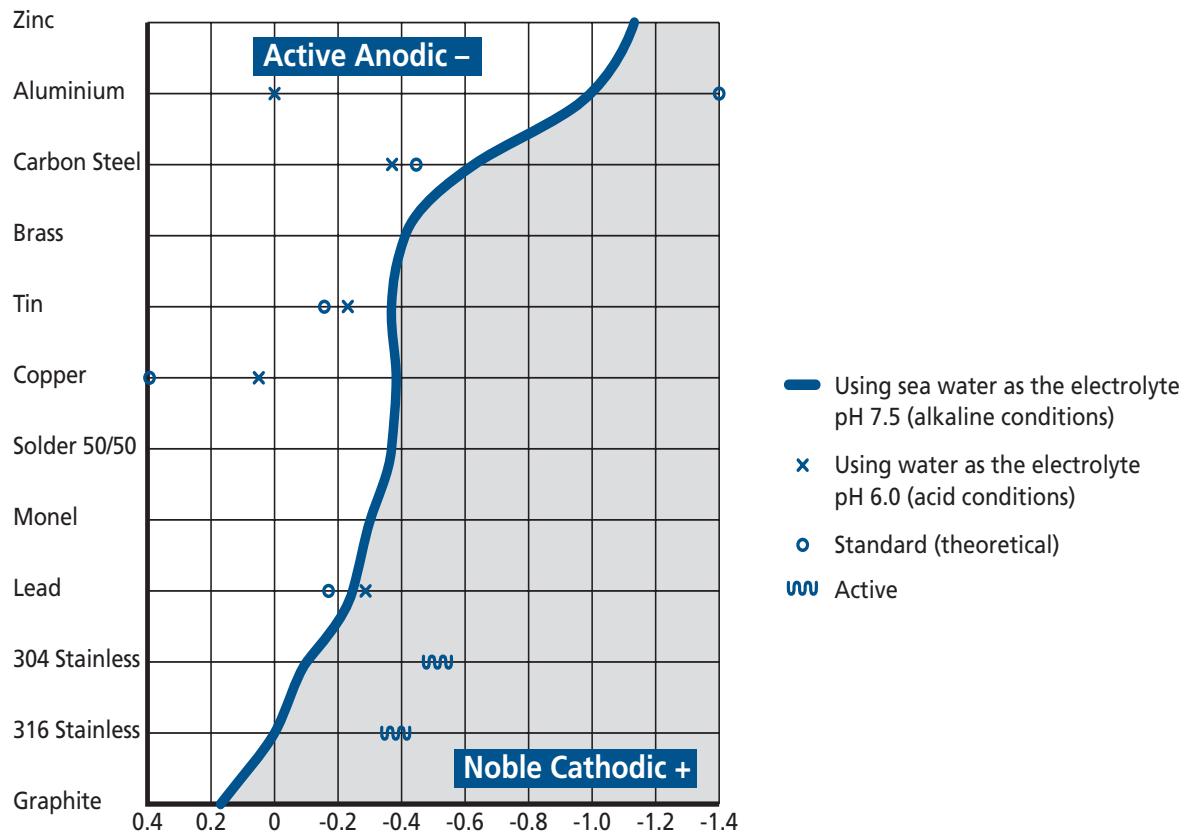
Polarity and voltage alter as can be seen in the table where the pH is altered. (*see table 2.4.9.*)

The surface relationship between anode and cathode is decisive in any fastening technique for metal cladding. If the fastener whose surface is small compared with the metal to be fixed becomes the anode, its current density will be high and the fastener will be subject to rapid corrosion.

e.g. an aluminium rivet in a copper sheet. When the opposite is the case the effect is not so great, which is why monel rivets have been used successfully for many years to join galvanised sheet and also the passivity of monel is a major factor.

From the table zinc is more active than steel and contact between steel and zinc, in the presence of moisture will cause the zinc to corrode or sacrifice itself, to protect the steel.

2.4.9 GALVANIC TABLE



Galvanic Series in Seawater pH 7.5
Volts vs Saturated Calomel Reference Electrode

Table 2.4.9. 

2.5 ENVIRONMENT

The performance of metal roof and wall cladding is very dependent on both the micro and macro-climates.

The micro-climate relates specifically to the design or position on the roof or wall, or a part of a building due to its orientation.

A major consideration of micro-climate is known as 'unwashed areas' i.e. areas not freely washed by rain.

Designers should be aware of unwashed areas and assess the suitability of the specified product in both micro and macro-climate for compliance with the durability provisions of the NZBC and this Code of Practice.

Unwashed areas are as listed in the Definitions and one such area is shown in drawing 2.6.7.B. (*see unwashed areas section 2.6.7.*)

2.5.1 ENVIRONMENTAL CATEGORIES

Although it is not possible to precisely define environmental categories, attempts have been made to identify specific areas in many Standards and publications. Because the definition of environmental categories is not an exact science, it is not possible to classify areas absolutely and a conservative approach is to apply the 'worst case' syndrome.

The environmental categories published in ISO and AS/NZS Standards are different and describe overlapping categories such as 'about', 'anywhere from' and 'several hundred metres', all of which preclude definition.

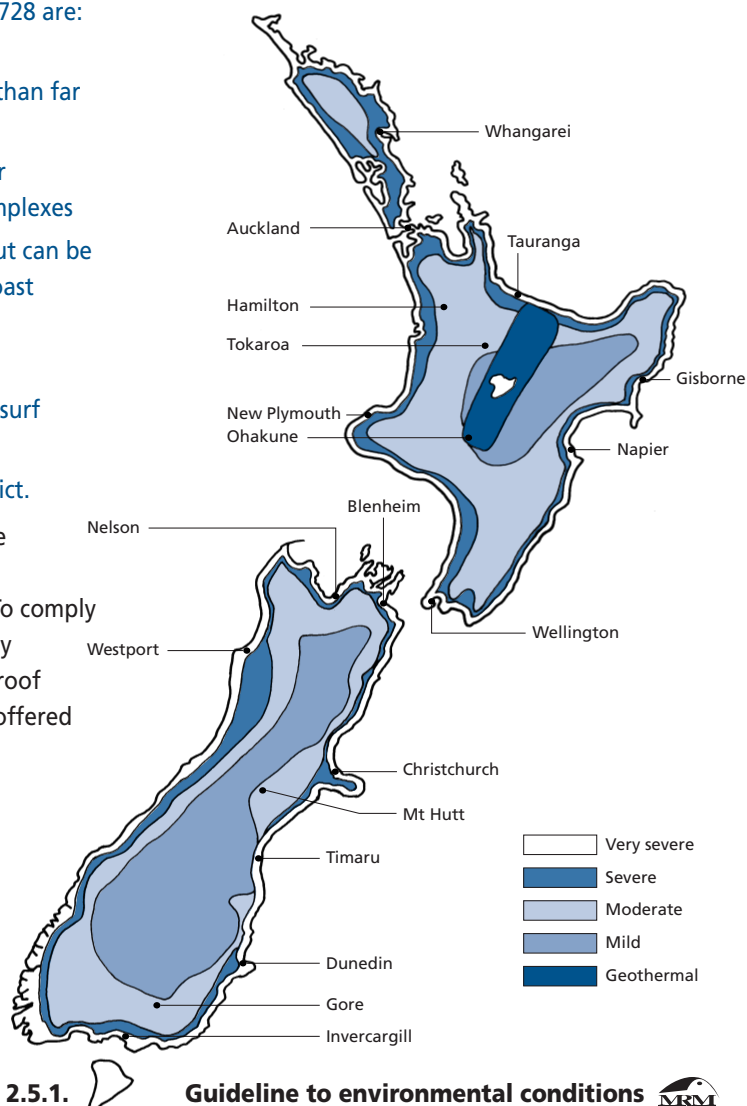
Normally, atmospheric corrosion increases in the order below however considerable local deviations do occur:

- | | |
|-------------|--------------------------|
| 1 very cold | 5 warm and humid |
| 2 cold | 6 moderately cold marine |
| 3 arid | 7 tropical marine |
| 4 moderate | |

The corrosion categories identified in AS/NZS 2728 are:

- | | |
|-----------------------|--------------------------------------|
| C1 Mild | Far inland |
| C2 Moderate | Inland other than far inland |
| C3-4 Industrial | Around major industrial complexes |
| C3 Marine | 300-1000m but can be 30km from coast |
| C4 Severe Marine | 100m-1000m from coast |
| C5 Very Severe Marine | 0-400m from surf and offshore |
| C5 Geothermal | Rotorua District. |

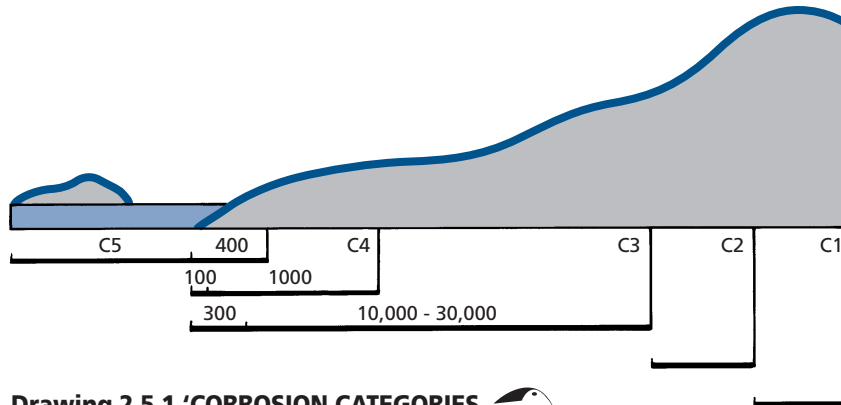
Suppliers of pre-painted metal offer alternative products, using different paint systems, paint thicknesses, metals and post-painted options. To comply with the NZBC these options should be carefully assessed and evaluated by the designer or the roof cladding contractor, before being specified or offered for any particular environment.



Map 2.5.1.

Guideline to environmental conditions





Drawing 2.5.1. CORROSION CATEGORIES 

Because Categories C5, C4 and C3 overlap, a subjective judgment call should be made by the designer or contractor to ascertain the most appropriate site category. If a warranty is required the advice of the supplier or manufacturer should be sought.

2.5.2 SPECIAL ENVIRONMENTS

In some areas in New Zealand where humidity or local conditions create an increased likelihood of corrosion, special consideration should be given to the specification and use of metal roof and wall cladding and accessories.

West Coast South Island.

The West Coast is characterised by high rainfall and a very severe coastal environment between the sea and the Southern Alps. It also has a predominance of coal burning fires that produce sulphur dioxide that is detrimental to metals. The combination of both of these factors means that either a shorter performance life should be accepted or the use of more exotic metals and or coatings considered.

Geothermal.

The North Island special conditions area drawn on map 2.5.1 is considered a special environment because of its geothermal activity. High humidity caused by steam bores and natural activity combined with Hydrogen Sulphide produce corrosive conditions. Some zones within this area close to bores or fumaroles are likely to have concentrations of hydrogen sulphide up to 5.0ppm.

Internal environments.

Internal environments with high humidity causing condensation, and pollutants generated within the building are considered to be special environments. These include:

- Swimming pools;
- Fertiliser works;
- Meat works;
- Animal sheds or shelters;
- Pulp and paper manufacturing

2.6 TYPES OF CORROSION

2.6.1 CREVICE CORROSION

Crevice corrosion occurs, as the name implies, in crevices and confined spaces. Crevices are often created as a consequence of the design of flashings and it is the duty of the roof or wall cladding fixer to avoid creating crevices that trap dirt and debris and which exclude oxygen.

Because passive films depend on oxygen for their continued integrity, metals which rely on their passivity for their corrosion resistance such as aluminium and stainless steel, are prone to crevice corrosion in the presence of moisture, particularly sea water. If the supply of oxygen in a crevice is limited, the ability of the metal to maintain passivity can be impaired. If the passive film is penetrated, a relatively small anodic or active area is exposed within the crevice, and because of the large cathodic or passive area outside the crevice, the localised corrosive attack will be extremely severe.

An oxygen deficiency can develop locally beneath drops of water, in wet thermal insulation, beneath protective coatings, through pollution, dirt and debris, and in laps where moisture can collect. Although air pollution is not a prerequisite for this type of corrosion, it will accelerate the process, and corrosion can occur even with a chemically neutral electrolyte. An example of this type of corrosion is the corrosion on metals underneath paint coatings and also 'white rust' the wet storage stain on close nested zinc coated roofing sheets. *See section 14.4.4. storage stain.*

2.6.2 PITTING CORROSION

Pitting corrosion is a form of highly localised corrosive attack that occurs in the form of pits which occupy a very small relative surface area, but which can be quite deep. Pitting can occur under particular conditions, which cause a protective passive film to break down at points where it has been weakened by contamination, or damaged. The presence in the corrosive medium of certain substances, such as chlorides in water, can promote pitting corrosion, such as the pitting attack on aluminium cladding in unwashed areas near the sea.

Pitting corrosion acts in a similar manner to crevice corrosion, and when break-through occurs in the oxide film, the actively corroding pit constitutes the anode and the large passive film surrounding the pit acts as a cathode surface. The rate of dissolution of the metal is strongly influenced by the ratio between anode and cathode areas, hence the "driving force" behind pitting attack can be very strong.

Resistance to pitting corrosion is strongly influenced by the nature of the passive film, and with coated steels, when the underlying metal is exposed. The presence or absence of oxygen clearly plays a part in the nature of the passive film and once started deterioration can proceed rapidly.

Corrosion on the underside of cladding or flashings can be caused by the accumulation of salts and other contaminants, that are not washed by rain or removed by maintenance. It can occur by the retention of condensation on the underside of capping flashings because of the lack of ventilation at a parapet wall. It can also be caused by condensation from the underside of the sheets, or by chlorine vapours from enclosed swimming pools or a corrosive ammonia environment from intensive animal farming or industrial processes.

Double sided organic coatings or stainless steel should be used in these environments.

2.6.3 POULTICE CORROSION

Poultice corrosion or 'under deposit corrosion' is caused when a collection of fine dust, such as that blown from the site of earthworks, quarries, or sawdust and shavings from timber processing plants collects in crevices behind laps or flashings, it can cause corrosion. The mechanism is such that because moisture is retained over a significant time, it produces the environment for metallic corrosion. The amount of debris collected can sometimes mean that the contaminated area never dries out, in which case the corrosion is severe and rapid. Bird droppings and sand can also cause this type of corrosion.

2.6.4 INERT CATCHMENT

Inert catchment corrosion is the term given to the rusting of unpainted galvanised steel by rainwater runoff from roof cladding such as glazed tiles, aluminium, fibreglass, precoated metals, glass or acrylic.

Rain water flowing over the zinc surface of unpainted galvanized metal roof and wall cladding dissolves traces of metal salts and minerals which can change its chemical nature and assist to promote and maintain the formation of zinc carbonate. This normally stabilised adherent and protective film protects the steel from atmospheric attack, however runoff from inert materials, together with condensation form carbonic acid and dissolve some of the protective film, with the result that the film does not stabilise. The unmodified runoff from inert materials causes rapid deterioration of the zinc coating to occur at the runoff points, creating corrosion and erosion, and is known as 'drip spot corrosion' for this reason.

To avoid inert catchment corrosion, do not use galvanised steel for valleys, guttering or downpipes on a pre-painted steel or zinc-aluminium coated steel roof or use it to drain rainwater from any inert material. Fibreglass or acrylic sheeting used in conjunction with galvanised steel cladding must run full-length down the roof and discharge into a gutter made from AZ coated steel or pre-painted AZ coated steel. Plastic sheeting or domes must not drain onto galvanised cladding or into galvanised gutters.

Aluminium/Zinc coatings have been shown not to suffer from inert catchment corrosion.

2.6.5 PONDING

Water or moisture is necessary to make a conductive solution to enable corrosion to occur.

To ensure that ponding does not occur, the minimum pitch for all metal roof cladding in New Zealand must be 3°. (see roof pitch table 4.8.1.)

Ponding can take place because of lack of fall, poor penetration design, excessive spans, or traffic damage, and consequently rainwater is retained in these areas. When this water eventually evaporates, it leaves behind a residue of concentrates that can be damaging when the next precipitation or dew occurs and so restarts the corrosion process. Damp debris and solar mats that retain moisture, all prolong the time that corrosion can occur.

In particular the interface at the area where wetting and drying occurs is very susceptible to corrosion, as can be seen where metal enters the soil, or where a gutter is continually holding water. Any debris such as wet gypsum board, wet insulation or fertilizer fallout, is particularly damaging to metal roof cladding and gutters.

All paint systems on pre-painted materials are permeable to a degree, and the only true barrier coating systems are high build coatings or plastic barriers that encapsulate the metal and even these can have 'holidays' in the coating. Due to the tanking effect, the protective chromates that are present in the pretreatment and the primer coating can be leached out due to immersion and then accelerated corrosion can occur. If corrosion is to be avoided good design and continued maintenance are required, as ponding is a major cause of metal corrosion. Ponding can occur in gutters and spouting when joints or outlets are higher than the sole of the gutter or when debris is left to accumulate however special PVC droppers can be used with metal spouting that minimise ponding.

Ponding leads to an increase in the 'time of wetness' that is a major contributing factor in the corrosion of metals. Turndowns are required on the ends of all roof cladding at pitches less than 8° and at the end of barge and apron flashings. End spans should be reduced in accordance with the requirements of this Code of Practice to avoid ponding caused by traffic damage. (*ponding as defined in the definitions*)

2.6.6 CAPILLARY

As the surface tension of water is greater than that of most other liquids its surface acts elastically. Smooth surfaces attract water to them as can be easily recognised when two glass surfaces are placed together with a drop of water between them. This interaction is called capillary action and the force that results is called capillary attraction, although the terms are commonly used as interchangeable. When porous materials become wet the capillary movement is often termed wicking.

Where two metal surfaces are mating or nesting closely together, any water that accumulates at the join will be attracted up between the two surfaces, and the vertical distance that this water will rise is dependent on the closeness of the two surfaces, the surface finish and the slope or pitch of the metal.

Gravity will affect the degree of capillary and steeply sloping valleys and flashings are not normally sealed because as their fit is imperfect, any water collecting at the joint will dry by evaporation.

If an air gap is introduced anywhere between the two surfaces the mutual attraction is broken and water will not rise. The method of introducing an air gap in roof and wall cladding and flashings, is to finish the overlap with a bead, hem or edged stiffener as shown in **section 5.2.2**.

Another way to avoid capillary attraction is to seal the lap.

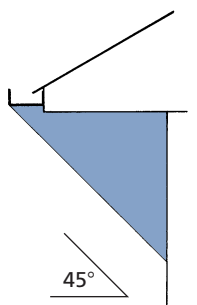
2.6.7 UNWASHED AREAS

Unlined soffits, spoutings, overhangs, sheltered walls and the upper part of garage doors require special design details, particularly in severe and very severe environments. Areas on a building that seldom receive the benefit of rain-washing gather salt, dust and other contaminants on these unwashed surfaces, then as condensation, dew or humidity moistens these particles, a reaction between them and the coated sheeting occurs. This reaction produces a white zinc corrosion product often seen on the underside of gutters, canopies, under roof vents or on sheltered areas of wall cladding. It can also occur on pre-painted steel in a severe or very severe environment, where the painted surface mirrors the microcracking of the Z or AZ coating.

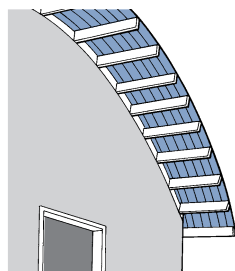
A building should be designed so that all areas of the structure receive adequate amounts of exposure to the rain. When this is not possible a maintenance programme is required as these areas should be washed down if premature corrosion is to be avoided. Walkways, snow boards, solar mats or any equipment should be fixed clear of the roof cladding and should not produce an unwashed area.

Where roof cladding does not have a closed soffit, and where canopies have large unwashed areas on the underside, such as dock-ways and service station canopies, more exotic coatings or double-sided coated material should be specified.

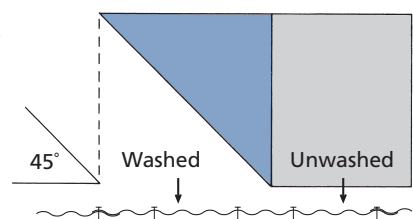
As unwashed areas are likely to suffer three to four times the corrosion rate of washed areas, the building occupier or owner should be made aware that maintenance of unwashed areas is required. (*see maintenance section 13*)



Drawing 2.6.7.A 



Drawing 2.6.7.B 



Drawing 2.6.7.C 

2.6.8 CORROSION RATE

The corrosion loss rate is expressed in weight per unit surface area, as the original weight, minus the actual weight, divided by the number of years exposure or the thickness of the layer loss per time unit.

The loss of metal or organic coating thickness over a certain period of time can be measured, but the use of an eddy current meter for this purpose should be used with caution and expertly evaluated. The type of meter should be suitable for the range of coating thickness and be calibrated every time it is used.

The corrosion rate depends on external conditions such as humidity, temperature, and the degree of air pollution and is particularly influenced by the 'time of wetness' and the pH of the rainwater. The climate plays a decisive role when longer periods of time are considered, as cold temperatures slow down the corrosion rate and high temperatures accelerate it.

Any maintenance programme will slow corrosion down and in some cases prevent it altogether.

It is the owners responsibility to decide on a time that is described as the 'Time to repaint decision'.

2.6.9 SOLAR COLLECTORS

The Acceptable Solution G12/AS2 allows for the direct fixing of solar collectors to metal roof cladding and this is not acceptable trade practice.

Solar collectors must not be fixed directly to metal roof cladding. The collector must be mounted so that there is provision for cleaning, washing and maintenance with a minimum of 100mm clearance between the collector and the metal roof cladding. Such cleaning must be carried out every three months in severe environments.

The mounting of any collector to create an unwashed area voids the manufacturer's warranty. Without a minimum of 100mm clearance it is not possible to brush down the tops of the cladding ribs and to prolong the life of any metal roof.

A suspended solar collector is very likely to cause condensation underneath it which will also collect on the roof cladding. Such condensation can accumulate contaminates and if premature deterioration is to be avoided, a maintenance program is required to remove the corrosive salts and dirt that cause corrosion. The person who creates the unwashed area is responsible for any subsequent damage.

Any structure fastened through metal cladding must comply with the compatibility Table 2.7.2 for both contact with and runoff from, dissimilar metals or materials and the other good trade practices contained in this Code of Practice.

Any structure fastened through the cladding must not inhibit the expansion allowances provided e.g. secret fix roof cladding.

The best method of installing a collector on a roof is to assume it is a penetration in a similar manner to a skylight or powered ventilator. In this way the mounting is made to the structure and the penetration flashings are made as detailed in section 6. This also automatically provides protection for any copper pipes, avoids the likelihood of runoff and gives them added insulation value because they are not exposed.

This is the only recommended method for mounting solar collectors on metal roofs because it does not create an unwashed area underneath it and does not require maintenance. For larger collectors and photo voltaic arrays the details shown in 6.2.10 should be followed.

2.7 COMPATIBILITY

Materials comprising the building envelope, although required to meet particular design criteria, should not be considered in isolation.

2.7.1 DISSIMILAR MATERIALS

A component, which may appear suitable, may prove unsatisfactory in service because of an unknown or unrecognised incompatibility with other material or substance in contact with it.

When different metals or materials discharge rainwater onto metal roof and wall cladding or gutters, accelerated corrosion may occur even though there is no direct contact between them. When a noble metal dissolves in water and flows over a less noble one, the more noble metal will deposit on the less noble metal and corrosion conditions will apply. (see *compatibility table 2.7.2.*) and (*galvanic table 2.4.9.*)

2.7.2 COMPATIBILITY TABLE

The compatibility table should be regarded as indicative only, because of the many permutations of environment, the amount of moisture present and the relative size of the components.

The indicator for use with caution in moderate environments should be interpreted as a warning that it could be unsuitable for any use if adverse effects of continued moisture or other contaminants could be present. The use of the words 'Aluminium' and 'Stainless Steel' should be regarded as a generality because of the numerous alloys of those metals available and some will be more suitable than others will be. Timber is generally acidic although some timbers such as cedar are more acidic than others and the interaction between preservative treated timber and metal is dependent on the moisture content of the timber, the type of treatment and the length of any drying cycle.

The environment will substantially alter the rate of corrosion, particularly in coastal areas or areas of high humidity.

Where the use of dissimilar metals is unavoidable, an inert material such as a synthetic washer or paint coating can be used as a separator, however long term corrosion resistance becomes dependant on the ability of the separation to remain effective. In order to minimise the risk of corrosion when using dissimilar metals they can also be isolated with butyl or PVC insulating lap tapes, polythene, silicone sealant or in the case of fasteners, an EPDM sealing washer.

All metals should be separated from mild steel structural members by a butyl or polyethylene DPC strip because paint is not considered to act sufficiently as an isolator.

For cut edges of coated steels see *section 2.3.1.*

When metals dissimilar to the roof cladding are used for gutters and spouting there can be splashing, or contamination due to the evaporation of condensate and for this reason special provisions such as painting the inside of a copper spouting, or the provision of an apron flashing should be made when using copper or lead gutters or spouting in conjunction with coated steel roof cladding. (see *13.3.*) The top of copper spouting should not touch coated steel cladding or tiles and should be separated by the underlay and the inside of the copper spouting should be painted.

AZ coated steel or aluminium should not be used as a flashing embedded in concrete or masonry, unless the AZ coated steel or aluminium is pre-painted or protected by a high-build barrier coating. To prevent deterioration of the embedded metal flashing, the plaster, which has a high alkaline content should remain dry after curing and be protected from the entry of water into cracks in the plaster or concrete. Coal-tar based polyurethane or bituminous paints can be used to protect Zinc or zinc coated steel embedded flashings into concrete.

- Suitable
 ● Suitable but may stain
 ● Use with caution
 ✕ Not suitable

		Aluminium	Pre-painted aluminium	AZ coated steel	Zinc coated steel	Pre-painted AZ steel	Zinc	Copper/Brass	Stainless steel	Lead	Plastics/glass	Concrete & plaster - wet	Concrete & plaster - dry	CCA treated timber
Aluminium	Contact with	○	○	○	○	○	○	✕	○	✕	○	✕	●	✕
	Runoff onto	○	○	○	✕	○	✕	○	○	○	○	●	●	○
Pre-painted aluminium	Contact with	○	○	○	○	○	○	✕	○	✕	○	✕	○	✕
	Runoff onto	○	○	○	✕	○	✕	○	○	○	○	○	○	○
AZ coated steel	Contact with	○	○	○	○	○	○	✕	●	✕	○	✕	○	✕
	Runoff onto	○	○	○	✕	○	✕	○	○	○	○	●	●	○
Zinc coated steel	Contact with	○	○	○	○	○	○	✕	●	○	○	○	○	✕
	Runoff onto	○	○	○	○	○	○	○	○	○	○	●	●	○
Pre-painted AZ steel	Contact with	○	○	○	○	○	○	✕	●	✕	○	✕	○	✕
	Runoff onto	○	○	○	✕	○	✕	○	○	○	○	○	○	○
Zinc	Contact with	○	○	○	○	○	○	✕	●	○	○	✕	○	✕
	Runoff onto	○	○	○	○	○	○	○	○	○	○	●	●	○
Copper/Brass	Contact with	✕	✕	✕	✕	✕	✕	○	●	●	●	●	○	○
	Runoff onto	✕	✕	✕	✕	✕	✕	○	○	●	●	●	○	○
Stainless steel	Contact with	●	●	●	●	●	●	○	○	○	○	○	○	○
	Runoff onto	○	○	○	✕	○	✕	○	○	○	○	○	○	○
Lead	Contact with	✕	✕	✕	○	✕	○	●	○	○	○	○	○	✕
	Runoff onto	●	✕	✕	○	✕	○	○	○	○	✕	●	●	○
Plastics/glass	Contact with	○	○	○	●	○	●	●	○	○	○	●	○	○
	Runoff onto	○	○	○	✕	○	✕	○	○	○	○	○	○	○
Concrete & plaster - wet	Contact with	✕	✕	✕	○	✕	○	●	○	○	●	○	○	○
	Runoff onto	✕	●	✕	○	✕	○	●	○	○	✕	○	○	○
Concrete & plaster - dry	Contact with	●	○	○	○	○	○	○	○	○	○	○	○	○
	Runoff onto	●	○	○	○	○	○	○	○	○	○	○	○	○
CCA treated timber	Contact with	✕	✕	✕	✕	✕	✕	○	○	✕	○	○	○	○
	Runoff onto	✕	✕	✕	✕	✕	✕	○	○	✕	○	○	○	○

Table 2.7.2. 

Use with caution - may mean separation required, or unsuitable in severe environments.

Wet concrete includes uncured concrete, fibrecement, or within plaster walls.

Dry concrete includes cured concrete not exposed to rain.

Bitumen, however should not be exposed to degradation by UV as the oxidation of bitumen forms a water soluble acid, which when combined with moisture from humid air can attack zinc.

Coal-tar based polyurethane or bituminous paints can also be used to protect aluminium from corrosion by wet plaster or when concrete or plaster is curing.

Stainless steels are unaffected by embedment into concrete and do not corrode other metals by run-off, however they should be separated from other metals in severe and very severe environments.

2.7.3 RUNOFF CORROSION

The combination of hot water and copper is very detrimental to all types of roofing.

Hot water from the exhaust pipes of hot water cylinders or pressure relief valves must not be permitted to discharge onto metal roofs. The insulation to copper pipes of solar panels, air-conditioning or other ancillary equipment must be sealed to avoid runoff onto all metal cladding or gutters other than copper.

An air space underneath any solar panels must be provided to allow for ventilation to avoid condensation.

Solar heating rubber mats must be made of a compatible material and must not be placed directly on a metal or painted surface.

Because all exposed timbers are required to be H3 treated and because these timbers are not coloured for easy recognition, no timber must be used where it provides runoff from or contact with metal roof and wall cladding. This includes walkways, gutter boards, support framing for air-conditioning or solar collectors and only aluminium, stainless steel or hot-dipped galvanized steel framing members are acceptable.

Flues and fume extractors can produce condensate that is damaging to any metal roof or wall cladding and should be filtered at the source.

2.7.4 FALL-OUT CORROSION

Corrosion of metal cladding can be caused by the fall-out from chimney heaters and boilers using wood, oil or other fuels. The burning of resinous woods, low-grade coal or oils with a high sulphur content can result in a fall-out deposit or condensate from flue gas. To minimize this problem, the flue should be at a sufficient height that will create a good draft, and it should be sheathed to provide a higher flue temperature, which avoids cooling of the gas that will form condensate, and it also minimizes fall-out.

Exhaust fans can also cause similar corrosion problems when corrosive gases are not filtered at their source.

2.8 ORGANIC COATING PROTECTION

2.8.1 UNDERSIDE PROTECTION

The underside of pre-painted steel has only the protection of a primer and a thin backercoat and if the sheeting is to be exposed to a severe environment and is unwashed, then further protection is required to avoid deterioration from the underside. Where roof cladding is designed without a closed soffit, the underside of the sheet should be painted before installation as this area is unwashed. Double-sided and barrier coated materials are available with the same durability on both sides, but such materials are subject to a special order and minimum quantities.

Rainwater dissolves traces of metal salts and minerals from the roof cladding which promotes the formation of a hard adhesive and protective film on bare galvanised steel, ZA coatings and aluminium sheeting, however the underside does not receive this benefit.

To avoid early deterioration all metal cladding surfaces should be kept dry.

All undersides of cladding, gutters and fascias should be included in a maintenance programme to ensure that they will comply with the durability requirements of the NZBC.

Internal environments can produce underside corrosion from chlorine from swimming pools and fumes from processing plants and ammonia from animals in animal shelters. Closed or open structures housing pigs, chickens, cows or sheep are subject to corrosion from any condensate, and special ventilation provisions are required. Closed structures may require powered ventilation, as passive ventilation may be inadequate to prevent the build-up of contaminants. Protective paint systems or an alternative metal should be considered.

2.8.2 COLOUR DIFFERENTIAL

It is both the cladding manufacturers' and the roof cladding contractors' responsibility to ensure that the same brands of pre-painted material are used on the same building.

Failure to do so could result in differences in colour, gloss and weathering which becomes obvious within a short period of time. These differences come from different paint formulations and do not necessarily indicate that the materials will perform differently in service. Branding on the reverse side of uncoated and colour coated steel gives information on the manufacturer, type of coating and the date of manufacture and is provided by all N.Z. manufacturers. Double-sided coatings are not branded.

2.8.3 TOUCH UP

Air-drying touch-up paints have different weathering characteristics to the baked-on finish of pre-painted coating systems and variations in natural light conditions will emphasise these differences producing an unacceptable aesthetic appearance.

Spray cans should not be used for repairing scratches on pre-painted sheeting.

If the scratch is obviously visible from 3m then the sheeting should be replaced, if it is not, then it should be left alone. Minor surface scratches become less noticeable as the coating weathers and are best left as they do not appreciably affect the corrosion inhibiting properties of the material. However, widespread damage caused by rough handling or accident should not be corrected by repainting but by replacement of the affected material.

2.8.4 LAP PRIMING

End laps should be avoided. (see 4.1.8)

Edge laps on profiled sheets do not require priming as they are designed with capillary grooves to drain naturally or other means to avoid the accumulation of condensation or rainwater. The priming of coated steel laps has been shown to increase the likelihood of corrosion when moisture is trapped in the lap and does not drain.

Laps should not be primed as primers are porous and can lead to early deterioration.

The minimum fall recommended for each profile ensures that laps drain naturally, although if snow or hail could accumulate for long periods edge laps should be sealed.

2.8.5 STRIPPABLE FILMS

Strippable plastic film coatings are available from the paint coating manufacturer to protect and prevent damage to pre-painted material used for roof and wall cladding and accessory products during roll forming, installation and transportation.

It is important that all film-protected metal should be stored dry, and out of direct sunlight and the film removed as soon as possible after installation. Where laps occur the film should be removed prior to installation and when drilling for fasteners the film should be removed after drilling but before fixing.

The protective film must never be left in a joint that is to be sealed as silicone and other sealants will not adhere satisfactorily to it.

The film should not be exposed to UV or left exposed for more than a few weeks after installation as it may be difficult to peel off. Any film should be disposed of in an environmentally responsible manner.

2.9 FATIGUE

The performance of metal roof and wall cladding is affected by stress as all metals are subject to fatigue under loading conditions.

It is not generally known that metal cladding can fail at a much lower point than the yield stress when movement is taking place under continued fluctuating stress. A cyclic load test is used to determine the performance of cladding under load reversal. For this reason load spreading washers are used in those areas that are subject to high wind design loads, to avoid any stress cracking at the hole in the metal made at fixing points.

All metal joints will suffer stress because of movement caused by expansion, vibration, traffic or wind, and a sealed joint should have sufficient fasteners to mechanically resist this stress which cannot be resisted by any sealant or solder alone.

High strength steel is subject to fatigue, and other metals such as lead and copper are restricted in length or the overall panel size to avoid cracking by fatigue. Sharp folded corners should be avoided on these materials and the minimum radii requirements should be followed.

As fatigue failure can be the result of a design or installation fault, the length limitations placed on all metals described in this Code of Practice should be adhered to if fatigue failure is to be avoided.

3.0 LOADINGS

The information contained in this section is intended to provide an understanding of the various factors used in deriving a design loading for the installation of metal roof and wall cladding. Additional reference should be made to the appropriate standards (*see section 1.6*) and to manufacturers published load/span graphs or tables. The designer should be aware of the requirements of this section of the Code of Practice and should follow the procedure *in section 3.4* to establish the maximum spans and fastening patterns to comply with the NZBC. (*see section 2.1.1. structure.*)

In most instances, the designer will determine the design load values on the cladding and therefore he should determine the fastener frequency and the design of flashings. Much of the damage caused to metal roof cladding occurs because of the lack of knowledge or disregard of the limitations of the metal cladding, as outlined in this section.

It is the responsibility of the roofing contractor to inform the designer or owner of any perceived or real shortcomings in the detailing or the design loading requirements of the metal roof and wall cladding before any work is commenced.

This section is not intended as a substitute for professional determination of the design load values as applied to metal roof and wall cladding. However, by means of factors and multipliers, a conservative value can be calculated for a specific building by using the information and load/span graphs contained in this Code of Practice (*see section 3.9*)

N.B. Manufacturers' published load/span graphs may not use the same design or test criteria.

By this means it is possible to comply either with NZS 3604 load requirements or those of AS/NZS 1170 as where these values differ, the most conservative or best practice solution is used.

3.0.1 AS/NZS 1170: 2002

Roof and wall cladding is required to comply with the requirements of the NZBC clauses B1, B2, E2, E3, and also with AS/NZS 1170 which is referred to in this Code as the 'Loadings Code'.

The Loadings Code is written in limit state format and is used where buildings are specifically designed, when the engineer or architect will decide what design loads are appropriate for a particular building. There are a number of alterations in the Loadings Code from previous requirements, and designers should be aware of these changes. Confusion can occur when comparing manufacturers previously printed technical literature if it has been published using different criteria or test values or using working stress design.

In AS/NZS 1170, a load is now termed an "Action", however the term "load" is synonymous and is used in this Code of Practice.

The four load categories relevant to metal roof and wall cladding for buildings determined from the Loadings Code.

- the wind forces, resulting from local wind flow acceleration effects as the wind flows around the building, This force increases with the height above the ground because the influence of ground surface drag decreases. (UDL, Uniformly Distributed Load)
- the dead load, being the self weight of the structure and the permanent part of any imposed live load, such as an air conditioning unit.
- the live load, being the variable load imposed on the building by its occupants and contents, such as a person standing on the roof. (point load)
- induced loads such as snow or ice, and ponding rainwater.

When a structure or part of it, fails to fulfil its expected basic functions, it is said to have reached a limit state. There are two limit states - Serviceability and Ultimate.

- Serviceability is a state when a building, or any part of it, becomes unfit for its intended use due to deformation or deflection.
- Ultimate is a state associated with collapse or failure or when a building or any part of it becomes unstable or unsafe.

These limit states are not specifically assigned to metal roof and wall cladding but are intended to be applied to the building structure. Because the prime function of metal roof and wall cladding is to exclude water from the structure, failure at the serviceability limit state, can quickly lead to failure at the ultimate limit state and in this Code of Practice, serviceability is assumed to be a failure criteria. The instances of metal cladding failing under a ultimate limit state load is rare, and caused by lack of fixings or the absence of flashings or aberrations caused by tornados, or failure of the structure. There is however, recent evidence that a serviceability failure of a roof, e.g. a leak, can subsequently cause ultimate structural failure of untreated timber.

3.0.2 NZS 3604: 1999

NZS3604 is an acceptable solution for compliance with the NZBC for light timber frame buildings not requiring specific design. If compliance with this Standard is sought, reference should be made to NZS3604. It contains prescriptive dimensions for purlin spacings and fasteners based on maximum design wind speeds of Low 32m/s, Medium 37m/s, High 44 m/s, or Very High 50 m/s.

Some of the limitations of the scope of NZS3604 are:

- Timber frame construction
- Height from lowest ground to the highest point on the roof not to exceed 10m
- A snow load not exceeding 1.0.kPa
- Includes private dwellings, hostels, hotels, nurse's homes
- Includes factories with restricted floor loadings
- Includes institutional and educational buildings with restricted floor loadings
- Excludes buildings dedicated to the preservation of human life
- Excludes buildings which contain people in crowds
- Excludes publicly owned buildings containing high value contents
- Excludes curved roof construction

NZS3604 is based on NZS 4203 and uses conservative figures to arrive at a design load. This NZ Metal Roof and Wall Cladding Code of Practice also uses the same philosophy of conservative simplification in order to prescribe a value that is known to perform either historically or by test, and which will therefore comply with the NZBC.

The monetary penalty for this conservatism is small in comparison the overall cost of the whole of the building, and unless the building is specifically designed, designers and contractors should not deviate from the loading requirements of this section of the Code of Practice.

It should be noted that the classification of NZS 3604 wind zones can be misleading because of the additional factors that are applied to a wind speed to calculate the wind design load e.g. kl factor *see section 3.3.2*

Wind Zone Ultimate limit state

Low	(L)	=	32 m/s	=	0.61 kPa
Medium	(M)	=	37 m/s	=	0.82 kPa
High	(H)	=	44 m/s	=	1.16 kPa
Very High	(VH)	=	50 m/s	=	1.50 kPa
Specific Design	(SD)	=	Requires AS/NZS 1170.2		

3.0.3 TYPES OF LOAD

Imposed Loadings on roof cladding are generally classified into two distinct types:

1. POINT LOAD (Concentrated live Load) (section 3.2)

2. U.D.L. (Uniformly Distributed Load) Wind (section 3.3) and Snow (section 3.5).

1. A point load is representative of a workman with a bag of tools, which is calculated at 112 kgs = 1.1 kN. As required by AS/NZS 1170.1 the point load is taken as 1.1 kN over an area of 100 mm diameter in the case of a person, or in the case of a superimposed load, such as an air conditioning unit, the area of contact if the load is not directly attached to the structure. A point load on a roof is always positive or downward (+).
2. A U.D.L. is either a wind load or a snow load. This load is variable as a wind load and is dependent on the location of the structure and many other factors, but does not often exceed 6 kPa.

Wind load is assumed to be an uplift load as being negative (-) and the most severe, and snow load is taken to be a downward load. (+). (see section 3.3.)

Different values are required for each loading condition, as the reaction of cladding to a point load and a U.D.L. is different. A wind load is considered as acting over the total area of the roof at the same time, whereas a point load is considered to be a 'worst case scenario', i.e. at a centrally loaded end or intermediate span on the under-sheet at the lap.

In many cases the point load will govern, as it is often the most severe of the imposed loads and will determine the purlin spacing of roof sheeting for design purposes, however the peripheral purlin spacings may have to be reduced in high wind design load areas or the fastener frequency increased.

Manufacturers roof and wall cladding design load data should be published with both point and U.D.L. loadings performance values given, however it can be assumed that traffic point loading can be ignored on walls or on buildings with roof pitches > 35°. These categories are described as 'No Access', and are required to withstand a point load of 0.5Kn.

3.1 PERFORMANCE UNDER LOAD

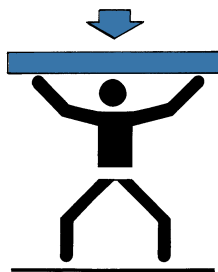
The performance of profiled metal cladding under wind, snow and point loads is dependent on its ability to resist the tensile (pulling), compression (squeezing), and shear (sliding) forces that it is likely to be subjected to during the lifetime of the building.

Tension (stretch)



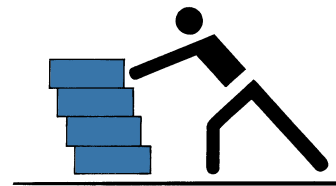
Drawing 3.1.A. 

Compression (squash)



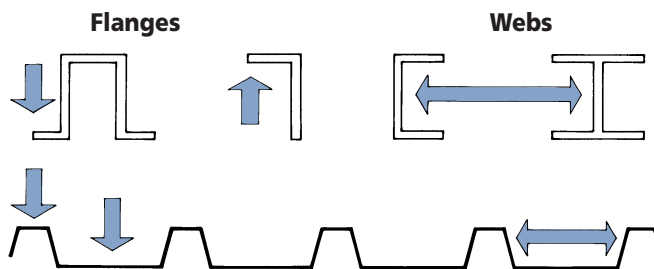
Drawing 3.1.B. 

Shear on fasteners (slide)



Drawing 3.1.C. 


Profiled metal cladding acts as a beam, which derives its strength from the ability of its flanges (pan and the crest), separated by the web to resist tensile and compressive forces. This strength can only be maintained while those parts in compression are restrained from buckling.



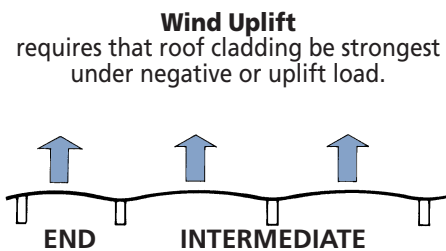
Drawing 3.1.D 

When a roof sheet deflects downwards under point load, the pan of the profile is placed under tension and the crest under compression, but in the adjacent continuous span, this condition reverses.



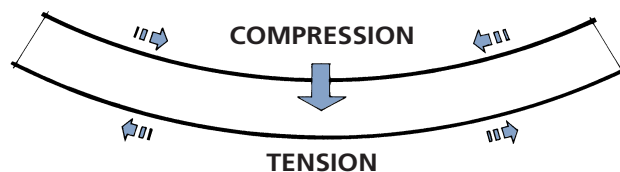
Drawing 3.1.E 


Under wind suction loading when all spans of the roof sheet are assumed to deflect upwards, the crest of the profile is placed under tension and the pan under compression, and the deflection and stress patterns are the reverse of those for point load.



Drawing 3.1.F 

The result of stress is **Deflection** which is the precursor for **Failure**. Steel is strong in tension.



Drawing 3.1.G 

To determine the performance of corrugated and low rib trapezoidal profiles, reference should be made to section 3.9. For all other profiles reference should be made to manufacturer's load/span tables, which give the maximum recommended span for end and intermediate should check precisely what is included in the load figures and determine the appropriate loading parameters because all manufacturers do not always present data in the same format.

The designer must carry the responsibility for considering all modes of loading relevant to each area of cladding to determine the performance requirements before completing their specification.

3.1.1 DEFLECTION

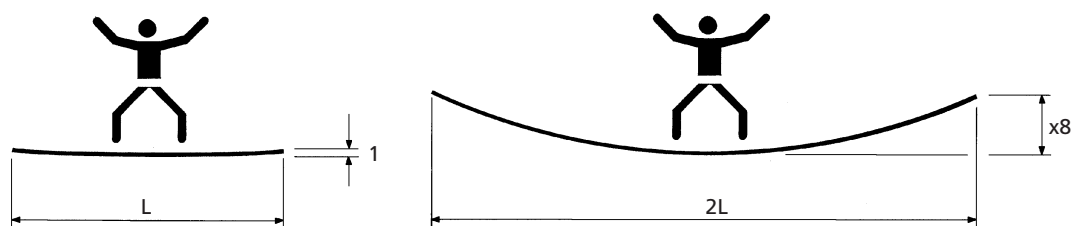
Deflection is a measured deformation of roof or wall cladding under a load but recognition should be made of the difference between permanent and temporary deflection.

When using high strength self supporting cladding, any temporary deflection under load can be ignored, because it is within the elastic limit of the steel and only permanent deflection is regarded as significant as it is the indication of failure in high strength claddings.

When roof cladding is made from low strength steels or non-ferrous metals, deflection is considered of greater importance because the material can progressively yield under wind loads or is deformed by constant foot traffic, which in turn depreciates its performance. Machine roll curved and some crimp curved cladding and metal roof tiles are usually made from low strength steels and are not intended for roof traffic.

Deflection varies with the cube of the span and so span becomes a very important criterion in the design and use of metal roof and wall cladding. As can be seen from *drawing 3.1.1.A*, the deflection of a simply supported span is increased eight times by doubling the span.

Simply supported span Deflection varies with span³



Drawing 3.1.1.A. 

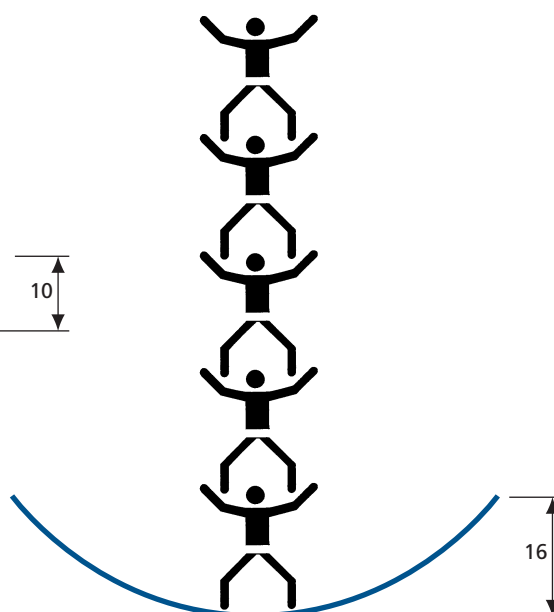
The position of the load greatly affects the deflection as shown in *drawings 3.1.1.B & C*, using a load of one man to the metre, by changing the load from a U.D.L to a point load in *drawing 3.1.1.C* the deflection is increased by 60%. For this reason point load is taken to be the most severe criteria for metal roof cladding.

Simply supported span

Deflection varies with the position of the load

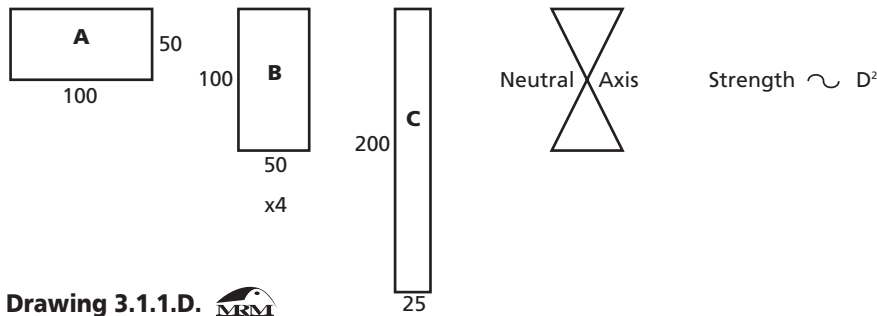


Drawing 3.1.1.B 



Drawing 3.1.1.C. 

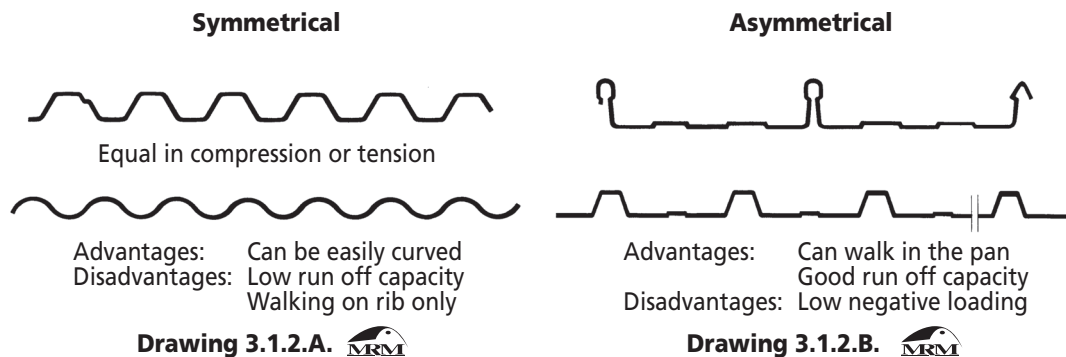
The depth of the profile of metal cladding is also a very important criterion in the design and use of metal roof and wall cladding. Given the same design criteria the deflection of the profile will vary with the square of the depth.



Drawing 3.1.1.D. 

3.1.2 SECTION PROPERTIES

The performance of each different profile of metal cladding cannot be accurately determined by their 'Section Properties' as these change during deflection, and there are various attributes or effects that can be recognised by looking at individual shapes or profiles of metal sheeting. A common profile traditionally used in roof and wall cladding has been 'corrugated iron' - a sinusoidal, or partly circular profile, which is symmetrical and therefore performs equally well under positive or negative loading or either side up, and has its 'neutral axis' through the centre of the profile or halfway depth.



Symmetrical trapezoidal or ribbed profiles manufactured in New Zealand have the advantage of being easily curved around a radius. Because the ribs are necessarily close together, they have the disadvantage of always being in compression when under point load although the load is spread over several ribs. They also have the disadvantage of a low run-off capacity.

Most profiles fixed on non-residential roofs in N.Z. are asymmetrical trapezoidal or ribbed profiles, with ribs formed at various spacings and different heights. The angle and height of the trapezoid rib is important when placed in compression as the steeper the angle the better the performance, but the cost efficiency is reduced. The rib spacing determines the position of the neutral axis, which is the point of zero stress, and the further apart the ribs, the lower from the centre is the neutral axis. When sheeting is loaded positively as it is under point load, the lower the position of the neutral axis, the better the performance, however when loaded negatively (wind) the opposite is the case.

Ideally roof sheeting should have a similar performance under both positive and negative loading. Because only symmetrical sections behave in this manner a compromise is sought by profile designers for optimum design when designing asymmetrical sections, and computer programmes are used to compare the 'Moment of Inertia' (deflection) and 'Section Modulus' (strength) of different profiles.

Strength and deflection are interrelated but not interdependent, and the design strength is determined by the stress (f), at which permanent deformation occurs. Stress is determined by the section property known as the Modulus of Section (Z). Although it is possible to calculate the sheeting performance from the section properties of the profile, only physical testing can prove the actual capabilities of the profile. Under increasing loads the deflection is changing the shape of the profile, and thus the section properties are continually changing, so that any assumptions about section properties become invalid. *(see section 3.8 testing)*

Deflection under load depends on the particular profile section dimensions or section properties, and is determined by the Moment of Inertia (I) and Young's Modulus (E). The value of E varies with the metal being considered which means that the same cladding profile made in aluminium will deflect to a greater degree than steel simply because it has a different E value. *(see section 15.3)*

The strength or grade of the metal does not affect the deflection, so a high strength steel profile will deflect to the same extent as low strength steel profile, but using high strength steel will increase the point at which yielding occurs. In practice, traffic damage to ribs occurs because workmen or owners do not understand that the rib is the weakest part of any roof to stand on, and by designers ignoring the end span reduction requirements. *(see section 14.6. walking on roofs.)*

3.1.3 CONTINUITY

The performance of roof cladding under point load is dependant on the continuity over several spans.

For this reason it is important to understand the relationship of strength and deflection when using multiple span profiled metal cladding.

The reaction due to a point load in an adjacent span assists the performance of profiled metal cladding as continuity can reduce deflection up to 50%.

The spanning performance provided by high strength profiled metal sheeting over long intermediate spans is provided by sharing the load, which does not occur in the same manner at end spans. *(see drawing 3.1.3.)*

Many hundreds of tests for point load have established a finite relationship between the end span and the intermediate span, when both spans will fail at approximately the same load, irrespective of the length of the span, profile or thickness. This end factor varies between .55 and .75, which for simplicity is taken to be .66.

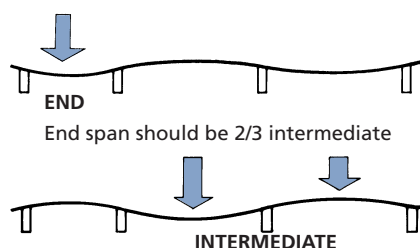
To efficiently design the spans of profiled metal cladding for both point and wind load, the end span should be reduced to approximately 2/3rds of the intermediate span.

Once the intermediate span has been calculated from the design load criteria and manufacturers load span graphs consulted, to obtain equal performance of the end and intermediate spans, the intermediate span should be multiplied by .66. The failure of end spans when subjected to foot traffic is due to neglect of this requirement.

The eave end span condition which gives rise to discontinuity, occurs also at the ridge, any roof step and on both ends of any penetration where any full width sheet is cut. Additional purlin support is therefore required at all penetrations that should be spaced at a distance to equal the end span spacing. Although these requirements are for point loading only they are also necessary for a wind load. *(see section 3.3. wind load.)*

Continuity
reduces deflection up to 50%

Drawing 3.1.3. 



3.2 POINT LOAD

The point load requirements of this Code of Practice classify roof and wall cladding as:

Type 1. Areas that can be accessed from opening windows or awnings. 1.8.kN.

Type 2. Areas that require access for maintenance purposes (including safety mesh) 1.1.kN.

Type 3. Areas for which support ladders or boards are required for maintenance access (including transparent surfaces) 0.5kN

Type 1 classification is intended to allow for people assembling to watch a parade or any similar situation.

Type 2 classification is for all other roofs that are readily accessible.

This classification is divided into two categories: Type A 'Unrestricted Access'

Type B 'Restricted Access'

- Type A is where a person may walk anywhere on the roof cladding.
- Type B is where access is restricted to walking within 300mm of the purlin line, and in the pan of the profile. Where the pan of the profile is < 100mm wide, any live load must be spread over two or more ribs.

Type 3. classification is for roofs that are not readily accessible. N.B. roof surfaces > 35° are regarded as unsafe or unable to be walked or worked upon without special provisions being made. Walls are included in this category.

As the 1.1 kN load is meant to represent the weight of a workman carrying tools and standing on one foot, no-one weighing over 112 kg, may walk on any roof cladding at mid span or on a rib, because the roof cladding has not been tested or designed for their weight.

The point load test is taken as 1.1 kN over an area of 100 mm diameter in the case of a person, or the area of contact in the case of a superimposed load if it is not directly attached to the structure.

Where roof access is required for maintenance and walkways are not provided, a minimum thickness of .55 mm for steel and a minimum thickness of .90 mm for aluminium roof sheeting must be used.

Temporary walkways or other provision should be made by the roofing contractor when 0.40 mm steel or 0.70mm aluminium roof cladding is used, to ensure that any damage is not caused by workmen or other following trades. (see section 14.6. walking on roofs.)

Although long length sheeting has the capacity to span large purlin spacings when loaded in tension, there is increasing expectation to use the roof cladding as a walkway and a roof-working platform, and to walk anywhere and in any position on the roof. As this entails loading ribs in compression, all 0.40 mm steel cladding and most non-ferrous metal cladding profiles manufactured in N.Z., cannot comply with this requirement, for the reason that the ribs will buckle under the testing requirements for point load.

As metals do not perform well in compression, where the expected requirement is 'Unrestricted Access' the purlin spacings would have to be reduced to an uneconomic level particularly at the end span.

The roofing contractor should inform the owner/occupier of any restriction to access onto the roof as provided by the manufacturer.

Any manufacturers design load data that does not comply with Type A 'Unrestricted Access', should be clearly headed Type B 'Restricted Access'.

Where pans are not wide enough to accept the width of a persons foot, it is possible to spread the load over two ribs, however as this capability varies between profiles, this assumption should not be made without testing. **(see section 14.6. walking on roofs.)**

Any permanent deformation or damage to the ribs of profiled sheeting or metal roof tiles will reduce their performance to the extent that they may leak or not meet the design load requirement.

Roof structures > 35° are regarded as unable to be walked or worked upon without special provisions being made, and walls also are regarded as inaccessible for traffic so these areas are designated Type 3 or 'no access'.

If access is available via a roof doorway, then a permanent walkway or a marked dedicated area should be clearly indicated. A notice should be prominently displayed on the door clearly stating, conditions of permission and the limitations of walking on the roof cladding. This area should have reduced purlin spacings, capable of withstanding traffic, thus providing an economical solution to walking indiscriminately over a roof.

3.3 WIND LOAD (U.D.L.)

A Uniformly Distributed Load (U.D.L.), is imposed on a roof structure as a wind load taken to apply perpendicularly to the roof cladding and equally over a nominated square area and is measured in kPa = kN/m². The design wind load is affected by the pitch of the roof and is modified by the use of other factors called pressure coefficients. **(see section 3.3.1.pressure coefficients)**

A U.D.L. on a roof can be positive or negative but the most severe load is negative, suction or uplift load that is trying to lift the roof away from its fastenings or from the structure.

AS/NZ1170 contains the design wind speed regions for N.Z. and the modifying factors that govern the calculated load. Although the wind design load is usually determined by the designer, it is important that the roofing contractor understands how these values are derived, and how to determine the fastening pattern for roof and wall cladding from the design wind load.

There are two regional wind speed regions for N.Z. nominated in AS/NZ1170. For all New Zealand and for a 50-year return period, the basic wind speed is 45m/s. The exception is Cook Strait when for a 50-year return period the basic wind speed is 51m/s. **(see map 3.4.1 B)**

Wind load is affected by factors such as building height, proportions, orientation, roof pitch, the number of spans, the nature of the terrain, windbreaks and obstructions.

However the most dominant factor is topography and the effects that adjacent hills and valleys have upon the building site.

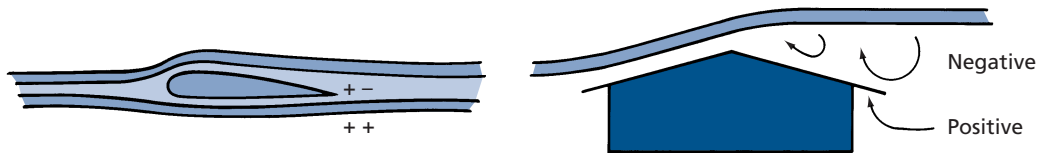
Airflow over and around buildings produces negative pressures (or suction) on much of the external roof and wall cladding, but the total wind force on the cladding depends on both the external and internal pressures.

Openings in walls on the windward side of a building lead to an increase in internal pressure thereby adding to the effect of external suction and subjecting cladding to tensile loads and fixings to potential pull-out, pull-over and washer inversion forces.

The use of light-weight profiled sheet cladding provides little by way of dead load to counteract this net outward wind created force. A ridge-vent installed on a low pitched roof can reduce the uplift force on the cladding under all directions of wind. Eave and verandah cladding is subject to both external suction and positive pressures from underneath and to a greater degree when they are not lined.

The pressure acting on the underside of any roof overhang will be related to the pressure on the adjacent wall surface, increasing the total load on the overhang, when that part of the roof is already subjected to external suction.

All wind forces are fluctuating loads and the dynamic and pulsating nature of the wind can produce the destructive forces associated with cyclones, because the pressure varies with the square of the wind speed.



Drawing 3.3. Wind Uplift 

3.3.1 PRESSURE COEFFICIENTS

A pressure coefficient is a factor applied to the design load and is particular to the building concerned.

This factor is dependent on building size, shape, the direction of the wind, and whether or not the building is permanently vented. The pitch of a roof has a major influence on the wind load imposed upon it and very flat and very steep roofs are less affected by the suction induced by the wind and the wind speed than pitched roofs. The design wind load is moderated or altered by using a multiplier or pressure coefficient that can be positive or negative, but for design purposes although the pressure coefficient can reduce the design load the worst situation is assumed.

All metal roof and wall cladding must be able to resist the total wind design load calculated to apply to the area of the building under consideration. To determine the wind design load on metal roof and wall cladding, both the internal and the external pressure coefficient must be considered together to provide a factor that reduces or increases the site wind design load.

3.3.2 LOCAL PRESSURE COEFFICIENT k_l

The local pressure coefficient k_l is a major design consideration required by the Loadings Code, as the periphery of roof and wall cladding is subject to a greater uplift load than the main body of the roof. This factor is required to provide for additional cladding strength, and because of the increased load at the cladding fixing points.

On the periphery of any building where the pullover value of the cladding is exceeded additional fixings and/or load spreading washers must be used to provide additional support to the sheeting. (see 7.8.2. *pull-over*)

The local pressure coefficient must be either:

- (a) 1.5. that applies to the edges of all buildings at a dimension equal to .2 or 20% of the width or height of the building whichever is the least.
- or (b) 2 that applies to the edges of all buildings at a dimension equal to .1 or 10% of the width or height whichever is the least.

The height of the building must be taken as the average roof height from the ridge to the eave.

The local pressure coefficient only applies to wind load and does not apply to the hips and ridges of roofs with a pitch $<10^\circ$.

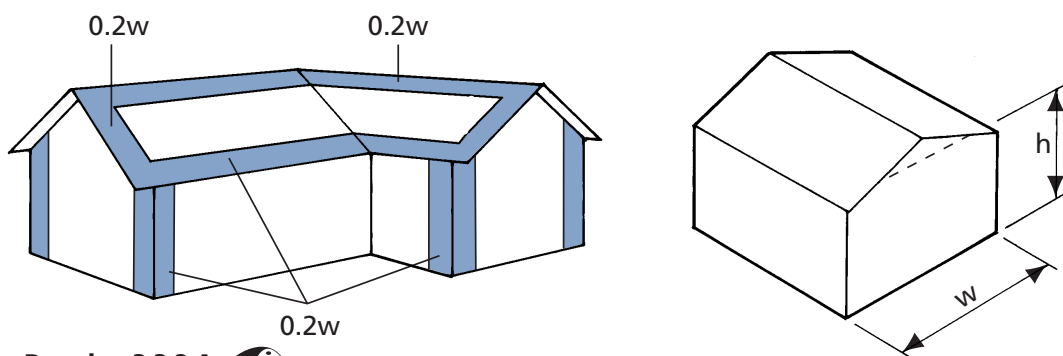
End spans must be less than the intermediate span in all circumstances.

When a roof is not designed for point load, the end spans must be reduced by the k_l factor. When a roof is designed for access the end spans must be reduced by the factor as described in section 3.1.3. *continuity*.

The local pressure coefficient factor is also dependent on building size, shape, roof design and the direction of the wind, and whether or not the building is permanently vented. It is recommended that for residential and other buildings less than 12m wide that the 1.5 factor x 0.2w, be used.

Many buildings are designed without provision for the reduced purlin spacings or increased fixings required at the periphery and roof cladding failures almost universally initiate from these areas.

Wall cladding is also subject to the same local pressure coefficient and cladding fixings on the corners of the building may have to be increased in a similar manner to roof cladding.



Drawing 3.3.2.A 

Because the wind load is increased by 50% at the periphery the purlin or the rafter spacing should be reduced to 2/3 of that for the main body of the roof. (see section 3.1.3.)

N.B. This reduction for wind is coincident with that required for point load. By reducing the purlin and rafter spacing by 1/3 the load at the purlin/rafter joint is equalized. L = load S = span

i.e.

$$L_1 \times S_1 = 1 \text{ kN}$$

$$L_1 \times 1.5 = L_2 = 1.5$$

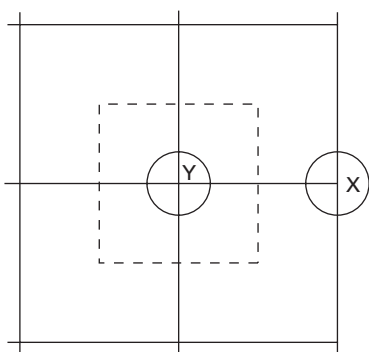
$$S_1 \times 2/3 = S_2 = 0.667$$

$$L_2 \times S_2 = 1.5 \times 0.667 = 1$$

The load on the purlin/rafter connection or joint is also increased and although it is shared by adjacent connections it should withstand its share, which is dependent on the distance from other connections. To obtain the load on such a connection, multiply the span by the spacing to provide the effective area and multiply the result by the wind design load in kPa for the building

The result in kN is the load on the connection.

N.B. The load at Y = 2X



Drawing 3.3.2.B 

3.4 LOAD CALCULATION

3.4.1 WIND LOAD CALCULATION

To calculate an accurate wind design speed for a building site is complex because wind is directional and the building orientation, ground topography, elevation and shielding all are major factors to be considered.

It is possible however to arrive at a conservative design load for the roof and wall cladding on a building by ignoring the direction of the wind and any shielding that may not be permanent.

The wind speed of the area where the building is situated does not alone provide sufficient information to determine the wind design load, but it is possible to determine the wind design load peculiar to any building site by using the multipliers in the following method. This method is conservative because the greater value from either NZS 3604 or AS/NZS 1170 has been taken.

Limitations of this procedure are:

- that the building is classified Importance level Class 2 in AS/NZS 1170.0 i.e. it does not include buildings dedicated to the preservation of human life, or public buildings such as libraries or halls.
- It does not include buildings that exceed 10 metres in height
- It does not include buildings above 500m in elevation
- it should not be used for the lee areas marked on the wind zone without additional factors being applied. See wind regions (3) map 3.4.1.A.
- The calculated result should not be used as a design load until all other factors are used to appreciate or depreciate the wind load.

The intention of this method of load determination is to ensure that the roof and wall cladding will perform without permanent deformation under load as required by the NZBC, and also to determine the fastening pattern required. If a more accurate assessment is required, a specific design is necessary.

The wind forces that act on any part of a building are dependent on:

1. wind region;
2. terrain roughness;
3. topography;
4. pressure coefficients.

The site design wind load can be determined by assigning a value to each of these four variables individually and by multiplying them together.

A six step simplified calculation is possible once information concerning the building and the site are known.

N.B. the site wind load must be determined before being modified by the pressure coefficients.

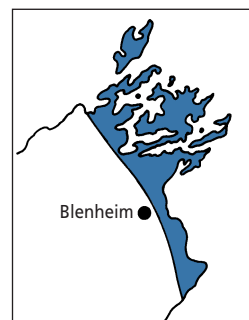
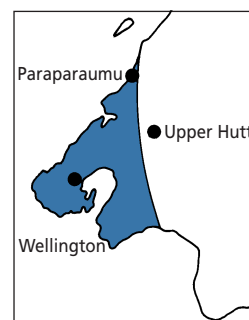
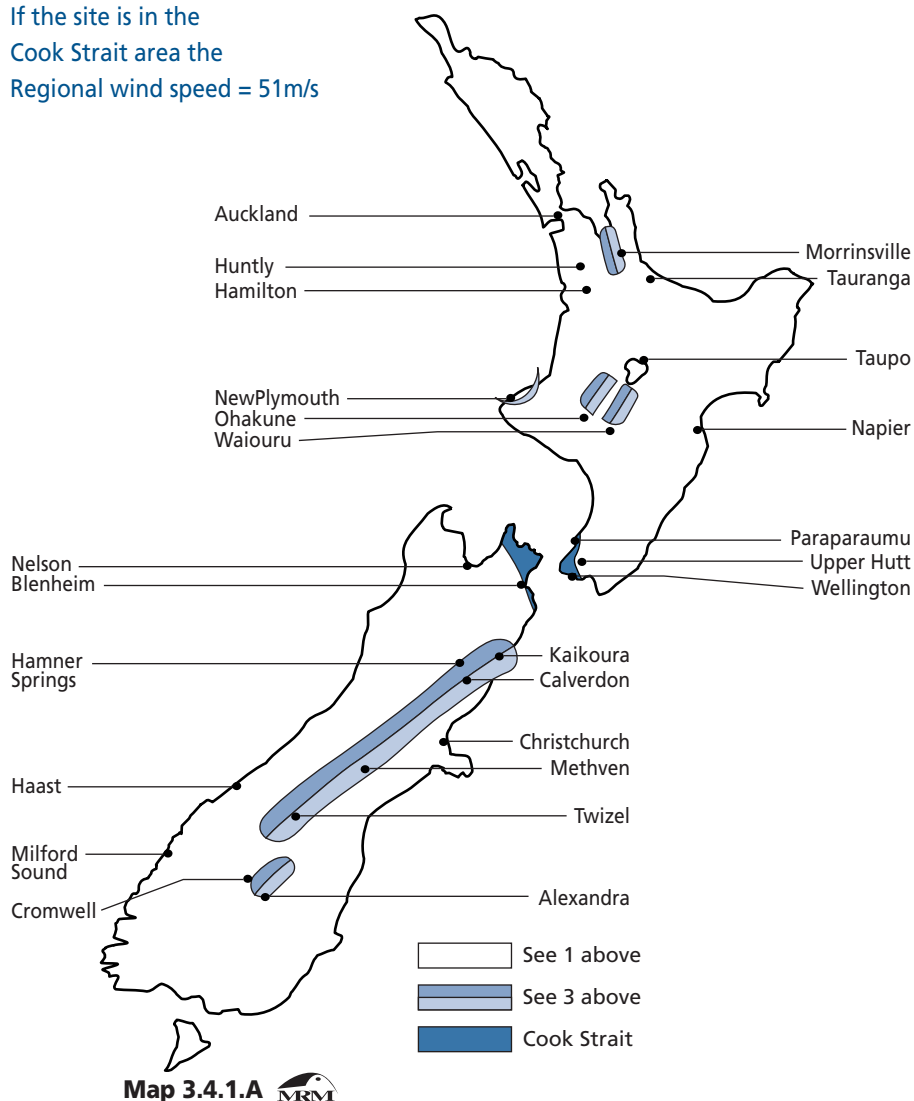
STEP 1 Determine the regional wind speed**Wind regions:**

New Zealand is divided into two main wind regions as illustrated in Map 3.4.1.A. (From AS/NZS 1170.2)

1. For a 3 second gust and a return period of 50 years and an annual probability of exceedance the ultimate wind speed is 45m/s for the majority of N.Z. N.B. Under NZ 3604 a medium wind speed is 37m/s
2. Strong winds commonly occur in the Cook Strait regions of both islands and in these regions for a 3 second gust and a return period of 50 years, and an annual probability of exceedance the ultimate wind speed is 51m/s. N.B. Under NZ 3604 a high wind zone is 44m/s
3. Some small pockets of specific local land formations that are known to experience strong winds are shown on map 3.4.1.A. These areas in the lee of mountains are up to 30kms wide and an additional lee multiplier of 1.35 is required for sites in the shadow lee zone within 12km of the crest of the range and other areas should be individually assessed.

If the site is not in the Cook Strait area or in a zone the Regional wind speed = 45m/s

If the site is in the
Cook Strait area the
Regional wind speed = 51m/s



Map 3.4.1.B

STEP 2 Determine the terrain multiplier

The Regional wind speed is multiplied by one of the four terrain multipliers described below:

Terrain

The terrain multiplier is the classification of the terrain roughness or obstruction over which the wind passes before it reaches the building site and increases or reduces the wind speed. Any obstruction should have permanence and not rely on vegetation. One of the four multipliers should be selected on the basis of the category that it most closely fits the description of the specific building site.

- A.** Exposed open terrain with few or no obstructions. The edge of coastal mudflats, flat beaches, deserts or airfields. N.B. This multiplier is not often used because the surface roughness on open water in high winds is assumed to be that of category B.
- B.** Open terrain, grassland or water surfaces with a few well-scattered obstructions between 1.5 - 10m high. Typically farmland.
- C.** Terrain with numerous closely spaced obstructions 3.0m - 5.0m high such as areas of suburban houses, and Industrial areas.
- D.** Terrain with numerous large 10m - 30m high and closely spaced obstructions such as city centres and well developed industrial complexes.

Multiplier = 1.12



Multiplier = 1.0



Multiplier = 0.87



Multiplier = 0.75



STEP 3 Determine the topographic hill multiplier

Topographic Classification

The topographic classification is the nature of the hills, valleys and plains that strongly influence and accelerate the wind.

The site wind speed is influenced by the topography of the land that will affect the wind flow in the vicinity of the building site, however if a peak is more than ten times its height away from the site any influence may be ignored. The most critical areas are those near the top of a hill, cliff or escarpment, and both the slope of the hill and the distance from the crest should be established to find the modifying factor. Valleys are subject to accelerated wind flow due to the convergence of the surrounding hills. Sites with a moderate classification include those that are: < 20 metres above a valley floor, over 150m from the crest of an escarpment, and below 150 metres of the crest of a hill, ridge or spur. Sites with a severe classification include those that are within 150 metres of the crest of a hill, ridge or spur or those at the head of a valley.

Any assessment of the effects of topography on the wind design load is indicative only as topography is three dimensional, and the evaluation is two-dimensional. It therefore is not possible to cover all situations and a subjective judgement is necessary, although a more accurate assessment can be obtained by specific design.

The following assessment and calculation of the Topographic Hill Multiplier is valid only for topography where the hill slope is <24° and because wind direction has been ignored the result will be conservative.

A. SITES ON FLAT LAND OR UNDULATING HILLS LESS THAN 3°. (1: 20)

The exception to this case is where the building site is on the flat area beyond a hill, cliff or escarpment. (see C) and if the building site is within a distance of equal to ten times the height of the hill.

Multiplier = 1.**B. SITES WITH A SLOPE > 3° AND < 24°.**

Graph 3.4.1. is only valid for hills up to 24°, and when the slope of the hill is reasonably constant, and applies to either side of the hill when the steepest side of the hill is assessed.

Both the slope of the hill and the distance from the top of the hill will determine the severity of the hill multiplier.

To determine the value of the hill multiplier the following information is required.

The building site	= S
Height of the hill	= H
The sloping distance from the base of the hill to the crest	= D_c
Distance from the crest of the hill to the site	= D_s
Slope of the hill	= ϕ

The slope of the hill can be determined by dividing the height H by the distance to the crest D_c

This value is not a tangent but is an approximation to within 2° (up to 24° slope). (The distance D_c can be more easily measured than the horizontal distance.)

Find the tangent (see section 18.2 roof pitch)

EXAMPLE:

H	=	240
D_c	=	800
ϕ	=	$240/800$
Tangent	=	0.30
	=	17°
D_s	=	235
$D_c - D_s/D_c$	=	$800 - 235/800$
	=	0.7 (value Y)

Using Graph 3.4.1.

Find slope 17°

Draw a horizontal line (a) from 17° to hill factor

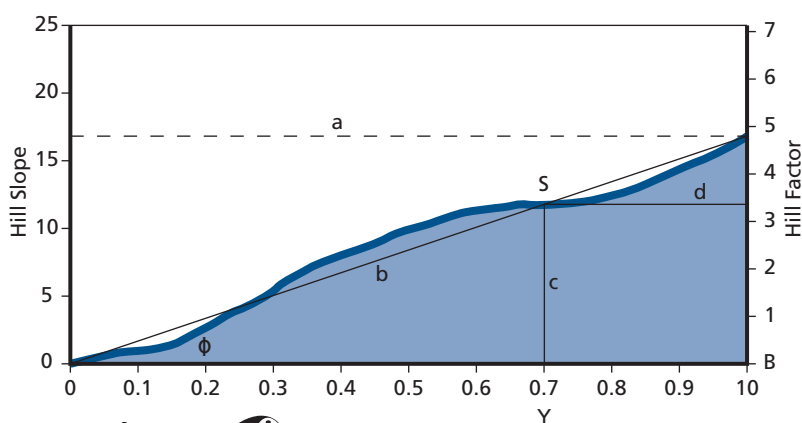
Draw a sloped line (b) from 0 to the same point

Draw a vertical line (c) up from Y to intersect b at S

Draw a horizontal line (d) from intersect S to hill factor

Read off value of the Hill factor = 0.33

The Hill Multiplier is $1 + 0.33 = 1.33$



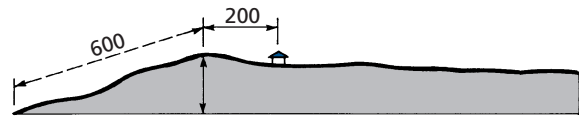
Graph 3.4.1. 

C. SITES WITHIN 10 TIMES THE HEIGHT OF AN ADJACENT HILL OR ESCARPMENT.

To determine the hill factor applying to a building site anywhere on the flat ($<3^\circ$) area beyond the hill, the distance that is affected is determined by the hill slope and the distance the site is from the crest.

e.g. A hill shown on drawing 3.4.1.

$$\begin{aligned} H &= 150\text{m} \\ D_c &= 600\text{m} \\ D_s &= 200\text{m} \\ \text{Hill slope as determined in B} &= 150/600 \\ &= 0.25 \\ &= 14^\circ \text{ (1 in 4)} \end{aligned}$$



Drawing 3.4.1. 

$$\begin{aligned} \text{From graph 3.4.1. Hill slope factor} &= 0.4 \\ \text{Effective distance } 10H &= 150 \times 10 \\ &= 1500\text{m} \\ \text{Site distance} &= 1500 - 200/1500 \\ &= 0.867 \\ \text{Site Hill slope factor} &= 0.4 \times 0.867 \\ &= 0.35 \\ \text{Site Hill Multiplying factor} &= 1.35 \end{aligned}$$

STEP 4 To determine the site wind speed multiply the regional wind speed and the terrain hill multiplier and the topographic hill multiplier.

EXAMPLE:

The following is a method to determine the site design wind speed for a 50 year return period for a residence of the same design in two places in New Zealand.

	SITE A Dannemora, Auckland	SITE B Wadestown, Wellington
Regional wind speed	45m/s	51m/s
Terrain multiplier	0.87	1.0
Topography multiplier	1.0	1.33
Site wind speed	$45 \times 0.87 \times 1$ $= 39.15\text{m/s}$	$51 \times 1 \times 1.33$ $= 67.83\text{m/s}$

N.B. The minimum site wind design speed is 30m/s

The regional wind speed multiplied by the two multipliers above, gives the site design wind speed (V).

To find the design wind load for a particular building site, the modified site wind speed in m/s is used to calculate this pressure (p) in Pa.(pascals.) $p = 0.6 V^2$.

Site wind pressure (see section 14.7.)

	SITE A Dannemora, Auckland	SITE B Wadestown, Wellington
Design wind pressure	$= 0.92 \text{ kPa}$	$= 2.76 \text{ kPa}$

STEP 5 Determine the pressure coefficients applicable to the roof or wall cladding**Pressure Coefficients**

Pressure coefficients are multipliers applied to the design wind load that may increase or decrease the design value. The value of pressure coefficients is governed by the aerodynamic shape of the building, and for unusually shaped buildings a specific design is required.

The assumed building shape is taken to be the ratio of the average height of the building to the width of the building. For simplicity this ratio is taken to be $h/w \leq 0.5$, where the height is not greater than twice the width of the building. (A)

Any dominant openings also determine the value of the pressure coefficient. A side of a building having a dominant opening is described as one that is greater than the sum of the openings on any other side. This is particularly relevant when large doors are on one side of the building. (*see definitions section 1.3.*)

If a ridge vent or other free venting area is provided in the roof cavity and equals the area of the dominant opening, the modifying internal pressure coefficient is reduced. (B)

If ventilation is not provided, allowance should be made for additional positive pressures to be added to the worst negative pressures. (*see section 3.3.1. pressure coefficients*)

In these calculations it is assumed that all buildings are able to have their openings closed in a severe storm and do not have permanent openings in the walls, and these assumptions also reduce the internal pressure coefficients. If this is not the case as in cyclonic wind zones, full internal pressurisation should be assumed and increased pressure coefficients are required.

The external pressure coefficient has been taken as the worst case, however some curved and multispan roofs can have reduced multipliers by using specific design.

Multiplier pressure coefficient.

- A** For buildings $h/w =$ to or < 0.5 , with all four walls of metal or similar cladding and no dominant openings.
Multiplier is = 1.0.
- B** For buildings $h/w =$ to or < 0.5 , with dominant openings or permeable walls and permanent roof ventilation equal to the area of the largest dominant opening
Multiplier is = 1.2
- C** For buildings $h/w =$ to or < 0.5 , with all four walls of different permeability (i.e. precast concrete walls on 3 sides and metal cladding on the other.
Multiplier is = 1.5

STEP 6 Determine the design wind load

By multiplying the site wind pressure by the pressure coefficient, the load on the cladding is established. This however only applies to the main body of the roof or wall, as the peripheral area requires an additional multiplier.

Multiplier: local pressure factor k_l

The edges of roofs and corners of buildings are subjected to different wind loadings than the main roof or wall areas, and will require different fixing patterns, and in some situations different purlin spacings to those of the main roof area.

The areas of highest negative pressures are around the perimeter of the building (*see drawing 3.3.2.A.*) and the size of these areas is determined by the size of the building.

There are two alternative options to determine the value of k_l and the distance over which it is effective.

Determine the width of the building or the length if it is less than the width, divide this by 5 = X

The affected distance around the periphery of the roof and wall cladding = X and the design wind load multiplier in this peripheral area is 1.5 x the design wind load on the main roof area.

Multiplier is = 1.5

Buildings with open soffits, where the cladding is open to the elements, will require additional allowance as the negative and positive external pressure coefficients require to be added together.

Where the structure is exposed under eaves, such 'skeleton' areas are subject to additional positive pressures that apply to the wall underneath them and these two pressure coefficients are added together to calculate the maximum allowable spans and fastening patterns.

Gable end structures are more vulnerable to uplift in the peripheral areas than hipped construction, and it is much simpler to reduce the purlin spacing on a hipped construction to comply with the kl factor.

Example	SITE A Dannemora, Auckland	SITE B Wadestown, Wellington
Design wind load Periphery	= 0.92 kPa x 1.2 = 1.10 kPa = 1.10 kPa x 1.5 = 1.65 kPa	= 2.76 kPa x 1.2 = 3.31 kPa = 3.31 kPa x 1.5 = 4.97 kPa

The examples are extremes cases illustrating the need to accurately assess the topography and exposure of the building site before designing and installing metal roof and wall cladding.

These values should be used to ensure both the profile and fastener capacity can satisfy this load by referencing the **load span graphs section 3.9** and the **fastener pattern section 7.9**.

Where the building is non residential and has a width >12m the alternative kl factor should be used ($2 \times 0.1w$).

Determine the width of the building or the length if it is less than the width, divide this by 10 = X

The affected distance around the periphery of the roof and wall cladding = X and the design wind load multiplier in this peripheral area is 2 x the design wind load on the main roof area.

Multiplier is = 2.0

All metal roof and wall cladding must be able to resist the total wind design load calculated to apply to the area of the building under consideration. To determine the wind design load on metal roof and wall cladding, both the internal and the external pressure coefficient must be considered together to provide a factor that reduces or increases the site wind design load.

3.5 SNOW LOADS

There is little evidence to support any suggested requirement to increase roof pitches in snow areas in New Zealand to prevent leakage at the side-laps of profiled metal roof cladding.

Leakage does not occur from fresh snow, because only water can penetrate laps and this does not occur because melt-water runs under the snow to exit at the gutter. However to allow for the extra imposed snow loads, it is necessary to increase the strength of the structure and, this is simply achieved by increasing the pitch of the roof, which also allows for easier shedding of snow.

Roofs where shedding of snow is prevented, such as roofs with valleys or high parapets, and saw tooth or barrel vault roofs may collect snow through drifting due to wind and by the sliding and creeping of snow. The most economical design of a roof structure for use in snow areas is to increase the pitch of the roof and keep the design simple.

New Zealand is divided into five snow zones where the maximum snow load is taken to be 0.5kPa or 1 kPa and any areas above specific altitudes in these areas require specific design. **Map. 3.5.** gives snow zones which are used with altitude to determine snow loads.

Buildings in the North Island located north of a line drawn through Opotiki, Turangi and New Plymouth, do not require to be designed for snow loads. Buildings located south of this line in the North Island, less than 200 metres above sea level, also do not require a snow loading. **See Map 3.5.** Most buildings in the South Island should be designed for snow loads, depending on their snow zone, and all buildings located higher than the altitudes given in table 3.5.1. require specific design.

The objective is to simplify otherwise rather complex loading patterns while remaining adequately cautious. The design load should take account of drifting of snow due to wind, but wind loads are not required to be combined with snow loads.

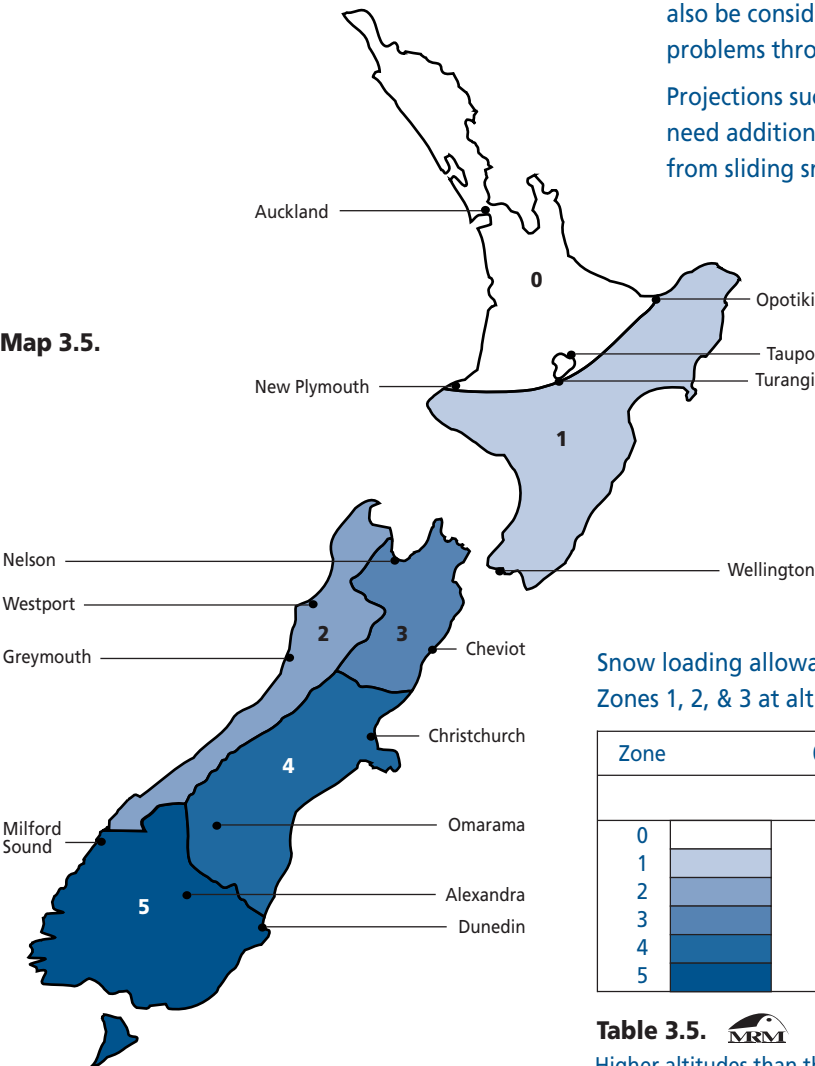
Snow loads are subject to variation due to wind drifting, and removal by wind and sun, however, they should be increased where roofs are expected to trap significant quantities of snow.

Special loading applies for cases where snow can be expected to accumulate, slide and drift. Simple valley forms will produce maximum intensities of load equal to twice the average. For extreme cases of roof planes forming an inverted pyramid, the maximum intensity of load will equal three times the average load intensity for a flat roof.

Problems of sliding of snow onto lower roofs should also be considered and it is preferable to avoid these problems through revision of the roof design and plan.

Projections such as gutters, flashings and chimneys need additional fixings and detailing to resist loads from sliding snow.

Map 3.5.



Snow loading allowance is not required for Zone 0 or for Zones 1, 2, & 3 at altitudes < 200m.

Zone		0.0.kPa	0.5kPa	1.0 kPa
Altitude in metres				
0		N/A		
1		200	500	750
2		200	400	550
3		200	350	550
4		N/A	150	250
5		N/A	150	450

Table 3.5. 

Higher altitudes than those shown are subject to specific design

3.6 FASTENER WITHDRAWAL LOADS

Withdrawal loads associated with metal roof and wall cladding, depend on the thickness and type of material into which the fastener is fixed, the shape of the thread, the diameter of the shank, and the depth of penetration.

When fixing into steel the results are consistent and within a standard deviation that can be easily assessed. When fixing into timber this is not the case because of the number of variables introduced when fixing into an organic material. The methodology used in assessing test results for withdrawal loads into timber, where statistical analysis and depreciating factors are applied, can produce conservative results.

The variability in the moisture content and density of the timber contribute to the uncertainty and these 'safety factors' are applied in order to overcome what is seen to be risk of failure.

What is not taken into consideration is that the tests are always performed individually, whereas in practice the load is 'shared' by many fasteners. What also is not considered is that a wind load is dynamic and automatically spreads what is calculated to be a maximum design load over an extended area.

For this reason, failure due to withdrawal load is not common, and where it does occur, it is usually because of an aberration such as a tornado or lack of the correct number or type of cladding fasteners at the building periphery.

The integrity of the cladding is however dependent on the fixing of the purlin or substructure to the framing, and this is of significance when it is the roofing contractors responsibility to fix the battens, counterbattens or purlins.

When roofing contractors install purlins or battens they should ensure that the connection between them and the structure is suitable for the uplift load conditions of the site. It should be designed using the same kl factor around the periphery as the roof or wall cladding and include the area over which the cladding is supported by this structural connection. Roofing contractors have a duty of care to ensure that structural purlin or counter batten have been fastened according to the load requirements by ensuring that the main contractor has 'signed off' this part of his contract.

Wall battens are not considered 'structural' and therefore the metal cladding is required to have a 'structural connection' i.e. 35mm penetration into structure.

How to achieve these requirements (Data obtained using 45mm purlin thickness)

Fastener	Size mm	No.	kN
Gun nail	90 x 3.15	1	0.4
Ringshank nail (gun/hand)	90 x 3.2	1	0.6
Gun nail	90 x 3.15	2	0.7
Ringshank (gun/hand)	90 x 3.2	2	1.0
Twist Shank Nail	90 x 3.3	1	0.9
Purlin Screw c/s head	10g x 100	1	2.5

Table 3.6.B.

A suitable single fixing for a purlin or batten to a timber structure is a 10# x 90mm self threading screw with a countersunk head and a square drive which will provide uplift resistance for the span/spacing and design wind load given in Table 3.6. The square drive provides sufficient torque to drill through pinus radiata timber without pre-drilling, giving a penetration of 50mm with a pullout of 2.5kN.

The end purlin spacing must be reduced to 2/3 rds of the intermediate span to equate with the intermediate load. i.e. $1 \times 1.5 \times .667 = 1$ and the load span graphs in 3.9. assume this ratio.

Attention is drawn to the increased connection value load required for curved roofs. (See 4.9.6.)

Table 3.6. gives withdrawal values required for purlins fixed on their flat for the main body of the roof. At the periphery where the purlin/truss load connection is higher, these values must be increased by a minimum of 50% and consideration must be given to using wind or cyclone straps or to reduce the truss, rafter or purlin spacings.

Timber purlin size	Maximum span	Spacing	Design load 0.61kPa	Spacing	Design load 0.82 kPa	Spacing	Design load 1.16 kPa	Spacing	Design load 1.50 kPa
	mm	mm	kN	mm	kN	mm	kN	mm	kN
70 x 45	900	900	0.59	900	0.80	900	1.13	900	1.46
70 x 45	900	1200	0.79	1200	1.06	1200	1.51	1200	1.94
70 x 45	900	1400	0.92	1400	1.24	1400	1.75	1400	2.27
70 x 45	900	1800	1.18	1800	1.59	1800*	2.25	1500	2.43
70 x 45	1200	1200	1.05	1200*	1.41	1000*	1.67	900*	1.94
70 x 45	1200	1400*	1.23	1400*	1.66	1200*	2.01	1000*	2.16
90 x 45	1200	1800*	1.58	1800*	2.12	1400*	2.34	1100*	2.38

Table 3.6.

When using timber grade MSG 8 at the spans and spacing shown on table 3.6., those spacings marked with an asterisk must be reduced by 10% or timber grade MSG 10 purlins must be used.

3.6.1 TIMBER PURLINS

Wind Loads are used to determine the load that primary fasteners are required to withstand when fixing metal cladding to roofs and walls.

Fastener withdrawal and pullover strength is particularly relevant to the selection of fastening used to attach roof cladding to timber purlins in high wind areas and around the periphery of the building. Failure under uplift loading usually occurs by deformation of the cladding around the fastener head before the withdrawal load is reached, and where this uplift load is critical it is standard practice that load spreading washers be located under the head of all fasteners to distribute the load on the cladding at the fastener, and thus avoid any fatiguing that may occur under fluctuating load.

To enable the designer or roof fixer to determine the suitability of fasteners their frequency or number per square metre, the wind design load should be determined as in **section 3.4. load calculation**.

Additional loads can be imposed on cladding when buildings are only partially braced during the construction period.

Where timber purlins are to be extended as cantilevers to provide a gable verge, the maximum overhang should be 600mm for a light roof. Where purlins are spaced further apart than 1200mm additional purlin outriggers should be provided fixed back to at least 3 rafters for rafter spacings of 600mm or less, or 2 rafters for rafter spacing of 900mm or more. The gable rafter is included in this provision.

Prefabricated timber trusses require specific design by the truss manufacturer, for purlin spacings greater than 1200mm at the periphery of the structure.

3.6.2 STEEL PURLINS

Failure by fastener withdrawal is not normally a risk with steel purlins provided the fasteners used are correctly selected to suit the purlin thickness. Care should be taken to ensure that the fastener is not under load from other factors such as thermal or building movement, which could be detrimental to its performance.

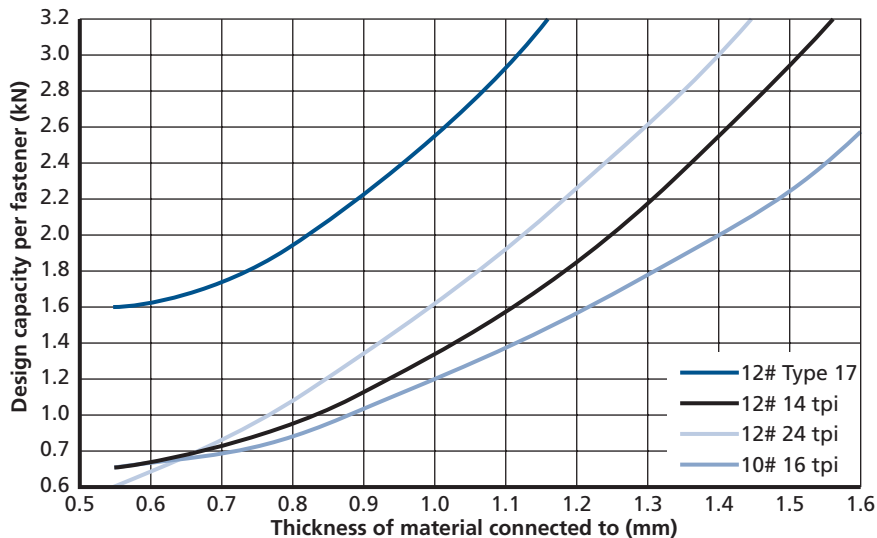
When using stronger long spanning profiles, the number of fasteners is less and consequently the load per fastener increases and when used in conjunction with lighter gauge high strength steel purlins, the fastener pull-over load becomes critical.

In these circumstances load spreading washers should be used.

The design load for screws in tension is provided in **graph 3.6.2**.

This graph shows that:

- Type 17 is the superior fixing into all thicknesses of steel up to 1.15mm
- Fixing into < 0.65mm the coarser thread (14tpi) form is superior.
- Fixing into > 0.65mm the finer thread (24tpi) form is superior



Graph 3.6.2. 

3.6.3 STEEL BATTENS

The withdrawal load of the screw becomes the design criteria when using light gauge steel battens.

Coarser threaded screws provide better pull-out performance in light gauge high strength steel than standard threaded screws and a load spreading washer should also be used. The design tension withdrawal load is dependent on the material thickness and the screw gauge and thread type.

Screw manufacturers withdrawal values should not be used as a design load criteria unless they have been tested under the testing provisions of AS/NZS 4600.

Where the steel batten is <0.95mm self-piercing coarse threaded screws only must be used. (Type 17). 0.55mm top hats must not be used for roof battens. Where the edge distance is critical (1.5d) washers must be used under the head of the screw.

3.7 SUPER-IMPOSED AND CONSTRUCTION LOADS

Any load which is added to the roof cladding or structure is termed super-imposed which includes air conditioning equipment, solar installations, television aerials, anchor points and walkways.

All permanent loads must be fixed through the rib as fastening through the pan is not permissible. The rib, even at the purlin line has little capacity for additional load and in many instances the roof cladding must be free to expand. Any attachment to the roof cladding must be compatible and if it is structural it must last 50 years.

Overlaying metal cladding with any structure that prevents natural rain-washing and creates an unwashed area which is excluded from any warranty.

No additional load must be directly connected to the cladding.

No additional load must be directly connected to the structure without undertaking additional engineering design considerations.

These include the profile, thickness, material, roof pitch, purlin centres, all of which can have a bearing on the support centres of walkways and distance from any structural support.

Where there are concentrated loads, the structure should be checked for design capability including seismic actions when such additions as solar water tanks are supported by the structure.

Construction loads on a building include the wind load on a partially clad or braced roof or building which depends on the method and sequence of construction, and can be greater than the load on a completed building.

Other forces that can apply during the installation of the roof or wall cladding include the intensity of internal wind pressures due to a temporary absence of ceilings, walls and glazing and all of these should be taken into account.

Bundles of roof cladding should be placed so that they do not cause overstress in purlins.

3.8 TESTING

Profiled steel metal cladding is manufactured from high strength and low strength steel. Non-ferrous claddings are classified as low strength.

Because the predominant material used for roof cladding in New Zealand is high-strength steel the following remarks do not apply to the testing of lower grade steels, because the testing provisions for each are different. When roof sheeting is made from low strength steels, deflection under load is of greater importance because it can be progressively yielded or is deformed by constant traffic, which in turn depreciates its performance.

Metal roof tiles are usually made from low strength steels and are not intended for roof traffic. (*see section 10 roof tiles*).

Wind and traffic imposed loads are dynamic, moving or fluctuating loads, whereas most test regimes are static load tests. It is for this reason cyclic testing is conducted to determine cladding performance.

The Loadings Code (AS/NZS 1170) requirements consist of serviceability loads and ultimate loads, however serviceability loads are more relevant to roof cladding for the following reasons.

Any permanent deformation of the ribs of profiled metal cladding caused by metal expansion or repeated walking, or deformation at the fasteners will eventually lead to leakage or failure.

Ultimate failure due to a point load on any metal cladding profiles manufactured in New Zealand has not been known to have occurred unless corrosion has affected the profiles structural capabilities.

The U.D. Load at which ultimate failure would occur on all metal cladding profiles manufactured in New Zealand is caused by failure of the structure or unsuitable fasteners and not of the material under test.

In the context of testing metal cladding, serviceability loads determine weather ability and the publishing of any strength criteria is therefore irrelevant and can be misleading.

The citing of AS/NZS 1170: 2002 in the NZ Building Code has meant that a reassessment of the testing load parameters were necessary. The test methodology has been under review for a considerable time and the joint AS/NZS committee have made considerable progress in reassessing a cyclic test regime suitable for New Zealands climatic conditions to be used as a verification for static UDL loads.

During the testing to the new criteria it became evident that in assessing roof and wall cladding performance a much greater emphasis should be given to the fastening pattern.

The effective area of the profile affected by one fastener is known as the 'tributary area'.

This means that although the previous calculations for this parameter have been confirmed, all load/ span graphs should be qualified by the fastener type and pattern.

The full text of the new regime, including the performance and test requirements is contained in section 18 of this document.

3.9 WIND LOAD SPAN GRAPHS.

Wind Load span graphs are determined by tests to criteria set out in current Standards or some accepted criteria that are derived from them, and some interpretation of the test results is necessary to fairly evaluate the capability of the product and system being tested. The wind load static tests are intended to simulate actual loads and to simulate wind uplift conditions, whereas cyclic loading would more fairly represent the conditions likely to be experienced over the life of the roof.

Although a number of tests would give the testing authority or manufacturer confidence and a “feel” for his product, because of cost, usually only one test per permutation is conducted requiring the use of a statistical reduction factor. Statistical methods and the analysis of variance are used to provide data to base manufacturers’ performance claims. The results are usually conservative and known rare roof failures have either not followed manufacturers’ recommendations or the “good trade practice” described in this Code of Practice.

Wind Load span graphs can be misleading unless they are well presented and qualified by the methodology used to obtain them. The load should be presented in kPa as a design load, not as a wind load, as this latter simplification can easily overlook dominant factors such as topography if the wind load is not appropriately factored. (*see load calculation section 3.4.*)

The load span graphs 3.9 A, B, C, D, E, & F have been determined by test using the methodology in section 18.

They represent a conservative value at which all profiles manufactured in New Zealand within the specifications noted will comply with the NZBC.

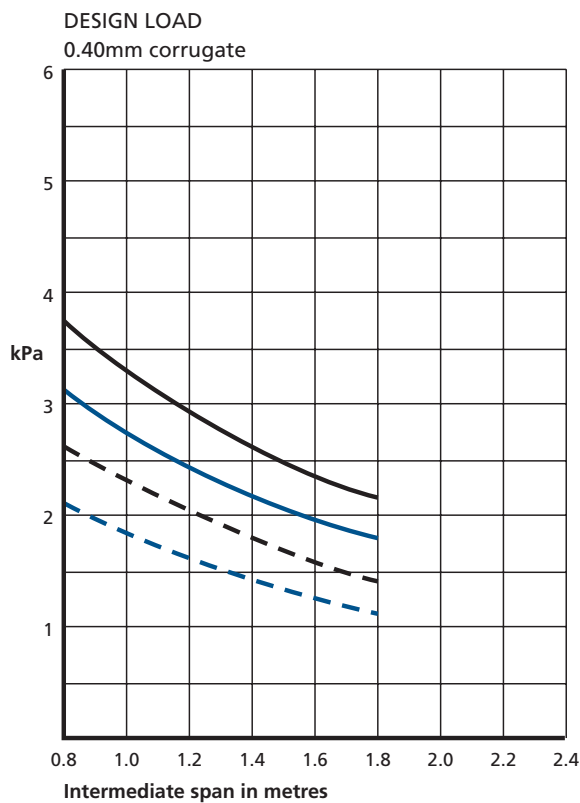
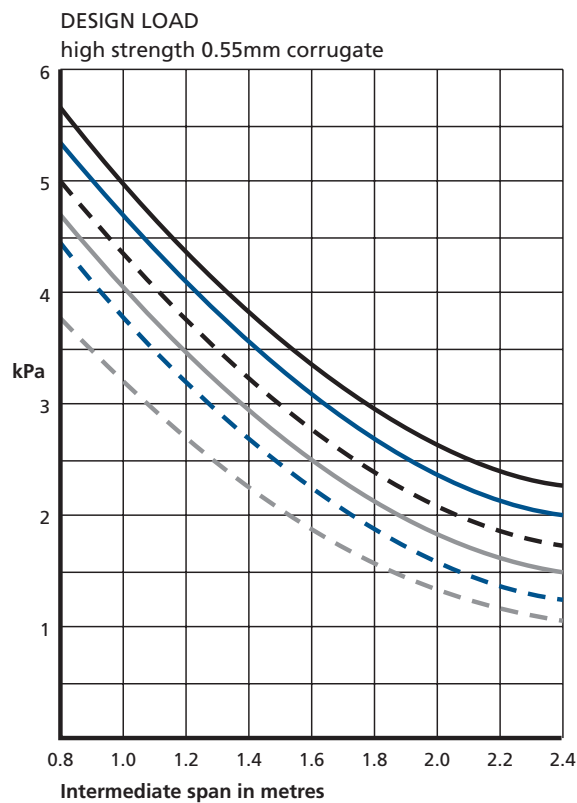
Wind Load span graphs should be read in conjunction with the constraint of access and the span at which the point load will be the limiting factor.

The performance of profiled metal cladding is not only very dependent on the thickness of the metal and the span but also the fastening pattern. While the number of fasteners per m² will determine the performance of the profile these values can be greatly enhanced by the use of load spreading washers.

This becomes obvious when the Load Span Graphs are studied on the following pages.

Although the increase in performance value is not consistent over all the profiles and thicknesses, it is significant.

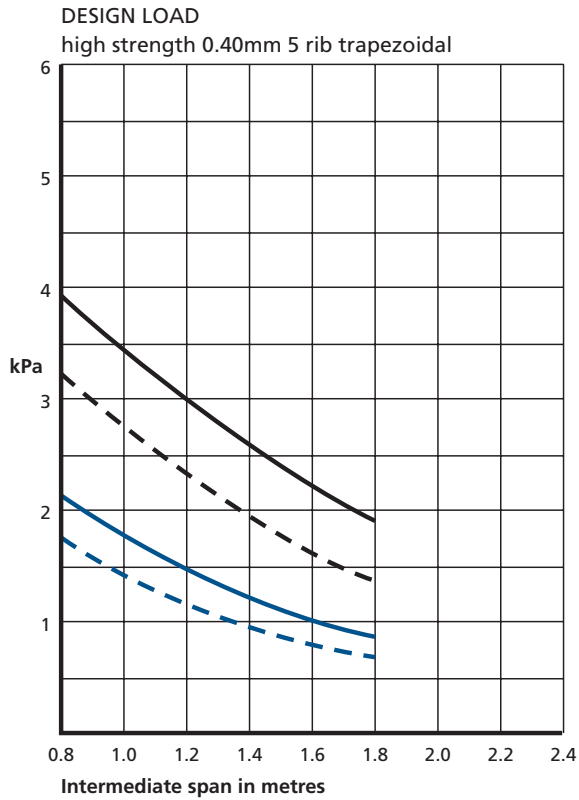
All the tests from which these graphs have been derived used the 2:3 ratio of end to intermediate span and the graphs shown are for intermediate spans only and end spans must be reduced by 2/3rds for these values to be assumed.

Graph 3.9.A. Graph 3.9.B. **Legend**

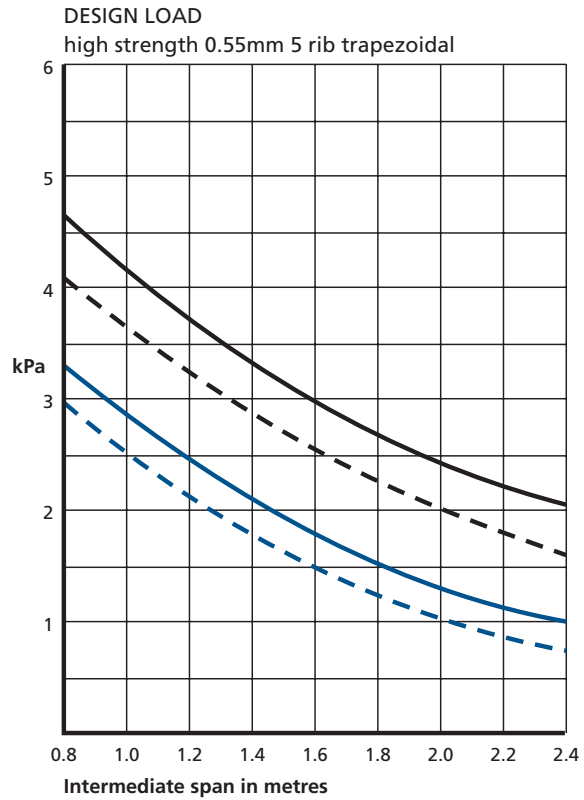
—	C1L	The dotted lines are fasteners alone
- - - -	C1	The solid lines are with load spreading washers
—	C2L	Fastening pattern C1 is every second rib
- - - -	C2	Fastening pattern C2 is miss 1, miss 2
—	C3L	Fastening pattern C3 is miss 2, miss 3
- - - -	C3	

Corrugate

The use of the miss two, miss three fastening pattern should only be used with caution on 0.40mm HS Steel cladding.



Graph 3.9.C.

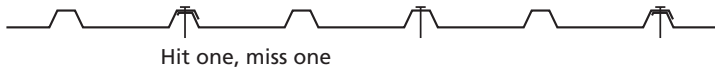


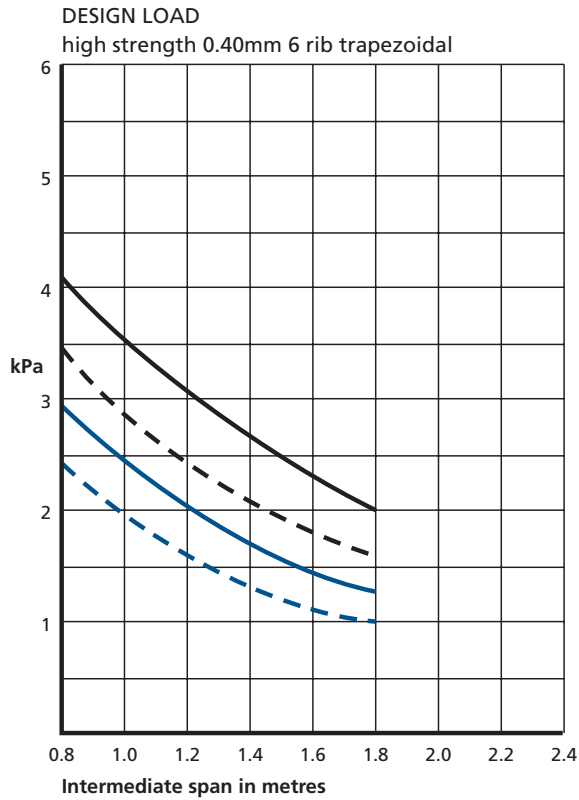
Graph 3.9.D.

Legend

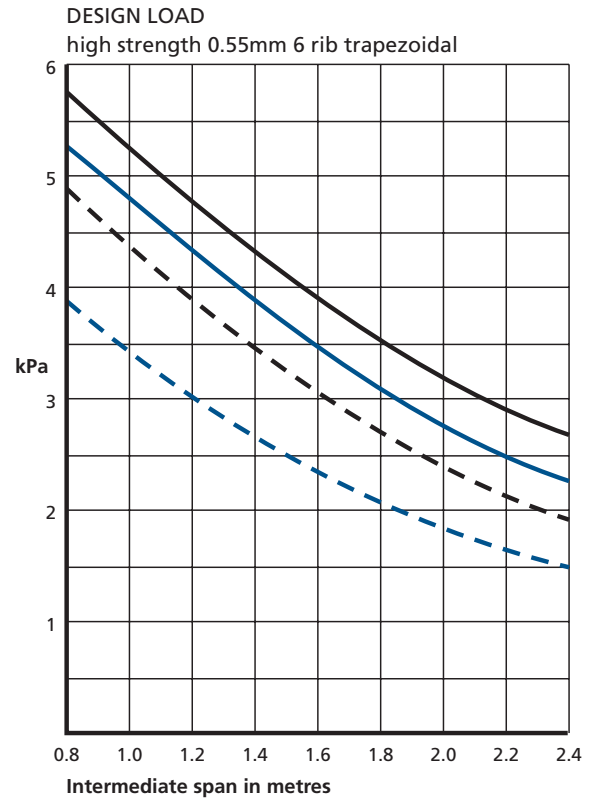
- | | | |
|-------|------|---|
| — | 5R1L | The dotted lines are fasteners alone |
| - - - | 5R1 | The solid lines are with load spreading washers |
| — | 5R2L | Fastening pattern 5R1 is all ribs |
| - - - | 5R2 | Fastening pattern 5R2 is every second rib |

5 rib trapezoidal





Graph 3.9.E. 



Graph 3.9.F. 

Legend

- 6R1L
- - - 6R1
- 6R2L
- - - 6R2

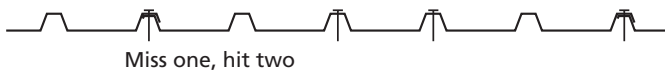
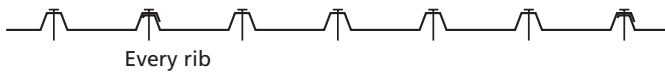
The dotted lines are fasteners alone

The solid lines are with load spreading washers

Fastening pattern 6R1 is all ribs

Fastening pattern 6R2 is miss 1, hit 2

6 rib trapezoidal

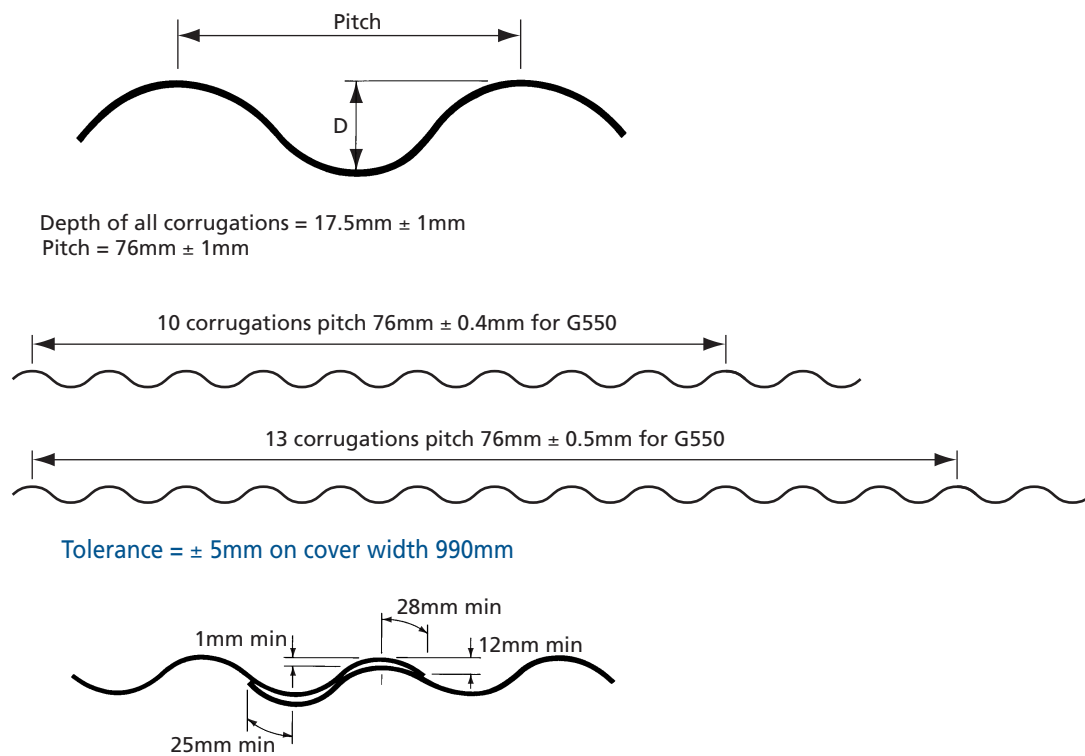


3.9.1 PROFILE SHAPE

The corrugate profile has been used in New Zealand for over 150 years and there has only been one significant change during that period. The major change came about in the 1960's when the grade of steel used for roof and wall cladding changed from a low strength steel of 250MPa, to high strength 550MPa.

Because of the springback associated with roll forming high strength steel the shape also changed from a profile 3/4" (19mm) deep to one of 17.5mm depth.

The NZ Industry Standard for the corrugated profile must be as shown in *drawing 3.9.1*.



Drawing 3.9.1. 

The performance of high strength steel corrugated cladding under point and wind loads is much higher than that of the more ductile grade (G300) that is still used for machine curving.

The mixing of the two grades of corrugate profile should be avoided, but if they are to be used on the same job, the manufacturer should adjust the module to provide an acceptable fit.

3.9.2 TRAPEZOIDAL PROFILES

The trapezoidal shape provides a greater water carrying capacity and provides greater spanning capabilities than a sinusoidal profile. The nomenclature or description of the parts of the sheeting used in this Code of Practice is described in *section 1.4.3. profile geometry*.

The fastener density (number per m²) on deep trapezoidal cladding profiles is usually lower because of the longer spanning capability of stronger profiles. The number of ribs will determine the number of fasteners and is therefore the determining uplift performance factor, particularly in the peripheral areas of the roof and in high wind design load areas.

3.9.3 MINIATURE PROFILES

Because miniature profiles have limited strength their spanning ability is limited and they should not be used for self-supporting roof cladding or structural applications without testing. Their water carrying capacity is also limited.

A number of miniature cladding profiles are manufactured in New Zealand, the most common being known variously under the names of 'mini-corrugate', 'sparrow iron', 'baby iron' and 'mini-iron'.

They are used for soffits, wall cladding, parapet and internal linings where studs are normally spaced at 600mm centres and the accuracy of the framing will determine the quality of finish obtainable.

Baby iron has been produced in New Zealand for many years from low strength steel and was made to the imperial measurement of 1" pitch and 1/4" height, which is metric converted to 25.4mm x 6.3mm. This material, and other miniature-ribbed profiles are also available as a roll formed product available in long length and in high strength steel. They are also available in all the metals and finishes described in this Code of Practice.

3.9.4 PURLIN OVERHANG

The allowable overhang distance of different cladding profiles will depend on their section properties, but because an overhang is a cantilever the deflections are greatly in excess of multi-span deflections. A limit is also set to ensure that the point load due to accessibility is not exceeded.

Greater overhangs can be achieved when using trapezoidal profiles by stiffening the edge of the sheet in various ways, the most common being the use of a square gutter with a horizontal flange but this should be fastened on every pan to achieve continuity.

The limit placed on low trapezoidal profiles for a stiffened overhang is 300mm but this detail is not suitable for corrugate. The maximum overhang for all corrugate and low trapezoidal profiles is 150mm and the first fixing at the gutter or spouting should be within 150mm of the end of the sheeting.

The overhang distance can be increased to 450mm for some trapezoidal profiles with a rib height greater than 28mm but this distance is required to be proven by test. Where the cladding is fixed at a ridge or apron the overhang distance can be increased to 250mm from the end of the sheet, as the cladding is not subject to the same point or U.D.Load, and the load is shared with the flashing.

4.0 DESIGN

4.1 HEAT

The design and installation of metal roofing is greatly influenced by the laws of physics, which include the conduction and radiation of heat and the convection of air. Both designers and Roofing Contractors should be aware of this influence.

4.1.1 CONDUCTION

Three different mechanisms convey heat. Conduction, Radiation and Convection, and in many instances, all three may operate together.

Conduction is the transmission of heat through a material by contact between particles of matter without their displacement.

Metals are excellent conductors of heat relative to most other materials. (*see section 15.3.1.*) Air and other gases are poor conductors because heat flow can only take place by movement of their molecules, which are much further apart than those of metals or solid objects.

The amount of heat that flows through any substance by conduction depends on the time, area, temperature differential and the type of material. Because still trapped air is a poor conductor, it acts as an insulator, which is why fibrous and cellular insulation materials are efficient insulators. Free air however, will conduct heat by convection.

4.1.2 RADIATION

Radiation is the transmission and emission of infra-red energy in the form of electro-magnetic waves when heat is transmitted from a warm body to a colder one without heating the substance it passes through. When the thermal rays from the sun reach the earth by radiation through ninety three million miles of space they are absorbed. Those bodies that are absorptive are also radiating bodies, thus much of the heat absorbed by the earth during the day is radiated at night-time, unless there is cloud cover to reduce radiation. When roof cladding radiates its heat, it is known as 'night sky radiation' (*see section 4.2.4. night sky radiation*)

All bodies are emitting and absorbing radiation continuously and attempting equilibrium, which is why a hot body radiates heat to all those colder than itself, and also is why it often feels uncomfortably cold in a room with cold walls, floor, or roof.

4.1.3 CONVECTION

Convection is the transport of heat within a gas or a fluid by the circulatory motion that occurs at a non-uniform temperature owing to the variation of their density and the action of gravity.

The law of gravity acts so that hot air rises because it is less dense than cold air and an example of the power of heated air is the hot air balloon. Convection currents produce ventilation, which is known as 'passive ventilation' because only heat and space are required for air movement to occur.

4.1.4 THERMAL EXPANSION AND CONTRACTION

All metal roof and wall cladding and flashings are subject to expansion and contraction caused by changes in temperature, and their design should make due allowance for this movement. The energy produced should be absorbed without causing damage to the cladding, fixings or structure or producing undue noise.

Metals have a high coefficient of thermal expansion and generate greater movement than many other building materials during heating and cooling, and plastic rooflighting, and non-ferrous metal cladding will move to an even greater degree than steel.

The ribs of metal trapezoidal or corrugated roof or wall cladding take up the expansion across the width of the sheets, but in the longitudinal direction special provisions are required.

Oversized or clearance holes are often required when long lengths of roof cladding are used, and load spreading washers or clips are also necessary to avoid roof noise and damage to the sheeting or to the fastening.

Where end laps are through fixed, or where the roof and wall cladding are connected together by curved sheets, they must be considered as one length.

Changes of direction of the cladding also require expansion provisions.

The amount of metal expansion given in various building related joint and N.Z Standards and other publications can be misleading because it is provided from theory and not real world conditions. Non-ferrous metals have a higher rate of expansion than steel and the length of copper, aluminium and zinc sheets, cladding or flashings, is restricted so that the material is not over stressed. As these materials are not as strong as steel, expansion provisions such as slip joints, sleeves and welts are necessary and although steel also requires expansion provisions, they are not needed to the same degree as non-ferrous metals. Vertical wall claddings do not require the same provisions as roof cladding because of the angle of the solar radiation.

Horizontal wall cladding is restricted to the same length requirements and fixing provisions as roof cladding.

The indicative figures for maximum fixed lengths of roof and wall cladding are given in **table 4.1.6.** and are based on a study of empirical data over many years. Although some movement can be provided by the provision of oversized holes with oversize washers, there is a maximum length of cladding when this provision is insufficient to accommodate movement without stress or distortion, and then the provision of a slip joint or expansion joint is required. The recommended method is to form a step in the roof structure, which allows the cladding to move independently, (*see drawing 5.3.5.2.*) or if the pitch is greater than the minimum by 2° the roof can be 'sprung'. (*see section 6.2.8.B*)

There should be no through fixing of both sides at any expansion joint to assure independence of movement.

Where warm roof construction or composite panel systems are used, thermal movement should be considered in relation to the top sheet, insulating core, and lining sheet. (*see section 12.*)

Changes in temperature differential from one surface to the other produces differential expansion and the resulting tendency to bowing that will occur will increase the tensile and shear forces on fasteners.

Site assembled semi-composite panel systems do not pose the same problem, as each element can be dealt with independently and no shear forces are transmitted to the insulation.

Where profiled metal sheets are fixed horizontally in long lengths or to curved corners, expansion provisions should be made as in **graph 4.1.6.**

The amount of linear expansion, especially in relatively short sheets, may appear insignificant but if the sheet is fully restrained at both ends and without deflection, considerable forces are developed.

The sheet lengths of polycarbonate (PC) and rigid PVC should be restricted to a greater extent than for other plastic rooflights, because they expand to a far greater extent per degree of temperature change than any metal or than GRP. Rooflights constructed from these materials should therefore have fixing holes larger in diameter than the shank of the primary fastener and the fasteners should be centred in the fixing holes to allow freedom for expansion or contraction of the rooflights.

When the outdoor temperature is significantly higher than that indoors, double skin rooflights fabricated from polycarbonate and PVC will exceed the amount of expansion for of a single skin, due to the differential expansion of the two skins. This may result in ponding on rooflights installed on low pitched roofs. (*see rooflights section 9.0*)

4.1.5 TEMPERATURE RANGE

Ranges of temperature likely to be experienced in N.Z. by different steel cladding are:

Max/Min Roof Temp °C No Wind

Insulated	Light colour	+60° -15°	=	75°
Insulated	Dark colour	+80° -15°	=	95°
Uninsulated	Light colour	+50° -10°	=	60°
Uninsulated	Dark colour	+65° -10°	=	75°

A flashing detail that provides for expansion in long horizontally clad walls is shown in *drawing 5.3.9.D*.

Aluminium and zinc which have twice the theoretical expansion rate of steel, do not necessarily expand to this degree because of the different characteristics of mass, emittance and radiance which affects the temperature, but they do require considerably more expansion allowance than steel. Copper and stainless steel theoretically expand one and a half times as much as steel. Figures published for metal expansion rates are given linearly per degree, which does not take into account the many various other factors that affect the expansion. The theoretical expansion of steel roof cladding is 12mm/100°C/10m, and aluminium is approximately twice that amount. Other metal expansion rates can be calculated. (*see 15.3. expansion*)

Given a length (say 40m) and that the material (e.g. a light coloured insulated roof) will move through a 75°C range (say + 60°C -15°C) the theoretical increase in length is:

$$12 \times 0.75 \times 40/10 = 36\text{mm}$$

In practice the maximum actual expansion would be 10mm.

In practice, this amount of movement of roof cladding and components does not have to be provided for the following reasons:

- The material would usually have been fixed when the ambient temperature would average 15°C, so that below that figure the metal in theory would contract and the amount of expansion would be therefore $45/75 = 20\text{mm}$.
- The building also expands with the ambient temperature, although only to a lesser degree.
- The flexibility of the building can accommodate a large amount of movement, dependent on the structural design and also by deflection of the purlins. Known as purlin roll, the amount of deflection is dependent on the type of attachment of the purlin to the structure, i.e. cleat or screw fixed.
- The roof cladding will bow between purlins when constrained, the amount being dependent on the strength and span of the profile. i.e. the stronger the profile the more allowance is required for expansion.
- The forces due to expansion and contraction are self-levelling, i.e. each component will move under load until the resisting force is greater than the expansion force.
- The sheet fixings will bend under load if the cladding is rib fixed i.e. if the point of fixture is a distance from the point of constraint. The extent of any constraint depends on the metal and the type of fixing.
- If the roof cavity is ventilated or an uninsulated building has open doors then any large temperature differential build-up between the ambient and the internal air temperature is unlikely.
- Radiation of heat from a metal roof or flashings will balance the temperature at which the roof sheeting reradiates as much heat as it is receiving. This temperature is dependent on the colour of the roof, the placement of any insulation, air movement and the ambient temperature.
- When a length of sheeting is fastened at the centre and unconstrained at either end, the movement is towards each end of the sheeting, i.e. the actual expansion or contraction movement is only half that of a full length of roof or wall cladding fastened at one end.

Other factors influence the amount of roof and wall cladding expansion and these include colour, metal, temperature, profile and insulation.

The colour affects the temperature of the cladding.

Solar radiation striking a roof is absorbed and heats the cladding, and some heat is reflected upwards, some is radiated downwards and some is convected upwards. The thermal performance of an unpainted Z or AZ coated steel roof may change after a number of years because of surface oxidation and the accumulation of dirt. A dark coloured surface absorbs more solar radiation than a white or light coloured surface and the amount of heat radiated depends on the thermal emittance of the surface. Emittance should not be confused with reflectance as shiny surfaces have a low thermal emittance and dull rough surfaces have a high thermal emittance irrespective of colour.

The amount of wind also affects the temperature of the cladding.

If there is little wind, the heat build up due to solar radiation can rise to an equilibrium point where emittance or radiation, equal the absorption. This seldom occurs in practice because the heat differential sets up air convection currents that conduct heat away from the roof cladding, and for uninsulated roofs, a breeze of 3 m/s (approx 11 k.p.h.) can lower the roof surface temperature by 25°.

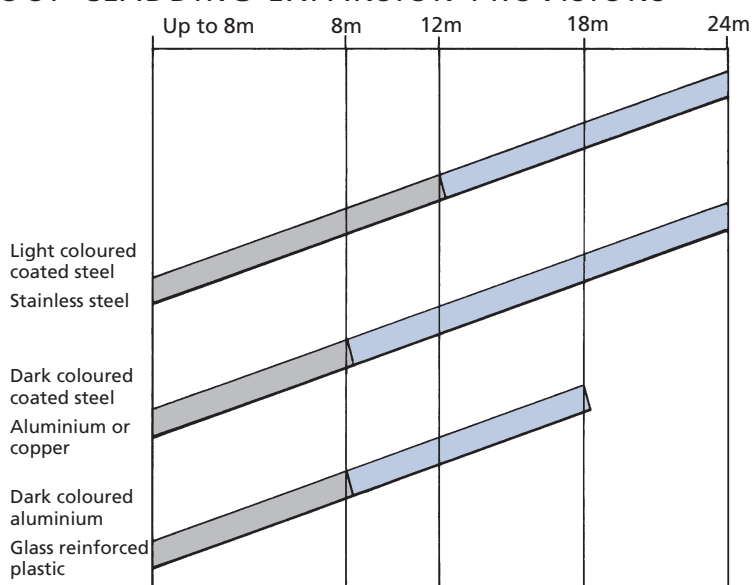
Statutory insulation requirements for domestic buildings have accentuated roof expansion problems and special design considerations need to be provided in domestic skillion or curved roofs to avoid noise resulting from expansion. *(see noise section 4.1.9.)*

Insulation must not be placed hard up to the roof cladding as this causes its temperature to rise considerably higher than that of an uninsulated roof, and unvented insulated ceilings can also increase the roof temperature by over 20°.

As established above the amount of expansion that should be allowed for long length metal cladding depends on many factors and these conditions require individual assessment peculiar to the environment, roof structure and cladding being considered.

However assuming the most unfavourable conditions the following graphics are indicative of this allowance.

4.1.6 ROOF CLADDING EXPANSION PROVISIONS



Graph 4.1.6.

No special requirements

Oversized holes and load spreading washers

4.1.7 PROFILE STRENGTH

Because corrugated steel is a weaker profile than trapezoidal or tray roof cladding it does not require the same expansion provision because longitudinal expansion will take place by bowing upwards between the purlins. Sighting down a corrugated steel roof on a warm sunny day will show an undulating line compared to a straight line when the roof is cool.

With stronger profiles the bowing tendency is resisted by the strength of the profile and so the stronger the profile, the greater the provision required for expansion.

The linear expansion of any roof is dependent on the many factors outlined in 4.1.1. but in addition before any fixing system is recommended, consideration should be given to the strength of the profile.

4.1.8 END LAPS

End laps should be avoided if possible when installing metal cladding. When the sheet length is greater than that which can be transported or exceeds the longest recommended length (*see graph 4.1.6*) the transverse or end lap joint can be avoided by using a waterfall step that should be designed into the structure. (*see drawing 5.3.5.3.*)

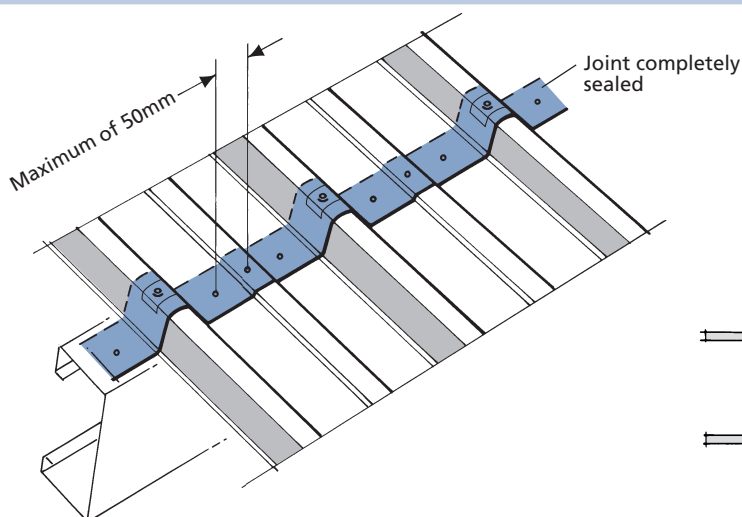
When long lengths are specifically required, secret fixed roof cladding can be supplied by transporting the roll-forming machine to the site.

Where end laps are unavoidable a completely sealed joint should be made by using a neutral curing silicone rubber sealant at both ends of the lap with mechanical fastening. (*see drawing 4.1.8.A & B*)

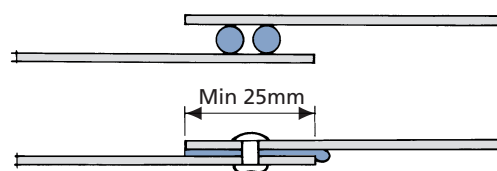
The two lengths should be regarded as one length for expansion.

Rivets are used to fix the sheets together and to provide a seal and should not be fastened to the purlin. The sheets are fixed to the purlin by using an oversized hole and a load spreading washer.

Sealed and fastened sheet end and flashing laps must be a minimum of 25mm wide, fastened using rivets with a minimum diameter of 4mm (5/32") spaced at 50mm centres.



Drawing 4.1.8.A 



Drawing 4.1.8.B 

Sealing of transverse laps is necessary to avoid condensation penetrating the inside lap from above, and to protect the cut edge of the top sheet.

To ensure durability the shear performance of the end lap fasteners should exceed the expansion force developed between the sheets or the sheets and the structure.

4.1.9 ROOF NOISE

It is impossible to prevent expansion, but it can be controlled by reducing the surface heat of the roof cladding by the use of lighter colours and ventilating the roof space.

Transverse expansion is accommodated by the concertina action of corrugation or rib of metal cladding and does not usually give rise to any noise. However because flashings are stiffened at 90° to the cladding, there is differential movement between them, which requires expansion provisions for fastening and to minimise noise associated with this movement.

All materials expand or contract with changes in temperature but those with a greater mass usually move less or more slowly than thin sheet materials. Metals have higher rates of expansion than other building materials, except plastics which can expand at a greater rate than steel. (see section 15.3.) Green or wet timber will contract on drying, producing shrinkage but will also expand or contract with temperature fluctuations.

Roof expansion noise can be caused by the energy released when the roof expands relative to its support and slipping movement occurs at the purlins, clips or fasteners. The slipping differential is controlled by the frictional forces between the roof cladding and its support, so that surfaces which have a lower coefficient of friction i.e. metal to metal would slip more easily than metal to timber. When the frictional force is exceeded and the metal roof cladding moves, noise is heard and any further temperature increase will cause a build up of stress until the limiting static friction point is reached again and the cycle is repeated. At each cycle the thermal energy is released impulsively and the higher the friction force the louder the noise.

This noise can be reduced if expansion can take place uniformly by using sliding fixings or interposing a material of low coefficient of friction (e.g. PVC noise tape) between the roof and its support.

Where the roof is rigidly fixed it is likely that the purlins will tend to rotate and this can also produce noise.

When long length roof cladding is used, oversize holes or other suitable expansion fixings are essential if noise is to be avoided.

There are many other factors that will determine if a roof will produce undue noise and they include the following:

- Secret-fix roofs where the clip fits too tightly over the rib or is misaligned.
- Roof cladding that is over-nailed. i.e. too many fasteners.
- Roof cladding that is over-tightened. i.e. nailed or screwed too tightly. The 'ticking' or creaking noise heard when the sun goes behind a cloud is usually caused by metal against metal or at the fastener hole.
- Using metals with a high rate of expansion. i.e. Aluminium.
- Gutters and valleys should be free to expand and move independently of the cladding and not have 'wings' which preclude any movement.
- Crest fixing produces more noise than pan fixing because of the movement of the fastener at the shank hole.
- Rigid framing and closely spaced purlins will cause more noise than a flexible structure. e.g. Steel portal frame construction is more flexible than laminated timber.
- When the insulation is placed hard up to metal cladding more heat is retained and the metal surface temperature becomes higher than that of an uninsulated roof.
- Dark coloured and unpainted weathered metallic coated roof claddings absorb more heat than light coloured claddings.

- An attic space with insufficient ventilation will increase the temperature within the roof cavity.
- Skillion roofs and curved roofs without provision for ventilation are subject to greater fluctuations of temperature than roof attic construction.
- Roof cladding in an exposed position will lose its absorbed heat more quickly than one that is in a sheltered valley.
- Where roofs are free to expand they should be kept clear of concrete walls or other structure.
- Specific problems are often due to structural detailing which require special provision. e.g. where solid timber construction and a dark coloured cladding are combined together.
- Impulsive energy release can give rise to 'pistol shot' noises that are very disconcerting to live with, but a dark coloured roof may only be a contributing factor, and often the cause may be a strong and rigid timber frame. N.B. Solid timber framing is well known for such noise.
- Noise can be caused by inadequate timber nailing causing differential movement at timber joints.
- Shrinkage associated with the drying out of timber with a high moisture content.
- Flashings should be limited to 12m in length otherwise noise is likely as transverse flashings expand to a greater extent than the roof cladding that they are attached to. Slip joints should be used >12m.
- The edges of all flashings should be formed as shown in section 5.2.2. to avoid 'whistling' or a wind created noise known as 'motor-boating' - a fast vibrating sound like noise of an engine.
- Underlay that overlaps too far into a spouting or gutter can give rise to a noise known as 'flutter'.
- Flashings should be 0.55mm steel or 0.9mm aluminium and no wider than 300mm.
- Flashings should not touch the pan of roof cladding.
- Insufficient clearance between a penetration and the cladding.

4.2 CONDENSATION

4.2.1 CLAUSE E3 INTERNAL MOISTURE

For NZBC clause E3 Internal Moisture see section 2.1.

4.2.2 CONDENSATION

To ensure that the installation of the roof or wall cladding does not cause moisture problems within the structure, it is necessary for both the roof designer and the roof or wall cladding contractor to understand the laws of physics that govern moisture and water. The designer must not design, nor the contractor build or create conditions that could jeopardise the durability of the roof or wall cladding or the structure.

The importance of condensation and the interaction of underlays, insulation and ventilation are given equal prominence in this Code of Practice to that of the external weathering of metal roof and wall cladding.

New Zealand being an island 2,000 km away from another major land mass is subject to high rainfall, high humidity, extremes of weather and high winds. Compared to the rest of the world where 70% humidity is considered to be the threshold of corrosion and health problems, New Zealand has very high humidity, particularly around the Auckland area where the relative humidity is often > 90%. The design requirements to deal with this problem are correspondingly more important than in other places, and this is reflected in designs substantially different to those required in many other countries. It is not acceptable to use design or installation practices used in other countries

when the environmental conditions are different. In cold places such as Europe and Northern USA where heated buildings are the norm, air is 'conditioned' to control the humidity and keep the heat in, while in hot countries where the emphasis is on cooling, the placing of insulation and vapour barriers is to keep the heat and moisture out. Suspended water vapour usually diffuses from warm to cold.

In the world-wide quest for energy efficient buildings condensation has become a major issue that can affect the design and installation of metal roof and wall cladding

Although New Zealand is in a temperate zone, there are air conditioned and heated homes and buildings and to avoid the detrimental effects of condensation, the use of underlays, vapour control layers and synthetic wraps, and the amount, type and balance of ventilation, should be suitable for the building.

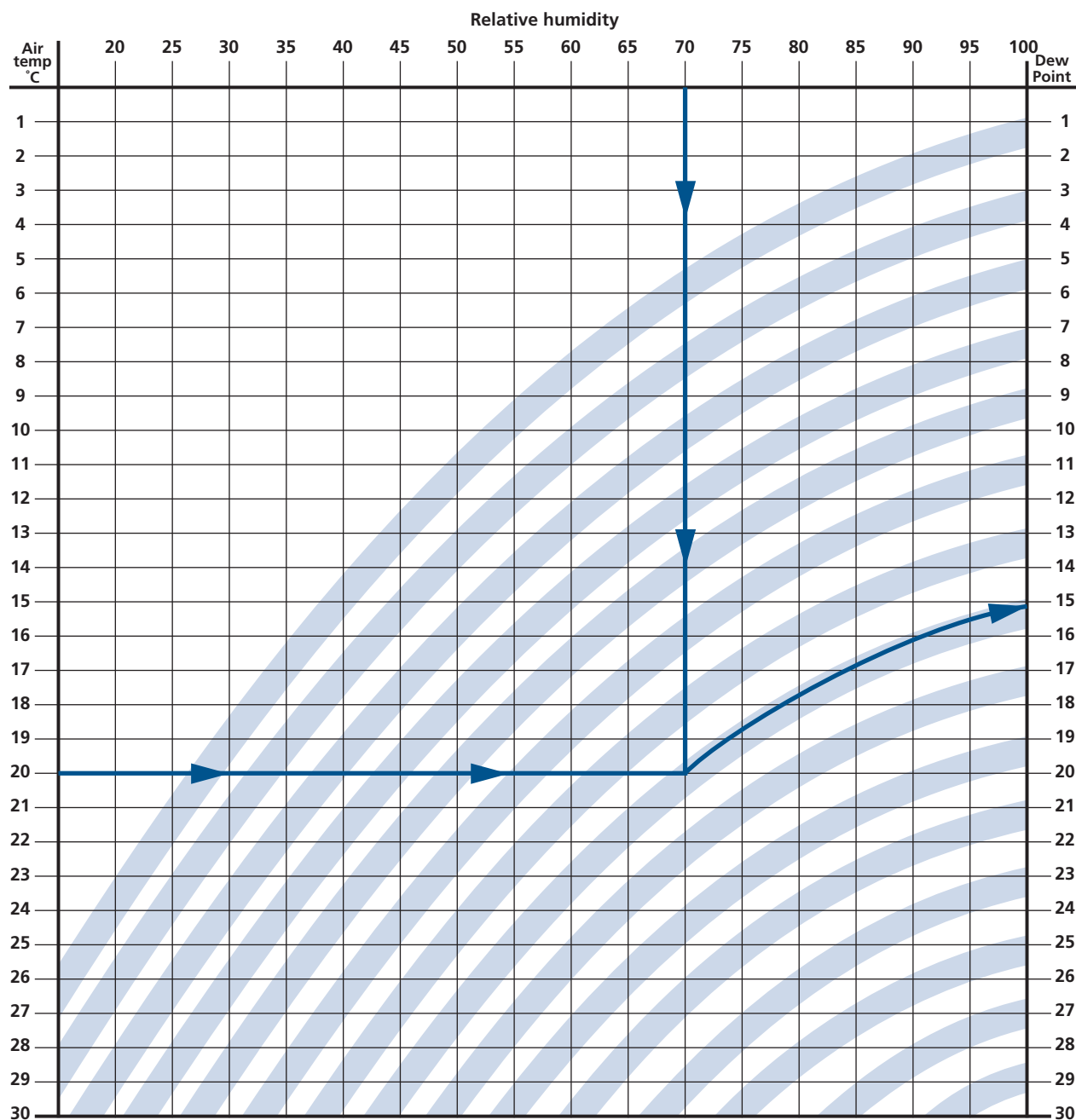
The type of construction will determine the methods that have to be taken to avoid or minimise condensation, but the principles of condensation, insulation and ventilation, and moisture control for roof and wall cladding are the same for domestic, commercial and industrial buildings.

The prime purpose of roof cladding is to act as a rain screen, so that no water enters the building from without; however it is equally important to ensure that the building is kept dry from within. Because metal roof and wall cladding is a good conductor of heat and is not absorbent, under conditions of high humidity or fluctuating or diurnal changes of temperature, condensation will form on metal cladding. As most metals will deteriorate when subjected to continued moisture, condensation will affect the durability of metal roof and wall cladding and can also affect the structure.

Water is very visible in its liquid form as rain or when frozen as snow or ice. Mist, fog, clouds, steam, and vapour trails or breath seen on a cold day, are all water vapour and are visible because the air is saturated. Water can also be present suspended in absorbent materials and is usually present in the atmosphere even though it cannot be seen, and the amount of water vapour suspended in the air depends on the environment, temperature, pressure, and the time of day or year.

Condensation occurs readily when the humidity is high, because at a relative humidity of 95% and a temperature of 20°C, only 1°C difference in temperature is required before dewpoint is reached, whereas at 50% relative humidity this difference is 11°C. People feel uncomfortable or lethargic at above 90% humidity and high temperatures when the atmosphere feels 'sticky'. When the humidity is below 30%, dryness of the mouth and throat can cause distress. Most people feel comfortable about 50% humidity and at a temperature of about 23°C.

The ratio of the mass of water suspended in vapour form compared to the value that saturated air could contain is known as 'Relative Humidity' and expressed as a %. The point at which air can hold no more water is called the 'Dew Point' or saturation point and equals 100 % relative humidity. When the dew point is reached, condensation is readily seen on impermeable materials that are good conductors of heat such as metal. Warm air can hold in suspension many times the amount of water vapour than can cold air, as shown in Table 4.2.2.e.g. Air at 20°C can hold three times more suspended moisture than air at 5°.



To find the dewpoint given the air temperature and the relative humidity. Intersect the two knowns and curved line gives the dew point.

Example: Ambient temperature 20°C relative humidity 70% = dewpoint 15°C

Dew point or saturation temperature. Table 4.2.2 

4.2.3 WATER VAPOUR

Water vapour moves to equalise the pressure inside and outside a building and the mechanisms that can control this movement should be understood to avoid or minimise condensation.

The presence of any water vapour normally present in the air in a domestic ceiling space is only of significance when it reaches a cold surface such as metal roof cladding. When the layer of air immediately adjacent to a cold metal surface can no longer sustain the suspended water vapour, it is deposited as water termed condensation. Because metal is an excellent conductor compared with many other claddings, it is more sensitive to the presence of water vapour than other materials. Excellent conductors of heat such as metal, are more prone to the effects of condensation when used for roof cladding than absorbent materials such as concrete tiles or timber.

During the day, metal cladding temperatures can be higher than the ambient temperature, but at night-time the opposite is the case because of a phenomenon known as night sky radiation. **(see section 4.2.4.)**

When the dew point is reached, dew will occur as condensation on the underside (and topside) of metal cladding as can often be seen on open structures such as walkways.

Condensation in wall or attic or ceiling spaces can be caused by moisture contained in saturated air from three different primary sources:

1. Water vapour produced by the occupants of the house.

Bathing and showering, cooking, heating and clothes drying are the most obvious sources of water, but respiration, perspiration, indoor plants and pets all produce moisture.

If it is not ventilated to the external atmosphere, water vapour can find its way through normal construction and into the ceiling space. Intermittent heating or a change in tenants lifestyle can also have a marked difference in the amount of water vapour present in the attic space.

Gas heating which uses the combustion gases to directly heat the air can be a major cause of condensation if the appliance does not have a separate flue. A large amount of water vapour is produced as a by-product of combustion when burning propane or butane, because 1kg of gas converts to 1.6 litres of water vapour that condenses and is often mistaken for leaks in the roof. The use of kerosene directly as a heating fuel also produces excessive water, more than the equivalent amount of kerosene.

A wet process within a factory or the housing of livestock can give rise to excessive amounts of condensation and other contaminants, which without special precautions or design, can make the use of metal wall and roof cladding unsuitable for that environment.

2. Water vapour generated in confined areas by construction processes, although temporary, can cause permanent damage to building components. Once construction has been completed and the source of the moisture generation is removed, a means of ventilation is required to remove excessive water vapour.

Sources of water vapour include the drying out of wet trade construction such as plastering or concreting, or because the timber framing has become wet. During the curing process, a 100mm thick concrete slab releases approximately 10 litres of water for each m² of surface area, and if buildings are left closed and unoccupied without ventilation, this moisture can condense on the roof cladding or any vapour barrier.

Temporary heating or drying during construction using gas-fired heaters, or the painting of interior surfaces can also release significant amounts of moisture. The most effective way to prevent damage to roof assemblies from moisture generated during building construction is to employ temporary mechanical ventilation.

Condensation problems can be caused if the internal linings are fixed before timber framing is sufficiently dry and when the moisture given off from the timber is trapped. The use of kiln-dried timber can reduce this problem.

It is the responsibility of the contractor to ensure that the substrate is suitable for the installation of metal roof or wall cladding.

The framing timber should be kept dry if it is to remain structurally sound, as continual dampness from leaks or condensation will cause untreated timber to rot within a short period. Treated timber should also not remain continually wet.

Before any metal roof or wall cladding is fixed the framing timber must have a maximum moisture content of 18%.

3. Air induced or vented into wall or attic spaces to ventilate the cavity can exacerbate condensation problems if the relative humidity and temperature are high. Gravity or natural ventilation requires either a temperature differential or a pressure differential induced by the wind to 'drive it', and is most efficient when there is an equal amount of inlet and outlet area.

Water vapour given off as moist air from the ground, can migrate from the basement areas through the structure into the attic space, and this should be avoided by venting the basement and cavity walls to the outside. Skillion and curved roofs without an attic space are more prone to condensation because of the lack of air volume beneath the roof and should have provision for ventilation. Curved roofs where there is an attic space are still prone to condensation unless positive measures are taken to ventilate this space.

Large volume areas such as unheated factories do not have the same temperature differential or water vapour pressure build-up as domestic buildings as they usually have a greater number of air changes per hour due to ventilation and open doors.

Unheated and uninsulated factories and warehouses for normal manufacturing and storage purposes, where the processes or the number of occupants do not add significant quantities of water vapour to the atmosphere, do not present the same condensation risk as other buildings. A building that is located in a valley subject to fog or frost can, however, cause condensation to drip from steel framing or roof-lights particularly during autumn or when the temperature drops sharply.

Construction using single skin metal cladding is not common outside Australasia, and because of its low thermal mass, this type of building is regarded as being hot in summer and cold in winter. If this type of construction is required to be heated, the building should be insulated and because of New Zealand's high humidity will require moisture control.

Insulated buildings that are prone to condensation are those in areas of high humidity because of the increased temperature differential between inside and outside and restricted ventilation. Buildings in areas where there are large diurnal temperature fluctuations are also prone to condensation.

Seasonal differences, particularly in the autumn, produce atmospheric conditions likely to give rise to condensation on any metal roof or wall cladding.

Buildings where large numbers of people congregate, such as public meeting halls, supermarkets, offices, old people's homes, or sports halls and church halls where heating is intermittent, all require water vapour control, ventilation and or humidity control.

Condensation or dew will accumulate wherever there is dirt or debris, and in adverse conditions when condensation forms between two metal sheets, corrosion will follow.

Cavity walls must be vented to the outside and water vapour must not be introduced into the attic space from the cavity.

Skillion and curved roofs without an attic space must have provision for ventilation.

Profiled metal roof cladding must not be overlaid with another profiled roof sheet or a flat sheet such as a long flat backflashing, without ventilating the space between the sheets.

4.2.4 NIGHT SKY RADIATION

Because roof cladding absorbs radiation from the sun and the attic space becomes warmer, some of this heat gained during the day is radiated at night into a clear night sky. Because all objects radiate heat to cooler objects, night sky radiation will occur when there are no clouds in the sky, at a rate dependent upon the emittance of the roof cladding. Radiation to the sky can cause the cladding temperature to drop as much as 5°C below that of the surrounding air and this will produce dew when the dew point is reached, or frost if the temperature falls below zero. If condensation freezes on the underside of metal cladding, it can drip when the temperature rises. Condensation will occur on the top and underside of metal once the dew point is reached, irrespective of the ambient temperature.

4.3 UNDERLAY

See NZBC Clause E2 EXTERNAL MOISTURE

The performance and properties of an underlay should be related to the purpose for which it is required and because an underlay performs more than one function, a definition is necessary.

The purposes of an underlay as referenced in this code of practice is used in conjunction with metal roof and wall cladding are:

- To provide a temporary means for the accumulation of condensation by absorption.
- To provide a permeable membrane to allow the passage of water vapour
- To prevent the ingress of external moisture into roof or wall cavities
- To provide a separation barrier between the metal cladding and copper preservative treated timber.

At the time of publication only kraft underlays are allowed to be used directly under metal roof and wall claddings and these are known to shrink under some construction and service conditions. Building designs that could cause excessive moisture or building sites that suffer high humidity require special ventilation provisions during and after construction to minimise underlay shrinkage.

It is the designers responsibility to identify such sites which are near to the sea, lakes or rivers, and designs such as skillion roofs and buildings with concrete floor and slab walls.

NZS 2295: 2006 pliable permeable underlays covers synthetic wraps as well as bituminous and fire retardant underlays. AS/NZS 4600 covers foils.

Specific requirements for these materials can vary for different cladding systems but the important features of absorbency, permeability and water resistance are important for metal roof and wall cladding so that they can comply with the requirements of the NZBC.

Underlay is not required under exposed eaves or open canopies but cladding should be isolated from the structure by a butyl or polyethylene DPC strip.

Because valley boards and boards supporting flashings are likely to be treated with copper preservatives, underlay can be used as a separator only if it does not remain wet. **(See 4.3.11)**

4.3.1 TYPES OF UNDERLAY

An underlay of one of the following types must be used under metal roof and wall cladding.

- Kraft paper (both bitumen-impregnated and fire-retardant)
- Self-supporting, (both bitumen-impregnated and fire-retardant)
- Synthetic complying with the requirements in Table 4.3.1.

As metal cladding can with maintenance last for 50 years, the underlay should also fulfill its function for that time. Minimum requirements for underlays for the metal roofing industry are as follows:

NZS 2295:2006 classifies underlays by their use in roofs or walls. N.B. Table 4.3.1. differs from NZS 2295.

Those that are suitable for metal roof and wall cladding are Roofs R1 (heavy) and R2 (self-supporting), Walls W2 (heavy) and W4 (synthetic)

	Roof Underlay (R1, R2)	Wall Underlay (W2, W4)
Absorbency g/m ²	140	100
Permeability g/m ² /day	36	26
Vapour transmission resistance (1/p)	≤ 13MNs/g	≤ 5MNs/g
pH	5.5.-8.0	5.5.-8.0
Water resistance mm head	> or = 100mm	> or = 20mm**
Max length m	10/7(FR)*	10/7(FR)**
Side and end laps mm	150	100

Table 4.3.1.

N.B. NZS 2295: 2006 limits the maximum run length of underlay to 10m if the amount of shrinkage is <0.5% and the maximum length to 7m if the amount of shrinkage is <1.5%. In many cases, particularly with fire-retardant underlay, shrinkage exceeds these figures and cannot be achieved and for this reason Table 4.3.1. does not nominate a shrinkage requirement.

* Fire retardant

** For direct fixing of metal cladding water resistance should be the same as R1, R2

4.3.2 USE OF UNDERLAYS AND VAPOUR BARRIERS

Underlays are an integral component of any metal roof or wall cladding system and the durability of the metal cladding is dependant on their correct use. Vapour barriers, or vapour checks that can be used as an air-barrier are also an important part of the system and this section covers the use of these materials used in domestic, commercial and industrial buildings in New Zealand and should be read in conjunction with section 4.2 Condensation.

Designers should understand how moisture can enter into roof cavities so that they can specify measures to prevent it, or to remove moisture from roof or wall cavity areas before it can cause damage to the metal roof or wall cladding or the structure. The use of metal cladding, underlays, vapour barriers, insulation, heating and ventilation are all interrelated and cannot be considered in isolation.

Absorbent type underlays must be used under metal roof cladding to absorb and remove moisture that could form on, or drip from, the cladding as condensation, and should exert the least possible vapour transmission resistance compatible with it remaining watertight.

As underlay acts as an absorbent layer a permanent air gap must be maintained and ventilation must not be inhibited by insulation or a second layer of underlay or foil underneath it. See 4.7.2.

Underlays, also known as breather or permeable membranes have minute pores created by the intersection of the fibres. These permit vapour to flow from one side to the other which, enables the equalisation of vapour pressure across the underlay but resist the passage of water.

Reinforced self-supporting roofing underlays are designed to span between purlins only without additional support where the purlin spacing is 150mm less than the width of the underlay when run horizontally or 1200mm when run vertically.

Underlays should not be allowed to become saturated or remain wet either during construction or in service.

Fire retardant underlays must be covered on the same day as installation.

Underlays often play a dual role by becoming a separator between treated timber and metal cladding however they should not become saturated as they may not perform this function. **See 4.3.11**

The roofing contractor is required to provide an underlay and sometimes insulation and vapour barrier at purlin level, which is part of the moisture control of the roof space.

The roofing contractor should use the correct underlay for each circumstance and therefore should understand the limitations of different underlays, synthetic wraps and vapour barriers.

The distinction between an underlay, a synthetic wrap and a vapour barrier within this Code is as described in the Definitions.

When used under metal cladding synthetic underlays must satisfy the requirement of table 4.3.1.

Underlays are intended and required to be permeable and absorbent, vapour barriers are not. An underlay is a flexible membrane "under-laying" wall and roof cladding and is known as "permeable" or "breathable" and reference in this Code to an underlay or a breather membrane means an absorbent and permeable underlay.

Excessive wetting, shrinking and consequential movement of kiln dry timber produces shear stress on fasteners, so underlay or roof cladding should not be installed until the moisture content of the timber is <18%. For the same reason, because some fire retardant papers are hygroscopic excessive moisture content and high humidity can cause shrinkage and on drying can produce splitting and maximum lengths are restricted for that reason.

The purpose of the underlay, the vapour control layer and the insulation should be clearly recognised by all those that design or install them, so that consequential damage does not occur due to condensation caused either by incorrect design or by incorrect installation. There is no universal method for their use, as different building requirements, insulation, ventilation and building volumes all have an influence on the design and positioning of the underlay and vapour control layers.

Although the insulation requirements can be different for domestic, commercial and industrial buildings the principles of moisture control are the same for all construction. The use of a vapour barrier or synthetic wrap directly under metal cladding can exacerbate condensation problems in severe or very high humid climates or where the building is not air-conditioned and the moisture content is not controlled. The method historically and successfully used in N.Z. to control the damage that can be caused by condensation moisture, is to provide some ventilation and use an absorbent permeable underlay, which can take up moisture and release it when atmospheric conditions change.

Condensation or dew can:

- fall from the roof as droplets and be absorbed by the underlay,
- remain as droplets on the underlay surface,
- drain down the underlay
- freeze and then drip from the sheeting when the temperature rises.

If there is sufficient condensation, and if the roof is steep enough, the condensate will run down the underlay to discharge at the eaves and the eave and penetration details should be designed to permit this drainage to occur.

Condensation on vertical profiled metal cladding can simply drain to the ground, however if used for more than one storey or interrupted by penetrations, additional provision should be made to ensure any condensation can drain.

A foil-faced vapour control layer is used in ventilated commercial or industrial applications for aesthetic reasons to reduce heat radiation from the roof cladding and to provide enhancement of light. It should not be used directly under metal cladding when the building is insulated, as in these circumstances it will act as a vapour barrier and be detrimental to the building structure.

An effective vapour barrier is not achieved until a vapour control layer (VCL), vapour check or retarder, is sealed. The main purposes of an underlay or vapour barrier are to:

- control or prevent condensation;
- prevent an unhealthy environment;
- improve energy efficiency;
- avoid damage to the structure.

Condensation can form within a structure due to poor design or inappropriate use of materials, which usually occurs in unseen or in inaccessible places. Trapped moisture can cause damage, such as the rotting of untreated timber, corrosion of metal cladding or structural steel, or mould staining of walls and ceilings. Once present condensation causes reduction in the efficiency of insulation, it is difficult to eliminate and it is expensive to rectify.

A waterproof permeable underlay should be placed above the insulation so that vapour can escape into the profile ribs or ventilated cavity, and also so that water cannot wet the insulation. The underlay should be uniformly supported, as sagging between purlins can promote ponding instead of allowing drainage.

Breather membranes are intended to absorb or trap condensation to allow evaporation, and if the pitch is shallow and the amount of condensate is small, the water may stay on the breather membrane until climatic conditions change and it is re-evaporated and vented away as vapour.

Because breather membranes cannot be continued under unit skylights and condensation does not have a drainage path to the eaves, roof lights and other penetrations should be designed to ensure that the drainage path is not interrupted. Profiled roof light sheeting starting at the ridge and running in continuous lengths to the eave can have either a double skin or UV stabilised clear sheeting under the roof light acting as an impermeable membrane to avoid condensation dripping from translucent sheeting. Continuous sheets are preferable to chequerboard layouts for this reason.

As the intended use for any building is likely to change during its lifetime, an expensive future retrofit can be avoided by assuming that the building may be heated in the future and that moisture control measures should be designed in at the outset. If a permeable underlay is provided then insulation can be added at a later date, but if a vapour barrier is used under the roof cladding, it would have to be removed when insulation was added. Uninsulated factory and storage buildings are not currently required by regulation to be heated, so the positioning of the underlay/vapour barrier is an arbitrary consideration usually made by the designer or roofing contractor. If a subsequent decision is made to heat such a building, retrofitting insulation under a vapour barrier will position it on the wrong side of the insulation and could cause condensation problems.

4.3.3 SYNTHETIC WRAPS

Polymeric synthetic wraps are made from different materials than kraft paper based underlays and therefore act and perform differently. A wrap is not a generic term for underlays as there are many types of synthetic wraps that cannot necessarily be classified in the same manner as paper based underlays even if they comply with the standard absorbency and permeability requirements.

Many synthetic wraps made from woven or non-woven polyolefin, (polyethylene or polypropylene) are not suitable as an underlay directly in contact with metal cladding on roofs and walls because they do not possess all of the requirements of an underlay. *(see 4.3.1.)*

Because metal cladding should not remain wet, those synthetic wraps, which could trap moisture at the interface of the structure are unsuitable for use directly in contact with the metal cladding.

4.3.4 COLD ROOF CONSTRUCTION

Cold Roof Construction design is when a large air space is provided above a flat ceiling, and the insulation and/or vapour control layer are placed at ceiling level. This is the most common construction used for New Zealand domestic dwellings and fall within this classification. *(see drawing 4.7.1.A)*

Regardless of the effectiveness of the vapour barrier and the amount of insulation used, at some time condensation or 'sweating' will develop on the underside of metal roof cladding. An air space between the cladding and the insulation is needed so that any condensation absorbed by the underlay can evaporate without restriction or wetting the insulation. This space requires some ventilation provision to minimise damage from moisture.

4.3.5 WARM ROOF CONSTRUCTION

Warm Roof Construction design is when a roof structure is designed with rigid or fibrous insulation adhered to or placed directly under the cladding. e.g. insulated panels *(section 12)* or fully supported roof cladding. Fully supported metal roof claddings without open ribs, fixed through and onto rigid insulation *(section 11.2.)* provide either a complete or near complete exclusion of the air that contains moisture and so do not necessarily form condensation on their underside. Domestic skillion or curved roofs, when the ceiling and insulation follow the roof line can also fall within the warm roof classification when ventilation is minimal and sometimes not present at all.

Variants of warm roof construction can provide ventilation at different positions in the roof assembly, but air should be excluded from between the metal and the insulation if condensation is to be avoided. This is not possible with the use of corrugated or profiled cladding unless all the voids are completely filled.

4.3.6 DURABILITY

With normal maintenance metal cladding can last 50 years and as the material beneath it should also last this length of time a 50 year durability is required.

As the failure of the underlay, vapour retarder, or synthetic wrap would go unnoticed, it could cause deterioration to the structure.

All types of underlay, vapour retarders, synthetic wraps and insulation used under or in association with metal roof and wall cladding must have a durability of 50 years.

Where an underlay is exposed to view and is easy to access or replace it must have a durability of 15 years.

Breather membranes must continue to provide their protection throughout the life of the roof or wall cladding and must not rot or deteriorate through ageing, moisture or changes in temperature.

Underlays should be protected and should not be degraded by UV radiation where they lap into the gutter.

Underlays are required to be either self-supporting or fully supported by using galvanised wire netting, safety mesh or other material that complies with the 50 year durability requirements of the NZBC. *(see 4.3.10. underlay and vapour barrier support.)*

Bituminous underlays should not be used in institutional buildings or where they are exposed and could spread fire.

4.3.7 PASSIVE VENTILATION

The amount of passive ventilation or air leakage through the ribs of metal roof or wall cladding depends on the ridge or eave details as the use of filler blocks can inhibit natural ventilation. Leakage also occurs through any unsealed laps of the underlay, a vapour control layer or from construction joints and cracks, and through structural movement. e.g. shrinkage of a tongue and groove timber ceiling.

A metal roof is a vapour check but if the laps are sealed it acts as a vapour barrier.

Vapour migration in most buildings will be in an upward direction because warm air rises, moving across or through barriers by either air leakage or diffusion. Air leakage also occurs around penetrations and through ceiling downlights and access hatches.

Diffusion under differential vapour pressure can occur through any permeable underlay, without any air movement or ventilation. The stack effect of warm air rising, produces natural ventilation or leakage at the ridge, particularly on steep pitched roofs but this cannot occur on curved roofs without special provisions.

Because synthetic wraps are available in 2.7m widths without laps, some types may effectively seal walls and limit any air leakage, which maybe insufficient to provide the ventilation necessary to avoid condensation. (*see 4.5.cavity construction*)

Air leakage is very limited in low- pitched and curved roofs without ridge vents or some additional means of ventilation.

Passive ventilation by convection allows moisture transfer through the building structure only if the building is weathertight and not airtight. These two terms are not synonymous and although the need for an airtight structure is sometimes seen as necessary for the efficient use of insulation and heating, it does not provide for ventilation. When insulation completely fills a cavity, ventilation is inhibited. The installation of a vapour barrier is considered unnecessary in some older New Zealand homes as moisture from within is removed by natural air leakage and the formation of condensation within cavities is not a common problem. Since the statutory requirement for the use of insulation the owners expectation of a degree of comfort has increased, and with it the incidence of condensation problems arising unless moisture control is addressed.

The use of aluminium joinery, the need for security at night and when the dwelling is not occupied during the day, and the lack of a chimney opening, all result in an 'airtight' house where leakage is minimal and the number of air changes per hour has been drastically reduced.

An air gap behind a permeable underlay is required to:

- allow ventilation
- prevent contact and moisture transmission between the underlay and any fibre insulation

As the temperature and humidity are constantly changing, building materials such as timber that are hygroscopic, can 'take-up' moisture and even out the peaks, in comparison to metals which are impervious.

A minimum air gap of 20mm must be provided between the underlay and any insulation.

4.3.8 HORIZONTAL LAYING

Horizontally laid underlay must be fixed to the purlins on both edges by the roof fastenings i.e. The purlin spacing must be 150mm less than the width of the underlay. If it exceeds this spacing it must be laid vertically.

Underlay laid horizontally must be laid commencing at the lowest point of the roof, running over the bottom purlin and lapped 20mm maximum into the gutter to avoid wicking. Subsequent layers must be lapped over the lower layer by a minimum of 150mm.

Horizontally laid underlay for roof cladding must have a minimum side and end lap of 150mm and on wall cladding the minimum underlay side and end lap must be 150mm.

Self-supporting underlay (R2) laid horizontally must have support on netting or safety mesh if used:

- Under dark coloured metal cladding
- On roof pitches < 8° pitch
- If support spacing > 1100mm.

Underlay must fit tightly and be lap-taped around all penetrations to provide drainage for condensation, and be free of tears, rips and punctures.

Flue penetrations must have a minimum distance of 50mm from the outer liner to any underlay or flammable material.

When ridge ventilation is required the underlay must be terminated at the ridge purlin to allow free passage of air.

As underlay can move downwards due to heat and shrinkage it must be fixed and be 'captured' by the fastenings.

N.B. Heavyweight building underlay (R1) is not recommended under dark painted metal cladding.

Rips < 75mm on walls can be repaired by using a compatible flashing tape but all roof damage requires a new piece of underlay captured by the cladding fastenings

To lay underlay horizontally, a number of rolls can be progressively unrolled by one roofing sheet width at a time, however, running multiple rolls straight can be difficult in windy conditions.

Horizontal laying allows condensation to be shed into the gutter without the risk of leaks at the laps and it also prevents leakage of warm air rising directly to the metal cladding.

To avoid splitting due to shrinkage or damage from structural movement, roofing underlay should be fixed securely and should not be laid taut but tensioned sufficiently to give fall on low pitches.

All underlay laid horizontally or vertically under metal roof cladding below 8° must be supported and have 150mm laps. Bituminous underlay must be limited to 10m lengths and fire retardant to 7m.

4.3.9 VERTICAL LAYING

When it is not practical to place underlay horizontally, it can be run vertically with a minimum side lap of 150 mm. When underlay is installed vertically on low pitches the support should be sufficiently taut to avoid leakage from any condensation at the side laps, as water can run through the lap if it has sagged or shrunk. Where there is no vapour barrier, open vertical laps of underlay can allow the ingress of moist air into the cavity causing condensation.

Underlay is run vertically when installing long length roof cladding on commercial and industrial buildings because the purlin spacings often exceed the width of the underlay and as it reduces the risk of wind damage.

Underlay can be laid vertically under roof cladding down to 3° but it must be supported and have minimum side and end laps of 150mm.

On wall cladding the minimum vertical underlay side and end lap must be 100mm.

Self-supporting underlay laid vertically must have support on netting or safety mesh if used:

- Under dark coloured metal cladding
- On roof pitches < 8° pitch.
- If support spacing > 1100mm.

Underlay laid vertically on roof pitches less than 8° will not ensure that condensation will drain to the gutter unless the support is flat and taut. To ensure this, vertical laps should be sealed with window seal tape.

Where the roof cladding changes direction, is cut around penetration flashings or terminates at the periphery of the building, the underlay should be carried up behind the cladding or flashings to ensure continuity so that condensation can be absorbed or exit at the gutter line.

N.B. The underlay under a curved roof abutting a wall should be dog eared under the apron flashing.

4.3.10 UNDERLAY AND VAPOUR BARRIER SUPPORT

Non self-supporting roofing underlay must be supported by safety mesh, hexagonal galvanised wire netting or alternative support except when it is used under tile battens fixed at 370mm centres.

Safety mesh, galvanised wire netting or alternative support for non-supporting roof underlay must have a 50 year durability. Self-supporting underlay must have support at pitches < 8° and also be durable for 50 years.

Safety mesh must be designed and installed to comply with the requirements of the Health and Safety in Employment Act 1992 and the Regulations of 1995, and it is accepted as a fall protection barrier.

All support materials must be tensioned to keep the underlay in a flat plane and must not be 'sagged' to accommodate insulation. This is particularly relevant at low pitches to avoid any ponding of condensation.

Metal roof cladding with good design and regular maintenance can last 50 years, therefore because it cannot always be seen or accessed for repair or replacement, the support should also have a durability of 50 years. For greater durability, standard wire netting and safety mesh are available with a PVC coating. Other means of support should be capable of supporting underlay and vapour barriers to avoid ponding and should also last for 50 years, as they cannot normally be seen. This is particularly applicable to skillion roofs.

It is the responsibility of the roofer and specifier to ensure that safety mesh, galvanised wire netting or alternative supports for non-supporting roof underlay meet the 50 year durability requirements of the NZBC.

While safety netting is not an approved safety mesh it does provide a degree of safety when securely fixed to the supporting framing. The safety requirements for the installation of netting are the same as those required for the installation of safety mesh. (*see safety mesh section 14.1.10.*)

Because underlay can suffer embrittlement due to exposure to excessive heat when in direct contact with dark coloured roof cladding it is recommended that mesh support be used.

In marine environments ingress of salt-laden air can corrode galvanised underlay support and in turn cause corrosion of coated metal and aluminium or zinc cladding. To avoid this possibility, polypropylene tape can be used or the cladding separated from the underlay by a high density polystyrene batten.

Safety mesh and some kinds of wire netting can be damaging to metal and in particular aluminium roof cladding. This occurs in two circumstances.

- When the roof cladding is used as a walkway. In this case purlin protection should be used (*see 9.7.6.*)

- In a marine environment when deterioration of the galvanised coating of the netting or mesh allows pitting corrosion of the aluminium or aluminium zinc coatings to occur at the netting contact points on the underside of the cladding. (see 2.6.2.) In this case a separating high density polystyrene batten should be used (see 4.3.8.) or an alternative inert underlay support material should be used.

4.3.11 SEPERATION

There are materials other than underlay that can be used to provide a separation between copper preservative treated timber and metal cladding.

Such material is termed 'underlayment' which can provide a 'slip joint' between cladding and the structure and can also provide an air gap. Some such materials are a three-dimensional mesh made from polypropylene synthetic monofilaments 6mm high which is tangled and welded where they cross and provides a ventilating and drainage gap between the metal cladding and the batten. This separation also will reduce noise transmission. If this material is used it is not necessary to provide an underlay as a separator between copper preservative treated timber and metal cladding, however an underlay is still normally required.

4.4 VAPOUR BARRIERS

4.4.1 TYPES OF VAPOUR CONTROL LAYER

- Aluminium foil laminated paper
- Anti-Glare foil laminated paper
- Polythene faced / foil laminated paper

A vapour barrier is an impermeable membrane that will prevent the passage of water vapour and should not be confused with permeable underlay. A vapour barrier that is not sealed is more correctly named a vapour control layer or a vapour check, as a true barrier is a completely sealed membrane.

If positive measures are not made for the provision of ventilation, to minimise the passage of water vapour into the roof space in cold or humid climates, a vapour barrier should be placed immediately above the ceiling lining in areas that generate water vapour and beneath any insulating material incorporated in the roof space. The application of a gloss sealing paint to a sheet ceiling lining can form an effective vapour check.

Most domestic buldings in New Zealand do not require a vapour barrier, however there are circumstances where one is necessary.

A curved roof does not allow the ventilation leakage that can occur at the ridge of sloping roofs and where the ceiling follows the roof line a vapour barrier should be placed directly above the lining to kitchens and bathrooms to ensure that water vapour will not infiltrate this space. Skillion roofs, particularly those with a permeable ceiling, such as tongue and groove timber, should also have a vapour barrier directly under the ceiling or rafters.

A sealed vapour control layer will only provide the greatest possible vapour resistance without any tears, rips or punctures and so any fasteners that penetrate it should have sealing washers to maintain the vapour seal.

In the high humidity areas in domestic or institutional buildings, such as bathrooms, kitchens and laundries, where the majority of internal moisture is generated, the presence of a vapour control layer such as a coat of gloss paint or vinyl wallpaper, the provision of a fan vented to the outside, or positive permanent ventilation will reduce the extent of condensation. Dehumidifiers assist by controlling humidity levels but are an ongoing cost and require all windows to be closed in order to work efficiently.

Where the interior space of a building, including the roof cavity, is air-conditioned or has controlled humidity, it normally does not require a vapour barrier.

A 100% vapour barrier is difficult to achieve, but to preserve continuity, openings around down-light fittings recessed into ceilings and around flues passing through insulated ceilings should be fully sealed to prevent the passage of water vapour. Electrical wiring or light fittings should not be embedded or placed under insulation unless specially designed to do so, as deterioration due to overheating can occur.

The main reason why aluminium foil laminated paper is installed in commercial and industrial buildings under roof cladding is to maintain surface reflectance, limit heat emission and enhance lighting conditions.

As the material becomes tarnished or dirty, the reflectance value of the foil value decreases. White polythene faced vapour checks are also used in public buildings with an exposed roof structure to enhance the appearance from below. If reflective insulating vapour control layers are also expected to perform as a vapour barrier, taping or adhesive bonding of the joints is required to form an air-tight seal.

Anti-glare foils are made from both fire-retardant and non-fire-retardant materials similar to aluminium foils. The upper foil side is coloured blue which can reduce the reflective radiation associated with standard foils.

At night when the temperature drops or if the moisture level is high within the building, if foil is in contact with the metal roof cladding it is likely to be at a similar temperature, and as it is non-absorbent condensation is likely to form on it.

In unfavourable conditions any thermal bridge contact between the foil and the roof cladding can initiate corrosion and for this reason foil should only be installed directly under metal roofing in non-residential, uninsulated and well ventilated buildings.

A vapour barrier is used to prevent water vapour moving into or out of the structure which should be mechanically vented to the outside by the use of a fan.

Insulated buildings with a vapour check or control layer must have a 20mm air gap between the metal cladding, and an underlay placed directly under the cladding.

A vapour check or control layer must have a vapour transmission resistance of at least 500 MNs/g.

A permeable underlay must have a permeability of 36 g/m²/day or a vapour resistance of no more than 7 MNs/g.

To prevent vapour condensing on its surface, the vapour barrier must be installed on the warm or inner side of the framing.

4.4.2 SPECIAL REQUIREMENTS

Buildings of the following types using metal cladding should have a sealed vapour barrier and are outside the scope of this Code of Practice and are subject to specific design:

- Swimming pools;
- Buildings containing liquids stored in open containers;
- Buildings where water is used in manufacturing, cleaning or storage processes;
- Ice rinks, cold stores and freezers;
- Buildings where unvented gas heating is used.

A vapour barrier incorrectly located on the cold side of a structure or poorly installed can result in rapid build-up of cavity or interstitial condensation and result in high costs for rectifying defects and damage.

Cold stores, freezers or buildings where the temperature is near or below 0° all require a fully sealed vapour barrier located on the warmer, outer side of the insulation but are subject to specific design. (*see insulated panels section 12*)

4.5 CAVITY CONSTRUCTION

There are certain types of building construction and claddings that are considered to have a higher risk of damage from leaking because of three main factors:

- the impermeability of claddings that do not have any capacity to absorb water
- the inability of a structure without ventilation to dry out any moisture accumulating within it
- the penetrations in, and the junctions between, the same or different cladding materials

Such higher risk buildings are required to have a drained and ventilated cavity behind the cladding when they:

- have a design wind load $\geq 1.5\text{kPa}$
- have monolithic cladding
- are built with a parapet
- are built with roof and wall junctions - other than simple barges

Although metal roof and wall cladding is an impermeable cladding and falls within this higher risk category, there are some metal clad walls that are considered to be exempt.

They are:

- Unlined and uninsulated metal clad roofs and walls because they have sufficient ventilation to disperse any moisture.
- Insulated pitched metal roofs with a 20mm air gap between any insulation and the underlay because they also have sufficient ventilation.
- Vertical metal wall cladding attached directly to the structure but where there are air gaps at corrugations or at trapezoidal ribs. Parapets with vertical metal cladding should have a space between the end of the sheeting and the capping. (*see drawing 5.3.4.C*)

Horizontally fixed metal cladding attached directly to an insulated structure does fall within the higher risk category and it is recommended that this type of construction should have a cavity. This is not required because of the risk of leakage but because of the likelihood of the accumulation of condensation.

Because roof and wall cavities are part the weathertightness system or 'moisture management' of metal roof and wall cladding, this section should be read in conjunction with **design section 4.2 and 4.3**

4.5.1 TYPES OF CAVITIES

Cavity construction is defined as:

- A roof or wall in which the structure and the external cladding are separated by a drained air gap. These may be unvented, vented or ventilated.
- A metal clad roof or wall having an enclosed air space between the underlay and any insulation is termed unvented, and when there is an air entry at the base it is termed vented.
- When an air space is provided and there is a purpose designed air entry and exit it is termed a ventilated roof or wall cavity.

Cavity construction is only required when the wall is insulated and lined and when free ventilation is not available behind the cladding. When using horizontal profiled metal cladding, an effective way to obtain a vented or ventilated wall cavity is to use battens to provide an air gap between the cladding and the structure.

4.5.2 ROOF CAVITIES

Most roof structures using metal roof cladding are vented whether they are designed that way or not. Upward sloping metal corrugations or ribs become natural tunnels that allow air movement by convection, and this takes with it any excessive water vapour that may accumulate within the corrugations.

The permeable underlay under roof cladding also allows water vapour to move through it from the ceiling cavity below provided there is an air gap beneath.

N.B. Metal roof cladding without any or with insufficient ribs for ventilation to occur require special provisions. (see **section 11**)

When the insulation is situated at the ceiling level of a pitched roof there is a large volume of air below the metal roof cladding and any water vapour accumulating in the attic space can move across the permeable underlay and exit via the ridging. However with skillion roof or curved roof construction in which the ceiling line follows the roof cladding, the air volume is significantly reduced and consequently there will be little or no ventilation in these types of roof structures. The condensation problems associated with skillion and curved roofs arise because of the restricted air space and the lack of ventilation. Although the principles of cavity construction are the same for all claddings, because metal cladding has negligible thermal mass, is impermeable and non-absorbent and is an excellent conductor, it has different cavity requirements to other claddings.

The amount of air movement designed into a cavity is primarily to equalize the pressure on both sides of the cladding. Metal cladding however requires a much greater amount of air movement to evaporate or diffuse the greater amount of condensation that is likely to form on metal at times or in areas subject to high humidity.

Drainage will occur quickly in walls given sufficient amount of water, but the drainage of condensation on low-pitched roofs may not occur without sufficient fall. In such cases condensation will drip or be absorbed by the underlay.

4.5.3 WALL CAVITIES

A cavity provides two functions:

- Drainage and/or
- Ventilation

The reasons for drainage are two-fold, to drain external moisture from leaks or solar driven moisture through absorbent claddings, and also to drain internal moisture accumulating as condensation. Any remaining water that is absorbed into the underlay or timber framing can be disbursed by ventilation.

Although gravity is the dominant force acting on rainwater or condensation, because the differential pressure produced by wind, water can flow vertically upwards depending on the type of material, its surface condition and its proximity to another material. Capillary action, absorption or wicking can transfer water from leakage or condensation within the wall space to another material or it can change phase.

Ventilation of cavities should be only sufficient to allow moisture to evaporate and to dry underlay or framing. However diurnal fluctuations in temperature may be insufficient for this to occur without outlet provisions and adequate air-gap clearance. (see **drawing 4.5.7.A**)

Nominal 20mm timber or polystyrene wall battens are not regarded as 'structural' therefore the metal cladding should be structurally fastened to the frame.

When cladding is fastened to the batten only it is the responsibility of the cladder to ensure that the batten is structurally secured to the frame. It is better practice to fasten cladding directly through the batten to the frame. All cladding must have a sealing washer under the fastener head.

4.5.4 VERTICAL CLADDING

Symmetrical trapesoidal and corrugated profiled metal wall cladding, if laid vertically with provision for top venting does not require a cavity but does require an absorbent, permeable and water resistant underlay in the same manner as roof cladding.

When corrugated cladding is fixed vertically to a wall the requirements are the same as those for roof cladding:

- a ventilation gap between the underlay and any insulation
- an exfiltration gap - a soffit flashing at the head of a wall (*see drawing 4.5.7.A*)

Although a metal roof or wall is expected to be made 100% watertight from external moisture, when condensation occurs to the extent that it will accumulate within the roof or wall, some provision should be made to drain and/or ventilate this internal moisture.

A roof or wall that is designed to shed all the rainwater that it receives without leakage is termed a 'rain screen'.

The purpose of an underlay is to temporarily absorb condensation and although it is often referred to as 'the second line of defence' against water ingress it is not designed to be and nor should it be considered for this purpose. An underlay can also act as the wind barrier required in high and very high wind design load areas.

When the metal cladding is fixed to a batten in cavity construction, the function of the wind barrier shifts to the underlay or wrap that is directly underneath the batten and attached to the structure. (*see drawing 4.5.7.B*)

N.B. Not all synthetic wraps or underlays are classified as wind barriers.

Vertical metal cladding can be used on a parapet wall without a cavity providing there are ventilation provisions in the design. (*see section 5.3.4.*) The apron flashing on a cavity wall should be placed behind the batten and in position before the batten is fixed.

Rain-screen or face sealed claddings such as profiled metal rely on joints for:

- Expansion
- butting or lapping of sheet materials
- abutting dissimilar materials.

These joints can either be covert or overt. Covert joints are those covered by a flashing, molding or facing, or can be a lapped flashing that is visible. Overt joints are usually butted and can be sealed or unsealed and have (or do not have) a hidden flashing underneath them. Some joints combine both types and they both can be used for vertical and horizontal metal cladding.

Butted sealed joints are not sufficient by themselves to provide the exclusion of rainwater and should always be used in conjunction with some other means of deflecting or controlling water such as a flashing, or by lapping.

4.5.5 VENTILATION

The rate and amount of evaporation of condensate will depend on many factors, one of the most dominant being ventilation. With good ventilation evaporation can occur within hours or days whereas diffusion alone is a slow process and can take weeks. This 'time of wetness' is important to the longevity of metal cladding. The change from water to water vapour is known as a 'change of phase' and will occur more rapidly when there is significant air movement.

A vented cavity is one that provides drainage and some degree of air movement and water vapour diffusion, whereas a ventilated cavity has been designed to provide a significant flow of air or water vapour to the outside.

Metal roof ridging will allow air movement provided that if filler blocks are used they are themselves vented. A ventilated ridge on a roof or a continuous gap at the top and bottom of wall cladding will provide air movement whenever there is a pressure differential between the lower inlet and the higher outlet and this movement is termed passive ventilation. The air movement associated with a temperature differential or pressure differential when there is a wind blowing is commonly called the 'stack effect'. Any gravity vents, as they are also termed, are very dependent on the direction and force of the wind and so in calm conditions, temperature becomes the dominant factor. Wind is highly variable both in direction and force and it is therefore not possible to rely on it alone for ventilation. At the edges of a building, where the wind force and the amount of rain can be much greater than at the centre of the wall, it is important that the vertical cavities created by the battens are inter-connected to allow air movement between the cavities and so that undue pressure does not buildup inside any one of the cavities.

Even in windy conditions total pressure equalisation between the cavity and the exterior will not necessarily occur, because any restriction such as a vermin proof ventilating strip at the cavity base will impede air movement. Pressure moderation will occur but it will depend on the amount of restriction there is at the head of the cavity and on the cycle frequency of wind gusting. Equal open areas at the top and bottom of the cavity are required to provide sufficient ventilation when there is no wind. Because of the move towards greater energy efficiency in buildings, leakage around penetrations such as windows has been minimised and without any temperature or pressure differential and a top vent outlet in a cavity, there will be virtually no air movement.

Relative humidity also plays a part in ventilating the cavity as water vapour moves from higher pressure to lower pressure and from wetter to dryer. This movement can occur either way through a truly permeable underlay, but some synthetic wraps can act as diodes allowing only one-way vapour movement, while some are impermeable.

The amount of water that can be suspended in air without condensing is very dependant on temperature. **(see condensation section 4.2.2.)** As conditions each day, week and month inside the wall are constantly changing, water vapour pressures will vary and the amount of water stored within the cavity by timber framing and other materials will also fluctuate. The ideal amount of ventilation is the minimum that can ensure some air movement under the worst conditions e.g. on a still morning on the south side of a building after a frost. Fortunately, as frosts occur because of night sky radiation to a clear sky, **(see section 4.2.4.)** they are usually followed by a clear day which brings a quick rise in temperature and induces air movement in the cavity. The amount of ventilation may need to be restricted so as to prevent undue loss of heat from the building.

The cavity depth is determined by the free space or air gap behind it. For metal cladding the minimum depth should be 20mm and should provide approximately half an air change per hour (1/2 ac/h). This coincides with the recommended number of air changes per hour for internal spaces of the building, and is achievable given a 50% restriction at the base vermin strip and the outlet space at the top of a 20mm cavity. **(see drawing 4.5.7 B.)**

N.B. This vermin strip should be made from non-ferrous metal or plastic to comply with the 50 year durability requirement of the NZBC.

A ventilated cavity wall must have means to vent the top but must not allow entry into the roof cavity.

4.5.6 DRAINAGE PATH

The leaks associated with monolithic claddings particularly around window penetrations, has led to the belief that 'all window flashings leak'. This is incorrect as there is sufficient historic evidence to show that hemmed metal underflashings provide a drainage path that will weather extremes of wind driven rain, and recent tests using horizontal metal cladding have confirmed this to be true.

Although flashings will allow some air leakage, the use of profiled filler blocks will inhibit ventilation unless they are themselves vented however they are not required except in very high wind design load areas. Silicone should not be used as a first line of defence against moisture ingress and for this reason the profiled metal cladding should not be slit at the head or at the sill flashings but should be lapped as shown in the **drawings in Section 6.4**.

A cavity wall is very similar in requirements to a cavity roof and the roles of the ventilation gap, underlay, synthetic wrap and vapour control layer are similar. The prime purpose of the cavity is to provide ventilation, not to provide a drainage path for leaks caused by faulty workmanship. Gravity has a greater influence on the drainage path of a wall, although since a roof can be 59° and a wall can be 61° there is little difference between them. Historically, cavity roof construction has been successful because there is a gap between the insulation and the underlay. This rule applies equally to cavity walls, and it is considered that the placement of fibrous insulation hard up to the underlay has been the cause of some wall and cladding failures.

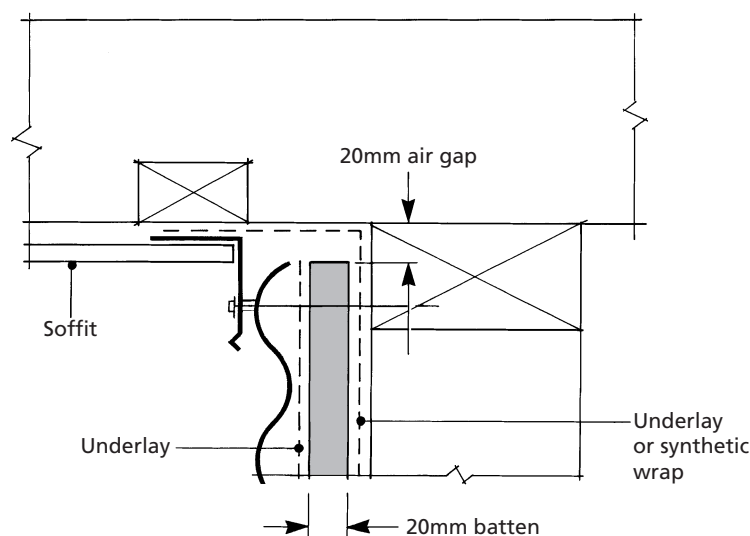
The performance of any wall will change with time as the accumulation of dirt will alter the surface tension on metal cladding and synthetic wraps which can retain moisture at their interface.

4.5.7 CAVITY UNDERLAYS

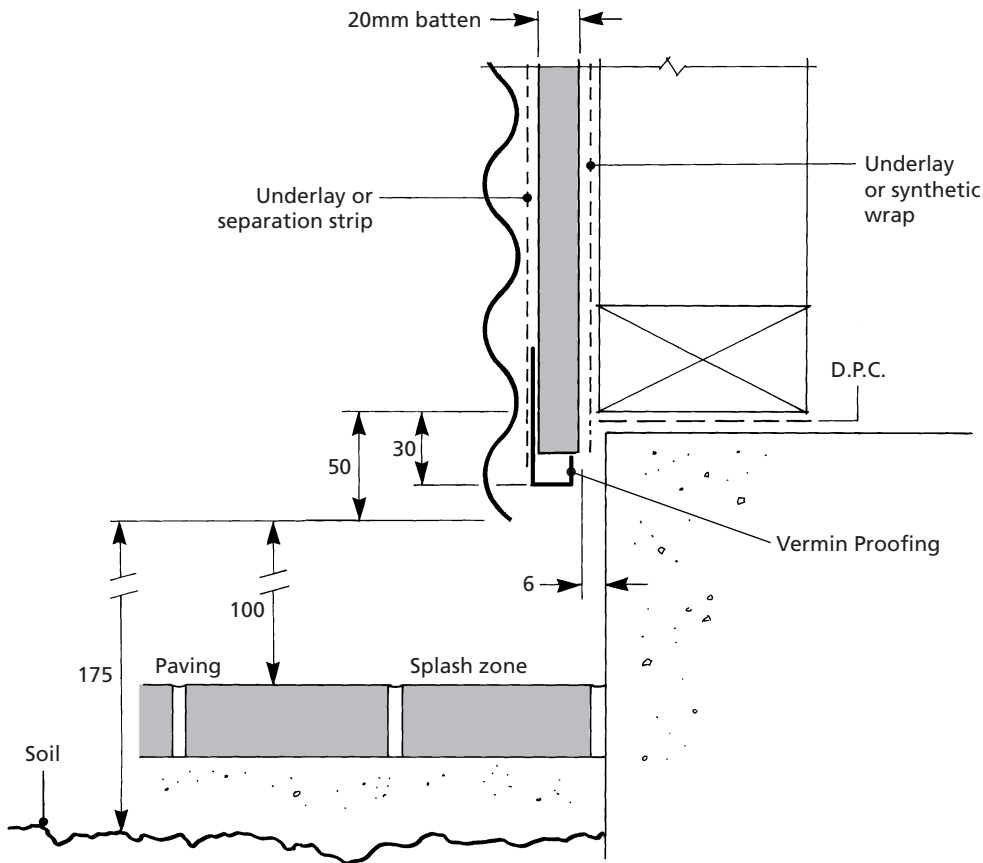
Underlay directly under metal wall cladding should provide the same absorptive, permeable and water-resistant properties that are required for use under roof cladding. The second wind barrier or synthetic wrap behind the batten provides a ventilation chimney but there should be no horizontal battens at the base, or head and sill of any window or penetration that would restrict and effectively seal the cavity. Continuity of an air passage should be provided to ensure maximum ventilation. (see **drawing 4.5.7.C & D**)

When assessing the comparative values of permeable underlay or synthetic wraps, the method of fixing and direction of laying should be taken into account as unless the laps are sealed, the theoretically tested and the performance permeability values will be quite different.

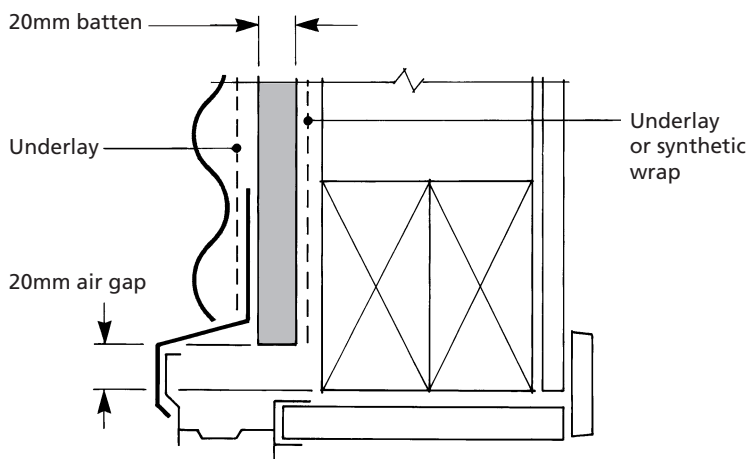
The environment at the splash zone should be considered as salt-laden moist air can be drawn into the cavity and the ground clearances should be maintained and not be altered by subsequent landscaping. (see **drawing 4.5.7.B**)



Drawing 4.5.7.A 

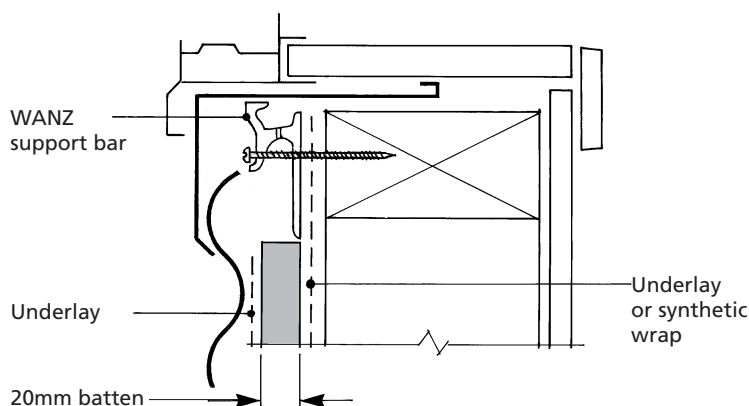


Drawing 4.5.7.B



Drawing 4.5.7.C Window head





Drawing 4.5.7.D Window sill 

There is a belief that the purpose of a cavity and an underlay is as a cure-all for leaks. The role of the underlay is only to provide an emergency path for minor and infrequent leaks and to provide a moisture sink for condensation when it occurs. Although the cavity does provide drainage its role is to ensure that by providing ventilation, evaporation and diffusion can occur in the manner described.

The free water or water vapour that is present within a cavity comes from separate sources,

- Leaks
- Building use
- Condensation
- Construction materials

The first can be avoided by using the better practice quoted in this NZ Metal Roof and Wall Cladding Code of Practice, and the second by the owner adopting a conscious effort to vent water vapour at its source, or by using permanently ventilated windows.

Whenever metal roof and wall cladding is used, condensation is inevitable and its severity will depend on both the design and the environment. It cannot be prevented unless warm roof construction using bonded or foamed insulated panels is used as the construction method. (*see section 12*)

Damage to metal cladding from condensation can be prevented by ventilation and the correct use of cavity construction.

4.5.8 BATTENS

Battens are fixed to the main vertical framing at 600mm stud centres and they can be made from timber, steel, polystyrene or other plastic materials.

The use of treated timber for battens and framing requires a separation barrier between the battens and the metal cladding to prevent wet contact and any moisture accumulation causing deterioration to the cladding. This can be provided either by a water resistant underlay, or an impermeable strip such as a PVC tape.

H3 copper based timber treatments are considered likely to cause deterioration to metal cladding if the timber moisture content exceeds 20%.

Polystyrene battens can be used in a similar manner to timber, but only very high-density polystyrene should be used. (28kg/m³)

4.5.9 FASTENERS

Fasteners used for fixing metal cladding through a timber batten into a timber structure become the primary fastener and should be a greater length than normal by the thickness of the batten. The size and frequency of these fasteners depends on the wind design load and should be calculated to allow for the extra load at the corners of any wall.

When fixing metal cladding in the pan through a 20mm batten into a timber structure, a minimum of 12# x 10 x 55mm hex head type 17 screw should be used. For fixing through a 20mm batten into a steel structure a minimum of 12# x 14 x 45mm hex head self-drilling screw should be used. Sealing washers are required under all fixing screws.

4.6 VENTILATION

The amount of ventilation required for domestic, commercial and industrial buildings should be minimised to provide an energy efficient structure, however ventilation is required to minimise condensation on those with metal roof or wall cladding. Approximately half an air change per hour within a cavity space is required to minimise condensation and remove excess heat, and ventilation via the ribs of some metal roof and wall cladding can achieve this, but additional provisions are often necessary. Ventilation at most times of the year at most pitches will be provided by corrugate and trapezoidal roof and wall cladding with open ribs and without filler blocks. The stack effect of hot air rising is considerably reduced on low-pitched roofs, and is virtually absent on still nights, when condensation is most likely to form.

The size and number of inlet and outlet vents required to provide additional cross ventilation to avoid condensation, depends on a number of factors. These include the profile, the pitch of the roof, the length of the rafter and the temperature difference between the inside and outside of the structure.

Uninsulated single skin metal clad buildings obtain adequate ventilation because of air leakage at the walls and the ridge.

Condensation cannot be totally eliminated in an enclosed roof space when using metal roof and wall cladding, and where "cold roof construction" metal clad buildings are insulated, ventilation becomes of much greater importance and provision should be made for air movement to take place.

A minimum breathing space of 20mm must be provided under the underlay for ventilation to occur.

Because it is difficult to construct a perfect vapour control layer that totally resists every trace of water vapour, it is necessary to ensure that any vapour that enters the roof cavity can be dispersed through ventilation. Water vapour above the underlay can escape through unsealed cladding side laps, or through the ribs of profiled claddings without filler blocks however ventilation through the ribs depends on air being allowed to enter at the eaves and escape at the ridge. Filler blocks will inhibit this air movement, but they can be perforated or omitted altogether if vermin are not a hazard and wind driven rain is not a threat to the weathertightness of the building. Ventilation becomes more efficient as the roof pitch increases and ventilated ribs are at their least efficient on long shallow pitches.

Additional venting should be provided when the roof pitch is $<15^\circ$ and the rafter length is $>30\text{m}$.

Air movement through the ribs depends on the rib spacing, rib area, roof pitch and overall length of the sheeting, while short, steep slopes and trapezoidal roofing provide more ventilation than secret-fix roofing.

In skillion roofs or when the insulation is cut between the purlins, the volume of air space available to absorb and dissipate condensation is greatly reduced. This situation can lead to excessive roof cladding expansion and noise problems as any heat build-up cannot easily be relieved by ventilation.

Curved roof construction with or without a roof cavity, with sealed laps and no ridge, does not provide air leakage, and therefore allowance should be made to ventilate the cavity by the use of louvre vents high in the gable end wall, or to ventilate the roof space at the barge in the top purlin spaces at both sides of each gable.

Passive ventilation of this type is uncontrolled, so only sufficient outlet is required to cause natural flow, with an equal size inlet at the eave height. When humidity is high and if there is excessive ventilation or large gaps are present, moisture laden air can be induced into the cavity and exacerbate the condensation problem.

Bathroom or kitchen vents must not exhaust into the ceiling cavity.

Warm air naturally rises but has little tendency to move laterally, except when a strong wind blows into roof vents or causes substantial differences in air pressure on opposite side of the building. Consequently, ventilation of the roof space alone will not necessarily prevent condensation forming on the underside of cold roofing. As wind can produce positive and negative loads on the roof cladding at the same time, there is usually some roof cavity air movement that is dependent on the force of the wind.

Ventilation of the ceiling cavity by installing louvre grilles at the gable end apex, soffit vents, a continuous slit in the roof soffit, gravity unit ventilators, or a ridge ventilator, will not only reduce condensation but can also reduce wind design load requirements. *(see loadings section 3.4)*

Ridge ventilators should always have eave vents so that wind-induced suction does not draw warm moist air from the rooms below.

If a ventilated airspace is not provided above the rafter insulation, a risk of condensation will remain even if a highly permeable underlay is used, as it may not have the capacity to absorb all the condensate.

Ventilating the air space directly under the roofing also reduces the likelihood of noise due to expansion from absorbed heat.

4.6.1 INTAKE VENTS

To prevent moisture accumulation and to remove excess moisture in buildings with metal roof cladding, attic spaces should be ventilated using static, balanced ventilation systems with a total of 1m² net free venting area per every 150m² of ceiling area (0.6%) For roof pitches <10° this ratio should be increased.

In a balanced ventilation system, air intake vents are used to allow outside air to enter into attic spaces and ventilation cavities. Approximately one-half of the required ventilation area located at each side of the eaves should be equal in total to the area of the exhaust vents at or near the ridge. Continuous or individual soffit vents can be designed, and installed to suit the specific aesthetic or other needs, and they should always be installed so as to allow free movement of air into the cavity, and should not be blocked on the interior side by insulation or other material.

Intake vents must be designed and installed to prevent rain, animals or insects from entering the interior space, and require to be shielded in exposed areas.

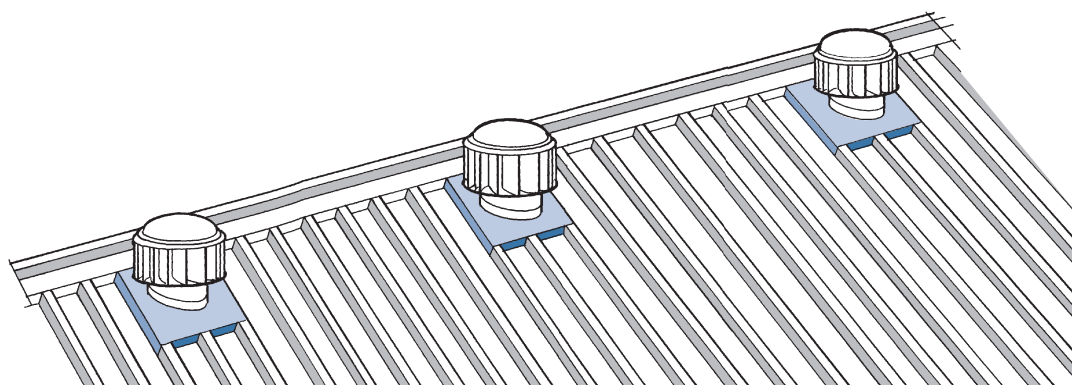
4.6.2 EXHAUST VENTS

Exhaust vents such as continuous or intermittent ridge vents, gable end vents and turbine vents should always be used in conjunction with intake vents. Some of these can be classed as fire vents.

When gable-end vents are installed in the walls of a building at the apex at both ends, they can be used without additional intake vents located at the eave, as they function as both intake and exhaust vents, depending on the wind direction. They are effective when sufficient wind comes from a direction perpendicular to the gable ends but are of only limited effectiveness when winds are light and come from a direction parallel to the gable ends.

Turbine vents rely on the wind to rotate the fan blades and when wind is present they draw air from the ventilated area at a greater rate than do passive vents when wind is present. The amount of air movement can be dampened but is normally uncontrolled as it is developed as a function of wind speed as well as turbine size and efficiency. They are not vulnerable to wind direction and their size and number can be calculated for a given air movement and wind speed.

One 300mm throat turbine vent will provide exhaust ventilation for a building of approximately 100m².



Drawing 4.6.2. 

Where a skillion, fully supported or a curved roof requires ventilation, small unit vents can be provided to a similar design as shown on *drawing 6.3.1.A*.

No penetration must be made in roof cladding below the minimum pitch for the profile.

4.6.3 MECHANICAL VENTS

Domestic ventilation systems are available that re-circulate attic air at a controlled rate of 1 change per hour which should be adjusted for the climate and type of dwelling. Other domestic systems include positive pressure forced air systems that can filter and heat outside or re-circulated air.

Mechanical ventilation is an alternative to a balanced gravity ventilation system for the attic or ceiling spaces of commercial or industrial buildings without air-conditioning, which is capable of providing up to 5 air changes per hour. This amount can be adjusted to suit the building design and use and the climate, but should be adequate to avoid any build up of condensation in normal conditions. Exhaust vents should be placed at or near the ridge or high point and may be operated by thermostats or humidistats that cause the vents to run only at or above a predetermined temperature or relative humidity. Consequently, the fan may not operate during winter conditions and therefore may not effectively remove moisture-laden air from the ventilation space unless manually overridden. Mechanical ventilation that is not automatically controlled is reliant on subjective judgement as to when and if it is required.

4.7 INSULATION

The insulation requirements for domestic buildings in New Zealand include the provision of prescribed values for walls and ceiling spaces that can only be assured by the correct placing of the underlay, insulation, and vapour control layer suitable for the design. If the bulk insulation becomes wet it not only loses the prescribed insulation value, but can cause metal and timber corrosion.

Although underlays, foil vapour control layers and synthetic wraps are part of the insulation value of a cavity, they do not have any insulation value of themselves except to provide an air gap or to control heat emission. A still air gap of the correct size can act as an insulator.

4.7.1 TYPES OF INSULATION

There are five main types of insulation used in domestic commercial and industrial buildings in N.Z.

- Fibrous- glasswool or mineral wool bonded with a non-flammable resin,
- Thermally bonded polyester
- Rigid board extruded or expanded polystyrene or polyurethane,
- Loose fill
- Wool- loose fill or blended with polymer

Insulating material, besides providing a measure of comfort for the occupants, serves to reduce heating costs and to slow down the heat transfer that occurs in all buildings, particularly those with single skin metal cladding. When using any insulating material with metal clad heated buildings, it is necessary to provide a roofing underlay and also a vapour barrier above areas where water vapour is produced during any manufacturing process. Insulating materials should be kept clear of roof cladding or roof underlay by a minimum of 20mm, to ensure that condensation can evaporate.

Although reflective foils are often described as insulating, because they are dependent on the surface or the air gap that they face, they are not described as 'Insulating' in this Code of Practice. The most efficient value of any insulating medium is by the use of trapped or still air and most fibrous and rigid boards obtain their insulating properties in this manner.

Building Insulation Blanket (B.I.B.) faced one side with foil (FF.B.I.B.) should always be placed with the foil facing the warm side.

Bulk insulation should stop short of and not extend to the full length of either the roof or wall cladding, because by wicking, the insulation can become wet and consequently by the retention of moisture can lead to corrosion of the cladding.

When Polyester B.I.B. is used in conjunction with metal roof cladding the insulation should not be placed directly under the roof cladding and special roofing screws should be used to avoid binding.

Composite insulated metal panels are described in **section 12.0**.

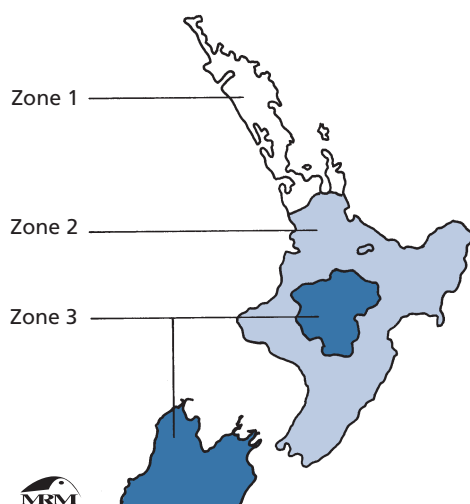
Extruded polystyrene rigid board cellular insulation is made up of a number of open or closed cells that can be filled with either air or gas, and some types have the advantage of being self-supporting between purlins.

All insulation rated values are dependent on the close fitting of boards or fibrous material to the structure without any gaps.

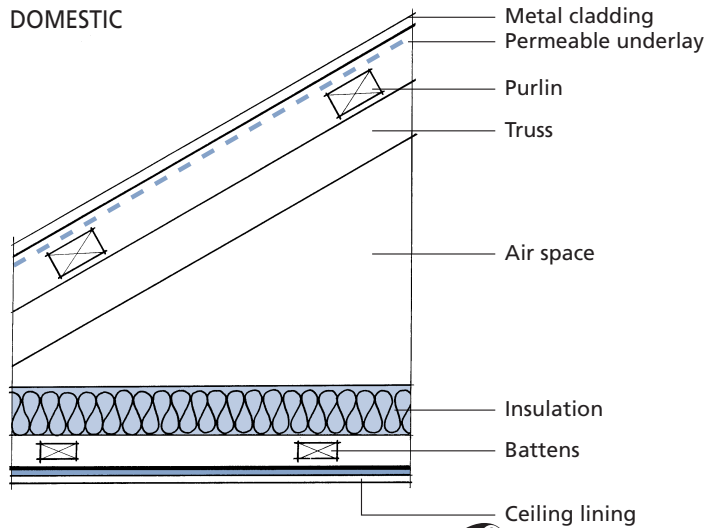
Loose fill insulation has the disadvantage that it can settle and the gaps so produced can reduce the insulation value to less than half of the original and is only useful if all the voids are filled.

In severe environments internal metal gutters should be insulated in the same way as the rest of the building, to prevent condensation on the underside of the gutter.

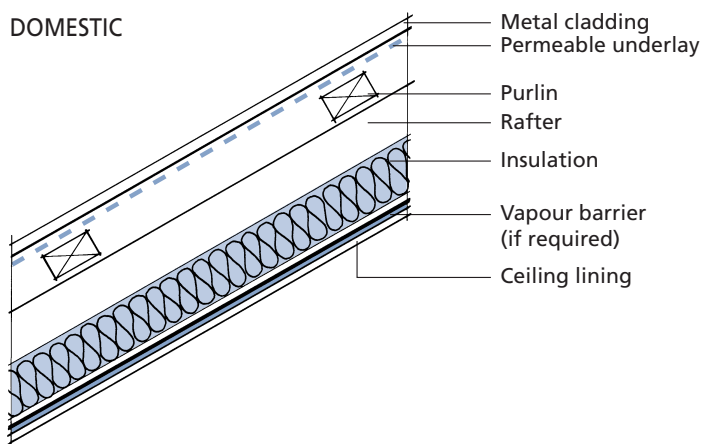
Insulating material can be laid either between or under the purlins, or between the ceiling joists but an air gap of 20mm must be provided under the underlay.



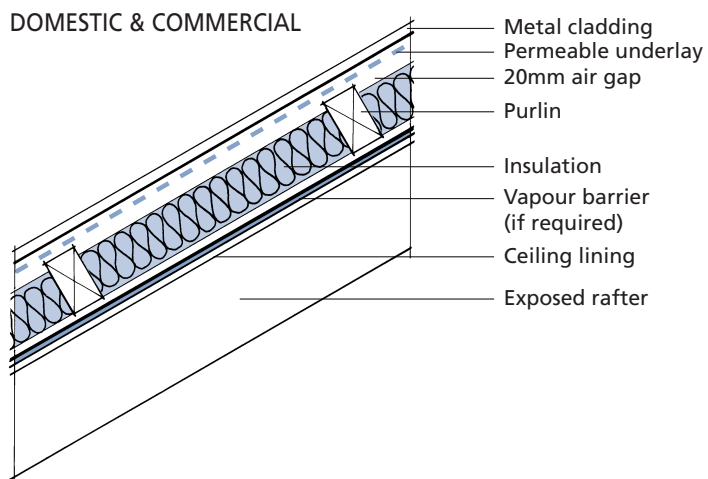
Changes have been made to the assessment of the Building Performance Index for housing and the requirements to comply with the NZBC H1. New Zealand is divided into three different climate zones as shown on Map 4.7.1. and because the height of fibrous insulation can vary, it could be >215mm to comply with Zone 3. This can mean that it is no longer possible to comply with the R-value (thermal resistance) requirements by using the detail on 4.7.1.C without the use of counterbattens as shown on 4.7.1.E.



Drawing 4.7.1.A Pitched truss roof 

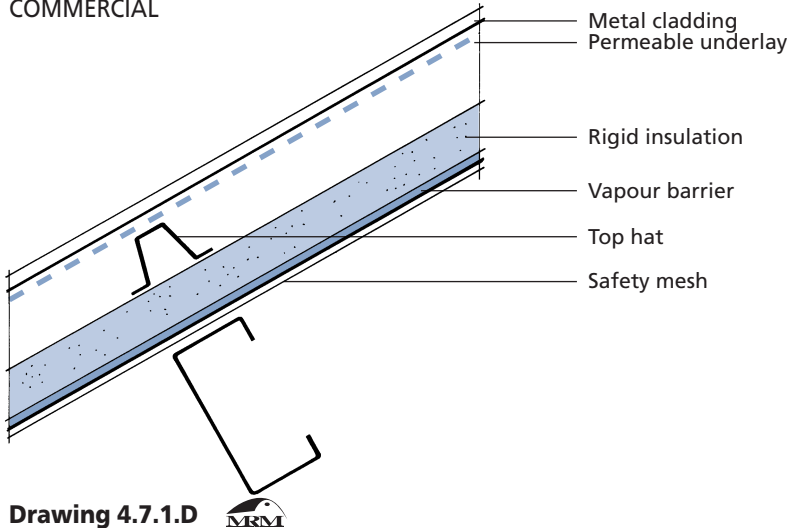


Drawing 4.7.1.B 



Drawing 4.7.1.C 

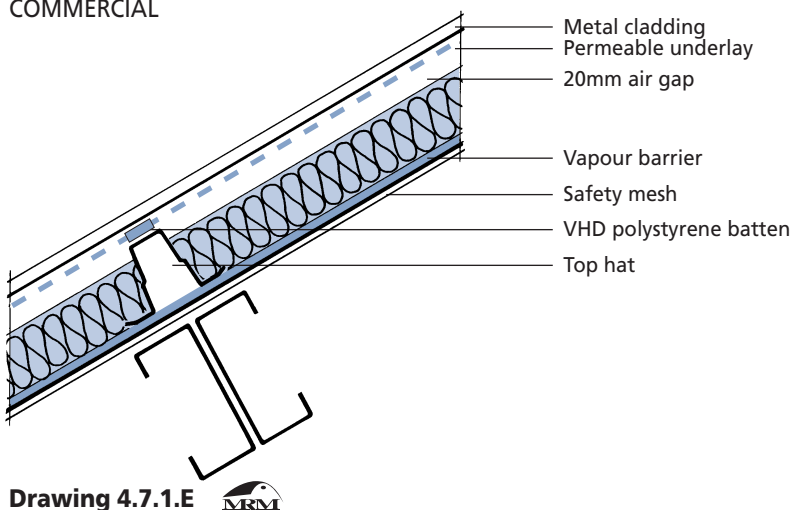
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Drawing 4.7.1.D



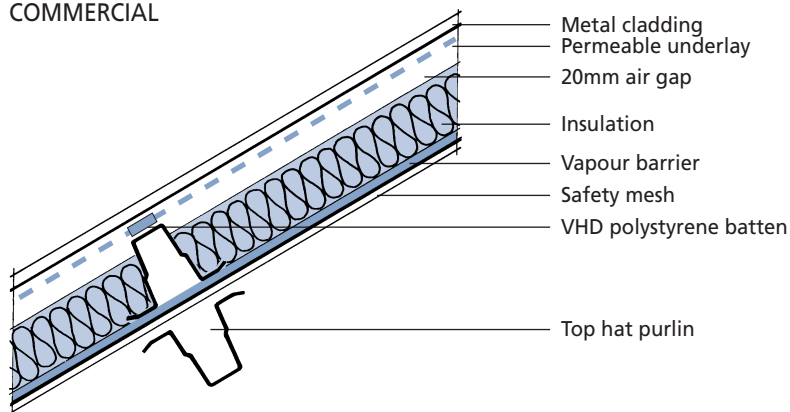
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Drawing 4.7.1.E



COMMERCIAL



Drawing 4.7.1.F



An insulated pitched skillion domestic roof, in which the insulation is placed at the rafter level, creates either a narrow airspace between the roof cladding and the insulation or none at all. Because of restricted air space and lack of ventilation this type of roof design has different requirements from a pitched roof in which the insulation is placed at ceiling joist level. In severe climates water pipes within cold roof construction require to be lagged to avoid freezing.

Domestic buildings are required to be insulated, but the NZBC does not require industrial buildings to be insulated unless they are heated. In any large span roofs or where there is no horizontal ceiling to support the insulation it is placed at the sloping rafter level only for constructional convenience.

When installing rigid boards that have to be cut at hips, valleys, dormers, roof windows, compartment walls and service pipes, the complete sealing of all gaps and joints is required to avoid trapping moisture within the insulation.

The method used to seal the insulation laps, joints and gaps, such as spray polyurethane, should be able to accommodate thermal and building movement.

4.7.2 INSULATION POSITION

Insulation must not be laid over the purlins.

Fibrous insulation should not be installed touching the underlay, as condensation will cause the insulation to become wet, severely reducing its value and causing corrosion of the underside of the cladding.

Without an air gap and sufficient ventilation the cladding temperature will rise considerably higher than if the roof was not insulated, and will consequently require greater expansion provisions.

Statutory insulation requirements for domestic and institutional buildings have in some cases accentuated roof expansion problems, where a noticeable increase in thermal related noise has occurred after insulation has been retrofitted.

If fibrous insulation is placed above the purlin and takes up the full purlin depth, air movement is inhibited, and to provide ventilation it is necessary to use a counterbatten to provide an air gap between the insulation and the underlay.

The use of rigid board insulation under the purlin also requires counterbattens to be used above the rafters to provide an air space. Acoustic insulation is better achieved with well fitted rigid acoustic board under the purlins than with fibrous insulation.

4.7.3 COUNTERBATTENS

Counterbattens or cavity battens are used to provide an air cavity for venting the underlay in a similar manner to that in cavity wall construction. The use of battens requires a sufficient number of fixings to transmit the uplift wind loads through to the roof structure and to allow extra penetration depth of the cladding fixings to provide the design fastener withdrawal resistance. If the counterbatten depth precludes the cladding fixings penetrating through to the structure the withdrawal resistance of the counterbatten fixings should ensure that the wind load is fully transferred to the structure.

The requirement for these fixings is greatest around the periphery of the building. (*see section 3.4. loadings*)

The type and number of fixings required to fix the purlins or the counterbattens to the roof structure must meet the wind load and nail withdrawal resistance values in (table 3.6)

The roof cladding fasteners must penetrate through the counterbatten and into the steel or timber purlin, unless the counterbatten is structurally fastened to the structure. (*see table 3.6.*)

The length of the roof-cladding fastener must be increased to provide fixing into the purlin when strips of rigid insulation are used as counterbattens. The height of the counterbatten must be greater than the thickness of the insulation to maintain a 20mm air gap. (see *drawing 4.7.1.C*)

Special fixings such as helical nails or screws must penetrate the centre of the purlins or rafters, and must provide a minimum of 35mm penetration depth into timber or meet the required withdrawal resistance in steel.

CCA treated timber used as a spacer counterbatten used in conjunction with metal roof and wall cladding must be separated by a waterproof underlay or P.V.C. tape and must be < 18% moisture content at the time of fastening.

If pinus radiata timber is used it must be <18% moisture content at the time of fastening and must be kept dry to prevent deterioration and avoid swelling as this will cause excessive shear stress on any fastening.

Battens or counterbattens can be fixed using countersunk purlin screws, or if fixed with hex headed screws they should be counter-bored before installation to receive a hex headed screw and driver, or so installed so that there is no protrusion of the head of the screw. When safety mesh is used it should be placed between the purlin and the counterbatten to provide support for the insulation and to prevent damage to the roof cladding.

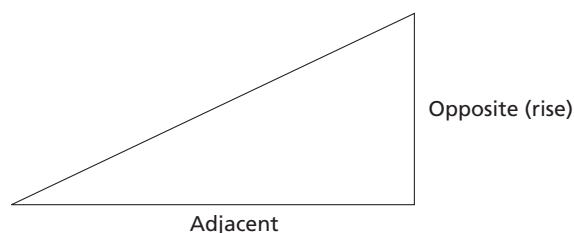
Steel top hat, cee or zed sections are also used as counterbattens but require an insulating spacer to avoid thermal bridging.

Fibrous blanket must not be draped over the purlins because this can produce distortion, noise, visible distortion of the roof cladding, and loose roof cladding fixings which can cause leaks and consequential wet insulation.

4.8 ROOF PITCH

(see NZBC Clause E2 EXTERNAL MOISTURE)

The pitch is the angle between the horizontal and the roof line. It is also the relationship between the opposite and the adjacent sides of a right angled triangle with the opposite side being the rise and the adjacent side the horizontal distance. It is known as the tangent of the angle and these values are tabulated in *section 18.2*.



Drawing 4.8 

There are two main reasons for the minimum pitch requirements:

- **PONDING.** Ponding seriously compromises the longevity of metal cladding, and a 3° pitch is considered to be the minimum that the metal surface is self-cleansing. Low pitch roofs are susceptible to ponding and suffer consequential accelerated corrosion caused from damage by imposed loads, workmen, or by purlins that are out of line.
- **RUN-OFF.** The run-off capacity of some profiles at their minimum pitch and maximum sheet length, is insufficient to cope with the design rate of rainfall. Depending on the length of sheet run or the size of the catchment area, the pitch should be increased or a different profile should be used. (see *profile capacity section 8.2.3*)

4.8.1 MINIMUM ROOF CLADDING PITCH

The NZ Metal Roofing Manufacturers Incorporated and the suppliers will not warrant metal cladding to meet the 15 year durability requirements of the NZB Code unless the minimum pitch is in accordance with table 4.8.1.

The minimum roof cladding pitch must be in accordance with table 4.8.1.

Trapezoidal asymmetrical profiles rib heights 20mm - 35mm	3°
Trapezoidal symmetrical and asymmetrical profiles rib heights 36mm - 60mm	3°
Trapezoidal symmetrical profiles with rib heights between 20mm and 35mm	4°
Secret-fix roof profiles with rib height 30mm or greater	3°
Secret-fix roof profiles with rib heights less than 30mm	8°
Standing seam fully supported flat sheet metal with rib height greater than 30mm	3°
All other types of fully supported flat sheet metal	5°
Corrugated and profile sheeting with profile height greater than 17 mm	8°
Corrugated and profile sheeting with profile height less than 17 mm	10°
Long run metal tile	10°
Horizontally lapped metal tile 25mm upstand	12°
Horizontally lapped metal tile/shingle <25mm upstand	15°

Table 4.8.1.

The minimum pitches quoted refer to the roof cladding pitch and not the building design roof pitch.

The allowable cumulative deflections of the frame, purlin and roof sheeting, which can take place over large spans, require the building design roof pitch to be increased in order to comply with minimum cladding pitch.

Buildings designed with widely spaced purlins and widely spaced portal frames may require a frame pitch increase of 1.5° to comply with the minimum pitches in table 4.8.1.

The blowback of water under positive wind pressure is often accelerated by suction due to negative pressure inside the building at ridges or gutters. Low pitches require greater attention to flashing details and the ability of side laps, end laps or flashings to withstand water penetration also becomes more critical, however good design of flashings can ensure weathertightness even in extreme conditions.

The back-up of water against vertical faces caused by high velocity localised wind eddies, especially inside parapets and at the bottom edge of walls, and also roof designs that do not incorporate overhangs, are all vulnerable details at pitches below 10°. Pressure equalisation designs and wind baffles are more effective in preventing water ingress than increasing the flashing cover width.

The roof pitch has a major influence on the wind load imposed on it and reference should be made to **section 3.4. loadings**.

There are exceptions to the minimum pitch requirements stated above.

These include:

- curved roofs where by design the minimum pitch at the crest will always be less than the prescribed minimum (*see curved roofs section 4.9*)
- The back curbs of penetration flashings where the minimum pitch is 1.5°. (*see penetrations section 6.0*)

4.8.2 RUNOFF

The ability of the roof cladding to discharge maximum rainfall without water penetrating through side laps, end laps or flashings is dependent on rainfall, the catchment area, the pitch and the profile geometry.

The pitch determines the rate of flow as steep slopes will shed water faster than shallow slopes, however, using the minimum fall based on **table 4.8.1.** with 100mm/hour maximum rainfall intensity and a maximum cladding length of 40m, no metal cladding produced in N.Z. will overflow the rib height. N.B. No allowance for penetrations.

The minimum pitches in table 4.8.1. should be increased by 1° for all profiles when the sheeting length exceeds 40m, but is <60m. Longer lengths require specific design.

This requirement has been calculated from the runoff for specific profiles under peak rainfall conditions, which is taken to be 100mm/hour for free fall roof cladding, however for areas where the rainfall is greater than 100mm/hour the minimum roof pitch should be further increased by an additional 1° per 10m over 40m.

Areas that require special consideration are where a downpipe outlet discharges directly onto a lower roof, at penetrations where skylights, dormer windows or vents collect the water flow from a number of pans or stepped roof designs. When there is a large catchment or parapet wall or the runoff is concentrated into one or two pans, these situations may cause damming, splashing or standing waves to occur.

Internal gutters, valleys and penetrations should have their capacity calculated for an ARI of 200mm/hour.

4.8.3 SNOW

Snow represents a significant U.D.L. on roof cladding in some areas of N.Z. and in areas where the open ground snow load exceeds 1.0kPa, a specific design is required for roofs. (*see map 3.5.1.*)

Each zoned area has a different snow load, with the altitude being the determining factor, with the Canterbury Alps and Plains being regarded as the most severe snow zone in N.Z.

Roof pitches of 30° and under are considered to be unable to shed snow, and roof pitches above 30° have a reduction factor applied to them which effectively reduces the snow load proportionately reducing to zero at 70°.

In snow areas designers using roof pitches between 30° and 70° should recognise that shedding snow from a roof can be a safety hazard during the thaw, and snow guards should be installed over doorways or pathways. For areas subject to 1.0kPa snow load, roof slopes in excess of 10° should have snow guards which should be a minimum of 50mm high and be able to resist the dynamic weight of sliding snow (which is dependent on the roof pitch) multiplied by the tangent of the roof pitch. Static load = 1kN/m x tan (*see section 18.2.*)

Secret fix roofs have a lower coefficient of friction because of their lack of protruding fastenings and purlin spacings should be reduced if there is a likelihood of de-indexing at the lap.

Areas on roofs where natural shedding is prevented such as at valleys, parapets, saw tooth and butterfly roofs, internal gutters, and high roofs above low roofs, are subject to accumulated drift and should be designed for twice the normal snow load.

Designers of structures required to resist snow loads, should ensure that their deflections under load will be within the same prescribed limits as for non-snow load buildings. The roof cladding span should be reduced to withstand the point load plus the snow load to comply with the minimum pitch as prescribed in **table 4.8.1.**

Side lap stitching should be considered to ensure there is no gap between sheets at the side lap which would allow the ingress of snow. Powder snow can infiltrate very small gaps in flashings, so neat fitting and sealing is required to a higher waterproofing standard than that required for wind alone.

Load spreading washers and sealed laps should be used on all roofs where they are to be subject to snow loads in excess of 1kPa.

Where a penetration such as a chimney pierces the roof cladding in a severe climate, it presents two problems.

- It offers an obstruction to snow drifts
- Leakage of heat from a flue will melt snow in the immediate vicinity of the chimney, which can turn to ice and can cause leakage at the lap when it thaws.

For this reason in snow areas chimney flues should be placed on a wall or at a ridge.

When the temperature of accumulated snow reduces the metal cladding to below zero temperatures, condensation will freeze on the underside of the cladding.

Continual low temperatures will inhibit the normal diurnal temperature fluctuations of roof cladding and if there is a heat source within an uninsulated building a considerable amount of condensation will flow down the sheeting.

If there is no heating or if the building is well insulated, sustained temperatures below freezing will allow a build-up of ice to form on the underside of the sheeting, which will be removed safely only if the provisions of **section 4.3 underlays**, have been complied with.

This condensation is often mistaken for leakage from the roof, because of the quantity and the continuous dripping that can be expected from a snow submerged roof.

The back and side curbs of penetration flashings in snow prone areas should have full height and be sealed and are required to be of a diverter or cricket design.

Internal gutters should be avoided in snow prone areas, but if they are fitted, the use of snow boards or gutter snow boards is required to avoid the blockage of gutter and outlets and consequential flooding. (*see drawing 4.8.4.A & B.*)

In snow areas the gutter should have additional depth, and be open ended to ensure full capacity overflows

External gutters should have snow brackets as well as standard brackets to be able to withstand the added weight of the total volume of the gutter filled with snow.

One cubic metre of fresh snow weighs approx.	100 kgs or a load of 1kPa
One cubic metre of old snow weighs approx.	400 kgs or a load of 4kPa
One cubic metre of water weighs	1000 kgs or a load of 10kPa
One cubic metre of ice weighs approx.	900 kgs or a load of 9kPa

As snow is 90% air, it is impossible to generate any head or water pressure until the thaw. Water by its definition is above 0°C and heavier than snow, so rain falling on snow will fill the air gaps, melt it and run underneath the snow to find its own level.

Prolonged sub-zero temperatures are unlikely in New Zealand below 500m - refer **snow map 3.4**. Often the mitigating circumstances of wind, ventilation and heat escaping from a building mean that the roof cladding temperature will be above freezing, at which time snow will run as water.

4.8.4 HAIL

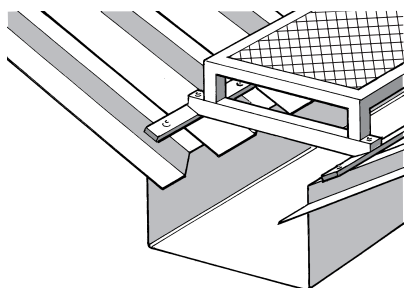
Hail is potentially a more serious leakage problem than snow in N.Z. because it is not restricted by altitude or zone, and, by accumulating at valleys and gutters, it can cause blockage and subsequent leakage.

For this reason all sumps and rainwater heads should have leaf guards that effectively offer a large free area of outlet and should not be of a tapered design because of the wedging action of the hail. Because hail can effectively block any overflows, external gutters should be installed with the back lower than the fascia board or cladding to avoid water overflowing into the building.

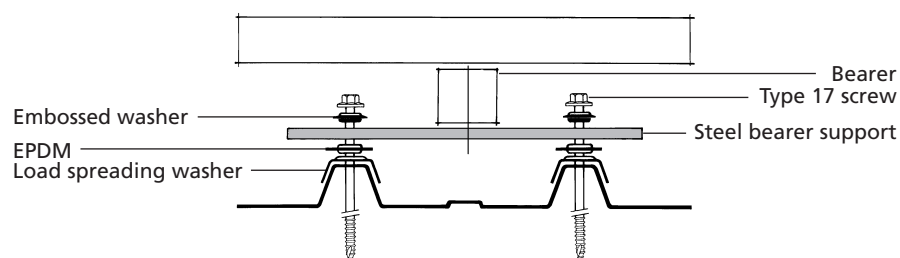
In hail prone areas, a baffle should be provided at the gutter purlin to allow melting water to escape.

Hail can be prevented from blocking a gutter by the installation of a 50mm x 50mm hot-dipped galvanised or aluminium RHS bearer fastened to the penultimate purlin fastenings in a similar manner to that shown in detail 4.8.4.B. using a proprietary galvanised plank or expanded metal walkway mesh.

Where areas are continually subjected to hail, gutter hail baffles must be provided. Timber must not be used.



Drawing 4.8.4.A Gutter snow/hail boards 



Drawing 4.8.4.B Detail 

4.9 CURVED ROOFS

There are two main methods used to clad curved buildings.

1. by the use of draped sheets, known as spring curving;
2. by the use of pre-curved sheets either;
 - (a) roll-curved
 - (b) crimp curved

The limitations on the use of profiled metal cladding for curved roofs as outlined in this section should be adhered to, in order to comply with the requirements of the NZBC. It should not be assumed that the curving process or crimping could produce any strength enhancement for point or wind load. As curved roofs usually have maximum purlin spacings to avoid distortion, they are 'Restricted Access' roofs, which means that walking traffic should be restricted to within 300mm of the purlins and in the pan or over two ribs if adjacent to the vertical lap.

Designers and contractors should recognise that the use of light gauges such as 0.40mm steel and 0.70mm aluminium are likely to show distortion when used for curving.

When asymmetrical pan trapezoidal cladding is used for curved roofs, and when appearance is paramount a heavier gauge cladding should be specified. Because of the changing pitch, edge protection must be provided, or a safety harness should be used when installing curved roofs. (*see section 14.1.*)

All side laps of curved sheets below the minimum pitch for the profile must be mechanically fastened and sealed.

Curved flashings are described in *section 5.5.*

4.9.1 SPRING CURVING

Spring curving, also known as draping or arching of roofs, is a method of providing continuous lengths of roof cladding over a curved roof structure from eave to eave without a ridding. It is suited to symmetrical roofing profiles of low rib height, which can follow a curve without excessive panning or distortion.

Because these profiles do not have a large rain- water carrying capacity they are limited in radius and length.

Maximum radius is limited to provide adequate drainage at the top of the curvature and minimum radius is limited to avoid distortion without pre-forming.

Asymmetrical and tray roof cladding can be draped but only to a large radius before panning or distortion occurs and they are therefore unsuitable for all except large radii. They do not have however the same restrictions on rain- water carrying capacity as symmetrical claddings. Because corrugate cannot be satisfactorily turned down into a gutter, wind pressure can drive rain up the corrugations, causing 'blow back' and allowing water ingress. Spring curved corrugate should not terminate below 8°.

Roof cladding must not terminate at a pitch lower than that permitted for the profile unless the designer can demonstrate compliance with the NZB Code by detailing an alternative method of weathering and durability.

All trapezoidal and tray roof cladding below 8° must have the pan turned down into the gutter.

All roof cladding at all pitches must have either a pull-up or a dog-eared stopend.

If the width and height of the roof are known, this information can be used to obtain the radius of curvature and subsequently the sheet length and the length of seal required for any profile.

RECOMMENDED RADIUS FOR SYMMETRICAL CONCAVE AND CONVEX SPRING CURVING IN METRES

Material	Profile	10	20	30	40	50	60	70
0.40 HS	Corrugate							
0.55 HS	Corrugate							
0.40 HS	Trapezoidal							
0.55 HS	Trapezoidal							

Table 4.9.1.A

RECOMMENDED RADIUS FOR ASYMMETRICAL CONCAVE & CONVEX SPRING CURVING IN METRES

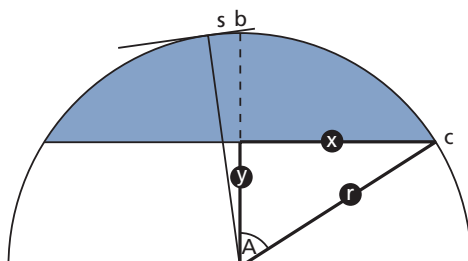
Material	Profile	30	40	50	60	70	80	90
0.40 HS	Trapezoidal							
0.55 HS	Trapezoidal							
0.40 HS	Tray							
0.55 HS	Tray							

Table 4.9.1.B

0.40mm G300 grade coated steel is not recommended for drape curving.

Tables 4.9.1.A & B assume the cladding is draped over an arc where the base chord is parallel to the ground. When the base chord is on an incline the maximum radius can be increased.

If the width and height of the roof are known, this information can be used to obtain the radius of curvature and subsequently the sheet length and the length of seal required for any profile.



Radius of curvature = r
 Width = w
 Height = h
 Minimum pitch = p
 Sheet length = l
 Length of seal = s

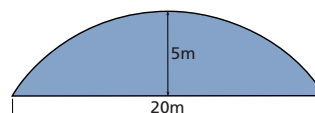
EXAMPLE: Width of roof = $w = 20\text{m}$
 Height of roof = $h = 5\text{m}$

TO FIND r THE RADIUS OF CURVATURE

$$r = \frac{4h^2 + w^2}{8h}$$

$$= \frac{(4 \times 25) + 400}{40}$$

$$r = 12.5\text{m}$$



TO FIND l THE SHEET LENGTH
 Find the length y

$$y = r - h$$

$$= 12.5 - 5$$

$$= 7.5$$

$$x = \frac{1}{2} w = 10$$

TO FIND THE TANGENT ANGLE A

$$= \frac{x}{y}$$

$$= \frac{10}{7.5}$$

$$= 1.33$$

$$= \tan 53^\circ \text{ (approx)}$$

N.B Tangent values can be obtained from tables in **Section 18**.

FIND THE ARC LENGTH $c b$

$$= \frac{2\pi r A^\circ}{360}$$

$$= \frac{2 \times 3.1412 \times 12.5 \times 53}{360}$$

$$= 11.56$$

FIND THE SHEET LENGTH l

$$= c b \times 2$$

$$= 23.12\text{m} + 100\text{mm} \quad (50\text{mm allowance to overlap gutter each side)}$$

$$l = 23.22\text{m}$$

TO FIND THE LENGTH OF SEAL

$p = \text{Min Pitch for corrugate} = 8^\circ$

$$s = r \times p (\tan 8^\circ)$$

$$= 12.5 \times 0.1405$$

$$s = 1.76\text{m}$$

N.B. This length of seal is required on each side of the crest. It is recommended that all profiles be sealed to 8° .

If the sheets are lapped laterally they must be sealed.

4.9.2 LAPS

By definition a curved roof is flat at the crest of a curve, and because it is below the specified minimum roof pitch required by the NZBC for unsealed laps, side laps should be sealed over the crest of the arch until the minimum pitch is reached.

All vertical laps should be sealed if the pitch is less than the allowable minimum as tabulated below:

Corrugate	8°
Symmetrical Low Trapezoidal	4°
Asymmetrical Low Trapezoidal	3°
Secret-fix Tray	3°

When the pitch of the roof is below the minimum, the side lap is required to be sealed over the crown, and lap tape or silicone sealant should be placed on the top of the rib and firmly held down while fixing takes place. Intermediate side stitching is required at mid point of all side laps using self-sealing rivets or stitching screws.

The side lap of profiled sheeting is designed with anti-capillary provisions to be self-draining.

Before the continuous manufacture of corrugate from coil, symmetrical corrugate sheets were often laid with two nesting laps, which commonly corroded due to condensation, even in spite of lap priming. All metal profiles now produced in N.Z. have capillary grooves. Trapezoidal profiles are designed for one lap only and corrugate used for roofing is designed for 1 1/2 laps with an under and an over.

Double lapping should not be used for the reason that condensation can become trapped in the lap which can cause accelerated corrosion with all steel products including pre-coated steel. Lap priming should not be used as the permeable paint surface can retain moisture and accelerate corrosion.

4.9.3 TRANSVERSE LAPS

To avoid a transverse lap, or if the length of sheet is greater than can be transported or safely handled, a step in the roof structure should be provided. (*see step flashings 5.3.5.3.*)

At a step or a lap, the end span must be reduced. (*see point load section 3.2.*)

If a transverse lap cannot be avoided it must be mechanically fastened and sealed and must be made watertight from the inside by lap tape or sealant.

Sealing should ensure that the condensation will follow past the joint and either be absorbed by the underlay or drain to the eave.

Severe corrosion problems have been caused on curved roofs by condensation running down the inside of roof cladding and into the laps. This was a common mode of failure when short lengths of galvanized corrugated sheeting were used in the past, but long run roofing without end laps has all but eliminated this type of failure.

It should not be assumed that the paint coating would provide barrier protection and since 1995 the manufacturer and industry requirement has been to seal all transverse laps.

When unsealed metallic coated steel cladding and flashing laps are subjected to a continuously damp environment, the 'time of wetness' is increased which is a major factor in corrosion. This situation is also detrimental to prepainted cladding metallic coatings, which are attacked through the permeable paint coatings and at cut edges.

Where the length of a draped roof is regarded as too long to transport or too difficult to handle as a drape curve in one sheet, the crown sheet should be as long as practical and the transverse lap should be placed as far down the roof as possible to increase the pitch at this point.

At the termination of curved sheets at minimum pitches in exposed areas, additional weathering is required at the turn down. Ventilated filler blocks and/ or baffles should be used to prevent blow back, which can cause corrosion because the underside of the sheeting becomes an unwashed area.

Penetrations or end laps must not be placed in the region of the curve where the roof pitch is below the minimum pitch for the profile in *table 4.8.1*.

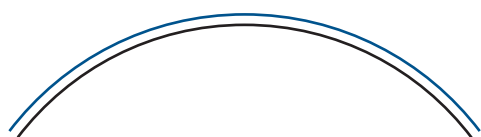
Additional timber or steel supporting structure must be installed upside and downside of any penetration hole greater than 300mm x 300mm to provide fixing for the sheet and a reduction of the end spans.

Support must be provided to resist the uplift on sprung curved sheets at all penetrations.

All side laps of curved sheets below the minimum pitch for the profile must be mechanically fastened and sealed.

Continuity over a minimum of three purlins is required for successful drape curving and therefore any interruption such as a penetration or other cutting of the sheet, may require machine curving to ensure the curvature is maintained.

Purlins must be accurately positioned with the top faces tangential to the radius of the arch and should be within 5 mm tolerance to avoid purlin creasing. Roof traffic should be restricted to avoid damage, particularly in the low pitch region or in highly visible areas. Damage as a result of walking traffic can be seen as creasing at purlin lines or canning in the profile pans. Some purlin creasing is to be expected with stronger profiles and at low pitches this can cause corrosion due to ponding. For convex roofs the minimum radii should be adhered to because the pans are in compression, whereas with concave roofs the pans are in tension and the panning or distortion of these roofs will be less although it is dependent on the profile.



Convex Pans in compression (black - bottom)



Concave Ribs in compression (black - top)

Drawing 4.9.3. 

Only vented profiled filler blocks should be used at the eave on curved roofs, so that some air movement is provided within the ribs. (*see ventilation section 4.6*)

Provision for expansion should be provided in the same manner as required for straight lengths, but the configuration of curved roofs means that some expansion will be taken up by a further up springing of the profile which results in less movement. When the total sheet length is considered for expansion, positive fixing using oversize holes, should be made at the crown.

4.9.4 DURABILITY

When draped curve roofs are unlined and used as canopies or exposed eaves, the underside of the sheeting becomes an unwashed area, and therefore is required to be washed and regularly maintained to comply with the durability requirements of the NZBC and the supplier's warranty. The underside of pre-coated roof cladding is provided with a primer and backer coat only and should not be regarded as weather or UV proof as the top-coat.

Because pre-painted cladding is not intended for use in this micro-climate without regular maintenance, the underside of the soffit should be lined in all severe and very severe environments. (*see section 13.0 maintenance*)

4.9.5 PURLIN SPACING

When the purlin spacing is close to the maximum allowable for the profile for ease of curvature, the roof cladding is more likely to be damaged by foot traffic, and be subject to distortion between the purlins. When the radius of curvature is close to the minimum the purlin spacing should be reduced to the end span distance for each gauge and profile. *(see load span graphs 3.9.)*

Access on curved roofs should be restricted and be regarded as Type B and extra care taken during installation because of the changing pitch. Because some profiles used for curved roofs are close ribbed, it is not possible to walk in the pan, therefore the walking pattern should be restricted to within 300mm of the purlin and the load spread over two ribs. This is more important when low strength steel is used for precurved sheets.

0.40mm G300 steel or 0.7mm aluminium should not be used for roof cladding subject to walking traffic.

When designing a curved roof, the radius of curvature, profile, thickness, grade, and purlin spacing, should be considered as these are all related parameters.

Maximum purlin spacings should be adhered to, and any sheets damaged by foot traffic in the area below the minimum pitch for the profile, should be replaced.

All curved roofs must have end spans reduced to $\frac{2}{3}$ of the intermediate span as required for straight roofs, because the k_l load factor requires a reduction in purlin spacing at the roof edges. Where translucent sheets are required to be curved, the normal purlin spacings should also be reduced.

If the design loads are high, or where the eave is not lined and the roof cladding is exposed, extra fixings and load spreading washers are required.

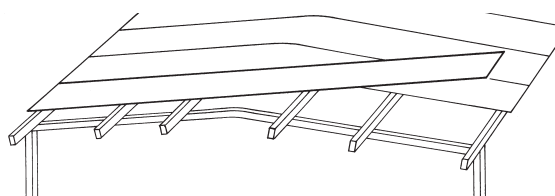
It is important that the specification of radii limitations and water drainage characteristics for specific products are considered at the building design stage so that water runoff over the low pitch region will not exceed the maximum for the profile used. The maximum radius of curvature permissible for corrugate and symmetrical profiles is limited for this reason.

Bull-nosed verandah or lean-to roofs, which are simply supported spans and do not have the continuity required for point load, should have their purlin spacings reduced to less than normal end spans.

Because the sheeting is continuous over the top of a curved roof and the wind dynamics are different, purlin spacings do not need to be reduced at the crest as is normally required at the ridge on gable or hipped roofs.

The two top purlins should be placed to enable the sheeting to follow an arc that minimises purlin marking.

Draped curved roof or curved ridges should be fixed by fastening each sheet first to one side of the roof, which is then pulled down to be fixed to the other side. Alternate sheets should be laid in sequence to avoid cumulative errors and be laid from opposite sides of the roof to ensure squareness is maintained.



Shift the two top ridge purlins to provide an even radius.

Drawing 4.9.5. 

Because extra uplift load will be taken by the end fasteners, screws and load spreading washers should be used on the penultimate and the last purlins, and although nails may be used on intermediate purlins, screws are the preferred fastener for curved roofs.

Rafters and purlins must have additional fixing to the structure in order to resist the additional uplift load at the eave caused by curved sheeting.

Any assumed increase in span due to an increase in strength of the roof curve should be discounted as purlin spacings for concave and convex draped curved roofs are limited to the maximum purlin spacing allowable for the particular profile, and are dependent on the wind design load.

4.9.6 CONCAVE ROOFS

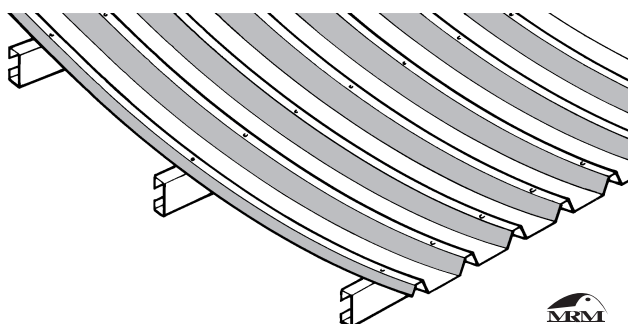
Roofing can be spring-curved into concave shapes however designers should be aware of the limitations on the minimum pitch where the curve is terminated, and be aware of the extra uplift load that will be taken by the fasteners at the centre of the curve and take into account the catchment area of the roof.

The pitch for concave roofs must not be less than 8° for corrugate, 4° for symmetrical trapezoidal profiles and 3° for other profiles. Screws and load spreading washers must be used for fixing cladding on all sprung concave curved roofs. The purlins must have additional fixing to the structure to resist the additional uplift load on sprung curved sheets.

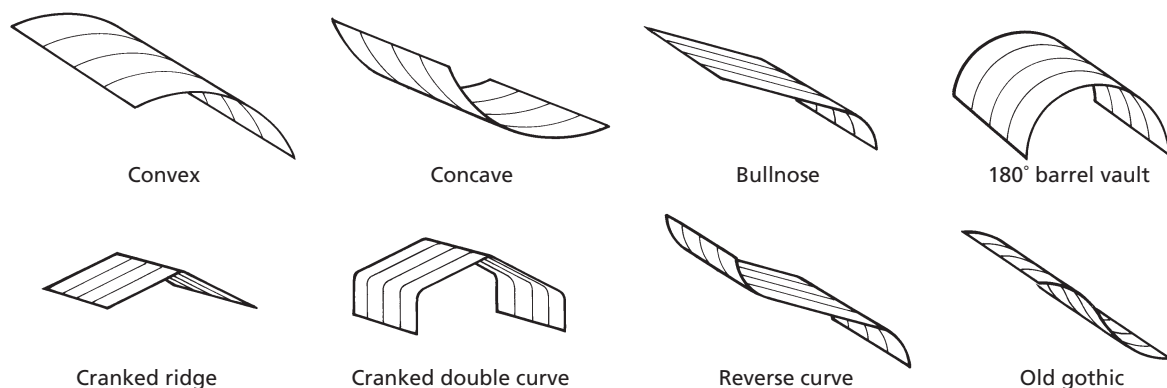
The additional load produced by draping concave and convex metal roof cladding depends on the radius of curvature and the thickness of the metal. The induced load has two forces:

- The additional load on the fastener
- The additional load on the purlin/rafter or truss connection.

Although the former is the responsibility of the roofer it is recommended that the purlin connection is inspected for adequacy. The connection prior to any additional load imposed by the draped roof will be determined by table 3.6. An economical solution to the increased connection load is to use a proprietary purlin strap.



4.9.7 PRE-CURVED ROOFS



Drawing 4.9.7. 

Low tensile metals and G 300 coated steels can be easily roll-curved in a pyramid rolling machine to small radii and can also be crimp curved to the curves as shown in **drawing 4.9.7.** (see 4.9.9.)

4.9.8 ROLL CURVING

Pre-curved corrugated roof cladding is used for bull-nosed verandah roofs, ridges, or for roofs where the radius is less than the minimum required for Sprung or Draped curved roofs.

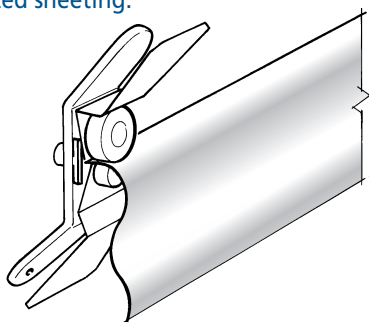
Corrugated (symmetrical sinusoidal) G 300 roof cladding is easily curved or bull-nosed and in this process ductile sheets are passed through matching curving rolls, which progressively form curves in a wide range of radii. If G300 and G 550 steel sheets are to be used together, because these two materials will not have matching profiles, adjustment of the roll-forming machine setting is necessary.

0.40mm steel has been used successfully on circular barns for many years, however 0.55mm steel or 0.90mm aluminium should be used for roll-curved roofs subject to any walking traffic, as 0.40mm G300 coated steels and 0.70mm aluminium are only suitable for roofs without access or for wall cladding.

G 300 steel can be curved to a radius as small as 300mm. however because of the use of pyramid curving rolls, there is a straight portion of approximately 80mm at the end of the sheet beyond the curve which may have to be trimmed off if a true curve is required.

If the edge of the sheet is too flat or long, rippled edges may result and these should be dressed out by using a dressing tool (*see drawing 4.9.8.*) or trimmed off before the sheet is installed.

For safety, roofs which are often used as a means of access to or onto a verandah, should be provided with an intermediate support as simply supported roofs cannot withstand foot traffic, to the same degree as continuously supported sheeting.



Drawing 4.9.8. 

A curve can be rolled on one end of a straight length of roof cladding to provide an over, or cranked ridge, but for ease of fitting and transport, a lap is usually made at the first purlin down the ridge. This should be sealed in the same manner as is required for any transverse lap.

An alternative ridge detail can be used with straight sheets, without any lap, by roll curving or draping the cladding over the ridge, where the ridge purlins are extended out to their maximum span.

4.9.9 CRIMP CURVING

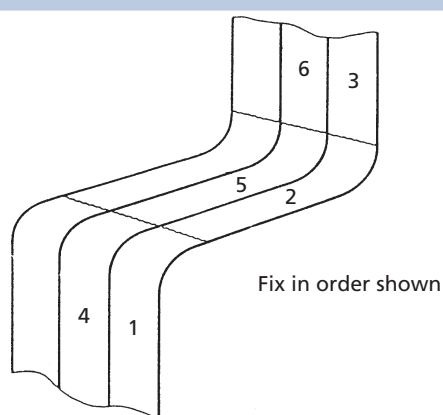
Crimp curving is applicable to all profiles however it is most suited to asymmetrical sections that cannot be roll or drape curved.

Crimp curving is produced by pressing a small crimp in either the tops of the ribs or the pans of the sheeting whereby the profile is progressively shortened at these points causing it to bend. The radius can be altered by the spacing of and the number of crimps. Some machines are capable of forming high-strength steel by a combination of compression and tension in the die design, and some machines require the use of strippable film as a lubricant to avoid coating damage. Where sheets are to be end lapped, and different strength materials are used together, machine adjustment is required to ensure an acceptable fit because their profiles are not usually consistent.

Fitting curved sheeting requires considerable care to ensure a satisfactory and aesthetically pleasing job. Setting out requires first checking that the materials delivered on site are within specified tolerances and before commencing work the building should be checked for squareness.

The curving process can cause dimensional changes, which can lead to misalignment, so the sheets should be kept square with the building. Some minor saw-toothing at the gutter end is to be expected when fitting curved sheeting. When multiple curves are required that cannot be provided on one sheet the sheets should be fixed in the order shown in **drawing 4.9.9.A**.

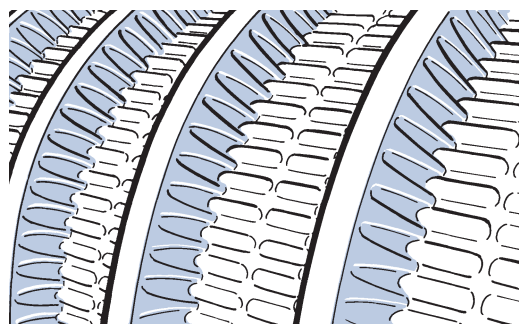
All transverse laps of crimped curved roof cladding must be mechanically fixed and sealed.



Drawing 4.9.9.A. 

Some paint checking and microcracking is likely to occur at the crimps on metallic coated steel cladding and these may show a white bloom. This is more readily seen in unwashed areas such as when crimp curved sheets are unlined as a canopy or over a walkway roof. This area is required to be washed regularly under the maintenance provisions of the supplier's warranty. The underside of colour coated roof cladding is provided with a primer and backer coat only and if this is exposed in an unwashed area and can be seen, it should be post-painted with two coats of Acrylic paint. This area however is subject to maintenance as an unwashed area. (*see over-painting section 13.7*) Because the top of crimped sheeting is also subject to the collection of dirt and debris, particularly at the low pitched area, it is therefore also subject to maintenance requirements.

All side laps of crimped curved sheets below the minimum pitch for the profile must be mechanically fixed and sealed.



Drawing 4.9.9.B. 

5.0 FLASHINGS

The purpose of a flashing is to divert water away from any point of entry, and to make any building weatherproof. Flashings are not only required to weather the many junctions on a roof or wall structure, but are also a very visible part of the roof and wall cladding design, and perform an important role in the aesthetic appearance of the building. The words weather, weathering, weatherproof and watertight used in this section and within this Code of Practice are used as nouns, verbs or adjectives, and reference should be made to the Definitions for their precise meaning.

Experience is required to design, cut and fasten flashings that will last the lifetime of the roof or wall cladding, and specialist assistance should be sought where this experience is not available.

The time required to make and install flashings to a high standard is often in excess of the time taken to fix the roof or wall cladding, and the roofing contractor is obliged to tender allowing for the acceptable trade practice described in this Code of Practice.

The standard of workmanship on straight and curved flashings and accessories will determine the overall acceptance of the workmanship on a building, and for this reason the designer and the roofing contractor should be aware of the requirements of this section of the Code of Practice.

The roofing contractor must be competent to design, make and install the flashings as described in this Code of Practice.

Flashings include all folded metal sections required to make metal roof and wall cladding weathertight at:

- the building periphery,
- roof and wall junctions
- changes of direction,
- intersections with other buildings,
- any roof or wall penetration,
- junctions with other materials

All flashings must comply with the lap, cover, expansion and compatibility provisions of this Code of Practice. Flashings that cannot be seen and are not easily replaced must have a 50 year durability.

The initial cost of good flashing design and the time taken to install flashings to good trade practice, is repaid not only by their appearance, but also because repair, replacement and maintenance is minimised. Replacement of flashings can require the costly replacement of cladding, because often it is not possible to remove one without the other.

This section contains acceptable and better flashing details for most possible junctions in the most unfavourable circumstances, but does not require the use of welting, seaming or crimping, which are used when flashing fully supported cladding. These techniques are described in **section 11**, but they can however be used to substitute any sealed lap, in lieu of mechanical fastenings. (see **section 5.4.5**)

Section 5 of this Code does not contain specific details of the interface with alternative roof cladding materials, such as butyl rubber, however the same good practice is applicable.

All flashings must be designed to prevent ponding of water or buildup of debris.

Flashings must be designed to weather the roof or wall cladding without reliance on sealant as the prime means of weathering.

The successful installation of flashings requires planning before any roof or wall cladding is installed. Both scheduling and sequencing are necessary to deliver flashings on site when they are required and to provide the correctly dimensioned cover required in **section 5.2** of this Code of Practice.

5.1 MATERIALS

To ensure equal durability, flashings, ridge cappings, and accessories should be manufactured from the same material, and have the same coating system, as the material used for the roof and wall cladding. When this is not possible, or if different materials are intended or specified, the alternative materials should be compatible for both contact and run-off. *(see compatibility table 2.7.2.)*

All flashings must be fabricated from a ductile grade of metal and designed for lateral strength by folding, stiffening or ribbing on external edges, having a maximum unstiffened width of 300mm.

Metallic coated steel flashings must have a bend radius complying with the minimum radii prescribed in section 2.3.4. to avoid visible microcracking.

Where a flashing is hidden, or is otherwise difficult to access or replace, it must have a durability of the life of the building or not less than 50 years.

In some corrosive environments, coated steel is unlikely to achieve this durability in an enclosed environment that lacks ventilation, such as cappings to parapet walls or flashings in contact with concrete.

In such situations non-ferrous metals or stainless steel should be used.

The use of other metals for flashings requires an understanding of their strengths and weaknesses, as any metal will suffer corrosion if used inappropriately.

The minimum thickness for metal flashings must be:

- Coated steel .55mm
- Aluminium .90mm
- Copper .60mm
- Zinc .70mm
- Stainless steel .45mm

When using pre-coated and AZ coated products and where the requirement is for a profiled shaped flashing or metal closure such as a ridging or apron, a soft aluminium or proprietary strip can be used. Soft sheet zinc or aluminium can also be worked and shaped by hand to form flashings.

Proprietary EPDM penetration flashings are detailed in **section 6.3.**

5.1.1 COMPATIBILITY

Materials must be used in accordance with the compatibility table in section 2.7.2

When two dissimilar metals are in contact and moisture is present, one metal is relatively protected while the other suffers accelerated corrosion. Galvanic or bimetallic corrosion can also occur when water flows over dissimilar metals. The design of flashings has a direct relationship to corrosion, as the underlying design principle is to keep the metal dry, to avoid any retention of moisture by debris, and to provide all flashings with a minimum fall of $1\frac{1}{2}^\circ$ to avoid ponding.

The designer and roofing contractor should be aware of compatibility issues when combining materials in a roof system or placing assemblies such as air-conditioning units, solar collectors and walkways on top of roof cladding. If materials are combined incorrectly, severe localised corrosion may occur.

Unpainted galvanised steel is incompatible with most inert materials and is subject to inert catchment corrosion. *(see inert catchment section 2.6.4.)*

5.1.2 DESIGN

All roof cladding edges located other than at the gutter, must have a cover flashing fastened on both faces.

Flashings at the periphery of roof or wall cladding are subject to high suction or negative wind loads that often exceed all other positive imposed loads. As a result the wind design load can be up to twice that of the main roof area and extra fixings are required to fix flashings.

The design wind load specific to any particular building, will determine the number and the spacing of flashing fasteners. There is however a minimum number of fastenings that should be provided to avoid flexing, oil canning or fatigue cracking of metal cladding under fluctuating loads and also to prevent noise or flutter. (see section 4.1.9.)

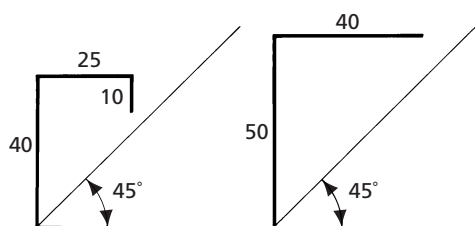
In very high wind design load areas and where the pitch is below 10°, mating flashings must be sealed and fastened with sealant at each end of the lap to prevent the ingress of dirt or water.

A hook or a hem must be used to terminate the vertical edge of hidden flashings to avoid capillary action or to prevent moisture ingress. Where a hook is not suitable the flashing height given in table 5.2. must be increased by a minimum of 25mm.

A hook is used into an open space when the depth of the hook will not interfere with any fastening. A hem is a flattened hook, but should not be completely closed because then it will act as a bridge and so will not fulfil the intended purpose of avoiding capillary action. A hem is also termed a safety edge as it will protect a person from injury by contact with a cut edge. (see drawing 5.2.2.B) As all flashings are used in areas that are likely to suffer from extreme macro and micro-climates, the folded edges of any flashings should not have visible micro cracking. (see section 2.3.3. microcracking)

The minimum edge that can be provided by most long length folding machines is 10mm, but for material thicker than .55mm or longer than 3.000m, the minimum is 12mm.

Long length folding machines have the folding beam angled at 45° which limits the dimensions that can be folded after making due allowance for springback. (see drawing 5.1.2.A)



Drawing 5.1.2.A 

The design load on, and the fixing frequency of all flashings must be determined by the loadings criteria in section 3.4. Loadings.

Screws are preferred to rivets for fastening flashings because the larger diameter shank gives a greater shear capacity, and as they have a bigger head a washer can be used to increase the pull over resistance per fastener.

The ingress of rain into the roof or wall cavity via the flashings is predominantly caused by the pressure differential between the outside air and that inside the roof or wall cavity.

This pressure differential caused by wind gusting is a dynamic one and fluctuates greatly, which means that a cyclic or pumping action can occur when water is sucked into the joint or cavity that a flashing is covering.

The design wind load is determined not only from the wind speed of the geographical area, but by a number of weighted factors, which include:

- building importance,
- topography,
- terrain category,
- roof pitch
- height.
- building permeability

As a result of these factors, an area with a low wind speed may have a high design wind load, and this is why any categorical reference to flashing width, depending on wind speed alone, is invalid.

AS/NZS 1170.2 tables a wind speed of 45m/s for all of New Zealand for a return period of 50 years, with the exception of the Cook Strait area, which is 51m/s, although greater cognisance is given to other conditions, such as topography, terrain and the micro climate which factorise the basic wind speed.

The designer should take these factors into account when determining the flashing design and fastener frequency. The ingress of rain into the roof cavity via the flashings can also be caused by capillary action. **(see capillary section 2.6.6.)**

An anti-capillary offset fold, a clearance gap of up to 5mm or a sealant should be provided on all flashing edges to avoid capillary action where flashings are in close contact with the roof or wall cladding.

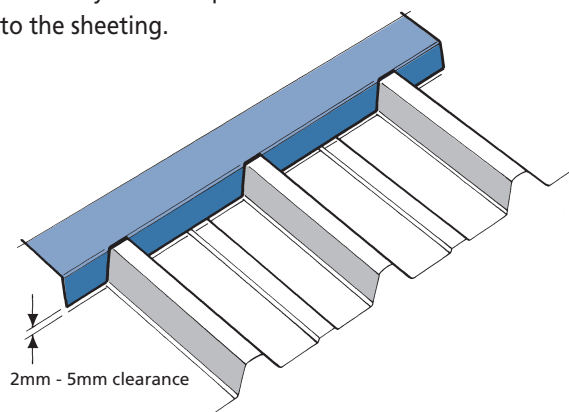
Flashings, other than standard ridging, are produced to specific order and are designed and manufactured from flat sheet or coil. If these flashings are required to match the colour of the profiled cladding sheets it is necessary for the pre-painted flat sheet or coil to be made by the same manufacturer using the same process in order to avoid differential colour matching or fading.

Preferred maximum length of flashing is 6m, with expansion joints provided after a maximum of two lengths of flashing (12m) have been fixed together, as any lap secured by rivets or screws effectively becomes one length. Flashings are restricted in length in the same manner as are roof and wall cladding sheets and are subject to the same requirements and expansion provisions. **(see section 4.1.6.)**

The edges of all flashings must be spaced at a minimum distance of 2mm - 5mm away from an adjacent horizontal surface to avoid moisture retention and deterioration at the cut edge of coated steel flashings. This clearance applies particularly when a cut edge is very close to concrete or plaster or butyl rubber. When scribed flashings are used the cut edge must not touch the pan, as this not only causes abrasion corrosion but collects dirt and remains wet and causes corrosion. (see drawing 5.1.2.B.)

Soft edge flashings also should be spaced away from the pan to avoid the accumulation of dirt and so that the bituminous backing does not adhere to the sheeting.

Drawing 5.1.2.B



5.2 FLASHING COVER

The weathertightness of a flashing is determined by the flashing cover, not the flashing dimension.

The minimum dimension for flashing cover over profiled metal roof and wall cladding must be in accordance with table 5.2.

Transverse flashings run across the roof slope at right angles to the ribs of the roof.

Longitudinal flashings run down the roof slope.

There are two categories of exposure or pitch that determine the flashing cover width.

Category A: 1. Normal exposure

2. Where the pitch is $>10^\circ$

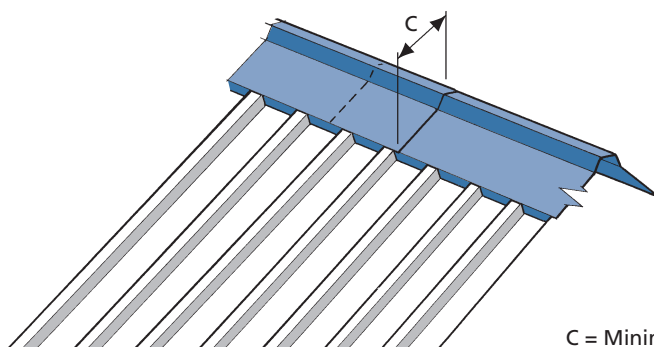
Category B: 1. Exposed (higher risk) where the design wind load exceeds 1.5 kPa.

2. Where the pitch is $<10^\circ$

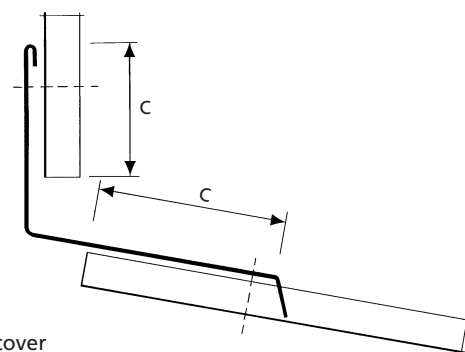
TYPE		Category A	Category B	Drawing
RIDGE	Transverse over sheeting	130	200	5.2.A.
BARGE	Longitudinal trapezoidal & tray	one rib	one rib, two ribs ($<20\text{mm}$)	5.2.C.
	Longitudinal corrugate	2 corrugations	3 corrugations	5.2.C.
	Vertically down face (smooth)	50	75	5.2.C.
	Vertically down face (profiled)	75	100	5.2.C.
APRON	Transverse over sheeting	150	200	5.2.B.
	Longitudinal trapezoidal & tray	one rib	two ribs ($<20\text{mm}$)*	
	Longitudinal corrugate	2 corrugations	3 corrugations	
	Vertically up face (smooth)	50+ hem or 75	75+ hem or 100	5.2.B.
	Vertically up face (profiled)	75+ hem or 100	100+ hem or 125	5.2.B.
PARAPET	Vertically down face (smooth)	50	75	5.2.D.
	Vertically down face (profiled)	75	100	5.2.D.

* Not to exceed 300mm.

Table 5.2. Minimum dimension 'C' flashing cover in mm.



Drawing 5.2.A. Ridge 

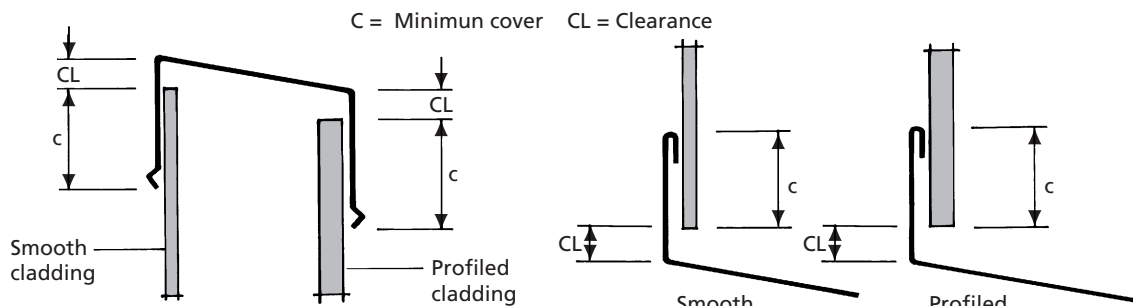


Drawing 5.2.B. Transverse apron 

C = Minimum cover



Drawing 5.2.C. Barge (Category A) 



Drawing 5.2.D. Parapet 

Drawing 5.2.E. Vertical apron 

The end of wall cladding should not extend down to any apron flashing, but should have minimum clearance (CL) of 25mm and a maximum clearance of 50mm. When describing a cover or a lap, the description should be clear and distinct, i.e., the designer and the roofing contractor should both be referencing the same item. For flashing laps. (see [section 5.2.1.](#))

The cover dimension for a flashing is the net width or length of the cladding covered by the flashing.

The factors that should be considered when determining the cover width required are:

- pitch of the roof,
- design wind load
- cladding profile,
- type of metal scriber flashing,
- provision for fixing,
- type of stopend,
- use of plastic filler blocks,
- sealing and the ventilation or otherwise of the cavity.

For high design wind loads, where dynamic pressures fluctuate, a flat flashing over profile metal cladding cannot stop water ingress without baffles or special design provisions.

To equalise or minimise the pressure differential within the cavity and interrupt the passage of wind, baffles are placed in the path of driven rain, firstly by a metal scriber or close fitting soft edging, then a profile closure and finally the vertical stopend of the roof cladding.

When closures or filler blocks are used under ridge or apron flashings, they should be placed midway up the cavity and adhered to the side ribs of the profile or the top of the apron to ensure they remain in position. They should not be sealed to the pan as this may result in any moisture that is in the cavity being retained.

Pull-up stopends must be provided for all pitches in all wind zones in Category A areas.

In all Category B areas where a full vertical dog-eared stopend cannot be made a pull-up stopend must be provided in conjunction with profile closures. (see [section 7.1.3 & 5.7](#))

Ridging

A soft edge, notched or scribed flashing must be provided to standard ridging and the roof cladding carried up to the ridge to provide a minimum 130mm cover. To ensure that primary fastening is provided between 25mm and 50mm from the edge of the ridging, the positioning of the top purlin must be adjusted with the pitch. A custom made ridging must be used where 130mm cover cannot be provided, or in a Category B area or where a vent ridge is used. Purlin spacings must be adjusted to suit.

Apron Flashings

A hemmed apron flashing must have vertical cover height of 50mm for flat cladding such as fibre cement or concrete panels, and for profiled claddings, the vertical cover must be 75mm or increased as per table 5.2. Where the roof pitch is $< 10^\circ$ or the wind design load is $> 1.5\text{kPa}$ flashing cover must be increased as per Category B in table 5.2.

The vertical upstand of an apron flashing must have a hem or weatherhook unless this impairs the fixing of the cladding. (see *drawing 5.2.2.B hems*) If a hem or weatherhook is not provided the vertical upstand must be increased by 25mm as shown in table 5.2.

Capping Flashings

The minimum vertical cover height of a capping flashing covering flat cladding such as fibre cement or concrete panels must be 50mm and for profiled claddings the vertical cover must be 75mm or increased as per table 5.2. Where the roof pitch is $< 10^\circ$ or the wind design load is $> 1.5\text{kPa}$ flashing cover must be increased as per Category B in table 5.2.

Barge Flashings

Longitudinal barge flashings that run parallel to the ribs of the roof must have a minimum cover of one rib for trapezoidal profiles and one and a half ribs for corrugate or other profiles with a rib height of $< 20\text{mm}$. Drawing 5.2.C. Where the roof pitch is $< 10^\circ$ or the wind design load is $> 1.5\text{kPa}$ flashing cover must be increased as per Category B in table 5.2.

The flashing cover of a cladding rib height $< 20\text{mm}$ is considered insufficient to ensure weathertightness.

When a parapet wall extends above the apron it can cause additional turbulence, and will also increase the water catchment and in these areas, one rib cover or 150mm is regarded as insufficient to weather either a longitudinal or transverse barge or apron flashing.

When ribbed or trapezoidal roof cladding finishes at the wall or an abutment, the aesthetic appearance of a longitudinal narrow single rib apron flashing may be unacceptable and in these cases the cover should be increased. Cover dimensions for claddings other than profiled metal are given in Table 5.2.

5.2.1 FLASHING LAPS

A lap is that part of a flashing that overlaps or covers any portion of the same shaped component, and is variously described as an end lap, overlap or underlap.

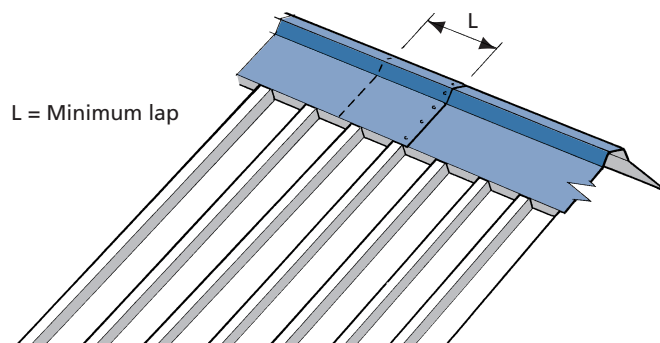
Laps should comply with the following criteria:

- an overlap must run in the same direction as the water i.e. downhill;
- an overlap must run over not under;
- an overlap must be across the fall or at a shallow angle;
- water must flow over a lap not into it;
- a lap must be self-draining and not rely solely on sealant;
- a lap must be mechanically fixed;
- a sealed lap must have a minimum of width of 25mm; (see section 5.6.4.1.)

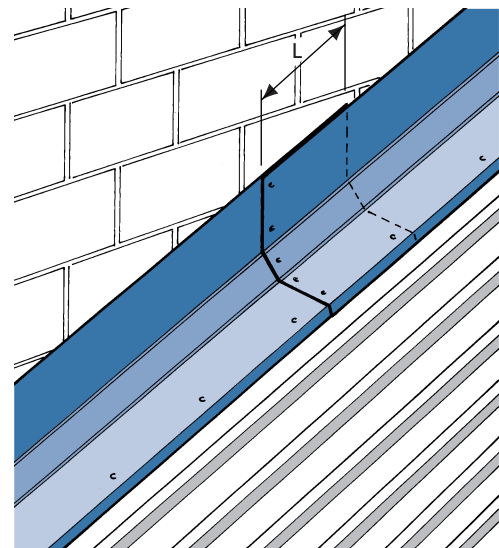
TYPE		Type A Unsealed	Type B Sealed	Drawing
RIDGE	Transverse over sheeting	150	25	5.2.1.A.
BARGE	Longitudinal	150	25	5.2.1.B.
APRON	Longitudinal and transverse	150	25	5.2.1.B.
PARAPET	Longitudinal and transverse	150	25	5.2.1.C.

Table 5.2.1. Minimum end lap of mating flashings in mm.

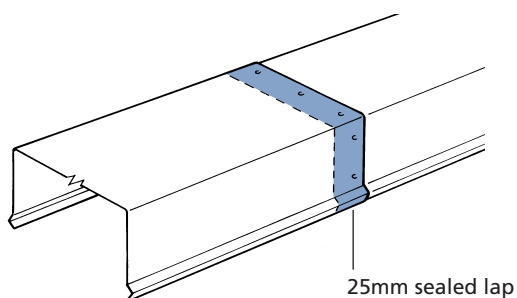
Unsealed laps



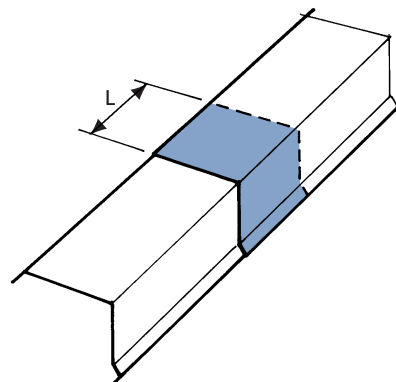
Drawing 5.2.1.A. Ridge 



Drawing 5.2.1.B. Apron 



Drawing 5.2.1.C. Parapet 



Drawing 5.2.1.D. Barge 

All sealed flashings must be mechanically fixed.

Rivets used for joining and sealing laps must be spaced at a maximum of 50mm apart and be sealed against moisture penetration or be of a sealed type.

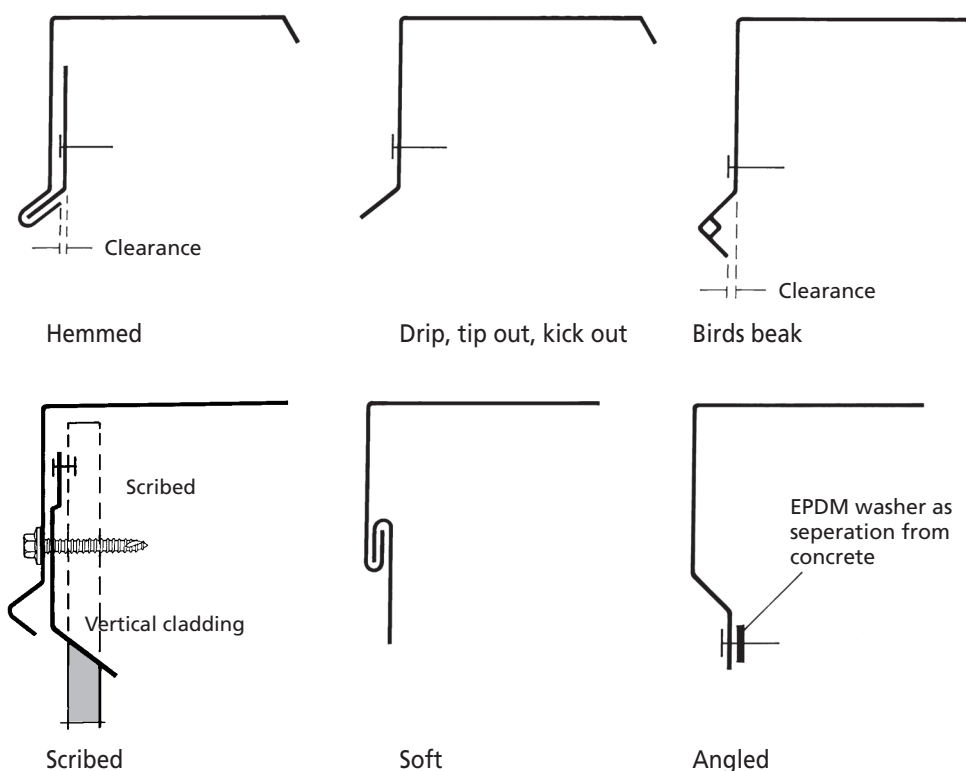
Aluminium Rivets used when fastening laps must have a minimum diameter of 4.0mm. but where they are subject to high shear, such as when fastening capping or ridging they must have a minimum diameter of 4.8mm.

Stainless steel rivets can be used with prepainted aluminium, and should have a minimum 4.0mm. diameter, but they must be factory painted.

Multiple nesting side laps of profiled sheets should be avoided because of the likelihood of condensation being trapped in the laps. The laps of roof and wall cladding with capillary edges should be limited to their intended design - one lap for trapezoidal profiles, and 1½ for corrugate. (see *capillary section 2.6.6.*)

For joined flashings with a combined length exceeding 12m, expansion joints should be formed with 200 mm laps. (see *drawings 5.4.7.*)

5.2.2 FLASHING EDGES



Drawing 5.2.2.A 

A 'kick-in' edge onto a flat surface is not acceptable because of the retention of moisture, the distortion caused by fixing, and the tensile force placed on the fastener caused by this design.

The longitudinal edges of all flashings must be designed to avoid capillary action.

All flashing edges must be fastened on both sides. A barge roll is not acceptable and a ridge roll barge must extend vertically down a minimum of 50mm and be fastened on the vertical face.

When a 'hook' or hem is formed on the top of the underside of soaker flashings and vertical flashings to prevent the ingress of water, it should not be flattened or crushed to the extent that water can bridge the intended gap nor left open to prevent the adequate fixing of any cladding. Hemmed edges that are protected from the weather such as soaker flashings can have the hemmed edge flattened using a spacer bar of 2T, but those edges exposed such as on cappings are not acceptable unless they can comply with a 4 tee radius by the inserting of a spacer bar when closing.

Anti-capillary hems must be flattened parallel but not be completely crushed. (see drawing 5.2.2.B)



Drawing 5.2.2.B 

Capillary attraction will occur wherever water has access to two surfaces in close contact, and this should be avoided because corrosion can occur when metal is subject to continuous moisture. (see *capillary section 2.6.6.*) When this contact is unavoidable, a capillary groove or gap can be formed on the flashing edge similar to those formed on the edge of most roof claddings or alternatively, a sealed joint should be provided.

Flashing edges that overlap concrete block, walls or slabs must have their edges 5mm clear of the concrete, to avoid edge corrosion, moisture retention and staining. This also applies to butyl rubber.

Metal scribe, notched or soft edge flashings must not touch the pan of the profile and must have a 2mm minimum clearance. Soft edged flashings must be dressed into the corrugations or ribs with a shaped wooden mallet or using a carpenter's hammer with a soft head attached and must also have clearance to avoid the accumulation of dirt and moisture.

5.3 FLASHING TYPES

- Ridge and Hip
- Barge and Verge
- Parapet Cappings
- Apron
- Valley
- Curved

For penetration flashings including window and door flashings see section 6.0.

5.3.1 RIDGE AND HIP

Ridge and hip roll top flashings are roll formed as a standard pitch flashing, with or without a soft edge, but have the disadvantage that, as the pitch is not custom made, when used on pitches steeper than 15°, the fit can result in visible distortion and stress around the fastenings. Custom made square top ridging can be made to any pitch and width and is available in lengths up to 8m, but recommended single lengths should be limited to 6m. The roll top, or square top of a ridging, besides allowing for expansion, also strengthens the ridge.

A vee ridge is not able to support walking traffic, however 0.55mm steel roll top or square top ridging can be walked on with care.

Both square top and roll top ridge flashings provide for cladding expansion that is not possible with vee ridging.

Vee ridging can be used on:

- ridge vents
- where the cladding length is less than 6m in length
- where the roof pitch is over 35° pitch
- where an expansion clip fixing is provided.

Vee ridging should not be used unless special provision is provided for expansion.

Where a soft edge is used to weather a pre-coated colour ridging or apron flashing, it should be primed and painted before it is fixed to the cladding.

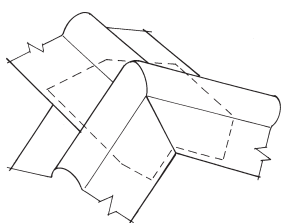
When flashings are notched, the process of notching will weaken the profile, so that the line of the flashing is determined by the frequency of the fasteners. It is better practice to use a separate scribe or spacer flashing folded so that a straight line can be preserved.

5.3.2 RIDGE - HIP INTERSECTIONS

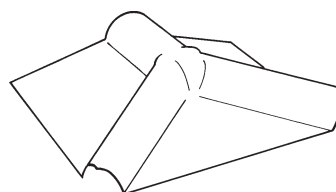
The transition at the ridge and the apex of a hip requires skill to make a neat and weathertight finish. An underflashing such as soft aluminium, underlay or butyl membrane is recommended to be used as a secondary means of making this joint waterproof in conjunction with this design of ridge-hip intersection. (see *drawing 5.3.2.A*)

The transition at the ridge and the apex of a hip must be made weathertight by either:

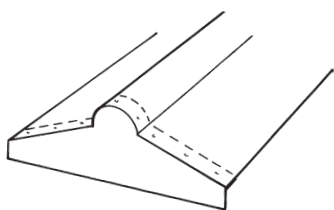
- cutting, lapping and sealing of the intersecting ridge flashings. (see *drawing 5.3.2.A*)
- the use of a soft aluminium or zinc over capping that can be formed to suit different pitches and profiles.
- the use of proprietary pressed three way roll caps made from coated steel, pre-painted steel, aluminium or Zinc. (see *drawing 5.3.2.B*) N.B. These preformed flashings are only suitable for a narrow range of roof pitches.



Drawing 5.3.2.A. Soaker 



Drawing 5.3.2.B. 3-way roll top ridge cap 

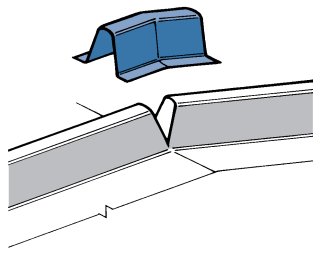


Drawing 5.3.2.C. Roll top end cap 

The gable end termination of roll ridging must be made vermin proof either by using a separate cap or by cutting the ridging back 25mm and closing it as shown in drawing 5.3.2.C

An alternative to continuous ridging on ribbed profiled sheets is the use of individual rib or ridge caps fitted to each rib after the ribs have been cut and the roof cladding bent over the ridge. Each cap should be accurately fitted and sealed because this method does not allow for free expansion to occur at the ridge of long length roof cladding. Although there is little run-off at the ridge pressed one-piece ridge caps are the preferred caps, such as Canterbury prickles or sharks, teeth however all caps rely on sealant to be made watertight.

Rib caps must not be used in Category B Table 5.2.

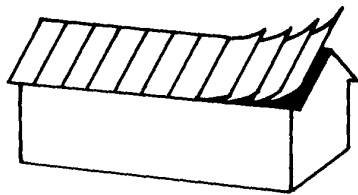


Drawing 5.3.2.D. Rib caps 

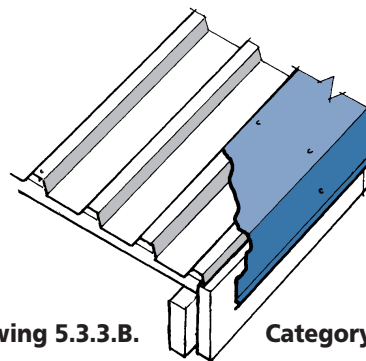



5.3.3 BARGE AND VERGE

Barge or verge flashings serve a dual purpose, which is not only to weather the junction of the roof cladding at the barge, but also to hold the roof cladding in place under greatly fluctuating wind suction loads. Unstiffened roof cladding without barge flashings can fail under high wind load conditions, because of the 'peeling' effect, which can lift a roof off in what appears to be a catastrophic moment, although the cause is actually the incremental failure of the fasteners at the verge. (see drawing 5.3.3.A.)



Drawing 5.3.3.A. 



Drawing 5.3.3.B. Category B 

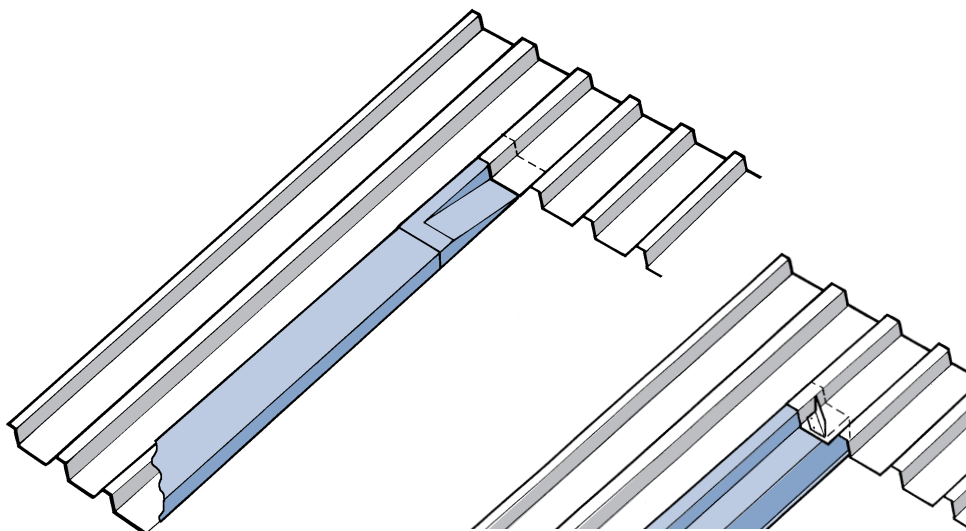
Barge flashings must be fastened on both the vertical and horizontal face at centres determined by the wind design load. (see section 5.4.2.)

Barge roll flashings or rolled roof cladding edges are not acceptable because they cannot be fastened on the vertical face.

Designers who design using 'skeleton' under eave construction which is open and not lined and omit any barge flashings, should take into account the significant additional loading placed on the roof cladding and their fixings. (see *kl loadings* section 3.3.2.) This type of design is considered an 'at risk' structure and is not acceptable trade practice. This flashing requirement applies to the barges of curved or monoslope roof structures and also at the top end of the roof cladding on a monoslope roof.

5.3.3.1 INTERNAL BARGE FLASHING

A transition flashing must be provided when the roof cladding weathers the barge at an internal angle. (see drawing 5.3.3.A)



Drawing 5.3.3.1 A. 

Drawing 5.3.3.1 B. 

Spouting has been omitted for clarity. The barge is overlapped by a transition piece, which in turn is overlapped by the higher sheeting. Where the pitch is low a sloping transition is required to drain the water into the spouting. An alternative is shown in drawing 5.3.3.1 B.

5.3.3.2

Where a shorter gable meets another with an overhanging eave, the difficulty of access can prevent fixing by normal methods. One solution is to block off this area and treat the internal corner as a penetration. See drawing 5.3.3.2.

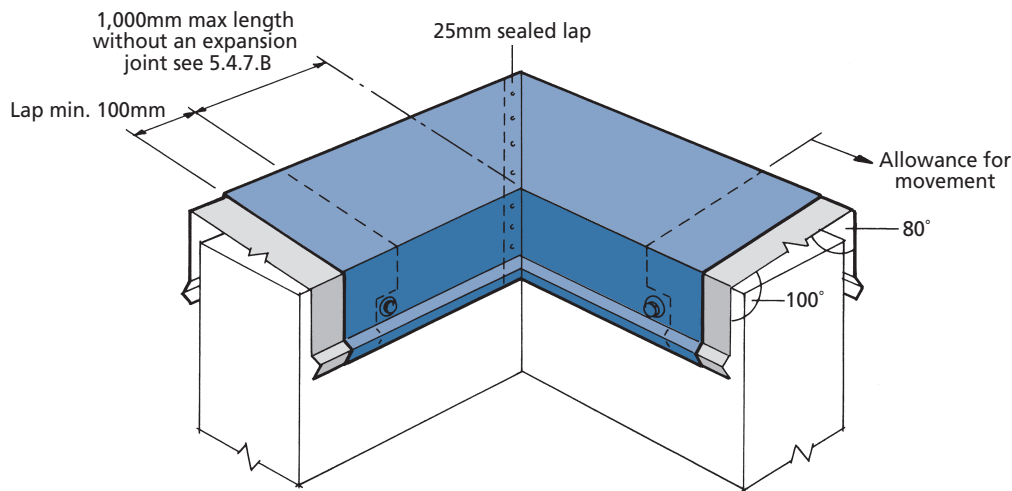
5.3.4 PARAPET CAPPINGS

Cappings or copings are used to cover the top of a parapet wall to protect the wall from the ingress of moisture. Metal cappings are used to cover existing wall materials that are porous, such as concrete block, precast concrete or EIFS . (Exterior Insulation Finishing System). In preference to chasing into the wall and using step flashings, the preferred detail is to cover the parapet wall with vertical ribbed metal or other cladding material, used in conjunction with an apron flashing. (see drawing 5.3.5.B)

Metal cappings must have a minimum of 50mm vertical cover overlap on each vertical face over flat cladding, but where the cladding is not flat, or profiled cladding is used in high or very high wind zones, the vertical cover must be extended. (see table 5.2. flashing cover)

Metal cappings must have a minimum unsealed horizontal lap of 150mm, or 25mm minimum sealed lap to provide a weathertight flashing (see table 5.2.1.) and an expansion fixing provision when the length exceeds 12m. (see section 5.4.7. expansion joints) Capping corners must be sealed, soldered, or welded (depending on the metal used) and expansion joints located at the corners within 1.0m from each direction of the corner measured on the interior side.

The corner of the wall is a fixed point for the capping and as thermal movement can only occur in one direction away from the corner, an expansion joint should be provided as shown. (see drawing 5.3.4.A.)



Drawing 5.3.4.A. Maximum internal dimension = 1000mm 

A slope is required to drain water from the exterior surface and also to drain any condensation from the inside of the building that would accumulate on the underside of the capping. A continuous timber packer should not be used under the metal capping because it will inhibit ventilation. Filler blocks should not be used for the same reason on vertical profiled metal cladding. Intermittent blocking at 600mm centres can be provided but the lap should have support and there should be provision for attachment at 600mm centres at the drip edges. A building underlay should be used as an isolation sheet for incompatible materials or to act as a slip-sheet for materials with differential movement.

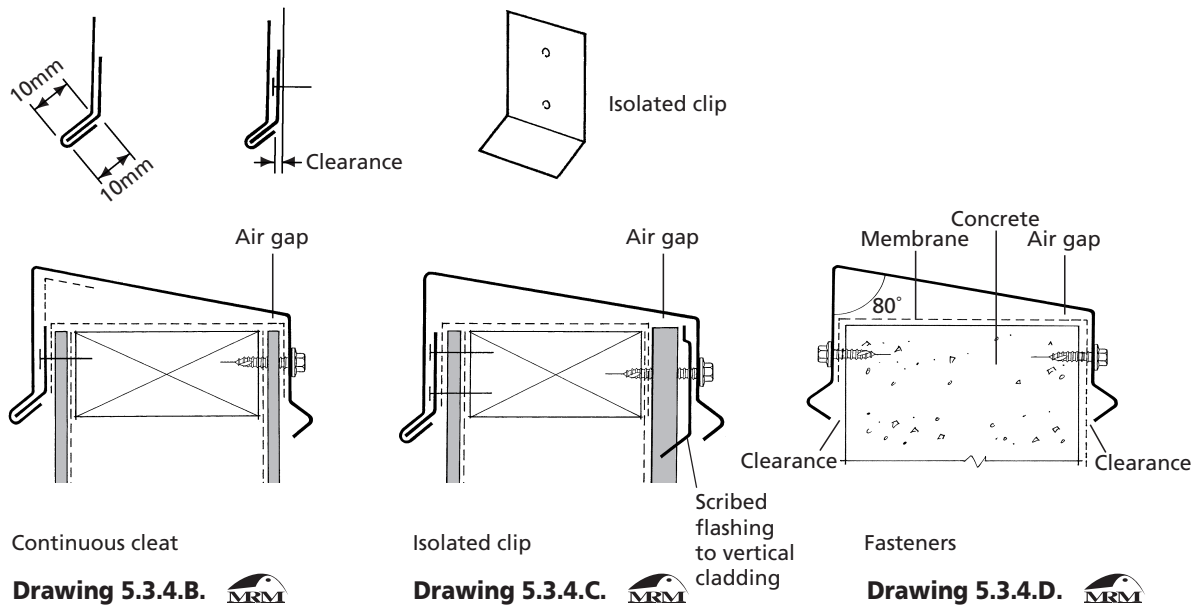
Parapet cappings must have a positive slope of 10° onto the roof side and must have a permeable and absorptive underlay. Synthetic wraps must not be used directly under metal cappings.

Parapet cappings that follow the slope of the roof do not require any fall across the capping.

Parapet cappings wider than 300mm can fall both ways with the 10° drainage angle provided to both sides of the capping. A 5mm gap between any flat wall surface and the capping will allow some air movement and reduce condensation. A gap is also required for aesthetic reasons to avoid marking or staining, and to allow condensation to drain.

Cappings must not be fixed to the structure through the top of the capping but can be fixed on the vertical leg by one of three alternative methods. (see drawing 5.3.4. B, C, & D)

- 1 Where a continuous cleat is fastened on the exterior face of the wall with an open hem at the drip for ease of application. After the exterior face of the capping is hooked to the cleat, the capping on the interior side is secured to the parapet with washered fasteners through oversized holes.
- 2 Where intermittent clips are fastened to the exterior face of the wall at 600mm centres.
After the exterior face of the capping is hooked to the clip, the interior face on the roof cladding side is fastened to the parapet with screws with sealing washers, through oversized holes.
All cleats and clips should be accurately aligned and clinched after fixing, while still allowing for expansion movement without chatter or vibration.
- 3 Where the capping is fastened to the parapet on both sides with screws with sealing washers, through oversized holes.
If a hem is used on a capping made from metallic-coated or pre-painted steel the hem radius should comply with **section 2.3.4.**



5.3.5 APRON FLASHINGS

Cladding should not fit tightly down onto the horizontal surface of any apron flashing as it will retain moisture and collect dirt and debris and should have minimum clearance of 25mm.

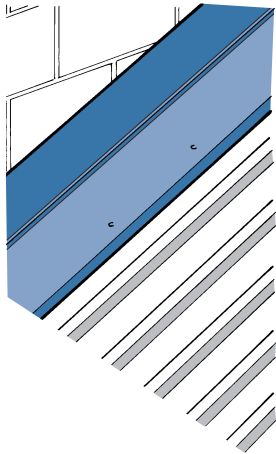
Apron flashings should be in position before any parapet cladding is installed. The vertical leg of apron flashings should be a minimum of 100mm high and be hemmed or hooked unless this would cause difficulty in fixing. This dimension provides 25mm clearance between the apron and the cladding and if a hook or hem cannot be provided the apron height should be increased by 25mm. To avoid capillary action, a break should be made between the capping and the vertical fixing surface by the provision of a 'birds beak' or similar break on the flashing edge.

Any turn down into the pan of the profile should not extend down to touch the pan, but should have a clearance of 2mm - 5mm from the pan. (*see flashing details 5.1.2.B*)

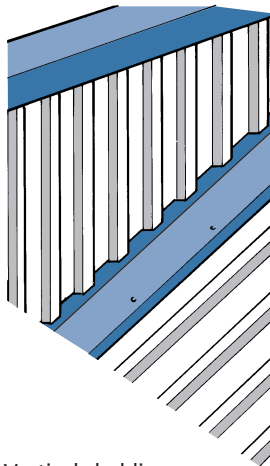
Where the finish above the apron is plaster or the durability of the cladding is 50 years the hidden apron flashing is also required to have a 50 year durability. It is therefore necessary for the apron flashing material to be non ferrous or alternatively a two piece apron should be used where the overflashing has a 50 year durability and the apron flashing can be renewed independently. (*see drawing 5.3.5.F*)

Any stiffening edge should not be turned inwards, as not only will this scratch the cladding when it moves, but it can also be the cause of roof noise. When plastering to parapet walls is required or when other trades are likely to follow the roof cladding installation, the roof cladding and flashings should be protected from damage. Provision should also be made for working and walking on the roof cladding during this time. It is the responsibility of the roof fixer to make this requirement known to the contractor, and it is recommended that photographic and documentary evidence should be taken after the roof cladding is completed to avoid any future claims for damage caused by others.

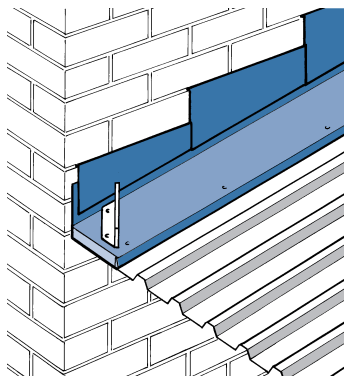
Where an apron abuts a block, brick or concrete wall, without any cladding above it, the apron flashing can be weathered by step or alternatively a continuous chase flashing, recessed into a groove cut into the wall. These flashings can be made from aluminium, stainless steel or zinc when used with metallic coated steels and should extend 25mm into the wall, should be hooked, be mechanically wedged and be sealed with a compatible flexible mortar or sealant. *See drawing 5.3.5.H.*



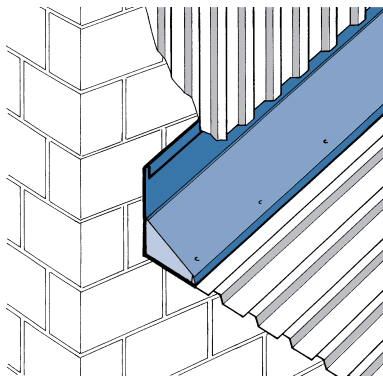
Chased apron

Drawing 5.3.5.A. 


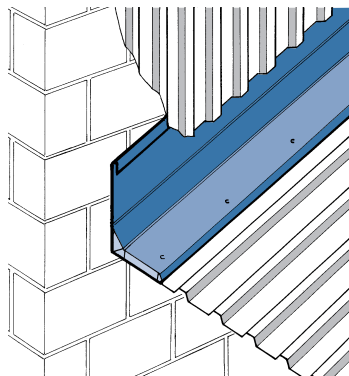
Vertical cladding

Drawing 5.3.5.B. 


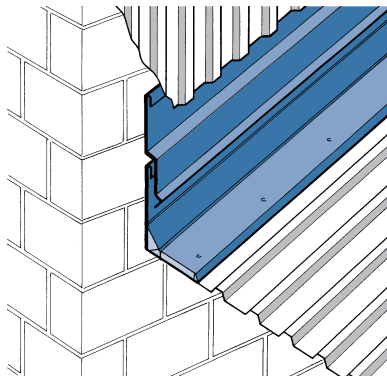
Angle diverter

Drawing 5.3.5.C 



Angled apron 110°

Drawing 5.3.5.D 


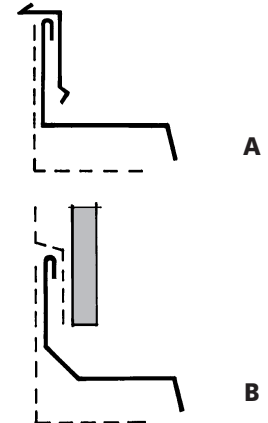
Angled apron 45°

Drawing 5.3.5.E 


Two piece apron

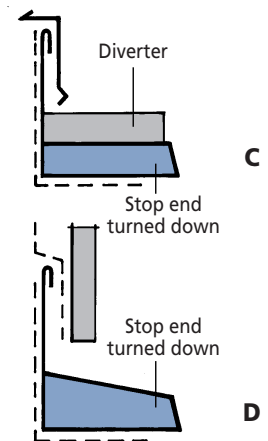
Drawing 5.3.5.F 

Spouting omitted for clarity



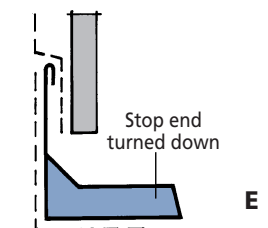
A

B

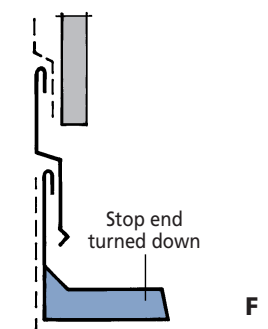


C

D



E



F

--- Underlay

Waterproofing, release of curing agents or the moisture content of the slab can inhibit adherence of the sealant to the concrete. This area should be primed to ensure the sealant bond.

5.3.5.A and 5.3.5.C are not the preferred details. A better practice detail that provides more positive weathering is provided by covering the wall with vertical metal cladding up to the capping as shown in **drawing 5.3.5.B**.

Where the roof sheeting stops short and does not extend to the wall, the unsupported apron flashing can have transverse fall back towards the internal angle of the apron flashing. It is not possible to ensure that all the water discharged from the apron flashing will be collected by the spouting at this junction unless special provisions are made including:

- An angle diverter can be sealed and fastened to the apron. 5.3.5.C
- Side apron flashing can be folded to 110°. 5.3.5.D
- Apron internal angle flashing can be folded to two angles @135°. 5.3.5.E
- A two piece apron 5.3.5.F

For clarity the spouting has been omitted. Spouting should be fitted after the wall has been finished and should be 10mm clear of the wall cladding.

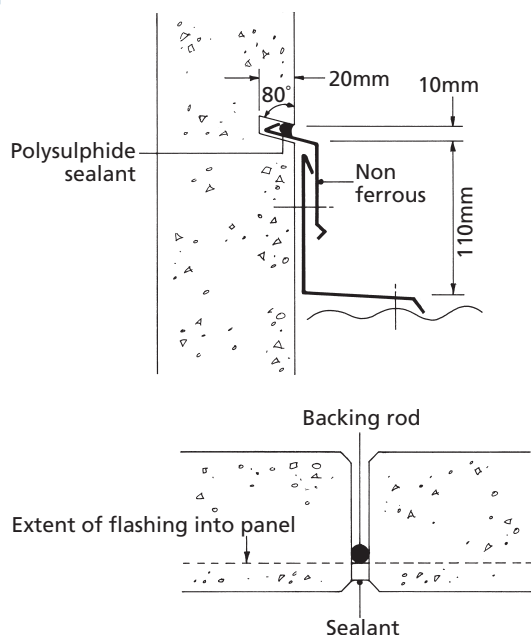
Aprons should be stop ended and be turned down to weather and to bird-proof the end of the apron at this junction.

N.B. Where a cavity parapet is used the apron should be in place before the cavity batten as it is not possible to retrofit the apron. The apron metal should have a durability of 50 years, unless the parapet cladding is easily replaced.

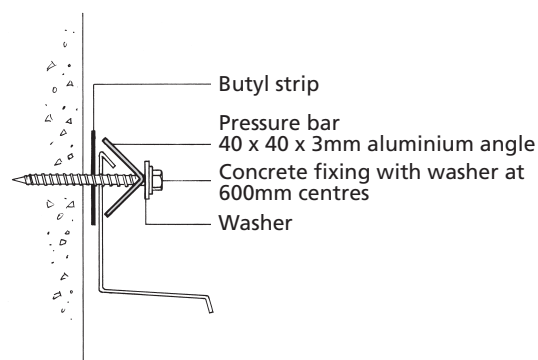
When a chase or reglet (**drawing 5.3.5.G.**) is not provided, in order to weather an apron flashing into a concrete tilt-up slab wall, a pressure bar flashing can be used. One method of obtaining a seal without cutting a chase is to screw-fix a rigid angle to the wall with an EPDM foam or butyl strip behind as shown in **drawing 5.3.5.H**.

This has the advantage that as the flashing can be easily replaced and can be the same material as the roof cladding.

Care should be taken to ensure that the junction of the chamfered edge of the slabs is sealed with a 'make-up' piece of backer rod or similar.



Drawing 5.3.5.G 



Drawing 5.3.5.H 

5.3.5.1 PARAPET AND APRON CAPPING TERMINATIONS

A parapet as defined and referenced in this Code of Practice is limited to 1m high. A wall with a parapet higher than one metre is termed a parapet wall and this area should be added to the catchment area. *(see section 8.2.1.)*

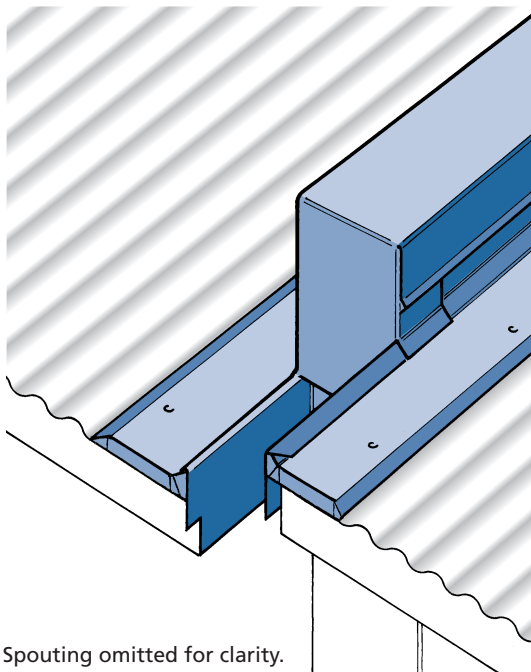
All apron and parapet flashings are regarded as being in a 'higher risk' weathertightness area, particularly in Category B areas. *(see section 5.2.)*

The large amount of catchment area from a wide or high wall and the turbulence created at the junctions requires precise detailing to avoid water ingress. *(see drawings 8.2.1.)* This can only be assured by following the better practice flashing details contained in this Code of Practice.

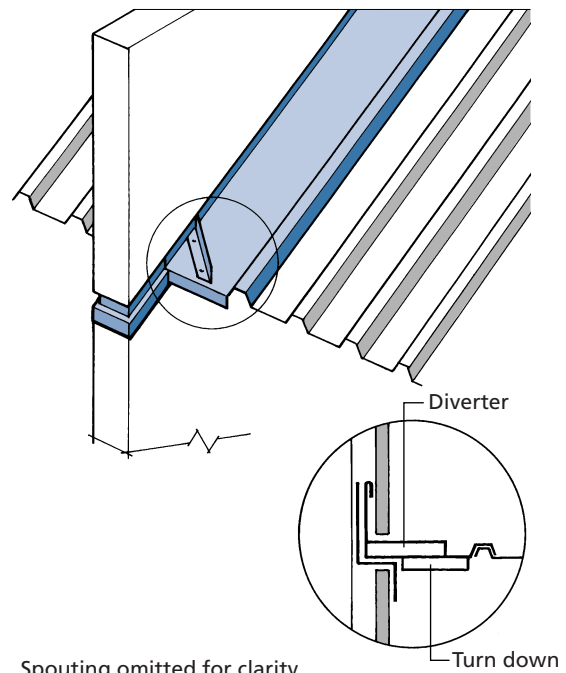
Face-sealed parapet claddings require a cavity wall construction *(see section 4.5.)* however this is not considered necessary if vertical metal cladding is used in trapezoidal, corrugated or mini corrugate profiles. These profiles will provide sufficient ventilation to avoid the accumulation of condensation providing the capping details are adhered to.

The sequence of finishing these junctions is essential as the cladding should be completely finished before the spouting or guttering is installed. The gutter or spouting should have 10mm clearance from the cladding. Where the apron terminates at the gutter line and the parapet extends beyond it as a fire-wall, the cladding should be broken at this point in order to avoid a sealant reliant joint. *(see drawing 5.3.5.1.B.)*

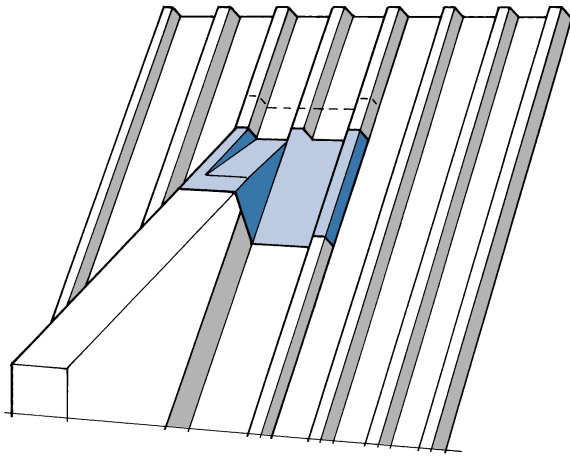
Apron flashings should not be turned up as this practice not only collects dirt and debris but causes water turbulence. Aprons should be turned down to birdproof the end of the apron as shown on drawings 5.3.5.C.D.E. & F.



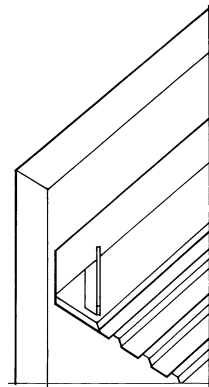
Drawing 5.3.5.1.A. 



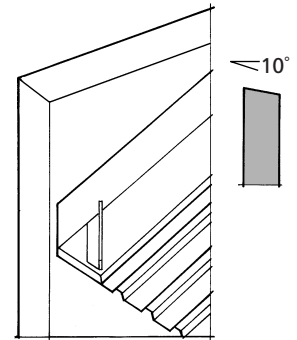
Drawing 5.3.5.1.B. 



Drawing 5.3.5.1.C. 



Parapet at roof pitch

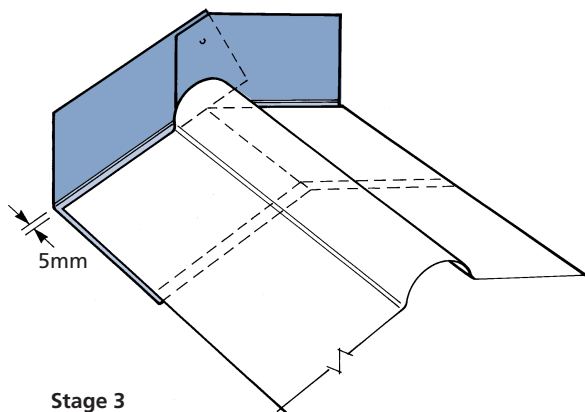
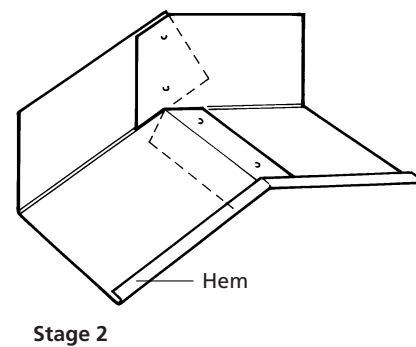
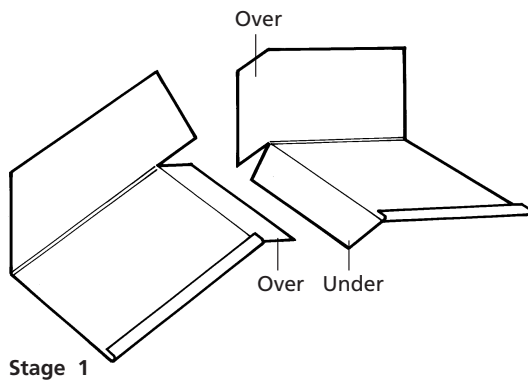


Horizontal parapet

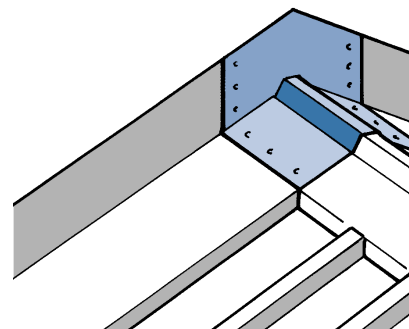
Apron

Where an apron flashing meets a ridge there are two alternative methods of weathering this junction

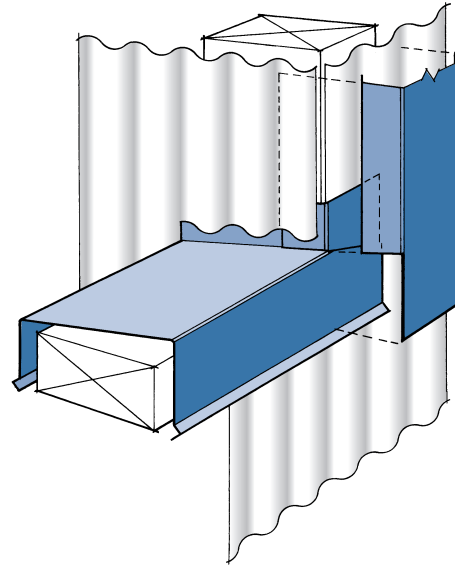
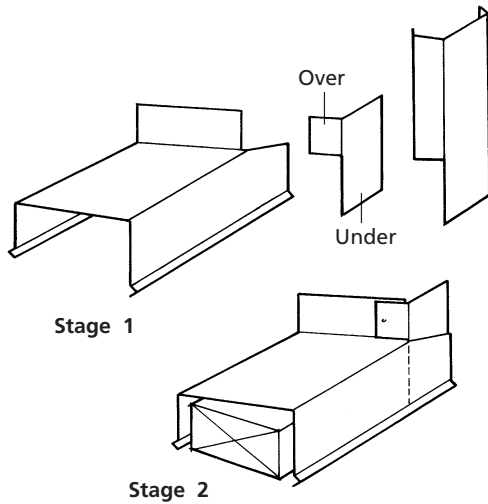
- By carrying the apron over the ridge and covering this joint with the ridging as shown on drawing 5.3.5.1.G.
- By making a separate saddle flashing as drawing 5.3.5.1.H.



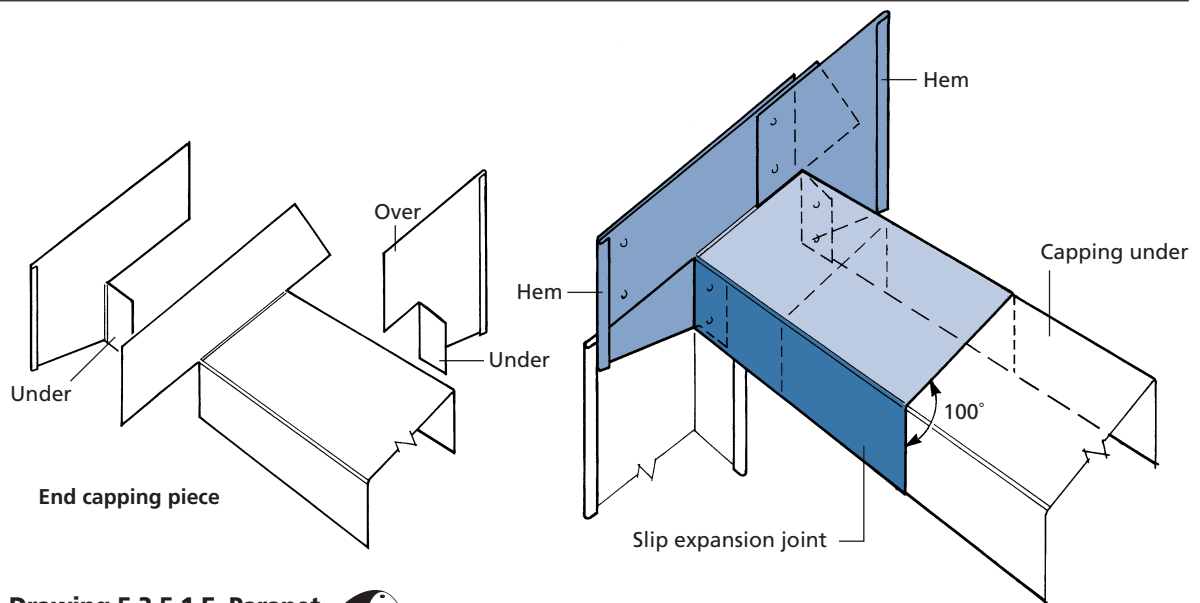
Drawing 5.3.5.1.G 



Drawing 5.3.5.1.H 

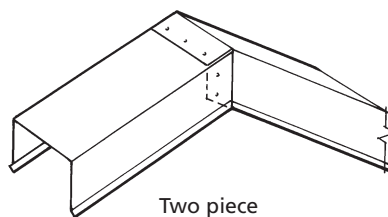
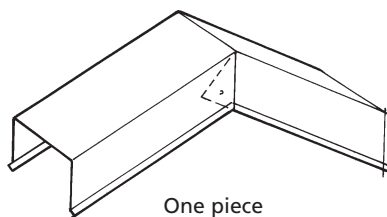


Drawing 5.3.5.1.D Corner abutment 



Drawing 5.3.5.1.E Parapet 

Parapet cappings should have a separate cap at the apex or be joined as shown on drawing 5.3.5.1.F

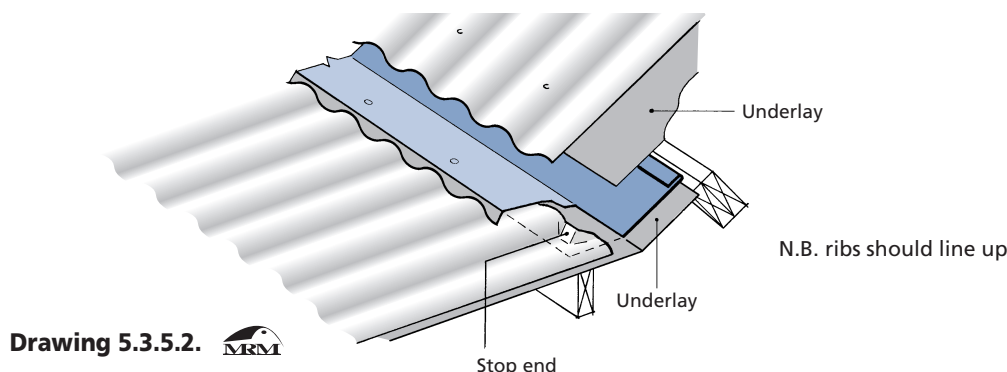


Drawing 5.3.5.1.F Parapet ridge 

5.3.5.2 CHANGE OF PITCH

At any change of roof cladding pitch, where the sheets are overlapped and butted together, differential movement will inevitably take place, and this movement will cause noise and deterioration of the coating at that point. For these reasons, a separate apron flashing as shown on drawing 5.3.5.2 is required.

Where sheeting is cut at any change of pitch a junction flashing must be used which must be hooked and have the minimum cover dependant on the exposure category as required in section 5.2.1. The underlay must overlap the flashing as shown.



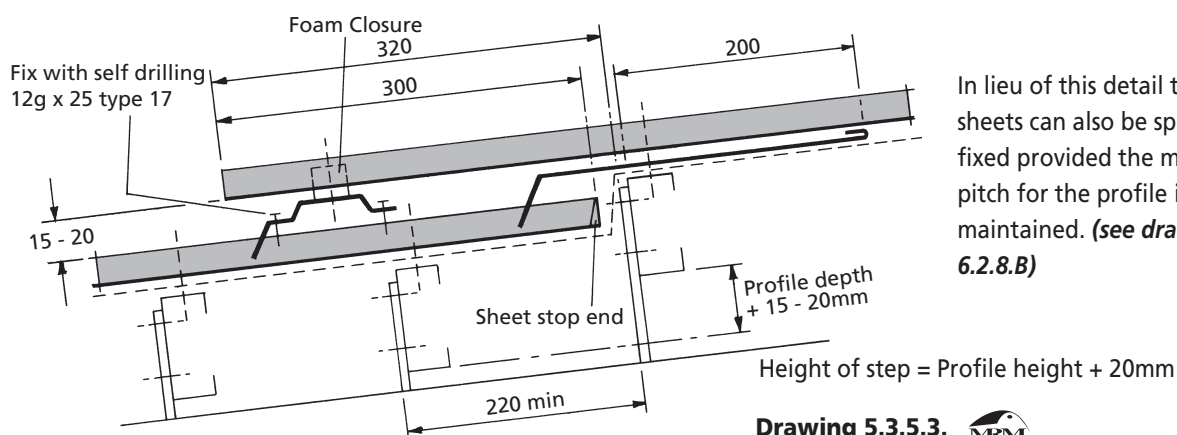
Drawing 5.3.5.2. 

5.3.5.3 STEP APRON

A step apron or waterfall flashing must be used where the length of roof cladding is greater than the length that can be transported, or exceeds the recommended length for expansion as shown in *table 4.1.6*.

End lapping of long length cladding is not recommended because of the inevitable deterioration due to moisture retention in the lap and the requirements for expansion.

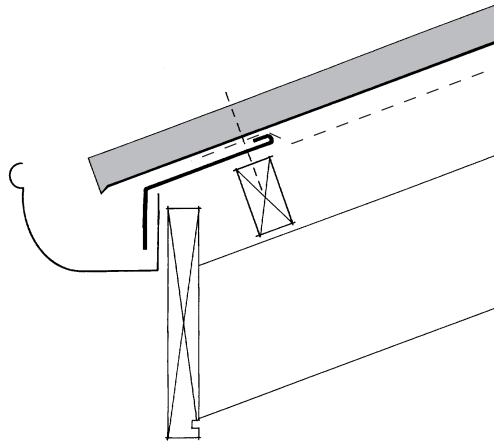
The designer should allow a minimum 20mm step in the purlin height to accommodate this detail, giving a total change of height = 20mm + profile height. The purlin height can be adjusted at the purlin cleat or by using a different size purlin. (*see drawings 5.3.5.3.*) The under sheet should be fully stop-ended, with a metal flashing closure strip as shown and closed cell filler blocks used on the lower roofs if it is < 10° or in areas of very high design wind load. The upper roof should have bird-proofing secured at the step support flashing to prevent bird and vermin entry at this point and an unwashed area can be created at any step in long length sheeting. Minimum fixing requirements are over-sized holes and the end spans at the step should be reduced as described in *section 3.2. point loads*.



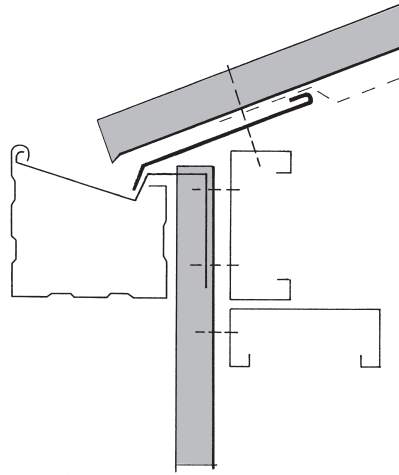
In lieu of this detail the top sheets can also be sprung fixed provided the minimum pitch for the profile is maintained. (*see drawing 6.2.8.B*)

Drawing 5.3.5.3. 

5.3.5.4 GUTTER APRON



Drawing 5.3.5.4.A 



Drawing 5.3.5.4.B 

Where the ends of roof cladding are exposed to contaminants such as sea salt or industrial pollutants it is better practice to provide an over flashing which discharges into the gutter or spouting for the following reasons (see *drawings 5.3.5.4.A and B*) :

- It provides a measure of protection to the underside of the roof cladding and the underlay.
- It provides support for the roofing underlay which is subject to damage from wind and UV.
- Where PVC spouting is used, there is an air gap between the spouting and the fascia because of the thickness of the brackets. In coastal locations where the ends of roof cladding are exposed this unwashed area becomes susceptible to corrosion and a gutter apron can minimise this risk.
- If there is no spouting or it has a low front.
- Where the ends of roof cladding are exposed in a severe environment, contaminants can be driven up the ribs of the cladding. Metal scribe flashings or filler blocks can be used to prevent or inhibit ventilation.

The over-flashing should extend 50mm into the gutter and the underlay finishes on the down-slope of the flashing. If there is no over-flashing to the gutter the underlay should be extended into the gutter by a minimum of 20mm.

This overflashing in some instances quoted above will become a sacrificial flashing which can extend the life of the cladding. In these instances it is recommended that this flashing be made from aluminium.

5.3.6 VALLEY

Valley flashings are centrally folded sloping internal gutters used where the roof pitch $> 12^\circ$ and they are required when there is a change in direction of the roof cladding at an internal corner, or where a pitched dormer window penetrates the roof structure. (see *valley gutters section 8.4.5.*)

Valleys should be fixed to provide for longitudinal expansion as they are subject to the same length restrictions as required for flashings and claddings, and should not be through fixed to the roof cladding.

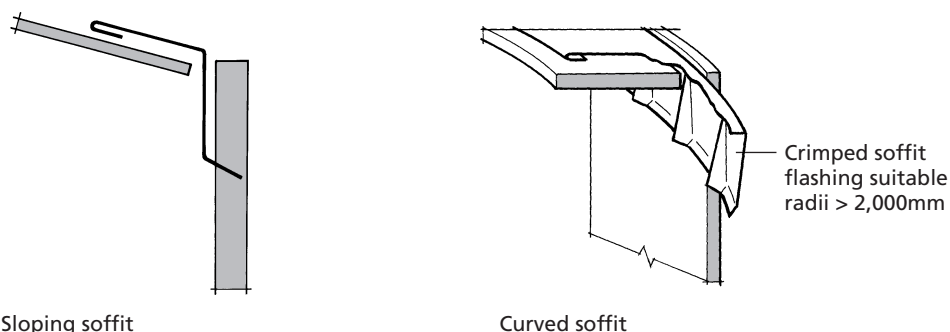
A valley should be regarded as part of the roof cladding and any vertical valley lap should be sealed to avoid any condensation accumulating at the top and to prevent the ingress of water by capillary action at the bottom of the lap.

5.3.7 SOFFIT FLASHINGS

Where a soffit and the horizontal or vertical metal wall cladding meet, the junction should be overflashed with an angled flashing which provides the same cover as is required for other flashings. (see section 5.2.)

This flashing is an under/over flashing i.e. it should be above the soffit lining and over the outside of the metal cladding.

Where a curved soffit meets a vertical wall the flashing can either be 'gear crimped' or crimped as shown or lockseamed. (see section 5.5.2 & 3)



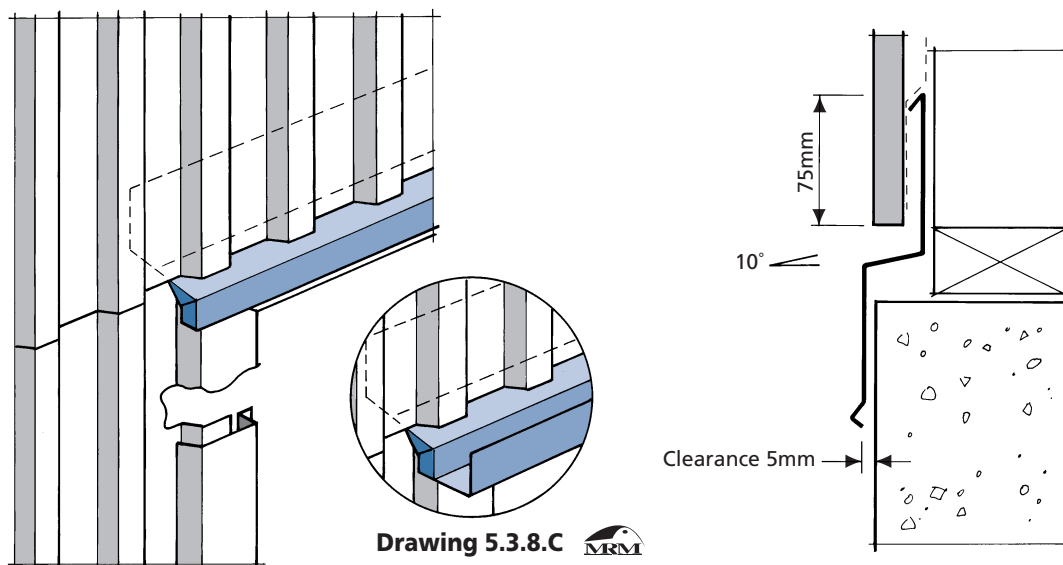
Sloping soffit

Curved soffit


Drawing 5.3.7. 

5.3.8 FLASHINGS FOR VERTICAL CLADDING

The flashing detailing for vertical cladding is similar to roof cladding penetrations, as the water from the 'under' has to drain over at the window or door head. The most satisfactory detail is to provide a sheet lap at the head flashing, which enables automatic weathering by profiling the vertical upstand of the head flashing or by flattening the lap. This detail can be used for corrugated, ribbed and trapezoidal cladding. Do not stop end the flashing but turn it down as drawing 5.3.8.



Drawing 5.3.8.A 

Drawing 5.3.8.C 

Drawing 5.3.8.B 

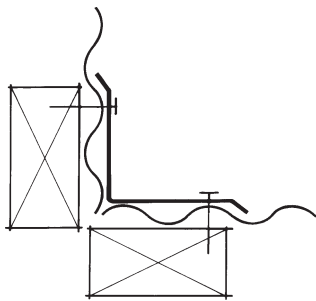
When vertical cladding is used, similar flashing details can be used for window and doors, which are similar to those described for horizontal cladding **section 6.4** using either flush or reveal styles.

When flush doorways without a protecting canopy are below a large or high catchment area above, they should have a small gutter included into the head flashing not only for weathering but the comfort of those people using the doorway. This detail using a small gutter should be used at other penetrations such as meter boxes. (see **drawing 5.3.8.C.**)

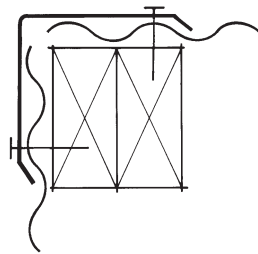
Where the cladding is of a crimp curve design without eaves gutters, a gutter is essential over doorways.

Flashing circular windows into metal cladding without relying on sealants can be achieved by regarding the window as two halves at the mid-height centre line, with separate flashings provided for the top and bottom.

External and internal vertical corners should have the same cover as described in Table 5.2.



Drawing 5.3.8.D. Internal corner 



Drawing 5.3.8.E. External corner 

5.3.9 FLASHINGS FOR HORIZONTAL CORRUGATE CLADDING

Designers and contractors using horizontally fixed corrugate sheets as a design feature on industrial developments and commercial buildings, as well as in domestic situations should recognise that a high standard of quality of detailing and fixing of the cladding is required and that there are a number of requirements which differentiate horizontal from vertical profiled cladding.

The designer's choice of colour for profiled horizontal sheets should take into account that horizontal cladding produces increased shadowing, and that most colours will show the accumulation of dirt. The ribs of deeper longer spanning profiles will collect dirt both inside and outside the building, particularly on the unwashed areas of the flashings and on the underside of the ribs of outside cladding.

Where insulated lined walls are externally clad with horizontally fixed metal sheeting without a cavity they should have some provision for ventilation. The better alternative is to use cavity construction. (see **section 4.5.**)

All cladding requires maintenance, and as horizontal cladding and flashings are not self-cleaning by rain, frequent washing is required to maintain the durability required by the NZBC, appearance and the requirements of any warranty. (see **maintenance section 13.0**)

If maintenance is not carried out regularly, dirt will accumulate at the horizontal and vertical joints with consequential deterioration in the durability and appearance of the building.

The maintenance schedule should be provided to the owner in writing, and he should be made aware that because horizontal cladding is particularly susceptible to damage by ladders that are used without spreader bars it is his responsibility to notify window cleaners.

Because horizontal cladding emphasises the defects in the line of the framing to a far greater extent than does vertical cladding, the plane of the supports both horizontally and vertically should be straight within a tolerance of 5mm in 10 metres, and there should be little or no twist between the vertical and horizontal planes of framing members.

The cladding contractor should inspect and approve the standard of framing before the commencement of any cladding installation. The use of 0.40mm coated steel cladding is likely to show any deviation in the line of the framing, and 0.55mm is therefore the preferred choice. The support centres should be reduced for horizontal cladding and a minimum flashing thickness of 0.55mm for steel or 0.9mm for aluminium should be specified. The width of the supports will be determined by the method of jointing and secondary framework may have to be provided, with all support fixings being counter-sunk.

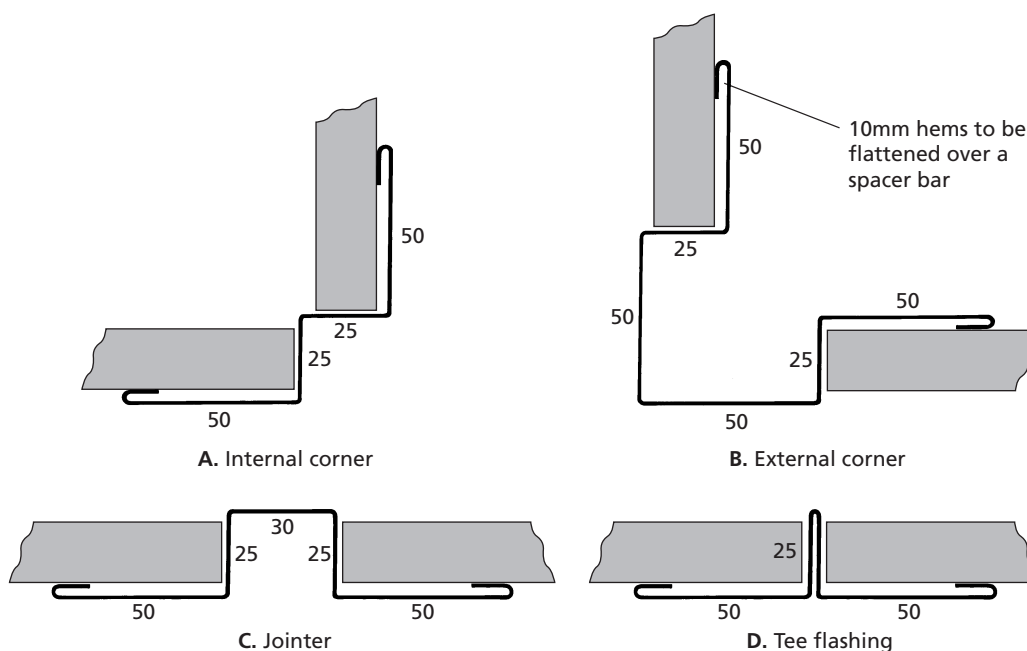
Horizontal cladding should be fixed in the pan as this provides a stronger, more economical and aesthetic fastening than crest or rib fixing. The number, spacing and the position of the fasteners are determined by the wind design load for the building. (see section 3.4.1.)

For aesthetic reasons only, or where the cladding is at eye level, the number of fasteners may have to be increased to every second corrugation for corrugate and one primary fastener placed at every trough and secondary fasteners at 500mm centres for other profiles.

A simple and aesthetically acceptable butt detail to join horizontal cladding is to provide a vertical break at structural steel frame centres by the use of a top hat or tee flashing section, but it is necessary to establish the exact sheet length required, and for these sheets to be cut accurately to within 1mm to provide a neat joint.

When horizontal metal cladding is directly fixed to a lined and insulated wall, designers should be aware of the likelihood of condensation and it is recommended that horizontal laps should be sealed with lap tape or sealant. (see 5.6.4.1. and 5.6.5.)

A ventilated cavity is the preferred option. (see section 4.5.) (see condensation section 4.2.2.)

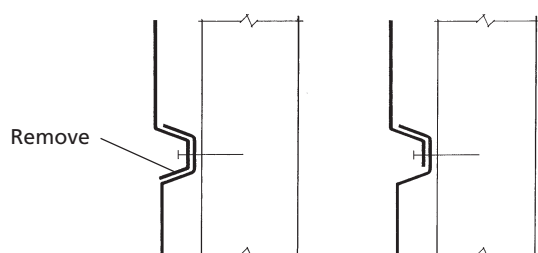


Drawing 5.3.9. A, B, C & D 

It is recommended that dwg 5.3.9.C be used where sheets exceed 8m to allow for ease of installation and thermal expansion. Foam filler blocks are recommended for exposed sites.

Butt flashings are not a recommended detail in areas of high design wind load when external flashings should be provided in lieu of, or as well as, the butt joint flashings and they should be used in conjunction with stop-ends and filler blocks. The fastening of horizontal cladding should be clear of the hemmed soaker and should not penetrate the flashing. In high wind design load areas, external flashings should be provided in lieu of or as well as the butt joint flashings.

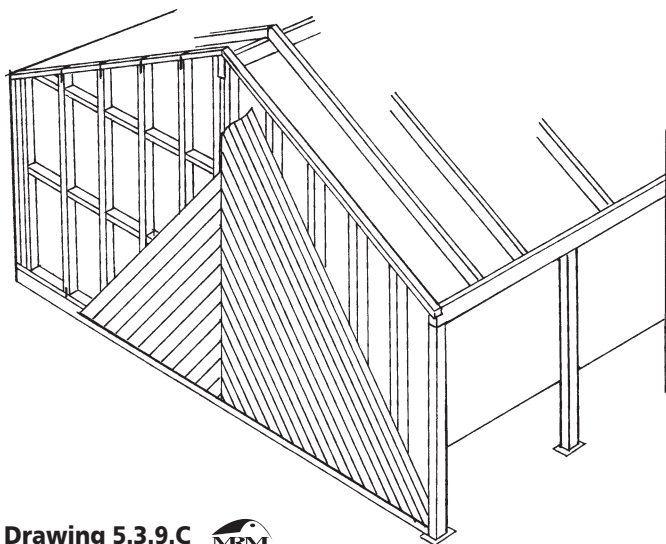
When profiled metal is used 'inside out' as a wall cladding, it is better practice to cut the overlap back to the plane of the structure. (see drawing 5.3.9B.)



Drawing 5.3.9.B 

When penetrations are required in horizontal or vertical metal cladding they should be installed in a similar manner to roof penetrations. For round penetrations a proprietary boot flashing can be used. (see section 6.0 penetrations)

The requirements for horizontally fixed cladding also apply where cladding is used at any angle other than vertically or such as a chevron style. Where sheets are placed on an angle the lap should be placed downside to shed the water and a soaker flashing provided to drain the run-off.



Drawing 5.3.9.C 

5.4 FASTENING

Flashings must be fastened in one of three ways, either:

- By primary fastening - fastening into main structure
- By secondary fastening - fastening into the cladding
- By means of clips, cleats or seams to allow for differential movement of the roof cladding and the flashings.

For full details on fixings, see section 7.3.

5.4.1 PRIMARY FASTENERS

Primary fasteners are fixings that attach flashings and cladding to the structural building frame and which should withstand all loads applied to the flashing including any provision for expansion. Primary fasteners are relied upon for structural performance. Those fixed into timber consist of nails or screws and those fixed to steel consist of self-drilling or self-tapping screws, or bolts.

Crest fixing is the most common type of primary fastening of roof cladding in N.Z. The minimum embedment into a structural timber member should be 35mm or 6 times the fastener diameter.

Flashings should be fastened at a point between 25mm and 50mm from the edge of the flashing and the maximum primary fastener spacing should be 600 mm. When this is not possible because there is no structural member provided, they should be fixed with secondary fasteners at a maximum of 200mm centres. If the sheet length exceeds 8m flashings should not be fixed rigidly to the structure without some provision for expansion. The allowance for movement will vary with the length of the material, its coefficient of expansion its colour and the temperature range likely to be encountered. (*see section 4.1.6*)

Both pull-out and pull-over resistance are critical elements in selecting the correct fasteners. (*see fasteners section 7.8.2.*)

Pull-out resistance, and the ability of a fastener to hold metal in place is a function of the size of the fastener, the thread, the type, and the density and strength of the substrate material. The pull-over resistance of the metal held in place where the fastener penetrates the sheet metal depends on the diameter of the head of the fastener, the thickness, type and grade of the material being secured, and the washer size.

Wide, large, and flat areas of flashings should be avoided as these will buckle with thermal movement, and require fixing at closer than normal centres. All flashings should be fixed with primary fasteners to the structure and the design wind load determines the frequency of fastenings per lineal metre.

Most flashings are within the periphery of the building, which incurs an increased design wind load factor, (kl) of a minimum of 1.5 times the design wind load for the main body of the roof.

For this reason all flashings should be fixed on both edges and have a maximum flat surface width of 300mm. Additional stiffening is required if the flashing width exceeds 300mm.

Only Class 4 screws complying with the corrosion resistance requirements of AS 3566 must be used when fixing profiled metal cladding (see section 7.8.3. durability).

All fasteners must be easily identified by a code stamped on the head to identify the manufacturer and the coating class. When using precoated steel and aluminium, only factory painted screws, washers, nails or rivets must be used.

5.4.2 SECONDARY FASTENERS

Secondary fasteners are fixings that attach flashings to sheets and to one another to transfer loads and provide side lap sealing. Rivets and stitching screws are secondary fasteners used to fasten cladding side laps and are subject to shear loading due to expansion and differential movement.

Sealing washers are required on all secondary fasteners with the exception of rivets, which should be sealed.

Where the purlin or girt spacing exceeds 1.200m. secondary side lap fastening must be provided at 600mm centers to fix longitudinal barge or apron flashings.

All rivets used as fasteners at sealed laps must have a minimum diameter of 4.00mm and be fixed at centres of not more than 50mm.

Except for self-locking profiles, flashings should be fastened to the roof or wall cladding, using coarse thread stitching screws with a neoprene washer, or self sealing bulbtite 4.8 mm aluminium blind rivets. Stitching screws, where the thread stops before the head, can be used so that "stripping-out" does not occur.

Screws or clouts fastening the vertical leg of a barge flashing should be at no greater spacing than 600mm.

5.4.3 SECRET FIXING CLIPS

A secret-fix clip is an individual metal component installed at predetermined locations along the edge of a metal roof panel or behind the leading edge of a flashing. It is used to engage and secure the metal cladding or flashing intermittently to the adjacent substrate or to another metal component.

Clips, cleats and fasteners are the components that secure metal panels, accessories and flashings to the substrate at discrete intervals.

They should be compatible with the cladding metal used, and be capable of resisting the design wind loads, particularly around the periphery of the building where the uplift loads can be up to twice those at the body of the roof. To allow for expansion on long length flashings, the clip fixing which secures the flashing in position should not restrain it lengthwise.

Pull-out resistance and the ability of a fastener to hold a clip in place, is a function of the type length and shank diameter of the fastener, and of the density or strength of the substrate material. The pull over resistance of the metal clip depends on the diameter of the head of the fastener, the thickness of the clip, and the grade and type of the metal being secured.

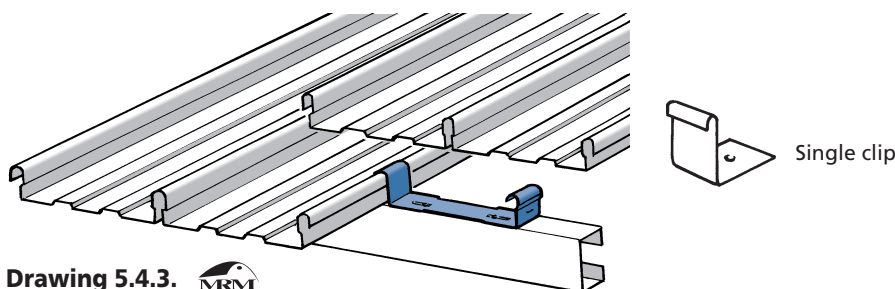
Both pull-out and pull over resistance are critical values in selecting correct fasteners for clips. Clips should be made from a grade and thickness of metal at least equal to the cladding thickness, but it is recommended that they be made from heavier metal than the cladding.

All fixing clips should be a minimum width of 30 mm, spaced at centres derived from **graph 11.4**. and fastened with two fasteners. Smooth shank nails should not be used and are not acceptable. Only enhanced shank nails should be used.

Clips that are used with long spanning profiles can be interlocked together in a run of a number of sheets, thereby controlling the sheet creep and avoiding an increase in cover width that can occur using single or double clips.

Screw fasteners used to fix self supporting cladding clips should comply with the design wind load requirements.

Clips that are used in very severe environments should be coated with a corrosion resistant paint system



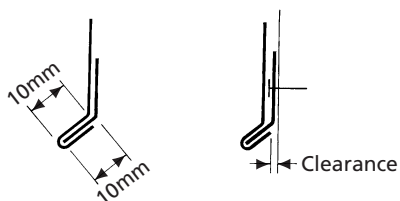
Drawing 5.4.3. 

5.4.4 CLEATS

A cleat is a continuous metal under-flashing installed behind the leading edge of a metal capping or flashing, used to secure it to the substrate or structure by means of a slip joint or by crimping the leading edge of the flashing to the cleat. Cleats and clips should be accurately aligned and clinched after fixing to avoid vibration or chatter, but still allow for expansion of the flashing.

Cleats provide continuous hidden anchorage for the flashing or sheeting by means of mechanical fasteners to the substrate, and should be made from the same metal as the flashing or sheeting being secured.

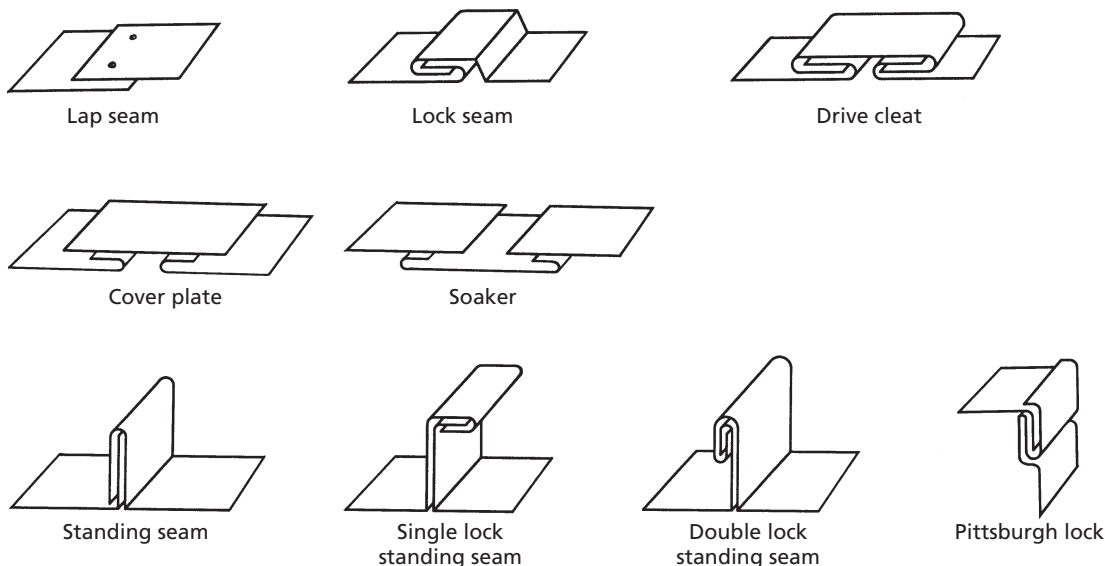
Cleats used at the eave and barge should be made from metal of an equal or heavier gauge than the flashings or cladding because of the increased wind load at the roof perimeter. To allow for differential expansion and contraction, the flashing should be securely hooked to the drip edge of the cleat but should not be attached directly to it.



Drawing 5.4.4. 

5.4.5 SEAMS

Flashings can be joined together by a number of different types of seam to avoid a plain lap joint without sealant. If the joint is likely to retain moisture and it is required to be sealed, the sealant should be introduced into the joint before it is completed.



Drawing 5.4.5. 

5.4.6 FLASHING EXPANSION

Before any metal roof or wall cladding or flashings are fixed the framing timber must have a maximum moisture content of 18%.

If flashings are positively fixed, framing timber that does not meet this requirement can cause failure of ridging and flashings due to timber shrinkage on drying.

The metal expansion allowances quoted in many publications can be misleading because the information is based on theoretical metal expansion values and is not related to real world conditions.

Figures published for metal expansion rates are given linearly per degree, which does not take into account the many various other factors that mitigate the theoretical figure. (see 4.1.4. expansion)

It is necessary to make provision for cladding and flashing movement because when long lengths are used and positively screwed or riveted together, they should be regarded as one length.

The maximum length before expansion provision should be made for either cladding or flashings will vary because of the many permutations of colour, micro-climate, ventilation and fixing spacings.

It is possible to provide indicative figures based on a study of empirical data over many years, and the maximum recommended flashing length without any expansion provision is similar to that of roof cladding. i.e. every 12m. for coated steel flashings.

Aluminium rivets, which have a low shear value, will fail when there is no provision made for expansion in fastening flashing lengths over 12m. Long lengths of coated steel ridging, cappings and apron flashings over 12m should have a slip joint as described in section 5.4.7.

Noise also results from cladding and flashings moving without adequate provision for expansion, and the use of aluminium rivets is acceptable only if they are used at the prescribed centres, and are not used in lieu of expansion joints.

5.4.7 EXPANSION DETAILS.

Non-ferrous metals have a higher rate of expansion than steel and therefore require a greater provision for expansion. This can be provided by means of slip joints, sleeves, butt straps, clips or welts, and although some of these details are complicated they have been used successfully for many years.

Expansion should be considered at the design stage and the flashing details should be included in the working drawings and tender documents. It is the responsibility of the designer to provide these details, however the roofing contractor also has a responsibility to install flashings so as to allow for expansion.

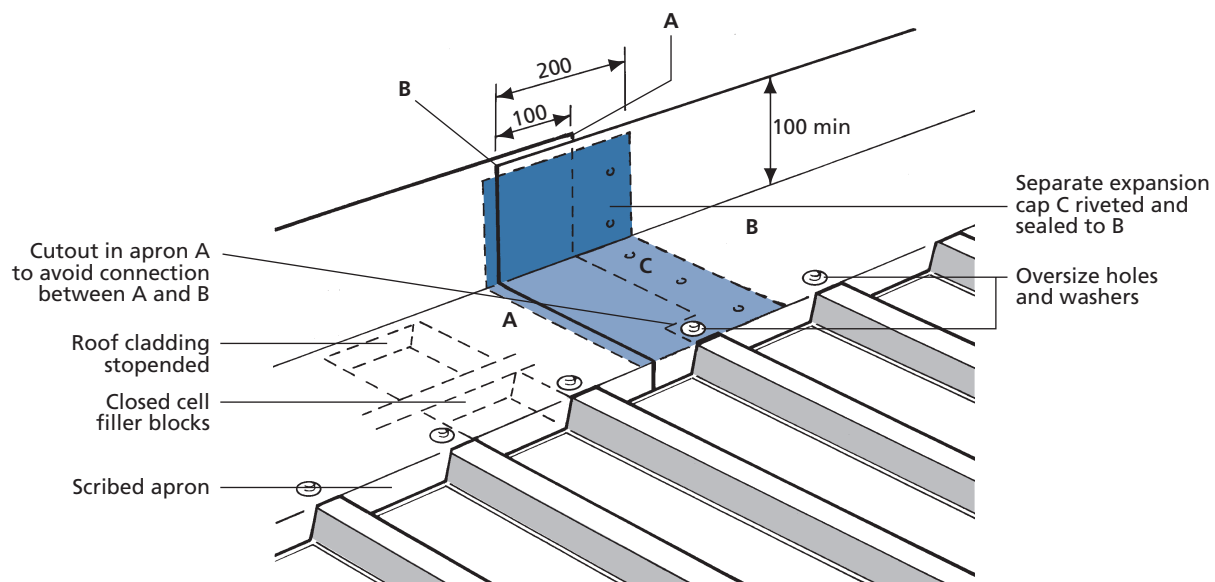
As flashings cannot move in the lateral direction without stress they should have some provision for longitudinal expansion.

Crest fixed primary fasteners allow some movement but oversized holes with round or shaped load spreading washers can only provide expansion provision for lengths up to 12m for coated steel flashings. For lengths greater than 12m this provision is insufficient to accommodate movement without distortion and the provision of an expansion slip joint is required at lengths as per **table 4.1.6**.

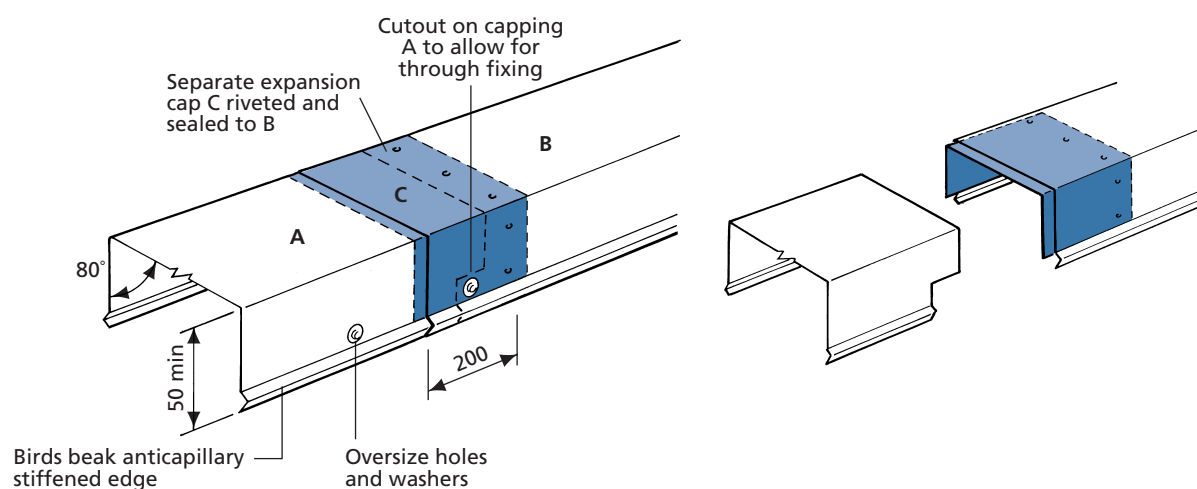
When using an expansion joint, independence of movement should be assured by the omission of any fixing through both sides of the joint. Preferred and acceptable slip joint expansion details are shown in drawings 5.4.7.A,B,C.

Soaker expansion joints relying on sealant should not be used.

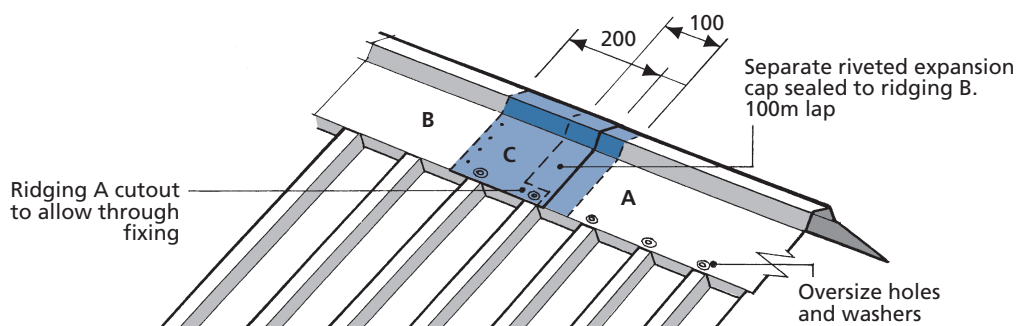
Sealant is required at the slip joint, not to make it weatherproof, but to exclude dust and dirt from two close fitting surfaces, which can retain moisture by capillary action and cause corrosion. In this case only, no through rivet or screw fasteners should be used in conjunction with the sealant.



Drawing 5.4.7.A. Apron slip joint 



Drawing 5.4.7.B. Parapet slip joint 



Drawing 5.4.7.C Ridge slip joint 

When steel flashings are joined together to be greater than 12 m in length, expansion slip joints should be formed with 200 mm laps. Longer laps than 200mm should be avoided as these may buckle with thermal movement and require a clip or cleat fixing to hold the flashing in position without restraint.

Barge and apron flashings greater than 12 m in length that are fixed to the sheet ribs to prevent uplift, should also be free to move with the structure, to avoid expansion 'creaking'. If the sheet length exceeds 12 m flashings fixed rigidly to the structure should be fixed using oversized holes.

The amount of movement required will vary with the length of the material, coefficient of expansion, colour and temperature range. Roll top and square top ridging, besides strengthening the ridge, provides some allowance for longitudinal expansion of the roof sheeting when oversized holes are used.

5.4.8 BUILDING EXPANSION JOINTS

Each building material component has a different coefficient of expansion, and when subjected to varying temperature changes results in different amounts of thermal movement. (see table 4.1.6.)

Building expansion or construction joints are used to minimize the effects of stresses and building movement and metal flashings should be located in the same location as the structural expansion joints of the building. For new construction, it is the designer's responsibility to provide details to allow for building movement and for the placement of expansion joints.

Roof expansion joints should be provided at the following locations:

- Where building expansion joints are provided in the structure.
- Where fire-walls separate roof areas.
- Where steel framing, structural steel or cladding change direction.
- Where separate wings of L or U shaped buildings or similar configurations exist.
- When additions are connected to existing buildings.
- At the junction between a new and an existing building.
- At junctions where a heated office abuts an unheated warehouse.
- Wherever differential movement between vertical walls and the roof cladding may occur.
- Where wind or seismic loading can cause building sway.

Expansion joints should extend across the entire length or width of the roof, and continue through to the roof edge or perimeter. Parapets can be designed as expansion joints.

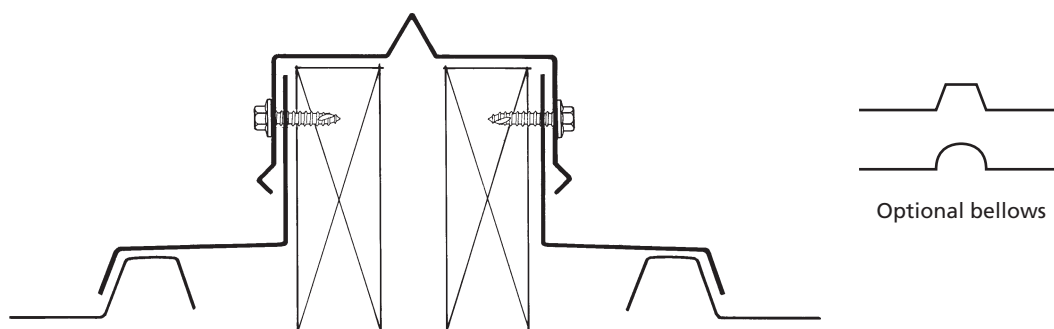
Where a valley occurs it can be used as an expansion joint, and the use of a central roll at this point will not only provide expansion provision, but will inhibit fast discharge across the valley. (see drawing 8.4.5.C.)

Expansion joints should be designed to accommodate contraction, as well as expansion. Expansion joints should be detailed and constructed to a minimum height of 100 mm above the roof cladding, and curb-type expansion joints should be designed and installed to ensure drainage of the roof and to prevent any damming of water.

Wood curbing secured to the substrate on both sides of an expansion joint should be flashed with a metal capping capable as acting as an expansion joint cover.

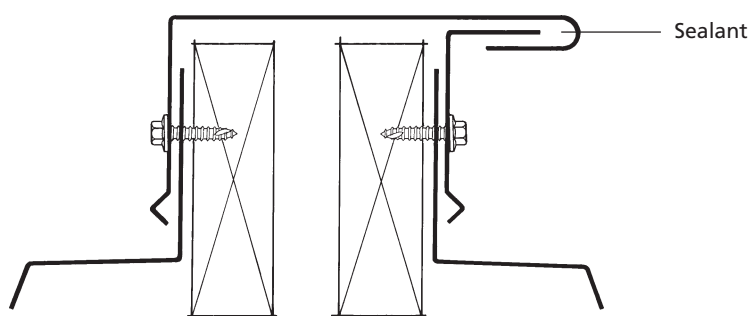
There are two main design types of expansion joint covers.

- 1 A one-piece design to accommodate movement by the use of a central bellows or roll that allows the flashing to be positively fixed on both sides. See drawing 5.4.8.A.



Drawing 5.4.8.A. 

- 2 A two-piece design to accommodate movement by the use of hemmed edges, with sufficient clearance for the expected movement.



Drawing 5.4.8.B. 

Both of these designs are shown as a parapet following the pitch of the roof. Where this is not the case, the top of flashing should have a 10° slope as for all other parapet flashings. (*see 5.3.4 parapets*)

Metal wall construction joint flashings that are embedded in the wall should be made with a bellows or other means of accommodating movement without fatigue and have a durability of 50 years.

5.5 CURVED FLASHINGS

Draped curved and crimped curved metal roof cladding requires curved barge and apron flashings to follow a curved shape which may not always have an even radius.

The prime purposes of curved flashings is to exclude the weather and to provide structural integrity to the roof cladding but they also have a role in the architectural or aesthetic appearance of the building and to finish the barge in a visually acceptable manner.

To provide acceptable appearance and weathering, curved flashing measurements should not be taken from drawings but require site measurement with a template taken from the as-built structure.

Considerable skill and care is necessary to obtain a good fit particularly at side laps, which should be sealed where they are below the minimum pitch for the profile.

There are three different ways to form curved flashings, all of which require specialist equipment.

- By lock-forming or lock seaming
- By 'Jennying'
- By crimping

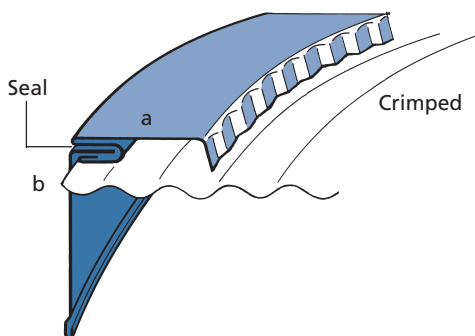
Manufacture of curved flashings is a highly skilled operation and should be done in a factory environment by skilled workmen. Lock-form roll tooling is not adjustable and can cause micro-cracking on external bends, although this can be minimized by forming the flashing material at a warm temperature.

Roll tooling can damage organic coatings and in order to minimise any marring of the surface, a strippable film should be used on all pre-coated flashing material. This film should be removed before the flashing is fixed.

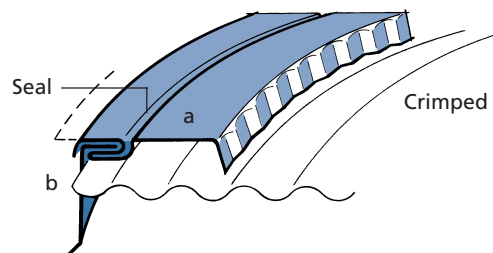
5.5.1 LOCKSEAMED FLASHINGS

All lock-seamed flashings should be custom-made to suit the profile shape and the rib distance from the fascia, with sufficient downturn on both sides to weather the junction. Lock-seamed flashings are made in two parts, the horizontal (part a) and the vertical (part b) and should be made from 0.55mm G300 steel or ductile aluminium or copper. (see *drawing 5.5.1.A and B*)

Edges can be either crimped or lockseamed as shown on the drawings.



Drawing 5.5.1.A 



Drawing 5.5.1.B 

A site pattern should be taken of the curve, (part b) to provide a template for the sheetmetal worker.

This shape is transferred to a segment of coil, plus an allowance for a jennied or turned edge on each side of the pattern, and the strip is then cut to this template.

After the flat strip with a lock-formed edge is formed (part a) and before it is curved to the prescribed radius, a flat strip of ductile metal should be inserted into the groove to provide a smooth and even curvature. On the opposite face, the turndown into the profile should be crimped with special tooling to the prescribed radius or, alternatively, the turndown edge should be minimised and the edge riveted and sealed to the roof cladding.

Part a and part b are then locked together. The joints are required to be internally sealed if the flashing is to be installed in an exposed area. Both the free edges should be stiffened by edge turning the bottom edge of part b outwards, in order that the fasteners do not distort the vertical face. Sufficient fixings should be used to provide a visually flat facing but they should be at no greater spacing than 600mm.

5.5.2 JENNIED FLASHINGS

Made in a similar manner but by an alternative method, the vertical barge component (part b) can be cut to the curve and edge seamed by a 'Jenny', with the horizontal component (part a) hooked and seamed together. (*see hand tools section 14.8.*)

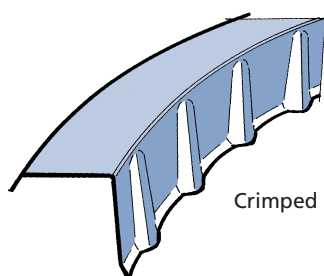
Shallow curved flashings can be folded straight in one piece and subsequently crimped on both edges.


The turn down at the curved rib can be neatly fixed by 'mini-crimping' or 'gear-crimping', and a limited amount of curving can be obtained by the use of the 'jenny' hand tool.

5.5.3 CRIMPED FLASHINGS

Crimped flashings are suitable for use on radii $> 2.000\text{m}$, with the crimp spaced and deformed at regularly spaced intervals. A flat strip should be placed on the template and crimped until the strip fits the template.

This type of flashing could be considered to be aesthetically unsuitable for domestic use because the distance from which the flashings are viewed is much reduced and the scrutiny more severe. (*see drawing 5.5.3A*)



Drawing 5.5.3A 

5.6 SEALANTS

Sealants play an important part in cladding, because AZ and organic coatings on metal roof and wall cladding cannot be sealed with solder.

The purpose of sealants used in the joints between metal roof and wall cladding and flashings is to prevent the entry of rain or snow and to exclude dirt, debris and moisture through:

- capillary action;
- end laps in flashings;
- side lapped joints between profiled sheets where the pitch of the roof is less than that permitted for the profile (curved roofs);
- end lapped joints between metal and plastic profiled sheets if the length of the roof cladding is less than the rafter length;
- side laps of plastic and metal roof cladding;
- any overlap that constitutes a joint designed to allow relative movement between flashings;
- penetration flashings where the back curb acts as a gutter;
- the passage of moisture vapour from within the building under the influence of vapour pressure differential;
- joints or outlets in spouting and gutters;

A sealant is the descriptive word used in this Code of Practice to describe polymeric sealants used in roof and wall cladding but which act in a different manner from other sealants used in the building industry. The main use for sealants in the building industry is to accommodate thermal movement in a building without any through fastening. Fasteners are always used in conjunction with sealants in the installation of roof and wall cladding because the sealant thickness sandwiched between two pieces of metal is insufficient to obtain the necessary shear strength for durability.

When sealants are designed to seal sheet components together a mechanical fastening such as a screw, rivet or a mechanical seam must also be used.

Although sealants are not adhesives they can act in this manner and their main purpose is to exclude moisture from joints or mating surfaces that would not drain and dry naturally.

Polymeric sealants are formulated to provide a continuous bonding layer to both opposing surfaces, to fill and seal a gap. They are cured either by polymerisation initiated by curing agents or by the evaporation of solvents. Polymeric sealants include natural rubber and synthetic elastomers of nitrile, neoprene, silicone and butyl generic types.

There are many sealants available and the designer and contractor should recognise that it is necessary to use the correct sealant, placed correctly, and in the correct manner to avoid corrosion.

The design of a penetration flashing or roof lap must not rely on sealants as the primary method of excluding the ingress of moisture. Joints must be designed to allow the discharge of water in the absence of any sealant and all sealants must be compatible with the metals being joined.

Only neutral curing silicone rubber sealants that are acetic acid free are suitable for, and compatible with all metals and organic finishes and possess the properties required for use with coated steel wall and roof cladding and flashing materials. Acetic cured silicone sealants can be used with stainless steel but are not suitable for zinc or zinc-aluminium coatings as the acid catalyst will attack metallic coatings.

Some silicone sealants have been modified to enable them to be painted, but most of these do not have the longevity of unmodified silicones, and they are unnecessary for most roofing work as the silicone is placed within the joint and is not exposed. When used in conjunction with mechanical fasteners the life of unmodified silicone sealants is expected to equal the life of the cladding because they are not exposed to UV radiation. Other cheaper types of sealants do not have the properties required for this longevity to be ensured.

5.6.1 PROPERTIES

The properties required of ideal sealants are;

- ease of application under construction conditions;
- adhesion;
- resistance to slump and creep;
- low resistance to compression;
- water repellency;
- minimal shrinkage;
- compatible with both surfaces;
- non-corrosive;
- flexible;
- water resistant;
- ultra-violet radiation resistant;
- heat resistant up to 80°C
- cold resistant down to -20°C
- mould resistant
- gap-filling
- no primer needed
- resistance to ageing
- resistance to weathering
- ability to accommodate shear movement in thin bands of sealant;
- ability to be fastened under compression, without creep;
- no maintenance required;
- long life expectancy (>20 years).

Sealants are also known as cold solder because they perform the same function on metals that cannot be soldered with a lead/tin solder.

All soldered or sealant sealed laps and seams must be mechanically fastened for strength.

The sealant does not require significant total adhesive strength, but it should bond positively to both opposing surfaces as a continuous layer and to ensure complete sealant cure, the width of sealant in a lap should not exceed 25mm when compressed

5.6.2 METHODS OF SEALING

There are three main methods of sealing metal sheets:

1. Gun applied sealants.
2. Self-adhesive tapes
3. Preformed sections

At low pitches, the watertightness of the overlapping sheets is dependent on the effectiveness of the lap seals to provide a continuous effective water barrier for the design life of the roof or wall cladding. Single lap vertical or angled ribs with a capillary groove do provide this barrier, but if this cannot be assured, such as with curved roof cladding below the recommended pitch, self-adhesive or foam lap tapes should be used.

Sealants should have a low resistance to compression so that metal sheets can be brought closely together by their fasteners and not held apart by the sealant. Compression should be able to be achieved with large variations (up to 4mm) in the gap thickness, for side laps, with long lengths of thin seals.

Any sealant used in end laps should be flexible and be able to accommodate large movements relative to the thickness.

Sealants must perform throughout the design life of the building at working temperatures without affecting the seal.

All tapes can be compressed by 20% and when this occurs, adhesion to both surfaces of the sheet lap is achieved. Foam tapes have a compression of about 30%, but can be subject to shrinkage.

As surface absorption and radiation result in metal sheets achieving much higher and lower temperatures than many other building materials, any sealant should have good resistance to large temperature variations.

The expected life of neutral cure silicone sealant is not known, however this material is the best available at the time of writing, and cheaper types are not expected to be as durable.

Butyl lap tapes are also an approved sealant for flashings when used with mechanical fasteners.

When lap tapes are used they should be 15-25mm wide and a minimum thickness of 1.6mm to provide a seal, but as thin as possible in order to provide a neat joint.

Mechanical fasteners should always be used in conjunction with gun-applied sealants or lap tapes.

Lap tapes are suitable for longitudinal laps, however they may not have sufficient flexibility to seal the pans of trapezoidal profiles, because the tape seals against the side of the rib preventing sufficient seal at the pan. Silicone sealants therefore are the recommended sealant for transverse laps.

5.6.3 SURFACE PREPARATION

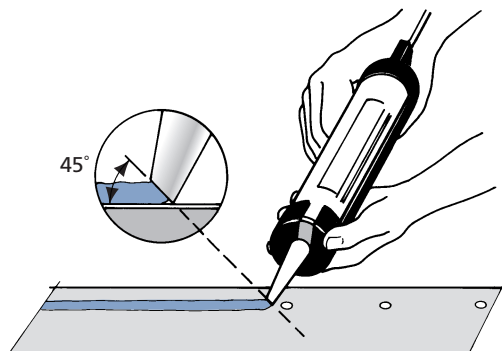
For adequate bonding, all surfaces must be clean, dry and free from contaminants such as rolling oils, dirt or dust. A detergent can be used to clean the surface, and it in turn must be wiped off with a clean damp cloth or sponge. Sealant must be applied within one hour from when the surface is first prepared and all surfaces to be bonded must be free from any strippable protective film.

5.6.4 SEALANT EXTRUSION AND PLACEMENT

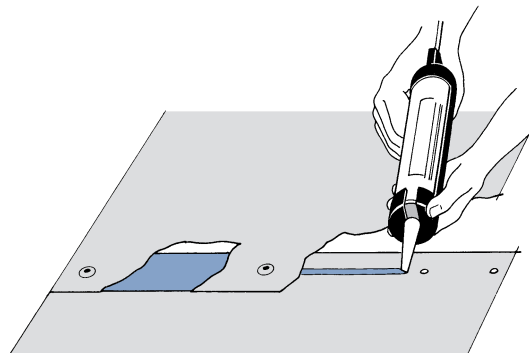
Sealant should be gun-applied in a continuous flow to provide a void free joint. This will prevent the entry of both condensation from above and water drawn up by capillary attraction, either of which can cause metal corrosion.

After placing the sealant cartridge in the gun, the tapered nozzle should be cut with a sharp knife at an angle of 45 degrees at a position which would provide a bead of sealant approximately 6 mm diameter. (see drawing 5.6.4.A)

Cartridges with removable nozzles, which screw on the end cap, need the end to be cut off prior to use.



Drawing 5.6.4.A 



Drawing 5.6.4.B 

Place the tip of the nozzle on the surface so as to provide a steady guide for a consistent void free run and extrude the sealant, adjusting the pressure and the speed of the nozzle across the surface to control the quantity. Only sufficient sealant should be used to seal the two mating surfaces.

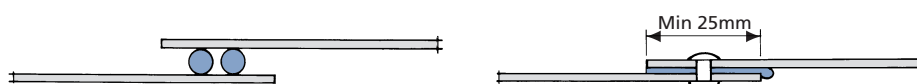
When a cartridge has been used previously, the sealant can cure inside the nozzle and form a plug, and this should be removed before further use.

5.6.4.1 SEALED LAPS

A sealed horizontal lap must be 25mm wide and completely filled with one 6mm or two 4mm sealant beads placed at the centre of the lap, covering any previously drilled rivet holes. (see drawing 5.6.4.1.)

The beads must be laid to avoid any air entrapment so that they cover the drilled fastener holes in a continuous line to ensure that the sealant under compression positively seals the fastener.

Sealed rivets are the preferred fastener. If normal blind rivets are used the stem hole must be sealed with silicone.



Drawing 5.6.4.1 

If a complete ring of sealant is placed around the fastener an air pocket forms which compresses during tightening of fasteners, and can blow a channel, thus preventing an effective seal.

The width of sealed laps should not exceed 25mm when compressed as this may prevent complete curing of the sealant. The lap should be sealed top and bottom or both ends if the transverse metal lap exceeds this dimension, as is usual with metal cladding.

The best method for lap fabrication is:

- Assemble and drill the components;
- Separate the components and remove any drilling swarf;
- Remove any strippable film;
- Clean the joint surfaces as described above;
- Apply a continuous sealant bead as described above;
- Relocate the components, align the holes and fasten;
- Externally seal the centre of all rivets;
- Remove surplus sealant.

When placing the overlapping sheet, care should be taken to avoid disturbing the sealant when fastening, however compression of the sealant is essential to achieve a satisfactory weather seal.

The correct placement and quantity of sealant is required to make the joint as any silicone outside of the joint is wasted and any clean up and squeeze-out removal will be minimised. Excess sealant extruded from the lap after fastening should be removed with a plastic spatula or purpose made plastic scoop as excess sealant collects dirt that causes corrosion and is unsightly. All surplus sealant should be cleaned off with detergent with a damp rag before it cures and the neatness of a sealed joint displays evidence of "good trade practice". Any sealant that can be seen is wasted sealant and as unmodified silicone sealants cannot be painted, when the time comes for repainting the roof cladding, this area cannot be protected.

The joint should be finished within five minutes after sealant extrusion to prevent premature curing causing poor bonding to the second surface.

Visible excess of sealant is not acceptable trade practice.

Sealants may cause eye irritation and if eyes become contaminated, flush immediately with water and obtain medical attention if the irritation persists.

Sealant must not be applied after the joint has been made and the joint must be left clean. The life of any sealant is compromised if it is submerged, and the design of any joint must ensure that this does not occur.

Transverse roof and horizontal wall sealed laps must encapsulate the cut edges of coated steel roof and wall cladding when using both silicone and butyl strip sealants.

5.6.5 STRIP SEALANTS

Solid sealants in tape form are generally semi-cured butyl rubber possessing positive initial adhesion to both opposing surfaces and as with all other sealants used with flashings, they should be used in combination with mechanical fasteners. The cladding thickness will determine distance between fasteners to obtain a seal.

For the tape to make positive contact with both surfaces and form a seal, it is important that the tapes initial thickness is greater than the gap between the components of the finished joint.

Soft grades are needed if joints are to be pulled together without bulging of the sheet between fasteners, and some types may be difficult to compress within a joint during cold weather.

All preformed strip sealants require compression after installation by fastening to ensure contact and adhesion to the joint faces.

Sealed side laps for roof and wall cladding must be fastened at maximum centres of 600mm.

Preformed sealant strip has a release backing paper attached while being applied in order to avoid placing the sealant under tension that could cause a reduction in cross-section and the elastic memory of the sealant which can cause shrinkage and discontinuity. The strip should be applied without removal of the backing, with the paper side uppermost and the paper removed immediately prior to the other component being placed in position.

Cellular foam strip produced from EPDM, PVC or other plastics in a range of sections and densities require from about 25% to 50% compression to achieve a seal.

Installation requirements for solid tapes apply equally to foam strip sealants.

5.6.6 SOLDERED JOINTS

Lapped joints used with galvanised steel and non-ferrous metals (excluding aluminium) can be soldered with lead/tin solder. The joint should be clean, free of grease and should be fluxed immediately after cleaning with a suitable proprietary, or the following fluxes.

GALVANISED STEEL	Diluted hydrochloric acid (HCl Spirits of Salts) Muriatic Acid (a 1:3 dilution of HCl)
ZINC/COPPER/BRASS	Zinc Chloride Hcl killed with zinc (Killed Spirits)
STAINLESS STEEL	Phosphoric Acid.

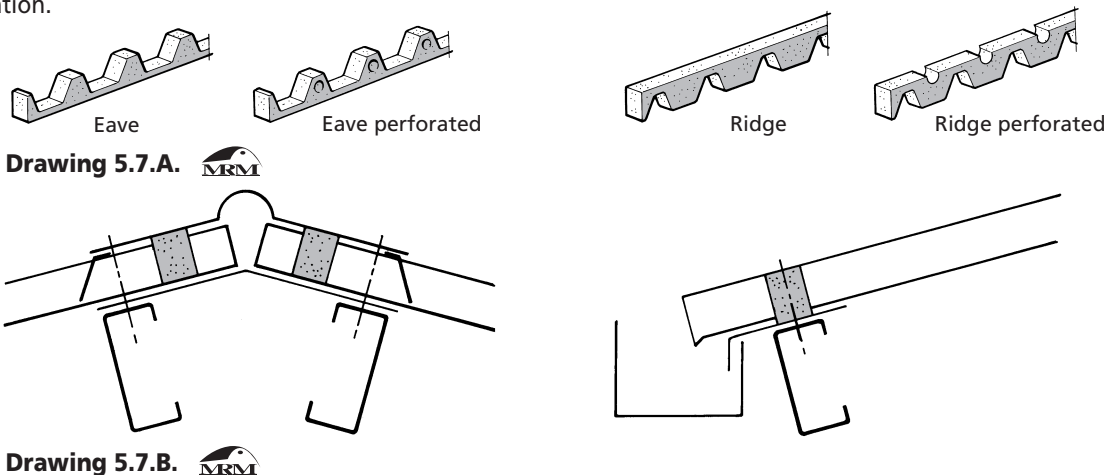
The joint should be made with mechanical fasteners at 50mm centres using rivets, screws and lapped 25mm in the direction of water flow. A locked seam does not have to be mechanically fastened.

The joint should be completely sweated to avoid leaving any flux residue in the joint preferably using a eutectic solder of 60% Tin /40% Lead. (see 14.3.) After completion the joint should be thoroughly washed with water to remove all traces of flux.

5.7 PROFILE CLOSURES

Profile closures, also referred to as filler blocks or profile foam fillers, are accessories capable of being compressed for retention and providing a means of closing the rib or pan cavities at ridge, where they are inserted between the roof cladding and ridging or flashing. (see drawing 5.7.B)

When profile closures are used at the eave they should be a closed cell and a vented or perforated type to allow some ventilation.



Filler blocks exclude wind, rain, snow, wind driven debris, insects, rodents and birds, however bird damage to the closures caused by pecking or other vermin damage can be minimised by using scribed metal flashings or caps in lieu of, or to cover the foam fillers. Filler blocks can be adhered to metal profiles prior to or after fixing very simply by the use of a spray contact adhesive or heat resistant double sided tape.

Closures are manufactured from closed cell plastic infill strips to match most metal and plastic cladding profiles, and are available in most profiles in 'over and under' configurations.

Closures should be used as a wind baffle and should not be used as a prime source of preventing water entering a gap, as the retained moisture will cause corrosion.

They should be used compressed between the sheets and supports or flashing, and be fastened or adhered to the cladding by tape or adhesive to avoid falling out or rolling over. They should be used on all roof pitches below 10° when the wind design load is high or very high. Absorbent filler strips should not be used as the retention of moisture will cause corrosion.

Closures should be placed midway in the cover gap between the stopend and the front of the flashing which avoids water ingress by providing an air gap baffle to reduce the pressure differential.

Although greater durability can be expected minimum durability is estimated to be 15 years for products made of closed cell cross-linked polyethylene, to 20 years for closed cell EPDM, which also has good UV resistance and nil water absorption.

5.7.1 VENTED FILLERS

To comply with the durability provisions of the NZBC, passive ventilation of metal cladding profiles at the eave is necessary for the removal of condensation or moisture. Perforated metal or mesh closures can be used, or the profile closure should be cut back, punched or notched to allow air movement or the closures should be omitted altogether. (see drawing 5.7.A.) In order for the breather underlay to fulfil its intended function of conveying any condensate from the roof cladding to the gutter, the closures should either be fitted in such a way that moisture can drain to the gutter unimpeded or they should be omitted.

When closures are fitted between ridging and sheeting, the ends should be butt-jointed over the profile crowns, to minimize the entry of wind-blown rain and for the same reason, ventilated ridge closures should be fitted with their openings uppermost.

Closures should be set back by a minimum of 50mm to discourage attention from birds, although the ingress of birds can also be prevented by screw fastening every rib of profiled metal cladding at the first purlin.

5.7.2 METAL CLOSURES

To prevent the ingress of weather, dirt, birds etc. it is necessary to close off the ribs or corrugations of profiled sheets using scribed metal flashings. In extreme environments they can be used in conjunction with or without plastic closed cell closures to match the profile.

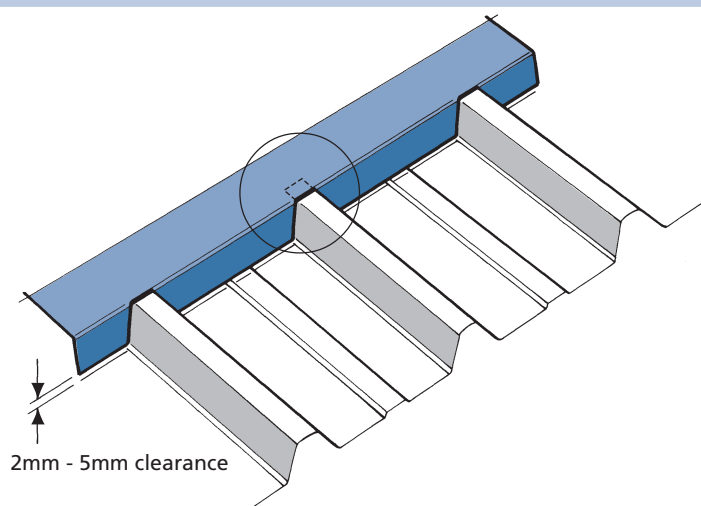
Proprietary soft edging is available but is only aesthetically acceptable for corrugate and low trapezoidal profiles. Where the profile height exceeds 30mm, cutting and notching by machine or hand snips is the preferred option.

All soft and scribed edges should have clearance to avoid the retention of dirt and moisture.

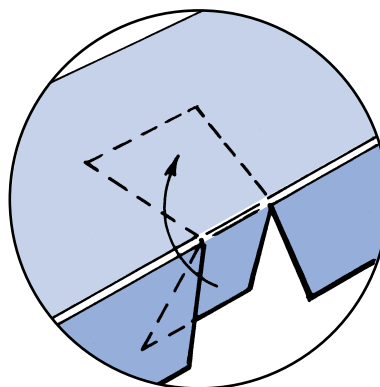
Ridging and flashings edged with a soft aluminium or zinc strip seamed together, provide a means of closing the voids for Pre-coated and Zinc/Aluminium coated roof and wall cladding. All soft edged flashings should be primed and colour painted before installation, but the preferred option is for the paint finish on soft edges to be factory painted under controlled conditions.

An AZ coating should not touch the pan or tray of the roof sheeting because the retained moisture will promote edge corrosion.

The scribed metal edge of any flashing must have a clearance of 2mm to 5mm.



Drawing 5.7.2 



Scribed edge can be turned under at rib

5.8 RIDGE VENTS

Permanent ventilation of the roof cavity may be achieved by using accessories such as gable louvre ventilators, purpose-made ventilators, wind or powered extractors or by the use of a ridge ventilator.

The need for roof cavity ventilation is explained in **section 4.6. ventilation**.

Continuous ridge vents used in conjunction with eave inlets, provide the necessary air movement to avoid the accumulation of condensation, and also provide an efficient means of preventing roof expansion noise caused by heat build-up. To be fully efficient, when a temperature differential exists and there is a little wind, the inlet area should equal the outlet area. When wind pressures dominate, the efficiency is dependent on the wind direction because when the wind is at 90° to the ridge there is a positive pressure on the windward side and a negative pressure on the leeward side. In very exposed areas, high winds may cause excessive air movement, in which case control louvres are used to block or lessen the air movement.

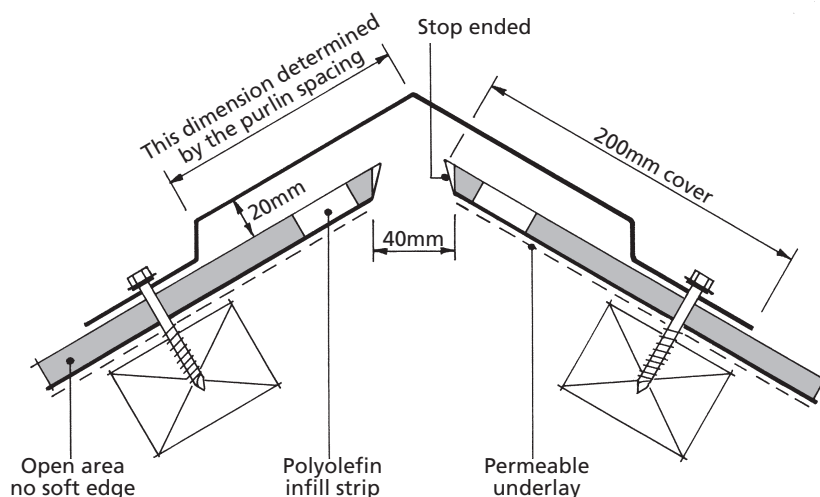
The steeper the pitch, the greater the stack effect and the better the air flow.

Although a good design will not allow water penetration, at times of high humidity associated with mist or fog, when ridge ventilators are subjected to negative pressures, saturated water vapour can enter the building, which then condenses on the structural framework and can appear as a leak.

On a summer day, with no wind, warm air in the ceiling cavity rises, creating a 'stack' or thermo-siphon effect causing an area of positive pressure at the ridge and negative pressure at the soffit. Outside air is then sucked through the soffits, and warm attic air is drawn out of the ridge vents. Air tight buildings will inhibit this air movement.

On a winter day, with no wind, a small amount of warm air can escape through the walls and ceiling into the ceiling cavity, even in a well-insulated attic. This is sufficient to create a minor thermo-siphon effect, which can cause outside air to be drawn into the attic through the soffits and moves moisture-laden air through the ridge vents.

Ridge vents provide an air flow along the underside of the roof cladding, keeping the cladding temperature close to the outside air temperature, and this amount of ventilation minimises condensation.

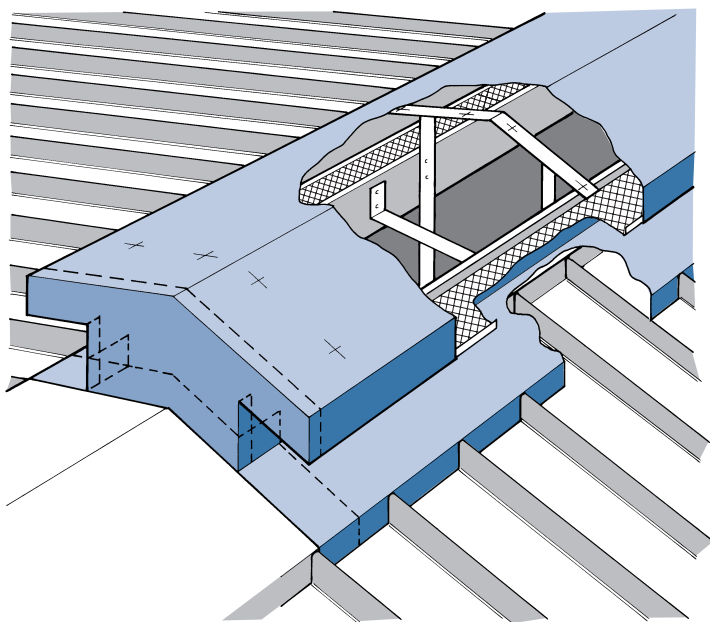


Drawing 5.8.A 

Ridge vents should always be installed with soffit vents, because if a ridge vent is installed alone, part of it would serve as an inlet because of pressure differences at various points along the ridge. This could cause weather infiltration and confine air flow to the top of the attic. A ridge vent is a large flashing and therefore should comply with all of the requirements of this Code of Practice for ridgings and flashings.

Care should be taken when installing ceiling insulation that soffit vents are not blocked off. The bird mesh or louvres on the underside of a ridgevent are in an unwashed area. They can also be subject to fumes from within the building and should be made from non-ferrous and compatible materials that will comply with the durability requirements of the NZBC. Ridge vents should not be used on a pitch of less than 10°.

Some continuous ridge vents can be considered as fire vents.



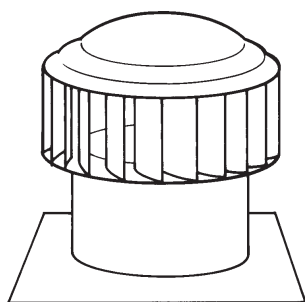
Drawing 5.8.B 

5.8.1 VENTILATING RIDGING.

Ventilating ridging, if not designed and installed correctly, can give rise to leakage in stormy conditions.

One type of ridging suitable for domestic buildings that can be adjusted for cover to suit the exposure conditions is shown in drawing 5.8.A. Ventilated ridging is useful where skillion roofs are used but should have soffit louvre vents or similar. (see 4.6.)

Alternatively for commercial and industrial use, wind operated turbine vents can be installed at the ridge and simply back-flashed as shown (see 4.6.2. and 4.6.3.).



Drawing 5.8.1. 

6.0 PENETRATIONS

A penetration is any hole cut in roof or wall cladding, where projections such as pipes, ducts, chimneys, doors and windows pass through roof and wall cladding. The type of penetration design is determined by how large the hole is, what shape it is, the pitch and type of the roof, the catchment area, where it is situated on the roof and how it matches or otherwise with the module of the cladding.

Designers are urged to provide for multiple penetrations such as air-conditioning ducts, by using a separate plant room that is not only the most weathertight method, but also the most economical one.

All penetrations must be made watertight by the use of flashings.

Where more than one rib of profiled cladding is removed, additional structural members must be provided to support the roof cladding.

For large penetrations, the supporting framework should be in position before the roof cladding is fixed, or alternatively if the position of the penetration can be adjusted to suit the profile, the supporting framework should be in position before the hole is cut in the cladding.

Small vent pipes and ducts less than 150mm do not require additional structural members, unless more than one rib is removed.

6.1.1 RESPONSIBILITY

The designer must provide details for the additional support required in the drawings for all penetrations greater than 600mm x 600mm. The weight of any penetration such as an air conditioning unit, or plant platform, must not be imposed on the roof cladding without additional support.

The removal of structural members must not occur without written permission supported by engineering calculation.

The person who cuts the hole in the roof must be responsible to ensure that sufficient additional support is provided for the roof cladding and the penetration flashing.

All holes greater than 300mm x 300mm cut in roof cladding must have additional structural support.

The person who cuts a hole greater than 600mm x 600mm in the roof is responsible to ensure that safety precautions are taken to prevent falling through a hole of this dimension as it is regarded as a hazard under the Health and Safety in Employment Act. Safety mesh complies with this requirement.

Once a hole is cut in self-supporting metal cladding, the continuity provided by the sheeting is destroyed and the ends of the sheeting should then be regarded as simply supported, or as end spans. (*see section 3.1.3. continuity*)

The end spans should also be reduced to a minimum of 2/3rds of the intermediate span to perform as specified for point load or U.D.L. To fix the roof cladding the end spans require additional fixing support upside and downside of the penetration.

When cutting a hole in a sprung curved roof, to overcome the tension induced in the cladding, additional fixings should be used to hold the roof cladding into position at the front and back of the penetration.

Often, the responsibility of the roofing contractor does not include the installation of the over-flashings or the weathering of the unit within the penetration; however it is his responsibility to inform those persons who are concerned, of the likelihood of deterioration from runoff if inappropriate materials are used.

It is also the responsibility of the roofing contractor to ensure that for all the work covered in his contract, the correct selection of materials, good design, and good installation practice is provided, as any warranty can be voided by poor design or workmanship.

Any roof warranty of penetration flashings may be voided if they are installed by other trades, or not in accordance with the requirements of the manufacturers warranty or this Code of Practice. Roof damage by other trades may also void any warranty. It is strongly recommended that designers include all roof penetrations within the scope of work of the Roofing contractor.

6.1.2 DURABILITY

The back curb of penetration flashings manufactured from metallic coated steel and which have no fall, will collect dirt and debris. Due to the presence of continued moisture, the subsequent ponding can cause deterioration and premature corrosion and affect the durability of the back curb. This design of flashing when manufactured from metallic coated steel, is not covered by any manufacturers warranty, therefore a diverter or cricket design with a back curb and a minimum fall of 1.5° should be used.

When the penetration design provides for the minimum fall and is maintained as described in **section 13.0.** of this Code of Practice, the penetration is covered by the normal manufacturers warranty.

The designer and the roofing contractor should satisfy themselves that the methods and materials used will satisfy the durability requirements of the NZBC. The specifier and contractor should follow precisely any manufacturers specific installation requirements, any certification or appraisal conditions, and this Code of Practice in order to comply with the NZBC. The durability compliance will only be met if the maintenance requirements of this Code of Practice are also followed.

Notwithstanding that the designer may have failed to detail explicitly what is required, the responsibility remains with the contractor, who has a duty of care to fulfil the requirements of the NZBC and this Code of Practice, unless written agreement has been made to the contrary.

6.1.3 CORROSION

Designers and tradespeople involved in installation of penetration flashings should have an understanding of the mechanism of the corrosion process to comply with the requirements of this section of the Code of Practice. **(see corrosion section 2.4)**

Corrosion is defined as the reaction of a material with its environment resulting in measurable alteration, which may impair the performance of a component or an entire system. Corrosion can result from direct contact with another metal or substance, or as the result of run-off, fall-out or poor design or installation such as would allow ponding. In some cases one metal alone can corrode without these conditions when either exposed to, or denied contact with, oxygen.

All fittings, such as fans, fitted above a penetration flashing, must be made from compatible materials and there must be no run off onto penetration flashings from incompatible materials.

Condensate from air conditioning units must not be discharged onto metal roof cladding but must be separately drained to an inert gutter or downpipe.

Where the roofing contract does not include the overflashing or installation of the cowlings of a penetration, the designer and the installer assumes the responsibility to comply with this Code of Practice, as the roofing contractor is not responsible for the work of others.

6.1.4 CATCHMENT

The profile capacity, the roof pitch, the catchment area and the ARI should all be considered to ensure that the catchment area behind the penetration can be drained without flooding.

The water flow can be restricted by the penetration side flashing up to 50% of the normal pan width only if the:

- design rainfall is no greater than 100mm/hr,
- sheeting length is less than 40m
- catchment is less than 20m²
- profile is asymmetrical
- pan is at least 100 mm wide

Symmetrical sinusoidal and symmetrical trapezoidal profiles must have full pan width for free discharge. (see *profile capacity section 8.2.3*)

When the total catchment area exceeds 40m² the discharge must be spread over two or more pans to provide for additional drainage. When the catchment area includes the walls of adjacent buildings it must be calculated as in *section 8.2.1*.

In snow zones more than 500m above sea level, only full pan width discharge must be used.

A diverter or cricket penetration design should be used when:

- the width of the penetration exceeds 600mm
- the catchment is greater than 40m²
- where there is a likelihood of snow

As rain flows faster on steeper pitches and will discharge at a greater speed, the capacity at the discharge area is determined by the roof pitch as well as the capacity of the pans, the height of the profile, and the catchment area.

Penetrations ideally should line up with the ribs of the sheeting, however as this does not often occur, the module of the roof cladding determines the width of the penetration.

The symmetrical profiles normally used on draped curved buildings to avoid panning, do not have sufficient rain carrying capacity to include large penetrations, and consequently the discharge should be shared over a number of corrugations or pans on a curved roof.

All metal roofs in N.Z. are required to have a minimum fall of 3°, and this is not possible when using a drape curve design.

No penetration must be made in the pitch area between 0° and 3° for trapezoidal or 8° for corrugate profiles on a curved roof.

6.1.5 OBSTRUCTION

A roof or wall penetration such as a dormer or a vent acts as an obstruction to the rainwater flowing off the roof.

The back and side curbs of a penetration flashing act as a gutter draining the catchment behind the obstruction which often discharges onto the roof into one corrugation or pan of a profiled sheet.

The position, orientation and the type of penetration design, as well as the roof pitch will determine the extent of the obstruction to the free flow of rainwater. A cricket penetration design will shed rainwater more efficiently than a flat back curb because it will reduce turbulence. (see *cricket penetration design section 15.8*.) The water carrying capacity of the roof cladding profile becomes critical when the penetration is wide or is distanced from the ridge. For this reason rectangular penetrations should be placed lengthwise or at 45° down the roof and a second penetration

should not be placed in tandem down the roof slope as this can cause flooding of the profile at the lower penetration. Where the use of metal cladding is unsuitable for multi-penetrations alternative materials should be considered. (see *alternative materials section 6.1.8.*)

Designers and roofing contractors often assume that one corrugation is sufficient to drain the catchment without making the calculations necessary to know if this assumption is correct. The discharge capacity of the profile should be calculated as section 6.1.6.

6.1.6 DISCHARGE CAPACITY

The back and side curbs of roof penetrations must be regarded as internal gutters and therefore must be designed with the same parameters as gutters.

As the catchment area above any penetration concentrates the runoff from above it, the design should allow for turbulence at the discharge exit and for the extra capacity required. The extra capacity required is interdependent on the catchment area, the profile and rainfall, and can require the discharge to be spread over two or more pans.

Corrugate and symmetrical trapezoidal profiles do not have the rainfall carrying capacity of those with wider pans or deeper profiles. To determine if one pan or corrugate valley discharge is adequate for the rainfall the catchment area behind the penetration should be calculated as per table 6.1.6.

Similarly, assymetrical trapezoidal sections may require the discharge to be spread over more than one pan.

Where it is necessary to increase the penetration outlet to more than one pan of a trapezoidal profile, the side curbs can be tapered from the pan to the height of the rib as shown on *drawing 6.1.6. A & B*

When a penetration 1m wide is situated at the bottom of the catchment area and the design rainfall intensity is over 100mm/hr, the discharge capacity of one pan or corrugation per side must be limited as per table 6.1.6.

Profile	Pitch	Max. catchment
Corrugate	8°	5m ²
Symmetrical trapezoidal	4°	10m ²
5 & 6 rib trapezoidal or tray	3°	20m ²

TABLE 6.1.6.

Table 6.1.6. is based on equal discharge on each side of the penetration and if the catchment area exceeds that given in table 6.1.6. the discharge must be spread over two or more corrugations or pans on each side. The maximum catchment area shown in table 6.1.6. must be adjusted proportionately if:

- the design rainfall is greater or less than 100mm/hr,
- the penetration is more or less than 1m wide,

The discharge capacity is limited by the capacity of one side of the penetration flashing (half the total catchment). e.g. The maximum catchment area for a penetration 1.000m wide using corrugate is 10m².

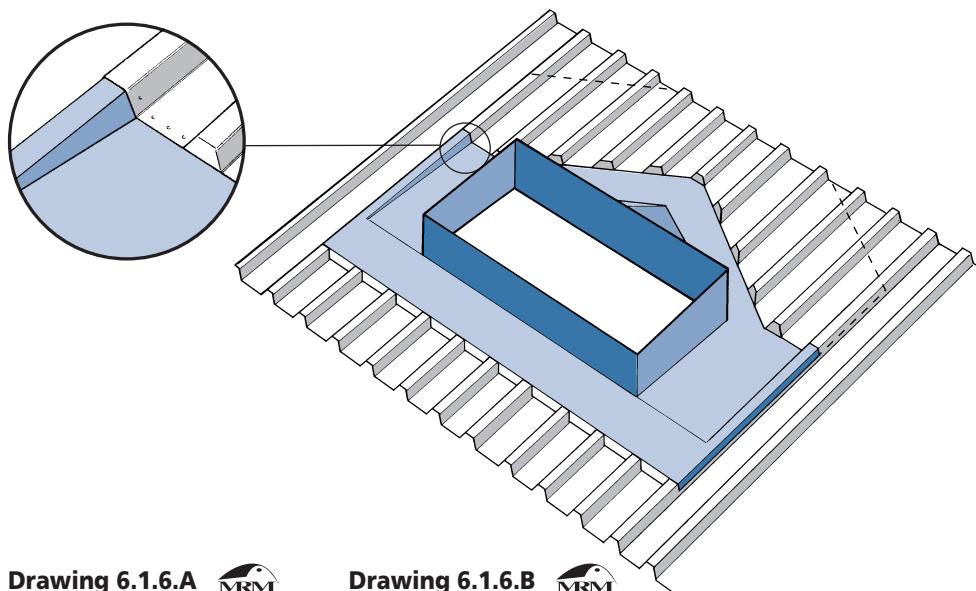
Example: The maximum catchment area for a penetration 1.200m wide using symmetrical trapezoidal when the rainfall is 140mm/hr

$$= 10\text{m}^2 \times \frac{1}{1.2} \times \frac{100}{140} = 5.95\text{m}^2 \text{ on one side}$$

$$= 6\text{m}^2 \times 2$$

Total maximum catchment behind the penetration = 12m²

If the catchment area is greater then the discharge is spread over two or more pans as shown in drawing 6.1.6.B.

Drawing 6.1.6.A Drawing 6.1.6.B 

The pitch of the side curb of the penetration flashing shown in drawing 6.1.6. is dependent on the pitch of the roof and the height of the rib, however it can be reduced to 1.5° as allowed for a cricket back curb.

6.1.7 SEALING

Although the design principles are the same for all metals, the method of sealing penetration flashings depends on the metals being used. Galvanised steel, zinc and copper can be soft soldered, however because aluminium, unpainted and painted Z and AZ coatings cannot be soldered, the acceptable method of sealing is either a neutral cure silicone sealant or a butyl sealing tape.

These sealants should only be used in conjunction with mechanical fasteners.

The penetration flashing should be made weathertight without relying on sealants as a first line of defence against water ingress. When a sealant is used to prevent the accumulation of dirt in the joint, the excess sealant extruded from the lap should be removed by a plastic spatula or purpose made plastic scoop because excess sealant not only collects dirt which can cause corrosion but is unsightly.

Sealant should always be used in conjunction with mechanical fastening and be applied between the two sheets to be lapped before they are fixed together. To apply the sealant after the joint has been made is not acceptable. (see *sealants section 5.6*)

6.1.8 ALTERNATIVE MATERIALS

Where the use of sheet metal is not the most pragmatic method to flash a penetration, alternative materials can be used providing that they are compatible and comply with the design requirements and conditions outlined in this Code.

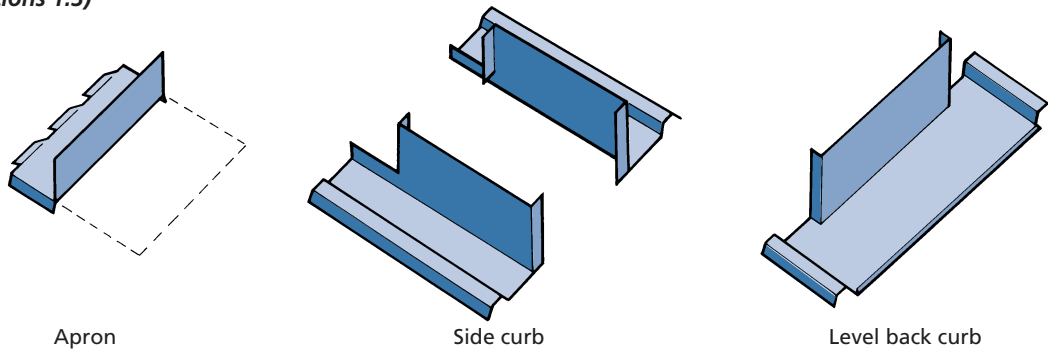
The preferred alternative material is butyl rubber installed on a substrate and in accordance with the recommended roofing standards for that material. The fully supported deck will provide access for maintenance to the penetrations which otherwise could damage metal roofing unless special precautions are taken. It can be used to install multiple penetrations in tandem and is also suitable for retrofitting penetrations in an existing metal roof.

The provisions of section 6.1.2. (obstructions), and the discharge capacity outlined in section 6.1.6. should be complied with.

6.2 PENETRATION DESIGN

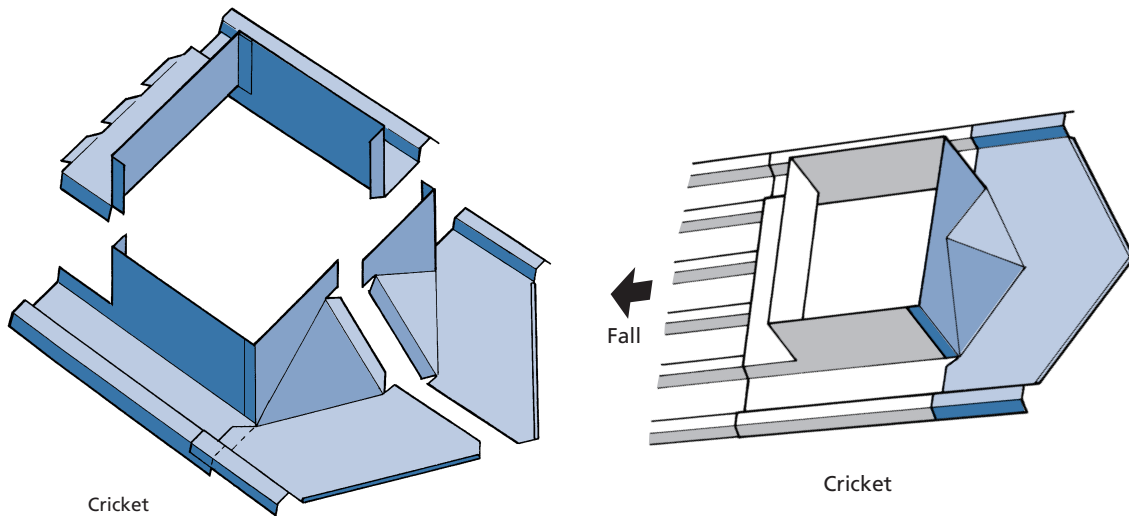
6.2.1 NOMENCLATURE.

The nomenclature used in describing penetration flashings may differ in different parts of New Zealand: (refer to definitions 1.3)

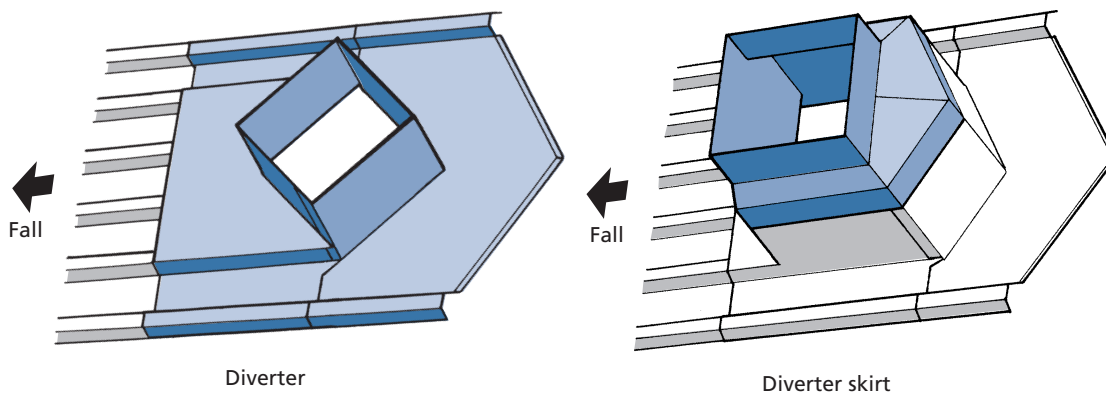


Drawing 6.2.1.A 

This detail is suitable for penetrations up to 600mm wide.



Drawing 6.2.1.B 



Drawing 6.2.1.C 

Level back curbs are acceptable only as penetration flashings when they are lapped and installed without ponding.

In practice this is very difficult to achieve and diverter and cricket designs should be used where the width of the penetration is > 600mm or where the pitch is < 10°.

The intention of cricket and diverter flashing designs is to provide a minimum fall of 1 1/2° to provide a self-cleansing action of rainwater at the back curb of the penetration. This action will be greater as the pitch of the roof increases but the designs are suitable for minimal fall roofs as described.

The back curb and the cladding can be cut at an angle, but roof fasteners should not penetrate the back curb flashing.

Roof underlay should lap the back curb by a minimum of 50mm.

Penetration flashings must:

- have back and side curbs 50mm higher than the cladding profile,
- have side and back curbs with a minimum height of 100mm except where the penetration is wider than 600mm or the catchment area exceeds 20m², when the height must be increased by the height of the profile rib.
- not restrict maximum likely water flow;
- be at least as durable as the roof cladding;
- not rely solely on sealant for the prevention of water ingress;
- have a fall to avoid ponding and debris build-up.
- have a back curb minimum lap of 150mm under the cladding unless it is sealed.
- have a minimum 100mm clearance between the end of the sheeting upside of the penetration and the back curb upstand.
- have no fasteners that penetrate the back curb
- have primary fastening to the structure

Where a penetration is used on a trapezoidal ribbed roof, the ribs upside of the penetration should be closed by folding, cutting and fastening, or with end caps, or by the use of plastic closed cell filler strips formed to match the profile.

The ends of the ribs should be closed but not sealed in order to allow ventilation and to disperse any condensation draining into this space. Building underlay should overlay the flashing so as to be able to drain condensation, because water ingress at the penetration caused by condensation is often attributed to a leaking flashing.

The end of the sheets on the downside of the penetration should be stopended vertically to the full height of the rib using a pull-up stopend, or if the position is exposed or in a high wind area, the ribs should be cut and the pans dog-eared or foam closures used. **(see section 7.1.3. stopends)**

In an exposed or high wind area it is necessary to provide a further wind barrier by using closed cell filler blocks to reduce the pressure differential in this cavity.

The design of a penetration flashing must not rely on sealant alone and must ensure that the lap is sufficient to shed water naturally.

The overflashing skirt or apron should overlap the curb by a minimum of 50mm and have a stiffened edge, and is not normally fixed to the side curb. If the site exposure or the size of the skirt necessitates fixing to the side curb, then the fixings should provide for expansion as well as for the vibration that occurs on penetrations venting fans or other dynamic equipment.

All side curb flashings should be made from one piece, having an upstand the same height as the back curb, and a side lap that overlaps the sheets.

The side curb can be cranked or splayed in order to preserve the penetration hole size or the skirt can be cranked or splayed to match the profile module. (see drawing 6.2.7.H.)

6.2.2 DIVERTER OR CRICKET DESIGNS

A cricket metal roof penetration flashing is designed and constructed to divert water around a penetration and to avoid ponding. Either a diverter or a cricket flashing design is required to avoid the build-up of debris behind the back curb of a square or rectangular penetration flashing with the minimum fall accepted as being self-cleansing as being 1.5°, and comply with any manufacturers warranty. If the roof pitch is at the minimum 3°, it is necessary that this be increased, if the minimum 1.5° fall is to be provided to the back curb. The amount of increase will depend on which angle of cricket or diverter flashing is used. (see section 15.8.)

The pitch of a valley, diverter or cricket flashing will always be less than the roof pitch, but the valley pitch is dependent on the angle of the valley to the roof. (see section 8.4.5.)

6.2.3 INSTALLATION

All penetration flashings should have all around clearance so that vibration, wind or expansion does not induce any stress or noise at the juncture of the roof, and if the penetration flashings are fixed positively to the roof, they should be considered part of it, and therefore expansion allowance should be provided. A 10mm minimum clearance allowance should be made for movement between the flashing upstand and the penetration structure.

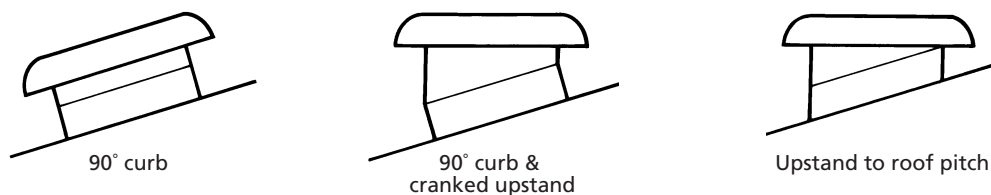
A minimum of 100mm clearance must be provided between the end of the sheeting upside of the penetration and the back curb upstand, to provide for any temporary obstruction or abnormal runoff. The back curb must be sufficient in depth to provide 150mm roofing cover and roofing fasteners must not penetrate this flashing.

All back curbs should pass the 'tennis ball test', which requires the free passage of a tennis ball down the roof, past the penetration. N.B. Back curbs without fall will not pass this test.

Roof underlay should lap the back curb by 50mm.

When several penetrations are in tandem or close proximity and it is considered that an alternative design is appropriate, another material such as membrane roofing can be used. Such materials should be compatible with the metal cladding and be designed with the same parameters as for metal penetrations as described in this Code. (see 6.1.8.)

It is usual with low pitch roofs to fold the back and side curbs and the front apron at 90° to the roof, which means that if the unit within the penetration is required to be vertical, then a transition is required, or the front and back curbs should be folded to suit the roof pitch. (see drawing 6.2.3.)



Drawing 6.2.3. 

There are two conditions under which a different design of penetration flashing may have to be considered.

- when it is provided in conjunction with the laying of the roof;
- when it is provided as a retrofit.

It is accepted practice when roofing large commercial or industrial buildings that the roof cladding will be laid over the openings for any intended penetrations, which means that timber or other support should not extend above the purlin line at the time of laying.

The penetration design must be determined before the roof cladding is installed temporarily over the opening and the extra purlin support for the cladding must be in position before roof cladding work commences.

This technique has the advantage that not only does it close in the building quickly, but it also provides safety for workers, when penetration openings are regarded as a safety hazard. The preferred method is to order longer sheets so that they may be lapped at the penetration.

There are two positional variations that can affect the type of design of the flashings used to weather any penetration. All other positions on the roof require soaker flashings Type A. (*see section 6.2.6.*)

Details of these flashings are:

1. When the opening falls between the ridge purlin and the penultimate or next purlin down the roof, a back flashing, known as a watershed, can be run up to the ridge for weathering, as shown in *drawing 6.2.8.A*
2. When the opening falls between the gutter purlin and the penultimate or next purlin up the roof, a flat tray under-flashing known as a soaker can be used to drain directly into the gutter, as shown in *drawing 6.2.7.I.*

6.2.4 LAPS

There are two main types of penetration laps described as under:

Type A:

This lap is the normal type of roof cladding flashing overlap, which is not necessarily mating or sealed, and has a minimum cover of 150mm. It can be an under or overlap, however an under-lap on a flat sheet requires a flattened hem or hook. Sealing is required if the lap is exposed to the wind, or if the pitch is below 10° or in a very high design wind zone.

Level back curbs without fall can be sealed if snow or ice are to be expected, except that 45° diverter or cricket flashings do not require to be sealed. Snow and hail do not cause leaks as it is only when they melt and water egress is blocked that leakage can occur.

Type B:

This type of lap is completely filled with sealant, is a minimum of 25mm wide is used with mating surfaces and is mechanically fastened using 4.0mm sealed rivets at minimum centres of 50mm. As all laps are required to be self-cleansing, they should be made in the horizontal plane, i.e. across the roof. If sheets or flashings require to be lapped vertically, i.e. down the roof, they also should be angled to be self-cleansing or lap in the vertical plane. (*see flashing laps section 5.2.1.*)

Because of the many permutations of roof pitch and penetration width, it is not possible to provide a universal design or pattern for penetrations. It is however possible to provide a pattern for cricket flashings and acceptable angles for diverter flashings using the same methodology by following the procedure as described in *section 15.8.*

6.2.5 DETAILS

The penetration details drawn in this Code of Practice have been endorsed by the New Zealand Metal Roofing Manufacturers Incorporated (NZMRM Inc) and the Roofing Association of New Zealand (RANZ), as being acceptable trade practice. The designs are conservative because the most unfavourable circumstances have been assumed; i.e. minimum pitch, ribs not aligning with the penetration, and maximum rainfall.

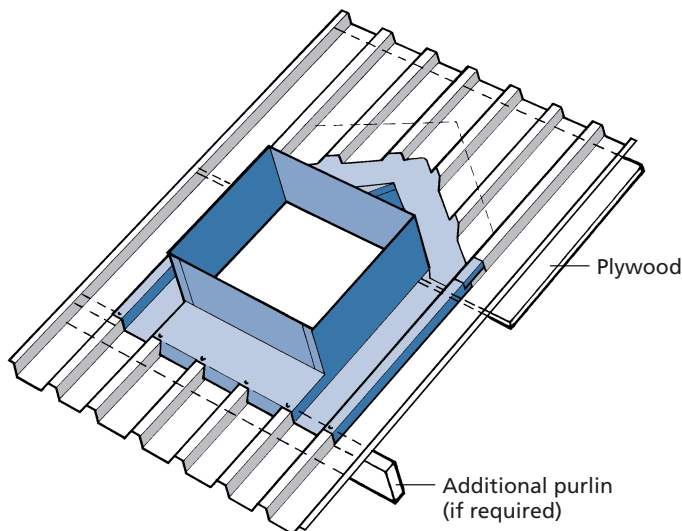
The techniques used and the details drawn can be used in most circumstances, and also be combined in various ways. There are many types of acceptable penetration flashing designs, however some are only suitable where the roof pitch is greater than the minimum recommended for the particular profile.

Some are acceptable practice only and the preferred method is recommended.

All penetration flashing details should be planned and on site improvised solutions are not acceptable. Where the skill of the roofing contractor does not extend to sheet metal work, other persons possessing those skills should be used for the design and manufacture of such penetration flashings.

All penetrations over 300mm wide require additional structural support to be provided either by additional purlins or plywood with a minimum thickness of 12mm. H3 treated plywood should be securely fastened to the structure and provide not only support for the flashings and sheeting, but is required for additional fixing.

The penetration flashing must be separated by a water resistant underlay.



Drawing 6.2.5. 

6.2.6 TYPES OF PENETRATION FLASHING DESIGN.

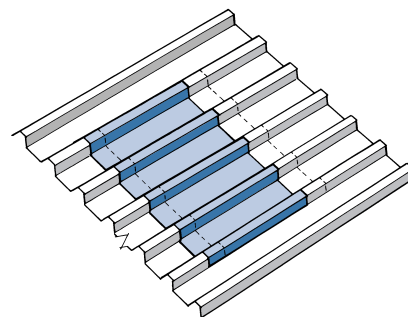
Penetration flashings can be divided into four different types.

Type A

Underflashings are those that drain at the plane of the roof pan.

Soaker (under) flashings

- Suitable for all pitches;
- The preferred detail;
- Make the side curb in line with the rib;
- Leave minimum all around clearance of 10mm;
- All upstands minimum of 100mm;
- Drill for rivets before sealing;
- Sealed laps must be minimum 25mm;
- Order cladding sheets longer for lapping;



Type A Under soaker

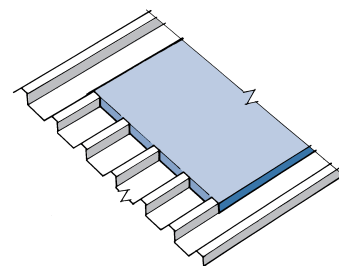
Type B

Overflashings are those that drain at the plane of the rib of the roof.

These are also known as Watershed or back flashings.

Watershed flashings (over or back)

- Simple
- Recommended to first purlin from the ridge if > 300mm wide.
- Not suitable if over 1.100m wide
- Not universally accepted aesthetically
- Can be used in conjunction with sprung or over-roof design.



Type B Over watershed

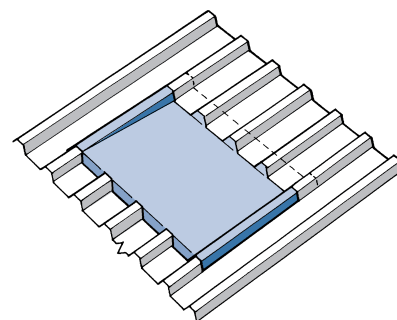
Type C

Tapered flashings that drain at the plane of the roof pan at the top, and over the ribs at the bottom.

These are also known as 'under/over' or transition flashings.

Tapered or transition flashings

- Provides greater run-off capacity
- Suitable for all roofs > 5°.
- Used for a retrofit
- Requires support.

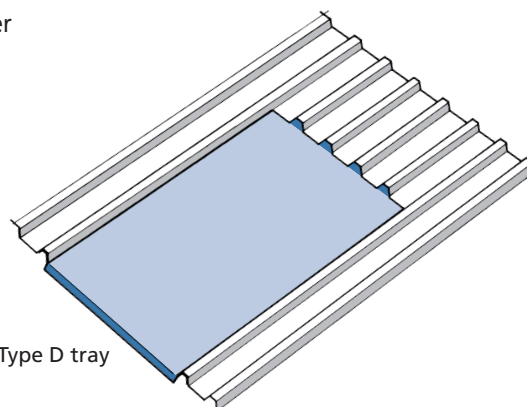


Type C Under/over tapered

Type D

Soaker flashings that drain at the plane of the roof pan at the gutter

- Simple
- Provides greater run-off capacity
- Suitable for all roofs > 5°
- Used for a retrofit
- Requires support
- Limited to 1.1m wide and 2.4m long



Type D tray

Drawings 6.2.6. 

6.2.7 TYPE A SOAKER

Soaker or underflashing penetration designs are those that drain at the plane of the roof pan.

They are the preferred design and will produce a weathertight flashing in any circumstance where a hole is cut in metal roof cladding.

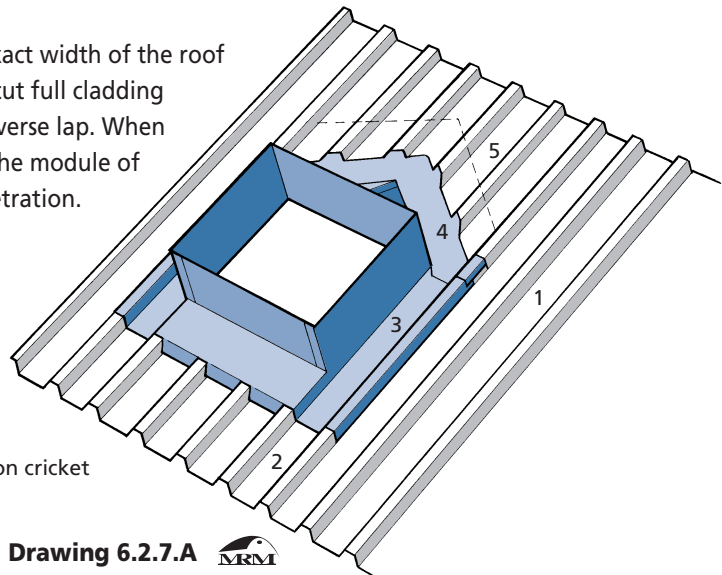
For new installations the location of penetrations should be designed and the position known before the roof is installed.

For safety and simplicity the safety mesh, underlay and roof cladding should be laid to cover the openings provided the sheets lengths covering the openings are increased by 150mm or the lap required to break the sheet at the head or back curb of the penetration. **(See drawing 6.2.7.B)**

All soaker flashings have an overlap to mate with the side overlap of the profile, which ensures that even in an overflow situation, water ingress is avoided.

It is highly unlikely that a penetration will be the exact width of the roof sheet so the preferred method of weathering is to cut full cladding sheets above the penetration and flash at the transverse lap. When penetrations line up with the ribs of the sheeting, the module of the roof cladding determines the width of the penetration.

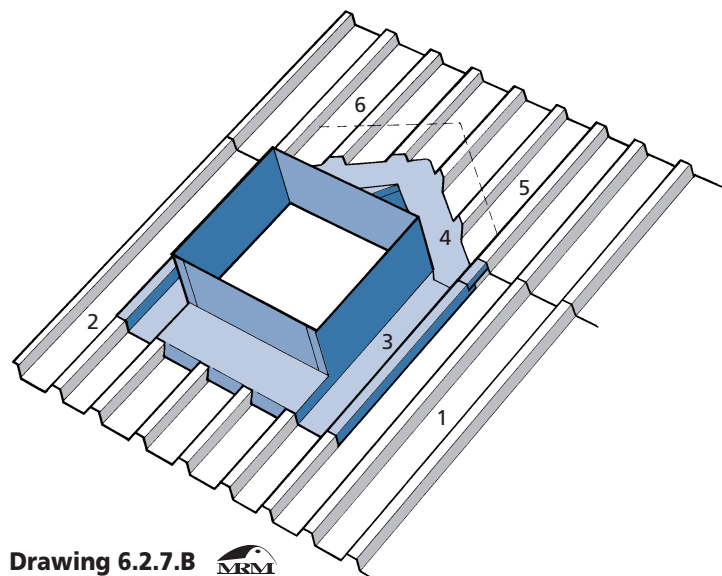
- Sheet 1 is full length
- Sheet 2 is cut to the bottom of the penetration dimension
- Flashing 3 is the side curb
- Flashing 4 is the back curb
- Sheet 5 is cut to the top of the penetration cricket + 75mm



Drawing 6.2.7.A 

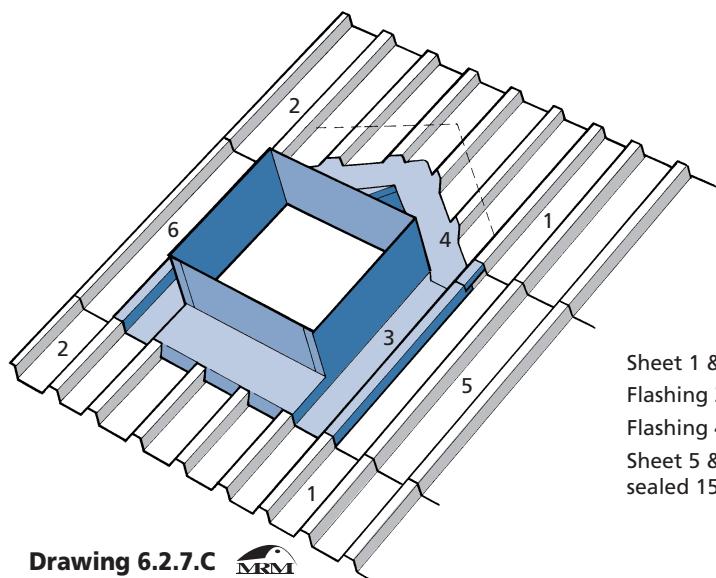
When the ribs do not align with the penetration, weathering can be achieved in several ways but the simplest and preferred method is to order longer sheets at the time of installation.

- Sheet 1 & 2 are cut to the bottom of the penetration and 150mm minimum above the cricket
- Flashing 3 is the side curb
- Flashing 4 is the back curb
- Sheet 5 & 6 are cut to the top of the penetration hole and shaped to the cricket.



Drawing 6.2.7.B 

The roof cladding sheets can be cut behind the penetration and overlap the longer sheets if the position of the penetration is known before any roofing sheets are ordered. When this is not the case it is either necessary to order longer new sheets, or install 'filler sheets'.

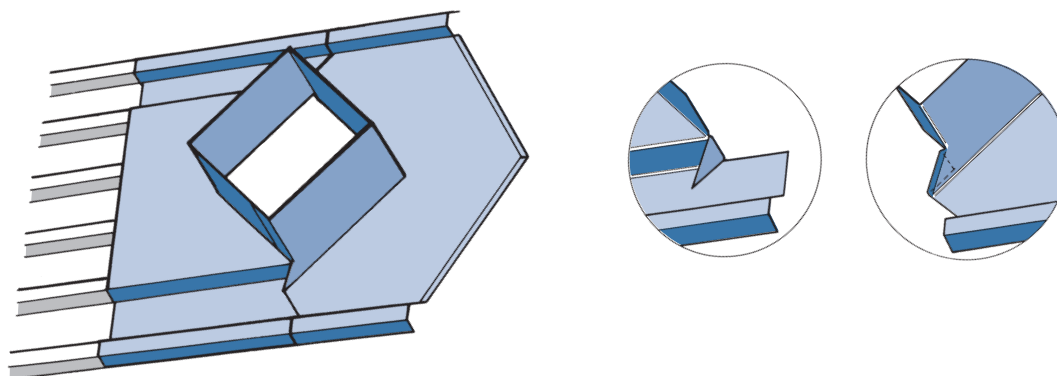


Sheet 1 & 2 are cut to the bottom of the penetration
Flashing 3 is the side curb
Flashing 4 is the back curb
Sheet 5 & 6 are additional filler sheets cut to provide a sealed 150mm lap at both ends of the penetration.

Drawing 6.2.7.C 

When a penetration is cut into existing sheets or when a retrofit is required it is recommended that the sheets be cut and a new insert piece is used to flash the sides of the penetration.

One alternative solution to providing a cricket flashing, which is particularly suitable for square fan housings, is to turn it through 45° to automatically provide a diverter. *See drawing 6.2.7.D below.*

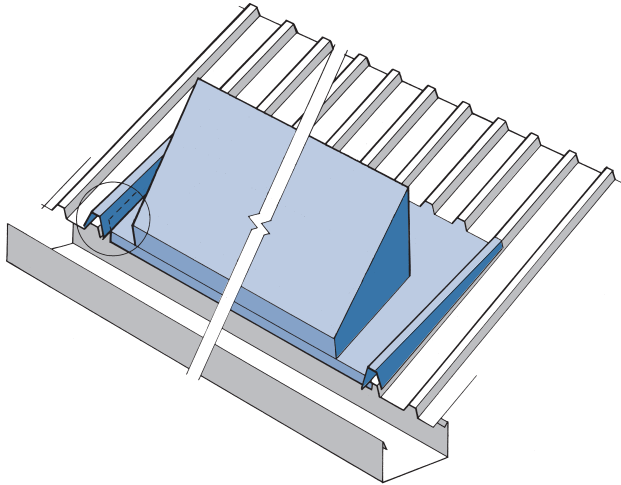


Drawing 6.2.7.D. 

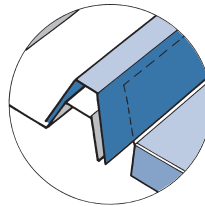
Where a wide penetration > 2.0m or has a large catchment area > 30m² behind it, or where the pan capacity is insufficient, special draining provisions should be made.

This design may require the removal of the purlins adjacent to the penetration to allow a gutter to surround the penetration and discharge at the eave or internal gutter line. The gutter should be sized according to section 8.2.2.

See drawings 6.2.7 E and F below.



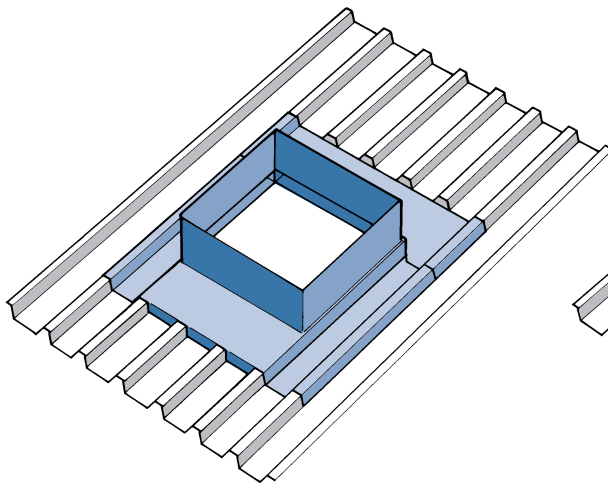
Drawing 6.2.7.E. 



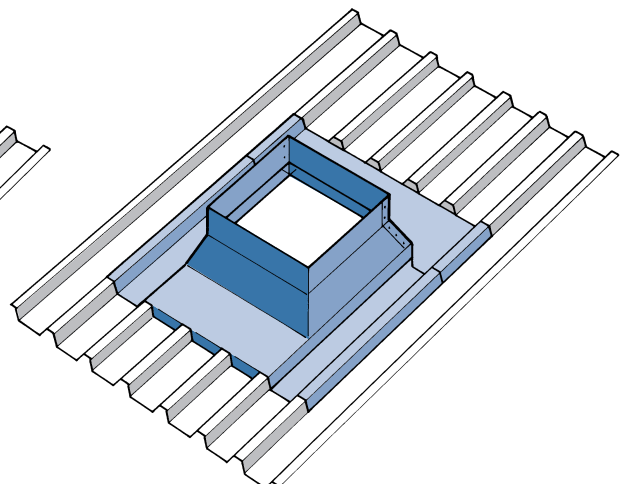
Drawing 6.2.7.F. 

- (C) C is the preferred detail for all penetration designs and has a separate side, back curb and apron flashing. The vertical corner intersection of the side and back curb can be 'double lapped' with the side curb under horizontally, and the vertical curb over. This technique makes a strong joint before fastening and sealing, and provides a double seal.

The module of the roof cladding determines the penetration flashing width and although it can be wider than the penetration hole required, by the use of a splayed skirt or by splaying the side curbs the original dimension can be maintained.



Drawing 6.2.7.G. Splayed side curb 

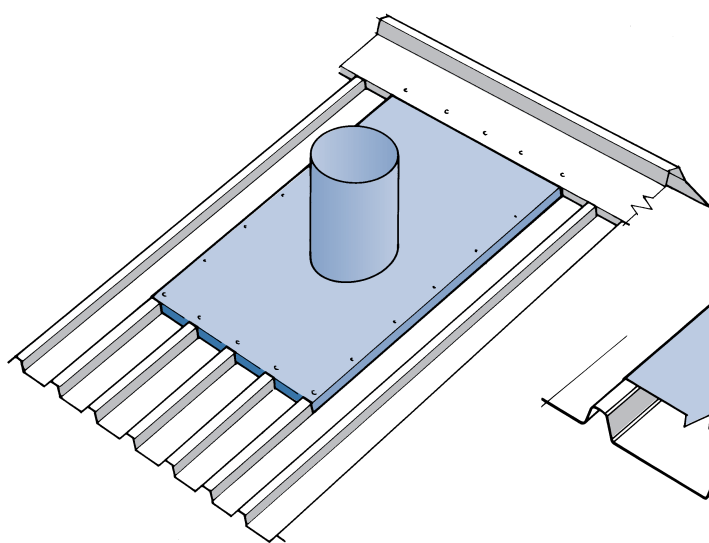


Drawing 6.2.7.H. Splayed skirt 

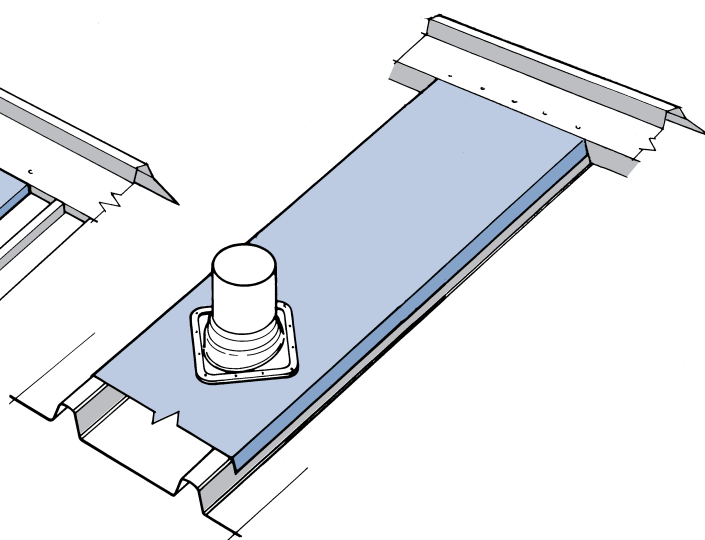
6.2.8 TYPE B WATERSHED

Watershed flashings are not the preferred method of roof penetration flashing, and they are not regarded as aesthetically acceptable in many installations. They are an acceptable method of penetration flashing within the restrictions stated.

A 'watershed' or back flashing is utilised in the end span, and is best restricted to within 1.5m of the ridge so that it will not restrict roof movement or cause expansion or condensation problems. If it is no wider than 1100mm (1200mm - 50mm downturn at each edge) the back tray can be made in one piece but a deeper or longer penetration is subject to another design detail. It is not acceptable to seam or join flat sheet as a back flashing. (*see detail 6.2.8A*)



Drawing 6.2.8.A Watershed 



Drawing 6.2.8.B 

When a watershed flashing extending further down the roof than the first purlin is not acceptable, alternative designs using a Type A soaker, a Type C tapered flashing or a sprung roof flashing should be used. (*see drawing 6.2.9.*)

If the width of the watershed flashing does not exceed 300mm in width then the only restriction on its length is the same as that for other flashings. (*see section 4.1.6.*) The overflashing should be made in maximum lengths of 6m using the same fixings and the same expansion provisions as the main roof cladding. (e.g. oversize holes)

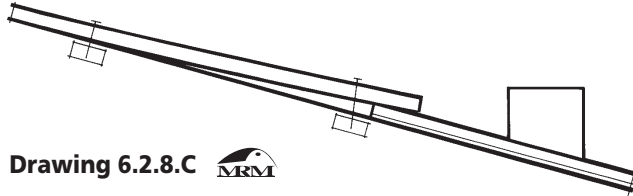
It is acceptable to use a boot flashing in conjunction with a such a watershed flashing without restriction on pitch.

Watershed design is used where the penetration would obstruct the water flow in the pan, and is used for a retrofit or where the pipe cannot be shifted.

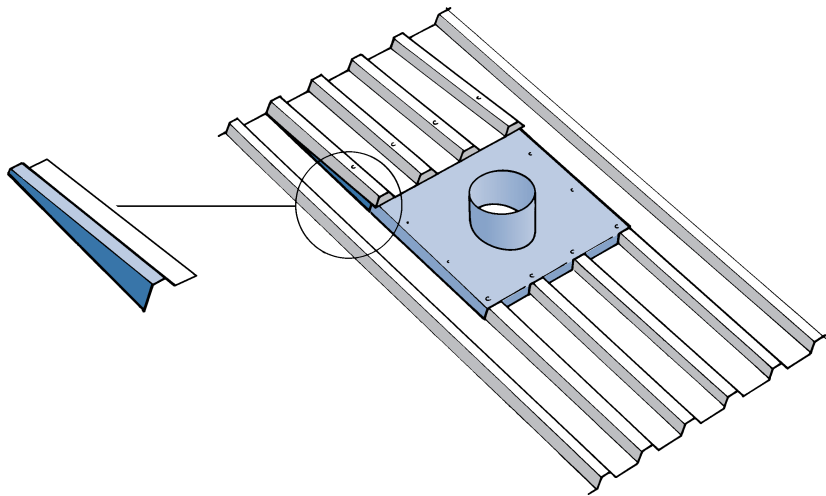
Washed screws should fasten the back flashing to the underneath roof cladding as rivets are not acceptable fasteners for this situation.

Another method of using a watershed type flashing can be achieved by a 'Sprung' roof. Using this method the sheet is sprung by lifting the sheet from the existing fastening by the rib height.

For deeper ribs this distance would be increased automatically because the purlin spacing is presumed to be greater. Additional support is required at the side lap of the sheeting. A tapered flashing is used at the sheet edges to provide the weathering as shown on *drawing 6.2.8.C and 6.2.8.D.*



Drawing 6.2.8.C 



Drawing 6.2.8.D Sprung roof 

6.2.9 TYPE C TAPERED

Tapered flashings are also known as transition flashings because they provide a method of changing from one level to another.

A tapered flashing can be made by tapering the flashing from the pan to the rib height in the depth distance of the penetration, however as this design lowers the pitch, it is only suitable where the pitch is not reduced below 1.5°. If the roof pitch has to be increased, it is necessary to add the tangent angle to the minimum permissible pitch for the particular profile being considered. (*see pattern section 15.8.*)

This amount is determined by the height of the rib and horizontal distance through which it is raised. It is therefore necessary to determine the angle which can be found by calculation using the formula $\tan \epsilon = h/d$.

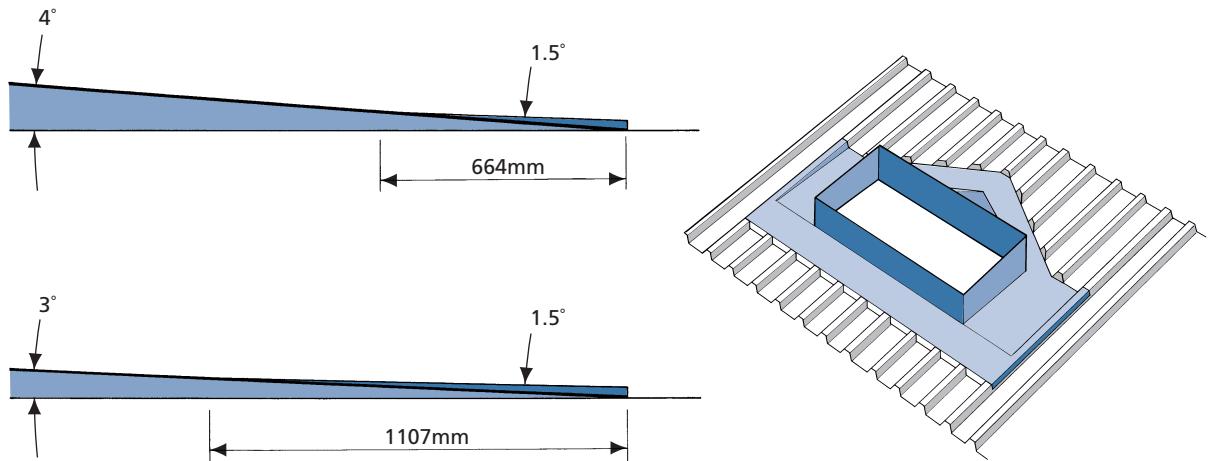
e.g. with a rib height of 29mm and a taper length of 664mm the flashing pitch is decreased by 2.5°, that means that at minimum 1.5° fall, the minimum roof pitch would have to be 4°. When the minimum roof pitch is 3° the taper length would have to be increased to 1107mm for this rib height.

The calculation is derived from the tangent of the difference in the roof pitch and 1.5°. Tangents are in section 14.

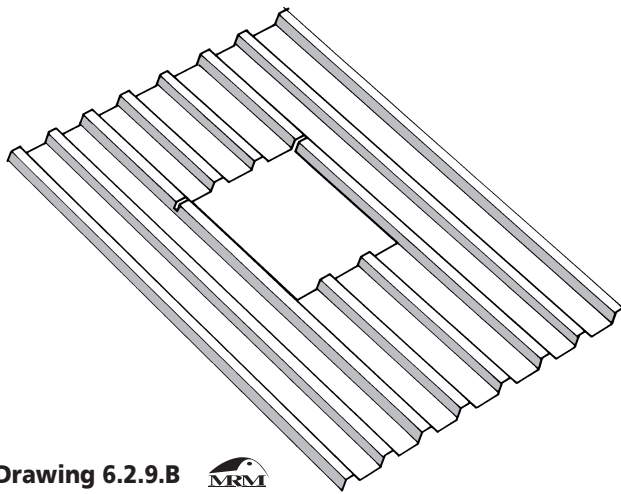
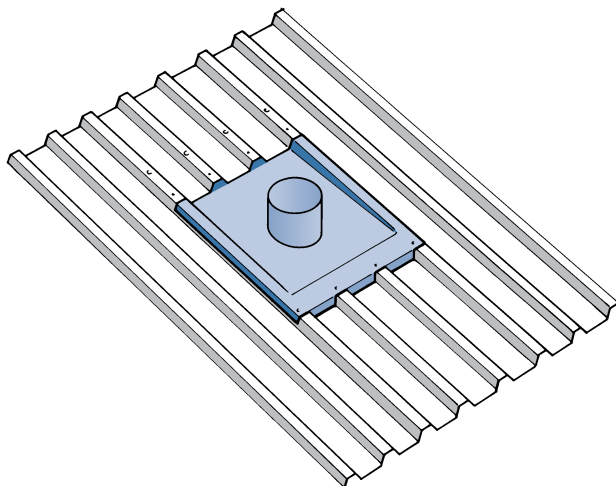
$$\tan 2.5^\circ = .0437 \quad \frac{29}{0.0437} = 663.6$$

$$\tan 1.5^\circ = .0262 \quad \frac{29}{0.0262} = 1106.8$$

(*see drawings 6.2.9.A,B,C.*)

**Drawing 6.2.9.A** 

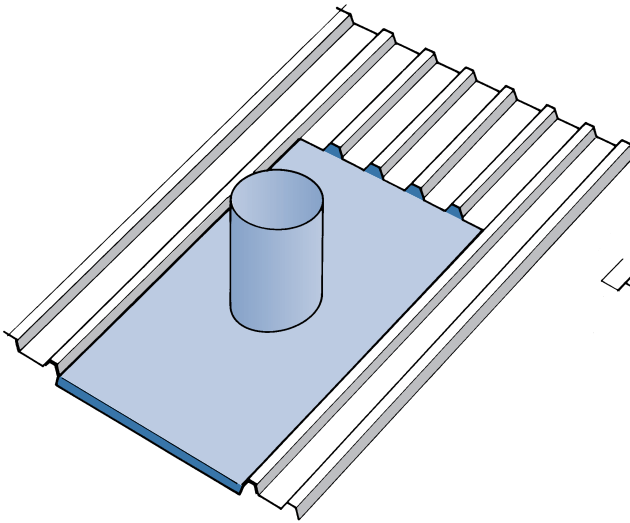
A tapered design can be used as a retrofit for any profile by slitting the ribs to half their height, and sliding the tapered flashing into position. When it is used in a new installation, extra sheets can be provided to weather the lap without slitting the sheets or the use of sealant.

**Drawing 6.2.9.B** **Drawing 6.2.9.C Tapered flashing** 

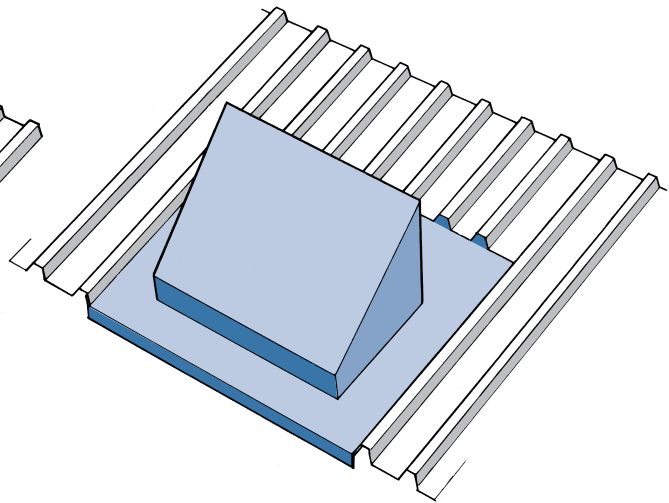
6.2.10 TYPE D

If the penetration opening falls between the gutter purlin and the penultimate or next purlin up the roof then a flat tray under flashing can be used to drain directly into the gutter, as shown in *drawing 6.2.7.I*.

This tray can be weathered under the ribs or over the ribs if the sheet is cut, but requires additional structural support.

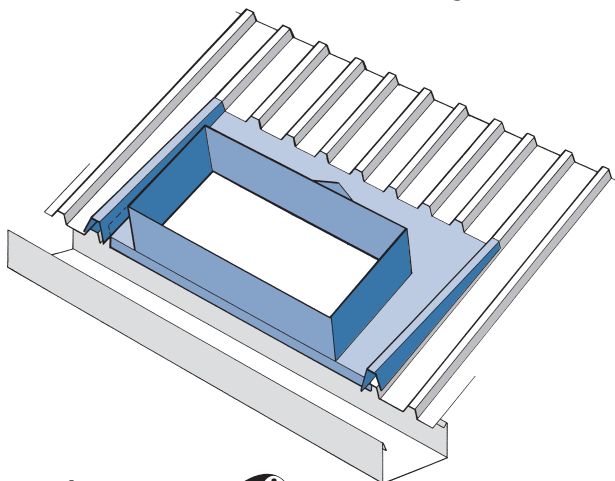


Drawing 6.2.10.A. Flat tray 



Drawing 6.2.10.B 

Drawing 6.2.10.B shows a simple method of providing a flashing for a penetration such as a solar collector. By enclosing the collector all the pipes are protected from the weather which eliminates the dissimilar metal contact with or runoff onto the metal cladding. Because this flashing is made from separate curb pieces (*see section 6.2.1.*) there is no restriction to the width of the flashing.



Drawing 6.2.10.C. 

The detail drawn on drawing 6.2.10.C. is required where a large air conditioning unit or a large solar collector is placed at the gutter line and where the catchment area behind the penetration is also large.

N.B. drawings 6.2.10.B and C require a cricket design.

6.3 COLLAR OR BOOT FLASHINGS

Proprietary EPDM pipe flashings are in common use in N.Z. but they have a number of disadvantages.

- they are lapped over the roof cladding, creating a dam that holds moisture and dirt
- they rely on sealant alone for their weathertightness.
- they cause obstruction to the rain water runoff if they block more than 50% of the pan.
- the E.P.D.M. flashing is flexible and requires structural support for the pipe
- their longevity is jeopardised if they are distorted or under stress.

To overcome some of these disadvantages, the following directions should be followed:

- The square base should be turned at 45° to the fall of the roof cladding. This will minimise the obstruction, and dirt and debris is more likely to be washed away. (*see drawings 6.3.A,B,C,D.*)
- All surfaces should be cleaned and sealant should be placed around the flange base of the flashing before it is placed in position.
- All surplus sealant should be removed.
- This type of flashing should never be used on a side lap.
- This type of flashing is unacceptable on asymmetrical trapezoidal profiles if the size of the pipe and flashing restrict or obstruct the passage of water to less than half of the normal draining area.
- This type of flashing is unacceptable on symmetrical trapezoidal and corrugate profiles if the size of the pipe and flashing obstruct the passage of water greater than one rib.
- The penetration hole in the roof cladding should be made through the rib, and the hole should be cut close to a purlin.
- Only one rib of a profile should be cut out, as any further cutting severely depreciates the performance of the cladding. If more than one rib has to be cut, additional structural support is required and an alternative penetration design should be used. (*see drawing 6.3.D.*)

E.P.D.M. flashings should not be used for single flues and for high temperatures 60° - 200° HT silicone flashings should be used.

Other tray type proprietary EPDM flashings are available to suit larger pipes or custom-made flashings and can be used as shown and described below.

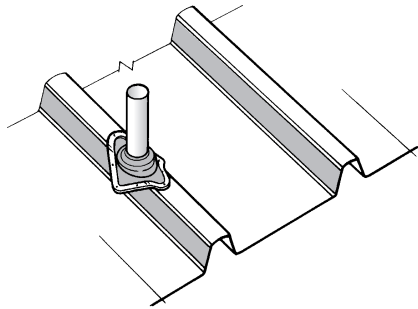
Drawing 6.3.A. Small vent pipes can be flashed as per drawing 6.3.A. Hole cut out through the rib, and close to a purlin and proprietary flashing placed at 45°.

Drawing 6.3.B. Bigger vent pipes that would obstruct more than 50% of the available pan width can be used up to 300mm in width.

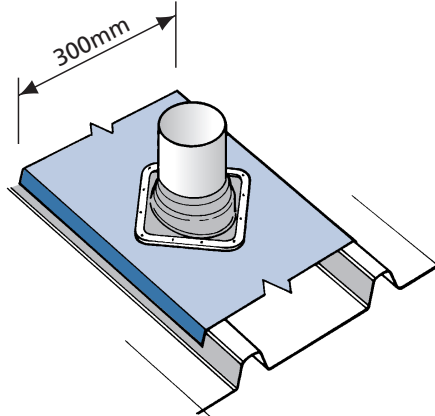
If more than one rib has to be cut, then additional structural support is required and an alternative penetration design has to be used.

N.B. This penetration design can be used down to the minimum pitch of the roof cladding.

Drawing 6.3.C. The alternative and preferred detail for larger pipes.

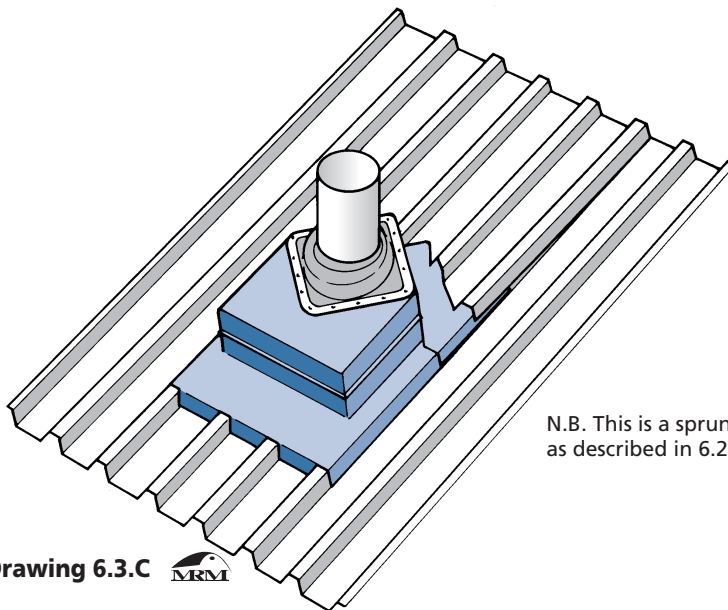


Drawing 6.3.A 



Drawing 6.3.B 

The flashings above can extend 8m maximum from the ridge.



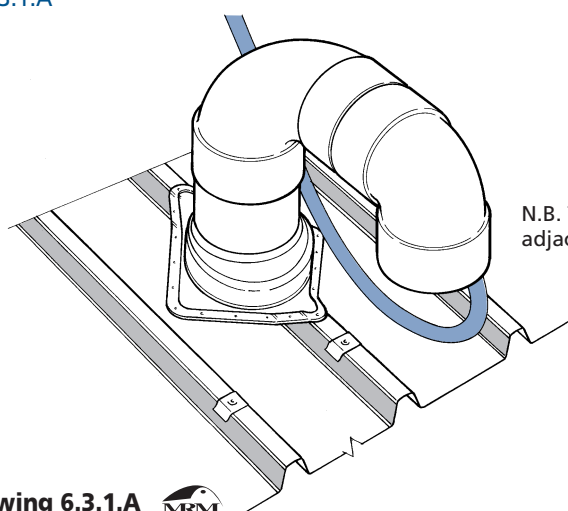
Drawing 6.3.C 

N.B. This is a sprung roof flashing as described in 6.2.8.C.

Drawing 6.3.C shows a large proprietary 250mm diameter EPDM flashing, which would obstruct drainage from the catchment above. It has been designed with a self cleansing 45° diverter flashing, while still providing the flexibility offered by this proprietary type of flashing.

6.3.1 PLANT ROOM AND CONDUIT PENETRATIONS

Where flexible power conduits or telecommunication cables are required to penetrate the roof cladding, to provide accessibility, a number of conduits can be weathered using P.V.C. pipe fittings and an E.P.D.M. flashing as shown on drawing 6.3.1.A

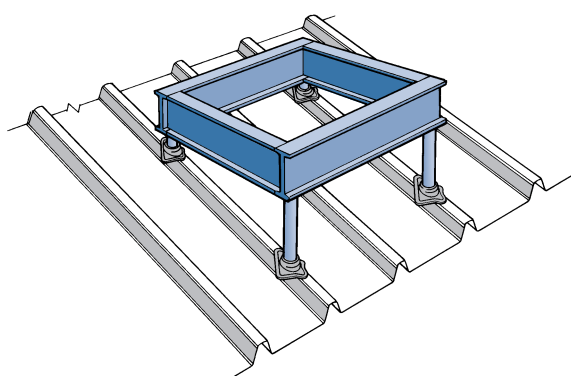


N.B. This boot flashing must be fixed adjacent to the purlin for support.

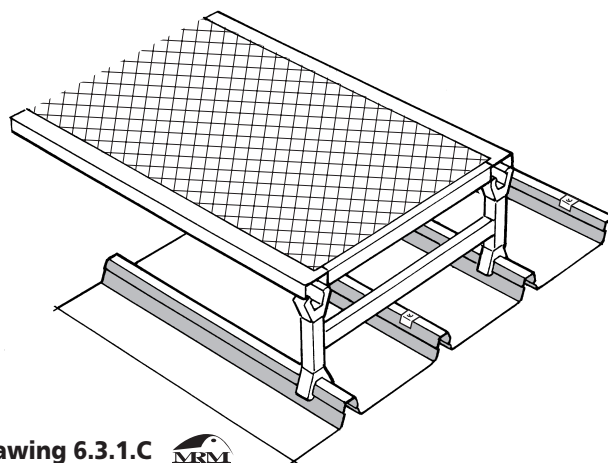
Drawing 6.3.1.A 

Safety bollards for fall arrest anchorages are required where regular maintenance is required, and these can be weathered by E.P.D.M. flashings.

Where plant room supports are required to penetrate the roof cladding the designer should provide the support framing from CHS (Circular Hollow Sections) in preference to RHS, (Rectangular Hollow Sections) or other hot rolled steel sections, because the CRS can be easily flashed with E.P.D.M. flashings. The support framing should be in place but below the top of the purlin before the roof cladding installation to allow it to proceed without the necessity to weatherproof the multiple penetrations at that time. This procedure will allow the E.P.D.M. flashings to be slid over the pipe framing during erection, and avoid the necessity of using retrofitting types. (see drawing 6.3.1B.)



Drawing 6.3.1.B 



Drawing 6.3.1.C 

Proprietary support systems are available for light weight support through to the purlins as shown in drawing 6.3.1.C. These types of supports provide clearance for cleaning but should not create an unwashed area underneath them.

6.4 WINDOW FLASHINGS FOR METAL CLADDING

Profiled metal cladding has been used for many years as both vertical and horizontal cladding, particularly on garages and farm buildings where the aesthetic requirements and weathering may not have been the prime consideration. As most of these buildings are open and unlined, the cavity is naturally vented and minor water ingress can be tolerated, but if the building is lined then there should be no ingress of moisture. For this reason for lined and insulated buildings in higher risk areas cavity construction is required. Buildings are considered to be higher risk when they are situated in a very high wind design load areas (<1.5.kPa.) and buildings that are two stories or more. **(see cavity construction 4.5.)**

The weathertightness of horizontal cladding is totally dependent on the flashings that surround the sheets and any penetrations and because it is susceptible to the accumulation of condensation a cavity is required for all lined buildings.

The use of unpainted metal cladding as an architectural feature on domestic buildings requires a high standard of flashing and junction detailing by both the designer and the installer to ensure acceptability for both durability and aesthetics. It is particularly important where there is no air gap or cavity and if the timber frame is untreated and kiln dried, that there should be no ingress of moisture. Moisture from within the building can accumulate from condensation, from leakage or from the building use, and horizontal cladding fixed directly to the structure without a cavity behind it can inhibit natural venting

Designers should be aware that when using cedar or treated timber in conjunction with plain galvanised or AZ coated steel that interaction between the timber and metal can occur if these materials remain wet.

Metal wall cladding should have some provision to remove condensation, which will occur when the humidity is high or when there is a large diurnal temperature differential. If the wall is insulated and the building is heated, the frequency of occurrence of condensation forming on the metal cladding will increase.

A permeable and absorptive underlay must be provided under all metal wall cladding, and when there is no air cavity behind it, provision must be made for ventilation. (see section 4.2. & 4.3.)

Synthetic wraps must not be used as an underlay directly under metal cladding unless they conform to table 4.3.1.

Where horizontal laps are enclosed in a cavity that is subject to condensation it is recommended that they should be sealed with lap tape. This is required to avoid the build up of moisture at the lap that can otherwise occur when dirt and condensation collect, increase the time of wetness and cause corrosion of the coated steel cladding.

Designers should recognise that unpainted metallic coated steel may not last 50 years in corrosive environments or where the design allows the metal to remain wet. **(see section 2.6.7 & 8.)** When replacement may not be easily achieved, aluminium or other metal options that require similar detailing to steel, should meet the 50 year NZBC requirement.

The minimum paved ground clearance of 100mm must be provided to ensure that rain splash or moisture from the ground does not accumulate at the drip edge of the cladding or be induced into the cavity. (see drawing 4.5.7 B)

Cavity construction using a batten is recommended for horizontal cladding in all areas that are exposed or where ventilation is inhibited and the metal cladding may suffer from the effects of condensation.

A window or door used in conjunction with profiled metal cladding is a vertical penetration, and the principles detailed in penetrations **section 6.0.** apply equally to window and door flashings.

Wall penetrations are similar to roof penetrations except that the nomenclature is different, as they require a head flashing (back curb), side flashing (side curb), and a sill flashing (apron), but the lapping and sealing requirements are the same.

There are different requirements depending on whether the cladding is laid horizontally or vertically, and the module of the cladding will dictate the flashing shape and size needed to provide an acceptable and weathertight detail. Because the natural ventilation of horizontal cladding is inhibited by any closures, when filler blocks are used a hole should be punched to provide some air movement to ventilate the cladding.

The use of closed cell closures should not be used externally to stop water movement as the accumulation of dust and dirt at the metal interface will eventually increase the time of wetness, which can be a major cause of corrosion.

It is the role of the designer to coordinate the window penetrations and the cladding as this task is not the responsibility of the cladding fixer, unless he is especially requested to do so.

It is common practice not to use any jamb or sill window flashings behind flat or shallow profiled cladding in garage buildings, although these profiles are usually plugged to prevent moisture or vermin entry at the window flange. This is not acceptable practice for domestic, commercial or industrial buildings, unless the cladding manufacturer provides specific cladding details.

Designers using different flashing designs other than those described in this Code of Practice, or using metal cladding without any flashings should assume the responsibility for this decision.

Sealant must not be relied upon as first line external weathering of penetrations through metal cladding.

To minimise the entry of wind driven rain into the framing surrounding a window, a pressure equalisation system can be used which requires a seal around the window frame on the inside of the wall.

The sill flashing should never be sealed to the window, as this prevents the exit of any water accumulated through ingress or condensation, and will void any pressure equalisation system.

There are options that may be dictated by aesthetics rather than weathering and the integration of these details should be established before any cladding work is commenced. The limitations of module creep should provide the cladding contractor with reasonable building tolerances.

Window flashing types

Window flashings have been divided into three types: (a) flush mounted, (b) recessed or reveal and (c) butt. The height of the window should determine the module set-out of horizontal cladding,

The sequence of flashing around penetrations such as windows can determine the design, as good weathering details can only be achieved if the windows are installed after the metal cladding and flashings. The installation of a head flashing requires that it is behind the cladding and weathers the window by exiting over the cladding, with the thickness or depth of the cladding determining the offset, which should have a fall to the front of a minimum of 10°.

When lapping horizontal cladding it is therefore logical to lap the cladding at the window or door head height.

Windows and doors can be flush in line with the cladding or recessed to the front of the frame and if the window is within the depth of the wall of the building, the flashings are termed 'reveal or recessed flashings'. Recessed and flush flashings have the same overflashing design, and a recessed design has the advantage of a better weathering detail but can result in areas of unwashed metal, which require maintenance for durability.

The butt flashing details commonly used on horizontal cladding of industrial or commercial buildings are not considered suitable for residential closed cavity construction, because they do not overflash the metal cladding.

The designer should recognise that the metal cladding is a modular material and after the decision has been taken to use a particular profile, the size of the window can be made to suit the cladding module as windows are usually custom made. Window heights should be the same to avoid different details at adjacent windows.

Unless specifically requested to do so, it is not the role of the installer to decide on the design of flashing details required. All details should be made with provision to allow for some air movement to dissipate condensation and without the use of sealant as a first defence against water ingress.

In high wind design load areas, all the details shown should be used in conjunction with vented closed-cell non-absorbent filler blocks fixed to the backside of the profile to baffle the wind pressure.

Filler blocks can be simply fixed and positioned to metal cladding by spray adhesive however in sheltered areas they are not a requirement.

The design and installation of metal flashings is a crucial part of the cladding weathering process, and without detailed requirements, definitive objectives, quality checks and known responsibility, the results can be unsatisfactory and expensive to repair or replace.

Ingress of water can be insidious and the resulting degradation of insulation, framing and internal linings poses a threat to the health and safety of the occupants.

All exposed horizontal metal flashings including the head or sill flashings must have a minimum 10° pitch to avoid ponding and the build up of dirt and debris. All hidden flashings must be durable for 50 years.

It is advisable to start the horizontal cladding at the window head level to provide a weathering the junction at this point. For this reason also it is advisable to make a horizontal break in multi-story construction to adjust the vertical module.

The details shown are not the only options, however they represent a standard of weathering principles outlined elsewhere in this Code of Practice and are consistent with good trade practice.

Deviation from the details provided therefore would require specific approval.

When the lap of the horizontal cladding does not coincide with the height of the penetration, in order to weather the head or sill flashings it is necessary to slit the cladding to enable the fitting of 'under/over' flashings to allow water egress.

This method requires accuracy and skill to make a neat joint, at what is a vulnerable point, and which should be sealed to prevent water ingress. Because this joint relies solely on sealant and cannot be mechanically fixed, it is not a recommended option.

To avoid slitting the sheets where a window is in a single storey building, a double hemmed jamb soaker flashing can be continued to ground level behind the cladding providing there is provision to enable water to drain clear of the building. This is not a recommended option unless there is a cavity behind the cladding. Multi-storied buildings should have a sill at each floor level in order that soaker flashings are not required to drain more than one storey.

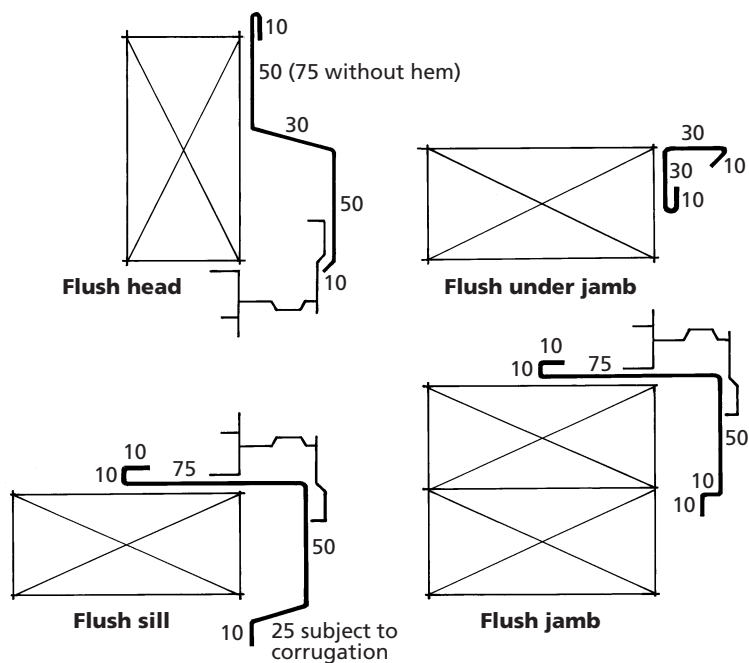
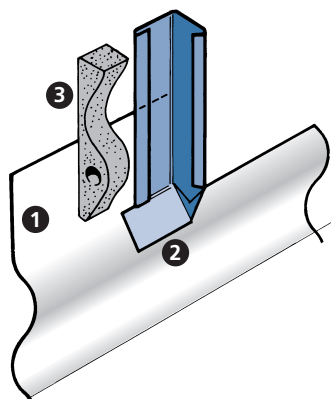
Underlay must be used under metal wall cladding on lined building in the same manner and for the same purposes as is required for roof cladding.

It controls condensation that will occur in an insulated cavity, and will offer a secondary provision to drain any ingress of moisture. For this reason the underlay should exit at the penetration (window or door), in the same manner that is required for roof penetrations. Failure to do so can lead to the retention of moisture in the wall, with consequential corrosion of metal and the degradation of timber.

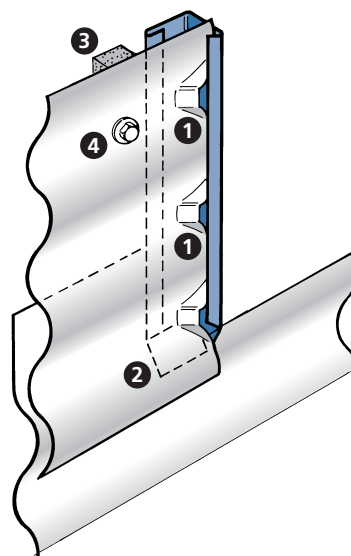
All sills should be dog-eared or riveted, and sealed to provide a weathertight joint.

The cross section details shown can be used for vertical cladding. For horizontal cladding refer to **section 6.4.2.A**.

N.B. Head flashings are not taken to the back of the cavity as they are provided to flash the window not the cavity. These details are similar to those supplied by WANZ WIS. See **sill detail 4.5.7.D**.

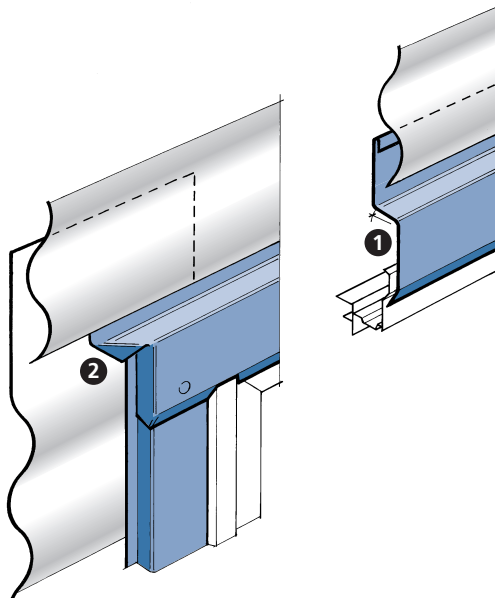
6.4.1 FLUSH WINDOW FLASHINGS**Drawing 6.4.1.A**  NB underlay is omitted for clarity.**STAGE 1**

- 1 Corrugate flattened
- 2 Underjamb folded out to suit profile
- 3 Closed cell filler block perforated for ventilation

Drawing 6.4.1.B **STAGE 2**

- 1 All ends stopended
- 2 Underjamb folded out
- 3 Closed cell filler block adhered to profile with contact spray adhesive
- 4 25mm 12# fasteners hidden behind overjamb

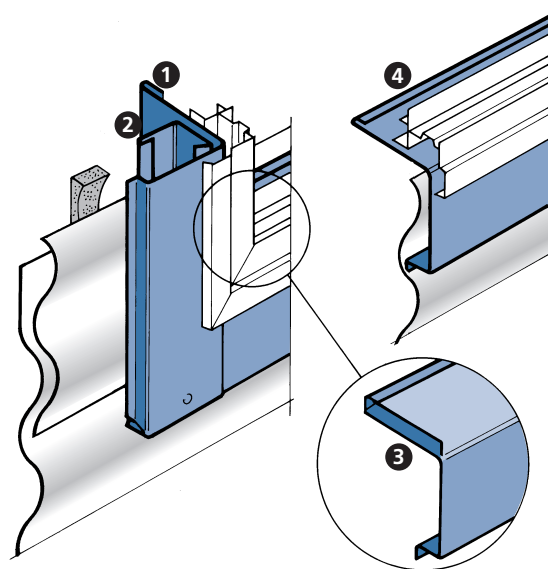
Drawing 6.4.1.C 



Flush window head flashing

- 1 10° angle minimum
- 2 Turn down end of extended head flashing

Drawing 6.4.1.D 



Flush window sill flashing

- 1 Overjamb hemmed behind window
- 2 Underjamb hemmed on face and hooked above profile. NB depth of underjamb is 12mm greater than profile height
- 3 End of sill dog-eared and turned up 10mm minimum to receive overjamb
- 4 Trim height increased 10mm to accommodate sill turn-up

Drawing 6.4.1.E 

The height of the sill flashing may have to be altered to suit the position of the profile

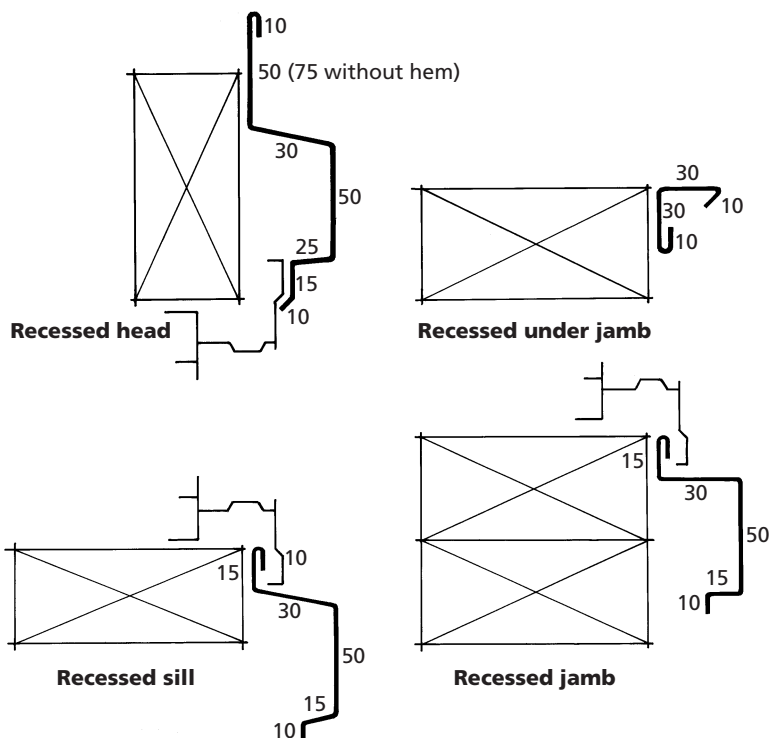

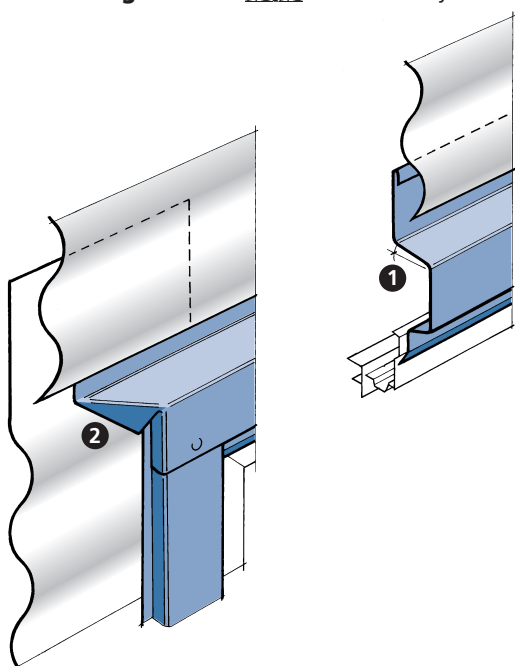
Flush mounted windows or doors can have picture frame flashings, which means that the window frame is mounted externally to the cladding, or can have timber facings, or a large number of alternative designs.

All types should be designed without total reliance on sealant, and improvised solutions are not acceptable.

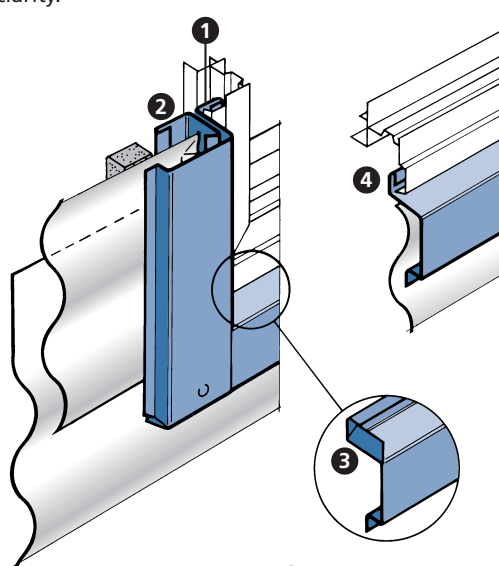
Both the flush and recess flashings have an under jamb and a front or face jamb.

Trim sizes for aluminium windows are usually plus 10mm on the jamb liner size, however in order obtain a vertical upstand the trim size for flush flashing design requires plus 15mm vertically, to allow for a 10mm packer.

An option for the head flashing profile can be provided if the corrugations on the underlap of the sheet are flattened which enables the head flashing to be folded vertically and not shaped to the profile.

6.4.2 RECESSED WINDOW FLASHINGS**Drawing 6.4.2.A**  NB underlay is omitted for clarity.**Recessed window head flashing**

- 1 10° angle minimum
- 2 Turn down end of extended head flashing

Drawing 6.4.2.B **Recessed window sill flashing**

- 1 Overjamb hemmed behind window
- 2 Underjamb hemmed on face and hooked above profile. NB depth of underjamb is 12mm greater than profile height
- 3 End of sill dog-eared and turned up 10mm minimum to receive overjamb
- 4 Trim height increased 10mm to accommodate sill turn-up

Drawing 6.4.2.C 

A recessed window flashing design is considered the best option for horizontal cladding but accurate flashing measurement and installation are required to provide weathertightness.

N.B. For lined buildings a cavity is required for horizontal metal cladding.

In a similar manner to the flush detail an option for the head flashing profile can be provided if the corrugations on the underlap of the sheet are flattened which enables the head flashing to be folded vertically and not shaped to the profile.

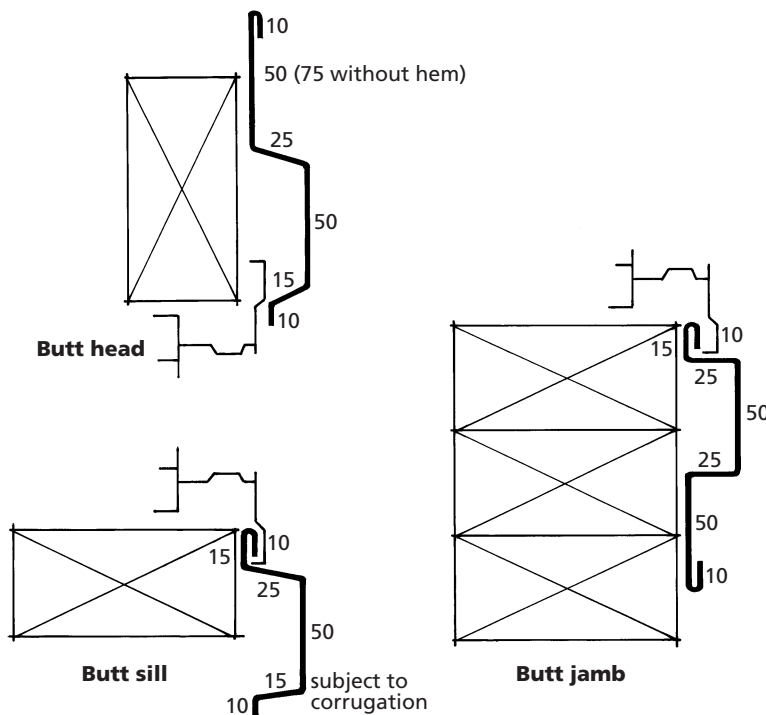
6.4.3 BUTT WINDOW FLASHINGS

Alternative details that allow the cladding to terminate up to a flashing without overflashing it, require accurate fitting in order to be weathertight. (*see drawing 6.4.3.B*). These details are known as butt flashings and can be used on flush or recess designs, with a one-piece jamb. They are only suitable for areas with low or medium wind design loads or in protected areas and require precise design, precision measurement and manufacture to provide a weathertight solution. Butt window flashings also require accurate installation to provide an aesthetically acceptable solution, they should allow for drainage of a large catchment, they require extra timber for fixing, and for these reasons they are not a preferred detail.

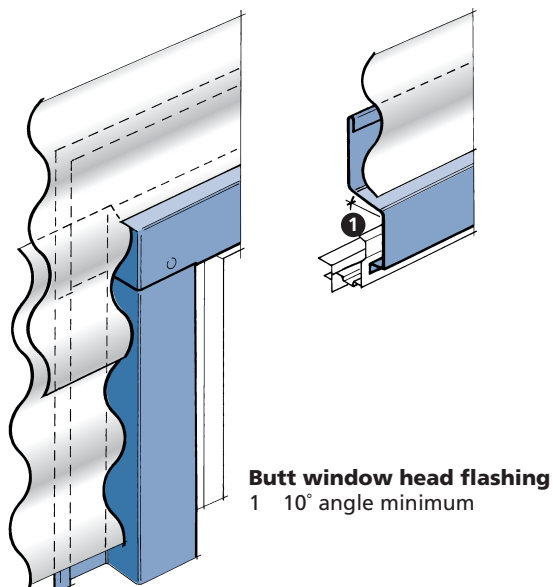
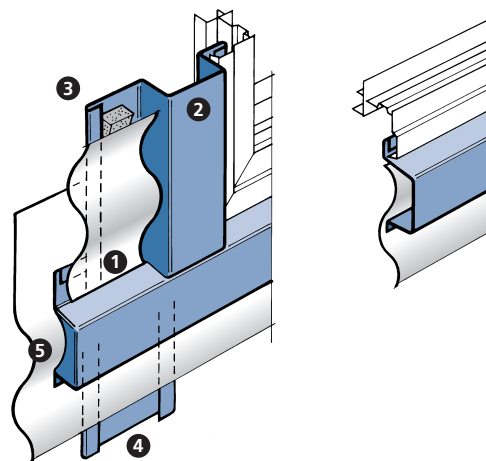
The total amount of water draining from the catchment area above from multi-storey construction can be considerable, and butt flashings should dispose of it as a penetration. The catchment is calculated by multiplying the width of the window opening by half the height.

Rain-water should discharge at a lap of the cladding or if the building is not lined or has a cavity, it can be tracked to the outside via a double hemmed soaker flashing to discharge at the base of the building.

To slit the cladding and discharge a large volume of rainwater from butt flashings is not acceptable and, as it should be assumed that butt flashings will leak, provision should be made to drain the water to the outside. (*see drawing 6.4.3C*)



Drawing 6.4.3.A  NB underlay is omitted for clarity.

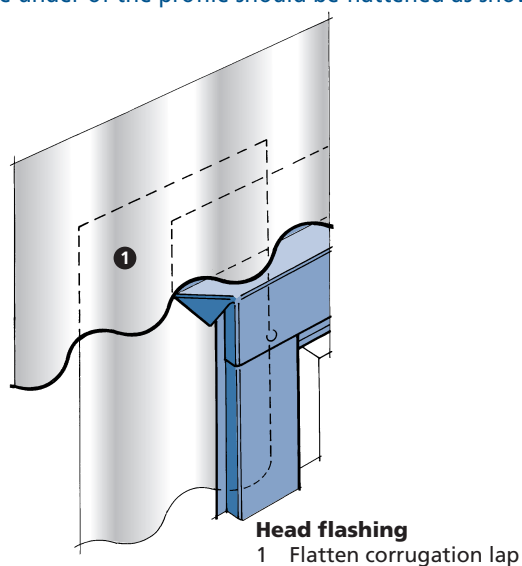
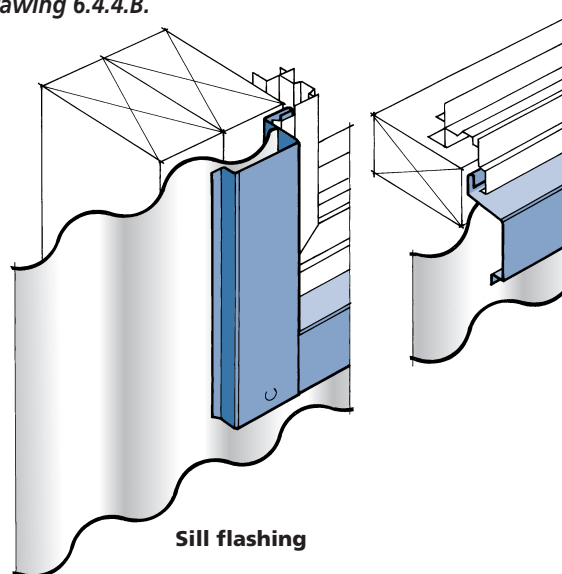
Drawing 6.4.3.B Drawing 6.4.3.C 

6.4.4 FLASHINGS FOR VERTICAL CLADDING

Window and door flashings for vertical cladding are similar to those used for horizontal cladding however a cavity is not required for vertical cladding.

The main difference is that the module is running horizontally and therefore some flexibility is required if the flashings are to be equal on both sides. To provide for this the trimming size of the window opening should be plus half the module dimension to allow adjustment for equalisation on both sides to occur.

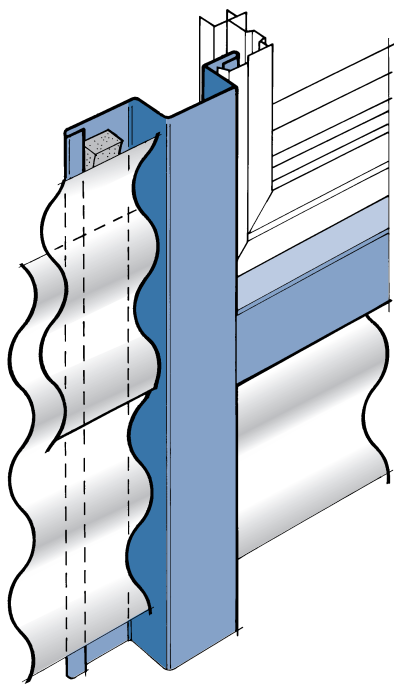
The under of the profile should be flattened as shown in *drawing 6.4.4.B*.

Drawing 6.4.4.A Drawing 6.4.4.B  NB underlay is omitted for clarity.

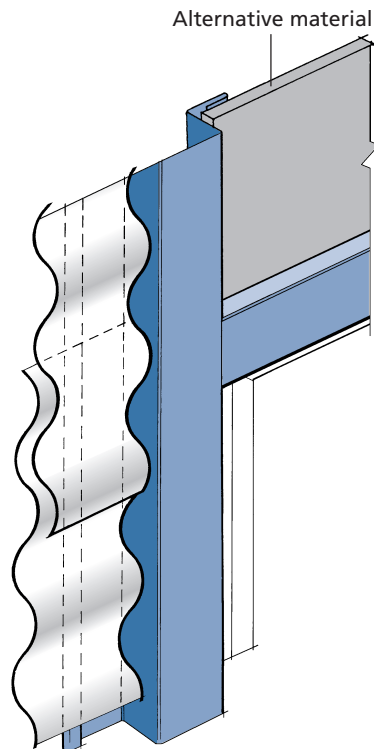
6.4.5 ALTERNATIVE FLASHING DESIGNS

There are other alternative design options to those shown that designers should consider for butt designs which provide a weather-proof window flashing alternative. If the opening is 'panelised' the vertical jamb flashing can be extended from soffit to the ground for single storey buildings or to a module break in a multi-storey building as shown in *drawing 6.4.5*.

This alternative provides the opportunity to use the same or an alternative material at the head and sill areas and a top hat flashing is used to obtain a module break.



Drawing 6.4.5.A 

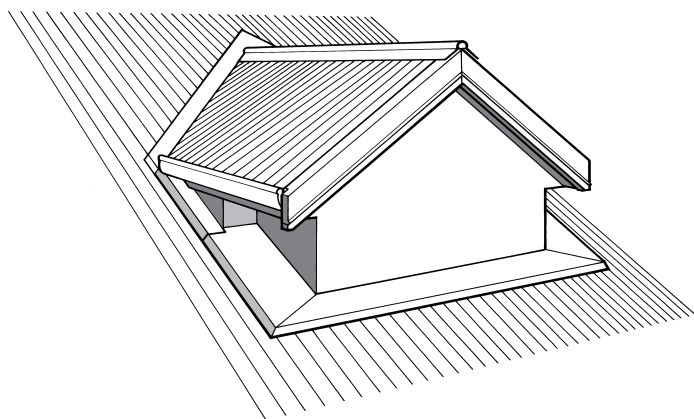


Drawing 6.4.5.B 

6.5 DORMER JUNCTIONS

Dormer or hip valley junctions where the rainwater from the catchment above discharges onto the roof cladding, should be detailed by either the designer or the roofing contractor. To weather these areas, particularly in high wind zones, requires a calculation of the total catchment area, the ARI, (*see section 8.2. rainfall*) and the capacity of the particular profile. There are many permutations of this design, however the principles are the same as those explained in *section 6.0. penetrations*.

The valley is the back curb of a wide cricket penetration, and therefore the catchment area restrictions on the discharge into one pan should be considered. Where low trapezoidal or corrugate profiles with limited capacity are used the concentration of large volumes of water can result in overflowing the profile. Designers should ascertain that the capacity of the profile chosen is adequate for the catchment area and for the 50 year return period for rainfall in the building location. (*see section 6.1.5. obstruction*)



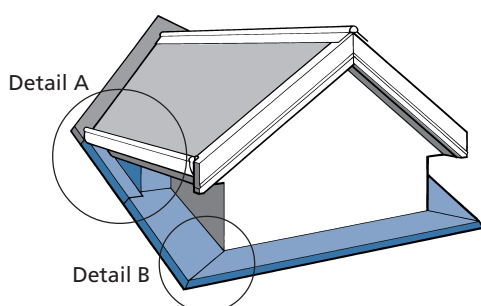
Dormer windows can be broadly classified into three types:

- A Dog kennel with overhang
- B Dog kennel without overhang
- C Gable

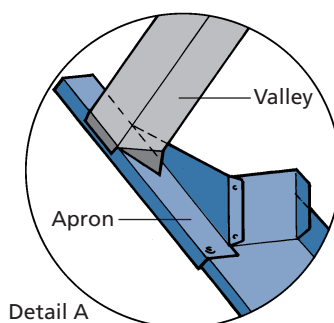
All of these can be situated either in the body of the roof structure or at the gutter line.

Drawing 6.5. 

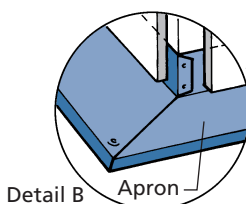
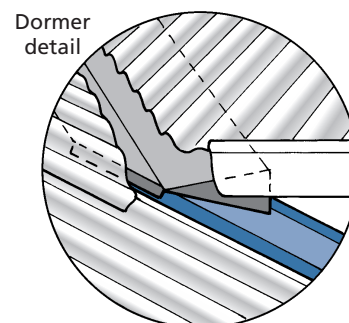
Dog kennel with overhang



Drawing 6.5.A. 

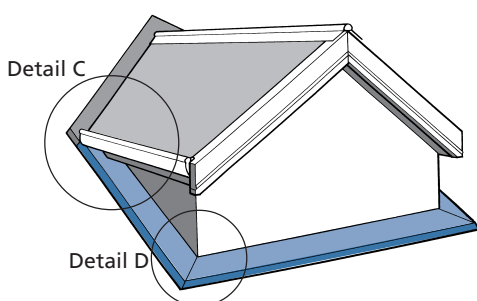


Detail A

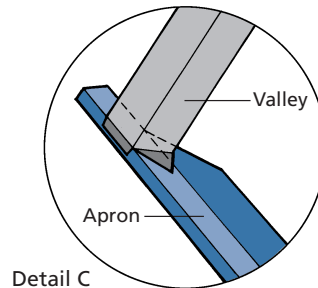


Detail B

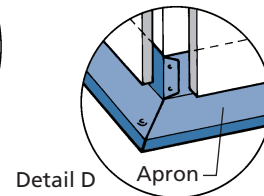
Dog kennel without overhang



Drawing 6.5.B 

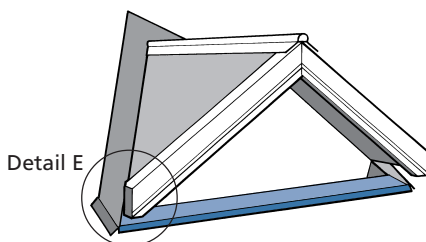


Detail C

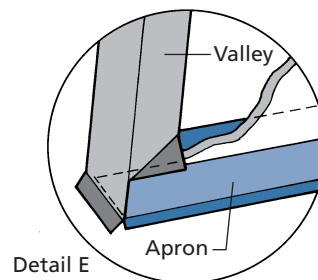


Detail D

Gable dormer



Drawing 6.5.C 



Detail E

SPOUTING AND BARGE BOARD OF THE DORMER OMITTED FROM THE DRAWINGS FOR CLARITY

Eye-brow and Lean-to dormers are usually roofed with membrane or other material than metal and specific details are not drawn or described in this Code. Where profiled metal is used the details should be the same as for change of pitch or cricket penetrations. Some dormers line up with the gutter line (**drawing 6.5.D**) and some discharge the dormer roof water via a downpipe situated at the dormer barge. This detail reduces the amount and turbulence of water discharging at the valley/ roof cladding intersection. (**see drawing 6.5.F**)

When fibre-cement or weatherboard cladding is used, the sequencing of the placing of the dormer flashings is critical for weathertightness. Apron flashings are custom made and require a profile set out if the roof cladding is not in position, and if the flashings are to be installed prior to the wall cladding.

An alternative apron design is to make a two piece apron with an overflow flashing installed first. (**see apron flashings section 5.3.5.**) The installation of apron flashings after the cladding is fixed is difficult unless full liaison is made with the contractor to leave the cladding loose (or alternatively screwed) to allow a retrofit.

The roof cladding profile will determine the details required to provide a weathertight solution, which has been traditionally obtained when using the corrugate profile by distorting the profile by the rib height. (17.5mm).

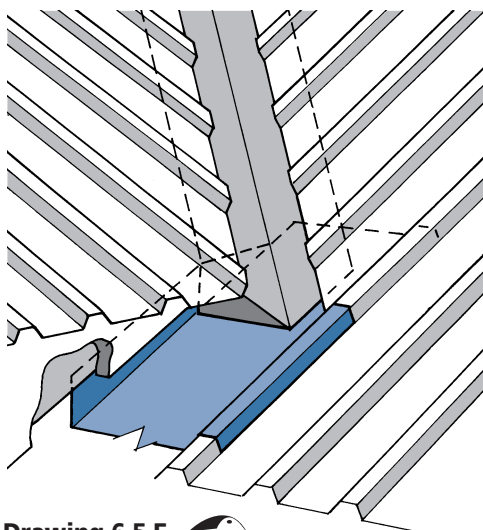
Although regarded as acceptable for corrugate, this method is not acceptable for ribbed or trapezoidal profiles, and as in a similar manner to roof penetrations, the rainwater exit should be planned to produce a weathertight and aesthetically acceptable detail that does not rely on sealant alone.

When water should drain from the 'under' to the 'over' a transition is required, which can be similar to the tapered detail shown in **drawing 6.2.9.** and the design should be known and approved by all concerned before the roof cladding is laid.

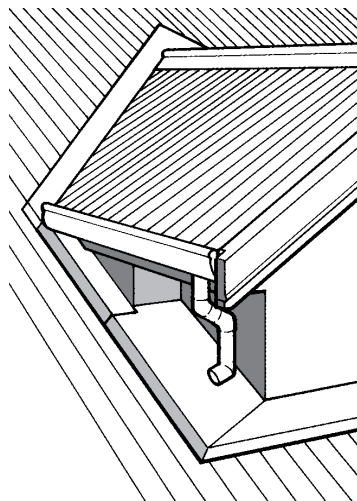
The detail shown (*see drawing 6.5.E*) provides for the discharge to be spread over the equivalent of two pans. It is common for the discharge from the dormer spouting to also free exit at the valley, which besides increasing the turbulence at this point increases the total volume of water. An alternative is to stop end the spouting and to discharge it from a downpipe directly onto the roof or into the gutter. (*see drawing 6.5.F*)

In some instances the roof framing may have to be altered to enable positive draining to occur, but roof fixers should not alter structural members without approval.

The detail in *drawing 6.5.B* is shown without any dormer overhang and the detail is similar to one with an overhang, except that a transition flashing is required to raise the discharge level from under to over.



Drawing 6.5.E 



Drawing 6.5.F 

The apron flashing is formed at the pan level with an overlap carried up beyond the valley exit.

The apron upstand is cut to the horizontal line of the barge and is covered by the fascia board.

The valley is carried past to overlap the apron, and is folded down to weather the transition and to birdproof it, making the apron an extension of the valley. Where the dormer finishes at the wall line the apron can drain directly into the gutter.

7.0 INSTALLATION

The installation of metal roof and wall cladding as described in section 7 should be followed to enable compliance with the NZBC and to satisfy the requirement of manufacturers warranties.

To minimize the risk of wind damage to partially clad structures during construction, it is necessary to plan the sequence and method of cladding.

7.1 PRE-INSTALLATION

Before commencing the installation of roof or wall cladding the roofing contractor or supervisor should have sighted a set of working drawings and specifications relating to the fixing of the cladding and the fasteners, and obtained knowledge of any special details particular to the specific job.

Before commencing major new or reconstruction roofing contracts, a pre-installation site meeting should be held attended by the architect, engineer or designer, the main contractor, the roofing contractor, and any other sub-trades whose work is associated with the roof or wall cladding contract. e.g. air-conditioning contractor.

The purpose of the meeting is to discuss the programme, which should ensure that all possible work to be done above the roof is completed before roof cladding is commenced, all penetration framing in position and that access to the roof is minimised once it is installed.

A site meeting is the opportunity to discuss any discrepancy between the plans and specifications and this New Zealand Roofing Code of Practice and any decisions departing from it should be agreed and written confirmation signed before work is commenced. Where specific details are not drawn and there are multiple replications, full-size models should be made for sample prototyping that are approved and remain on site for reference. A full-size mock-up is required to integrate components into a weathertight system that can be accepted by all parties. Temporary access, roof protection and the safety provisions of Section 8.1. should be discussed, and the responsibility for their placement and cost be agreed between the parties

The roofing contractor is required to have in place safety provisions that satisfy the HSE Act as outlined in **section 14.1. Safety** before work is commenced.

The supporting structure should be inspected and the purlins and girts should be checked to see they are in a true plane and securely fixed, all trimming completed for penetrations, and that any work by other trades is completed. It is the roofing contractors responsibility to ascertain if there are any penetrations or protrusions through the roof or wall plane that require additional structural support or that interfere with the correct fixing of the sheets.

Access to the finished roof should be restricted and liaison with the main contractor should provide the roofing contractor or supervisor with the assurance that the roof access would be controlled.

Structural steel work, treated timber or any other materials that might be incompatible with the roof or wall cladding and lead to deterioration should be painted or otherwise prevented from direct contact with the sheeting.

If the roofing contractor is in any doubt about the requirements, he should seek clarification and receive it, preferably in writing, before commencing the job. It is a requirement of the NZ Building Act that the contractor be responsible for his actions once he starts the contract, and failure to understand or follow this N.Z. Roofing Code of Practice, the manufacturer's recommendations or the drawings or specifications, will make him liable for rectification.

Where a warranty is required it should be arranged with the suppliers prior to ordering any material. (see **section 13.5.1. material selection**)

7.1.1 SETTING OUT AND LAYING

Netting support or safety mesh should be in position before roof cladding is commenced, and the underlay should be placed concurrently with the sheeting. *(see 4.3. underlay)*

Sheets should be ordered cut to length from the manufacturer to minimize any cutting on site. If onsite cutting is necessary, the underneath sheet should be protected from damage or marking. *(see section 7.1.5. Cutting and drilling)*

String lines should be used over purlin centre lines to keep fastenings in line and avoid 'missing' the purlin with the fastener. Staggered purlins require special attention and the pre-drilling of sheet stacks can be a risky option. Sheets should not be marked with black graphite pencil, as this can cause permanent etching or marking. Chalk, coloured pencils or any water-based pen will provide safe temporary marking.

Where it is possible sheets should be laid with side laps facing away from the line of sight. It should be noted that the local topography or obstructions can change the directional wind forces, and no reliance should be assumed that the weathering will be assisted in this manner.

The building squareness should not be assumed and should be checked.

The first sheet should be positioned square and straight to the end of the wall or the barge end of the roof area. The roof should be marked out so that when the last sheet is fixed the distance between the first and last sheet to the barge board is the same so that the barge treatment is identical for both ends of the structure.

The sheeting alignment should be checked every few sheets to prevent creep caused by stop ending or unequal fixing. The alignment should also be checked during fixing to ensure that the sheets are maintained at their product module to avoid any tendency to creep or spread particularly when the building is not square.

The sequence of fixing should be: laps first, then the internal fixings, and each sheet should be completely fixed as soon as possible.

Where transverse laps are unavoidable such as for curved laying procedures *(see section 4.9.3.)* where two or more sheets are used to cover from ridge to gutter they should be sealed and fastened with a minimum end lap of 150mm.

Roof cladding end laps should be avoided below 8°, by using a step flashing detail. *(see drawing 5.3.5.3.)*

The minimum end lap for horizontal wall cladding should be 100mm and be 75mm for vertical wall cladding.

A minimum overhang of 50mm should be allowed to extend beyond the gutter or spouting but this overhang dimension should be increased as the pitch of the roof decreases. *(see 7.1.4.)*

Sheets should be laid square to the building or this will give a saw-tooth effect at ridge and gutter lines, which is not acceptable. Any visible deviation greater than 5mm at the lap should be trimmed to a straight line.

Ladders should not be leant against sheeting unless precautions are taken against damage, and all cat ladders and roof boards should be padded.

7.1.2 DOWNTURNS

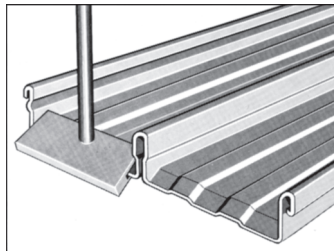
All roof cladding with a pitch less than 8° must be provided with downturns after the roof is fixed, using special tools to ensure water flows directly into the gutter.

Downturns are recommended for all profiles at all pitches using special tools to ensure water may easily flow directly into the gutter.

As the corrugate profile cannot be satisfactorily turned down, it is not permissible to terminate this profile below 8°. *(see section 4.9. curved roofs)*

Providing a profile with a downturn will provide a positive drip edge and minimise the amount of sediment build up at the gutter line.

Distortion should be avoided because it causes ponding and the collection of dirt, which in turn causes corrosion.



Drawing 7.1.2. 

7.1.3 STOPENDS

Stop-ending is more critical on low roof pitches or roofs in exposed positions.

Stopends for trapezoidal profiles are of two types:

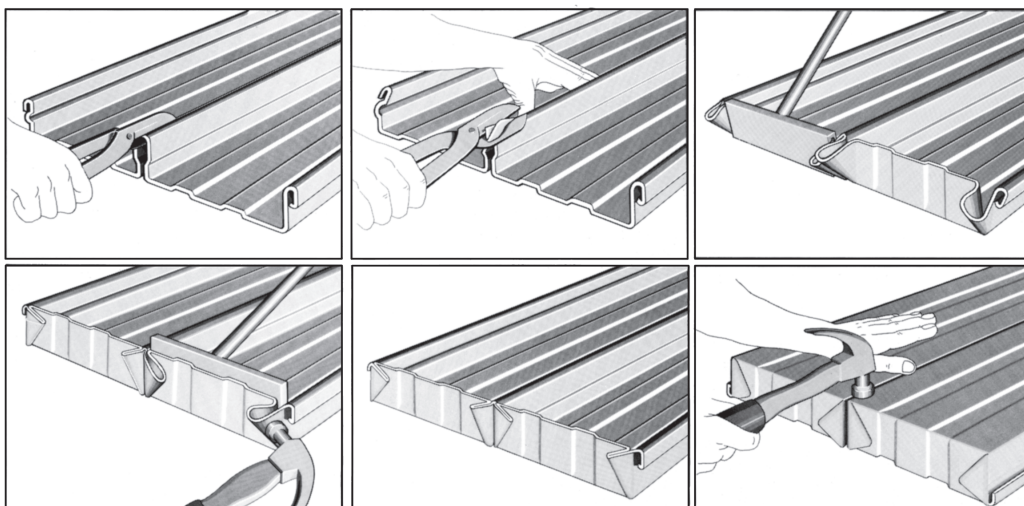
- 'dog-eared'
- 'pull-up'

All profiles at all pitches must have either 'dog-eared' or 'pull-up' stop-ends at the top end of the sheet.

Because most roofing profiles are manufactured from high tensile metals it is not possible to dog-ear stop-end some profiles. In exposed areas in addition to a pull-up stopend it is recommended that profile closures are installed to provide an additional baffle in the following circumstances. (see section 5.7.)

Vertical stop-ending for sinusoidal corrugate is simply achieved by the use of a 200mm adjustable type spanner, which has had the sharp edges removed. (see drawing 7.1.3B)

A 'dog-eared' or full stopend is made by cutting the rib back to the height of the profile so that the material can be dressed and 'wrapped around' 90°. (see drawing 7.1.3A) This is done to avoid blow back, which could occur if the stopend was left in the original 'pull-up' position.



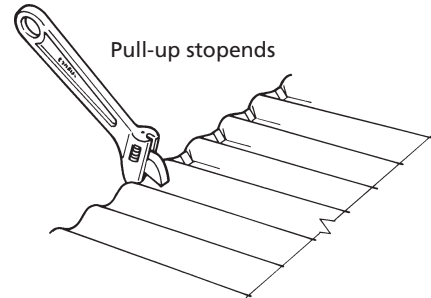
Drawing 7.1.3.A 

- Slit all ribs to length equivalent to their height.
- Cut away the tops of the ribs on a slight angle upwards and remove.
- Insert turn-up tool to full depth and turn up more than right angles
- Knock dogs ears flat onto stop-end tool as shown.
- Ensure tray is lying flat

Care should be taken when forming a full stopend as a depression can occur with some tray or wide pan trapezoidal claddings that can cause ponding at low pitches.

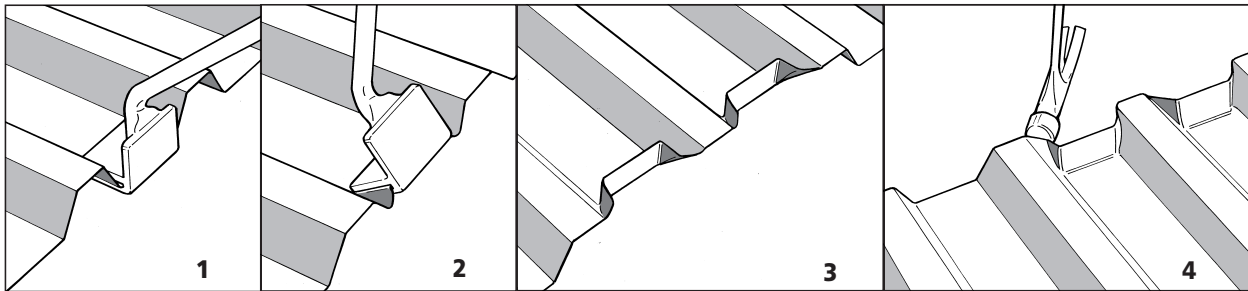
The rib height should be added to the sheet length when the material is ordered to provide an allowance for a full stopend.

Stopends are required on horizontal metal wall cladding at penetrations in exposed areas and they are also required where a horizontal sheet is cut at an angle at a gable end.



Drawing 7.1.3.B 

Stopends for corrugate (*see drawing 7.1.3.B*) should be pulled up full height of the profile, and on low pitches at exposed sites additional weathering may be provided by the use of filler blocks. (*see section 5.7. profile closures*)



- 1 Place stopend tool centrally in the pan.
- 2 Lift up steadily until the end is vertical.
- 3 Remove tool.
- 4 Hit up the open corner to reduce channel.

Drawing 7.1.3.C 

A 'pull-up' stopend is not cut back, but pulled up to the maximum allowable without tearing the metal. No extra material allowance is required for a 'pull-up' stopend. (*see drawing 7.1.3.C.*)

Stop-ending tools should be in good condition so that they do not mark the coating. This is particularly important when using pre-painted material.

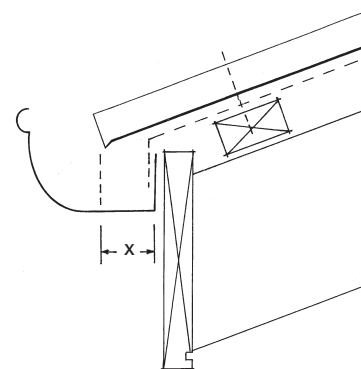
7.1.4 OVERHANG

The length of the overhang of sheeting into a gutter or spouting is dependant on the pitch of the roof and the site exposure to wind and rain.

The minimum overhang for roof cladding with a pitch between 10° and 35° is 50mm. and for a roof above 35° 40mm is regarded as suitable. When the ends of the ribs are not baffled by a spouting, and the pitch is below 10° the overhang should be increased to 70mm to avoid blow-back.

In areas of high or very high wind load additional methods are required to ensure there is no water ingress at this point and filler blocks, end-caps and overflashings will normally suffice but in exceptional cases a baffle may also be required.

(*see section 5.7. profile closures*) (*see drawing 5.3.5.4.*)



x = 50mm 10°- 35°
= 40mm >35°

Drawing 7.1.4. 

Where a ridgevent is used, the gutter or spouting line will be a natural inlet point of entry for air, and may by suction induce air and water up the open ribs of trapezoidal metal profiles. The length of the overhang on a step in the roof is greater as it is more vulnerable because it does not normally have a spouting or gutter to baffle the elements. (see drawings 5.3.5.4.)

Very wide gutters can also expose the roof cladding in a similar manner.

The overhang into a valley is also dependant on the pitch and for pitches greater than 12°, 50mm is the minimum with up to 80mm in very exposed areas. Pressed tiles should overhang a minimum of 40mm.

The roofing contractor should ensure that the precautions taken for the particular profile, including turndowns, overflashings, filler blocks and end caps are sufficient, either together or separately, to prevent blow-back at any particular building site.

7.1.5 CUTTING AND DRILLING

Metal roof and wall cladding must be cut using a guillotine, tin snips, power nibbler or a power shear. Sheets must be cut with the top surface facing downwards and must not be cut on top of unprotected roof cladding.

Swarf resulting from cutting or drilling holes must be removed from under fastenings, laps and the cut area.

A circular abrasive or metal cutting saw must not be used as the metallic or the paint coating is destroyed.

Areas adjacent to all cutting, sawing or drilling operations on cladding and flashings should be protected from deposits of swarf that can be carried by the wind. Such areas can include motor vehicles parked in the street below where the work is being carried out.

When nails are used, or where holes are punched, care should be taken to prevent localised distortion of the profile. Holes in roof sheeting should penetrate vertically through the crest of the ribs or corrugations except where pan fixing or side lap side fixing is specified.

Predrilling sheets prior to nailing prevents distortion and if sheets are drilled on the ground prior to lifting onto the roof, the removal of swarf is simplified, however the purlin distances should be checked and aligned to within $\pm 10\text{mm}$.

Where sheets or flashings are to be sealed, the rivet hole should be drilled prior to sealing, swarf and any protective film removed from the lap.

Only the correct size of drill should be used for drilling rivet holes or predrilling roof sheets but where oversize holes are required for washered screws, it is good practice to drill a pilot hole first.

7.2 SWARF

Cutting or drilling operations on any metal produces fine metallic filings known as swarf. Steel swarf will rust immediately on reaction with oxygen and water to produce a stain that is very often mistaken for the rusting of the substrate. Such damage to metal cladding and pre-painted steel coatings is avoidable but is the result of poor fixing practice or can be the result of the work of other trades.

If swarf is not immediately cleaned from pre-painted steel building products, damage can appear either as localised rust stains or as fine scratches from swarf embedded in shoes, and such marks will naturally detract from the performance or the appearance of the product. Non-ferrous metals also produce swarf, however as it does not rust it is not so obvious. It should however be removed in the same manner as for steel swarf.

There are several different types of swarf. The most common swarf left on metal roof sheeting is that left as a result of using self-drilling screws, which consist of helical shaped coils and small chips. This local type of swarf should be

regarded as a necessary part of the roofing process and can be easily removed by the worker who creates it, by regularly sweeping swarf into a receptacle with a nylon brush. Swarf can collect under flashings, screw heads, washers and in sheet laps, particularly with the use of horizontal cladding and staining can arise if swarf is not removed as soon as it is generated. A small magnet can be used to collect steel swarf, and extra care should be exercised when fastening the sheeting to structural steel as drilling heavy steel can produce a large amount of swarf.

Power nibblers provide a clean cut, but produce a metal cut out that can become embedded in the soles of footwear of persons working on the roof and be detrimental to the roof coatings.

For this reason any nibbling operation should be performed on the ground and not the roof, and this type of swarf should be cleaned up as it is produced. N.B. A power shear does not produce swarf.

Swarf produced by friction cutting or abrading equipment consists of fine metal particles, which have a large area of exposed steel and therefore corrode very readily. It can be easily distinguished from drilling swarf by the 'sandy' feel of round particles, and by close inspection of the area giving the appearance of rust marks having a central round spot with a diminishing stain halo. The particles generated by hole saws are also as the result of friction and are included in this category. This swarf is produced as hot particles and oxidation is rapid and they are not easily removed because they can embed themselves by melting or burning into the surface of the metal or coating.

Friction cutting equipment by definition produces heat, which destroys the metallic and paint coating in the vicinity of the cut and this method of cutting is unacceptable and material cut in this manner is not covered by any warranty.

Friction blade or carborundum disc cutting is not permissible on metal roof or wall cladding.

The roofing contractor will safeguard himself from any damage claim if round swarf is discovered, by not using any friction type cutting tools on site. Power shears, guillotines and hand snips do not produce swarf and in skilled hands are capable of cutting any shape required for the installation of metal cladding.

A common cause of swarf complaints arises because other trades have used grinding equipment in the vicinity of a newly completed roof. Wind carried swarf can contaminate large areas so designers and other contractors should be aware of the likelihood of such damage and project planning should include scheduling of all cutting or grinding work to be completed before any roof cladding is laid. Failure to do so can result consequential damage and the necessity for a reroof or repainting. The liability remains with the person who caused the damage and is not the responsibility of the roofing contractor.

Other debris that is created from the roof cladding process, including rivet stems, nails, screws, broken drill bits, tools, and used sealant cartridges if left lying on a roof surface, can all cause rust staining.

All debris should be removed daily from the roof cladding and gutters.

7.2.1 SWARF REMOVAL

Prevention of swarf damage is much easier than repair.

At the end of each day a clean up should be made of the work area by either sweeping or hosing down with a soft-bristled broom thus ensuring the removal of all debris from the roof and gutters.

Dew or condensation will produce rust overnight so the swarf should be collected as it is produced. A screw gun with a magnetic bit can be useful for this purpose.

As swarf particles are sharp, care should be taken not to damage the surface coating by wearing clean, soft-soled shoes that do not collect swarf, dirt and gravel. Damage can be minimised by placing a mat or sacking at the base of the ladder so that shoes can be cleaned before moving on to the roof. Safety shoes should be removed at the roof level because they cause damage to roof cladding.

All contractors with access to the job should follow the same rules for cleaning up, work practices and also footwear, as other trades are often responsible for causing damage that is incorrectly attributed to the roofing contractor.

7.2.2 SWARF DAMAGE

If the swarf staining comes from drillings only, it is likely that the effect on pre-coated claddings will be aesthetic only and that the performance of the sheeting will not be greatly affected. This is not the case when hot swarf has embedded itself into the paint surface and is in contact with the metallic coating. In weathering away by oxidation, the metallic coating will sacrifice itself to the bare steel swarf in the immediate vicinity and the life of the coating will be shortened. This situation occurs with plain AZ, ZA, and G metallic coatings, where claddings are not pre-painted, and any swarf left on the surface will be detrimental to the longevity of the sheeting.

No cure will restore the surface to its original condition, but damage can be reduced by prompt action.

Mild swarf stains can be removed by the use of a dishwashing liquid that should be applied sparingly with a soft cloth to the immediate area. For stubborn swarf that has been left for some time and adhered to the surface, the careful use of a nylon pot cleaner may be necessary. The immediate area should be cleaned without undue pressure, as this could mar the paint surface, and the whole area should be washed down with copious amounts of water to ensure there is no remaining cleaner left on the roof.

The factory applied acrylic coating on AZ coatings, can be easily damaged and should not be scrubbed as it will cause a patchy darkening of the surface that will become evident in the repair areas.

Where extensive areas have been affected by grinding swarf, more drastic action may be required. In severe cases the immediate swarf areas should be scrubbed with a stiff bristle brush until all the swarf particles are removed, as any remaining swarf will bleed through subsequent coating. If the affected areas show through to the metallic coating, these should be primed first, and the total area of the visible roof cladding over-painted with two coats of acrylic paint. Air-drying paints weather more rapidly than factory applied coatings, and quickly display colour changes, so patch painting is not a recommended option. Minor scratching or abrasions should be left alone and not be painted for the same reason.

7.3 FASTENERS

A fastener is a mechanical device used to secure cladding and components to a structure or to another component and includes nails screws, clips, and bolts. Fasteners are also commonly known as fastenings and fixings, which is confusing because a fixing describes the result achieved by the use of a fastener by a fixer, and the verb to fix and to fasten are interchangeable.

The strength of a fastener relates to the mechanical properties of the fastener alone, whereas the strength of a fixing relates to the minimum value of pullout, pull-over, washer inversion and strip-out capacities. These values are obtained from the strength of the member into which the fastener is secured and also of the component that is being restrained.

The performance data published by the fastener manufacturer, and that described in AS 3566 relate to the product only and should not be used for design purposes. Values assessed by the manufacturer do not necessarily follow the methodology required to obtain applicable design load values.

The design load required for metal cladding and accessories is for the joint and not the fastener.

Because the durability of a fastener will determine the long term performance of the metal cladding the fastener and its coating should be compatible and suitable for the environment.

7.3.1 PRIMARY FASTENERS

Primary fasteners are those that attach roof or wall cladding to the building frame, and because they are relied upon for structural performance, they should be capable of withstanding the design withdrawal load, specific to the site and to their location on the building. They should be able to withstand all loads applied to the sheeting including those due to expansion and still remain watertight.

All types of fasteners should not be overdriven as this can damage the sealing washer and distort the roof cladding and cause leaks. Screw fasteners should not be overdriven as this can affect the pullout values and cause strip-out when fastening to light gauge purlins or battens.

The shank diameter and thread type of the fastener will determine the withdrawal loads into either timber or steel, so the designer or contractor should ensure that the fastener complies with the requirements of **graph 3.6.2.** for steel fixing or **table 3.6.** for timber fixing.

The number of fasteners per m² required to resist all wind or other loads on a building depends on the type of fastening.

Primary fasteners for timber consist of nails and screws with varying diameters but their performance should be individually assessed.

When using light gauge metal roof and wall cladding the size of the head will determine the performance of the sheeting under load as the calculation of pull-over strength assume that either the screw or the nail washer has a minimum head size of 12mm. (*see pull-over values section 7.8.2.*)

Fasteners with heads less than 12mm, such as wafer heads and proprietary screws for fixing miniature profiles used without metal or sealing washers, should not be regarded as a substitute for primary fixings for metal claddings. These fixings can be used with different fastening patterns to those in **section 7.9.** but the pull-over load should be determined from tests and not confused with the pull-out values provided by the manufacturer.

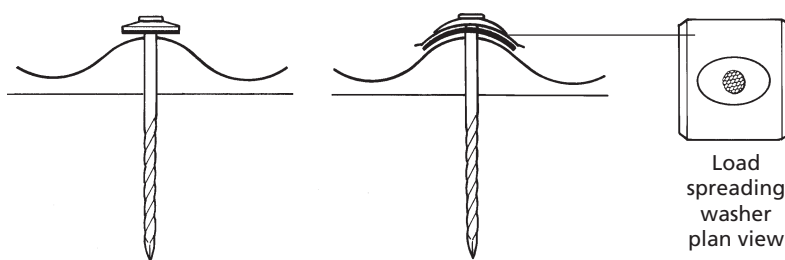
The fastener to connect battens or purlins to the structure is a primary fastener and if the roofing contractor is responsible for attaching these members, the wind uplift load should be determined. (*see wind load section 3.3.*) and **table 3.6.**

7.3.2 NAILS

Only enhanced shank nails with metal and sealing washers must be used as primary fasteners to secure metal roof and wall cladding and smooth shank nails must not be used.

Nails are usually hand driven except when used for fastening clips for secret fix or fully supported roof or wall cladding, when air or gas operated nail guns may be used.

The withdrawal load of nails from timber is very dependent on the type of wood and its moisture content at the time of driving. The moisture content should be < 18% but if it is higher then screws should be used in lieu of nails.



Drawing 7.3.2. 

The traditional New Zealand roof fastener was until 1980 the "Lead Head", a flat-headed smooth shank steel nail with a lead head cast on it. Lead heads often 'backed out' causing leaks, which has led to the mistaken belief that nails have to be "hammered home".

Spiral Shank nail fasteners rely on the frictional grip of the spiral shank of the nail to hold into the timber, and the holding power of a spiral shank exceeds that of a smooth shank by two to three times. The seal produced by a resilient washer bonded to a metal washer requires only 50% compression to produce a seal.

Spiral shank nails should not be overdriven or the washer seal will be impaired. Spiral Shank nails used to fix metal roof and wall cladding should have a hot dipped galvanised coating of 70 microns in thickness. Potentially rust-causing damage to the head from hammering can be minimised by using a nylon-faced hammer. Only factory paint coated nails and washers should be used with pre-painted cladding and galvanised nails should only be used with zinc or AZ coated sheeting. Painted stainless nails can be used for fastening non-ferrous and plastic roof and wall cladding in severe and very severe environments and if other exotic coatings are to be used or unusual corrosion conditions exist, painted stainless steel nails should be used.

Only paint coated stainless nails and washers may be used with paint coated aluminium roof and wall cladding. Factory coated stainless steel nails and washers are available to colour match cladding for environmental conditions where zinc coated fasteners would not perform their function for the 15 years required by the NZBC, or where aesthetic appearance is paramount.

Acrylic paint should not be applied directly onto galvanised nails or washers without a suitable primer. The nail should always be hammered in at right angles to the roof and if the purlin is missed no attempt should be made to "skew" the nail and the hole should be sealed with a rivet and neutral cure sealant or the sheet should be replaced. The holding power of any nail in timber is reliant on the timber moisture content not only when nailed but also in service.

Any nail, including those with an enhanced shank, can 'back-out' during the life of the roof cladding if the moisture content exceeds 18% when it is driven.

Minimum penetration of nails into timber must be 40mm.

7.3.3 SCREWS

Self-drilling screws with a pierce point and a thread suitable for drilling into timber with a hexagon head are designated as Type 17. A screw gun can provide sufficient torque for a type 17 screw to pierce metal roof cladding profiles and thread themselves into softwood whereas hardwoods may require a pilot hole.



Drill point



Pierce point

Drawing 7.3.3.A 

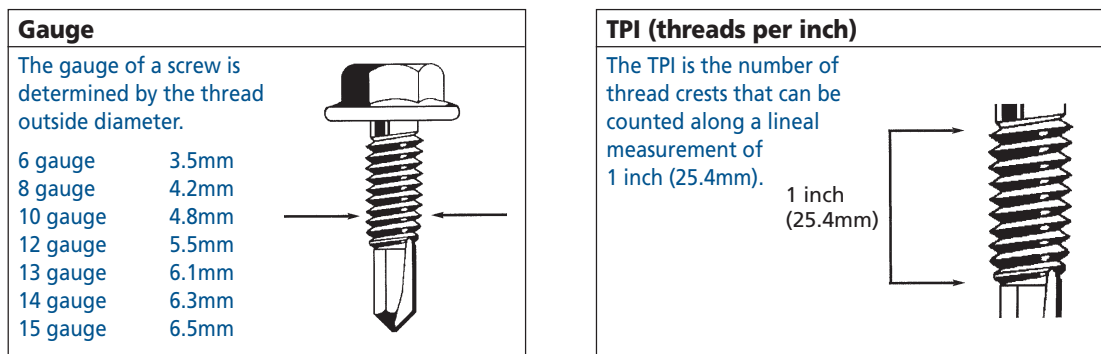
Drill pointed screws designed to drill a hole into steel suitable for the thread and metal thickness are known as self-drilling screws and have three common thread types, known as A, B, and C.

The threads per inch (TPI) vary. T.P.I. is the number of thread crests that can be counted in a length of 1" (25.4mm)

GAUGE	DIAMETERS NOMINAL		THREADS PER INCH TPI			HEAD
	SHANK mm	THREAD mm	THREAD TYPE			
			A	B	C	
6	2.5	3.5		20	32	Pozidrive/Philips
8	3.0	4.2		18	32	1/4" HEX
10	3.5	4.8		16	24	5/16" HEX
12	4.1	5.5	11	14	24	5/16" HEX
14	4.8	6.3	10	14	20	3/8" HEX

Table 7.3.3. Self drilling screws

Coarser threads less than 17 TPI are used to fix roof and wall cladding, however when fixing to steel thicker than 2.4mm a finer thread, known as a metal thread, is used. Different thread configurations are available for special applications and some shanks are provided with a gripping thread at the top of the shank



Drawing 7.3.3.B 

All fasteners must be easily identified by a code stamped on the head to identify the manufacturer and the coating class. The size, type, length, head type and the standard to which the fastener is manufactured must be identified on the packaging and in the manufacturers literature.

When counterbattens are used, and the primary cladding fastener does not always penetrate the structure, the fastener used to secure the counterbatten to the structure also becomes a primary fixing.

When solid sarking, insulation or decking is interposed between the cladding and the structure, the design uplift force on the decking should be resisted by the total number of fasteners per m² multiplied by their individual capacity. (**section 3.0. loadings**)

Screws that are to be used as a structural fastener such as in a stressed skin roof design or structural purlin/rafter connection should be made using a screw gun with an adjustable torque setting to ensure consistency of fastening.

Stainless screws should be driven with a new driving socket so that steel smear from a used or worn socket head does not contaminate the stainless steel screw head. Alternatively a stainless socket should be used.

While the common roofing screw is a class 4 coated steel screw, stainless steel and aluminium are alternatives.

The 14# aluminium screws available are suitable for rib fastening of profile metal cladding into timber purlins and 12# are suitable for pan fixing.

They require the predrilling into timber and are not suitable for fixing into steel. Care should be taken not to overdrive aluminium screws as their shear strength is less than steel.

Stainless screws are available in 304 and 316 with 304 being the preferred fixing for aluminium cladding. Both types of screw are suitable for very severe environments provided their shank is isolated by a predrilled over size hole and a load spreading washer made from the same metal with a EPDM sealing washer is used.

7.4 SECONDARY FASTENERS

Secondary fasteners are used to attach cladding sheets to one another, to transfer loads, to provide side lap sealing, and should be used in conjunction with primary fasteners to comply with the site wind design load. Because side and end laps are subject to shear loading caused by expansion and differential movement, the wind load and point load requirements will not be met unless secondary fasteners are used.

On all purlin spacings that exceed 1.200m all laps should be stitched at mid-span with coarse thread stitching screws or self sealing bulb 4.8mm aluminium blind rivets. This applies when fixing all ribbed metal profiled self supporting cladding, except for self-locking profiles.

Screw fasteners where the thread stops short of the head and ensuring that "stripping out" cannot occur are available for side lap fastening.

7.4.1 RIVETS

The rivets used in fixing roof and wall cladding and referred to below are 'blind' or 'pop' rivets that are able to be fastened only from one side. Sealed type rivets are recommended

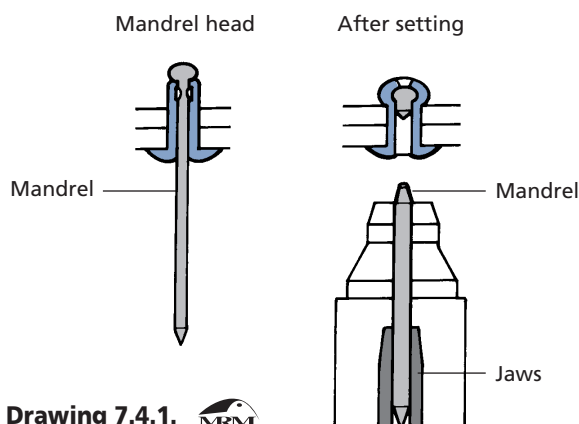
Zinc-plated steel rivets should not be used for roof or wall cladding in New Zealand because they do not meet the durability requirements of the NZBC. 3.2mm diameter rivets should not be used because they do not have the shear capacity required for fixing metal roof and wall cladding.

Rivets are manufactured in various shapes, sizes and materials and because the head sizes are usually smaller than screws they are all subject to pull-over failure in tension. It is therefore necessary to use a greater number of rivets than screws to fasten the same joint because washers provide increased pull-over capacity for screws.

The correct drill size should be used when drilling metal for blind rivets which is 0.1mm greater than the nominal rivet diameter.

RIVET DIAMETER	DRILL SIZE
4.0mm	4.1mm
4.8mm	4.9mm
6.3mm	6.4mm

Rivets should not be spaced $< 3d$ or $> 20d$ to minimise distortion when d = diameter of the rivet.



Drawing 7.4.1. 

Minimum shear and axial tensile capacity (strength) of break mandrel blind rivets

Code	Drill size	Nominal diameter		Nominal head diameter	Minimum shear capacity (strength) (kN)			Minimum axial tensile capacity (strength) (kN)		
	mm	Inches	mm	mm	Al	M	S/S	Al	M	S/S
5	4.1	5/32	4.0	8.0	1.3	2.5	3.0	1.62	3.24	3.8
6	4.9	3/16	4.8	9.5	1.6	3.7	4.4	2.3	4.63	5.5
8	6.5	1/4	6.3	12.7	3.2	6.48	7.8	4.26	8.56	9.72

Al = aluminium alloy, 5154, 5056, 5754 with carbon steel mandrel

M = nickel-copper alloy (Monel) with carbon steel mandrel

S/S = 300 series stainless steel with carbon or stainless steel mandrel

Table 7.4.1. 

The values in table 7.4.1 should be multiplied by ϕ the reduction factor = 0.65 for shear and 0.50 for tilting and bearing.

7.4.2 MONEL RIVETS

Monel Rivets have been used to fix galvanised steel flashings for many years. In theory because zinc and monel are far apart on the galvanic scale, corrosion of the galvanised steel could be expected to occur. This does not often happen in practice because of the natural passivation of the monel that occurs in normal environments, and because the area of the rivet (the cathode) is small compared to the sheeting (the anode). The copper content of the monel is low and being alloyed with nickel gives good performance in most environments. In an aggressive marine or industrial environment a barrier coating is needed to avoid any likelihood of corrosion.

N.B. The use of monel rivets with Zinc/Aluminium coating may compromise the manufacturers warranty.

7.4.3 ALUMINIUM RIVETS

Aluminium Rivets are compatible with zinc or AZ coated steel but have a shear performance of less than half that of monel or stainless steel rivets. They are available in open and sealed types.

Because of the high shear expansion forces developed in roof cladding and flashings the minimum diameter of aluminium rivets used in roof or wall cladding must be 4.0mm 5/32"

7.4.4 STAINLESS STEEL RIVETS

Stainless Steel rivets have been used historically in a similar manner to monel but in aggressive marine or industrial environments a separation barrier should be used between dissimilar metals.

7.4.5 SPACING

Spacing and size of rivets is related to the likely stress imposed at the connection, so as the strength of the rivet increases, the spacing may also increase.

The following maximum spacings should not be exceeded when sealing and joining gutter or cappings.

Diameter	Spacing
4.0mm (5/32")	50mm
4.8mm (3/16")	60mm

N.B. This equates to approximately 12d where d = diameter of the rivet

7.4.6 FASTENER FREQUENCY

The fastener frequency for fixing roof and wall cladding is determined by the wind uplift load for the particular site and the gauge of the cladding. In low wind load areas the frequency may be determined by a sufficient number to prevent the cladding from 'flutter' or noise associated with the relative movement of the cladding against the structure.

Uniform linear fastening pattern should be used to resist wind uplift loads, however, additional staggered fastening may be necessary to avoid noise and flutter.

Nailing and screwing patterns are shown *in section 7.9.* and the pullover values *in section 7.8.2.*

The frequency for primary fasteners should not exceed 600mm and where this is not possible a secondary fastener should be used at closer spacings. Where fixing is not provided for primary fasteners, secondary fasteners such as stitching screws, type 17 and 4.8mm alum rivets can be used providing their number and frequency equates with the equivalent primary fastening for the wind design load.

7.5 FIXING

7.5.1 CREST FIXING

Crest fixing is the most common type of fastening of roof cladding in New Zealand.

For fixing into timber a Type 17 self-drilling fastener that has a pierce point slot thread is used, which penetrates the roofing metal and then threads itself into timber.

The embedment into softwood must be a minimum of 35mm and greater than 6 times the screw thread diameter.

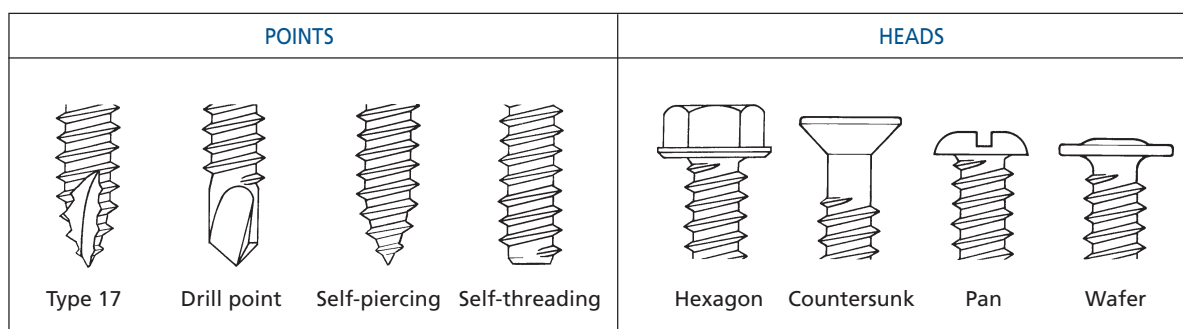
For fixing into steel a self-drilling fastener is used that has a drill point of a diameter suitable for the tapping size of the fastener. Extended drill points are available for drilling up to 12mm thick steel and the pitch spacing of threads should be increased as the steel thickness decreases. (*see table 7.3.3.*)

Steel embedment should be 5 - 6mm beyond the drill point with a minimum of 3 threads beyond the drill point.

Screws are specified by gauge, TPI (threads per inch), and length.

Self-threading screws require a pre-drilled hole in the cladding and structure and the required tapping size drill diameter is specifically determined by the T.P.I. and gauge of the fastener.

Both self-drilling and self-tapping screws can have different points, TPI, and heads to suit the particular requirements of the connection.



Drawing 7.5.1. 

7.5.2 PAN FIXING

Pan or trough fixing is commonly used for wall fixing although it is not widely used for fixing roof cladding in N.Z. Pan fixing is common practice in Europe and offers an economical alternative to rib fixing.

Pan fixing can be used for roof as well as wall fixing provided certain fixing conditions are met:

- Light coloured roofs are limited to 12m thereafter with sliding washers and crest fixed.
- Dark coloured roofs are limited to 8m thereafter with sliding washers and crest fixed.
- If the insulation is laid close to the roof cladding, deduct 4m of pan fixing from the above.
- If the ceiling is insulated the roof cavity should be vented by a ridge ventilator or other permanent vents.
- Metal roofs that are not post painted should be regarded as dark coloured due to the oxidation and change in colour and surface over a number of years.
- Translucent fibreglass sheets can be pan fixed for 8m then crest fixed with sliding washers for 4m limited to 12m maximum.
- Fasteners should be a minimum of 12 x 20mm self drilling for steel purlins and 12 x 40mm for timber both using a 25mm metal and sealing washer.
- All fasteners should be driven "snug tight" with a torque driver, or depth locator
- Fasteners should be placed within 50mm of the rib of the sheeting but allowing 25mm clearance for water egress.

N.B. The pull over design values established by test for pan fixing are more than twice those for crest fixing.

All sheets should have full bearing on all purlins that they cross, to ensure a positive seal. Care should be taken to fix at right angles to the roof, and purlin flange alignment is critical if purlin creasing is to be avoided.

Corrugate and symmetrical profiles should not be pan fixed for roof cladding.

Pan fixing of roof cladding, is used in USA and Europe because of its cost and efficiency, as the pull over values are increased and it also provides a much more effective shear diaphragm up to 8m cladding length.

7.5.3 EXPANSION FIXINGS

By drilling an oversize hole for the fastener, a limited amount of movement between the fastener and the cladding can be provided. When a greater amount of expansion is required, sliding fixings are necessary to allow for expansion and contraction with long lengths of sheeting. (see table 4.1.6)

They are of two main types:

- Sliding washers are used where the sheet and the fastener are separated by a material of low coefficient of friction such as teflon, enabling them to move independently in elongated holes.

N.B. The seal should be made between the roof cladding and the washer by placing the sliding face (teflon) upwards and the sealing face down onto the cladding.

Where an oversized or elongated hole is used the sealing washer must be wide enough to seal the hole.

- Sliding Roof is where a clip is securely fastened to the structure and a longitudinal groove in the roof cladding profile provides clearance to enable movement of the roof cladding to take place.

7.5.4 LAP STITCHING

All roof or wall cladding must be lap stitched at midspan when purlin spacings exceed 1.200m except self-locking and fully-supported cladding profiles.

Lap-fixings must be coarse thread stitching screws with a neoprene washer or self sealing bulbtite 4.8mm diameter aluminium blind rivets.

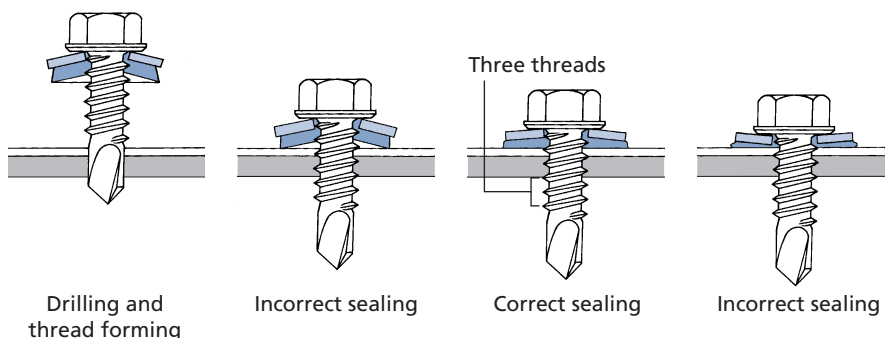
Without lap stitching the wind and point load performance will not comply with the load span graphs *in section 3.9*.

7.6 INSTALLATION

7.6.1 DRIVING

Self-drilling screws used for drilling into steel require the correct length and thread type, and should have three threads extending past the fastened metal, as shown *in drawing 7.6.1.A*. The drill should have finished drilling into the structural member before the thread engages into it. When driving pan fixings and the fastened material and the material fastened into are similar in thickness, the fastened material should be predrilled.

Pre-drilling is also necessary when multiple plies are fastened. Different headed fasteners are used for different purposes, but the driving bit should be capable of providing sufficient torque to ensure the fastener is not under-driven. Socket headed screws provide better torque than recessed heads and square heads provide better torque than other types.



Drawing 7.6.1.A. 

The correct depth setting on a screw gun is provided either by the depth gauge or by a clutch torque adjustment, and an adjustment should be made every time a different screw or material thickness is to be drilled.

The sealing of the resilient washer under the fastener head will only provide a watertight seal if an adjustment is made. Experienced operators can, in most instances, drive screws correctly by using a variable speed screw gun, however when fastening into light gauge structural components, the cladding to be fastened should be predrilled to avoid stripping out.

Screw drivers driving screws into timber 'part' the fibres rather than cut them which provides a self-locking action against withdrawal.

Impact drivers do not drive in this manner and are therefore not recommended for driving roofing screws.

The rolled thread on crest fasteners longer than 25mm, stops before the head, whereas a shorter length screw has the thread rolled up to the head. This means that when driving a crest fixing a clearance hole is provided for the material being fastened and the only driving torque required is that to fasten into the structural member. When driving a pan fixing, both the material being fastened and the structural member should be threaded together and if they are not sufficiently clamped, broken screws or stripout will occur.

Common problems encountered when fixing roof or wall cladding with type 17 or self-drilling screws are usually the result of incorrect screws, incorrect screw gun or adjustment, or user error.

When drilling into steel, the drill point travels approximately ten times slower than the thread engagement speed, so if the drill point is not long enough to penetrate both thicknesses of material, the screw is likely to shear.

Problem	Answer
Difficult to start	Hold screw gun at right angles to the cladding Check rotation of screw gun Apply greater force
Screw wobbles and is difficult to start	Wrong driver bit Check rotation of screw gun Drill point malformed
Screw heads break off	Incorrect clutch or depth adjustment Drill bit not long enough Too small a screw for the material thickness
Threads strip out	Incorrect screw thread for material thickness Incorrect clutch or depth adjustment Material not predrilled
Drill point breaks	Clamp material together if there is an air gap Pre drill multiple plies Check rotation of screw gun Drill bit not long enough
Driver bits break	Incorrect bit (Phillips or Posidrive) Incorrect adjustment
Sealing washer squashes out	Incorrect adjustment Too much force.

7.6.2 TOOLS

Power screwdrivers should be provided with an adjustable depth setting or a torque setting clutch to avoid overdriving. Ideally the driver should have variable speed.

Recommended drilling speeds

MATERIAL	SCREW	RPM
Steel into Steel	Drill Point	2500
Steel into Timber	Pierce Point	1500
Steel into Steel (.9mm)	Drill Point	1000
Stainless Steel	Drill Point	800
Any self-tapping	Self-threading	300

To avoid damage to the head of the fastener or coating, sockets should be well-fitting and in good condition and drive bits should be the correct size (2 or 3) and type (Phillips or Pozidrive) or square drive.

The speed of the drill point into steel is only 1/10 of the speed at which the thread of the screw advances, so that a clutch or depth gauge is necessary to avoid stripping out. When drilling 3mm steel the actual drilling takes seven seconds but the threading takes less than one second, so the reaction is immediate and should be automatic to avoid damaging the roof cladding.

When drilling thick steel, elongated drill points are necessary to avoid breaking the screw. Alternatively a self-threading screw can be used using a pre-drilled hole suitable for the gauge and thread of the screw.

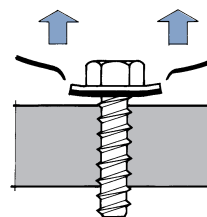
When fasteners are used to secure to a metal < 0.9mm even at a low torque setting strip-out can occur if the screw is driven at too fast a speed.

7.6.3 MODES OF FAILURE

Failure of the cladding/structure connection can be caused by several different causes.

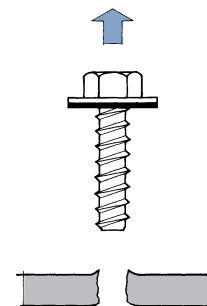
- 1. Pull-over.** Where the service load causes the sheet to be pulled over the fastener head due to:

- insufficient number of fasteners
- no load spreading washers
- incorrect washer diameter or shape
- insufficient washer thickness



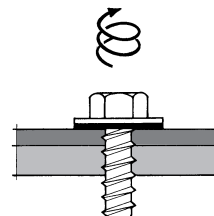
- 2. Pull-out.** Where the fastener is pulled out of the support member due to:

- insufficient number of fasteners
- insufficient penetration
- incorrect choice of type of fastener
- failure to install correctly



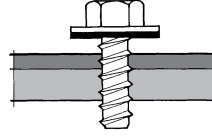
- 3. Thread strip-out because:**

- the fastener is over driven
- the predrilled hole is too large
- screw gun depth gauge is incorrectly set
- tilting and bearing failure caused by differential movement



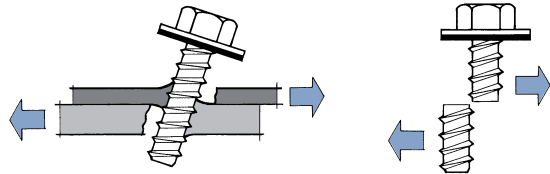
4. **Backout.** Where the fastener works loose due to:

- insufficient number of fasteners
- incorrect selection of thread type
- timber moisture content over 18%
- mechanical vibration of the structure
- predrilled hole too large



5. **Shear of fasteners**

- insufficient number of fasteners
- too small a screw diameter
- differential movement between sheet and support



6. **Corrosion from:**

- incorrect fastener material selection for the type of external environment
- incorrect fastener material selection for the type of internal environment
- damage when the nail, or screw is driven
- using non-compliant fasteners see AS 3566

7.7 FASTENER LOADS

Fasteners used to fix metal cladding can fail by pulling out of the structure or the cladding can fail by pull-over or profile collapse.

Where wind design load is high and the purlin spacings are designed for maximum roof cladding spans, sufficient fasteners should be used to avoid permanent deformation that can cause leakage.

Because of the increase in wind design load around the edges of roofs and corners of buildings, the fastener load is increased and more fasteners should be used than are used on the main body of the roof.

The purlin subject to the highest load is often the penultimate purlin - the second purlin from the eave, and as the edges of roofs and the corners of buildings are subject to higher wind loads, different fixing patterns are required.

Failure of most roofs at normal spans under wind uplift load occurs first as a serviceability failure by a dimpling the roof cladding at the fastener and will lead to ultimate failure as the cladding will not be able to sustain the design load.

An increase in the load capacity can be obtained by using load spreading washers under the fastener which can increase the load to failure by over 60%.

7.7.1 LOAD SPREADING WASHERS

Load spreading washers are used to provide additional support for metal roof or wall cladding under high design wind loads and the type, size and stiffness of washers are critical for the integrity of the cladding. Load spreading washers should be manufactured from metal that will withstand the effects of weather and atmosphere over the expected life of the roof and fasteners. The shape of the washers should be specifically and accurately formed to fit the profile and should not deform under serviceability loads.

Large metal load-spreading washers should be used when the purlin spacing is large or the design wind load is high but they should not be so large as to impede water runoff or to prevent sealing.

When oversized holes are used to accommodate thermal movement of the sheeting, load spreading washers should always be used. Load spreading washers are made to suit individual profiles and are not interchangeable, they should not be used inappropriately, as this can cause a lack of seal and consequent leakage.

Load-spreading washers should be made from a greater thickness than the sheeting to avoid inversion, and although it is interdependent on the size and shape of the washer, they should be a minimum thickness of 0.95mm coated steel for steel cladding. Non-ferrous washers should be a minimum of 1.2mm. (see *drawing 7.3.2.*)

Load-spreading washers are also used to avoid fatigue failure at the hole, particularly when this is drilled oversize and subject to cyclic loading. Fatigue failure has been recorded at much lower design values than those of static loads derived from wind design loads. Round aluminium embossed washers are not regarded as load-spreading on profiled metal cladding.

7.7.2 SEALING WASHERS

All fixings that pierce the sheeting should be provided with adequate sealing washers to prevent leakage.

Fixings should be tightened only sufficiently to form a weatherproof seal without damage to the sealing washer or deformation of the sheet profile.

Where pan or valley fixings are used, positive sealing is necessary to prevent leakage. The fixings should not obstruct the free flow of water and should not be over-tightened. When driving the fastener, rotating the washer will also cause inadequate sealing.

Nails or fasteners should also not be overdriven as this can damage the washer or deform the roof profile with consequence that water will pond around the seal. Swarf should be removed from under the sealing washer as it not only will cause staining, but can also interfere with the seal.

Sealing washers should be made from:

- Ethylene Propylene Diene Monomer (EPDM)
- Neoprene containing no more than 15% carbon black filler by volume or 25% by weight.
- Closed Cell PVC foam or other UV resistant resilient material that will perform its function for at least 15 years and is compatible with the roofing material. N.B. some foam washers do not remain flexible over this period of time and this may jeopardise the sealing capacity of the washer.

7.8 PERFORMANCE

The ideal structural design performance for a fastener is to fail simultaneously with the sheeting or the structure. Most failures occur due to negative load or uplift conditions and testing procedures are designed to closely simulate these conditions.

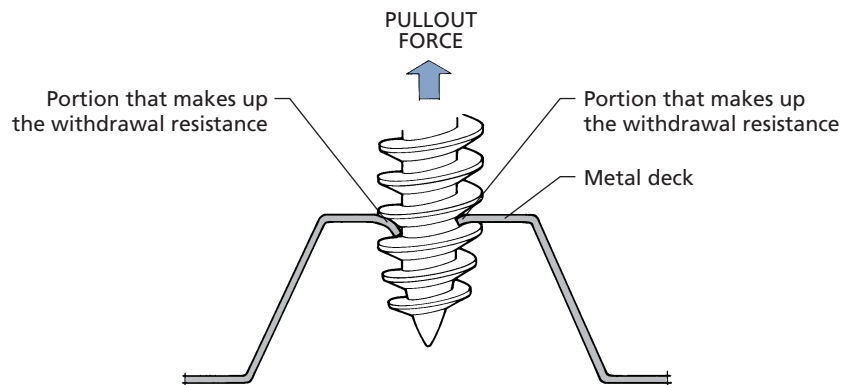
Because high strength roofing profiles have been designed for maximum performance and increased purlin spacings, the fastener is also required to have improved performance. If every rib has a fastener the only way to improve performance is to use a load spreading washer under the fastener head.

The withdrawal load of a fastener is determined by the material to which it is fastened. The pull-out load of the fastener from timber is determined by the density and moisture content of the timber, the shank type, surface of the nail and the depth of embedment. The pull-out load of the fastener from steel is determined by the thickness of the steel and the threads per inch (TPI) of the screw. Failure under serviceability limit state will occur when permanent deformation around the screw or nail allows water ingress under the sealing washer. This failure is often the precursor of ultimate failure, which under ultimate limit state occurs either when the fastener pulls out or when the sheeting pulls over the fastener.

7.8.1 PULL-OUT VALUES

When fastening into steel, it is necessary to match the number of threads per inch (T.P.I.) - the thread pitch to the material thickness and to use a torque limiter or a depth gauge to avoid stripping out.

Coarser pitch threads give better results with thinner sheets as the thread-rolling manufacturing process determines the depth of thread i.e. the finer the thread pitch the shallower the thread depth. The extrusion process caused by driving coarser threads into light gauge steels also allows for higher torque loads before strip out.



Drawing 7.8.1. 

Self drilling screws should not be used for structural purposes if the thickness of the steel is $< 0.75\text{mm}$, where only self piercing coarse threaded screws should be used.

The type of head of the fastener often determines the torque obtainable. Recessed Phillips or Pozidrive heads, unless driven in a controlled factory situation, are self limiting, i.e. the driver will slip out of the screw head before maximum torque is achieved. Square or hexagon head drive bits offer more consistent results.

AS3566 requires the same minimum pullout values for screws from 1.6mm G250 steel or F5 Radiata Pine with a maximum moisture content of 15% and a minimum density of 380 kg/m^3

10#	2.5 KN
12#	2.8 KN
14#	3.1 KN

These values should not be used for design pull-out values in steel $< 1.6\text{mm}$ in thickness or $< 35\text{mm}$ embedment in timber.

If this value is equated to one fastener per m^2 , it can be seen that a greater number of fasteners would be required to prevent the roof cladding from rattling. Where there are large purlin spacings and high design loads these values may be critical.

The pull out load of a self-drilling fastener fastened into steel is determined by the ratio of the hole diameter to the thread diameter. The drill point should have flutes longer than the total thickness of the steel being drilled to prevent swarf clogging the flutes. The helix of drill points used for drilling heavy structural steel is shallower for this reason, but care should be taken with some metals that the flutes are able to remove the swarf, and if they are not, the screw should be withdrawn and cleared.

To avoid breaking fasteners the drill point should have completed drilling before threading. Minimised points are available to avoid the removal of too much metal when fastening light gauge steel.

Pull out loads are usually in excess of those that will cause failure of the sheeting profile, either by buckling or by dimpling at the fastener or washer.

Nail pullout can be the mode of failure if nails are driven into wet timber or have insufficient penetration depth, or an insufficient number of fasteners are used. All nails used for fastening roof and wall cladding should have enhanced shanks.

7.8.2 PULL-OVER VALUES

When metal cladding is subjected to uplift wind loads within the withdrawal capacity of the fastener, the failure mode will be pull-over or pull-through. The pull-over value is determined by the thickness and strength of the metal, and the area over which the load is spread and is given in **table 7.8.2**.

If the pull-through or pull-over load is likely to be exceeded then the only options are to increase the thickness of the metal or use a load spreading washer. The pull-over value when using 0.70mm aluminium is approximately the same as 0.40mm steel.

The design value given in **table 7.8.2** for the pull over of screws and nails for crest fixing with and without load spreading washers is subject to a minimum penetration depth of 35mm in pinus radiata, or a minimum penetration of three threads past the steel to which the cladding is fastened. It should be noted that the pull over load is very dependent on the head or washer size, and as 12# and 14# screw heads are approximately the same diameter there is no design load value difference between these sizes of screws for pull over. The nail washer diameter of 18mm compared with a 13mm head for a screw has been ignored.

Cladding mm	Nail/screw	Load spreading washer	Design value
0.40mm	*		0.4 kN
0.40mm	*	*	0.7 kN
0.55mm	*		0.5 kN
0.55mm	*	*	0.9 kN

Table 7.8.2. Pull over values for crest fixing

These values are for individual screws and nails, and to obtain the pullover value for roof cladding in service, this value should be multiplied by the number of fasteners per m².

The pull over values for the pan fixing of cladding are in excess of those obtained by crest fixing by a factor greater than 2, although this is dependent on the position of the screw in the pan. (*see pan fixing 7.5.2*)

As wall cladding is also subject to the same kl factor load as roof cladding, an increase of fastener pull over load is required at the corners of all walls and a decreased purlin spacing may also be necessary.

Common roofing practice in New Zealand is to use load-spreading washers to prevent pullover where high uplift loads exist. 12 gauge screws are usually more than adequate for rib fixing, but if extra provision is needed for expansion when using long lengths of strong roofing profiles, then 14 gauge screws should be used.

Round load spreading washers must always be used when pan fixing roof cladding for both strength and weathering reasons. (*see section 7.5.2. pan fixing*)

7.8.3 FASTENER DURABILITY

The NZBC requires fasteners to perform their function for at least fifteen years. The function of the fastener is to hold the roof in position, but this requirement does not include the aesthetic appearance of the fastener i.e. after ten years the fastener head could be rusted and still perform its function.

Customer expectation and consumer legislation would probably consider the rusted appearance of fasteners to be unacceptable and the roofing contractor or specifier should ensure that suitable fasteners compatible with the roofing or cladding are specified and used.

To comply with AS3566 steel fastenings require a minimum coating to be used in certain environments. (see 7.8.5. *coating thickness*)

Only paint coated stainless screws and washers should be used with pre-painted aluminium roof and wall cladding.

Screws are available with an additional paint coating of aluminium filled polyester, which is intended to enhance the durability of the screw, however this is reliant on the coating remaining intact throughout the driving process. Die cast headed screw complying with class 4 AS 3566 are also available for use in severe environments and which are compatible with AZ, Z and pre-painted steel and aluminium roof and wall cladding.

If sealing washers are made from EPDM or neoprene using carbon as UV filters, the level of carbon should be < 15% by volume.

7.8.4 CORROSION

Corrosion of fasteners is subject to the same type of corrosion and is caused by the same factors as metal corrosion described *in section 2.4. corrosion* and should be read in conjunction with that section.

Steel fasteners used for the external fastening of metal roof and wall cladding can be protected from corrosion by many different methods including:

- hot-dipped galvanising
- mechanical or peen plating

When steel is galvanised by the dipping process using a bath of molten zinc, it is not possible to control precisely the amount of zinc deposited particularly on large articles that are not batch dipped. With small articles such as nails, screws and bolts, some degree of control can be obtained by centrifuging the article while hot, although this is usually done only to remove excessive zinc and to provide a more acceptable product.

The zinc thickness deposited on steel in non automated galvanising lines is usually proportional to the shape of the product and a heavy mass section will have many times the thickness of zinc than that deposited on a thin article. The thickness of the zinc is therefore determined by the mass of the article.

Self-drilling screws and high tensile bolts are made from case hardening or heat-treatable steel and can be subject to hydrogen embrittlement when they are hot dipped galvanised. Alternative methods of galvanising such as peen plating and zinc/tin coatings are now regarded as equal to hot-dipped providing the porosity associated with this process is strictly controlled.

The fastener should be driven perpendicularly and not overdriven, and care should be exercised when using colour matched painted hot-dipped galvanised nails, bolts and screws, to minimise damage to the head when the nail or screw is driven. Where extremes of climate are encountered such as an on shore beach wind, the resulting sandblasting can significantly reduce the coating thickness and the longevity of the fastener.

All fasteners should be easily identified by a code stamped on the head to identify the manufacturer and the coating class.

7.8.5 FASTENER COATING THICKNESS

Class 4 fasteners must be used for all external environments as deterioration of the fastener can cause corrosion of the cladding.

The durability of the fastener must at least equal that of the cladding material and the head must be stamped with the coating class and identify the manufacturer.

The coating thickness in microns (μm) required on a class 4 steel screw as designated in AS 3566.2 is:

45 μm for mechanically plated zinc- tin

50 μm for hot-dipped galvanised

N.B. These thickness's apply to the head only and not the shank.

The porosity of the 30% tin alloy should adhere to the limits designated in AS 3566.2. 2002

7.8.6 COMPATIBILITY OF FASTENERS

The fastener should not only give the same service life as the sheeting but should also be compatible with it when used in the expected environment.

The only relevant standard for fasteners used in N.Z. is AS 3566, which gives four accelerated exposure tests which the fasteners should pass in order to comply with the Standard, Chloride, Sulphate, Humidity and Ultra violet exposure conditions. It has been found that some products do not meet all accelerated test requirements but perform satisfactorily in real life and some products can pass the tests but do not perform well in service.

The use of stainless steel fasteners with AZ coated sheeting is considered to cause deterioration of the roof sheeting or cladding in severe and very severe marine and industrial environments and therefore stainless steel fasteners are not recommended by the steel manufacturers. Tests have shown that if the stainless steel fastener is etch-primed and factory coated, corrosion is minimised, and that when using stainless steel fasteners with ZA coated steel the deterioration that can occur initiates at the cut edge of the hole.

The performance of the shank of the fastener is most relevant for internal environments when the contaminant is inside the building e.g. Animal Shelters, Fertiliser Works.

Where there is a likelihood of shank deterioration, a plastic tube sleeve can be cut slightly longer than the gap between the cladding crest and the timber purlin and inserted through an oversized hole in the cladding.

Load spreading washers must be provided whenever oversized holes are drilled in the cladding

7.8.7 PURLIN CREASING

Due to improvements in colour coating technology the level of reflection of new pre-painted roof sheeting is now considered to be higher than previously. Overdriven nails or screws can produce visible distortion in the pan of trapezoidal profiles on the line of the purlin that cannot be easily remedied.

Trapezoidal profiles with a wide pan manufactured from 0.40mm steel and 0.70mm aluminium are particularly susceptible to purlin creasing, and although it does not affect performance, their appearance can be aesthetically unacceptable

It is the responsibility of the roofing contractor to ensure that overdriving of nails does not occur as a nail or screw should only be driven into the purlin to produce a 50% compression of the sealing washer or until the roof is firm. Using too many fasteners should also be avoided and nails should always be fixed at right angles to the roof.

Before fixing the roof cladding the contractor should check the alignment of the purlins or girts. Purlins should be aligned within 5mm tolerance of each other to avoid purlin creasing.

Purlins should be accurately positioned with their top face parallel with the rafter and should be fixed to a straight line.

When appearance is paramount or where wide pan trapezoidal cladding is close to eye level, heavier gauge cladding should be specified because light gauges such as 0.40mm steel and 0.70mm aluminium are likely to show distortion. Purlin creasing will occur on both concave and convex curved roofs if the recommended purlin spacings are exceeded and great care should be taken to align purlins on these roofs.

Purlin Creasing can be exacerbated by traffic on the roof. (see section 14.6.)

7.9 FASTENING PATTERNS

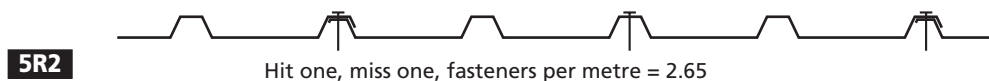
The following fastening patterns are designated in the following manner.

Corrugate

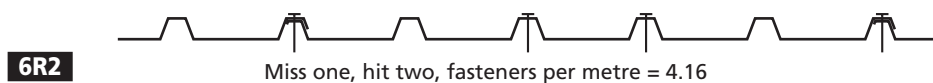
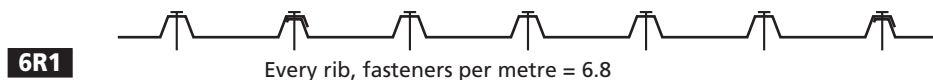


The use of the miss two, miss three fastening pattern should only be used with caution on 0.40mm HS Steel cladding.

5 rib trapezoidal



6 rib trapezoidal



Where the suffix L is used this indicates the use of load spreading washers.

These fastening patterns should be used in conjunction with the load span graphs in 3.9.

7.10 RE-ROOFING

When any roof cladding has reached a stage that maintenance may cost more than a renewal, there are a number of decisions that will determine if the renewal will require a building consent.

If the material is 'comparable' then the contract may not require a consent but if the decision was made to renew 0.55mm roof cladding with 0.40mm material or a different profile then this would not be regarded as comparable or 'like with like'. In this instance the purlin spacing would have to be changed if it did not comply with the existing wind load requirements.

It is therefore recommended that either a consent be applied for or inquiries be made with the BCA or Building Certifier before proceeding with any re-roofing.

Before any existing roof cladding is removed an inspection must be made of the structure to ensure that it is sound and does not represent a hazard as outlined in Safety section 14.

The provisions for working at height must also be in place before any cladding removal is commenced.

All underlay must be renewed because it is possible that the new cladding material could last 50 years with appropriate maintenance. The underlay support must be inspected and any material with any visible deterioration must be removed and replaced.

Flashings must also be renewed when there are different materials involved.

Some older buildings have been built with a pitch or purlin spacings that do not comply with the current requirements or the manufacturers conditions of warranty. If a warranty is to be given or a consent required the current requirements should be met. When reroofing an old tile roof with profiled metal cladding the battens should be replaced and new purlins installed and checked for compliance with the NZBC.

The roofing contractor is responsible to ensure that the owner and occupier are fully aware of the work programme and the need to take precautions against temporary water ingress due to the removal of cladding or flashings. Where expensive, delicate or essential equipment such as computers or switchboards is beneath the roof to be renewed separate precautions may have to be undertaken by those parties that assume this responsibility. Some factory or essential services may require the roof renewal to be completed outside normal hours or at night. In such instances the police, alarm companies or other services may have to be notified. It is the roofing contractors responsibility to make the owner and occupier fully aware of such arrangements and assign the responsibility.

If the old roof or wall cladding has been nailed it is possible that damage to ceilings could occur unless special care is taken and for this reason screw fixing of the new cladding is better practice.

'Patching' with slip sheets is not a recommended practice because:

- It produces transverse laps
- It can mix metallic and painted coatings
- It is only a short term solution
- It is visually unattractive

The removal of all material, flashings and other debris is the roofing contractors responsibility unless otherwise assigned.

7.11 FIXING ALUMINIUM SHEETING

Currently under review.

8.0 ROOF DRAINAGE

8.1 DESIGN

The roof drainage system for a building consists of four separate parts:

- gutter or spouting
- outlet, sump, rain-water head
- downpipe
- drain.

N.B. Ground drainage is outside the scope of this Code of Practice.

This section specifies good trade practice for the design of roof drainage systems including eaves, valley and box gutters, sumps, rain-water heads and downpipes, based on the Average Recurrence Interval (ARI) (**see 8.2.**) and the applicable catchment area calculations.

The objective of roof drainage systems is to maintain a weatherproof building, to minimise risk of injury or inconvenience due to flooding, and to avoid potential monetary loss and property damage including the contents of buildings. Any ingress of moisture can lead to dampness that encourages the growth of moulds some of which are detrimental to health. Flooding, not necessarily related to the intensity of rainfall or the design of the drainage system, is often caused by gutter or spouting blockages arising from inadequate regular cleaning and inspection. Drainage systems as described in this section will not perform as required without on-going normal maintenance. (**see maintenance section 13**)

Roof drainage design requires consideration of the following:

- rainfall intensity
- catchment area
- cross-sectional gutter area
- sump design
- cross-sectional area of downpipes
- water disposal from downpipes
- overflows
- roof cladding profile capacity
- roof pitch
- penetrations which obstruct water flow

This section details specific requirements for the sizing of all drainage components and for design purposes only, level gutter design is assumed.

8.2 RAINFALL INTENSITY

When calculating roof drainage where significant inconvenience or injury to people or damage to property, including building contents is unlikely the Average Recurrence Interval (ARI) used must be 10 years.

e.g. due to an overflow of external eaves gutters.

When calculating roof drainage where significant inconvenience or injury to people or damage to property, including building contents is likely the Average Recurrence Interval (ARI) used must be 50 years.

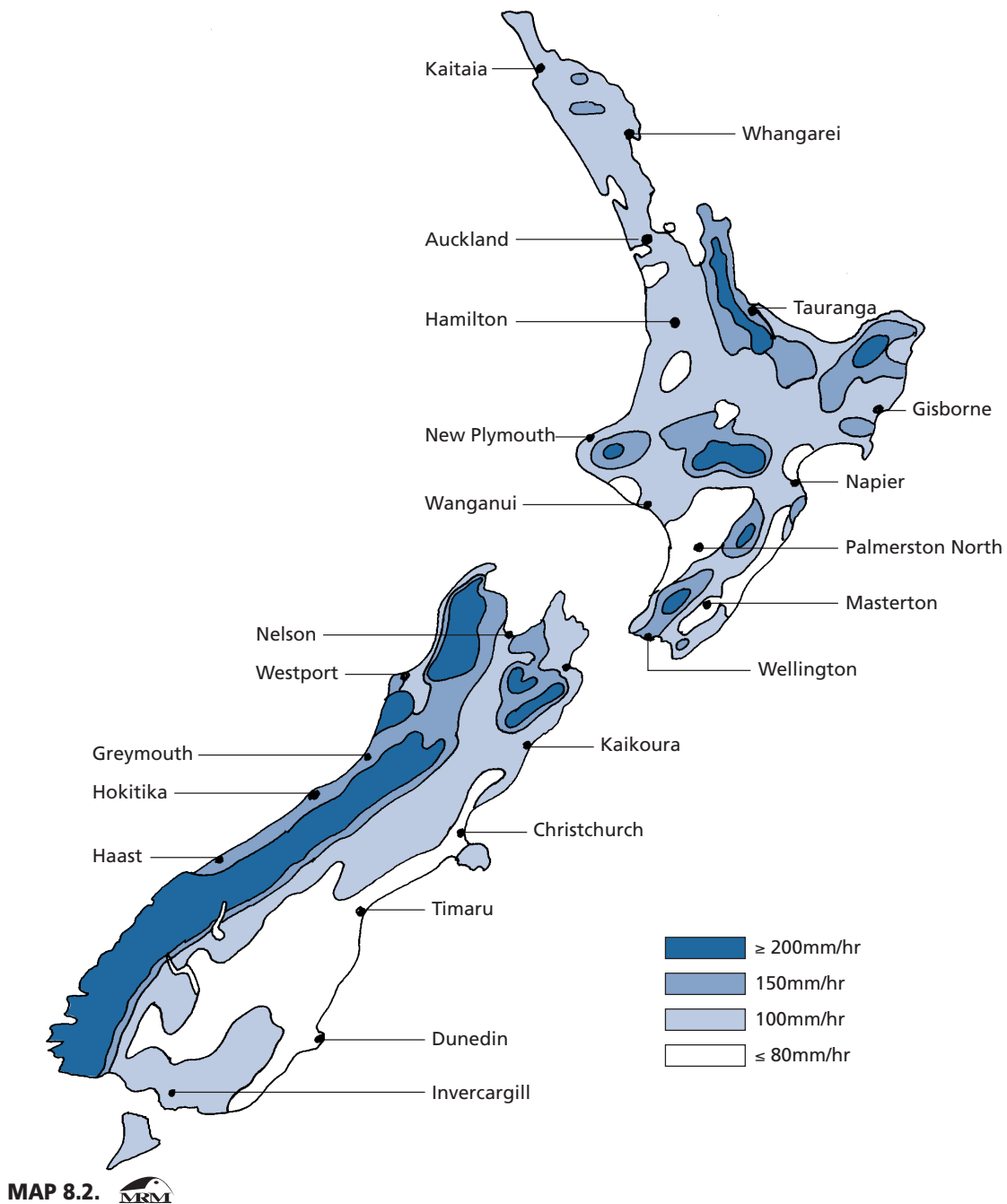
e.g. due to an overflow of internal gutters.

A higher level of rainfall should be allowed when designing for higher risk situations.

The rainfall intensity in New Zealand is determined by the rainfall during a ten minute period measured in millimetres per hour, and different areas in New Zealand vary considerably in their rainfall intensity.

Although a rainfall of (say) 17mm in ten minutes (100mm/hr) is considered unlikely, the equivalent of 3mm in two minutes is likely and is therefore used as a basis to avoid flooding.

N.B. The local Territorial Authority can determine the rainfall intensity.



The NZ Rainfall Intensity Map 8.2 shows areas with a 10% probability that rainfall will exceed the specified mm/hr for a 10 minute duration for an ARI of 50 years.

During rainstorms, long periods of steady rainfall are interspersed with heavy downpours for short periods, and the roof-drainage system should be capable of handling the peak intensities without flooding. A considerable time-delay occurs on large low pitch roofs between the on-set of rain and when the water discharges at the downpipe. This time lag alters the rate of flow capacity required for the gutter and downpipe to discharge without overflow.

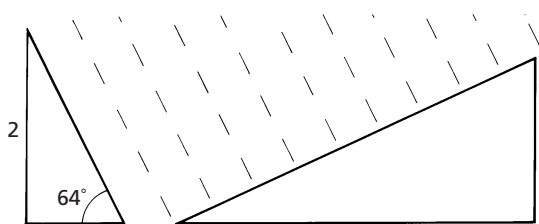
Gutter overflow is acceptable on eaves gutters or freely discharging downpipes if they are designed to do so, but cannot be permitted from internal gutters or downpipes.

When the site rainfall intensity shown on Map 8.2. is greater than 100mm/hour the gutter and downpipe cross-sectional areas must be proportionally increased as prescribed in Table 8.2.2.1.

8.2.1 CATCHMENT AREA

The rain catchment area for a roof, or roof and wall, is determined by the direction of wind-driven rain, and depends upon the descent angle of the rain or if there is a wall adjacent to the roof.

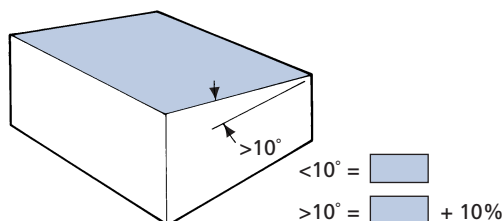
This allowance for the effect of wind on rainfall is required for all roofs with a greater pitch than 10° and a slope of 2:1 is used for this calculation. (*This is the tangent of 64° see drawing 8.2.1.A*)



Drawing 8.2.1.A 

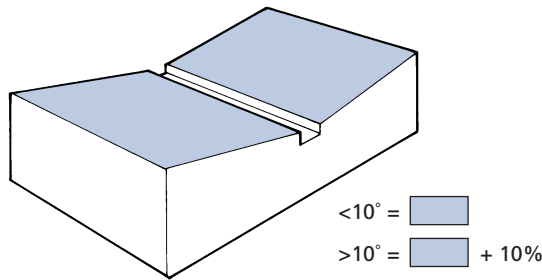
Adjustment to the roof catchment area is required because it is recognised that rain is usually accompanied by wind, which can effectively increase the catchment area. There are a number of formulae and slope factors that can be used to determine the wind drift effect specifically for each building, some of which are contained in AS/NZS 3500. This assumption assumes the worst scenario and provides a conservative answer because when the wind is in the opposite direction, shielding would decrease the catchment area.

The sloped roof catchment area for all sloped roofs with a pitch $>10^\circ$ and freely exposed to the wind, must be increased by 10% to allow for the wind drift effect. (see drawing 8.2.1.B)



Drawing 8.2.1.B 

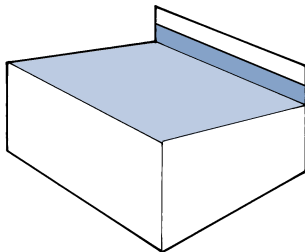
For multiple roofs some allowance can be calculated for shielding, however in the interests of simplicity, and because of the permutations of roof pitch and length, the sum of the sloped roof areas will give a conservative figure to be used when calculating the required internal gutter capacity. (see **drawing 8.2.1.C**)



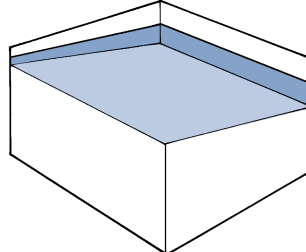
Drawing 8.2.1.C. 

For roofs where there is a vertical wall adjacent to the roof slope there are three different situations.

- Where the roof pitch is $< 10^\circ$. The catchment area is the sum of the sloped surface area and 1/2 of the vertical wall surface area. (see **drawing 8.2.1.D.**)
- Where the roof pitch is $> 10^\circ$. The catchment area is the sum of 1.1 x the sloped surface area and 1/2 of the vertical wall surface area. (see **drawing 8.2.1.D.**)
- Where there are adjacent vertical walls at right angles to each other, the catchment area is the sum of the sloped surface area and 1/2 of both of the vertical wall surface areas. (see **drawing 8.2.1.E.**) The catchment area for high vertical walls such as a multi-storey building, may be considerably less than half its surface area.



Drawing 8.2.1.D. 



Drawing 8.2.1.E. 

When a high vertical wall is subsequently built adjacent to an existing gutter, it is likely that its capacity would be overloaded. In this case either the increased catchment area should be drained separately or the gutter should be redesigned.

All roofs freely exposed to the wind	$< 10^\circ$	= sloped roof area
Sloped roofs freely exposed to the wind	$> 10^\circ$	= sloped roof area x 1.1
Vertical wall/s adjacent to the roof slope	$< 10^\circ$	= sloped roof area + 1/2 wall area
Vertical wall/s adjacent to the roof slope	$> 10^\circ$	= sloped roof area + 1/2 wall area x 1.1

Table 8.2.1. 

Catchment Area Calculation

After the catchment area has been determined by Table 8.2.1., the capacity of the gutters and downpipes can be calculated by two simplified methods:

- Method 1 Graph for pitches $< 10^\circ$
- Method 2 Calculations for any pitch.

8.2.2 CAPACITY CALCULATIONS

Because the roof pitch, length of run, gutter and downpipe size, shape and fall are all inter related in the determination of the capacity of each other, the calculations in sizing these components can be complicated.

Assumptions can be made to provide a conservative and simple assessment of the capacity of spouting, gutter and downpipe for roof drainage by two methods.

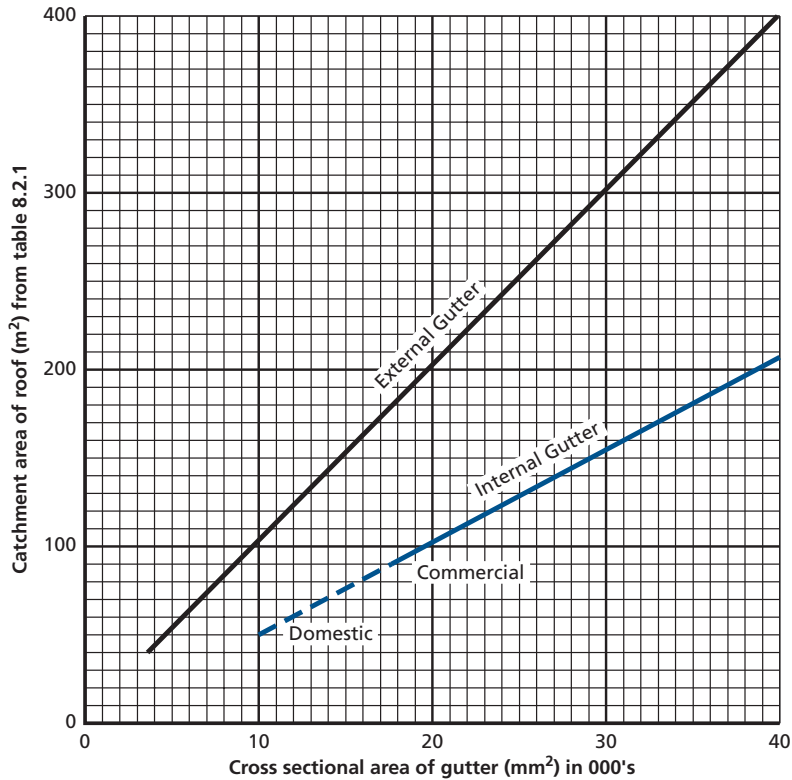
GUTTER AND DOWNPIPE CAPACITY DETERMINED BY GRAPH

METHOD 1

When using the simplified graphs 8.2.2. the following assumptions have been made:

- roof pitches 3° – $<10^{\circ}$ (for greater pitch see *table 8.2.2.C.*)
- roof area 50m^2 – 300m^2
- minimum cross-sectional area of gutter = 4000mm^2
- flat gutter or spouting (for design purposes only)
- no restrictions – no spouting, gutter or downpipe angles
- free discharge – weir into a sump or R.W.H. with overflow
- rainfall intensity = 100mm/hour (for greater rainfall see *table 8.2.2.A.*)
- external vertical downpipes

Given these assumptions the design capacity of gutters and downpipes is given in graph 8.2.2

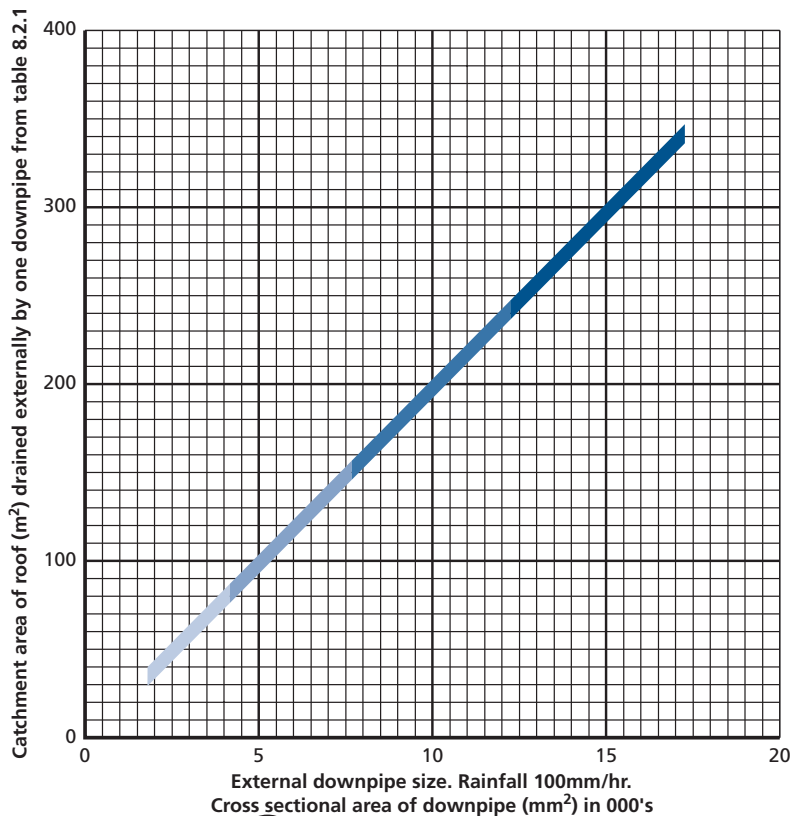


These graphs are suitable for roof pitches up to 10° and a rainfall intensity of 100mm/hr.

For other roof pitches and rainfall intensities see the example.

Graph 8.2.2. is based on 100mm/hr for other intensities refer to table 8.2.2.B.

For internal gutters a safety factor of 2 has been used.



Graph 8.2.2. 

GUTTER AND DOWNPIPE CAPACITY DETERMINED BY CALCULATIONS**METHOD 2**

After the catchment area has been determined by table 8.2.1., the capacity of the gutters and downpipes can be determined by using the tables below.

Table 8.2.2.A Cross-sectional area per m² for rainfall 100mm/hr

external gutter or spouting	= 100mm ²
internal gutter	= 200mm ²
vertical external downpipe	= 50mm ²
horizontal downpipe <15°	= 100mm ²

Table 8.2.2.B Rainfall

For rainfall >100mm/hr the catchment area must be factorised to allow for the increased rainfall as per map 8.2.

80mm/hr	multiply by a factor	0.8
100mm/hr	multiply by a factor	1.0
150mm/hr	multiply by a factor	1.5
200mm/hr	multiply by a factor	2.0

Table 8.2.2.C Roof pitch

For roof pitches >10° the catchment area must be increased to allow for the increased rate of run-off.

Pitches		
10° – 25°	multiply by a factor	1.1
25° – 35°	multiply by a factor	1.2
35° – 45°	multiply by a factor	1.3
45° – 55°	multiply by a factor	1.4

Example: Calculation to find capacities using simplified method.

Given: Freely exposed monoslope roof
 Tauranga
 Sloping rafter length 5.9m
 Length of building 10m
 Roof pitch 24°

Step 1 Find rainfall intensity from map 8.2 150mm/hr
 From table 8.2.2.B factor = 1.5

Step 2 Roof pitch from table 8.2.2.C. factor = 1.1

Step 3 To find the factorised catchment area from Table 8.2.1.

$$59\text{m}^2 \times 1.1 = 65\text{m}^2$$

Calculation $65 \times 1.5 \times 1.1 = 107\text{m}^2$

$$\text{External gutter} = 100\text{mm}^2 \times 107 = 10,700\text{mm}^2$$

$$\text{Internal gutter} = 200\text{mm}^2 \times 107 = 21,400\text{mm}^2$$

$$\text{Vertical downpipe} = 50\text{mm}^2 \times 107 = 5,350\text{mm}^2$$

$$\text{Horizontal downpipe } <15^\circ = 100\text{mm}^2 \times 107 = 10,700\text{mm}^2$$

Step 4 From table 8.2.2.3. Find suitable spouting and downpipe.

Standard gutter

	mm ²
125mm 1/4 round	5,000
125mm x 75mm rectangular	9,375
175mm x 125mm rectangular	21,875
300mm x 125mm rectangular	37,500

Standard downpipes

Round	mm ²	Rectangular/square	mm ²
65mm	3,318	100 x 50mm	4,500
80mm	5,027	100 x 75mm	6,750
100mm	7,854	100 x 100mm	9,000
125mm	12,272	(N.B. square and rectangular downpipe capacities have been depreciated by 10%)	
150mm	17,671		

Table 8.2.2.3.

External gutter or spouting = standard 175 rectangular O.K.

One vertical downpipe = 100mm round or 100mm x 75 O.K.

OR 1/4 round with two downpipes (one at either end *see drawing 8.2.2.*) O.K.

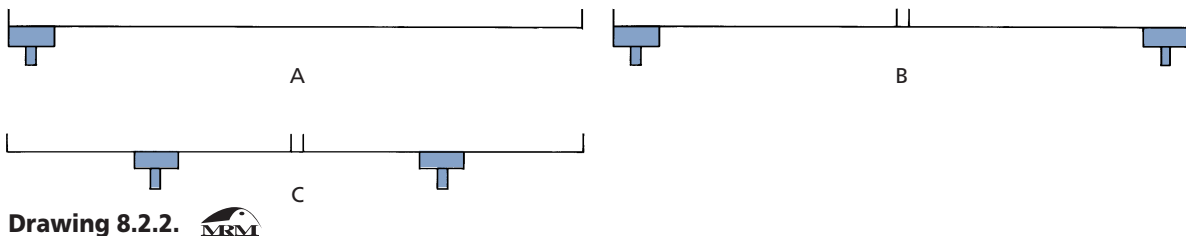
Two vertical downpipes = 63mm round O.K.

Step 5 Internal gutter = custom-made = 220 x 100 = 22,000 O.K.

An internal gutter normally requires 20mm freeboard, however using this simplified calculation method for rainfall areas >100mm/hr, having the catchment basis of 200mm/hr, an internal gutter would be over designed if additional freeboard was added. Similarly internal downpipes having no overflow to the exterior of the building could be underdesigned and their capacity should be increased by 25%. N.B. Flooding usually occurs due to the incapacity of the drain rather than the downpipe.

For domestic and small commercial buildings, standard spouting, gutters and downpipes represent the most economical method of complying with the capacity requirements, but if large gutters are required these should be custom made to specific dimensions.

The position of the outlet can make a significant difference to the size of the gutter required.



Drawing 8.2.2. 

As can be seen in drawing 8.2.2. when the catchment area is identical, the gutter capacity at A can be reduced by half at B and to one quarter at C. The downpipe capacity required at both B and C is half that of A.

The preferred proportion for an internal gutter is 2:1 i.e. the sole of the gutter should be twice the height. The minimum height of an internal gutter should be 70mm however the height is recommended to be 1/60 of the length. Recommended maximum length of a coated steel gutter without an expansion provision should be 12m. However 6m

can be the maximum length if the outlets are spaced at 12m as shown in drawing 8.2.2. Non-ferrous metal gutters have restrictions on their length depending on their thickness.

When an external spouting has a dropper outlet or an external angle, the capacity of the spouting should be depreciated by an allowance of 10% for each outlet or angle. Outlets should be placed within 2m of an angle.

Dropper outlets must not be used on internal gutters.

Sumps or Rain Water heads must be used to drain all internal gutters and also be placed at gutter angles.

8.2.3 PROFILE CAPACITY

The capacity of metal cladding profiles is determined by their geometry, the roof pitch and rainfall.

The height of the lap is the determining factor for overflow and water ingress and therefore the lap should be sealed if it is below minimum pitch, as is required for curved roofs and bull-nosed verandahs.

All roof cladding profiles manufactured in New Zealand have adequate free discharge capacity for a rainfall of 100mm/hr, except corrugate. This profile should be restricted to a maximum length of 40m or 30m² of catchment area for a rainfall of 100mm/hr, or decreased or increased dependent on the rainfall. (*see section 8.2. catchment area*)

Where the rainfall is greater than 100mm/hr or lengths greater than 40m or multiple roofs are designed, it is recommended to increase the minimum pitch by 1° per 10m over 40m.

A step in the roof or any penetration will require an increase in the drainage capacity of the profile required.

Where multiple roofs are drained directly or indirectly onto a lower roof, the total catchment area is the sum of both roof areas.

When penetrations concentrate the run-off into one or more corrugations or pans the capacity must be calculated as described in section 6.1.6. discharge capacity.

8.3 SNOW

The installation of metal roof cladding in snow areas does not require any increase in the capacity of gutters, but does require the installation of snowguards so that the gutter will remain free to drain the melt-water. As the gutter is required to withstand the dead load when full of water, and as the weight of snow will be less than that of water, no additional strength is required in the gutter, if snowboards are provided.

Gutters without snowguards are vulnerable to leakage, as they can be blocked by snow but with snowguards the size of the openings should allow melted snow to escape.

In snow areas all internal gutters must have snowguards. (*see section 3.5. snowloads*)

The U.D.L. imposed by the additional weight of snow will vary because one m³ of fresh snow weighs approx 100kgs or a load of 1kN. Fresh snow will be partially melted by rain, and will be a combination of ice and snow. (*see snow section 3.5.*)

As one m³ of ice weighs approximately 900kgs (or a load of 9kPa) and because one m³ of fresh snow weighs approx 100kgs (or a load of 1kPa) it is reasonable to assume that approximately 100mm of snow accumulated on roof cladding will impose a load of 0.5kPa. (50% snow/ice)

When temperatures are prolonged at sub-zero, melt-water can resolidify and build-up as an ice dam, particularly if the roof is insulated. In this circumstance, to prevent the ingress of water, an impermeable membrane should be installed and supported between the last two purlins to discharge into the gutter.

Purlin spacings should be reduced at the eave to allow for the added snow load, which is likely to be greatest at this position.

In snow areas the snow load must be added to the downward wind load and purlin spacings must be reduced at both end and intermediate spans by the amount as shown on the load span graphs. (see section 3.9.)

In snow areas, special designs are required for spoutings and their supports. (see section 8.4.2.)

Leakage due to snow can occur at penetrations that are not designed in accordance with this Code of Practice.

Penetrations such as chimneys or vents from a heated building should be placed at a ridge or in the peripheral area around the roof because diurnal temperature fluctuations can provide a freeze / thaw cycle that will severely test any sealed hole in the middle of the roof cladding.

All penetration flashings >600mm in width in snow areas must use a cricket or diverter design. (see section 15.8. and 6.2.2)

Snow loads are subject to variation due to drift and melting, and roof areas expected to trap significant quantities of snow present complex loading patterns. The design loads should take account of drifting of snow due to wind, but wind loads need not be combined with the snow load.

Roofs with internal gutters, valleys or high parapets, saw tooth or barrel vault roofs, can all retain accumulated snow through drifting due to wind and sliding snow. Where snow can be expected to accumulate, or where the shedding of snow is prevented, special loading should be applied as snow slide and drift can impose a load of up to two or three times greater than normal on the roof cladding and the structure.

Projections such as gutters, flashings and chimneys present obstructions that accumulate snow, and should also have special designs to resist loads from sliding snow.

When an additional building is to be built alongside an existing one, or where it is likely that snow can slide onto a lower roof, a revision of the original roof design loadings must be made.

8.3.1 HAIL

Hail is frozen water, and by accumulating in valleys and gutters it can, like snow, cause blockage and subsequent leakage. For this reason sumps and rainwater heads should have leaf guards that are the same size as the sump and provide a large free overflow area and should not be tapered because of the wedging action of hail.

Snow gutter boards should be provided for all internal gutters as a baffle to allow hail melt water to drain safely without overflowing the gutter. If the gutter is blocked by hail, water should not overflow into the building

In all areas prone to hail, spouting, gutters and their supports should have additional fixings. (see section 8.4.2.)

8.4 GUTTERS

All external and internal gutters should discharge freely without flooding.

External gutters must be installed with the back lower than the fascia board or cladding.

External and internal gutters must have a cross-sectional area in accordance with graph 8.2.2. and sumps, rain-water-heads and downpipes must not restrict the flow from the gutter.

For design purposes gutters are assumed to be level as this is preferable to obtaining fall by tapering the gutter thereby reducing the cross-sectional area. With the limited fall available it is not always possible to ensure that all internal or external gutters will remain dry without ponding, and so to avoid premature corrosion, consideration should be given to using non-ferrous metals. (see fall section 8.4.9.)

Unpainted galvanised steel is not warranted for spouting and gutters.

Because dirt retains moisture and causes corrosion, ponding as described in the definitions section 1.4. will void any warranty.

All AZ coated steel spouting and gutters must be maintained to prevent ponding due to the collection of debris or dirt as required in (section 13 maintenance)

Where their renewal within 15 years would be difficult, AZ coated or pre-painted steel must not be used for internal gutters

All gutters are subject to expansion and therefore there is a maximum recommended length before an expansion joint is required. This maximum length is determined by the metal, its thickness and colour and is similar to the limit recommendations for roof cladding but should not exceed 12m. (see *maximum lengths section 4.1.6.*) N.B. A sump or spouting angle provides sufficient movement for expansion.

Where a spouting or gutter can be shown to be able to move freely and independently then the increase in length should be as per section 4.1.6. for sliding washers and such a spouting or gutter should be of a cross sectional dimension capable of resisting expansion forces. Copper or aluminium spouting or guttering that has been softened by brazing is not suitable for this extension to longer length.

Outlets are only required at twice the length module because an expansion joint can be either a sump, rain-water-head as well as a saddle flashing. (see *drawing 8.2.2.*)

8.4.1 GUTTER INSTALLATION

Any fixings should not penetrate the gutter as they will prevent free movement of the gutter.

Gutters must not return or be folded back under the roof cladding or be fastened to it, as this will prevent free thermal movement and expansion to occur. All internal gutters must be hooked.

The roof cladding must overhang the gutter by not less than 50mm, with a down-turned drip edge when the pitch is $<8^\circ$. All internal gutters must have a flat sole to avoid premature corrosion caused by the accumulation of dirt and debris.

A separate overflashing is recommended to be used:

- In coastal environments
- Where the pitch of the roof is $<8^\circ$ and in a very high wind design load area
- When the gutter does not shelter the profile. (see *5.3.5.4.*)

Turn downs are formed at the end of the cladding over the gutter to prevent water blowing back along the underside of the roofing. For overflows and *outlets see 8.6.2.*

8.4.2 GUTTER SUPPORT SYSTEMS

The gutter bracket system must withstand the potential weight of a gutter full of water.

In snow load areas external spouting or gutters must be fitted with snow straps and brackets at a maximum of 600mm centres to withstand the additional potential weight of any build-up of snow.

If the pitch of the roof is greater than 15° snow may slide off the roof and when this is likely to occur over doorways, snow guards should be provided and fixed to the structure above. (see *section 4.8.3.*)

All bracket material should be compatible with the gutter material and brackets for pre-painted gutters should be painted or powder-coated before installation.

Brackets must be installed so as to ensure a gutter gradient towards the outlets. (see *section 8.4.9. fall*)

The support system for internal box gutters must be flat, able to support the gutter when full of water and to withstand a point load of 1.1 kN.

To prevent permanent deflection of the gutter, full support for the sole of an internal gutter should be provided by either a plywood lining, or by close ribbed sheets of roof cladding, both of which require an underlay to reduce condensation. Underlay is also used to protect metal from any effects resulting from timber treatment.

Brackets should be located at all stopends, at both ends of sumps, at rainheads, at a maximum of 750mm spacings for external gutters <180mm wide and at 600mm centres for gutters 180 - 300mm wide.

8.4.3 EAVES GUTTERS

External domestic guttering, also known as spouting, is available in standard profiles and in long lengths from the manufacturer or, in some areas, made to length on site.

The useful cross-sectional area of an external gutter is governed by the back height and not by the often high front profile.

Eaves gutter systems, including downpipes, must be designed so that water cannot flow back inside the building.

Eaves gutters should be designed to ensure that no ponding occurs.

Prepainted spouting and guttering has only a backer coat on the inside but can have the expected life lengthened by painting the internal surface prior to installation or can be manufactured using double-sided pre-painted coil.

Permanent leaf guards do not provide the protection claimed and assumed for metal gutters, as, although they do prevent large pieces of debris from obstructing the outlets, they allow finer particles to collect on the sole of the guttering. The continual wetting of the interface between any debris and the metal will lead to early corrosion if regular maintenance is not carried out. The decay of organic matter such as leaves can produce organic acids, which will accelerate corrosion.

Vertical outlets to eave gutters or spouting must have an area equal to half the cross sectional area of the gutter and horizontal outlets must have an area equal to the cross sectional area of the gutter.

Eave gutters should have an outlet within 2m of an external corner, but where this cannot be provided eave gutters should be given additional fall to avoid ponding. Any change of direction can negate the fall of lengths up to 6.000m and the number of outlets will be determined by the catchment area. For fall (*see section 8.4.9. fall*) For over flows (*see section 8.6.2.*)

All eaves gutters should allow free expansion to occur. Such joints can be either a sump, rainwater head or a saddle flashing but they should not be fastened to the gutter. (*see drawing 8.4.4.*)

8.4.4 INTERNAL GUTTERS

When internal gutters are difficult to replace and their failure could cause major disruption to the building below, to comply with the NZBC they must be made from materials that will last 50 years.

Only non-ferrous metals or alternative materials must be used as coated steels are unsuitable for this purpose.

Aluminium of a thickness of 1.2mm has given service for this length of time and therefore should be considered as well as stainless steel. Copper should be used only with extreme caution as any copper touching or splashing coated steel cladding will lead to early corrosion.

Both internal and external gutters can be economically designed by positioning the outlets at quarter points as shown *on drawing 8.2.2*. By positioning the outlets as shown, additional fall can also be provided.

Internal, Parapet, or Box gutters are subject to the same requirements as eaves gutters except that being internally situated they are designed with a greater safety factor based on an ARI of 50 years and a minimum design rainfall intensity of 200mm/hr.

The overall depth of the gutter should be greater than that required by the design capacity, to prevent the gutter overflowing by splashing or by standing waves produced by strong winds.

For commercial and industrial buildings, internal box gutters must have a minimum depth of 70mm. For domestic buildings internal box gutters must have a minimum depth of 45mm. All internal gutters must be capable of supporting 1.1kN point load.

All internal gutters must be provided with a weir outlet and discharge to a rainhead or sump, to provide full drainage without ponding.

All sumps or rainheads must have an overflow and the bottom of the overflow must be below the sole of the gutter. For over flows. (see section 8.6.2.)

A freeboard allowance of 20mm must be added to the net capacity calculation to increase the maximum depth of flow in internal gutters.

It is not permissible to change the direction of flow sharply of an internal gutter, within the building area, and where two buildings meet at an angle, each gutter must be drained separately. This does not apply to valley gutters.

Horizontal or back outlets must not discharge directly from the gutter, as they restrict the capacity of the gutter. (see section 8.4.5.2.)

When a scupper gutter overflow is used at the stopend or high end, the lowest level of the overflow should be located at a minimum of three-quarters of the height of the gutter. At the outlet end, a weir overflow at the level of the sole of the gutter should discharge into a sump or rainhead.

Scupper outlets should be avoided where possible as they are difficult to make weathertight and they can inhibit expansion.

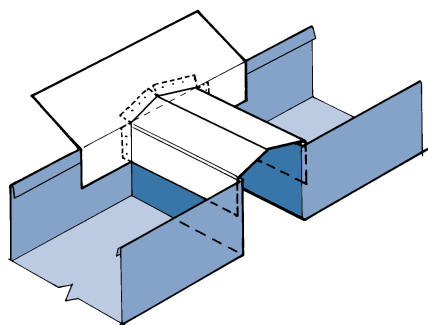
The position of the sump for internal gutters is commonly at a column with downpipe bends close to the sump. Sharp bends less than 15° will cause restricted flow into the downpipe and will reduce the downpipe capacity to drain the gutter. In this case the downpipe size should be increased to that of the cross-sectional area of the gutter.

Internal gutters should have an expansion joint at the stopend as shown in drawing 8.4.4.

When using net capacity and not the simplified calculation method a freeboard allowance of 20mm should be added to the net capacity calculation to increase the maximum depth of flow in internal gutters.

It is better practice to provide internal gutters with a minimum width of 300mm for commercial and industrial buildings and a minimum width of 200mm for domestic buildings.

For maintenance purposes and general access, internal gutters are assumed to be capable of supporting a traffic load.



Drawing 8.4.4. 

8.4.5 VALLEY GUTTERS

Valley gutters are installed on pitched roofs $> 12^\circ$ and are fully supported, but they should not be positively fixed except at the head as this will inhibit expansion, and can produce noise. For this reason the valley sole or upstand should not be returned or fixed under the roof cladding but should be terminated with a weather hook.

Valley gutters must be fixed at the head to avoid creep but must not be through fastened to the roof cladding. Valley gutters must discharge into a rainwater head, sump or eaves gutter, which must have an adjacent downpipe within 2m. of the valley discharge if the total catchment area serviced by the downpipe exceeds 50m^2 .

Valleys gutters must be designed for the greatest rainfall likely in the area in a 50 year return period (ARI). The valley capacity must be capable of discharging the total roof catchment area above the valley plus half the area of any dormer. (see section 6.5. dormer) Where the roof pitch is $< 8^\circ$ a valley gutter must not be used, however an internal box gutter can be used complying with the design criteria outlined in section 8.2.2.

The dimensions of a valley gutter complying with drawing 8.4.5.D are suitable for most domestic roofs provided that the depth at the centre of a valley should be a minimum of 50mm. Where the catchment area is $> \text{m}^2$ the valley dimensions should be increased by recessing the valley boards into the rafters or cutting them between the rafters supported on dwangs. *(see drawing 8.4.5.C)*

When the roof pitch is between $8^\circ - 12^\circ$ the capacity of the gutter should be similarly increased and the minimum depth should be increased to 75mm. Alternatively the width can be increased to increase the valley capacity by 50%.

The design capacity of the eaves gutter should not be compromised by cutting down the back of the gutter at the valley. If the valley is below the top of the eaves gutter, the gutter should be lowered at the discharge point or the valley should be 'sprung' to this level.

If downpipes discharge into the catchment area served by a valley gutter the total catchment should not exceed the capacity of the valley.

Where the roof pitch is $> 35^\circ$ it is best practice to provide a central baffle, which can also act as an expansion joint. *(see drawing 8.4.5.C.)*

When the roof pitch is $8^\circ - 12^\circ$ the valley should be made in one piece or the joints sealed.

The valley pitch will always be less than the roof pitch by a calculated value. e.g. where the roof pitch is 12° the valley pitch is 8.5° . *(see penetrations section 6.0.)*

To find the valley pitch when the roof pitch is known and the valley is at 45° to the rafter

1. Find the tangent of the roof pitch (see section 18.2.)
2. Divide the tangent by $1.414 (\sqrt{2})$
3. Find the pitch (see section 15.2.)

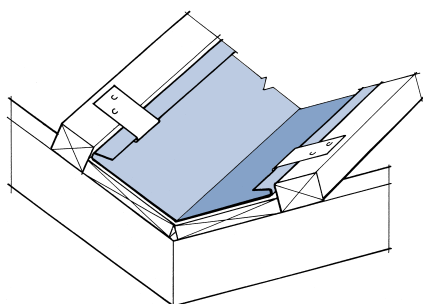
$$\begin{aligned} \text{EXAMPLE: Roof Pitch } 20^\circ &= \text{tangent} = 0.364 \\ \text{Valley pitch} &= \frac{0.364}{1.414} \\ &= 14.5^\circ \end{aligned}$$

N.B. The valley pitch = Valley angle.

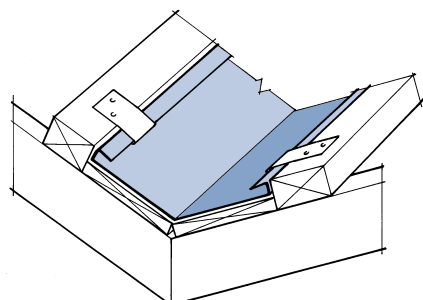
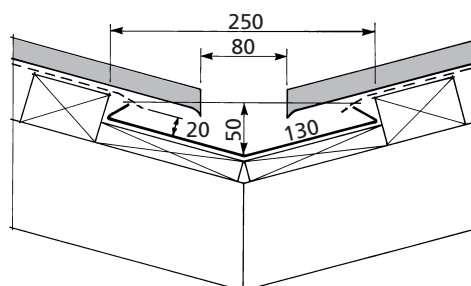
The total clearance between the sheeting on either side should be 80mm to allow a tennis ball to pass freely. The valley should be free to expand but should be positively fixed at the head to avoid creep caused by expansion or by snow on steep roof slopes.

Valleys should not have a "wing" or return under the cladding which would be penetrated by any fixing, inhibit free movement, and cause noise. The sides of the valley should have an upstand or a weather hook or folded as shown in drawings 8.4.5., and the hook should extend full height to the underside of the roof cladding.

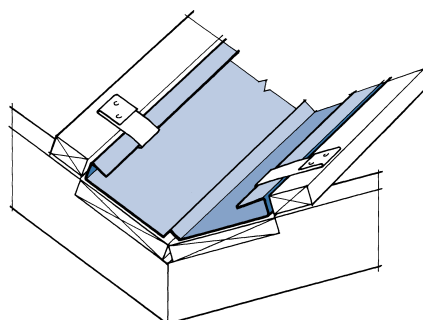
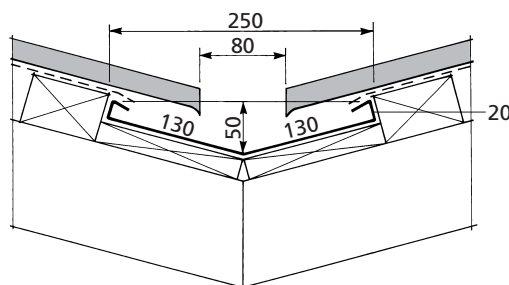
There are alternative means of securing the valley gutter to the substrate. A simple clip system allows for movement and security, and a compatible washered nail or screw is a suitable alternative but a bent nail is not, as it can cause damage to the metal cladding and is not durable. (see *drawing 8.4.5.*)



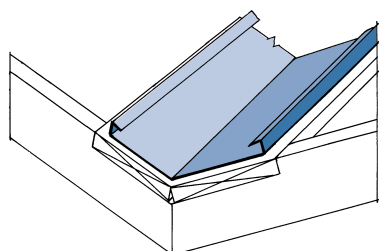
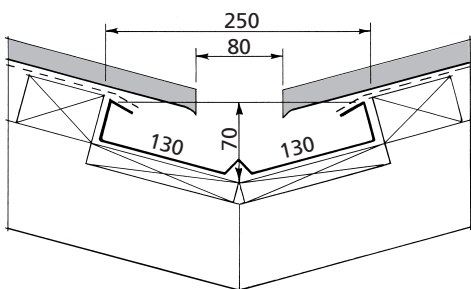
Drawing 8.4.5.A 



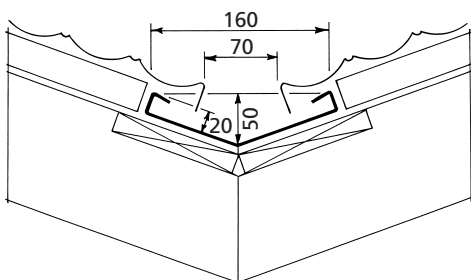
Drawing 8.4.5.B 



Drawing 8.4.5.C 



Drawing 8.4.5.D Metal tile 



Alternative valley designs where valley boards are on top of rafter (a) or cut into the rafter (c). Where they are cut into the jack rafter, the rafter depth should be increased or the valley board cut between the rafters.

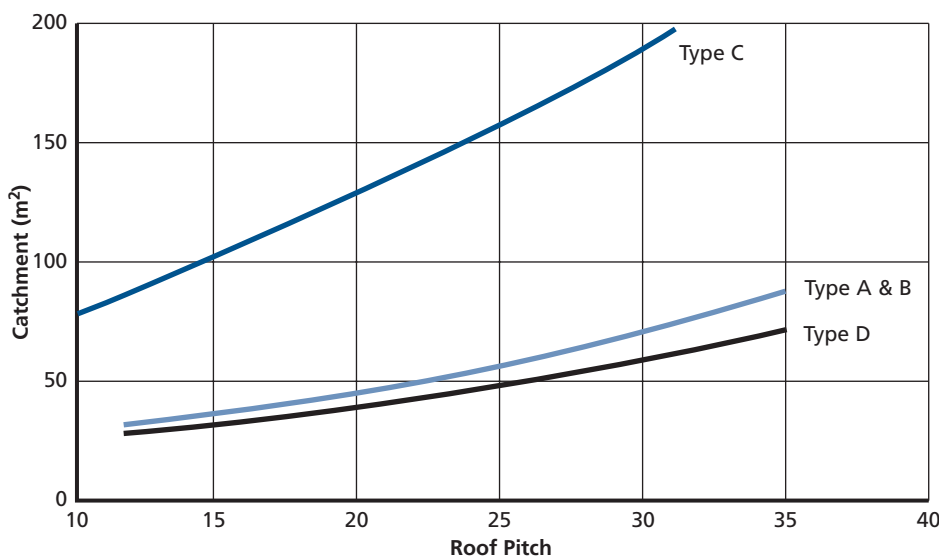
8.4.5.1 VALLEY CATCHMENT

The capacity of a valley gutter is determined in a different manner than that for normal gutters that are flat or very near to flat. By definition a valley is a gutter at the internal intersection of two sloping planes of roof cladding where the roof pitch is $>8^\circ$.

Because the minimum slope of a valley is $>5.5^\circ$ the discharge rate is greater than that of a flat gutter and as the roof pitch increases, the rate of flow, and therefore the catchment area that can be drained, increases proportionately. To establish this factor the research work that has been done by Martin & Tilley CSIRO Australia has been used as the basis to provide the graph 8.4.5.1.

With the pitch of the roof known the maximum catchment is determined from the graph.

The graph 8.4.5.1. has been calculated by allowing for 10mm freeboard and roof cladding interference.



N.B. A & B capabilities only equal if hook section A has 20mm height
Type C recommended when roof pitch $\leq 12^\circ$

Graph 8.4.5.1. 

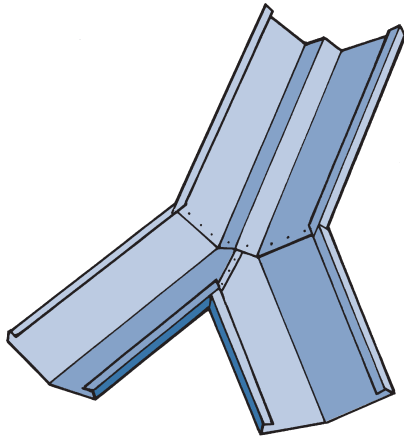
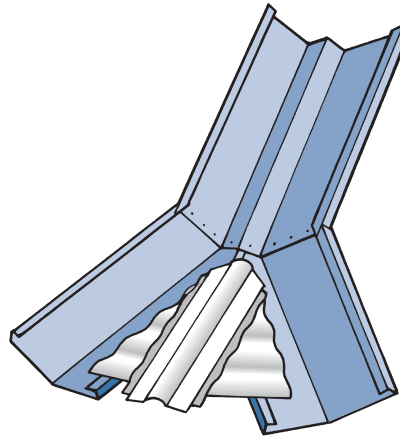
8.4.5.2 BIFURCATED VALLEYS

The detail 8.4.5.E is required as the result of placing a gable roof at an oblique angle to two other gables but at a different width. Because there are two gable roofs at 90° the catchment area is increased and consideration should be given to channeling rain-water away from this vulnerable area.

The detail shown in drawing 8.4.5.F provides for a baffle valley detail 8.4.5.C which diverts the water away from this point as the NZMRM code emphasises 'silicone sealant should not be used as the primary defense against water ingress', the design principle is to use a diverter, which channels the water away from the line of flow using vertical overlapping flashing design.

Although the NZMRM Code of Practice 8.4.4. places restrictions on changing direction within an internal gutter there are three differences:

- An internal gutter is normally laid flat whereas 8.4.5. requires a minimum roof pitch for a valley gutter is 8° .
- The deviation from a straight line is only 22.5° which is not regarded as a 'sharp' change in direction.
- At the confluence the catchment area is small and measured only in 0's of m^2

Drawing 8.4.5.E. Drawing 8.4.5.F. 

8.4.6 FASCIA GUTTERS

A fascia gutter is an eaves gutter that has a high front that shields the ends of the profiled cladding from view.

The fascia gutter design must ensure that water cannot enter the soffit or overflow into the building if the gutter system outlet becomes blocked.

Where a fascia gutter system is not easily replaced and cannot be seen or cannot provide any fall, it must be designed using non-ferrous metals or alternative materials to comply with the durability requirements of the NZBC. (see section 8.4.9. fall)

Overflow slots or an alternative overflow system must be provided to concealed gutter systems where the back of the gutter is lower than the front. Overflows must be capable of discharging the total amount of water from the roof catchment area. For over flows (see section 8.6.2.)

8.4.7 CONCEALED GUTTER SYSTEMS

Concealed gutter systems are proprietary systems that can be used either with or without a fascia.

External fascia systems with internal gutters have brackets nailed or screwed to the soffit bearers or rafters providing gutter support. When the external fascia is spring clipped to the brackets it conceals both the brackets and the gutter. The fascia has a soffit groove that will accommodate a 6mm soffit lining and should be installed before the roof is fixed. (see section 8.4.9. fall)

The concealed gutter design must ensure that water cannot enter the soffit or overflow into the building if the gutter system outlet becomes blocked.

Where a concealed gutter system is not easily replaced and cannot be seen or cannot provide any fall, it must be designed using non-ferrous metals or alternative materials to comply with the durability requirements of the NZBC. (see section 8.4.9. fall)

Over flows must be provided for concealed gutter systems within 1.000m of either side of the downpipe to discharge through the soffit immediately behind the fascia, and be capable of discharging the total catchment area served by the downpipe. For over flows (see section 8.6.2.)

Where a valley, downpipe or other water source discharges into a concealed gutter, provision must be made for an overflow within 2.000m. of the turbulence that is created by such a discharge.

The external fascia system can be used as a matching gable flashing and also as a fascia with an external gutter or spouting.

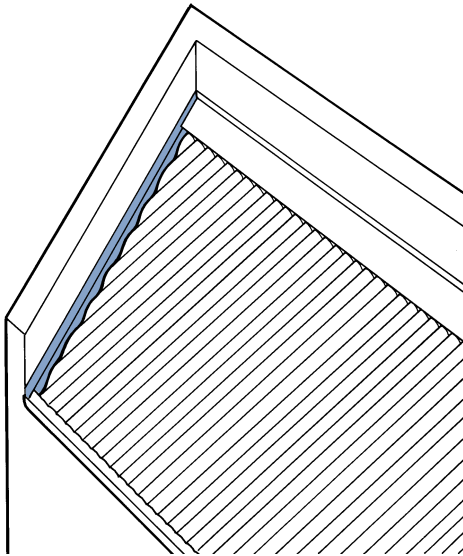
8.4.8 SECRET GUTTERS

A secret gutter is used where the roof edge runs at an obtuse angle to a wall or parapet and drainage is required for the roof cladding tapering to the barge.

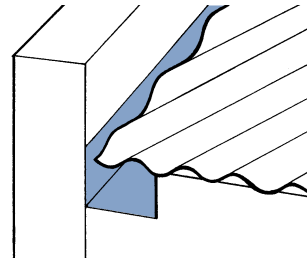
Because secret gutters are difficult to replace and their failure could go undetected they must be made from non-ferrous metals and be compatible with the roof material as per section 5.5.1.

A valley gutter used where the roof pitch $> 12^\circ$ is regarded as a secret valley gutter. (see sections 8.4.5. and 5.3.6. valley gutters). When the roof pitch is $< 12^\circ$ a sunken secret gutter must have a minimum depth of 45mm and be designed in accordance with 8.2.

Because it is hidden from view, sufficient space and fall should be provided for this type of gutter to be self-cleansing. It is recommended that a secret gutter should terminate at a rain water head.



Drawing 8.4.8.A 



Drawing 8.4.8.B 

8.4.9 FALL

All metal internal gutters must have a minimum fall of 1:200 (5mm in 1 metre) and all metal eaves gutters must have a minimum fall of 1:500 (2mm in 1 metre).

For external gutters, drainage can be significantly improved if there is a weir outlet however to ensure there is no significant ponding, regular maintenance is required. Where trees are in the vicinity, significant ponding is likely to occur in spouting without leaf guards. Leaf guards should not be permanently fixed to the roof cladding so that gutter maintenance can be carried out.

Where rain-water remains evident in the sole of a spouting or gutter and does not evaporate with the sun or wind within three days, it is considered permanent ponding and any warranty for AZ coated spouting or gutters will be voided.

8.5 DOWNPIPES

Water collected by the gutters is transported to the storm-water disposal system via downpipes, and *graph 8.2.2.* details the size of downpipes required for both external and internal gutters.

Greater carrying capacity for downpipes can result from the head obtained by the use of sumps and rainwater heads.

The cross-sectional area of external downpipes must be half the cross-sectional area of the external gutter.

All internal downpipes must be sealed to internal sumps by a compression ring or similar fitting and must have access for cleaning at the base where they are connected directly to the drain. To comply with the 50 year durability requirement of the NZBC, all hidden downpipes must be seamless and must be able to withstand a water test with an applied head of 1.5m of water without leakage.

Internal downpipes that are easily replaced require a 15 year durability.

Where vertical downpipes are sealed to the drain internally within a building they must be designed with a minimum of half the cross-sectional area of the internal gutter.

The exterior junction or manhole must be vented to enable free discharge to the ground in the event that the drain is blocked.

Major internal building and consequential damage has been caused by failure to comply with these requirements rather than as often assumed, because of inadequate design capacity of the roof drainage system. For over flows (*see section 8.6.2.*)

Horizontal drains are not designed for the maximum rainfall that is required for gutters and therefore it is likely that their capacity will be exceeded during the life of the building.

To avoid any water back-up if the drain capacity is overloaded or obstructed an air break should be provided for all downpipes to ensure that drain water does not back up the downpipe.

Ground outlets should be built up to avoid debris and surface water entering the drain.

All exterior downpipes must discharge freely over a grated gully trap or into an oversize pipe which must be a minimum of 50mm above the adjacent ground level.

Sealed water systems such as siphonic tank systems must have an overflow capacity of 200mm/hour.

Downpipes fixed at an included angle of less than 105°, must have a cross-sectional area equal to that of the gutter.

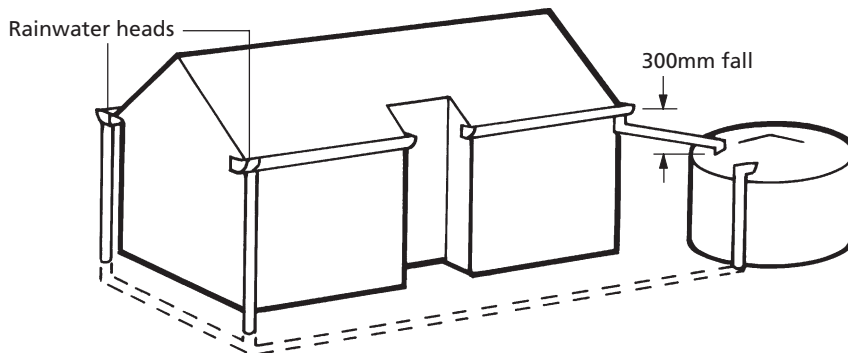
Downpipes must be compatible with the roof and gutter material and must comply with the 15 year durability requirement of the NZBC.

Galvanised steel downpipes should not be used to discharge rainwater from AZ coated or painted roof cladding.

When using galvanised rain-water goods with other materials, special attention should be given to inert catchment corrosion (2.6).

P.V.C. downpipes that are run horizontally should have a greater provision for expansion than metal, as they will absorb heat, particularly if they are painted a dark colour. They should have a maximum length of 9.0m before discharging into a rainwater head that will act as an overflow. P.V.C. downpipes and spouting are also prone to damage by hail.

When rain-water is collected into a water tank, there is often insufficient distance in order to obtain adequate fall for one downpipe outlet. In this instance or whenever the roof design pre-empt a continuous spouting to the tank it is possible to have several sealed PVC downpipes some of which can run underground to discharge into the tank. As these will remain full it is necessary for the spouting outlet to be a rain-water head to avoid flooding.



Drawing 8.5. 

8.5.1 DOWNPIPE SPREADERS

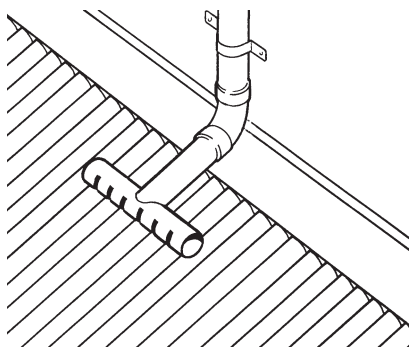
All downpipes that discharge onto a lower roof, must have a spreader to ensure wide distribution of the water. Spreaders must not discharge directly over fasteners or at a lap and must have holes equalling twice the area of the downpipe.

Maximum catchment area above and downpipe size discharge onto a lower roof must be:

- 60m² and 63mm for corrugate and symmetrical trapezoidal profiles
- 80m² and 75mm for asymmetrical trapezoidal profiles
- 100mm downpipes must not be drained onto a lower roof.

Copper spouting and downpipes must not drain onto metal roof or wall cladding below them unless the cladding is also copper.

A spreader should be used over several pans but is only suitable to distribute a limited amount of water before the pan capacity is exceeded. Large downpipes could overflow the profile if the downpipe is discharging at maximum capacity and therefore it is better practice for all downpipes to be continued separately to the drain at ground level.



Drawing 8.5.1. Minimum length of spreader is 400mm. 

8.6 SUMPS

The discharge capacity of a gutter increases with the depth of water over the outlet, and the best way to increase the head is to discharge the open end of the gutter into a sump. Swirl at the outlet will reduce its performance so the positioning of the outlet is important.

Sumps must have a grating or leaf-guard the same area as the sump, have a flat base, must project above the calculated level of flow.

Overflows must provide a conspicuous warning that maintenance is required and must discharge clear of the building. Sumps must be the same width as the gutter and have a depth of 300mm. Internal sumps must have an overflow as shown on drawing 8.6.B otherwise they will act as an overflow and cause damage to the inside of the building. Outlets must be placed at a distance less than or equal to the outlet diameter from the nearest vertical side of the sump.

Sumps must have a grating or leaf-guard the same area as the sump but must not be placed directly in the outlet. The grating must have a flat base and not be tapered. See drawing 8.6.C.

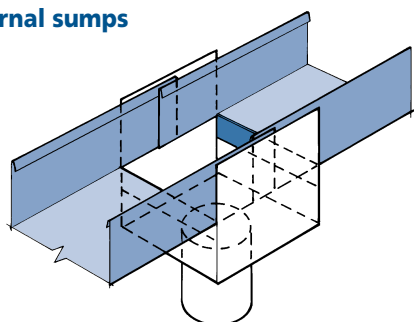
The overflow from an internal gutter can be an unsealed joint at ground level between the downpipe and the drain. For over flows (see section 8.6.2.)

Gratings can be a cause of sump blockage and can reduce the outlet capacity.

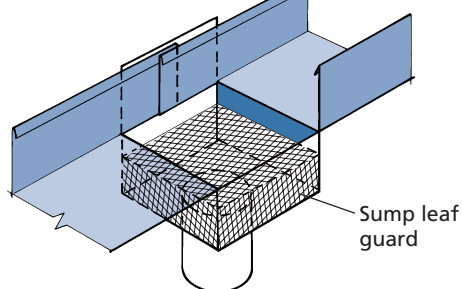
Gratings or guards should be designed so that any debris will float, and hail or obstructions such as a ball will not wedge and block the guard. Gratings or guards should be cleared of accumulated debris regularly during normal maintenance.

An internal sump should have a guard that prevents debris from blocking the outlet. An aluminium expanded metal removable loose fitting box can be fitted as shown in drawing 8.6.C a minimum of 40mm below the sole of the gutter. Because the top is flat it is unlikely that the entire surface area of the outlet can become blocked as is the case with balloon type guards.

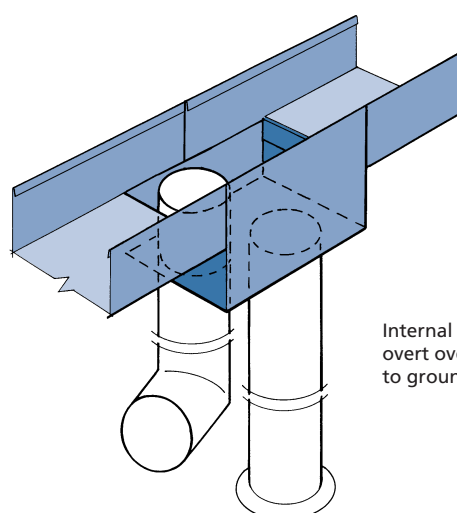
Internal sumps



Drawing 8.6.A MRM



Drawing 8.6.C MRM

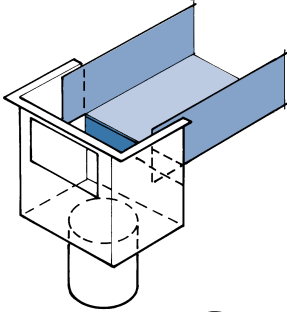


Drawing 8.6.B MRM

Internal sump with
overt overflow
to ground level

8.6.1 RAINWATER HEADS

Rainwater heads should be placed on the outside of the building to ensure that the gutter will not overflow. Both rainwater heads and sumps can reduce turbulence and provide a head of water to maximise downpipe flow.



Drawing 8.6.1. 

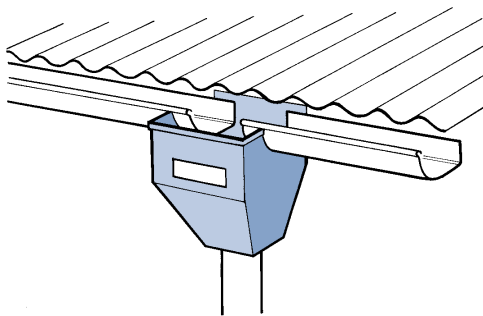
8.6.2 OUTLETS AND OVERFLOWS

The type of outlet affects the flow rate of water from a gutter. Weir outlets are recommended as the best way to ensure positive flow from gutters or spouting with limited fall and they also provide an automatic overflow because the spouting or gutter is not sealed to the downpipe or rainwater head.

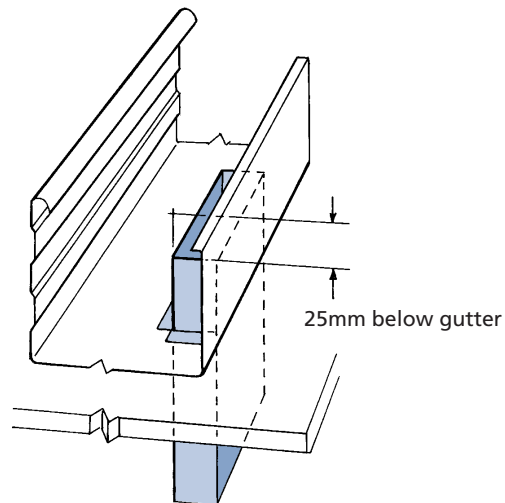
The overflow opening of a rainwater head from an external gutter must have a cross-sectional area equal to that of the downpipe. The bottom of the overflow must be no higher than 25mm below the bottom of the spouting.

The overflow opening of a rainwater head from an internal gutter must have a cross-sectional area equal to that of the gutter, (see *drawing 8.6.1.*) and the overflow weir must be 25mm below the sole of the gutter.

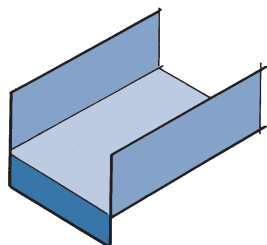
Overflows must provide a conspicuous warning that maintenance is required and must discharge clear of the building.



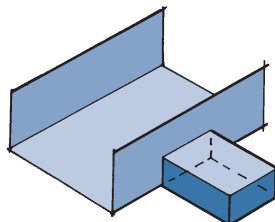
Drawing 8.6.2.A. 



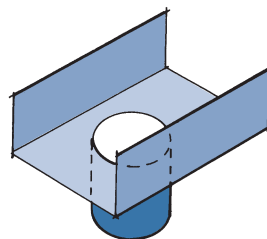
Drawing 8.6.2.B. 



Weir



Scupper



Pipe

Drawing 8.6.2.C. 

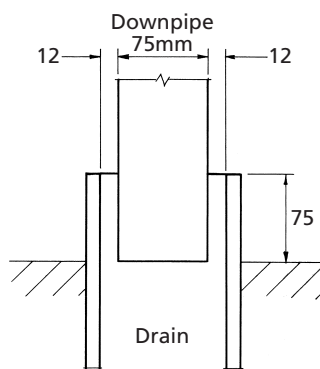
Where the position of an outlet of a parapet wall gutter is on an outside wall, any scupper overflow cut through the wall should discharge on to the same property.

For parapet wall gutters, where the position of an outlet is within the building, a minimum of two downpipe outlets from the sump should be used, joined separately to the downpipe beyond any offset. Alternatively a separate overflow pipe can be used equal in capacity to the outlet with the top 25mm below the sole of the gutter and run to discharge onto the ground. (*see drawing 8.6.2.B.*)

Downpipes that discharge over a gully trap or ground sump provide an automatic overflow if the drain becomes blocked. (*see drawing 8.6.2.D.*)

Using an oversize drain without any sealing can also act as an overflow by providing an air break. (*See drawing 8.6.2.E.*)

Spouting can be made failsafe for overflowing by providing a rain water head as shown in *drawing 8.6.2.A & B.*

**Drawing 8.6.2.D.** **Drawing 8.6.2.E.** 

9.0 PLASTIC ROOF LIGHTING

Plastic roof lights are used in conjunction with profiled metal cladding in many industrial and commercial buildings to create an acceptable level of natural lighting in the working environment.

9.1 CLAUSE G8 NZBC

1. 'The work place must have suitable and sufficient lighting'.
2. 'The lighting must, so far as reasonably practical, be by natural light.'

When used with profiled metal cladding in N.Z., all plastic sheets should comply with AS/NZS 4256.1. and be tested in accordance with Section 18 of this Code of Practice.

The most common form of roof lighting used in commercial and industrial buildings comprises of single skin matching profiled translucent sheets, running from ridge to eave. Alternatively, discontinuous profiled sheets placed in a chequer board pattern, or barrel-vaults or domes can be fitted on both sloping and flat roofs. All plastic roof lighting materials are supplied with films or surface coatings and stabilisers for durability and long-term resistance to weathering and the discolouration termed 'yellowing'.

Roof lights are available to match metal profiles in a range of thicknesses, and fire resistant qualities, and these are varied according to structural and safety requirements and imposed loadings. They should comply with the test provisions of AS/NZS 4257.

Only full-length roof lights running from ridge to eave must be used with unpainted galvanized roof cladding to avoid inert catchment corrosion.

To maintain water-tightness and avoid thermal distortion, roof lights should be installed within the spanning capability of the profile, which depends on the profile shape and thickness. Additional support can be obtained from adjacent metal cladding by the use of mid span supports (span-breakers) (see *section 9.7.4. spanbreakers*) or alternately the thickness of the roof lights should be increased.

Safety mesh should be provided under all translucent sheeting which is accessible and >500mm wide.

9.2 MATERIALS

There are two groups of plastic roof lighting materials commonly used in New Zealand in conjunction with profiled metal cladding:

- a. thermo-setting: GRP translucent glass-reinforced polyester.
- b. thermo-plastic: acrylic, uPVC and polycarbonate.

Thermo-plastics will soften and collapse under heat, and GRP can distort at 80° but will yellow more rapidly above 60°. Distortion temperatures will vary between different materials and thicknesses.

As performance of plastic sheeting is related to thickness as well as profile, designers should be aware that a nominal weight per m² does not relate to differing profiles.

The weight per m² or mass per unit area has a tolerance of ±10% but is a confusing measure, because the test provisions of AS/NZS 4257 require the measure to be calculated from the area of the profile including the overlap. Because the mass of plastic sheeting will vary between profiles, the thickness will vary.

This is the opposite measure to metal where one thickness will have varying mass per m² for each profile.

When differing profiles have the same mass per m² then their thickness will vary. It is not therefore possible to simply compare the performance of plastic sheeting by the weight and it is recommended that all plastic roof lighting sheets be described by thickness.

9.2.1 GLASS REINFORCED PLASTIC. GRP

GRP combines polyester resin and chopped glass fibre. AS/NZS 4256.3 requires sheets to contain not less than 22% by mass of glass fibre and also to be marked with their classification and weight.

GRP is suitable for in service temperatures of -10° to 70°C. and some GRP sheets are available in a fire resistant grade.

GRP should have a minimum thickness of 1.1mm. but it is available up to 3.0mm thick

GRP Flat Sheet Theoretical weights $\pm 10\%$

mm	=	g/m ²
1.1		1800
1.2		2000
1.3		2100
1.5		2400
1.9		3000
2.1		3300
2.5		4000
3.0		4880

The exterior surface of GRP is covered either with a polyester film or has a layer of gel-coat cast as the sheet surface. Sheets can have a film or a coating on one or both sides or have a film on one side and a coating on the other. The performance of G.R.P. is related to both light transmission and durability of the various films and coatings can provide different performance for each category in different environments.

N.B. Performance in both of these areas is not necessarily directly related.

The roofing contractor must ensure that the correct weathering surface of plastic sheeting is placed uppermost as the durability and any warranty is dependent on placing the sheet the correct side up.

9.2.2 POLYCARBONATE

Polycarbonate is a tough clear thermoplastic polymer with a higher deformation temperature than PVC.

Polycarbonate is manufactured with a co-extruded UV resistant top layer, which will resist weathering, but its durability is dependent on the thickness of the top layer.

Profiled polycarbonate sheeting has a limited spanning capacity and also requires greater provision for expansion than GRP. It is available in thickness's from 0.8mm to 1.5mm but is available only in a limited range of profiles.

Flat multi-wall extruded sheets with one or more air gaps have a thinner wall thickness but derive their rigidity from the shape of the profile. They are limited in spanning capability, but come in wide sheets fixed into proprietary extrusions and are suitable as continuous barrel vaults and as double skin roof lights.

Surface coatings provide different levels of durability, chemical resistance and weather resistance.

Polycarbonate sheets must not be fitted above sprinklers as they can drop out in a fire and interfere with the sprinkler's function.

9.2.3 PVC

PVC is a compound of polyvinyl chloride manufactured with stabilisers but without plasticisers, that complies with AS/NZS 4256.2. Profiled PVC roof lights have a limited spanning capacity and require greater provision for expansion than other plastics or metals.

Profiled PVC sheeting ranges from 0.8mm to 1.5mm in thickness but is available only in a limited range of profiles.

PVC softens at 80°C and will act as a smoke vent when heated during a fire and has a service temperature of 60°C, and a tensile strength of 52 MPa @ 20°C.

As PVC may not satisfy the 15 year durability requirements of the NZBC it is not regarded as being suitable for commercial or industrial use and should not be used in habitable buildings.

PVC sheets must not be fitted above sprinklers as they can drop out in a fire and interfere with the sprinkler's function.

9.3 TYPES OF ROOF LIGHTS

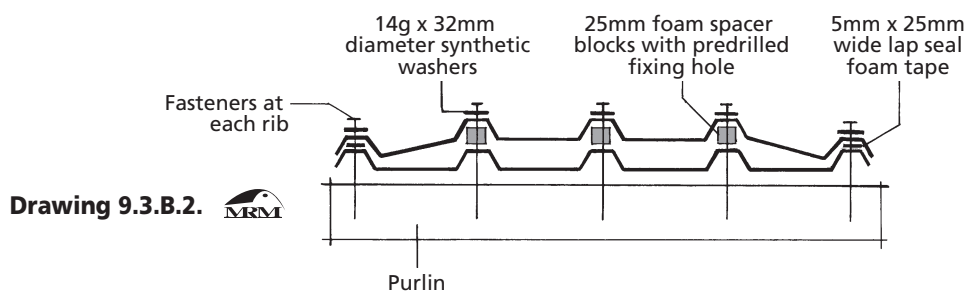
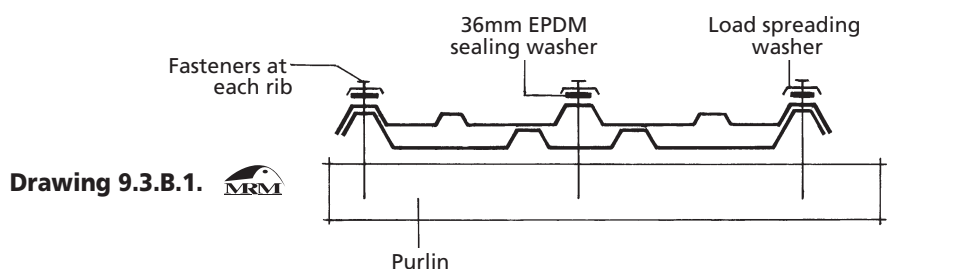
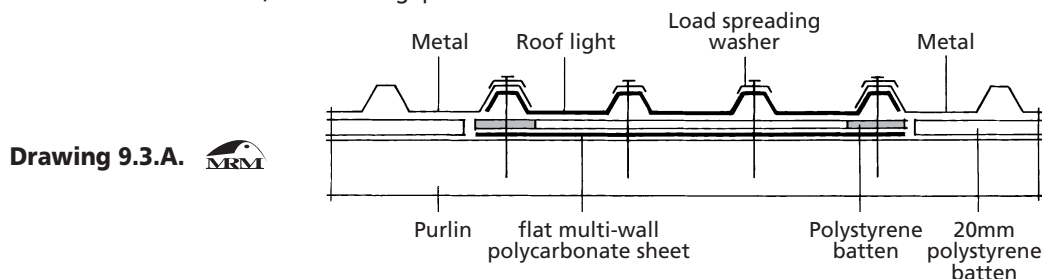
Roof light installations can be grouped into one of the following types:

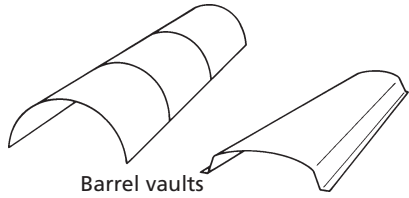
1. single skin.
2. double-skin. (see *drawing 9.3.A.*)
 - (a) where the roof cladding is fixed to battens and uses a flat multi-wall polycarbonate sheet.
 - (b) where an additional sheet is fixed above as shown in *drawing 9.3.B.1 and 9.3.B.2.*
3. continuous vaults. (see *drawing 9.3.C.*)
4. individual domes. Light tubes made from acrylic or polycarbonate usually are manufactured with a flashing suitable to weather most roof cladding profiles. (see *drawing 9.3.D.*)

Proprietary opening window units or skylights made from acrylic also have powder coated frames and are provided with weathering curb flashings, but they should be compatible with the roof cladding and should be installed as required in *section 6.0. penetrations.*

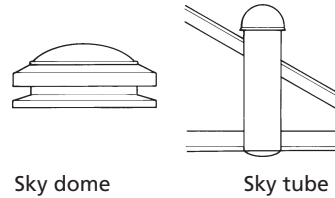
Acrylic or polycarbonate tubes, skylights or domed roof lights should not drain onto unpainted galvanised roof cladding or onto galvanised fasteners. (see *section 2.6.4. inert catchment*)

Proprietary GRP sheets are available that can be used as double skin roof lights. A liner panel GRP or PVC sheet can be used to minimise condensation, but the air gap should be sealed.





Barrel vaults

Drawing 9.3.C. Continuous vaults 

Sky dome

Sky tube

Drawing 9.3.D. Individual domes 

9.4 LIGHT TRANSMISSION

Daylight glare levels, diffusion and location are more important than light intensity and these considerations should be determined so that the plastic sheeting will be suitable for the intended use or purpose of the building. Normal roof light areas range from 5% of floor area for warehouses to 10%-15% for industrial buildings, and 20% for sports halls and for factories where intricate work is done. For urban areas where air pollution reduces the level of natural light, or where roof lights are double skin or are specified tinted, the proportion of roof lights should be increased. Typical light transmission for double-skin roof lights is around 70% when new, and diffusing agents can be added during manufacture, to minimise glare and solar gain. Roof lights will perform better, maintain maximum light transmission and last longer if they are kept clean by washing down with water and mild detergent, at 1-2 year intervals. Although films and gel-coats will vary in their resistance to surface deterioration, if any dirt or lichen deposits are allowed to build up they will shorten the life of roof lights. The light and heat transmission of plastic roof lights can be reduced by adding tints to polycarbonate sheeting, or pigments to GRP sheeting. Such tints can lower the light transmission to as low as 25%, compared to 90% for clear sheets and heat transmission can also be reduced by over 50%.

9.5 WEATHERING AND DURABILITY

Plastic roof lights are resistant to normal weather conditions because they are protected by surface coatings or laminated films from ultra violet light (UV), temperature changes and the ingress of moisture.

Surface protection includes PVF or polyester films, liquid gel-coats on GRP sheets, or co-extruded layers on thermoplastic sheets and their resistance to yellowing, surface crazing and erosion, fibre prominence in GRP and embrittlement all depend on this protective treatment. The surface protection provided may also determine their resistance to aggressive chemical environments. PVF films provide very good chemical resistance provided that the film is not damaged during the life of the product. Gel-coats can also be used in chemically aggressive environments that would be unsuitable for metallic coated steel cladding.

Surface protection films and coatings are very weather-resistant but should be kept clean and well maintained, but it is to be expected that the translucence of all plastic sheeting will reduce over time even if the sheets are cleaned regularly.

UV degradation depends on location, orientation to the sun, and on the UV intensity. Some inferior films on GRP sheets can discolour and craze in as little as 3 years, however higher grade films have been proven in New Zealand to provide useful light transmission for 15 years and certain types of gel-coat have shown the potential to provide useful light transmission for up to 20 years. Polycarbonate sheet with good protection to avoid degradation by UV, can provide useful light transmission for up to 20 years. PVC has only a useful light transmission life of 2-5 years and it can become embrittled due to UV exposure.

Fire-resistant sheeting exposed to UV light may discolour more quickly, due to the fire-retardant additives.

All plastic sheeting is subject to mould growth particularly in areas of high humidity and if this is removed, care should be taken not to damage the film surface. (*see mould section 13.6.1*)

Where the roof is constructed using composite panels, factory assembled roof lights are the most appropriate roof light solution. (*see section 12*)

The use of double skin sealed rooflight panels will reduce the risk of condensation.

9.6 LOADINGS

9.6.1 POINT LOAD. WALKING TRAFFIC

All plastic roof lights are classified as brittle roofing and should not be walked on unless specifically tested under the point load test provisions of AS/NZS 1562.1 1996

AS/NZS 1562.3 requires the provision of safety mesh under all plastic sheeting subject to local statutory or national building code regulations. The HSE Act 1992 classifies accessible roof lighting as hazardous and requires the use of safety mesh under or above translucent sheets over 500mm in width.

Although normal chopped strand GRP of sheet thickness greater than 1.7mm can resist the impact load to demonstrate resistance to accidental fall, this strength is not expected to be retained for more than 5-10 years, and the sheeting is therefore classified as brittle. GRP sheet that is reinforced with a woven glass mat, may remain trafficable for 20 years, but this should be proven by test.

Safety mesh can damage plastic sheeting by movement due to expansion and walking traffic, and should be isolated at the purlin. (see section 9.7.6. purlin protection)

The mechanical properties of plastic roof lights differ from those of profiled metal cladding as they are more flexible which allows them to deflect to a greater extent without damage. Foot-traffic and or access for maintenance should be considered at the design stage, so that one sheet or a reduced width is provided in order that a workman may step over and not on, the roof light.

Safety mesh must be provided under all translucent sheeting which is accessible and >500mm wide.

A temporary walkway must be provided for installation where the plastic sheeting is more than one sheet width, and if access for maintenance is required the walkway must be permanent. (see section 14.6.)

All plastic roof lights are classified as brittle roofing and must not be walked on unless specifically tested under the point load test provisions of AS/NZS 1562.1 1996 and the impact test of AS/NZS 4040.4.

9.6.2 U.D.L. WIND AND SNOW LOADS

The maximum performance of plastic roof sheeting for spanning capability and deflection under a uniformly distributed load depends on the section properties and type of material of the profile. The section properties depend on the number and depth of corrugations and the thickness of the profile. (see section 3.1.2.) The uplift pull-through load performance is dependent on the number of fasteners per m² and the type and size of washer.

Profiles which have deeper ribs are more rigid and will deflect less, but will not provide any greater resistance to pull over at the fixings unless the sheet thickness is increased. Greater spans also require thicker sheet. Additional fixings will increase resistance to pull-over failure at fixings, but will not limit deflection.

Roof lights located in the peripheral zones of high wind design load, should have provision for the higher load in this area by the use of additional fixings, reduced purlin spacings or by increasing the roof light thickness. Deflection of plastic roof lighting due to UDL wind or snow loading should be limited to <1/30th span, or 50mm.

All plastic roof lighting should be tested to withstand wind loads and extrapolation is not acceptable as a statement of performance.

On buildings higher than 10m, or areas located in the peripheral zones of high wind design loads, near verges, eaves or ridges, it is better practice for roof lights to be omitted.

Plastic roof sheeting must match the design load of the adjacent metal roof cladding. This can be achieved by using a mid-span support or by increasing the weight of the plastic sheet.

Excessive deflection due to long spans can open up side laps or cause failure in compression at the fixing points.

9.7 FIXING

Translucent sheets should be fastened in a similar manner to metal cladding except that as plastic sheeting deflects to a greater degree, extra or special fixings are required. A different depth or screw gun torque setting may be required to avoid over tightening and subsequent distortion around the fixing. Because of their differential thermal expansion plastic and metal sheeting fixings should be fastened through oversized holes. Support for plastic sheeting is obtained from the metal sheeting for downward loads, and span-breakers for uplift loads. *(see section 9.7.4. span breakers)*

All plastic roof light sheets must be laid on top of the metal sheeting at both edges.

Side laps must be fixed at a maximum of 600mm centres to drawing 9.7.1. and are required to be sealed where the roof pitch is $< 10^\circ$ and in high wind design load areas.

Oversized holes and load-spreading washers must be used when fixing roof lights and metal sheeting together. All plastic roof lighting must have pre-drilled intermediate side lap fastenings with oversized holes on all spans $> 1.200\text{m}$. *(see drawing 9.7.1)*

To avoid stress, roof lights should always be fixed progressively from one end, and not be fixed at both ends before fixing at the intermediate purlins.

Deflection limits should be placed on the performance of plastic sheeting to ensure longevity and to avoid incremental failure due to flexing at the fixing points. This can be achieved by the use of mid span supports. Plastic sheeting should not be used in applications where it approaches its deflection limits. (50mm)

Shallow symmetrical profiles of plastic roof lighting can be curved to suit draped curved metal cladding, however the radius is determined by the profile and material type and thickness. *(see draped curving section 4.9.)*

When long lengths of plastic sheeting are not supported at mid-span their longevity is reduced and incremental failure can be caused by the flexing that occurs at their fixing points.

The two main factors that limit spanning capability are deflection and pull-through over the fasteners.

As standard weight plastic roof lights have a low pull over load and the critical condition is that imposed by wind suction, their performance is determined by the number of fasteners per m^2 .

Load-spreading washers specifically made to fit the plastic sheeting must be used under all fasteners.

All fixings and washers must meet the same durability standard as the roof and wall cladding.

All plastic sheeting must have an enlarged fixing hole for provision of thermal movement, predrilled to the following diameters for 12# or 14# self drilling screws for both timber and steel purlins.

The fixing must be positioned in the centre of the oversize hole to ensure that the sheet has equal movement in all directions around the fixing.

For G.R.P.

Sheets up to 6 metres	8mm
Sheets 6 to 9 metres	10mm
Sheets 9 to 18 metres	12mm

For PVC and Polycarbonate

Sheets up to 4 metres	10mm
Sheets up to 6 metres	12mm
Sheets over 6 metres	NR

The minimum fixing pattern for roof lighting cladding is determined by the span, the design load and the profile thickness, however except for spans <1.000m, fixings and load spreading washers are recommended on all profile ribs.

Tray profiled GRP roof sheeting must be mechanically fixed to provide for the uplift load specific to the site, and must be placed on top of the adjacent metal sheeting.

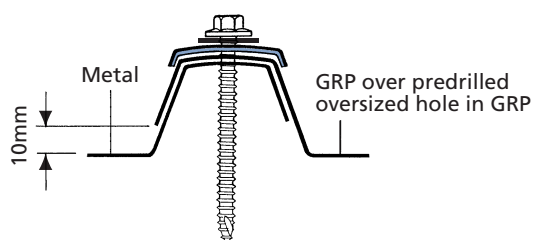
In extreme environments where there are chemical fumes and the fixings are prone to chemical attack from the inside of a building, stainless steel fixings should be used.

When pan fixing is used, the fastener should be positioned within 25mm of the rib.

9.7.1 SIDE-LAP FIXING

As there is no capillary bead formed on the side laps of plastic roof lighting, the fixing should be in the top and not the side of the rib. The length of the overlap rib of the translucent sheeting should not extend down to the pan and should have a minimum clearance of 10mm from the pan to avoid capillary action.

The side-laps of GRP sheeting and of the adjacent sheet must be fixed through the top of the rib with oversize holes in the GRP and load spreading and sealing washers. (see drawing 9.7.1.)



Drawing 9.7.1. 

9.7.2 SIDE LAP FIXING BETWEEN PURLINS

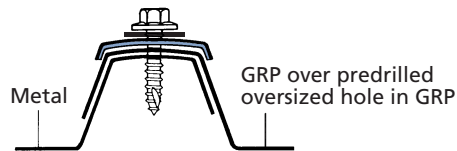
When side lap fixing GRP to metal, an oversize hole should be pre-drilled in the GRP and a coarse thread Type 17 screw used with a profile metal washer and EPDM seal. (see drawing 9.7.2.A.)

The side-lap fixing between purlins of GRP sheeting and of the adjacent sheet must be fixed at maximum 600mm centres through the top of the rib with oversize holes in the GRP and load spreading and sealing washers

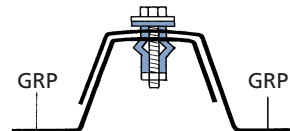
When fixing GRP to GRP, a rubber-nut or grommet can be used and installed from the top side of the roof sheet using a 35mm long 4.5 diameter aluminium or stainless steel gutter bolt and a 20mm diameter metal and EPDM sealing washer. (see drawing 9.7.2.B.)

Alternatively if bulb-tite rivets are used a clearance hole is required and care should be exercised when setting the rivet so that stress is not developed at the connection. This fixing is not suitable for use in high design wind load areas.

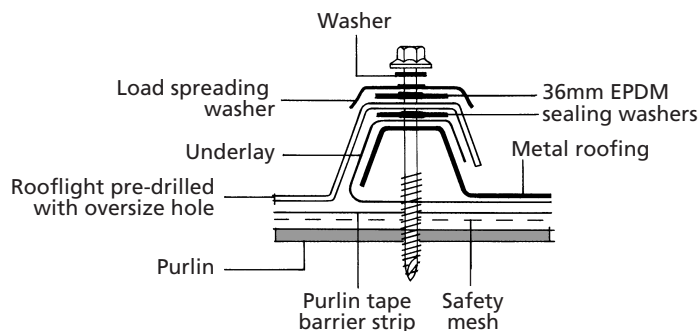
Underlay or foil must be terminated at the lap as shown in drawing 9.7.2.C to provide continuity for any condensation that may occur.



Drawing 9.7.2.A 



Drawing 9.7.2.B 



Drawing 9.7.2.C 

When fixing tray decking profiles and using matching roof lighting sheets there are several fixing options depending on the configuration of the profile. The independence of the metal and plastic sheeting should be maintained with all profiles to allow for their differing rates of expansion.

9.7.3 END LAPS

The minimum end lap of GRP sheets with metal or GRP profile sheeting must be 200mm. and sealed, and the bottom end of the over lapped sheet must be within 50mm of the lower side of the purlin or saddle flashing.

Two lines of sealing beads or compressable strips must be placed, one within 15mm from the bottom of the top sheet and the other 15mm from the top of the bottom sheet.

All sealants used with plastic sheeting must be compatible

Silicone sealants should not be used with polycarbonate roof lighting.

The sealant materials for end laps of plastic sheeting should be either neutral cure silicone, or EPDM closed cell foam with self adhesive on one face 25mm x 3 - 5mm thick, or polythene butyl tape.

9.7.4 MID SPAN SUPPORTS

Unless the thickness of the plastic sheeting is increased to equal the performance of the metal sheeting, mid span supports or span breakers with a minimum thickness of 0.95mm coated steel must be used as a mid span support for all purlin spacings >1.200m.

Mid span supports must not be used where more than one plastic sheets is laid adjacent to one another. Where two or more adjacent sheets are used together, the purlin spacings must be reduced to the maximum allowable for the plastic sheeting profile, the thickness of the sheet and the design load.

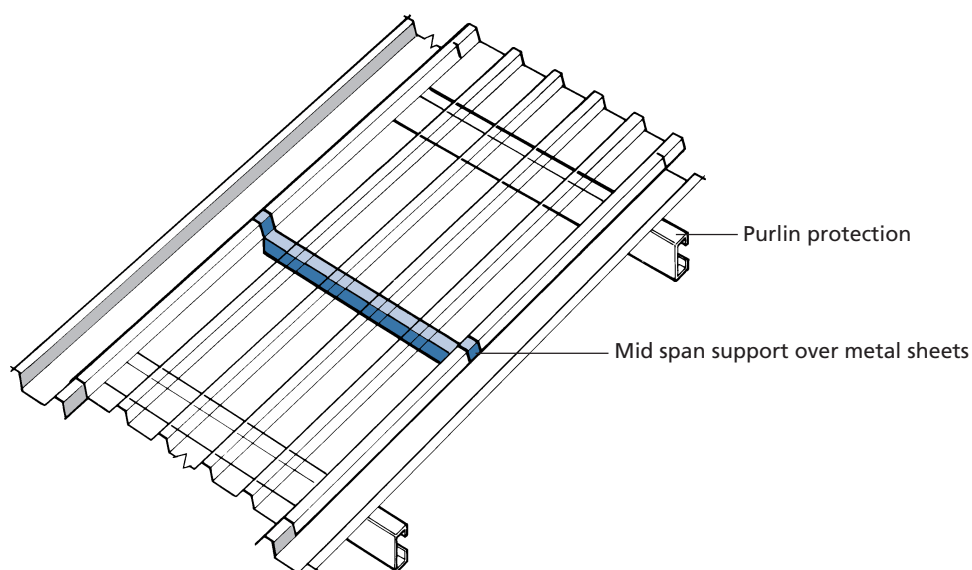
A mid span support is used at mid span at spacings, dependent on the profile, to gain additional support from the metal cladding for the plastic sheeting.

Single sheets of plastic roof sheeting placed between adjacent metal sheets, can only have the same purlin spacings as used for the metal roofing profile when a mid span support is used or the plastic sheeting thickness has been

increased to provide the same performance characteristics as the metal sheeting. The exception to this condition applies only when the plastic sheeting has been tested for point loads as described in **section 3.8 testing**.

The mid span support member is not intended to support point loads from foot traffic and should be of sufficient strength and stiffness to prevent the plastic sheet deflection being greater than that of the adjacent metal sheeting.

Mid span supports provide the uplift strength required to reduce sheet flutter in high winds and to prevent any movement between adjacent sheets they should be fixed with a type 17 screw and load spreading washer through the GRP, span-breaker and fixed to the metal sheeting. (*see drawing 9.7.4.*)



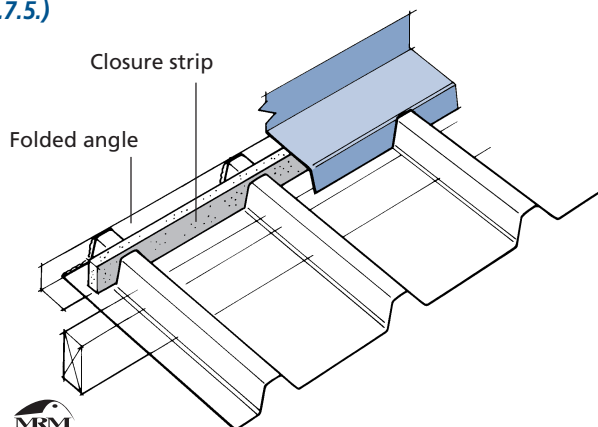
Drawing 9.7.4. Plastic roof light sheets over metal 

9.7.5 STOPENDS

Stopends can be provided to weatherproof the ends of the sheets in two ways.

1. By the use of profiled closure strips fitted close to the screw fixings of the over flashing.
2. By the use of an angle made from a durable material equal to the adjacent metal sheeting and sealed to the sheeting.

If (1) is used in exposed areas the profiled closure strip should be sealed to the plastic sheeting to act as a wind barrier. (*see drawings 9.7.5.*)



Drawing 9.7.5. 

9.7.6 PURLIN PROTECTION

Because of movement due to expansion, safety mesh will cause damage to the plastic sheeting at the purlin line, and it should be isolated at the purlin. This protection should be a foam tape or other durable and non-absorbent material and be of sufficient thickness and resilience to avoid damage. It should extend the full width of the purlin flange and where purlins are lapped, it should include both purlins.

When plastic roof lighting is laid over safety mesh or wire netting, protection must be placed over the mesh or netting to avoid damage to the underside of the plastic roof lighting.

9.7.7 DRAINAGE

When acrylic or fibre-glass domes are used, the design of the penetration flashings should allow for adequate water drainage and not rely solely on sealants for weather-tightness.

A water diverter type penetration design must be used where any penetration is >600mm wide and proprietary synthetic rubber flashings must be placed at 45° to the roof pitch as prescribed in penetrations (see penetrations section 6.0)

Acrylic domes must not be used with unpainted galvanised flashings, and plastic roof lighting must not drain onto galvanised roof cladding or gutter.

To avoid inert catchment corrosion galvanised metals must not be used in conjunction with plastic roof lighting.

9.7.8 CONDENSATION

In areas or buildings likely to suffer heavy condensation, the use of a second translucent sheet to form a double skin can be used to minimise condensation. (see drawing 9.3.A)

Twin skin plastic sheeting should have a gap of a minimum of 20mm and should be spaced with insulating material between the sheets at the fixing points. It is standard practice to place the second sheet above the first after it has been fixed, however a special ridge is required as shown on drawing 6.2.8.D

The top sheet fasteners should be of sufficient length and penetration into the structure to resist the negative wind load.

Elevated roof lights designed specifically for long run tray roofs from ridge to eaves are fixed to the ribs of the sheet and permit condensation to run off onto the trough.

A UV stabilized grade of clear polythene film or sheeting can also be used in order to help control any condensation dripping from the plastic roof lighting, but its durability may be less than that of the plastic roof sheeting.

9.7.9 PITCH

The minimum pitch is the roof cladding pitch and not the building design roof pitch. The allowable cumulative deflections of the frame, purlin and roof sheeting, which can take place over large spans, require the building design roof pitch to be increased to comply with minimum cladding pitch.

Plastic roof lighting profiles deflect to a greater degree than do metal roof or wall claddings of the same dimension. (see section 3.1.1. deflection) For this reason it is recommended that the roof pitch be increased for plastic roof lighting profiles above the minimum for the profile in addition to that recommended for allowable deflections (1.5°).

It is better practice that all plastic roof lighting profiles with sheet lengths >15m in length should be a high rib profile >35mm or that the roof pitch should be increased by 3° over that required in Table 4.8.1.

9.8 THERMAL EXPANSION

Although the figures quoted following are the theoretical expansion rates of different plastic roof lighting materials, the actual expansion rate will not be the same. *(see expansion section 4.1.6.)*

As P.V.C. and polycarbonate expand almost six times more than steel they should only be used in lengths not exceeding 3.000m however translucent plastic sheets do not normally reach the same temperatures as adjoining metal sheets.

mm per 50° per 1.0m length	
Steel	0.6
GRP	1.1
PVC	7.0
Polycarbonate	3.2

PVC and polycarbonate sheet in lengths up to 3.000m require 6mm oversize holes to all fixings that should always be fitted in the centre holes which can be achieved by pilot drilling. It is recommended that a stepped drill bit be used to ensure the correct size hole.

GRP roof lights also require provision for thermal movement but to a lesser degree. *(see table 4.1.6.)*

Special screws which drill there own clearance hole are suitable for polycarbonate and GRP sheeting.

9.9 TRANSPORT, HANDLING AND STORAGE

All roof lights should be handled and stacked with care as film surfaces are easily scratched, and heavy stacks can damage lower sheets.

All roof lights should be stored flat, the right way up, on 75mm wide battens not more than 1.2m apart. Stacks should not be higher than 1m, and should be covered and protected from rain and sun. Thermoplastic sheets can overheat and deform in a stack, and exposed stacks can permanently discolour, due to action of sun and water.

9.9.1 MAINTENANCE

First maintenance after 12 months requires cleaning down with warm water and a stiff bristle brush, and cleaning off any grime or debris. Every 2-3 years other maintenance required is an inspection for damage, and a check on fixings for tightness and on the condition of flashings and sealants.

Because painted roof lights appear no different in place than metal sheets, this practice can be dangerous for any workers carrying out maintenance work on the roof. Painting also can cause heat distortion which can lead to premature failure.

Roof lights must not be painted over as this renders them hazardous to maintenance workers.

As a warning, primary and secondary fasteners can be brightly coloured, providing a contrast with the remainder of the roof cladding surrounding the roof light areas. The area can also be ringed with a distinctly painted stripe.

Lichen will accumulate on plastic roof lighting wherever there is a source of nutrients but it should be removed with care. *(see section 13.6.1. lichen and mould)*

10.0 PRESSED METAL TILES**10.1 DESIGN**

Metal tiles, shingles and shake panels are press formed to provide a variety of shapes resembling clay tiles and wooden shingles or shakes. They are interlocked or overlapped together laterally and longitudinally and are clipped or fastened to timber or steel battens.

The metal used for the manufacture of metal tiles, shingles and shakes is metallic coated steel, although aluminium or other metals can be used. Pressed metal tiles made from steel invariably have an additional protective coating applied over the metallic coated steel. This may be an organic paint coating applied either by the steel manufacturer before the tiles are formed, or by the tile manufacturer after the tiles are formed. An alternative coating can be provided by applying crushed stone or ceramic granules to the base metallic coated steel and attached by an adhesive coating. In this case a clear acrylic coat is normally applied on top of the stone coating.

These coatings give protection to the metallic coated steel base, as well as providing a decorative finish.

Pressed metal roofing tiles are installed by fixers, trained and appointed by the manufacturers or their representatives, and they are not normally supplied to other installers.

10.1.1 DURABILITY

The principles behind detailed requirements for fixings, flashings, corrosion, compatibility and maintenance as described elsewhere in this Code of Practice should also be applied to the design and installation of pressed metal tiles. Exceptions result from the specific differences between tiles and other forms of metal roof cladding and include the height of laps and specific dimensions of metal shingles and shakes prescribed in this section.

Steel based metal tiles, shakes and shingles must have hot-dipped galvanised fasteners that are compatible with the base metal and provide a service life equivalent to the durability of the panel.

Panels are fastened to the roof structure by fixing horizontally through the front of the panel and because the fixings are in shear they provide wind uplift resistance suitable for very high wind design loads.

10.1.2 PITCH

Tiles with an upstand of a minimum of 25mm must not be laid on roof structures less than 12°, unless approved in writing by the tile manufacturer, the B.C.A. or the Territorial Authority.

Tiles, shakes or shingles with an upstand of less than 25mm must not be laid on roof structures less than 15°.

N.B. The pitch of the roof is not the same as the pitch of the tiles because this varies with the height of the batten and the height of the upstand. If the minimum pitch cannot be complied with, a method approved in writing or a producer statement should be given before work is commenced.

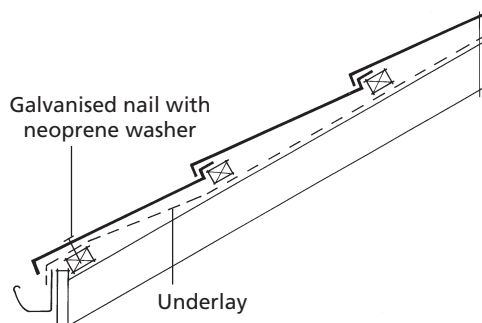
10.1.3 UNDERLAYS

Permeable self-supporting underlay must be installed on all new roofs as specified in section 4.3. of this Code of Practice.

The underlay must be installed horizontally with a minimum 75mm overlap.

The first length of underlay should be positioned so that it lays over the eave batten and the fascia, and into the gutter.

When pressed metal tiles are installed, the underlay is laid horizontally on top of the rafters before the battens are fixed and so there is an air space between the underlay and the tiles, except at the eave.



Drawing 10.1.3. 

10.1.4 ROOF FRAMING

Roof framing should provide support and fixing for the tile battens that will satisfy the design load wind requirements. Installers should check that the framing has been erected to an accurate and even line before roof fixing is started.

An inspection and any rectification to the framing alignment must be carried out before roof fixing is commenced.

10.1.5 TILING BATTENS

Tiling battens must be:

- H1.1 boron treated when used in attic roof construction
- H1.2 treated when used in skillion roof construction
- Douglas fir of moisture content <20%
- KD Pinus Radiata of moisture content <18%
- not less than 50 x 40mm for 900mm rafter spacing
- 50 x 50mm for 1200mm spacing

Copper preservative timbers must not be used with Zinalume coated tiles. Battens required for rafter spacings greater than 1200mm must be specifically designed and be spaced to suit the tile module.

Battens at 370mm centres must be fixed to the rafters or trusses over the underlay using fasteners to comply with Tables 10.1.5.A, B and C.

N.B. Battens at different centres may require different values.

Table 10.1.5.A. for buildings with ceilings and 370mm batten spacing

cpe = -0.9, cpi = 0, cp = 0.9

Pullout resistance in kN required for battens for buildings with ceilings

Purlin/ batten size	Max span	Wind Zone 0.61kPa	Wind Zone 0.61kPa	Wind Zone 0.82kPa	Wind Zone 0.82kPa	Wind Zone 1.16kPa	Wind Zone 1.16kPa	Wind Zone 1.50kPa	Wind Zone 1.50kPa
mm x mm	mm	Low 32m/s	Low 32m/s	Medium 37m/s	Medium 37m/s	High 44m/s	High 44m/s	Very High 50m/s	Very High 50m/s
		M	P	M	P	M	P	M	P
50 x 40	900	0.2	0.3	0.3	0.4	0.3	0.5	0.5	0.7
50 x 50	1200	0.2	0.4	0.3	0.5	0.5	0.7	0.6	0.9

M = main body of the roof P = periphery as described in drawing 3.3.2.A.

Table 10.1.5.A.

Table 10.1.5.B.

cpe = -0.9, cpi = 0.2, cp = 1.1

Pullout resistance in kN required for battens for buildings without ceilings but with a permeable windward wall

Purlin/ batten size	Max span	Wind Zone 0.61kPa	Wind Zone 0.61kPa	Wind Zone 0.82kPa	Wind Zone 0.82kPa	Wind Zone 1.16kPa	Wind Zone 1.16kPa	Wind Zone 1.50kPa	Wind Zone 1.50kPa
mm x mm	mm	Low 32m/s	Low 32m/s	Medium 37m/s	Medium 37m/s	High 44m/s	High 44m/s	Very High 50m/s	Very High 50m/s
		M	P	M	P	M	P	M	P
50 x 40	900	0.2	0.3	0.3	0.5	0.4	0.6	0.6	0.8
50 x 50	1200	0.3	0.5	0.4	0.6	0.6	0.9	0.7	1.1

M = main body of the roof P = periphery as described in drawing 3.3.2.A.

Table 10.1.5.B.

Table 10.1.5.C.

cpe = -0.9, cpi = 0.8, cp = 1.7

Pullout resistance in kN required for battens for buildings without ceilings and with a dominant windward opening

Purlin/ batten size	Max span	Wind Zone 0.61kPa	Wind Zone 0.61kPa	Wind Zone 0.82kPa	Wind Zone 0.82kPa	Wind Zone 1.16kPa	Wind Zone 1.16kPa	Wind Zone 1.50kPa	Wind Zone 1.50kPa
mm x mm	mm	Low 32m/s	Low 32m/s	Medium 37m/s	Medium 37m/s	High 44m/s	High 44m/s	Very High 50m/s	Very High 50m/s
		M	P	M	P	M	P	M	P
50 x 40	900	0.4	0.5	0.5	0.7	0.7	1.0	0.9	1.3
50 x 50	1200	0.5	0.7	0.6	0.9	0.9	1.3	1.1	1.7

M = main body of the roof P = periphery as described in drawing 3.3.2.A.

Table 10.1.5.C.

How to achieve these requirements (Data obtained using 45mm batten thickness)

Fastener	Size	No.	kN
Gun nail	90 x 3.15	1	0.4
Ringshank nail (gun/hand)	90 x 3.2	1	0.6
Gun nail	90 x 3.15	2	0.7
Twist Shank Nail	90 x 3.3	1	0.9
Purlin Screw c/s head	10g x 100	1	2.5
Type 17 screw	14g x 100	1	7.3

Table 10.1.5.D.**Battens must have square cut ends and must be butt jointed over the centre line of the rafter.****Adjacent rows of battens must not be joined on the same rafter and must span at least 3 rafter spacings at the roof edge.****A batten must be installed immediately behind the fascia as fixing for the eaves tiles****Eaves tiles must overhang the gutter by a minimum of 30mm.**

Eaves tiles are recommended to overhang the gutter by 40mm.

Because an eaves tile batten is installed immediately behind the fascia the position of the next batten up the rafter will be less than that of the tile normal batten spacing.

The position of this batten may vary depending on the pitch of the roof.

The edge of the roof should be taken as 20% of the roof width measured from the fascia, barge, hip or ridge line, and will apply all round the periphery of each roof plane.

The batten layout is marked on the rafters by placing nails at the line of the batten fronts. The roofing underlay is then laid over this, onto the rafters. The battens are then laid from the lowest part of the roof upwards, using the marker nails to locate the front edge of the batten. The marker nails are removed before the tiles are laid.

10.2 ROOF DRAINAGE

10.2.1 VALLEYS

Valley gutters must be made with the same metal or coating or a compatible material as the roof tiles, and when the roof tile is painted or coated the valleys must also be painted.

Where secret gutters are used or where the flashings are unseen, they must have a durability of 50 years.

The valley up-stand dimension must be a minimum of 20mm and the fasteners must not penetrate the valley.

For valley sizing see *roof drainage section 8.4.5. Valley*.

10.2.2 VALLEY INSTALLATION

The valley boards installed between the valley jack rafters to support the valley and tile battens are required to be set with their outer edge a minimum of 90mm from the centre line of the valley. Valley boards are required to support a point load of 1.1.kN, which is taken to be the weight of a tradesperson with a bag of tools. Valleys are installed so that water discharges over the back of, and into, the eaves gutter. The valleys are held in position by clips specially designed to allow for expansion, or by compatible nails and washers placed along side the valley or bent over the top lip of the valley.

Under no circumstances must the fasteners penetrate the valley surface.

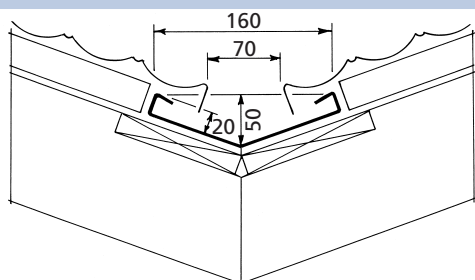
Where joins occur the minimum overlap is to be not less than 200mm.

The top end of the valley should be turned up against the hip or ridge battens to the height of the batten. Where two valleys meet over a dormer they are cut, shaped, joined and sealed so that they form a continuous valley.

The tile edge should be bent down to a minimum of 5mm from the valley floor.

The gap between tiles on opposing sides of the valley must be a minimum of 70mm.

Valley boards and boards supporting flashings must be treated H.3 and separation by underlay is required between any metal and the treated timber.



Drawing 10.2.2 Section through valley 

10.3 FLASHINGS

Standard flashings are supplied for most locations on a roof, and are in two styles, only one of which is used on any one roof. All flashings and roofing accessories are made from the same base metal as the tiles.

- “Long” accessories are 2 metres long, with fixing holes every 500mm, and there are specific accessories for ridges, hips, barges, aprons and walls.
- “Short” accessories are 400mm long trims, and can be used for most flashing applications on a roof.

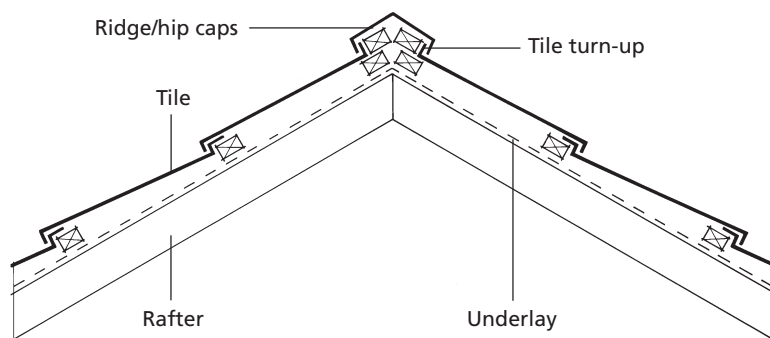
Special flashings are made as required by the manufacturer or the roofer from uncoated steel and subsequently factory coated using the same coating process as used for tiles.

10.3.1 RIDGE

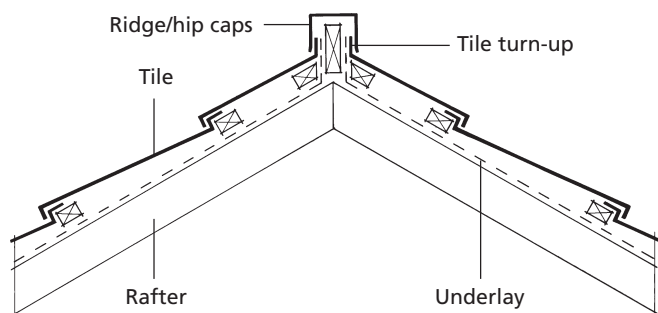
Tiles must be turned up a minimum of 40mm against the battens, hip board or where they butt against a vertical or an inclined surface.

The ridge trim cap or side flashings must cover the tile turn-ups by a minimum of 35mm.

Ridge tiles are bent up and then cut to form a turn-up that fits under the ridge/hip cap or short accessory. To ensure a watertight joint and prevent the ingress of water, a tight fit is required between the tile and the ridge cap.



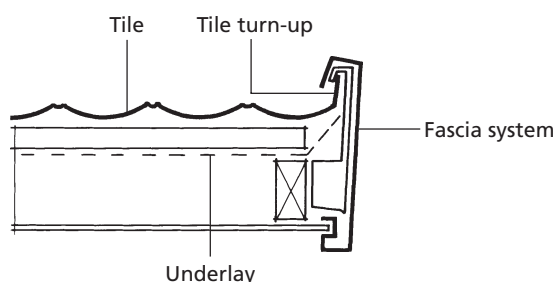
Drawing 10.3.1.A. Ridge and hip short trim installation 




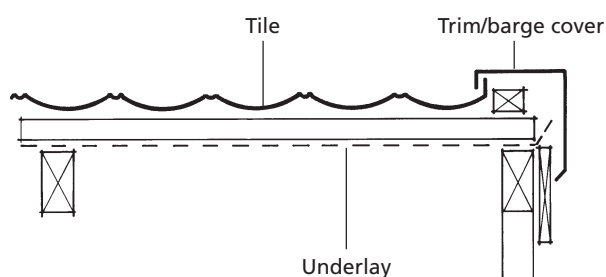
Drawing 10.3.1.B. Ridge and hip long trim installation 

10.3.2 GABLE ENDS

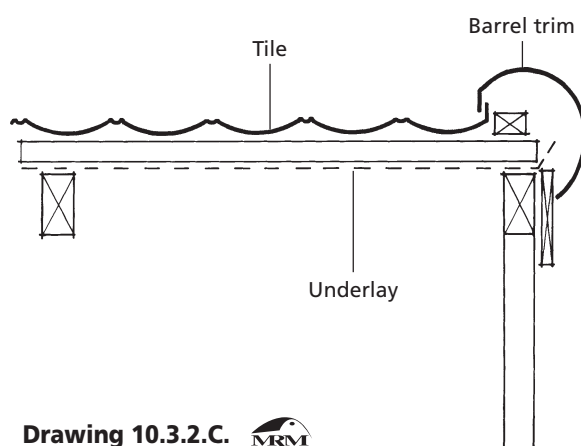
Tile ends are turned up a minimum of 40mm and installed against a batten that will be covered by a barge cover, or under a metal fascia. If a hidden gutter is used tile edges should be turned down into the gutter by a minimum of 20mm.



Drawing 10.3.2.A 



Drawing 10.3.2.B. 



Drawing 10.3.2.C. 

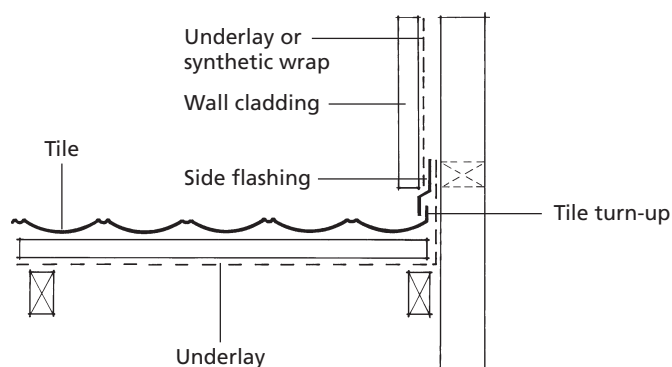
10.3.3 HIP

Tiles should be turned up against the battens or hip board by a minimum of 40mm. (*see drawing 10.3.1.*)

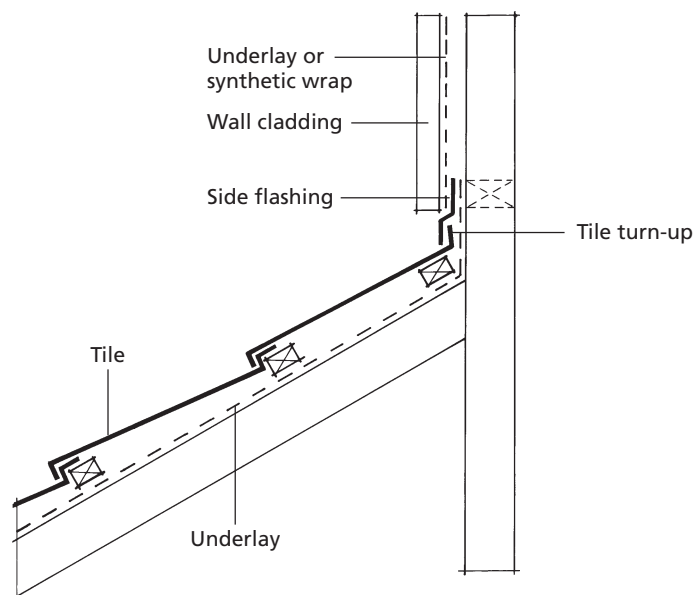
10.3.4 VERTICAL WALL

The wall cladding flashings must be positioned before the tiles and must be designed so that the turned up tile can be inserted behind the flashing.

All preparatory work of under-flashing, fixing of eaves, gutters and valley gutters must be completed and all tiling battens must be in place before laying tiles.



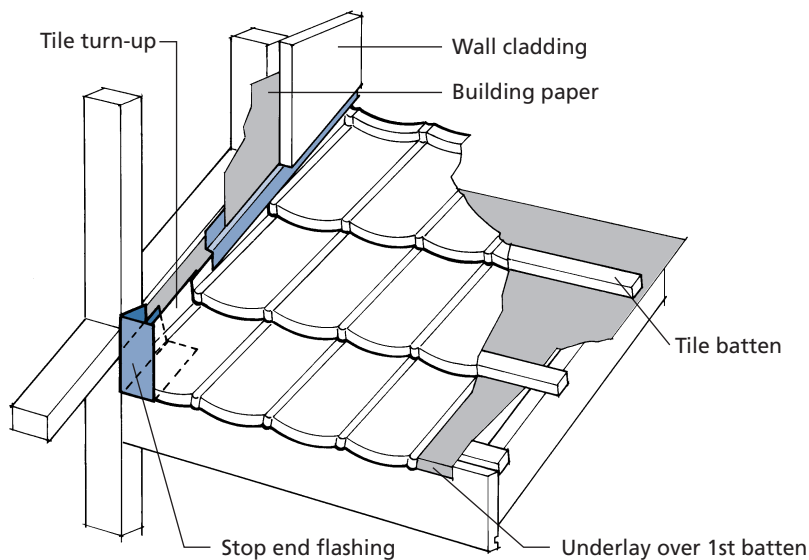
Drawing 10.3.4.A. 



Drawing 10.3.4.B. 

10.3.5 WALL TO ROOF JUNCTIONS

Flashings at the ends of roofs where the roof does not end past the wall require a stopend flashing that ensures water is directed into the gutter. Sufficient material should be left standing out from the wall so that cladding installers can ensure a weather secure finish.



Drawing 10.3.5 

10.3.6 PENETRATIONS

Tiles cut for penetrations through the roof should be provided with up-stands and over-flashed to provide drainage from above without restricting the water flow. The flashing should finish 15mm beyond the tile head lap above the penetration, and should be wide enough to cover the nearest tile rib or up-stand. When the construction is solid masonry or brickwork, and flashings cannot be installed under the wall cladding, a chase should be cut and an over flashing installed in the chase to provide weather protection.

10.4 INSTALLATION

10.4.1 LAYING

Underlay and tile battens for the section of roof being covered should be completed before laying tiles. The roofing supervisor will establish when the roof should be installed, after all sub-trade work has been completed.

All preparatory work of under-flashing, fixing of eaves, gutters and valley gutters must be completed and all tiling battens must be in place before laying tiles.

If substantial work, such as texturing walls, is to be carried out on a wall above or adjacent to where metal tiles are to be laid, they should be installed after such work has been completed.

Tiles should be inspected and selected, as tiles of different colour match should not be installed on the same plane of a roof. If more than one pallet of tiles is required for one job the colour uniformity should be checked.

Tiles damaged during installation must be removed and replaced and any deformed tiles or tiles with surface damage must be rejected.

Tiles should be laid from the ridge down to avoid unnecessary traffic and can be laid broken bond or straight down the roof.

The eave gutter tiles should project over the edge of the fascia to ensure that water discharges directly into the gutter system and tiles should be laid so that they prevent any water penetrating into the roof cavity.

Before tiles are laid, the direction of lay should be determined by:

- Taking into account whether the profile can be laid only one way or both ways;
- Appearance, so that laps face away from the line of sight;
- Allowing for prevailing weather exposure.

Installation of perimeter tiles (excluding eaves tiles) can be completed before the main body of tiles are laid.

10.4.2 ROOF TRAFFIC

Metal Tiles are classified as a Type B roof cladding as they cannot be walked on indiscriminately without the risk of damage.

Persons authorised to walk on a metal tile roof must walk only in the pan of the tile where it is supported by the batten, and wear flat, soft-soled shoes to prevent damage to the tiles and surface coatings.

Other trades must be made aware by the contractor or site supervisor of the method of walking on pressed metal tiles without causing damage, and that the cost of repairing damaged tiles is their responsibility.

10.4.3 WORKMANSHIP

Graphite pencils must not be used to mark AZ coated steel products as carbon can cause premature corrosion failure of the coating.

Finishing of tile cuts and bends must leave straight lines up the roof section, to provide a true line for flashings.

When cutting tiles for their installation at ridges, hips, valleys and barges, damage to the surface finish must be avoided by using a guillotine or metal shears. When cutting the tile lengthwise it must be bent before cutting to reduce the amount of distortion that occurs as the profile is flattened during bending.

Tiles turned up and down for ridges, hips, valleys and barges must be bent using a bender designed specifically for this purpose. Tiles must be turned up at ridges, hips and barges by a minimum of 40mm, and down into the valleys to a minimum of 5mm from the valley floor.

10.5 SITEWORK

The requirements of *section 14.0. site practice* also apply to the installation of metal tiles, and in addition all gutters, valleys, roof channels and the roof should be left clean and free from debris on completion of the work.

10.6 LONGRUN TILES

A longrun tile is a hybrid roof cladding providing the appearance of pressed metal tile with the fixing attributes of long run profiled metal cladding.

The minimum pitch is 8° and underlay and battens are fixed in the same manner as for pressed metal tiles.

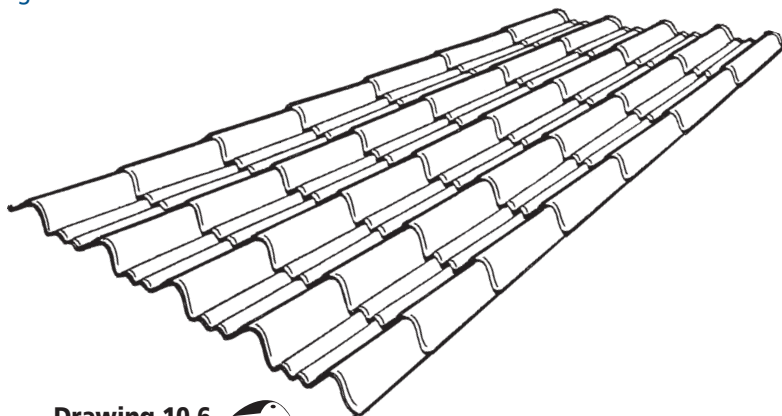
The module or step size of the profile can be adjusted and the pitch of the tile can be varied to suit any batten spacing on an existing roof or to alter the roof appearance.

Maximum sheet length is 7m however transverse laps are possible.

The material is pre-painted metallic coated steel of a yield strength of G250Mpa and is fixed with nails or screws at the front of the tile.

Sheets should be back-laid working from right to left which prevents creep at the gutterline due to the back-step in the underlap of the profile.

Longrun tile can be curved to a 250mm radius.



Drawing 10.6 

11.0 SECRET FIXED CLADDING

Secret fixed roof and wall cladding is a type of roof or wall cladding that can be divided into two main types:

- Self supporting cladding
- Fully supported cladding

Both types are installed without visible fixings that penetrate the cladding and have provision for expansion due to the design of their clipping system. The advantage of secret fixed roof and wall cladding is that longer lengths can be used than is possible when using pierced fixed cladding and that there are no exposed fixings.

11.1 SELF SUPPORTING CLADDING

Self supporting cladding is roll-formed with different means of interlocking the adjacent panels together, and can be either;

- Spring snapped together
- Rotated through 180°
- Machine closed in situ

Where the lengths required are greater than can be transported easily and the contract is sufficiently large, the roll forming machine can be transported to the site to avoid packaging and transport costs, and also avoid damage.

Because there are no external fixings the wind uplift load on the cladding is resisted by all of the following:

- the strength of the profile
- the clip
- the screws, nails or rivets
- the substrate.

The loads imposed on the cladding are described in *section 3.4*.

In many cases the uplift load that can be resisted by these component parts or the re-entrant cladding design is not as great as that for pierced fixed cladding so designers should recognise this limitation when using this type of cladding in high and very high wind design load areas.

The weakest parts of the clipping system are usually the clips or the clip fixing to the substrate as the clips are secured by using screws, nails or rivets.

Each clip must enable free movement for expansion within the clipping system to occur and must have a minimum of two fixings and the pull-out or withdrawal load of each fixing must exceed half that of the wind design load. The fixings must be suitable for the substrate and should not be less than:

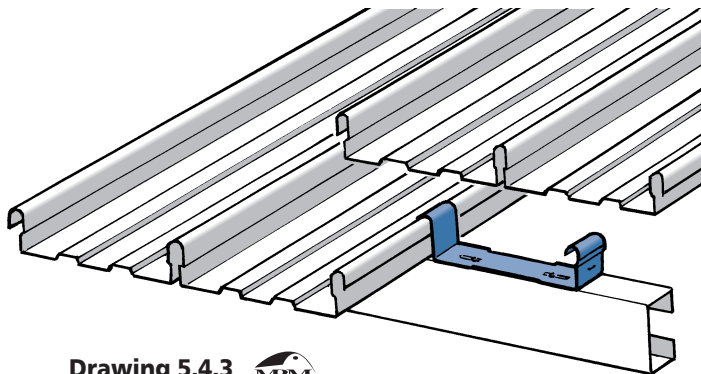
for timber:

- nails with an enhanced shank 50mm long
- 10# x 25mm wafer head screws

for steel:

- 10# x 16mm wafer head
- 12# hex head (where profile provides clearance)

Secret fix clips must not bind the cladding as this will erode the metal and produce excessive noise. Clips must be fixed at centres determined by the panel width and the wind design load. Additional clips must be used to provide resistance to the high wind load in the peripheral areas of the roof.



Drawing 5.4.3 

Self supporting secret fixed claddings can be curved over a radius, but as they are asymmetrical profiles the radii should be shallow to avoid purlin creasing and panning.

Unless expansion provisions are made to positively fix elsewhere, secret-fix sheeting should be fixed at the highest point to avoid creep on steep roof slopes or due to the action of snow.

11.2 FULLY SUPPORTED ROOF AND WALL CLADDING

Fully supported roof and wall cladding is a secret clip fix type of flat roof or wall panel, which is joined by seaming, welting or clipping and does not have any external through fixings.

Fully supported cladding is described as non-structural because it requires continuous underneath support, as distinct from self-supporting metal cladding which is described as structural.

Individual sheets are described as bays, or panels, and they are not intended to support walking loads span without a structural deck of timber or rigid insulation beneath them, although some spanning support is offered by the standing seams or batten rolls. Wall details use similar detailing to roof details except that panels are positively fixed at the top.

The metals used for fully supported roof and wall cladding have historically been non-ferrous and have a reputation of providing a trouble and maintenance free roof, often for centuries. The methods used to fix this type of cladding are labour intensive and therefore fully supported cladding is regarded as an expensive option, however in terms of life cycle cost, fully supported cladding should be regarded as a better option.

This type of cladding is termed architectural because as vertical cladding or curved roof cladding, it is a dominant feature of the architectural style of the building. Unlike modular profiled metal cladding, the width of the bays can be custom made and they can be tapered or curved. Because the role of the architect or designer is expected to be more dominant giving greater attention to detail than with other types of cladding, it is strongly recommended that early liaison occurs with designated or nominated roofing contractors.

Also because of the skill required to install this type of roof cladding, the designer is advised to seek out the very few companies that specialise in this field and whose tradesmen are capable of installing fully-supported cladding that will last for over 100 years.

In this prescriptive Roofing Code of Practice it is not possible to detail every junction or option for fully supported cladding but it does provide typical details. Because there are no through fixings and few separate flashings, the integrity of fully supported cladding relies on seaming, welting or clipping all with provision for expansion.

11.2.1 TYPES

There are two types of fully supported cladding:

- Traditional architectural annealed metal panels, limited to 1.8m in length
- Long length strip roof cladding up to 10m in length.

Both traditional architectural and long length strip roof cladding types share the same seaming methods and also many of the same flashing and fixing details. The cover requirements may differ from profiled metal cladding because whereas profiled laps are overlapped, fully supported cladding laps are seamed.

When annealed grades of metal are used in short lengths, because the details are hand worked, the folds can have a generous radius, and do not possess the straight lines associated with machine folded or roll formed cladding.

The use of both types of fully supported metal roof cladding without structural ribs, gives rise to undulations in the wide flat pan, which are not only to be expected, but are an architectural feature of fully supported cladding.

A perfectly flat metal surface cannot be obtained when using wide flat panels, and designers should be aware that fully supported roof or wall cladding will reflect light unevenly particularly when it is new and this will not change by increasing the thickness of the cladding.

If designer or customer expectations include flat panels without distortion, then narrow pan secret fix profiled and ribbed metal roof cladding should be considered, and if wide flat panels for walls or facades without ribs are required, then the use of bonded panels is advised.

Most metals used for this type of cladding are non-ferrous and naturally weathering, and acquire a patina over time that enhances the appearance and the durability of cladding.

Zinc and copper can be supplied in a pre-weathered or pre-patinated finish, and this can avoid the discolouration caused during installation and the uneven colouration of individual panels in sheltered areas.

Other sections of this Code of Practice are applicable to fully supported cladding and should be read in conjunction with this section. Loadings, installation, performance, maintenance, corrosion, drainage and site practice are all applicable and should be regarded as part of this section, which contains only specific detailing and reference to fully supported cladding.

11.2.2 TRADITIONAL ARCHITECTURAL METAL PANELS

Traditional roofing or architectural non-ferrous metal panels have been used in short lengths for many centuries, and they are associated with longevity and a distinctive architectural style. Traditional fully supported roof cladding is made from sheet whereas long length cladding is made from pre-formed continuous strip.

There are two reasons why traditional roof cladding has been restricted to short lengths:

- Until the 1950's continuous strip was not available.
- Fixing did not include expansion details

Annealed metals used in short lengths are now limited to specialised uses such as turrets, domes or curved structures requiring a considerable amount of hand-working.

The availability of metals in continuous coils has permitted the industry to take advantage of the old technology and apply it to long lengths of fully supported roof and wall cladding.

11.2.3 LONG LENGTH STRIP ROOF CLADDING

Long length roof and wall cladding is roll-formed in longer lengths generally using the same joining and fixing methods and installation techniques as traditional roofing or architectural metal panels.

Long strip copper roofing systems have been used in the United Kingdom and in Europe for over fifty years and aluminium has also been used in N.Z. for a similar length of time.

The main advantage of the longer lengths of the system is the elimination of cross welts on sloping roofs and of drips on flat roofs, thus effecting reductions in the labour cost of laying short lengths of metal roof cladding.

The length of individual panels is governed by the type of edge seam, the metal, and the provision for metal expansion of the panel. By using expansion clips incorporated in the standing seams, longitudinal movement of the panels is permitted while still providing a secure fixing to the under-structure

Roll formed tray roofing panels can be varied in their width to suit the architectural design and the wind design load on the building. They can also be supplied with various upstand heights and details including locking edges in a similar manner to profiled secret fixed profiles.

Long strip copper roofing can be laid where the minimum pitch is 3° dependant on the type. With individual panels up to 10m long by 600mm wide compared to the maximum 1.8m by 600mm bays used with traditional annealed panels. Where the rafter length is greater than 10m, either a step or a cross welt is required, dependent on the roof pitch and the wind design load. This length can be extended to 13m if special expansion provisions can be provided.

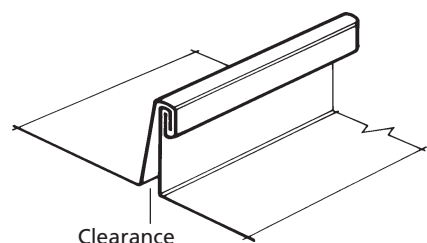
11.2.4 TYPES OF JOINTS

There are three main systems used for joining fully supported roof cladding which applies for all metals:

- The standing seam Drawing 11.2.4.
- The angle seam Drawing 11.2.6.
- The roll cap Drawing 11.2.7 A & B

The batten roll is a variation of the standing seam because it has two standing seams one on either side of a square or trapezoidal timber batten. The conical roll has only one seam.

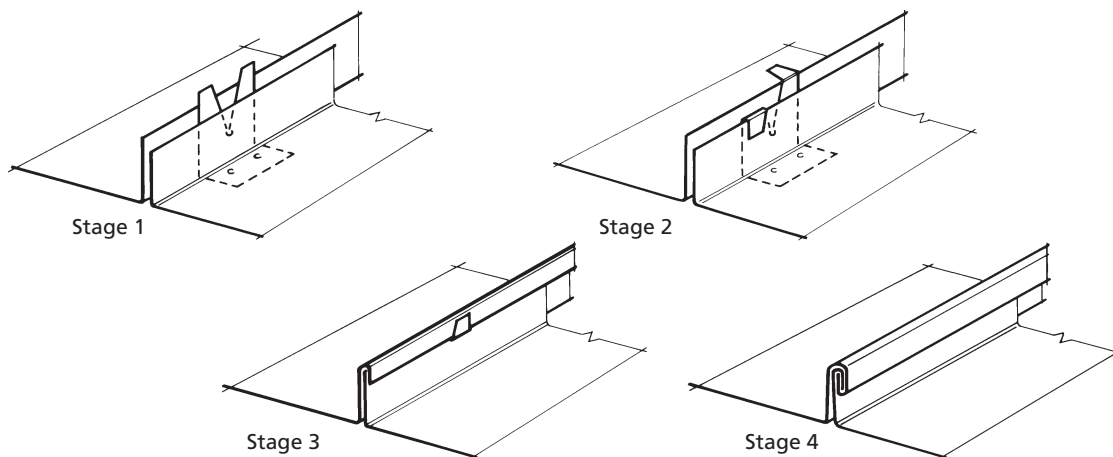
Batten roll, conical roll and other types of jointing have been used in the past, but the most common systems are outlined below. The thermal movement across the width of all types of metal panels is taken up by the provision of a gap at the base. *(see drawing 11.2.4.)*



Drawing 11.2.4. 

11.2.5 STANDING SEAM

The standing seam system. (see drawings 11.2.5.)



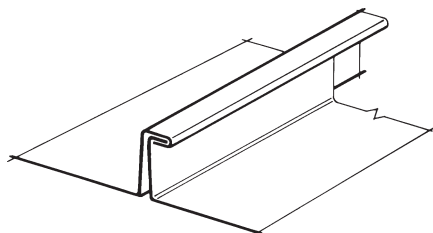
Drawing 11.2.5. 

The term 'standing seam' derives from the way the panels are joined or seamed, and as the seam is vertical it is said to be 'standing'. After being laid on the substrate and clipped it is finally seamed over by hand or by seaming machine.

The minimum pitch of standing seams > 30mm in height running from ridge to eaves is 3°. The minimum pitch for standing seams < 30mm high is 5°.

11.2.6 ANGLE SEAM

The angle seam is the same as a standing seam but has only been folded over 90° not 180°, and it therefore is considered only suitable for walls and pitched roofs, and not suitable for low slope roof cladding in exposed areas. It has the advantage of a more dominant and a straighter line, which is obtained by a roll forming machine rather than hand working, and is used when the aesthetic expectations are high. The angle seam is restricted in snow areas to a roof pitch of >25°.



Drawing 11.2.6. 

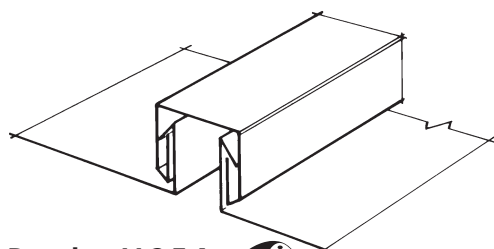
11.2.7 ROLL CAP

Roll cap systems are made from materials of a temper suitable for springing or snapping together. They have many variations, but all depend on the interlocking of a cap and the panel, with some panels having their edges interlocking, and so do not require a separate capping.

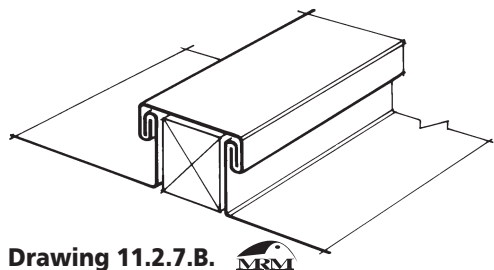
Designs using steel or harder tempers for this type of system are therefore not able to offer the same designs of interlocking panels or flashing details as for standing seams and require separate flashings as used with profiled metal cladding. *(see section 5.0 flashings)*

When using traditional short lengths, the method used to join adjacent sheets of metal lengthwise in the direction of the slope, is by the use of cross welts or drips for the transverse joints which can accommodate some expansion movement.

Ridges and eaves panel fixing details must accommodate the lengthwise expansion movement of the sheeting.



Drawing 11.2.7.A. 



Drawing 11.2.7.B. 

Batten rolls running from ridge to eaves can be used on all roofs where the minimum pitch is 5°.

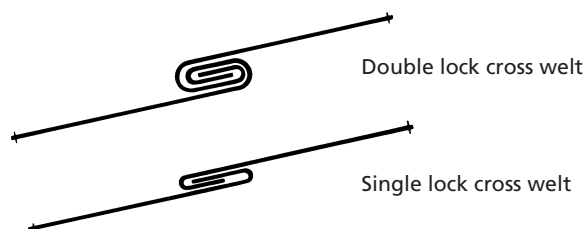
11.2.8 TRANSVERSE LAPS

The transverse seams on standing seam roofs <20° in areas of high or very high wind design loads, must be soldered or sealed.

A double lock cross welt transverse joint must be used for joints on roofs >7° and single lock cross welts must be used on pitches above 25° or on vertical surfaces. The double lock cross welt must be used in all cases where severe weather conditions exist.

The maximum length for roof pitches of <30° must be 10m. Where a roof slope exceeds 10m in length, a step flashing 50mm deep must be placed at regular intervals to provide for panel expansion in the direction of the fall.

Transverse joints may be either double or single lock welts or drips depending upon the pitch of the roof. The double lock cross welt can be used for joints on roofs >7° and single lock cross welts may be used on pitches above 25° or on vertical surfaces. The double lock cross welt should be used in all cases where severe weather conditions exist. Where the pitch is below 20° the edges of the metal forming the double lock cross welt should be soldered or sealed with silicone sealant before closing the welts and seams and folding together.



Drawing 11.2.8. 

Because of the accumulation of the many thicknesses of metal, cross welts used in conjunction with standing seams should not be fixed in a line, but staggered in adjoining bays but where batten roll joints are used from ridge to eaves they may be used in a continuous line across a roof.

Although a long strip roof can be laid entirely by means of conventional hand tools, power or hand operated machines are used on long length panels to increase the speed of laying.

The standard acceptable fabrication methods of forming joints in weathering details for penetrations, rain water heads, stop ends, expansion flashings, in sheet copper work is by brazing with silver solder, and in zinc, by the use of lead/tin soldering. All metals should be mechanically locked before sealing.

All transverse and longitudinal joints on fully supported metal roof and wall cladding, must only be welded, lock seamed or capped and must not be joined solely by soft soldering, welding or brazing.

Where the direction of fall is diagonal to the standing seam and welts, the laying direction of the bays must be away from the flow.

Where rainwater will drain to one side of the bays, high velocity streams of water flowing down the seams and welts should be directed away from the seamed side of the panel.

Light gauge wide pan widths should be avoided because they give rise to sheet drumming and consequential fatigue.

11.3 MATERIALS

Metals used in traditional architectural panels and used as fully supported cladding include lead, annealed copper, zinc and aluminium.

Metals used in long length architectural panels however generally use a harder temper or alloy, and include copper, zinc alloyed with titanium/copper, aluminium, stainless steel, and plain and pre-painted AZ coated steel.

The metals described in 11.3.1 - 11.3.5 are suitable for long length fully supported cladding.

Copper Aluminium and stainless steel can be supplied with an embossed surface finish, which not only reduces glare, but can also provide additional strength.

11.3.1 COPPER

Roof cladding, gutters and expansion and fixed clips, should be made from a minimum of 0.6mm 1/2 hard temper strip, conforming to the British Standard, BS 2870.

Roll formed panels using secret fix interlocking edges that are made from 1/2 hard temper, should not be silver soldered or braised because the heat required will anneal the copper.

When 1/2 hard copper is softened in an area, differential stress patterns are caused by expansion which often can result in fatigue and eventual failure of the metal.

Where penetration or other flashings require an amount of workability or are to be silver soldered or brazed, they should be made using fully annealed copper sheet or strip 0.6mm thick. *(see section 2.2.11. copper)*

11.3.2 ZINC

Zinc roof panels and flashings should be a minimum thickness of 0.7mm, although heavier gauges are used.

99.995% pure zinc is alloyed with titanium and copper which provide additional strength. *(see section 2.2.13.)*

11.3.3 ALUMINIUM

There are many aluminium alloys available for use in roof cladding, *(see section 2.2.9.)* and roll formed panels can be made from soft, 1/2 hard or 3/4 hard tempers with a minimum thickness of 0.7mm.

Pure aluminium strip (99%) known as 'dead soft' is used for flashings in widths between 150mm and 600mm in thicknesses of 0.30mm, 0.45mm, 0.55mm, and 0.70mm.

11.3.4 STAINLESS STEEL

Stainless steel has a higher strength than most other metals and can therefore be used in a lighter gauge or thickness. It is compatible with copper but should be used with caution with other metals. *(see compatibility table 2.7.2.)*

11.3.5 COATED STEEL

Metallic and organic coated steels can also be used for fully supported roof and wall cladding. They require the same treatment as described for self-supporting roof and wall cladding and the same design criteria as for other metals.

11.4 LOADINGS

The uplift forces on fully supported roof cladding are transferred through the building via the clips and fasteners to the substrate.

The performance criterion is the number of clips or fasteners per m², which can be varied by the spacing of the clips, or the width of the bays. The withdrawal load of the fasteners is dependent on the metal, shank diameter, shank type, penetration depth and the type and thickness of the substrate.

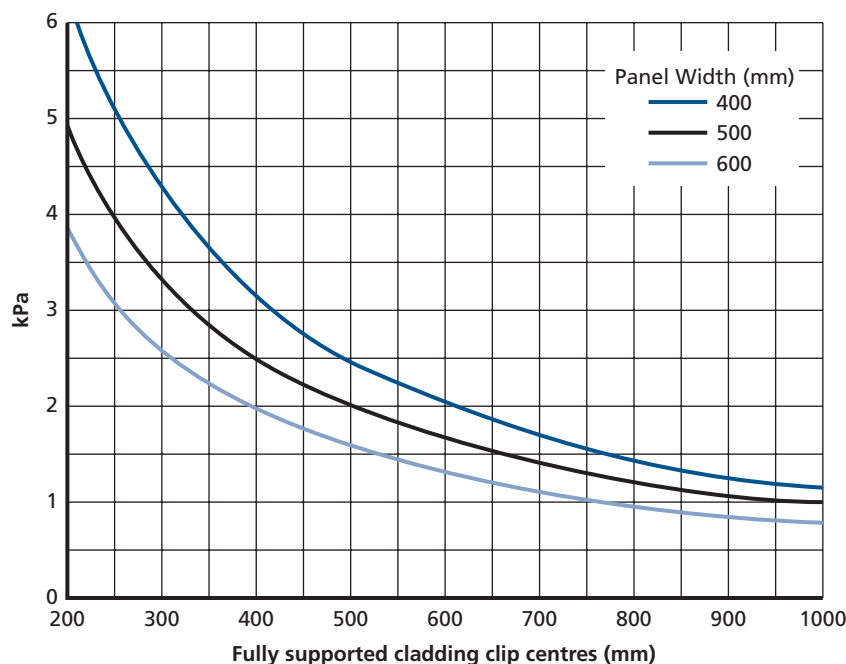
The design load capacity of a clip can depend on the material of the clip, the type and number of the nails and their penetration and the thickness of the substrate.

The design load capacity in New Zealand for a clip with two screws enhanced shank nails fixed to a 12.5mm plywood substrate should not be assumed to be greater than .5kN. and this value should be derived from tests.

The clips and fasteners should be capable of withstanding the wind design load, measured in kN, which is derived from the square measure of kPa.

The number of secret-fix clips and fasteners m^2 for fully supported roof cladding must be derived from Graph 11.4.

Load/clip spacing graph



Graph 11.4. 

The wind design load on fully supported roof cladding must be obtained by the method as described in *section 3.4.* for other types of roof cladding.

To improve the uplift resistance of fully supported roof cladding, the design options are:

- to reduce the width of the end bays,
- to increase the metal thickness
- to place the clips closer together.

The latter is the most usual and accepted method.

Extra fixings are required around the periphery because of the increased wind design load on all buildings, as required by the local pressure factor (k_l). Additional fixings are also required in exposed situations subject to high winds.

The clip spacing is determined by the wind design load, the thickness, type of substrate and the holding strength of the nails or screws. To comply with the wind design load criteria, the withdrawal load of the clip/nail assembly should be known for the thickness and type of substrate.

The width of gable or verge panels must not exceed 400mm, and the spacing of fixing clips must be decreased on edges of all roofs in high wind design load areas.

Unlike profiled metal cladding, the point load imposed on fully supported cladding is assumed to be supported by the substrate.

11.4.1 FIXING

Smooth shank nails must not be used for fixing clips as they do not comply with the loads given in Graph 11.4.

The holding power of smooth shank nails in 12mm plywood is not capable of withstanding uplift loads assumed in Graph 11.4. although the withdrawal load of annular groove nails is over twice the value.

Hand or gun driven screws both provide better performance and are the preferred fixing. The depth of penetration is a major performance factor when considering the wind design load. If the clips can be spaced coincidentally with the purlins and the length of the fastener can be increased to provide a minimum of 50mm penetration, the uplift capacity of the clip is considerably increased.

11.4.2 SUBSTRATE

When plywood substrate is used beneath fully supported roof cladding, it should be smooth, dimensionally stable with a moisture content of <18% and made windtight. All nails should be punched or screws countersunk to prevent damage to the metal cladding.

Plywood with a minimum thickness of 12mm should be fixed to the framing at 600mm centres, with 40mm x 8# countersunk screws or 40mm x 2.5mm galvanised deformed shank nails, at 150mm centres around the panel edges and 200mm centres on the intermediate supports. The fasteners should not be closer than 10mm to the edges.

17.5mm plywood will span 1200mm but the length of the fasteners should be increased proportionately.

A 2mm expansion gap should be provided between sheets and a nail or screw can be placed in the gap and be used as a spacer for this purpose. All joints should be staggered and taped over before placing the underlay.

Framing centres should be designed to withstand the increased loads at the periphery of the building.

Ventilation must be provided for all fully supported roof designs using plywood substrate. (see ventilation section 4.6)

CCA treated plywood must not be used under Zinc, aluminium, metallic coated or prepainted steel cladding without an underlay complying with Table 4.3.1. or separated by an underlayment as described in Section 4.3.11.

Where the design wind load is >1.5kPa, the minimum fixing centres for 12mm ply substrate must be 400mm.

11.4.3 CLIPS, CLEATS AND FASTENERS

For specification of clips and cleats see section 5.4.3.

Nails.

For Zinc or Aluminium:

Nails: stainless steel or hot dipped galvanised enhanced shank nails 25mm long

Screws: stainless steel or hot dipped galvanised countersunk 25mm long x 8#

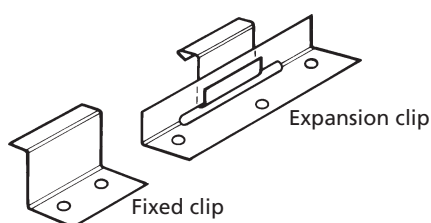
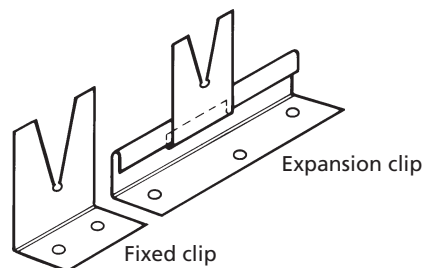
For Copper:

Nails: copper or stainless steel 25mm long x 2.6mm barbed shank flat heads.

Screws: Stainless steel countersunk 25mm long x 8#

Two kinds of clips are used:

- fixed clips
- expansion clips. Illustrations of both types of clip are shown in drawings 11.4.3 A & B

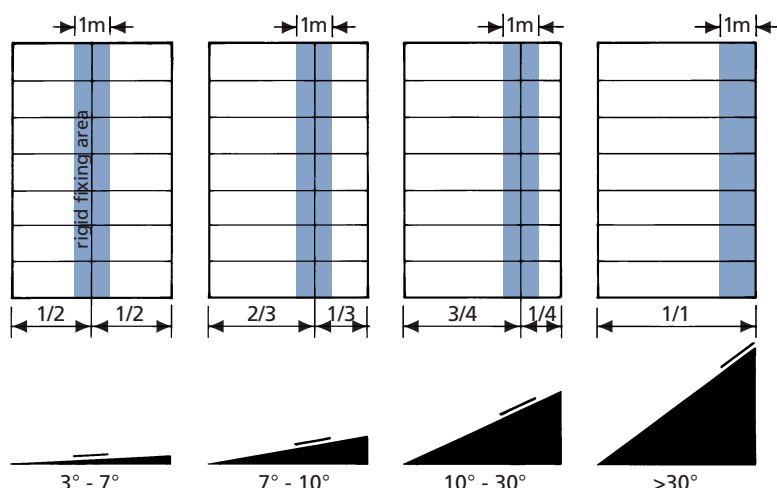
Drawing 11.4.3.A Drawing 11.4.3.B 

Standing seams up to 3m long may be secured entirely with fixed clips, but for longer lengths than 3m, expansion clips should be located above or below the fixed clips to allow for longitudinal movement of the panels.

Fixed clips should be positioned at centres dependent on the design wind load. (see graph 11.4)

The position of the fixed clips is dependent on the roof pitch as illustrated: (see drawing 11.4.3.C)

For standing seams the fixed clips are placed dependent on the roof pitch up the slope, and $>30^\circ$ the fixed clips should be placed at the top of the slope

Drawing 11.4.3.C 

11.5 UNDERLAY

All fully supported metal roofs must have an absorbant and permeable underlay to absorb condensation. Underlay must be laid as detailed in section 4.3. and be covered on the same day.

The permeable felt or paper underlay should be laid before any metal work is commenced and should be permeable, absorptive and of a type that will not adhere to the metal cladding under temperature changes

The underlay serves several purposes:

- To allow the passage of water vapour;
- To lessen the possibility of abrasion between the metal and the decking;
- To absorb condensation;
- To deaden the sound of wind and rain;
- To separate metal cladding from timber treated with copper preservative.

11.5.1 VENTILATION

All fully supported metal roofs must have provision for ventilation of the timber substrate to allow condensation to dissipate.

Copper is not affected by retained moisture but all other metals can suffer degradation from continued exposure to moisture. Zinc is particularly prone to attack although zinc coil is available with a high-build lacquer or specially treated underside to avoid the effects of retained moisture. Where the design is likely to cause continued moisture or cannot provide sufficient ventilation, enhanced underside treatments should be considered for zinc.

The best provision is always to provide sufficient ventilation at the eaves and ridge and the minimum of a half an air change per hour to ensure that any condensation is not retained. Proprietary vents made from aluminium or polyethylene can also be used at one per 50m². These should be placed over a purpose made hole or at the intersections of the 3mm gap between the plywood sheets. (see *ventilation section 4.6.*)

11.6 DRAINAGE

11.6.1 INTERNAL GUTTERS

Fully supported parapet and internal gutters should comply with *section 8.4.4.*:

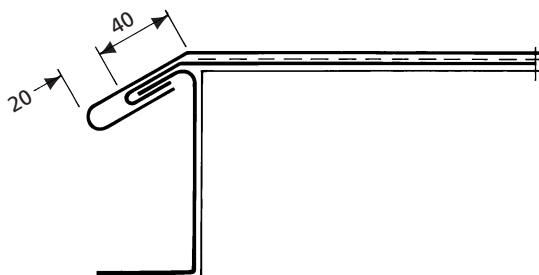
- laid to a minimum fall of 1 in 200 - 12mm in 2.4m;
- designed to discharge rainfall of 200mm/hour without flooding;
- not less than 50mm deep at the highest point;
- designed to discharge the rainfall clear of the building if the outlet becomes blocked;
- designed with expansion drips at a minimum depth of 50mm;

The width of a rain water head or sump must be equal to that of the gutter.

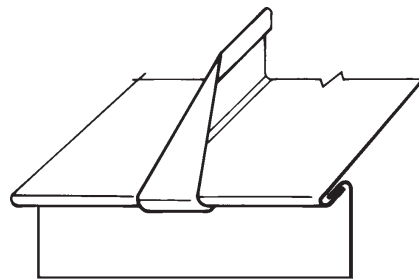
The rain water head must have an overflow area equal to or greater than the area of the gutter at a level below the height of the sole of the gutter. (see *drawing 8.6.1.*)

Expansion joints must be provided to accommodate the thermal movement at the gutter high points between outlets. (see *drawing 8.4.4.*)

The roof side of a parapet gutter upstand should be joined to the roof sheeting by means of a drip edge flashing. (see *drawing 11.6.1*)



Drawing 11.6.1.A. 



Drawing 11.6.1.B. 

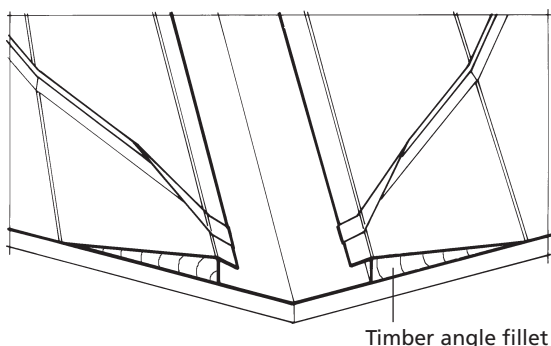
11.6.2 VALLEYS

Fully supported valley gutters should comply with **section 8.4.5**.

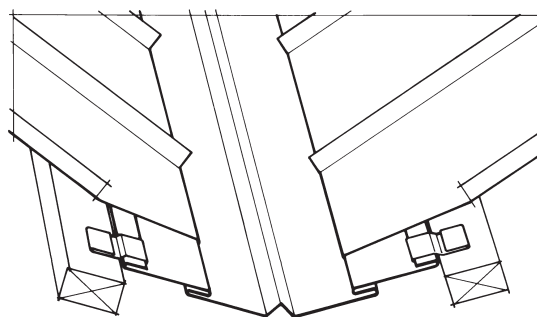
Where a valley is formed between two roof slopes, a separate valley gutter welted to the roof sheeting should be used.

Jointing between the valley gutter and roof sheeting can be carried out by two methods:

- by dressing over a timber angle fillet with a single welt on the top front edge of the fillet. (*see drawing 11.6.2.A*) This detail is not suitable for high or very high design wind loads;
- by forming a re-entrant fold in the valley to accept the panel turn under; (*see drawing 11.6.2.B*)



Drawing 11.6.2.A 



Drawing 11.6.2.B 

Valleys should be secured using clips with a minimum of two fasteners, installed parallel to the valley, and be formed from at least the same gauge metal as is the valley metal flashing.

Securing clips with two fasteners side by side, holds the clips in place more securely than using one fastener per clip because with only one fastener, cyclical thermal movement of the valley metal will loosen the fastener and the valley can bind against the misaligned clips.

The back tab of a clip should be bent over the fastener heads, and the tab flattened, to keep the fasteners from backing out and from damaging the underside of the metal roof panel.

Because valleys attached with clips can move within the clips due to thermal expansion and contraction, and slip downslope with time, the head of the valley should be securely attached to the substrate. A raised centre within the valley flashing not only allows for some expansion, but also prevents water flow from running across the valley from one side to the other. (*see drawing 11.6.2.B.*)

Where a valley drains a dormer roof and the capacity of the panel or bay does not equal the discharge, it must be spread over two or more bays. (*see section 6.5*)

11.7 FAÇADE CLADDING

Fully-supported facade or wall cladding is used for architectural effect. The width of the panel and the metal thicknesses can be different from those used for roof cladding. As flat panels do not have a perfectly flat surface, and also to improve its visual effect, the maximum panel width should be restricted to 500mm and for panel lengths over 5m, 400mm width should not be exceeded.

The substrate should be true and in line as any defect will show and care in seaming is necessary, particularly at the clip positions. To avoid large flat areas, panels can be divided into smaller lengths by single welts, by varying the length or using a diagonal pattern. New panels require precise and clean preparation of the individual components by skilled tradesmen prior to the completion of patination and special care is required for the storage of the panels, flashings and components to avoid dirt and staining.

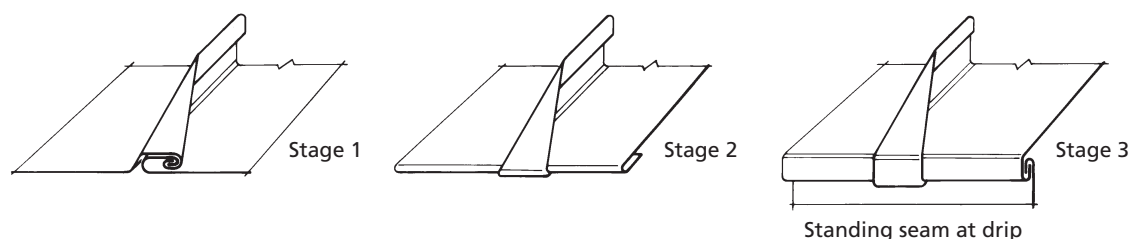
11.8 EDGE FINISHES

Because the standing seam or the batten roll should terminate at the peripheral areas on the roof, this detailing will be determined by the type of intersection.

The three considerations are:

- Weathering
- Expansion
- Appearance

All flashing intersections must be made weatherproof without primary reliance on sealants. Provision must be made for expansion in two directions and alternative acceptable joints are shown in the drawings shown in 11.8.



Three stages in preparation of standing seam for cross-welt at drip, ridge, apron or junction to valley gutter

Drawing 11.8 

A double standing seam can be turned down through 90°, 150mm from the eaves, with the folded side uppermost, and the end of the turned down standing seam folded into a cleat, drip or valley. (see drawing 11.8)

When the sheet is engaged into the folded edge at the stepped fall an allowance should be made to allow for thermal expansion of the metal. The turned down edge of the bay should not be able to disengage itself from the eaves flashing during thermal expansion, and there should be sufficient room to allow for free contraction of the pan or bay. (see drawing 11.6.1.A)

The double seam need not be folded over in roofs with pitches greater than 30° as the eaves flashing will prevent any ingress of moisture. The double seam is cut at the eaves and only the end of the sheet is engaged in the eaves flashing.

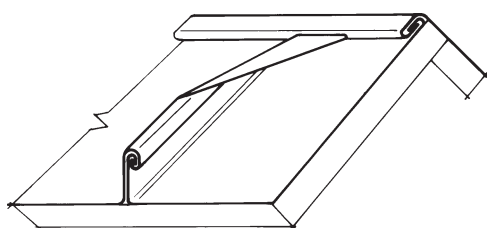
The double standing seam with a splayed or angled lower end is the most demanding end detail but it is the most visually acceptable.

11.8.1 RIDGE AND HIP

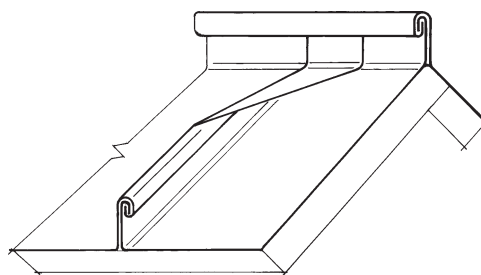
The method that is used to finish the ridge and a double standing seam depends on whether the type of ridge detail is vented, or has a separate ridging, or is welted, a standing seam or a roll.

Where the panel passes over the ridge or hip of a roof, a roll not less than 38mm higher than the intersecting rolls or standing seams should be provided. The ridge roll should be undercut to accommodate thermal movement of the panels.

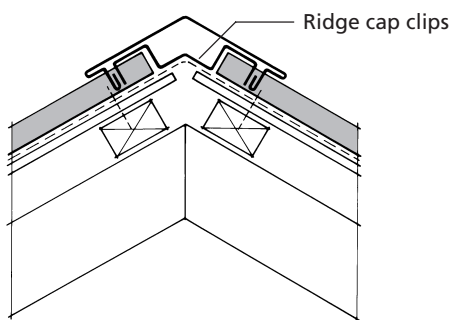
An alternative edge finish is to flatten the seam similar to that shown in *drawing 11.8*.



Drawing 11.8.1.A Welted 



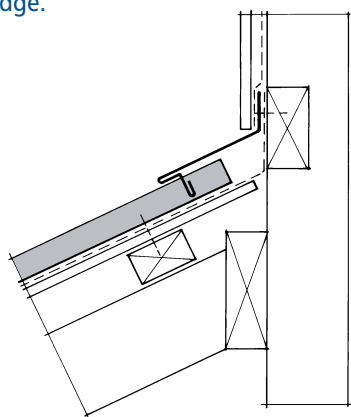
Drawing 11.8.1.B Standing seam 



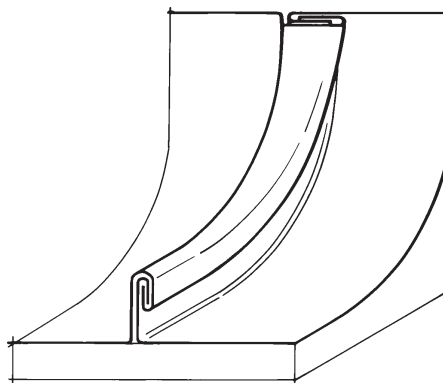
Drawing 11.8.1.C Separate ridge 

11.8.2 APRON OR ABUTMENT

Where the panel terminates at a wall there are many different details some of which are similar to those required at the ridge.



Drawing 11.8.2.A. Apron 



Drawing 11.8.2.B. 

Aprons and flashings to walls and upstands should consist of an independent, preformed strip of metal of not more than 1.8m in length, welded to the roof sheet or cover flashed to give a minimum 100mm cover to the vertical upstand.

Where a standing seam meets an abutment, the standing seam can be finished as for profiled metal roof cladding with an apron or the end of the seam can be flattened to facilitate folding the metal to form the upstand.

At the highest point of the roll, where it meets an abutment, the sheet is dogeared to form a corner and the upstands are welded to the capping and cover flashing. (*see drawing 11.8.2.*)

Where an apron abuts a block or brick wall, the cover flashing should be folded a minimum of 25mm into the wall chase with a 10mm hook wedged into the chase, and pointed with a flexible sealant or cement. All free edges should be stiffened as described in Flashings (*see section 5.2.2.*) and when retained within a cleat the edge should be free to provide expansion.

11.8.3 EAVES AND VERGE

Joints at eaves and verge edges should provide a secure, wind tight termination for the roof, but be capable of accommodating the thermal movement of the panels without overstressing the metal.

Expansion provision must be made at eaves and verge edges and at the joints. (*see drawing 11.8.3.*)



Drawing 11.8.3.A 

11.8.4 PENETRATIONS

Penetration flashings for fully supported metal roof cladding must be installed by the roofing contractor only and other trades must not cut any hole in fully supported metal roof or wall cladding.

Penetration flashings used in conjunction with fully supported metal roof cladding require specialist detailing, and the specific details for weathering penetrations in fully supported roof cladding that are included in this section should be read in conjunction with *section 6.0. penetrations*. The back curb of the flashing upslope from the penetration should be installed under the roof panels, and the front apron of the flashing should be installed over the roof panels.

The designer is responsible for coordinating the penetration location to be sure that a penetration will not coincide with the panel seams.

When the penetration is less than 50% of the width of a panel, the hole can be weathered by using a fabricated flashing made by forming an upstand by soldering, welding or sealing.

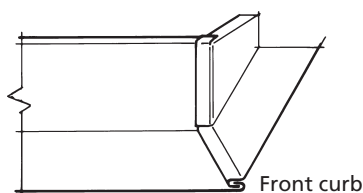
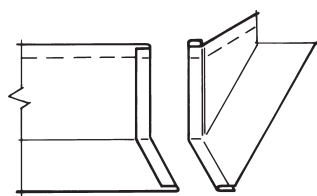
Small pipe penetrations that can be installed within the width of the individual roof panel can be weathered using an EPDM proprietary flashing as described in *section 6.3*. These are not the preferred option as the expected life of these flashings is not likely to equal that of non ferrous fully supported roof cladding. Shop fabricated flashings may require a conical metal rain collar or a 'Chinese hat' to provide sufficient movement if the pipe is sleeved or insulated.

Large penetrations are more complex and require additional considerations during design and installation, however, regardless of the penetration size, weatherproofing should be achieved without relying solely on sealant and independent movement of panel and penetration should be allowed for.

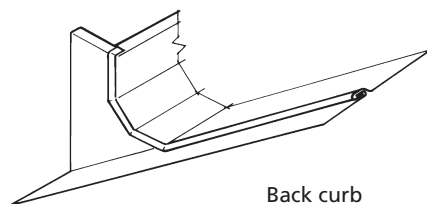
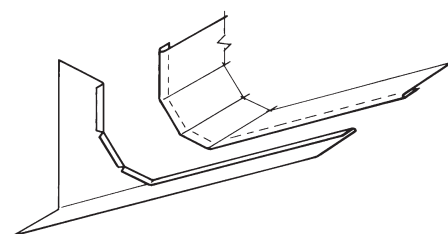
When the penetration width is over 600mm the panel ribs should be stopped short of the upslope face of the curb so that water can flow past the ends of the ribs and not be trapped against the curb.

Large penetrations that require flashing through the panel ribs and are over 600mm wide should be factory manufactured to a cricket design as described in **section 15.8**.

Flues should be terminated at a sufficient height above a metal roof and discharged in such a manner as to ensure that concentrated flue gases do not come in contact with the cladding.



Drawing 11.8.4.A. 



Drawing 11.8.4.B. 

Dormer windows, chimneys, vents and other penetrations projecting through the roof can impede drainage and require special design. (see **section 6.5**.)

The majority of flashings are made from fully annealed or dead soft metal, but where rigidity or a straight line is required, only 1/2 hard grades of material should be used.

11.8.5 CAPPINGS

All capping details should allow for expansion and be the same as those detailed in **section 5.3.4**.

Cappings can be welded to the upstands of panels in lieu of using through fixings.

11.9 DURABILITY

Corrosion problems can be caused by using dissimilar metals in contact with, or run-off from, other roof cladding materials.

Designers and tradesmen should be aware of the electrolytic corrosion that can take place when small particles of metal are deposited on another metal, and when the same tools are used with a variety of metals. (see **section 2.7.2. compatibility**)

For maximum durability, no water should be allowed to penetrate between stacked panels, strips or other profiles or coils during storage and transportation. In high humidity with the simultaneous exclusion of air, white rust will develop on the surface of zinc and zinc coated cladding, and aluminium and copper will also suffer permanent staining. All metals in storage should be kept dry. (see **site practice section 14.4**.)

11.9.1 PATINA FORMATION

Metals and metal alloys used for the fabrication of architectural roof panels and accessories are mostly those that are naturally weathering, and whose surfaces develop a layer of protection upon exposure to the elements. Aluminium, copper, lead, stainless steel, and zinc are all naturally weathering.

A naturally weathering metal, forms its own protective layer by oxidation, sufficient to withstand environmental exposures and to develop oxidation layers that are durable and well-bonded to the base metal, with minimum porosity and minimum solubility in water. This weathering and subsequent oxidation can result in a different colour and appearance as well as protecting the metal.

11.9.2 COPPER

On exposure to the atmosphere, copper develops a protective film called patina and it's composition depends on varying regional atmospheric conditions.

In industrial and urban atmospheres it consists mainly of basic copper sulphate, while in nonurban environments it consists of basic copper carbonate. These copper salts have chemical compositions similar to those found in natural minerals, and once the patina has developed, no further copper corrosion occurs under normal conditions, and as it is self-healing any superficial mechanical damage is repaired by the renewed formation of patina.

The patina, consisting of green copper salts, is often described as "verdigris" which is inaccurate, as verdigris is caused by the chemical reaction of copper with acetic acid.

In contrast to copper salts, which form a natural patina, verdigris is water soluble and is visually recognised by its strikingly green colour.

Atmospheric corrosion of copper occurs at 2-3µm per year dependent on the environment but this rate is applicable only during the first few years, and with time decreases until it reaches zero after 70 years.

As a reference mark, a µm (a micron) is 1/1000 of a millimetre, and the AZ coatings on steel are approximately 20µm each side.

Copper components exposed to the atmosphere undergo various stages of discolouration from the time of installation to the development of the natural patina. When new, components have a bright, red, polished surface and during a transitional period the copper surface will display varying degrees of tarnishing. Minor marking will become invisible after a few weeks, when the copper has developed a primary protective film due to the reaction with atmospheric oxygen, and a uniform matt brown oxide film is developed. The intensity of the brown colouration increases with time until the patina develops as a secondary layer of various shades of green colour. This is due to various copper salts, is dependent on prevailing local atmospheric conditions, exposure to moisture and air pollutants, the pitch of copper roof or wall areas, and on time. The composition of the atmosphere dictates the rate of patina development and the following periods are considered normal for the formation of the protective patina film:

Moderate	18 years
Industrial	10 years
Marine	5 years

In mild environments it may take over 30 years to turn green and in some dry environments, it may never turn colour. Strength properties and the degree of purity of the copper do not affect the rate of patina formation.

In some locations or positions, the slope of the roof, or vertical surfaces or soffits, can affect the development of the patina to the degree that copper may never turn green.

Copper can be pre-patinated or patinated after installation, and these field methods may provide rapid patination, but the resulting colour can vary significantly.

Patination can be affected by any streaking, marking, or soiled areas or by perspiration caused by handling which can be avoided by the use of cotton gloves during installation.

Water run-off from copper can visibly stain light-coloured building materials, such as concrete, brick and stone.

11.9.3 ZINC PATINATION

The chemical process which results in the formation of the protective film on the surface of zinc has several stages and may take a long time to develop, dependent on seasonal, weather and other factors. During this transitional phase, due to light reflection the surface appears to be irregular however with progressive patination these reflections will disappear and the greyish blue protective film will become denser and the colour more uniform. Patination can be artificially accelerated, and Titanium Zinc can be supplied pre-weathered to prevent any difference in appearance of adjacent panels.

Unwashed areas of zinc and aluminium cladding can show an uneven and patchy surface film when they are in an aggressive environment. Maintenance is required as for other metals. (*see maintenance section 13*)

12.0 INSULATED PANELS

12.1 DESIGN

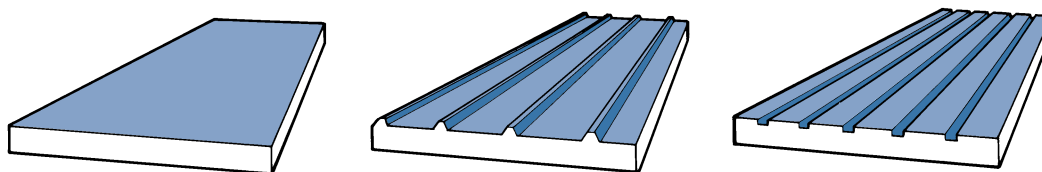
The use of double skin composite or insulated panels for roof and wall cladding requires the same or similar detailing for flashings, penetrations and design considerations that are required for single skin roof and wall cladding described in this Code of Practice. Reference should be made to the relevant section when designing insulated panel systems, as only specific differences are described in section 12.

As insulated roof and wall panels are specialised proprietary systems, few specific details are offered, however the principles of water shedding, fastening and maintenance described in this Code, are all applicable.

Composite or insulated panels are factory made from different core materials laminated and permanently bonded together by adhesive or by foaming in place but acting as a single structural element.

Insulated or sandwich panels have metal facings on both sides, with the space between them filled with an insulating core permanently and continuously bonded to both surfaces. There are three types of sheeting use on bonded panels:

- Flat metal panels (Coolroom)
- Profiled metal panels (Roofing)
- Miniature ribbed panels (Architectural)



The manufacturing process for bonded panels that are adhered together, consists of rollforming the flat or profiled sheeting, followed by the adhesion of the insulation core to both surfaces or skins. There are three methods:

- continuous metal panel production by glueing panels of insulation to metal skins;
- individual panel production;
- continuous metal panel production by foaming;

Site assembled, or built-up systems are also known as composite panels and are of two main types:

- where two profiled sheets have rigid insulation boards adhered to their troughs, having no metal spacers,
- where the sheeting is mechanically fixed on both sides to a structural girt. The girt can however form a thermal bridge, unless spaced away from the structure and this type of built up system commonly uses fibre insulation.

Bonded composite panels develop their strength from the sandwich of skins and insulation, and are made with a tongue and groove side lap detail that incorporates concealed fasteners.

Flat continuously produced panels suffer minor undulations in the metal skins that arise from built-in tensions in the metal coil and introduced during panel manufacture. Panning can be minimised by using an embossed or matt finish or forming minor ribs or swages on the flat face of the panel.

12.2 MATERIALS

The facings or skins of composite panels can be metallic coated or pre-painted steel or aluminium and are either profiled or flat on either or both sides. The internal skin is also known as the liner skin or sheeting.

The thickness of steel metal facing or skin is commonly made of grade ZM 300 and thicknesses of 0.40mm to 0.63mm B.M.T.

Aluminium facings are used in very humid conditions, or a severe marine environment and can be supplied with a mill or embossed surface, or be pre-painted.

12.3 INSULATION CORE

The bonded insulation core material contributes to the panel strength by providing most of the resistance to shear forces, and the depth of the core will determine the panel resistance to deflection.

The core can be made from different types of material all with different insulating values, fire ratings and strengths. The most common are; EPS Expanded Polystyrene, PIR Polyisocyanurate and PPS Phenolic/Polystyrene.

Expanded polystyrene is used for flat factory bonded panels and can be shaped to the profile when the top skin is of profiled metal.

The insulation thickness of a profiled roof panel varies from 30mm - 300mm, and the U-value is based on the average thickness, so to achieve the same insulating value as a flat panel, the profiled roof panel is required to be thicker.

Dense rigid mineral fibre insulation may be selected for applications where fire resistance or acoustic insulation properties are considered to be most important.

Built up or composite panels insulated with extruded closed cell polystyrene, or fibre insulation material, may need to be of a different thickness to achieve the same insulation value.

12.4 STRUCTURAL

Composite panels are integral units in which the insulation layer together with the two metal skins act as a beam to resist wind and point loads. The synergy acquired by the combined strength and stiffness of the metal and insulation core is far greater than the sum of the component parts, and large spans are possible. The strength and stiffness of insulated panels are determined by both the metal and its thickness, and the core material and its thickness. Using profiled sheeting for one or both faces can further increase the strength, and increasing the thickness of the core will permit the use of larger spans under the same loading conditions.

The number and strength of the fasteners under wind suction loads can limit the maximum purlin spacing. If roof-lights are required, then the maximum purlin spacing will be limited by the strength of the roof-light sheeting. Polycarbonate or G.R.P. barrel vault roof-lighting may avoid this restriction.

Insulated panels, unlike single skin profiles, can support normal foot traffic without damage, because the foam core provides continuous support to the external sheeting to resist deformation and indentation.

All persons walking on the cladding should wear footwear suitable to comply with the safety requirements in **14.1. Safety**, and also to avoid marking or scratching the surface coatings.

Structural bonded composite roof panels contribute to site safety because, once fixed, they provide a safe working platform. Fixed panels are fully trafficable at all practical spans, however foot traffic on unfixed panels should be restricted to the roof panel erectors.

12.4.1 SUPPORTING STRUCTURE

Composite panels are supported on purlins or girts, which should be accurately erected to a maximum tolerance of $\pm 3\text{mm}$ and $L/600$ as due to their inherent stiffness insulated panels do not have the flexibility to follow uneven structures.

Where composite roof panels are required to have end-lap joints, the external sheets are overlapped, and the joint in the lining and insulation is a butt joint. As both sides of the joint require support, and the fasteners are at one side of the joint, the purlins should be wide enough to provide this support.

All transverse laps should be fixed and sealed to prevent the passage of air, water or water vapour.

If composite panels are expected to provide restraint to the purlin or girt flanges, through fixing with oversized holes is required which allows panels to slide under thermal movement, as clips do not provide sufficient restraint. Where fixings are widely spaced panels may not effectively restrain the purlin or girt flange.

Composite panels should not be used in lieu of sag bars as their function is to hold the purlins or girts in their correct location while the panels are erected.

Composite panels have a structural integrity which single skin profiled sheets do not possess, and are able to accommodate penetration openings of 350mm diameter or 300mm square without the need for additional structural supports or trimmers.

Where larger holes are required trimmers should be in place before the erection of the panels.

12.5 THERMAL

Thermal bowing can occur when the two skins are at significantly different temperatures such as north facing walls. e.g. when a coolroom roof panel is in direct sunshine. The effect is accentuated when the external surface is a dark colour, and is more severe for aluminium facings.

A method of limiting the thermal bow is to make stress relief cuts in the panels as follows:

- When a panel is restrained in three or more points a cut completely severing the cold skin may be required at the intermediate point.
- When a panel is attached along its edge, a partial stress relief cut may be required.

The through fasteners or fixing clips are cold bridges, but it has been shown that these are unlikely to increase the U-value by more than 1-2%.

Where the roof panel length is >15m a joint may be required. This can be a sealed lap joint where provision for expansion is provided or a stepped or waterfall detail. (see section 5.3.5.3.)

12.5.1 FIRE

Most panels have a fire resistance when used as a non-loading panel, and the cores are made from insulating foam incorporating fire retardant materials. Fire regulations aim at reducing the risk of death or injury to occupants, the public and the fire service, and this is achieved by the selection of materials which behave in a predictable manner.

Steel and aluminium liners achieve classifications for combustibility, ignitability and surface spread of flame, but for fire resistant wall construction steel skinned composite panels must be used as aluminium has too low a melting point.

Polystyrene cores are not easily ignited behind the metal skins, but can melt and flow out of the panel and must not be used for internal partitions or ceilings, where there is a high fire risk. Polystyrene cored panels must be isolated and protected from radiation from hot flues.

Once fire has been established within the foam core, Fire Services are unable to trace or extinguish it and then the building should be regarded as unsafe.

Because the use of nylon bolts may jeopardise the integrity of the building during a fire, other mechanical connections should be used if the building is required to have a fire rating or is considered a likely fire risk.

N.B. Fire ratings are available for non-load bearing applications.

Aluminium skinned composite panels, nylon bolts or polystyrene cores must not be used where the building is required to have a fire rating or is considered a likely fire risk.

12.6 CONDENSATION

Metal facings are effectively impervious to penetration by vapour, while polystyrene insulation has a closed cell structure, which does not permit significant transmission of vapour. Interstitial condensation cannot occur without the presence of vapour in the insulation so to prevent this it is necessary to seal all laps and gaps.

The side-lap joints require sealing to prevent condensation on the overlapping edge of the external sheeting. Transverse laps, joints and ridges should also be fastened and sealed.

When composite panels are used as cold store insulation a complete and continuous vapour barrier is essential to prevent inward moisture vapour pressure. Any discontinuity will result in a build up of ice which can destroy the panel.

12.7 ACOUSTIC

Acoustic insulation properties are related to cladding mass and as composite panels are relatively light they do not have inherently good acoustic insulation properties. They can be installed with sealed joints to reduce airborne sound and they can perform as well as some built-up systems.

Acoustic absorption depends on the nature of the lining, which if flat and metal, absorbs very little acoustic energy, and it may be necessary to install additional acoustic lining systems.

12.8 FIXING

Composite roof panels with trapezoidal ribs are through-fixed with a load spreading washer on the rib, and require sealing at the side-laps, whereas flat concealed fix composite panels require more complex jointing systems.

Profiled cladding side laps require to be stitched at the rib at 500mm centres with a strip sealant of approximately 9mm x 3mm or similar. **(see side lap fasteners section 5.4.2.)**

The through fixings may also be pan fixed or located on a mini-rib or swage within the trough, but purpose designed fasteners are required to maintain the weather seal between the metal skin and the washer. Pan fasteners should not be over-tightened as this will cause shallow dents around the fastener head and washer. The washer should have a minimum diameter of 25mm to provide good pull-over strength.

All fixings must have a pullout strength and frequency to equal the wind design load. (see fasteners section 7.8.1.)

The maximum practical length of panels is restricted to approximately 25m as greater lengths may present handling problems because of the panel weight. Where a transverse joint is required there are two options:

- At end-laps, the lining and insulation is butt jointed over the purlin, and a 150mm overlap is formed in the external weather skin only using two lines of sealant. The sealant should be silicone or preformed strips, and be positioned at the top and bottom of the lap. With flat or wide pan profiles to provide a secure seal additional sealed rivets or stitching screws are required through the top skins only. This detail is only suitable where the roof pitch is $>10^\circ$ and where the maximum length is $<15\text{m}$.
- Where the pitch is below 10° or the length is $>15\text{m}$ a stepped or waterfall joint is required. **(see section 5.3.5.3.)**

The bottom skins of composite panels have an integral side lap with a re-entrant sealing space which acts as a vapour control, but in high risk applications such as food processing buildings, textile mills and indoor swimming pools, an additional sealer strip is required at the lining.

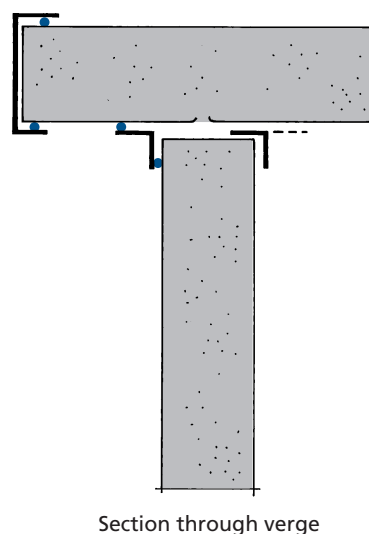
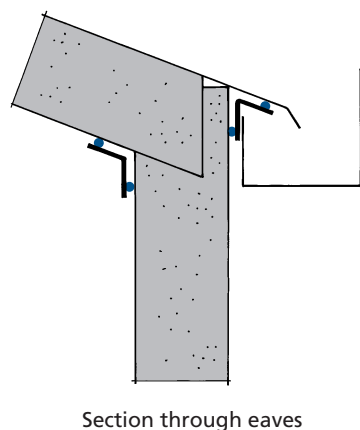
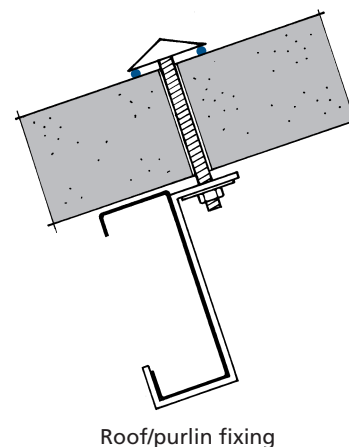
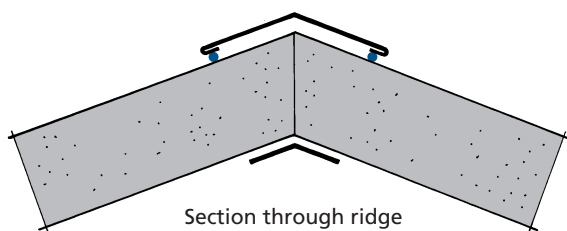
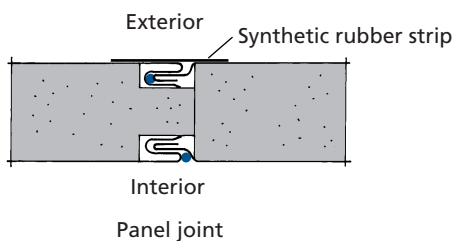
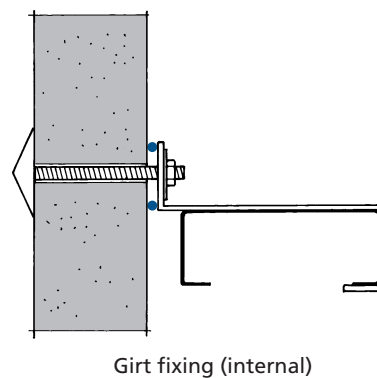
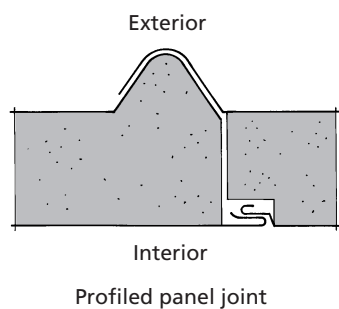
Concealed fix systems may be used on very low pitches to conceal the fasteners from the weather and from view.

12.9 FLASHINGS

Flashings detailing is similar to that used with single skin roof and wall cladding or built-up systems, but there are minor differences that may influence design choices, and special requirements that should be addressed.

The panels at the ridge should be sealed and the lining closed with a metal trim mounted on the ridge purlins. Any gap between the ends of the composite panels should be insulated to eliminate cold spots or cold bridging, and this can be done with in-situ injected foam or mineral fibre. In high humidity applications the liner trim should be sealed to the panels, and at end laps or any gaps foam injected to provide a vapour tight seal.

Eaves panels should have the ends turned down to direct water to drip into the gutter, and to have a metal flashing to cover the exposed end of the insulation and metal liner.



Drawings 12.9 

13.0 MAINTENANCE

Maintenance is difficult to define as it can have a different meaning for different people. A cladding manufacturer has little control over the end use of his product, but he is obliged to warn that it can deteriorate under certain circumstances if it is not maintained. Producer advertising has raised customer expectations to the extent that 'maintenance free' products are being purchased so as to avoid maintenance. It is suggested that nothing is truly maintenance free, and therefore it is a relative term only.

The public perception of maintenance is closely related to what is readily visible. If the lawn 'needs' mowing, or the windows or the car 'needs' washing, then it is done. If the gutters are blocked with leaves, they probably will not be cleaned out until they overflow. This could be regarded as 'normal maintenance'.

The interpretation of maintenance is also governed by the subjective opinion of the viewer. The owner's attitude to maintenance is likely to be different to the tenants, and one of the reasons that compliance schedules are required for commercial and industrial buildings is to ensure that maintenance is done. There is no regulatory requirement for any maintenance for domestic buildings.

The use of pre-coated or pre-finished roof and wall cladding with a minimum 15 year warranty, has led to the belief that no maintenance is required for that period. This is not correct as the terms of the warranty state that maintenance is required, and the performance of metal claddings is entirely dependent on the environment. (*see section 2.5.1.*)

Individual components of a building system that are difficult to access or replace must either all have the same durability, or be installed in a manner that permits their replacement without the need to remove building components that have greater durability.

In this context the performance requirements of the NZB Code means that there should be no moisture penetration due to product failure. As the NZBC does not include aesthetic appearance this means that coated steel external fasteners used to fix roof and wall cladding, could have deteriorated but still remain functional without failure and comply with the NZBC.

Continued maintenance and over-painting will not only enhance the decorative appearance but will also by protective means, greatly extend the ultimate life of all roof and wall cladding and rain water products.

Maintenance is defined as 'to keep in good condition or repair', and can be divided into categories:

- Normal
- Scheduled or Planned
- Preventative
- Special

13.1 NORMAL MAINTENANCE

The maintenance described in this section refers to the maintenance of the building envelope and not to any equipment located on the roof cladding, such as air-conditioning or communications equipment.

Maintenance work and workers must comply with section 14.6. walking on roofs. Normal maintenance is that work necessary to achieve the claimed or expected product durability and the extent and nature of that maintenance will depend on the material, its position on the building, geographical location and the macro and micro-environment of the building site.

It is the responsibility of the person specifying the building product to determine the normal maintenance requirements for the material, as prescribed in section 13.1. of this NZ Roofing Code of Practice.

Because of the natural disinclination to carry out maintenance where any part of the building that is not seen or is higher than 3m, 'Normal' maintenance should become 'Scheduled', and will require washing as per the schedule in 13.2.

13.2 SCHEDULED MAINTENANCE

Scheduled maintenance is regarded as routine maintenance that is performed at regular intervals.

All roofing and cladding products are subject to the cumulative effects of weather, dust and other deposits, but normal rain washing will remove most accumulated atmospheric contaminants and little maintenance is required on an exposed well designed and installed roof.

All other areas are regarded as 'unwashed areas' i.e. those areas protected from the direct effect of rain. These include all vertical wall surfaces that are above an angled line drawn at 45° to intersect the edge of the overhang or soffit, the underside of gutters, fascias and the sheltered areas of garage doors. (see *drawings 2.6.7.*)

To prevent the accumulation of dirt, debris or other material not removed by rain, manual washing is required. For wall cladding, every:

- 6 months in severe environments.
- 12 months in moderate environments.

For unwashed areas that do not receive adequate or any rain washing such as soffits, wall cladding under eaves, underside of gutters, fascias, sheltered areas of garage doors and unwashed roof areas, washing is required every:

- 3 months for severe environments.
- 6 months for moderate environments.

Scheduled maintenance comprises the inspection, maintenance and reporting procedures for building elements required to have a compliance schedule in terms of section 44 of the Building Act. By those procedures the building elements concerned are effectively deemed to have a durability of the life of the building because they are required to perform as designed at all times. The relevant maintenance procedures may include total replacement.

Warranty requirements and durability compliance will only be met if the maintenance requirements specified by the coil coating manufacturer are followed.

13.3 PREVENTATIVE MAINTENANCE

Good design can avoid frequent maintenance, but preventative maintenance may provide the most economic solution. This can be achieved by enhancing the product before installation, or by painting metal cladding at a nominated period.

Where the underside of metal roof cladding is subject to contaminants such as salt at the gutter line, an over-flashing should be inserted between the roof and the gutter to prevent such deposits which lead to 'inside out' corrosion. (see *drawing 5.3.5.4.*)

This flashing can become a sacrificial one where dissimilar metals are used for gutters or spouting, and where splashes and contaminants can corrode the roof cladding.

Where the gutter line micro-environment is likely to be severe the underside of metal cladding should be painted with a two pack epoxy primer or elastomeric polyurethane paint prior to installation.

Building underlay alone can provide this protection if carried down into the gutter, but does not have the a 50 year durability if exposed to UV, and can give rise to flutter noise if lapped too far into the gutter.

Where roof cladding is exposed to the elements from the underside, it should be included in the maintenance schedule for unwashed areas.

Seagulls perching on ridgings or parapets on buildings that are close to the sea can cause damage from rubbish dropped onto the roof, and from their alkali droppings. Discouraging devices such as wire or spikes can be used to prevent this. Unpainted aluminium or AZ coatings are particularly prone to attack from alkali.

13.4 SPECIAL MAINTENANCE

High Risk areas such as around flues, near fumes from exhaust fans, under television aerials or overhanging trees, and sites prone to mould, lichen, bird droppings or debris, all need to have extensive manual washing. Proximity to a motorway can cause the collection of fine dust, as can earthworks in the vicinity, and shavings from wood processing plants are often blown into crevices under flashings which retain moisture and can create 'poultice corrosion'. Bird droppings should be cleared away regularly to avoid premature failure at ridges or bird perches. Canopies above load-out doors have large unwashed areas on their undersides and service station canopies are subject to a harsh environment so they should be treated as a special maintenance cases.

13.5 INSPECTION

To preserve the asset, the building owner should be informed of the maintenance required to keep the cladding within the terms of the warranty and he should be provided with documentary evidence of his obligations. Regular inspection by specialist consultants should be undertaken annually. Records should be kept of all such inspections, which will support any subsequent claims against the manufacturer, supplier or installer. Records will also assist in the process of mediation or arbitration of any such claims.

Without documentary evidence of regular maintenance any rectification is solely at the discretion of the supplier. Any subsequent work undertaken on the roof cladding by others that does not comply with this Code of Practice will void any warranty.

Inspections and the report should cover the fixings, gutters, downpipes and flashings as well as the surface condition of the cladding. The reports should be placed in the 'Building Maintenance Manual', which should contain dated particulars of the original contract, the type of cladding and its colour and gauge, and the warranty, and reference should be made to any leaks reported and repair work or additions carried out. Regular inspection should be regarded as preventative maintenance.

13.5.1 INSTALLATION

Approved fixers of the members of The New Zealand Metal Roofing Manufacturers Inc (NZMRM Inc) and members of the Roofing Association of New Zealand, (RANZ), will provide a warranty for five years to cover the workmanship and installation of the roof and wall cladding if requested. This means that if the standard of workmanship of the roofing contractor does not comply with this N.Z. Roofing Code of Practice, and he is a member of RANZ, the installation will be renewed or restored so that it does comply.

This warranty does not extend to any work undertaken on the roof or wall cladding or accessories by other trades or subsequent to completion of the contract by the roofing contractor.

Designers and owners are therefore strongly advised to only deal with members of both of these recognised Trade organisations in order to obtain this warranty.

13.6 WASHING

Regular washing of pre-painted roofing products increases their durability by reducing attack from airborne salts and pollutants. Unpainted products, although not recommended for use in severe or very severe environments, will also benefit from routine washing.

Washing may be carried out with a hose and a soft bristle brush, using fresh water. In areas where heavy industrial deposits dull the surface, a thorough cleaning can be ensured by using a 10% solution of household detergent and fresh water followed by a thorough rinse with clean water.

Stronger concentrations of cleaners than those recommended can damage coating surfaces, and organic solvents and abrasive cleaners should not be used. When cleaning coated surfaces, tar and similar substances may be removed with mineral turpentine, but the surfaces should then be washed thoroughly with detergent and water.

Always clean coated surfaces from top to bottom, and rinse immediately and thoroughly with fresh, clean water avoiding over-cleaning or scrubbing, which can damage painted surfaces.

The scrubbing of bare AZ coated steel cladding can remove the thin factory applied clear acrylic film and should not be done for this reason.

High pressure water blasting must not be used to clean pre-painted metal as it can damage the paint surface and water blasting can also force water into areas that it would not be subject to under normal weathering and thus cause water ingress.

If water runoff is used for drinking water, before washing any roof or wall cladding using detergents, roof outlets must be disconnected. Care must be taken not to contaminate waterways.

13.6.1 LICHEN AND MOULD

Some types of local environment are particularly conducive to lichen or mould growth. This includes areas of wet, dark, or shaded surroundings, where trees are in the proximity, or overhang roof cladding, or low lying valleys where moisture-laden air accumulates as fog or mist. Lichen are a naturally occurring phenomenon with their spores being dispersed by the wind and lichen will grow even on inert materials such as G.R.P. and glass. There are many different kinds of lichen, some of which appear to favour different colours, and this phenomenon can be assumed to relate to the temperature of the roof. As lichen and mould all retain moisture, their removal is in the best interest of the longevity of metal cladding, however recolonisation is very likely to reoccur. Mould growth can be removed by washing down the roof or wall cladding, (*see washing 13.6*) and applying a 2% solution of sodium hypochlorite to all surfaces by low-pressure spray, broom or brush. The surface should be left for 5 minutes but should then be rinsed, and then thoroughly washed down with cold water. Household bleach contains sodium hypochlorite but to a varying degree therefore it may be necessary to dilute it.

e.g. One brand has 30 grams/litre solution = 3%

To obtain a 2% solution, 2 parts of bleach should be diluted with 1 part of water. ($3 - 2 = 1$)

Another brand has 40 grams/litre solution = 4%

To obtain a 2% solution, 2 parts of bleach should be diluted with 2 parts of water. ($4 - 2 = 2$)

Another brand has 50 grams/litre solution = 5%

To obtain a 2% solution, 2 parts of bleach should be diluted with 3 parts of water. ($5 - 2 = 3$)

If the roof is used for the collection of drinking water see section 13.4.

13.6.2 GRAFFITI

Metal wall cladding like most vertical surfaces is subject to being defaced by graffiti. Graffiti removal is likely to affect the pre-painted finishes on metal roof and wall cladding and before removal is attempted, a small area should be cleaned as a trial. Graffiti removers may soften the paint, remove the gloss or may cause permanent damage.

Do not use MEK (methylethyl ketone), toluene, acetone or thinners. Overpainting or replacement are the alternative options.

There are clear removable anti-graffiti coatings available but they are an expensive option and should be compatible with the paint system.

13.7 OVERPAINTING

To achieve a satisfactory result when overpainting it is vital that preliminary preparation is carried out prior to painting, and the same cleaning process can be used for new, weathered or prepainted roofs.

The surface preparation, painting and over-painting of metal roof and wall cladding should be carried out by specialist contractors, using the following methods.

To achieve satisfactory adhesion and optimum results all dirt should be washed away and cleaning agents such as soap or detergent should be fully washed off the surface prior to paint application. Over-painting a dirty or wet surface results in poor adhesion of the paint and consequently a reduced life and can also cause premature corrosion of steel cladding.

Thoroughly clean the surface with fresh flowing water and a medium stiff nylon bristle broom or waterblast @ 20 MPa (<3,000 p.s.i.). When cleaning the profile of any dirt, lichen or mould, care should be taken not to drive water under laps or flashings. Rinse the profile swages well, as any remaining dirt will dry and impair subsequent paint adhesion. Particular attention should be given to the drip edge where the final 15mm is prone to heavy dirt build-up and to coating the front edge of tile profiles as dirt collects in this area and gives rise to mould and algae growth.

Special cleaning will be required around flues, as fall out in these areas will require removal before painting. Allow roof to dry.

13.7.1 UNPAINTED CLADDING

The practice of leaving metallic coated roof cladding to weather prior to painting is no longer recommended as with the latest developments in primers, roofs can now be painted immediately after installation, and which should be carried out within one month.

For new AZ coated cladding, only acrylic galvanised iron primers should be used as solvent based primers are not recommended. A solvent borne corrosion resistant galvanised iron primer should be used for optimum performance on weathered zinc coated cladding over one year old.

After the primer, two coats of acrylic roofing paint should be applied in the selected colour to provide a paint thickness of 50 microns (typically two brush applied coats achieve 50 microns).

If the cladding is weathered but shows signs of white or red rust corrosion or damage back to the metal base, proceed with painting as described in *sections 13.7.3. and 13.7.4.*

13.7.2 REPAINTING PAINTED CLADDINGS

Repainting painted claddings should be regarded as part of the maintenance programme to extend the life of all metal claddings. There is an optimum time at which to repaint painted claddings which is called 'the time to repaint decision' and this decision should be made by the owner after specialist consultation.

It is also known as 'the life to first maintenance' and is the time before excessive chalking has taken place or the top coat weathered away. Painted products can be readily over-painted with high quality acrylic roof paints to extend the life of the roof cladding and if over-painting is carried out while the top coat is still in sound condition there is no need to use a primer.

To prepare the surface for painting all pre-painted products should have their surfaces abraded with a fine grit sand paper, stiff nylon bristle broom or similar, to improve the adhesion. Care should be exercised not to sand through the existing paint surface on external bends.

13.7.3 WEATHERED WITH WHITE CORROSION

If the white corrosion can be easily removed and no red rusting has developed, the roof cladding should be cleaned as outlined above. Neutralise the areas where white corrosion is present with a proprietary metal cleaner designed for this purpose and follow instructions on the container closely. If all residues from the metal cleaner are not removed prior to painting poor paint adhesion will result.

Painting should take place as soon as possible after this pre-treatment.

The presence of white corrosion indicates that the primer has been consumed and so isolated areas of white corrosion should be spot primed once these areas have been cleaned and neutralised. If all external bends are showing corrosion, coat the whole area with an acrylic galvanised iron primer.

For unpainted products it is necessary to use a primer over the whole surface.

13.7.4 RED CORROSION

Red corrosion, or corrosion at the edges of the profiled steel cladding should be prepared as follows:

Manually de-scale and remove all white and red rust by abrading to bright, firm metal, ensuring that the surface is as smooth as possible. Thoroughly clean the roof as described previously and neutralise the corrosion reaction with a commercially available metal cleaner made for this purpose.

This type of solution should not be allowed to dry on the surface before fully washing off, and all residues of the metal treatment should be removed prior to painting, which should follow immediately. Dry all surfaces before spot priming the cleaned bare red corrosion affected areas with a zinc-rich primer, which should be applied as directed.

Coat the whole prepared areas with a water based galvanised iron primer and apply two topcoats of acrylic roofing paint to the dry, primed area.

13.7.5 PAINT

High quality 100% acrylic paints can give a service life of up to 10 years when applied to specification on correctly prepared metal surfaces. This life span will vary slightly with colour, roof orientation and the aesthetic requirements of the situation but poor paint curing will downgrade durability.

Paint should not be applied on wet days, or when condensation in the form of dew, has not completely dried, on cold days below 10° or on hot days above 30°. Windy days are also not suitable as curing is impaired.

The painting of very hot roofs will result in the evaporation of the solvent before full film formation can take place, and so will reduce the life of the coating.

Ridge ladders should be fitted with protective buffers or rubber pads as they can cause extensive abrasion damage to pre-coated metal cladding. Where it is possible the painter should walk in the pan, but when it is necessary to step on the rib, attention should be paid to sheet overlaps as these may spring up after a painter's weight is removed and reveal an unpainted line. Decking profiles have a tight roll-formed bend at the top of the upstand and care is necessary to ensure the specified film build is applied in this area.

13.7.6 BRUSH APPLICATION

The use of nylon brushes is advisable, and these should be wetted with water prior to use to avoid clogging, and in warm weather should be washed out completely at every rest break.

Apply two full even coats of acrylic paint to a dry film build of 50 microns, allowing sufficient drying time between coats, but do not over-brush and thin only sparingly.

13.7.7 ROLLER APPLICATION

Apply to the spreading rate and film build specified for brush application. Dampen the roller prior to use, then load up the roller and apply two full even coats, allowing sufficient drying time between coats. Apply with even pressure, and do not over-roll. Profiled rollers are available for corrugated profiles, but some profiles may require the combined use of brush and roller of the paint for complete application.

13.7.8 SPRAY APPLICATION

Apply to dry film build specification of a minimum of 50 microns. Airless spray equipment can achieve very high film builds giving rise to runs and uneven coatings. When using spray equipment on hot or windy days, the paint spray may dry before it has reached the metal, which leaves a sandy appearance and feel. This is not aesthetically acceptable and will not provide the even coating required, even though it may measure 50microns.

Do not spray before 10.00am or after 3.00pm as condensation can be present and also as the steel will cool rapidly and impair cure that can result in incorrect film formation and leading to early failure of the coating. These hours could be extended in mid-summer to before 9.00am or after 4.00pm.

The gloss and weathering characteristics of oven cured and air dried paints are different, and over time a significant difference in colour may become apparent. Variations in natural light conditions will emphasise these differences producing unacceptable aesthetic variations. For this reason the whole roof area should be painted and not patch painted and this also is the reason why 'touch-up' paint should not be used.

Spray cans should not be used for repairing scratches on pre-painted cladding. Minor surface scratches are best left because they become less noticeable as the coating weathers. If the scratch cannot be seen from the ground, it should be left alone.

13.8 MATERIAL SELECTION

The selection of the most suitable material for metal roof and wall cladding that will comply with the durability requirements of the NZBC is dependent on the design of the building and its location or environmental category. The designer should recognize that there are many factors that will govern performance and some are under his control and some are not. The environment is generally determined by the location and manufacturers offer different metallic and paint coatings and different metals that are suitable for all different environments. Because of their total thickness, non-ferrous metals and stainless steel can perform better than metallic coated steels in severe environments.

Designers are urged to select the material in conjunction with the conditions of any expected warranty before the material is specified. The durability of the material is not necessarily confined to the number of years stated in any warranty and is only indicative of the performance of differing substrates and coatings.

Those factors that the designer can influence are covered in many other sections of this Code. Cost and colour should not be the major determining factors, and designs using unwashed areas or detailing using dissimilar metals requires considered material selection.

Any warranty for roof or wall cladding is divided into two parts, the material and the workmanship. Workmanship warranties are usually provided by the Roofing Contractor for a minimum period of two years, however this period is extended to five years by Roofing Contractors who are members of RANZ.

There is a difference between the warranty offered for residential and commercial use of metal roof and wall cladding.

The maintenance of metal roof and wall cladding is very dependent on two factors – design and materials.

The preparation of a maintenance manual for owners is an indication to the owner that periodic maintenance is required to comply with the manufacturers warranty conditions.

13.8.1 RESIDENTIAL

Material selection for residential construction requires different consideration that commercial buildings, particularly when maintenance has to be considered. Consumer expectations include appearance in relation to performance whereas the NZBC does not. The ease of replacement will satisfy the Building Code but not satisfy the consumer.

Trade literature is available from the coated steel or pre-painted metal supplier and the product manufacturer which sets out prescriptive design, installation and maintenance instructions that should be adhered to if any warranty is to be upheld. Although the product manufacturer or the contractor has no control over the maintenance part of these conditions, it is his obligation to inform the owner or his representative of the maintenance requirements specific to the material to comply with the NZ Building Code.

This material warranty is for a minimum of 15 years against perforation, unless specifically stated.

13.8.2 COMMERCIAL

Material selection for commercial and industrial construction may require a different approach if the maintenance can be carried out as tax-deductible expenditure. Any commercial warranty offered by the coated metal or pre-painted metal supplier is specific for the environment and end use and a request should be made to the supplier prior to installation as they are only issued upon the satisfactory completion of the contract.

Such warranties are also issued for different types of metal substrate and coatings only on condition that the requirements for their use and maintenance are complied with.

13.8.3 RESPONSIBILITY & LIABILITY

There is a joint responsibility between all the parties to ensure compliance with the terms of the warranty.

The designer, manufacturer, contractor, roofing contractor and owner should be made aware of their responsibilities and all parties are considered to have been informed of their obligation if they have sighted or signed a warranty.

If the requirements of the NZBC or consumer legislation knowingly cannot be met, or if the conditions of the warranty or the requirements are knowingly impractical or ignored, the liability remains with those who ignored them. There is an implied warranty requirement within the Building Act that the material selected and used will be suitable for purpose. Material can be used without compliance with the NZBC, but only on a written statement to that effect given by the roofing contractor and with the consent of the T.A.

Tables 13.5.4.A & B provide an indicative performance of the number years that metal roof and wall cladding will not perforate from corrosion in a well washed situation providing maintenance requirements are met. (*see maintenance section 13*)

In unwashed areas the durability of wall cladding, spouting or flashings are likely to be less than that indicated in the tables.

Tables 13.5.4.A & B do not necessarily consider the aesthetic appearance of the metal coating or the 'time to repaint decision'. (*see section 13.7.2.*)

The indication for rainwater goods is dependent on the environment and the ability of any spouting or gutter to be able to drain and avoid ponding.

As Tables 13.5.4.A & B are not warranties it is strongly recommended that prior to any material selection being finalised and before the tender documents are issued that an enquiry is made to determine the conditions of any expected warranty.

The range in years provides for differences in each environmental category as described in *environments section 2.5.1.*

- C2** = Category 2 Moderate Inland
C3 = Category 3 Moderate Marine
C4 = Category 4 Severe
C5 = Category 5 Very Severe

- = Check with supplier as materials used in these areas may not satisfy the durability requirements of the NZBC.

R/W = Roof and walls

RGS = Rain-water Goods

INDICATIVE PERFORMANCE IN YEARS THAT NATURALLY WASHED METALLIC COATED STEEL BASED CLADDING WILL NOT PERFORATE FROM CORROSION.

Environmental Category	C2/3	C4	C5	C2/3	C4	C5
Coating	R/W	R/W	R/W	RGS	RGS	RGS
Galvanised Z450	15/30	•	•	•	•	•
AZ 150	15/40	•	•	10	•	•
Prepainted AZ150	30/40	15/25	•	10/15	10	•
Prepainted AZ200	30/50	20/40	15	12/15	10	•

Table 13.5.4.A.

INDICATIVE PERFORMANCE IN YEARS THAT NATURALLY WASHED METAL CLADDING WILL NOT PERFORATE FROM CORROSION.

Environmental Category	C2/3	C4	C5	C2/3	C4	C5	C2/3	C4	C5
Coating	Roof	Roof	Roof	Wall	Wall	Wall	RGS	RGS	RGS
Unpainted aluminium	25/40	20/30	15/25	15/40	15/30	10/20	10	10	5
Polyester/Acrylic Aluminium	30/50	25/50	20/40	25/45	20/40	15/35	15	15	10
PVF2 Aluminium	35/50	30/50	25/40	30/45	25/40	20/35	15	15	10
Zinc	>50	>50	50	>50	>50	50	10	10	10
Copper	>50	>50	>50	>50	>50	>50	>50	>50	>50
Stainless steel	>50	>50	>50	>50	>50	>50	>50	>50	>50

Table 13.5.4.B

13.8.4 SPECIAL ENVIRONMENTS AND EXCLUSIONS:

- Maintenance requirements not fulfilled
- Unwashed areas
- Garage Doors
- Damage due to handling, storage, roll-forming and installation
- Design not in accordance with N.Z. Roofing Code of Practice.
- Consequential loss
- Accumulation of debris
- Geothermal areas
- Internal environments from fumes or pollutants
- West Coast South Island

13.9 DRINKING WATER

Rainwater collected from roofs clad with products made from steel and prepainted steel, will comply with the provisions of NZBC G 1 2.3.1, provided the water is not contaminated from other sources.

The first 25mm of rainfall from a newly installed roof should be discarded before drinking water collection starts, and always disconnect downpipes when painting a roof. Spouting should be regularly cleaned to avoid the build-up of dirt and debris that can affect water quality.

Where a paint or paint system is applied to the roof, its suitability for the collection of drinking water should be established. When rainwater from pre-painted roof cladding is used for drinking it is advisable to repaint the roof as soon as its surface has weathered.

Water collected from metal roof cladding, spouting or gutters made from aluminium, copper and stainless steel will not normally be contaminated by rainfall in suburban and rural areas. However fallout from manufacturing plants, top dressing and the contamination resulting from roof cleaning can affect the water quality, and in these cases downpipes should be disconnected.

14.0 SITE PRACTICE**14.1 SAFETY**

The NZBC requires that people are safeguarded from injury during construction but this relates to injury as a result of structural failure rather than due to mishap. (see *NZBC B1.*)

This section on safety includes a summary of the legal requirements imposed on persons working on site and working at height. It includes the responsibilities of employer, employee and the self-employed under the Health and Safety in Employment Act 1992 and the Regulations of 1995. For a more precise definition, reference should be made to those documents. The highlighted paragraphs in this section relate to the HS & E Act.

Because the installation of roof and wall cladding requires working at height, and as falling from a height is the major cause of fatal work related accidents in N.Z., it is important that this section be understood by all concerned.

The legal requirements are aimed at preventing injury, while other parts of this section are related to good housekeeping on site, and to describing good work habits that will not put workers or other people at risk.

Safety provisions made by others can lead to complacency, but they should in no way diminish the individual caution and prudence that should be shown by all persons working at height.

Although the regulations for working at height start at 3 metres, safety provision should be made for guard rails on scaffold and roof edges at any height above ground, as serious injury and death have occurred at less than 3m in height.

14.1.1 RESPONSIBILITIES

Compliance with the legal requirements of the HSE Act is not the only responsibility of anyone associated with working at height. Employers have a duty of care to take all practicable steps to ensure the safety of employees, to provide and maintain a safe working environment, and to provide and maintain facilities for the safety and health of employees. They must also ensure that equipment is safe, that working arrangements are not hazardous, and that procedures are in place to deal with any emergencies that may arise. Taking "all practicable steps" means doing what is reasonably possible to be done in the circumstances, taking into account:

- The severity of any injury or harm to health that may occur
- The degree of risk or probability of that injury or harm occurring;
- The availability, effectiveness and cost of the possible safeguards,

Employers are also responsible for the health and safety of people who are not employees, and must take all practicable steps to ensure that employees do not harm any other person, including members of the public or visitors to the site.

The HSE Act requires employers to keep a register of work-related accidents including every accident that harmed or might have harmed someone. Employers are also required to investigate all these accidents to determine whether they were caused by a significant hazard. Employers are required to notify serious harm that occurs to employees to the nearest DOL Workplace (see *definitions*) office within 7 days.

If a person suffers serious harm, the scene of the accident must not be disturbed unless to:

- Save life or prevent suffering;
- Maintain public access for essential services, e.g. electricity or gas;
- Prevent serious damage or loss of property.

The DOL Workplace office will advise if the accident is to be investigated.

Supervisory persons who control places of work must take all practicable steps to ensure the safety of persons in the place of work. They are responsible for the safe use, handling, transport and storage of all materials and substances used on work site, or in any other place of work.

14.1.2 TRAINING

Employers must ensure employees are either sufficiently experienced to do their work safely or are supervised by an experienced person. Employees must be adequately trained in the safe use of the equipment in the place of work, including protective clothing and equipment.

Employees and self-employed persons have a responsibility for their own safety and health, and they must also ensure that their actions do not harm anyone else. Self-employed persons have equal responsibilities as the employer to ensure that they are adequately trained and informed in all legal and practical matters regarding safety.

14.1.3 WORKING AT HEIGHT

Where a person may be at risk of an injury from a fall means that are both suitable and safe must be provided to prevent such a fall.

Safety fall protection systems include:

- (a) The installation of an approved safety mesh over the total area to be clad. (barrier)
- (b) Edge protection for the total periphery of the area to be clad, including a scaffold or a guardrail fixed 1.0m high to standards which includes a bottom and middle rail. (barrier)
- (c) Travel restriction consisting of an anchorage line and a safety belt.
- (d) Fall arrest devices such as an individual safety harness.

(a) and (b) are the preferred methods of working safely at height.

Surfaces that have fall-protection barriers (a) and (b) are regarded as an enclosed working environment and the roofer is free to work within this area.

A minimum safety standard for all workers on roof areas over 3 metres high requires that:

- For all areas that do not have a fall-protection barrier, (a) and (b), a safety harness (fall-arrest system) (d) must be used.
- For all roof areas that do not have a fall-protection barrier or secure footing, travel restriction equipment is required (c)

A fall protection barrier includes any barrier that will prevent a person from falling.

A fall protection barrier can also be tile battens or roof framing at less than 500 mm centre to centre, a roof safety mesh or a work platform.

On completed roofs or where persons are kept more than 2 metres from any fall hazard by a bump rail, edge protection may be unnecessary. A bump rail consists of a rail or tensioned rope supported on posts at a height of 0.9 to 1.1 metres.

A bump rail is only suitable for flat roofs and must not be used on a roof pitch greater than 5°.

Where a bump rail is not practical, edge protection, travel restriction systems, or a fall-arrest system must be used. Edge protection can include scaffolding, scissor hoists or a guardrail system.

Safety mesh must be tied off as shown *drawings 14.1.10*.

Permanent anchor points for a static line or other fall arrest device, must be installed in all buildings, exceeding 100m² or where the roof pitch exceeds 20° or where maintenance is required for the servicing of air conditioning units or other roof mounted equipment.

14.1.3.1 ROOF EDGE PROTECTION

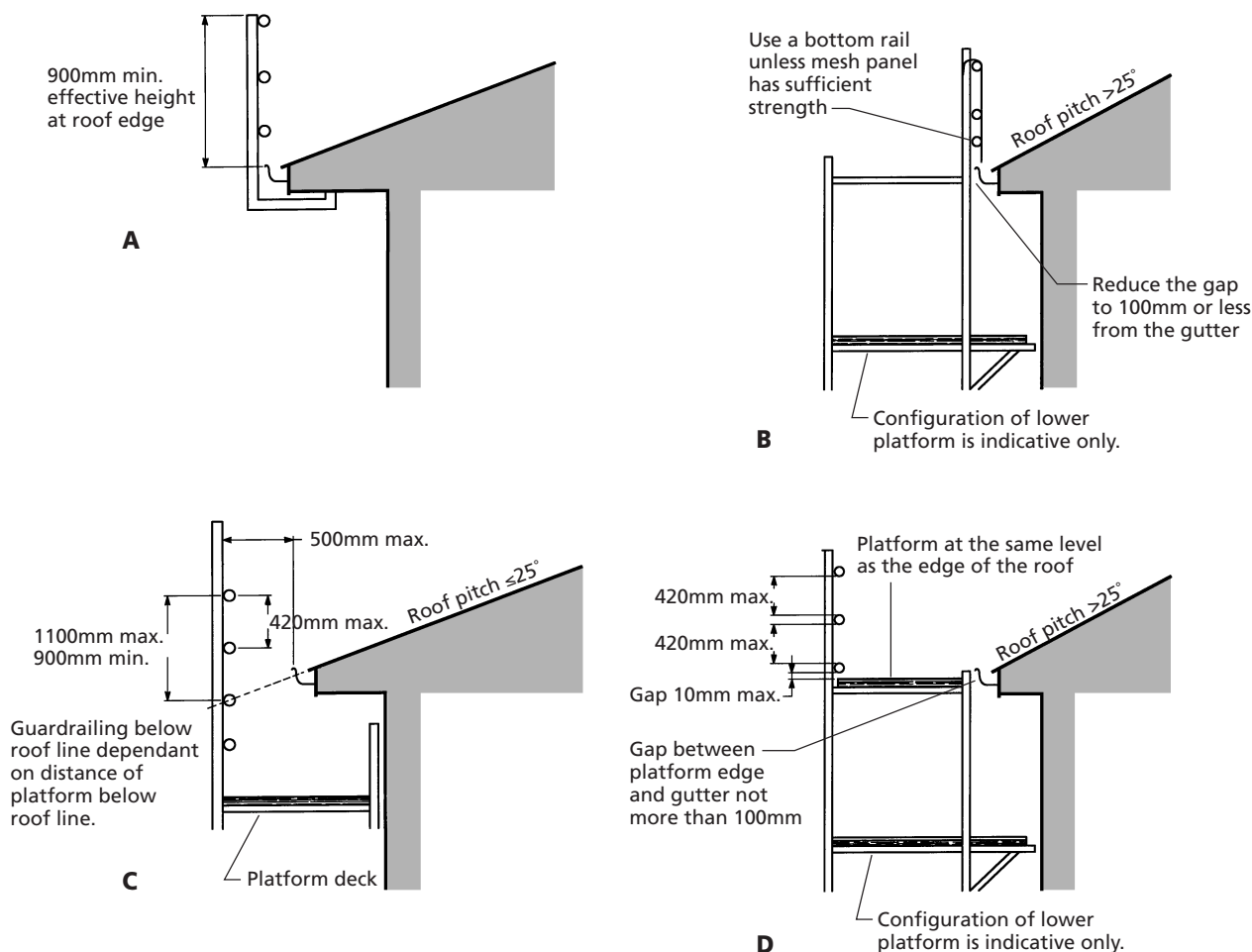
Where a person may fall more than three metres and there is no other means to prevent a fall, edge protection must be provided.

Edge protection is required to comply with AS-NZS 4994.1 general requirements & 4994.2 installation and dismantling.

Persons must be able to gain roof access without climbing over guardrails.

Access points must not undermine the integrity of the edge protection. Gates or other devices that guard openings must be self-closing and ladders must be placed as close as practicable to the entry and fully secured.

Main contractors and sub-contractors should liaise to provide an integrated fall protection method for all persons working on a roof, as a common safety system is more efficient than every subcontractor installing their own system. There are many options of acceptable scaffolding and guardrail edge protection, some of which are shown in drawings 14.1.3.1. A-D.



Drawing 14.1.3.1. A-D. 

This Code of practice states ways of managing exposure to the risk of falling and encourages the use of an enclosed environment so that it is not possible to fall from or through the structure.

Personal fall protection systems are only useful in a limited range of applications on a roof and may add unnecessary risk to those persons working on a roof.

14.1.4 RESIDENTIAL AND LIGHT COMMERCIAL ROOFING

DOL Workplace is unable to give any dispensation to the Roofing Industry from the requirements of the Health and Safety in Employment Act 1992 and the Regulations of 1995. Most residential buildings fall within a 3 – 4m height category and this height is measured from the edge of the soffit. DOL Workplace recognize that experienced workers may work within these heights without the necessity of edge protection or harness however, certain conditions apply.

- Workers should have undergone safety training.
- Pitched roofs with a smooth surface less than or equal to 30°.
- Pitched roofs with a textured surface less than or equal to 35°.

The intention of these conditions is to make the act of cladding the roof by skilled and trained workers, a separate act to that of working on a roof by other trades.

Textured surface roofs that are regarded as providing a secure footing for an extra 5° pitch over a smooth surface include textured metal tiles, unglazed clay tiles, and asphalt shingles.

Smooth surface roofs include painted metal tiles, and unpainted and prepainted profiled metal cladding.

Before any work is commenced, in all cases there is a requirement that the roofing contractor will have had sufficient safety training and education, that site hazard identification has been undertaken, and that a contractors safety policy is in place.

If there are individual site hazards, precautions need to be implemented at all heights. Hazards should be eliminated, isolated, or minimised by the use of fall protection equipment.

Site hazards include:

- Brittle roofing such as skylights, translucent, fibre cement or corroded sheets.
- Slippery roof surfaces resulting from paint finishes, moss and lichen or dew and rain;
- Roof pitches above 35°.
- Roof projections such as pipework and flashings;
- Any roof penetration larger than 600mm by 600mm;
- Steeply sloping building sites
- Open foundations or drains
- Within 2m of any roof edge.
- Wet or muddy ground conditions
- Rotten timber framing
- Fire damaged elements
- Plant and equipment
- Reinforcing starter bars

A guideline for the prevention of falls is available from DOL Workplace.

14.1.5 LIMITATIONS OF FALL ARREST AND TRAVEL RESTRAINT

Whenever possible an enclosed environment should be provided for roof installation and repair work so it is not possible to fall through or off the roof.

Harnesses are only appropriate for certain conditions such as maintenance after the roof is completed, or reroof work and they are not satisfactory when snagging hazards are present.

The use of fall arrest harnesses or travel restraint systems is not the preferred alternative for persons working on roofs as these methods have limitations including the following:

- Individual fall arrest anchors should have a capacity of at least 15 kN and roofs are generally not designed for such loadings while other anchorage points should withstand a load of 6 kN without failure.
- The location of fall arrest anchorage points on roofs cannot be located directly above head height.
- Fall arrest systems require a minimum of 5.5 metres vertical clearance below the working surface to ensure the user does not hit the ground or another obstruction prior to the fall being arrested. This distance is required to be greater if static lines are used or ropes are slack.
- In contrast to guardrail or scaffolding, fall arrest and travel restraint systems require a high level of training and supervision to ensure their safe use.
- Ropes and lanyards can become tangled and snag on obstructions on the roof particularly when a number of workers are located on the roof.
- It can be difficult to have an effective rescue procedure to ensure users are rescued before injury occurs, without putting other people at risk. Persons suspended in harnesses after falling can lose consciousness or suffer modified cardiac rhythm if not rescued promptly and the rescue procedure should ensure persons can be rescued in less than 5 minutes.

Fall arrest systems must not be used unless specific training has been completed, that more than 2 persons are located on site and any rescue procedure must not put other persons at risk.

The solo operation using fall arrest equipment is hazardous because there will not be a person to rescue the worker who could be unconscious and heavy and in some situations at least two persons may be required to safely rescue a person who has had a fall in a harness. The use of systems that prevent a fall from occurring should be used in preference to fall arrest systems. Travel restraint systems are a higher order control in comparison to fall arrest systems because they prevent a fall actually occurring. However, travel restraint systems can be very difficult to set up and often impractical to use, particularly where corners of a roof require accessing or the roof has a number of penetrations.

Where access to the corner of a roof is required workers must be attached to two or more sets of ropes and anchorages to prevent a fall from either edge of the roof. While accessing the anchorage points the user must be restrained so that a fall cannot occur.

Persons using travel restraint systems require a high degree of training, as do persons using fall arrest systems, but the training for these systems differs.

When used in isolation, fall arrest and travel restraint systems are nearly always unsuitable control measures for a complete roof installation and it is extremely difficult to set up a fall arrest system so that the user will not hit an obstruction prior to the fall being arrested.

The travel restraint system must prevent a person falling from the edge or through the roof. The use of travel restraint systems is not acceptable on fragile roofs such as plastic or asbestos cement roof cladding.

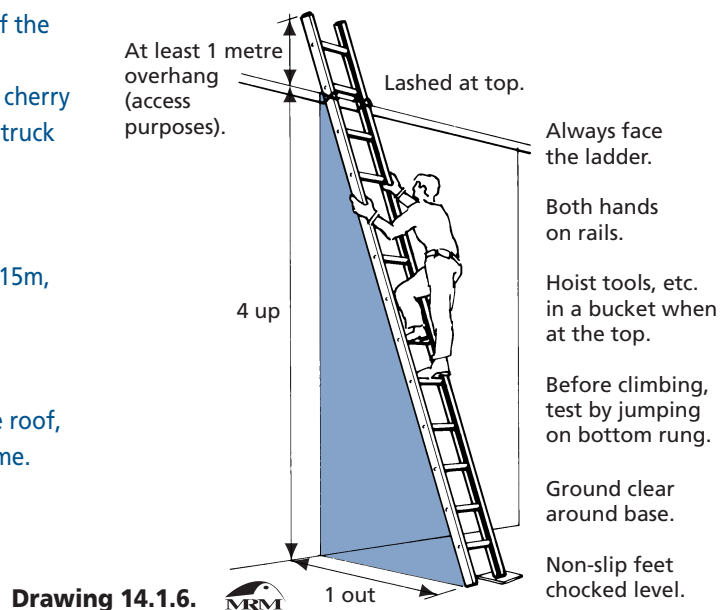
Fall arrest and travel restraint systems are generally only suitable for minor work such as:

- Roof inspection (not on fragile roofs);
- Installation of skylights and ventilation fixtures;
- Installation and removal of perimeter guardrail systems;
- Fitting ridge capping on metal roofs;
- Replacement of some isolated parts of the roof;
- Installation and removal of television aerials and other similar communication equipment
- Painting and cleaning;

14.1.6 ACCESS

Safe access should be provided to the working area at height by the provision of one of the following:

- A permanent access platform or tower if the height is over 9m.
- A power operated work platform; e.g a cherry picker, scissor hoist or approved forklift truck
- A ladder providing it is:
 1. a step ladder of maximum length 6m,
 2. a single ladder of maximum length 9m,
 3. an extension ladder of maximum length 15m,
 4. set at an angle of 76° (4 up - 1 out),
 5. secured against sliding top and bottom,
 6. set on firm level ground,
 7. protruding by one metre higher than the roof,
 8. used by no more than one person at a time.



Drawing 14.1.6.

All persons walking on a roof must wear soft soled shoes capable of providing a secure footing.

The ability of a surface to provide a secure footing will vary depending on the type of surface of the cladding, environmental conditions and the type and condition of the roofer's footwear. For the correct type of shoes in good condition on a clean dry surface, the steepest pitch that will provide a secure footing is on a textured surface roof is 35° and on a smooth surface roof 30° .

The supervisor is responsible to decide if work can proceed safely if a safety hazard exists when roof cladding is wet due to rain or dew, or if there is a wind in excess of 20m/sec.

No persons other than those authorised by the roofing contractor, or as required for supervision and inspection are permitted access to any area over which roof sheeting is being laid.

Access to any area below that which roof cladding is being installed, must be cordoned off and adequate means of warning provided of the danger above.

It is the responsibility of the main contractor to inform the owner of any safety restrictions concerning roof access for maintenance.

14.1.7 SCAFFOLDING

Scaffolding must comply with AS-NZS 1576 Scaffolding Standard.

Any person can erect scaffolding providing that it:

- is less than 5m high to the top of the working platform;
- is erected in a tradesmanlike manner;
- uses sound materials;
- is properly braced and tied;
- conforms with the scaffolding regulations;
- conforms with AS/NZS 4576;
- conforms with the SARNZ guidelines.

Scaffolding greater than 5m in height must be erected by a certified scaffolder and must be notified to the construction safety inspector at the nearest district office of DOL Workplace.

Working platforms more than 3m high must be protected with guardrails, midrails and/or toeboards, however it is recommended that all working platforms be so protected.

These requirements also apply to the erection, alteration or dismantling of all suspended scaffolds.

To prevent any inward or outward movement, ties must be fixed to standards and be uniformly spaced vertically and horizontally over the face of the scaffolding.

To stiffen the scaffold, transverse diagonal bracing is required and must be fixed to each end pair of standards and at not more than every tenth pair of standards. To resist movement due to wind, longitudinal diagonal bracing must be fixed to the face of the scaffold and at regular intervals along its length.

Ladders, steps or stairs must be securely fixed to the scaffolding either internally or externally. to provide safe access.

14.1.8 MOBILE SCAFFOLDS

Mobile scaffolds are freestanding scaffolds supported on wheels or castors and must only be used safely on firm level surfaces with the wheels effectively locked, and braced and stable against overturning.

Working platforms must be fully decked and provided with guardrails and toeboards as per fixed scaffolds .

14.1.9 PERSONAL SAFETY

Workers installing roof and wall cladding should take personal precautions to avoid damage to skin and eyes due to ultraviolet radiation.

Sunscreen or sunglasses should be used, particularly during the time of highest exposure (11a.m. - 2p.m.)

Ultraviolet radiation burning can be mistaken for windburn on windy days, and cloudy days can also produce severe burning. Some workers with a fair or sensitive skin, should always wear sunscreen protection when laying roof cladding. Glare from aluminium foil vapour barriers and from new metal roof and wall cladding can cause sunburn to some areas of the body not normally exposed to the sun.

Special care must be exercised when handling long-length sheeting particularly in wet or windy conditions.

If the work is interrupted for any reason, or at the end of the workday, all loose sheeting and incomplete sections must be adequately secured against possible movement by wind.

When cutting metal with power equipment, eye protection must be used. Loose packs or loose sheets that have not been securely fastened must not be walked on.

Gloves should be provided as personal protective equipment (PPE), and are an option for workers learning to handle sheet metal, however as experienced roofers often regard them as a hazard, they are not required unless expressly requested by the roofing supervisor or person in authority.

Reroofing presents a number of personal hazards. The condition of an old metal or any other type of roof cladding cannot be ascertained until a detailed inspection is made. This should first be done from underneath, however all translucent, asbestos and fibre sheets should be regarded as brittle, and safety precautions taken.

A booklet entitled 'Guidelines for the Management and removal of Asbestos' is available from DOL Workplace.

Translucent sheeting is not designed as a trafficable roof and it must not be assumed that a worker can stand anywhere on translucent sheeting.

Some owners over-paint translucent sheets or skylights to remove glare, and this is not always obvious when viewed from the top of the roof. These sheets present a safety hazard, which should be investigated before re-roofing commences.

If the sheeting is too wide for a worker to cross safely a short metal sheet should be temporarily secured over the translucent sheeting further than 2m back from the edge of the roof.

Footwear should be in good condition, as worn footwear or loose or torn clothing can be a self induced hazard, for which the worker himself is to blame. The weight should be evenly distributed on the soles of the feet without concentrating it on the toe or heel, and be placed in the pan of the roof cladding. When this is not possible the weight should be spread evenly over two ribs. *(see walking on roofs section 14.6.)*

Roof cladding is tested to a static load of 1.1kN, which equals 112kgs, and is meant to represent a worker carrying tools. It is therefore unlikely that a roof worker weighing more than 14 stone (approximately 90kgs) could avoid damaging a roof, because of the dynamic nature of the task. Site supervisors should be made aware of the weight of all persons requiring access to the roof, and should recognise that for inspection or work purposes no two people should stand within the same purlin spacing at closer than two metres.

Tools should be hoisted up in a bucket when at the top of the ladder.

Workers should be aware of the added danger of climbing a ladder initially to secure it at the top, and another person should secure the ladder at the bottom while this is achieved.

A ladder that extends less than one metre above the roof gutter, does not provide sufficient security for access, and alternative arrangements must be made. The carrying of equipment up a ladder must be limited to small items that still allow both hands to grip the rails.

Inspections of roofs are sometimes made by persons other than workers, such as owners, architects, and engineers who are not conversant with safety requirements for working at height. It is a 'Duty of Care' of the Supervisor or person in authority to point out the specific hazards on the site, and to provide the safety equipment necessary to carry out their required tasks.

Workers taking medication without notification or who have ingested alcohol or other drugs are at risk when working at height. Because by their actions they place other workers at risk as their balance and judgment may be impaired, this is sufficient cause to dismiss a worker from the workplace or worksite.

14.1.10 SAFETY MESH

Safety mesh when designed and installed to comply with the requirements of the Health and Safety in Employment Act 1992 and the Regulations of 1995, is accepted as a fall protection barrier. It provides a double role, both for safety and as a support for underlay or insulation dependent on the position within the structure.

The NZBC durability requirement for safety mesh is 50 years and includes the total safety mesh system, including fastenings.

To comply with AS/NZS 4389:1996 safety mesh is required to be constructed from galvanised welded steel wire, minimum diameter 2.00mm, with a minimum tensile strength of 450 MPa. and with wires spaced 150mm \pm 5 mm., longitudinally and 300mm \pm 5 mm. transversely. Other materials are deemed to comply if they pass the test requirements of the standard.

In corrosive, severe marine, and industrial atmospheres, safety mesh must be protected by the application of a U.V. stabilized protective coating as required by AS 2312 and the mesh must be free of sharp edges and burrs that may cause injury to the handler or installer.

The mesh joins and the connections to roof members must withstand the same point loads as the roof cladding, and the rectangular apertures resulting from the lapping and joining of longitudinal strands must have the same orientation and must not be larger than those of the mesh.

The mesh must withstand an impact test so that the test load sand bag must not penetrate the mesh during or after impact and a 350mm sphere must not pass through any part of the test specimen.

The safety mesh must be fitted under the roof sheeting so that it rests upon the purlins, battens, or rafters and so that the transverse wires are closest to the roof cladding.

When installing safety mesh or hexagonal wire netting, workers must use scaffolding or fall protection equipment as described in *section 14.1*.

One acceptable fixing method is first to position the rolls of mesh on mobile or other suitable scaffolds either side of the roof and then to take a continuous rope across the ridge to pull the mesh on top of the purlins across the roof.

The mesh must not be used as a work platform and is not safe until it is tied-off at each end as described and shown in *drawings 14.1.12*.

The longitudinal wires, parallel to the direction of the corrugations of the roof sheeting, must be on top of the purlins, and the transverse wires at right angles to the direction of the corrugations must be on top of the longitudinal wires.

Protection must be provided to G.R.P. or light gauge or soft metal roof cladding between the mesh and the cladding to avoid marking or damage by expansion or by walking traffic.

The joins between adjacent lengths of mesh must be side lapped by one mesh spacing and if the purlin spacing exceeds 1.700 m, intermediate tying, twitching or stapling with 2 mm wire is required.

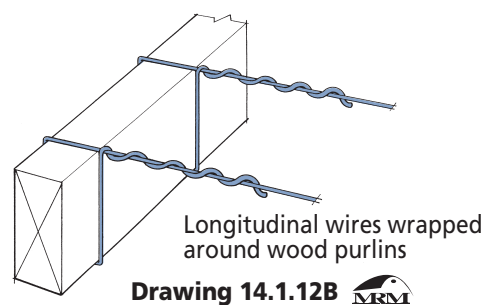
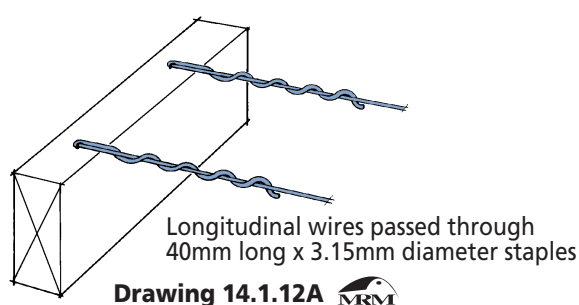
Safety mesh is accepted as a fall protection barrier if it is constructed of:

- galvanised welded steel wire with a minimum diameter of 2.00mm
- wire strength of 450Mpa
- with wires spaced 150mm longitudinally x 300mm transversely
- with the transverse wires closest to the roof cladding.

14.1.11 TIMBER FIXING

When attached to timber purlins, the longitudinal wires of the safety mesh must be either, bent over and down and fixed to the sides of the purlins, or fixed to the tops of the rafters by 3.15mm diameter galvanized steel staples 40mm long, spaced at 150mm.

Staples must be driven so that a cross-wire is between the end of the wire and the staple, or the end of the wire is bent back and twisted four times around the same wire so that individual wires cannot be drawn from a staple (see drawings 14.1.12 A.)



The longitudinal wires must be fixed to the purlins or rafters by galvanized steel wire loops of not less than 3.15mm diameter by placing the centre of the tying wire around the longitudinal wire at an intersection, so that a transverse wire is between that point and the end of the longitudinal wire. The tying wire must be passed once completely around the rafter, and then drawing the two tails of the tying wire in opposite directions over the two strands of the tying wire and twisting together with at least three complete turns (see drawing 14.1.12. C)

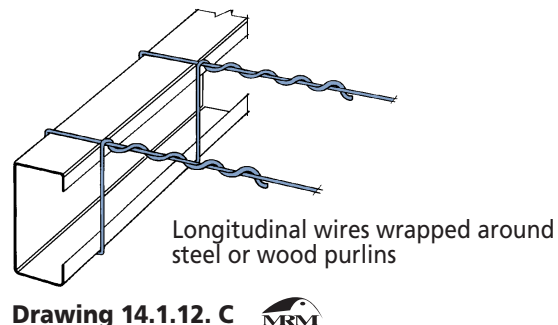
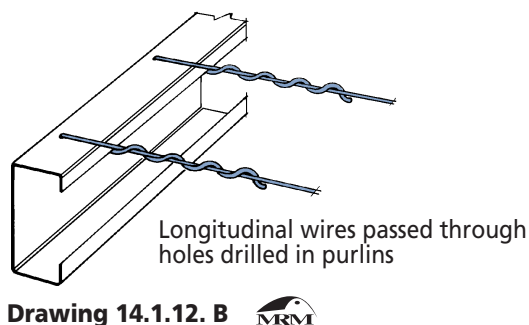
When joining rolls or sections the two transverse wires must be placed together and the longitudinal tail wires must be twisted around each other. One longitudinal tail wire must be twisted four times around the main portion of the same wire. The other longitudinal tail wire must be twisted once around the main portion of the same wire and then four times around the two transverse wires (see drawings 14.1.12. D)

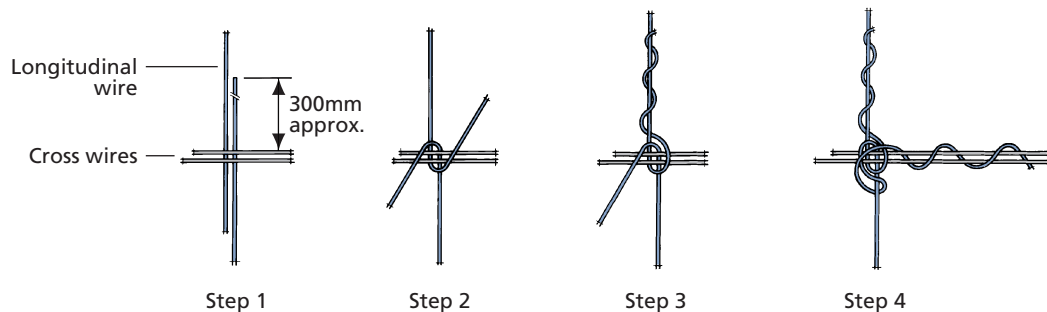
14.1.12 STEEL FIXING

When attached to metal purlins, the longitudinal wires of the safety mesh must be passed through a hole drilled in the top of the purlin and tied off with at least four full turns around the same wire. (see drawing 14.1.12. B)

Alternatively the longitudinal wires of the safety mesh must be passed once completely around the purlin, the tail of each wire being twisted four times around the main portion of the same wire. (see drawing 14.1.12. C)

Safety mesh must be tied off as shown below.





Drawing 14.1.12. D Longitudinal wire joining 

14.2 TRANSPORTATION

Metal cladding should be packed and handled with care to ensure that damage does not occur during transportation. The packs of metal cladding should be clearly labelled, placed on the deck of a truck without overhanging, securely strapped to the deck and protected from wet weather.

The load should also be well supported to stop any flexing during transport which can cause fretting, and no other cargo should be stacked on top of any metal cladding.

Packaging for transport should be designed to ensure protection of edges and corners against damage, to avoid fretting or abrasion due to movement and to prevent corrosion or staining of surfaces from rain or condensation. Packaging tape should be a non-permanent adhesive type as the force of cleaning can affect pre-painted surfaces and particularly the acrylic film on AZ coatings. This film is very thin and if it is rubbed through, the surface will become patchy and unsightly.

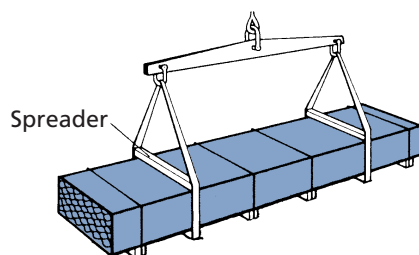
Slings or strops should be nylon with leather sleeves to prevent fraying or cutting, and damaged slings. Single slings and chains should not be used to lift packs of cladding. Slings and booms should be approved or certified as safe and suitable for their purpose.

Spreader bars should also be used with slings to prevent them causing crushing damage to the edges of sheet packs, and lifting booms may be available from roof cladding manufacturers for longer lengths than 15m.

To transport cladding lengths greater than 25m, approval from the Regional Traffic Land Transport Authority is required and the Design Engineer should seek this approval at the building design stage.

Where transport is expected to be over long distances or rough terrain, pre-coated sheets stacked in bundles should either have strippable film, or be interleaved with paper or plastic to prevent fretting. Bundles should be supported on dunnage, which lines up vertically and top and tie downs should be provided with edge protection.

Short sheets should be packed on top of longer ones which should have end and edge protection to avoid cut end damage to the sheets below them.



Drawing 14.2. 

14.3 HANDLING

It is important that due care is taken at all stages from through manufacture, transport, handling, storage and installation, and to final fixing to ensure that performance specifications are not impaired by damage.

The maximum bundle and weight and sizes of sheet that can be safely and satisfactorily handled on site should be ascertained before the consignment is sent. Lifting booms should be used when lifting long length cladding using tag lines for guidance and if a crane is not available, sheets should be lifted manually onto the roof.

Sheets should not be dragged either from the pile or over eaves or purlins, and each sheet from the stack should be turned and lifted directly onto the roof.

Sheets longer than 3.0m should be handled by two persons, and carried on edge to avoid buckling.

The packs must not be tipped or slid from the deck of the truck, and sheets must be stored away from areas where people may walk across them.

Soft soled shoes must be worn when fixing roof cladding, to provide safe handling and to prevent damage to the coating.

Contact must be prevented between the cladding and any dirt, soil, cement, lime, concrete, mortar and other deleterious substances.

14.4 ACCEPTANCE OF MATERIALS

A visual inspection of the packs of roof or wall cladding should be made to check for damage prior to lifting the bundles off the transport vehicle. Insufficient dunnage under and between packs can cause permanent indentations of sheet surfaces.

Upon delivery, a check should be made that the correct quantity of material has been delivered and an inspection made for any strapping damage.

Inspection should be made where overtightening of bundle straps or load tension straps may have deformed the edges of the sheets. N.B. a 50mm x 50mm timber batten to the top of the bundle used in conjunction with the strapping system can avoid such damage.

When unpacking sheets they should be inspected for coating damage that may have occurred during transport due to coating fretting or pick-off.

14.4.1 PRESENCE OF MOISTURE BETWEEN SHEETS

The presence of moisture should be notified immediately to the manufacturer as water damaged sheets should not be installed on the building.

All damaged materials should be replaced and sheets exhibiting marks of mechanical damage to the profile should be rejected and the manufacturer notified.

14.4.2 COLOUR MATCH

Precoated roof, wall cladding and accessories should be sourced from the same manufacturer to avoid any difference in colour matching, both for top coat and backer coats.

14.4.3 STORAGE

Roof and wall cladding must be kept dry, covered and protected from damage while stored on the site.

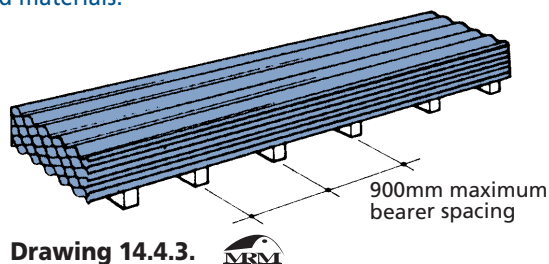
When sheets are to be stored on the ground they must be stacked horizontally on firm and level ground, on cross stacked untreated timber fillets, inclined slightly for rainwater run off and be covered with a loose tarpaulin allowing air to circulate.

Sheets should be stacked in sheltered positions preferably near areas of the building where it is to be fixed, and should be stacked in the order in which they will be used.

The height of such stacks should not exceed 1 metre and they should be clear of the ground. If it is necessary to stack sheets in an exposed position, they should be secured against any movement by the wind.

Well ventilated storage is essential as rainwater, or condensation in humid weather, can penetrate and damage close-stacked metal cladding by capillary action. Always store metal products under cover in clean, well ventilated buildings.

Once packs are opened and laying of the roof or wall cladding commences, a continual visual check should be made to ensure the surface of the sheets are free of any noticeable defect or damage. This is particularly important with pre-coated materials.



Drawing 14.4.3. 

14.4.4 STORAGE STAIN

All metal cladding and accessories should be kept dry before installation, including during storage on the roof structure, as it should not be assumed that because the cladding will be eventually installed out in the weather that protection is not required. Accelerated corrosion or staining can occur with all metals if close stacked cladding, or packing becomes wet.

If zinc coated nestable profiles have become wet while closely stacked, either in transportation or storage, the formation of wet storage stain or “white rust” is inevitable. AZ coatings are mill coated with an acrylic passivation film to give temporary protection and minimise the possibility of product deterioration. Pre-painted sheets will also deteriorate if they remain wet as moisture can cause paint softening and sheets may exhibit paint bubbling.

Aluminium, copper, zinc and stainless steel will all be permanently stained if left wet or if stored in this condition. Translucent cladding, and all metal roofing accessories with a strippable film should be protected from direct sunlight.

If moisture is present, individual sheets should be dried and then re-stacked to allow air to circulate and complete the drying process.

The extent and severity of wet storage stain is usually proportional to the length of time the sheeting has been wet.

In the case of superficial attack, exposure to the atmosphere and careful cleaning will sufficiently reduce surface imperfections, but heavier deposits can damage the sheets to the extent that they require replacement.

Where it is likely that the roof or wall cladding will be stored on site for more than one week before installation, consideration should be given to ordering waterproof packaging from the manufacturer.

14.5 ROOF LOADING

Bundles or packs of roof cladding must remain banded when being lifted by a crane. They must be placed adjacent to the portal frame and not mid span on the purlins. Bundles must be placed so that their weight is spread over the entire area of the roof and should be positioned with the laps in the direction of laying. Workers who are receiving a bundle of roof cladding on the roof, must have sufficient mobility to avoid the load, and use tag lines to control the swinging of the load while it is out of reach.

Where safety mesh and edge protection is in place, full freedom of movement is permitted in the enclosed work environment, otherwise the safety precautions in section 14.1 must be strictly adhered to. Packs must be securely fixed to the structure, and part-packs must be re-fixed at the end of every day. It is the responsibility of the roofing contractor to avoid damaging the roof sheeting during its installation and fixing.

14.6 WALKING ON ROOFS

It must not be assumed that it is safe or permissible to stand on any roof structure or roof cladding.

All roof cladding has access restrictions that are described in section 3.2. (*see point load section 3.2.*)

The manufacturer of the roof sheeting must provide technical literature stating the point load limitations of the profile. Information must indicate the positions on the sheet where persons may safely walk or stand without causing damage or alternatively indicate the necessity to provide temporary walkways.

Where free access or if heavy walking traffic is expected on the roof cladding, consideration should be given to using 0.55 mm coated steel or 0.9mm aluminium roof cladding. Roof cladding on pitched roofs $<10^\circ$ is particularly susceptible to traffic damage and low pitched roofs using 0.40 mm thickness steel or 0.7mm aluminium are considered unsuitable for foot traffic and should be provided with walkways. The people employed for maintenance work on air conditioning plant, chimneys, painting, or the fitting of television aerials, are often ignorant of where to stand and consequently cause permanent deformation that can lead to ponding and eventual failure.

When access to the roof is necessary following construction, workers must walk in the pan of trough type profiles, or within 300mm of the purlin fastenings.

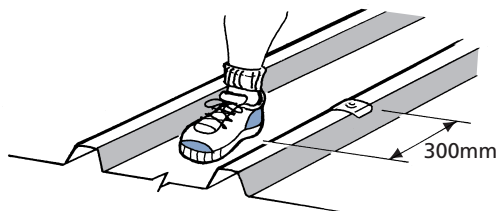
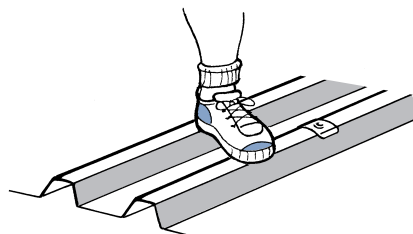
If ribs are close together so that a workman cannot place his foot in the pan, then his weight must be spread evenly over at least two ribs when walking up the roof, and when walking across the roof access must be close to but not over the fastener.

Translucent sheeting must not be walked on unless it is designed specifically for that purpose.

Where it is necessary to use the roof as a regular access way, specifically constructed walkways must be provided. Permanent walkways must be compatible with the cladding, securely fixed to the roof structure and supported clear of the roof sheeting. Permanent walkways must not be made from timber, or produce an unwashed area beneath them or allow the buildup of debris.

If permanent walkways are not provided, cat ladders should be available for use at any time when inspection or repairs to the roof are necessary. They should be designed to be at least 375mm wide, and the battens or steps should not project beyond the edges of the board or stringers.

It is the responsibility of the main contractor to inform the owner of any restrictions concerning roof accessibility.

Drawing 14.6.1.A Drawing 14.6.1.B 

14.6.1 ROOF ACCESS DURING CONSTRUCTION

It is not safe or permitted for other trades to access the roof while the metal roof cladding is being installed. Before any person seeks or gains access to the roof, safety precautions must be taken. (see *safety section 14.1.*)

Safety information must be kept on site during construction and it must be the responsibility of the main contractor to inform all trades that they must adhere to these requirements.

The main contractor must provide a prominent notice stating any limitations to, and the safety requirements for access. (see *14.6. Walking on roofs*) The roof must not be used as a storage area or used as a work platform or be used as support for scaffolding without total protection and planking out onto adjacent purlins.

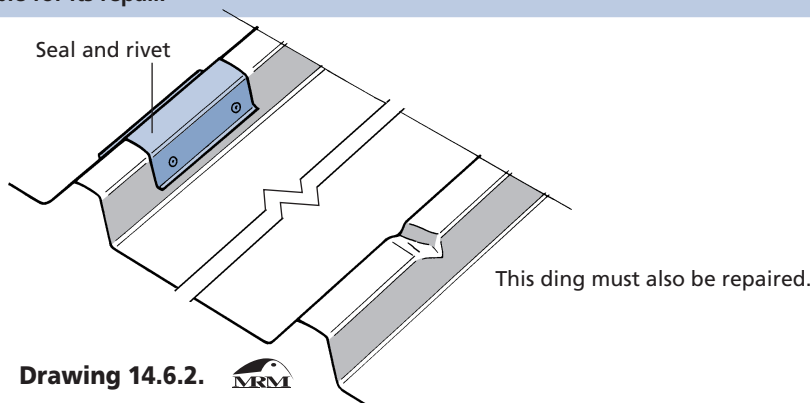
When other building work is required to take place adjacent to, or above a roof area such as a podium roof, no work should proceed until safety and damage precautions are taken. To prevent damage occurring from above, where any plastering, concreting, welding or grinding are likely, the whole area should be protected by a temporary structure or tarpaulins.

14.6.2 ROOF CLADDING DAMAGE

Damage occurs more easily by standing on ribs with obtuse or flatter angles.

Any permanent deformation or damage to the ribs of profiled sheeting or metal roof tiles will reduce their performance, to the extent that they may leak or not meet the design load requirement. (see *section 14.6. walking on roofs*). Damaged roof or wall cladding sheets must either be repaired or replaced, and to restore a damaged rib load capability to the original to comply with the NZBC, all damage must be repaired within prescribed limits.

For aesthetic reasons any damage at all may be unacceptable, however if the roof cladding is not visible, ribs can be repaired by using a saddle sealed and riveted as shown on drawing 14.6.2. It is technically acceptable to have two dings or creases on one sheet within one purlin spacing, providing two adjacent ribs are not damaged. Any greater level of damage requires the sheets to be replaced, and the person who causes the damage must report it and be responsible for its repair.

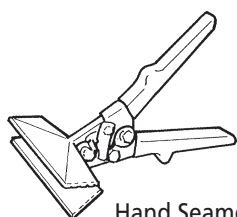
Drawing 14.6.2. 

14.7 COMPLETION

The roofing contractor should notify the main contractor, architects or owner when he has completed the scheduled work. If the contract is completed to the satisfaction of all parties the roofing contractor should be released in writing from further obligations except those included in any warranty. Any subsequent damage should be the responsibility of the main contractor or owner.

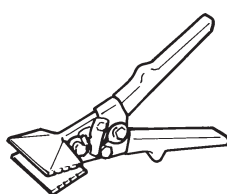
All gutters, valleys, roof channels and the roof cladding should be left clean and free from debris on completion of the work.

14.8 TOOLS OF THE TRADE.

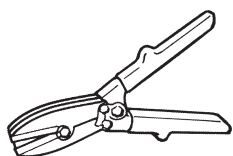


Hand Seamer

Drawing 14.8.A 

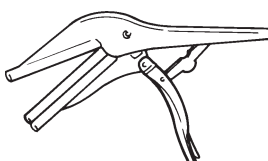


Hand Seamer

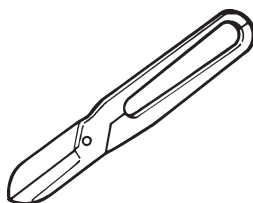


Crimping Tool

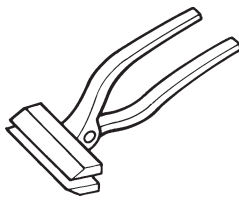
Drawing 14.8.B 



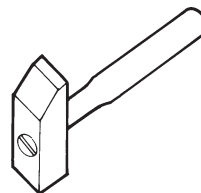
Crimping Tool



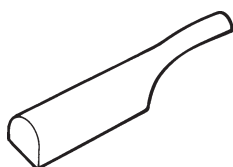
Shears - straight and curved



Seaming Pliers

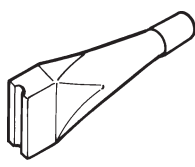


Setting Hammer

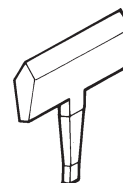


Hardwood Dresser

Drawing 14.8.C 



Hand Grooving Tool

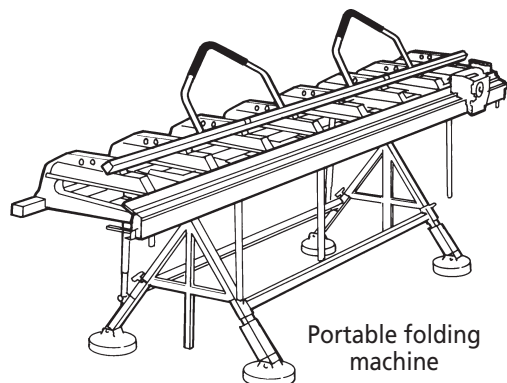


Clinching Tool

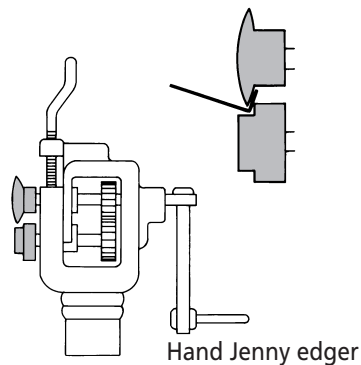
It is not possible to install metal roof cladding and accessories to acceptable trade practice without the specialised tools required to cut, fold, position and fix them in an acceptable manner and where these tools are not available, trades-people can make their own to enable a particular joint to be made.

Some of the tools may require a vice, but most hand tools are portable and can be used on site. Portable lightweight folders are now available that can bend from 2.000m - 4.400m up to 0.95mm steel. (*see drawing 14.8.D*)

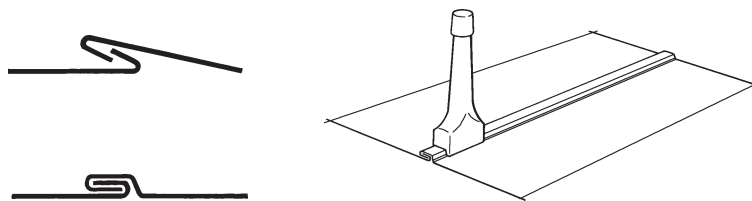
These machines can also slit the material for flashings so that they can be measured, cut and bent on-site and fitted without the delays associated with off site manufacture.



Drawing 14.8.D



Drawing 14.8.E



Drawing 14.8.F



All metal joints that are to be sealed should be mechanically joined and one positive means of joining two pieces of metal together is by seaming.

The two pieces are folded so each hooks into the other and then they are locked together by the means of a hand seamer or groover. (see drawing 14.8.F)

The material allowance is dependent on the hook dimension but is usually 6mm, which means that as there are four thicknesses of material, the extra allowance for this seam is 18mm. This type of seam can be used on a flat surface or on a round surface.

15.0 TESTING DESIGN AND PERFORMANCE REQUIREMENTS FOR SHEET ROOF AND WALL CLADDING SYSTEMS

15.0 CONTENTS

Section 15 sets out the design and performance requirements for sheet roof and wall cladding systems specifically for New Zealand. While it is intended that only those people associated with testing would be concerned with the details of the test procedures it is of general and historical interest as to the reasoning behind the performance requirements.

For this reason a commentary is provided which follows each part.

Section 15 is divided into general requirements and specific methods of testing sheet roof and wall cladding for point load and also to determine their resistance to wind pressures. (UDL – uniformly distributed load)

These procedures apply to all metals and plastic sheeting however because of their different characteristics some of the performance criteria are different.

15.1

1.1. SCOPE

To demonstrate the compliance with this Code of Practice, roof and wall cladding systems must be tested in accordance with section 15 of this Code.

1.2. ALLOWANCE FOR VARIABILITY OF MATERIALS

Provision is made in Table 1.2 for the testing of more than one sample of a test specimen to allow for variability of materials. If a number of tests are carried out, each sample is required to satisfy the performance criteria. Where a number of tests are conducted on pierce fixed roofs at different span lengths but use the same profile, type and thickness of cladding, fastening type and pattern, and have the same mode of failure they must be included as complying with the number of units in Table 1.2.

Where only static testing is conducted and cyclic test verification testing is not used the variability factors must be strictly in accordance with Table 1.2.

The design capacity (R_d) must satisfy

$R_d < R_{min} / k_t$ where R_{min} is the minimum test value and the factor k_t is given in Table 1.2.

FACTOR (k_t) TO ALLOW FOR VARIABILITY OF STRUCTURAL UNITS

No units to be tested	Coefficient of variation			
	5%	10%	15%	20%
1	1.20	1.46	1.79	2.21
2	1.17	1.38	1.64	1.96
3	1.15	1.33	1.56	1.83
4	1.15	1.30	1.50	1.74
5	1.13	1.28	1.46	1.67
10	1.10	1.21	1.34	1.49

Table 1.2.

NOTE: For values between those listed in the table interpolation may be used.

It is recommended that the Coefficient of variation is established by using the standard deviation method.

1.3. RESISTANCE TO POINT (CONCENTRATED) LOAD

1.3.1. General

The point load requirements of this section of this standard classify roof and wall cladding as:

- Type 1. Areas that can be accessed from opening windows or awnings. 1.8.kN.
- Type 2. Areas that require access for maintenance purposes 1.1.kN.
- Type 3. Areas for which support ladders or boards are required for maintenance access (including transparent surfaces) 0.5kN

Type 1 classification is intended to allow for people assembling to watch a parade or any similar situation.

Type 2 classification is for all other roofs that are readily accessible.

Type 2 classification is divided into two categories:

- Type A. 'Unrestricted Access', where a person may walk anywhere on the roof cladding.
- Type B. 'Restricted Access' where access is restricted to walking within 300mm of the purlin line, or in the pan of the profile.

Type 3. 'No Access' is the classification for roofs that are not readily accessible which include, plastic sheeting, roof surfaces > 35° or that are regarded as unsafe or unable to be walked or worked upon without special provisions being made. Walls are included in this category.

SERVICEABILITY TEST

When subjected to a point test load as prescribed in this section none of the following must occur -

- Permanent local deformation (except within residual deflection limits)
- De-indexing or Unclipping;
- Fracture or failure of any part of the cladding;
- Failure of the fastening

The residual deflection under the point of application of the load within a minimum of 1 min after removal of the load must not exceed $S/400$.

For Type A access the concentrated load must be applied to those parts of the cladding which will produce maximum deflection and maximum permanent deformation.

For Type B access the concentrated load must be applied to the pan of the profile at mid-span or any part of the cladding within 300mm of the purlin line. Where the pan of the profile is < 100mm wide, any point load must be spread over two or more ribs.

1.3.2. Strength test

When any part of the cladding for Type 2A & B, is subjected for not less than 1 min, to a concentrated test load for strength limit state in accordance with section 15.5, the load must be sustained, irrespective of any permanent deformation that may occur.

Where it is intended to conduct a number of tests, the point load is determined by multiplying the load given in 1.3.1. by the factor in the 5% variability column of Table 1.2.

1.4. RESISTANCE TO WIND PRESSURES

1.4.1. Serviceability test**SERVICEABILITY TEST**

When the cladding system is subjected to the Uniformly Distributed Load (UDL) test load as prescribed in section 15.7 none of the following must occur -

- Permanent local deformation (except within residual deflection limits)
- De-indexing or Unclipping;
- Fracture or failure of any part of the cladding;
- Failure of the fastening

1.4.2. Strength test

When the cladding system is subjected to the test pressure for strength limit state as specified in accordance with section 15.7 the pressure must be sustained, notwithstanding any permanent distortion that might occur in the sheeting and fastenings.

15.2**COMMENTARY ON THE TEST PROCEDURE DESIGN AND PERFORMANCE REQUIREMENTS FOR SHEET ROOF AND WALL CLADDING SYSTEMS****C1.1. GENERAL**

Historically there has not been a specific New Zealand based Standard for testing sheet roof and wall cladding, so that most testing has been carried out using requirements and methods based on the Australian Standards AS 1562 and AS 4040. These two standards are closely interrelated as AS 1562 sets out the performance requirements while AS 4040 sets out the test methodology.

Although both of these standards have been the subject of a review by a joint Australian New Zealand standards committee for many years, major differences stemming from the respective National Building Codes as well as climatic conditions have been difficult to resolve. While the adoption of the joint Loadings Code AS/NZS1170 Structural design actions, has resolved many of the issues relating to the determination of wind forces on buildings, this has not assisted progress in adopting agreed testing methods and performance benchmarks. For these reasons this New Zealand test procedure has been adopted by the NZMRM.

C1.2. ALLOWANCE FOR VARIABILITY OF MATERIALS

Extensive testing has been carried out in New Zealand over many years but for economic reasons generally only a single test has been carried out on a specific area of the roof profile for each span, material thickness, grade and fastening pattern. Where replication of tests has been carried out, the variability due to materials has been negligible. Concentrated load results are very consistent as are those from top fixed steel roof and wall cladding and from the results of hundreds of previous tests the Coefficient of Variation (COV) can be assumed to be taken as <5%.

The same cannot be said for self-supporting and fully supported secret-fixed roof and wall cladding as the variability occurs from small but significant differences in profile or clip tolerances. It is necessary therefore to establish a variability factor from Table 1.2 that is acceptable for the metal and profile.

The assumption that where the mode of failure is the same but at varying structure spacings, the number of tests can be agglomerated, is taken from Australian practice. While this is permissible for pierce fixed roof cladding because of the greater variability of clip fixed roofs these results cannot be treated in the same manner.

Extensive testing both static and cyclic on standard profiles with varying fastening patterns have validated the

variability values given in Table 1.2. The use of static testing alone means that the 1.2 factor must be used not the 1.15 factor provided for in 1.2.

The factors in Table 1.2 are the same as those found in AS/NZS 1170 and AS/NZS 4600.

C.1.3. RESISTANCE TO CONCENTRATED LOAD

The requirements and general descriptions are taken from AS/NZS 1170.

The division of Type 2 is taken from the NZMRM Code of Practice.

C1.3.1.

The residual deformation criterion of L/400 has been set to allow for the use of different metals and plastic for roof and wall cladding. This is a limiting factor because permanent deformation is an indicator of potential stress failure and is also likely to cause ponding and visual distortion.

C.1.3.2.

Because the concentrated load is known and the number of tests is predetermined it is possible to factorise the test load from Table 1.2., unlike a UDL test where the test load is unknown and the results are factorised. Multiple concentrated load tests can be carried out on the same sheet provided that there is nil influence of any failure from a previous test.

C.1.4 RESISTANCE TO WIND PRESSURES

AS/NZS 1170.0:2002 defines Serviceability as "Ability of a structure or structural element to perform adequately for normal use under all expected actions"

The main function of a roof or wall is to provide a durable weather tight membrane and therefore serviceability is the ability to continue to provide a weather tight seal where the fixings penetrate through the cladding under maximum design load. For a Uniformly Distributed Load this requires finding the applied load under which sufficient permanent deformation occurs that may cause loss of a weather seal at a fixing location. This is regarded as a serviceability failure.

Any buckling from point load that impairs the ability of the profile to be able to carry the same repeated load is also regarded as a serviceability failure.

From these definitions of serviceability for roof and wall cladding serviceability failure is considered the most important performance criterion rather than Ultimate failure where the roof would blow off or a person would fall through it. Testing of pierce fastened profiled metal roofs has determined that failure under serviceability loads occurs at less than half the load at which strength load failure occurs, hence serviceability load failure is considered the most important criterion for such roofs.

15.3

METHODS OF TESTING SHEET ROOF AND WALL CLADDING

1. REFERENCE DOCUMENTS

AS/NZS 4040.1 Resistance to concentrated loads

2. TEST METHODS

The serviceability load test is intended to determine the maximum load at which the cladding and its fastenings would cause permanent deformation where the roof cladding would leak or when replicate test loads could not be sustained.

The ultimate-load test is intended to assess the maximum load at which the cladding and its fastenings would not blow off, or a person would not fall through the roof.

3. SUPPORTING STRUCTURE AND EQUIPMENT

The design of the support system must consist of a rigid frame air box sealed on the bottom and four sides. For UDL testing a pressure fan or blower is required, capable of controlling and maintaining the required test pressure by computer programme, while for Cyclic Load testing the speed and number of cycles must also be computer controlled. The deflection is measured through a differential displacement transducer and traced and recorded coincidentally with the increasing load.

N.B. This is a pressure test from beneath the sheeting to simulate a negative load from above.

For point load testing, a hydraulic cylinder and calibrated load cell is contained within a moveable rigid yoke attached to the main air box frame, providing universal access to all parts of the supporting structure.

The force measured by the load cell using either a separate digital display or forming part of a computer based data system, must be able to provide an accurate indication of the applied load.

The deflection during the load application must be monitored through a differential displacement transducer and indicator, to enable the recording of the deflection at maximum load, and the residual deflection after load removal.

The structure must not provide any constraint or longitudinal support (e.g purlin braces) that will prevent membrane action in the cladding under UDL loading.

4. TEST SPECIMEN

4.1 Resistance to concentrated loads and to wind pressures must be determined by tests of full-scale models of sections of the system as they are intended to be installed.

A cladding system must consist of sheeting, fastenings and supporting members assembled together in a manner identical within those parts of the particular roof or wall of which the test specimen is intended to be a model.

4.2 Width of specimen. The width of a model or the test section of a lapped system must be the width represented by at least two sheet laps. For cladding systems in which the interlocking of the edges of adjoining sheets is essential to their fastening, at least two sheet interlocks must be incorporated in the test specimen.

4.3 Number of spans. For testing the resistance of a roof to concentrated loads, and for testing resistance of continuous cladding to wind pressures, the test specimen must incorporate no fewer than four spans i.e. two end and two intermediate spans.

4.4. The ratio of the end span to intermediate span must be between 0.6- 0.7.

5. INTERPRETATION OF RESULTS

5.1 Derivation of design data.

When using data from testing for the production of graphs, tables or other design aids, the following conditions apply:

- (a) Data must not be extrapolated except where a minimum of four span combinations within the limitations of (b) below can be shown to provide a statistically* reliable load span graph. In such case an extrapolation of a further $\pm 20\%$ at either end may be calculated.

* Refer commentary re statistical reliability

- (b) Interpolation of data between different spans of a specific type of test is acceptable only in the following circumstances:
- (i) Where the data is taken from tests for a single type, size and profile of cladding and type and spacing of fastener.
 - (ii) Where at least three different spans or support spacings have been tested for the same type, size and profile of cladding and fastener details and that in all three tests the failure mode was the same.
 - (iii) Where test loads were derived from the same test criteria.

Serviceability limit state failure modes that are classified as different are: permanent deformation around the fastener head that would compromise weatherproofness, excessive residual deflection from point load or the onset of any de-indexing, unclipping, fracture of the cladding or its fixings.

Common strength limit state failure modes which are classified as different include cladding pulling over the fasteners, clips disengaging, de-indexing of sheet interlocks or fasteners pulling from the supporting member.

The Variability factors must be those contained in Table 1.2 and must be applied to both the UDL and point load test results.

15.4

COMMENTARY ON 15.3.

C4.1.

It is not valid to interpolate results from tests that are not identical except as exempted in 5.1. Any change in fastening pattern or substrate or differing end/ intermediate span ratios can have a marked effect on the result. Likewise the practice of making the insertion of every screw 'perfect' for test purposes is an invalid practice because this does not happen in real life. Overdriving of screws, off-centering or driving a fastener that is not at right angles to the sheeting can make a significant difference to the failure load.

C4.3.

As the purpose of the tests is to determine the effects of the wind uplift pressure or a point load, it is essential that the arrangement of intermediate and end spans of the test specimen will provide similar results to that encountered by the actual building installation. A single span or even a two span test arrangement will not accurately simulate the reaction forces and bending moments at the purlin fastening positions, with a consequence that the actual real world performance cannot be accurately determined or interpolated.

Calculation of performance is considered invalid because it assumes the section properties remain static under load.

Although in the past much of the testing of N.Z. roof and wall cladding has been done with a three equal span arrangement, it evidenced awareness that end spans should be approximately 2/3 of intermediate spans, which means that a three span test which consists of two end spans has no true intermediate span. Because the reaction forces are not the same it is not possible to test a true intermediate span without using a four span test arrangement.

A further complicating factor in the determination of performance loads is the use of varying or different fixing patterns. Many pierce-fixed roof cladding profiles are not fixed on every rib which gives rise to variability in the serviceability results depending whether the fixings on the missed ribs are co-linear or staggered.

When using a four span test configuration, there is only one fully loaded central purlin. If the penultimate purlins have a staggered fixing pattern in relation to the central purlin, the rib that is fastened at the central purlin, will fail at approximately 10 -15% less load than had the fastening pattern be fully linear. Linear fastening is where the same rib is fastened at each purlin and the adjoining ribs are not fixed, except at the ends. Where a staggered fixing pattern is to be tested a minimum of five spans must be used.

C4.4.

The end span is reduced to approximately 66% of the intermediate span because at one end it is simply supported. This proportion coincidentally approximates the increase in the peripheral wind load at the proximity of the end spans and is also often the area that suffers the highest point loads caused by people accessing the roof structure.

C5.1.

A plot of $\log P$ v $\log L$ has straight line fit with R^2 better than 0.95 will provide a means of determining that the extrapolation is statistically reliable.

The most common serviceability limit state failure mode is permanent local deformation, which commonly precedes fracture or buckling.

Current research indicates that small changes in load can significantly affect the fatigue performance of the cladding.

15.5**METHODS OF TESTING SHEET ROOF AND WALL CLADDING****METHOD: RESISTANCE TO POINT (CONCENTRATED) LOADS****1. SCOPE**

This Section sets out a test method for determining the resistance of sheet roof and wall cladding to point (concentrated) loads.

2. REFERENCED DOCUMENTS

The following documents are referred to in this part:

AS/NZS

1170 Minimum design loads on structures

1170.1 Part 1: Dead and live loads and load combinations

3. SUPPORTING STRUCTURE

The supporting structure must be as specified in section 15.3

4. LOADING SYSTEM

- 4.1. Concentrated load must be applied in a direction normal to the roof through a circular loading pad of rubber or similar material 100 ± 2 mm diameter and 50 ± 2 mm in thickness. The loading pad must have a Shore durometer hardness of 30 ± 3 .

The force must be transmitted to the rubber pad through a disc of steel, 100 ± 2 mm in diameter and not less than 10 mm in thickness.

Where the dimension of the sheeting profile does not allow the use of a 100 ± 2 mm diameter pad the shape must be spread over two ribs and not $>0.01\text{m}^2$ in area nor exceeding 200mm in length.

NOTE: The 50 mm thickness of rubber may be made up of an appropriate number of layers 10 mm or greater thickness.

- 4.2. Measuring devices. Deflections must be determined by means of a device capable of measuring to an accuracy of within ± 0.05 mm. Pressures or loads must be determined to an accuracy of within $\pm 2\%$.

5. TEST SPECIMEN

The test specimen must be as specified in section 15.3.

6. PROCEDURE

6.1. Loads

The loads and Variability factors must be those contained in section 15.1

To determine design loads (target load) for test purposes the concentrated loads must be those contained in Section 1.3. The position of the test load must be determined by the type of test as prescribed in section 15.3., 1.3.1.

The target load must be increased by the variability factor determined by the number of tests according to Table 1.2 section 15.1.

6.2. A preload of 50% of the calculated maximum load must be applied for a period of 1 minute, before removing the load and zeroing the displacement transducer.

6.3. The load must be applied incrementally up to the required maximum load.

6.4. Measurements during serviceability tests

Displacements of the test panel must be measured at a point on the specimen as close as practical to the load application.

If failure from buckling or other load discontinuity is evident prior to reaching the required load, the maximum force at failure must be recorded.

After not more than 1 min following the removal of the load the residual displacement of the test panel adjacent to the load application pad must be recorded.

6.5. Strength limit state. The part of the cladding furthest removed from the substructure and from the supporting members must be subjected to the specified concentrated load for a period of not less than 1 minute, applied to those parts of the cladding which will produce maximum deflection and maximum permanent deformation.

The behaviour of cladding, fastenings, supporting members and substructure must be observed and recorded. The maximum load is that which can be sustained irrespective of any permanent deformation.

7. REPORT

The following information must be supplied in the report:

- (a) The number of the report and the name of the client.
- (b) The date and location of the test.
- (c) The name of the testing officer.
- (d) The type of test –Serviceability/ Ultimate
- (e) The test Procedure -reference to this section of the Code of Practice.
- (f) Details of the material under test – Type/Profile/ Material/ thickness/ Spans.
- (g) Substructure.
- (h) Fastener type and fixing pattern
- (i) Mode and point of failure- Permanent deformation at fastener, mid span buckling
- (j) Deflection under maximum serviceability load.
- (k) Residual deflection.

15.6**COMMENTARY ON SECTION 15.5.****C6.2.**

The reason for the required 50% load is that it is used as a 'preload' which settles the sheeting to a stable position before proceeding with the test.

C6.3.

It is suggested that the increments be in 10% intervals

C6.4.

Although deflection under load is not regarded as a design criterion, it is an important indicator of stress leading to permanent strain.

Residual deflection, after all load has been removed is regarded as the only deflection criterion that will affect the performance of the sheeting.

15.6**METHOD: RESISTANCE TO WIND PRESSURES FOR NEW ZEALAND****1. SCOPE**

This section sets out a test method for determining the resistance of sheet roof and wall cladding to wind pressures in New Zealand. (UDL)

2. REFERENCED DOCUMENTS

The following documents are referred to in this part of this Standard:

AS/NZS 1170 Minimum design loads on structures

AS/NZS 1170.2 Part 2: Wind loads

3. SUPPORTING STRUCTURE

The supporting structure must be as specified in section 15.3.

4. LOADING SYSTEM

4.1. The test system used for UDL testing consists of two parts.

Part A Static Uplift Pressure Test : A sequential static uplift pressure is applied to the cladding assembly with pressure increments based on the fractional proportions, as specified in 6.2., to determine the maximum sustainable pressure before permanent deformation occurs. Pressure is returned to zero after each pressure increment to allow assessment of the onset of permanent deformation

Part B Cyclic Uplift Pressure Test; The test is replicated on an identical cladding assembly with a series of cyclical pressure loadings, with pressure increments based on the fractional proportions, as specified in 6.2., of the factored pressure obtained during the static uplift test. The cyclic regime and number of cycles is specified in 6.4.

Where failure due to cracking or other permanent damage from the repeated cyclic loading (Part B) occurs at a lesser pressure than that obtained from the factored Part A static pressure test, the cyclic pressure increment prior to the incidence of failure must be substituted as the performance load.

- 4.2. The required cyclic wind pressure must be applied by an air box method that will provide a uniform distribution of uplift pressure appropriate to the part of the cladding being tested and maintain such distribution irrespective of the extent of deflection.
- 4.3. A calibrated manometer must be used to monitor the applied air pressure and ensure accuracy of the applied air pressure as measured by a transducer. Pressures must be determined to an accuracy of not less than $\pm 2\%$.
- 4.4. The cycling rate must be between 1 Hertz and 0.3 Hertz (approximately 1-3 seconds).
- 4.5. Where the measurement of the deflection of a cladding under load is required, measurement must be made with calibrated displacement transducers, measuring to an accuracy of not less than ± 0.05 mm. Where such measurement is taken it must be by a three point arrangement, to allow for movement of the ends of the span being measured.

5. TEST SPECIMEN

- 5.1. The test specimen must be as specified in section 15.3.

6. LOADING PROCEDURE

- 6.1. To determine the static and cyclic target load for Uniformly Distributed load tests the Target loads (TL) must be those determined by:
 - the type of the material
 - the thickness of the material
 - the size of the fastener head or washer (if pierce fixed)
 - the maximum tributary area

For pierce fixed cladding the Tributary Area (TA) of a fastener must be determined by half the sum of the spacings between three adjacent fasteners*, multiplied by the sum of the distances between adjacent supports.

* NB these distances will not always be identical.

- 6.2. The Static test load must be applied incrementally, held for a minimum of one minute and the pressure released to zero. Where a target load has been established the Static Test loads must be applied incrementally to the target load and zeroed after each cycle.
 - i.e. 1 @ 80% of the target load
 - 1 @ 90% of the target load
 - 1 @ 100% of the target load

Where a target load has not been established or where it has been exceeded the Static Test loads must be applied in conservative increments based on visual assessment under load.

A visual inspection must be made after the load has been removed to determine if permanent deformation has occurred. Where Load spreading washers are used these must be removed to determine if permanent deformation has occurred.

At the conclusion of each pressure increment, if there is no visible permanent deformation, the static test must be continued until permanent deformation is observed. The last test pressure to be applied prior to the cladding being assessed as having visible or measurable permanent deformation must be considered the passing static test pressure (P_s)

- 6.3. Where multiple tests are conducted at alternative spans and replication is attained as prescribed in section 15.1 (1.2), the Cyclic Load does not need be applied to each of the cladding test configurations. In this instance

the cyclic test must be applied to only one of these tests and because it is a verification test the result is not required to be factored.

- 6.4. Each cyclic test must consist of a series of sets, each containing 1000 cycles with the pressure within each cycle varying from not more than 50% to 100% of the test load pressure. At the completion of each 1000 cycle set and after all loading has been removed a visual inspection must determine if permanent deformation has occurred. Where Load spreading washers are used these must be removed to determine if permanent deformation or cracking has occurred. If there is no visible or measurable permanent deformation the next cycle must be commenced.

The maximum cycle pressure of the initial set of cyclic loading must be 80% of P_s as determined from 6.2, with subsequent sets being incremented by 10%

- i.e. 1000 cycles at 80% of P_s , cycling from 40% -80% P_s
 1000 cycles at 90% of P_s , cycling from 45% -90% P_s
 1000 cycles at 100% of P_s , cycling from 50% - 100% P_s

Any observed initial onset of cracking or permanent deformation together with the presence of audible sound from the mechanical stress reversals of cladding materials must be recorded for each set.

N.B. P_s may be substituted by TL as determined in 6.1.

- 6.5. Serviceability limit state. The model must be subjected to the static and cyclic loads as prescribed in 6.2. and 6.4. Failure is deemed to have occurred when permanent deformation or cracking is visible around the fastener. Where cracking or permanent deformation occurs during a cyclic pressure test set at a pressure below the factored passing static test pressure P_s , this must be deemed the failure load. All static test results for that particular cladding and fastening arrangement must be multiplied by the same factor $P_{cy}/P_{sf} - P_{min}$ being the lowest value of the undamaged cyclic pressure sets.

Roof and Wall cladding that is clip fixed is deemed to have failed if any of the performance criteria in section 15.1. (1.4.1). has occurred.

- 6.6. Strength limit state. The model must be subjected to the specified static pressures for a period of not less than 1 min. The behaviour of cladding, fastenings, supporting members and substructure must be observed and recorded. The maximum load is that which can be sustained irrespective of any permanent deformation.

N.B. There is no requirement for a cyclic test for strength limit state.

7. REPORT

The following information must be reported:

- (a) The number of the report and the name of the client.
- (b) The date and location of the test.
- (c) The name of the testing officer.
- (d) The type of test – UDL/ Cyclic / Serviceability/ Ultimate
- (e) The test Procedure -reference to this section of the Code of Practice.
- (f) Details of the material under test – Type/Profile/ Material/ thickness/ Spans.
- (g) Substructure.
- (h) Fastener type and fixing pattern
- (i) Mode and point of failure- Permanent deformation at fastener, mid span buckling, pull-over, pull-out, cracking
- (j) Deflection under load (if measured).
- (k) Residual deflection (if measured).

COMMENTARY ON SECTION 15.6**C1.**

It is well known and accepted that New Zealand suffers from frequent and numerous gales, which sometimes approach the wind speed of the cyclonic areas of Australia and the Pacific Islands. This situation has been assisted by the publication of AS/NZS 1170, which places the emphasis on specific location rather than wind speed, and factorising a basic speed dependent on terrain and topography.

Wind is a dynamic force and the method of testing sheet roof and wall cladding solely by a static load is not logical. Any test procedure should as closely as possible resemble the loading conditions likely to be experienced by the cladding in the field during its lifetime. This anomaly has come about historically because it was expedient to do so and the cost of cyclic testing, as the alternative to static testing, was considered to be unjustifiable. The validity of static testing results is questioned, particularly when cyclic testing of roof and wall cladding has shown that fatiguing can occur at load level much lower than the static test results. This is particularly true of high strength steel, which has been and continues to be a common material used for domestic and industrial roofs in New Zealand.

For these reasons the New Zealand Roofing Industry has established a cyclic regime suitable for verifying the static testing of roof and wall cladding in New Zealand. Factoring static test loads alone has been considered and discarded as being inaccurate and invalid.

Results from many tests using high strength steel points to a value at which no damage will occur even up to 10,000 cycles but a small increase in value will quickly initiate crack propagation within a 1000 cycles. It is for this reason that cyclic tests have been increased incrementally. Once the target load has been passed successfully the test can be continued incrementally until failure.

The point at which permanent deformation occurs in HS Steel is very close in value to the point when cracking will be initiated and eventually fail over a prolonged cyclic regime. Because of the consistency of test results obtained, there appears to be no justification to test to 10,000 cycles as required in other cyclic test regimes. The use of cyclic testing is intended to be used as a check for the static test as the frequency of cyclic test checking can be adjusted for the material. i.e. low-strength steels are unlikely to suffer fatiguing at their lower levels of performance.

The importance of cyclic testing is to provide a performance value for the area of cladding serviced by a single fastener, (the Tributary Area) below which fatiguing is unlikely to occur. Once crack initiation has begun it is inevitable that failure will occur under repeated load.

The fastening pattern is a major determining factor where failure due to fatigue is determined not only by the number of fasteners per m², but also by the washer size as can be seen by the greatly increased performance when using load spreading washers.

Any failure is likely to be subjective, as it is with the static test, but any visible cracking or permanent deformation around the fastener in position is deemed to be failure. This means that both the static and the cyclic tests can never be fully automated and will require a physical examination and assessment.

Because this standard is material non-specific it requires subjective judgment as to (say) if the fibreglass reinforcement of GRP sheeting has been permanently deformed.

Where clipped sheeting (secret-fix) is used the design value for the tributary area can be a lesser value than for pierce fixed sheeting. Because this value is dependent on the profile shape and clip design, the tributary value leading to the target load, must be established for each profile.

It is common practice in NZ to use plastic sheeting in conjunction with metal sheeting at the same purlin spacings. For this reason plastic sheeting should also be included in any test programme.

C6.1.

The tributary load (TL) is calculated by multiplying the area serviced by the fastener by the test load in kPa. Because fastening patterns are not always symmetrical the maximum mean distance between fasteners is used.

Some TL values have been given in the NZMRM Code of Practice for specific thicknesses, profiles of steel, with and without using load spreading washers. Recent tests have confirmed these values however different thicknesses, grades of material and different thicknesses, grades of material, metal and shapes of load spreading washers will give very different results. For this reason their TL values must be established by the method prescribed.

All static tests must be subject to checking that the tributary area of the purlin spacing and the fastening spacing fit within the 'no cracking' criteria established and verified by cyclic loading.

C6.2.

The static test load is applied incrementally to provide opportunity for the observation of the performance of the profile under load. A 'feel' for this performance is easily obtained after conducting a number of tests and these can be used as a practical learning tool for roofers in training.

The use of load spreading washers has a major bearing on the performance of sheeting under negative loading which is mainly due to the increased area over which the load is shared. The most commonly used screw fasteners used in NZ are 12# & 14# fasteners and both sizes of Type 17 for timber and self-drilling for steel, have the same screw head diameter. This means that there is no advantage in using a larger screw for 'pull-over'. The load spreading washer as manufactured in New Zealand follows the profile of the sheeting and provides an increase in profile performance of up to 100% as well as providing a seal for the fastener. Because the increase of load of up to this amount applies at the periphery of a building, by using load spreading washers, the additional load can be taken by the sheeting without changing the purlin spacing or fastener frequencies.

Calculation does not take into account the changing section properties of the profiled sheeting with increasing load and nor can it allow for the interaction and support provided by adjacent spans. These are very much related to profile and the proportionate relationship with the end and intermediate span.

C6.3.

The minimum number of sequential tests to provide information for a load/span graph is three. It is suggested that a cyclic test be conducted on one of each of these series per permutation. i.e. with and without load spreading washers, or staggered fixings etc.

The reason for this level of static load checking (1 in 3) is because of the varying loads placed on the fixings by different purlin spacings and span configuration. It is therefore not critical as to which span is cyclically tested but it is recommended that the median of the three spans be cyclically tested.

Because the cyclic test is a verification test only to demonstrate that the static test would not fail under repeated load, it does not require to be factored by the factors in Table 1.2.

C6.4.

The cyclic regime used for New Zealand does not follow the Australian or other models.

1000 cycles at 80% of the target load, cycling from 40%-80% of the target load

1000 cycles at 90% of the target load, cycling from 45%-90% of the target load

1000 cycles at 100% of the target load, cycling from 50%-100% of the target load

The reason why the cycle is not dropped to zero is because gusting under storm conditions more closely resembles these sequences.

C.7. (j) & (k). Deflection.

One of the reasons why deflection is regarded as a performance criterion in Australia is because of ponding. Although rainfall does not normally occur at maximum wind load, in adverse circumstances standing waves and turbulence could still give leakage at the minimum pitch allowable in Australia (1°).

It is for this reason as well as many others that NZ has adopted 3° as a minimum pitch.

Note 5 following Table C1 of AS/NZS 1170 states:

“Problems with visually sensed deflections are frequently dependent on the presence of a visual clue for the observer to gauge linearity. Deflections are therefore a function of the line of sight of the observer.”

Although measured deflection under load is a performance indicator, performance under load is not considered a test criterion. The deflection design criteria also must be material non-specific, so the use of different metals and plastic for roof and wall cladding could impose unnecessary limitations on the use of these materials because they possess a very different Young's Modulus compared to steel.

Residual deflection is therefore set to a lower level at L/400 than would be normal for HS steel at L/1000.

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Metalcraft Industries Limited Roofing Division	PO Box 51 286 Pakuranga Auckland 2014	26 Trugood Drive East Tamaki Auckland	(09) 273 2820	(09) 274 0251
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MT MAUNGANUI				
Dimond - Mt Maunganui	PO Box 1167 Mt Maunganui	99 Aviation Ave Mt Maunganui	(07) 572 9696	(07) 572 9699
Gerard Roofs - Harvey Roofing Centre	PO Box 4517 Mt Maunganui South	Unit 3/6 Newton Street Mt Maunganui	(07) 574 1248	(07) 574 1249
ROTORUA				
Dimond – Rotorua	PO Box 463 Rotorua	Ti Street Rotorua	(07) 348 2730	(07) 347 1468
Metalcraft Industries Limited	PO Box 388 Rotorua	15 Monokia Street Rotorua	(07) 350 1138	(07) 350 1148
TAUPO				
Roofing Industries Taupo Ltd	PO Box 408 Taupo	1158 Rakanui Road Taupo	(07) 376 7971	(07) 376 7972
GISBORNE				
B J Moss Ltd	269 Awapuni Road Gisborne	269 Awapuni Road Gisborne	(06) 867 1219	(06) 867 1218
NAPIER				
B R Roofing & Walling Co Ltd	Ford Road Onekawa Napier	Ford Road Onekawa Napier	(06) 843 6968	(06) 843 6792
H B Longrun Ltd A division of Stratco NZ Ltd	PO Box 3056 Onekawa Napier 4182	65 Niven Street Onekawa Napier	(06) 843 6159	(06) 843 6157

Member Company	Postal Address	Physical Address	Phone	Fax
HASTINGS				
Dimond – Hastings	PO Box 1319 Hastings	Manchester Street Hastings	(06) 873 9029	(06) 879 7909
TAUMARUNUI				
King Country Longrun	PO Box 7 Taumarunui	Huia Street Taumarunui	(07) 895 6464	(07) 895 6858
NEW PLYMOUTH				
Dimond – New Plymouth	PO Box 3067 New Plymouth	14 Constance Street New Plymouth	(06) 758 3003	(06) 757 8259
Metalcraft Industries Taranaki	PO Box 3064 Fitzroy	218 De Havilland Road New Plymouth	(06) 755 2113 0508 589 145	(06) 755 0021
Taranaki Steelformers Ltd	626 Devon Street New Plymouth	626 Devon Street New Plymouth	(06) 758 3831	(06) 758 5784
STRATFORD				
Taranaki Steelformers Ltd	PO Box 36 Stratford	3466 Mountain Road Stratford	(06) 765 5191 0800 655 142	(06) 765 8185
WANGANUI				
Wanganui Steelformers Ltd	PO Box 91 Wanganui	380 Heads Road Wanganui	0800 800 077	(06) 344 6766
FEILDING				
Tri-Web Industries	PO Box 408 Feilding	3 Mahinui Street Feilding	(06) 323 6037	(06) 323 6037
PALMERSTON NORTH				
Dimond – Palmerston North	PO Box 1399 Palmerston North	Rangitikei Street Palmerston North	(06) 357 1061	(06) 354 0475
Metalcraft Industries Limited	Private Bag 11026 Palmerston North	76 Maiden St Palmerston North	(06) 358 9149 0508 589 145	(06) 358 7967
Continuous Spouting Central	PO Box 36 Stratford	3466 Mountain Road Stratford	0800 867 833	(06) 765 8185
Roofing Industries Central	PO Box 4584 Palmerston North	653 Tremaine Ave Palmerston North	(06) 353 8480	(06) 353 8470
WELLINGTON				
Brockelsby Roofing Products Ltd	49 Rutherford Street Lower Hutt	49 Rutherford Street Lower Hutt	(04) 566 1971	(04) 566 1921

Member Company	Postal Address	Physical Address	Phone	Fax
Dimond – Wellington	PO Box 36085 Petone Wellington	Burnham Street Petone Wellington	(04) 570 8460	(04) 570 8461
Gerard Roofs - Harvey Roofing Centre	PO Box 51 083 Tawa Wellington	12 Wall Place Linden Wellington	(04) 232 5184	(04) 232 0635
Metalcraft Industries Limited	PO Box 38 509 Wellington Mail Centre Te Puni	201 Gracefield Road Seaview Lower Hutt	(04) 566 2253	(04) 566 2256
Silbery Longrun Upper Hutt	69 Montgomery Cres Upper Hutt	69 Montgomery Cres Upper Hutt	(04) 526 9343	(04) 526 6615
Silbery Longrun Welington	57 Hutt Road Thorndon Wellington	57 Hutt Road Thorndon Wellington	(04) 472 7408	(04) 472 7404
Steel & Tube Roofing Products	39-41 Randwick Road Moera, Lower Hutt	39-41 Randwick Road Moera, Lower Hutt	(04) 568 4359	(04) 568 6770
NELSON				
Contour Roofing and Windows	PO Box 9015 Annesbrook 7044 Nelson	9 Merton Place Tahunanui Nelson	(03) 546 4260	(03) 546 4290
Freeman Roofing	PO Box 2317 Stoke 7041 Nelson	4 Elms Street Stoke Nelson	(03) 544 3108	(03) 544 3109
BLENHEIM				
Roofline Marlborough	31 Stuart Street Blenheim	31 Stuart Street Blenheim	(03) 578 8793	(03) 578 8028
GREYMOUTH				
Ellerys Roofing	PO Box 178 Greymouth	111 MacKay Street Greymouth	(03) 768 5029	(03) 768 0512
CHRISTCHURCH				
AZKO Roofing Ltd	41 Shakespeare Road Christchurch	41 Shakespeare Road Christchurch	(03) 365 9808	(03) 365 9809
Calder Stewart – Christchurch	PO Box 8356 Christchurch	127 Wrights Road Christchurch	(03) 338 0013	(03) 338 0791
Dimond – Christchurch	PO Box 7124 Sydenham Christchurch	89 Buchanans Road Hornby Christchurch	(03) 336 0045	(03) 342 3670

Member Company	Postal Address	Physical Address	Phone	Fax
Gerard Roofs - Harvey Roofing Centre	PO Box 11348 Christchurch	6 Parkhouse Road Sockburn Christchurch	(03) 343 1590	(03) 343 2434
Metalcraft Industries Limited	PO Box 33056 Barrington Christchurch	85 Columbia Ave Hornby Christchurch	(03) 962 7280 0800 333 056	(03) 962 7286
Stratco (NZSI) Limited	PO Box 8494 Riccarton Christchurch	55 Hands Road Addington Christchurch	(03) 338 9063	(03) 338 2829
Steel & Tube Roofing Products Christchurch Branch	106 Antigua Street Sydenham	106 Antigua Street Sydenham	(03) 377 0994	(03) 377 2680
The Architectural Roofing Company	PO Box 8052 Riccarton Christchurch	Westland Drive Izone Park, Rolleston Christchurch	(03) 344 5991 0800 502004	(03) 344 5992 0800 201 993
ASHBURTON				
Glenwood Roofing Industries	PO Box 5009 Tinwald Ashburton	Shearman Street Tinwald Ashburton	(03) 307 0593	(03) 307 0594
TIMARU				
Dan Cosgrove Ltd	PO Box 211 Timaru	31 Leckie Street Timaru	(03) 688 4169	(03) 687 9438
Canterbury Long Run Roofing	PO Box 2138 Washdyke 7941 Timaru	66 Racecourse Road Timaru	(03) 688 7224	(03) 688 7231
CROMWELL				
Calder Stewart – Cromwell	1 McNulty Road Cromwell	1 McNulty Road Cromwell	(03) 445 3303	(03) 445 3304
Metalcraft Industries Limited	PO Box 193 Palmerston North	28 McNulty Road Cromwell	(03) 445 4180	(03) 445 3581
QUEENSTOWN				
Calder Stewart – Queenstown	PO Box 437 Queenstown	Frankton Industries Estate Queenstown	(03) 442 2202	(03) 442 2204
The Architectural Roofing Company	PO Box 8052 Riccarton Christchurch	Unit A, 210 Glenda Drive Frankton Industrial Estate Frankton, Queenstown	(03) 344 5991 0800 502004	(03) 344 5992 0800 201 993
DUNEDIN				
Calder Stewart – Dunedin	PO Box 1027 Dunedin	26 Fox Street Dunedin	(03) 479 0658	(03) 455 4196

Member Company	Postal Address	Physical Address	Phone	Fax
Dimond – Dunedin	PO Box 1380 Dunedin	26 Orari Street Dunedin	(03) 466 4091	(03) 456 1869
Gerard Roofs - Liteweight Roofing Tiles	60 North Taieri Road Abbotsford Dunedin	60 North Taieri Road Abbotsford Dunedin	(03) 488 4175	(03) 488 4885
GORE				
Marshall Industries	PO Box 196 Gore	Ashton Street Gore	(03) 208 5561	(03) 208 5571
INVERCARGILL				
Calder Stewart Roofing (Head Office)	PO Box 1400 Invercargill	120 Bond Street Invercargill	(03) 214 5544	(03) 214 5577
Marshall Industries Ltd	PO Box 846 Invercargill	189 Bond Street Invercargill	(03) 218 2579	(03) 214 9816

17.0 APPENDIX

This appendix is intended to be a summary of acceptable trade practice for the fixing of metal claddings and accessories to roofs and walls as described in the NZ Metal Roof and Wall Cladding Code of Practice.

It applies to buildings of Classified Uses 2.0 to 7.0 as defined in the First Schedule of the Building Regulations 1992.

At the publication date of this Code of Practice V2 (Version 2) April 2008 it is unclear what is required by the Department of Building and Housing for an industry document to become a Compliance Document to the NZ Building Code as provided for in Section 22 of the Building Act 2004.

The intention is that the shaded requirements in this published version containing the word 'must' and are the normative part of the NZMRM Code of Practice will form the basis of such a Compliance document.

This section will become available when the protocol is established.

Until that time the NZMRM Code of Practice remains an Alternative Solution to the NZ Building Code and as such must be taken into consideration by BCAs as one means of complying with the NZ Building Code and Regulations 'on reasonable grounds'.

SUMMARY OF COMPLIANCE REQUIREMENTS

- 17.0 APPENDIX**
- 17.1 NZBC**
- 17.2 PERFORMANCE**
- 17.3 LOADINGS**
- 17.4 DESIGN**
- 17.5 FLASHINGS**
- 17.6 PENETRATIONS**
- 17.7 INSTALLATION**
- 17.8 ROOF DRAINAGE**
- 17.9 PLASTIC ROOFLIGHTING**
- 17.10 PRESSED METAL TILES**
- 17.11 SECRET FIXED CLADDING**
- 17.12 INSULATED PANELS**
- 17.13 MAINTENANCE**
- 17.14 SITE PRACTICE**

18.0 USEFUL INFORMATION**18.1 CONVERSION FACTORS**

To convert from this	into this To convert this back	multiply by this divide by this
atmosphere	millibar	1013.25
atmosphere	pascal	101.325
cubic foot	cubic metre	0.028317
cubic inch	cubic millimetre	16387.1
cubic yard	cubic metre	0.764555
foot	metre	0.3048
foot per minute	metre per minute	0.3048
foot per minute	metre per second	0.00508
foot per second	metre per second	0.3048
foot pound force per second	watt	1.35582
gallon (Imp)	litre	4.54609
gallon (US)	litre	3.785 41
inch	metre	0.0254
inch	millimetre	25.4
inch mercury	kilopascal	3.38638
inch water gauge	kilopascal	0.248642
knot	kilometre per hour	1.852
mile	kilometre	1.609 344
mile per hour	kilometre per hour	1.609 344
millimetre mercury	kilopascal	0.133322
millimetre water gauge	pascal	9.78904
ounce	gram	28.3495
ounce per square foot	gram per square metre	305.152
ounce per square yard	gram per square metre	33.9057
pound	kilogram	0.45359237
pound force	newton	4.44822
pound force foot	newton.metre	1.35582
pound force inch	newton.metre	0.112985
pound force per square inch	bar	0.69
pound force per square inch	pascal	6894.76
pound force per square inch	kilopascal	6.89476
pound force per square foot	kilopascal	0.0479
pound force per square inch	megapascal	0.006895
pound per cubic foot	kilogram per cubic metre	16.0185
pound per foot	kilogram per metre	1.48816
pound per square foot	kilogram per square metre	4.882
square foot	square metre	0.092 903
square foot per ton	square metre per tonne	0.091436
square inch	square millimetre	645.16
square mile	square kilometre	2.59
square yard	square metre	0.836127

To convert from this	into this To convert this back	multiply by this divide by this
ton	tonne	1.01605
ton, freight (40 ft ³)	cubic metre	1.13267
ton force foot	kilonewton metre	3.03703
ton force per square inch	megapascal	15.4443
ton per cubic yard	tonne per cubic metre	1.32894
yard	kilometre	0.000914

1 knot = 1 nautical mile/h = 6080 ft/h = 1.853 km/h = 0.515 m/s

1 km/h = 0.539 knots

Head of water = 9.8 kPa per m

Water 0° – 100° increases in volume by 4.4%

1 litre = 1 kg = 0.001 m³

1 m³ = 1000 litres

Weight of steel kgs/m² = thickness in mm x 7.85

1 kN = 102 kg

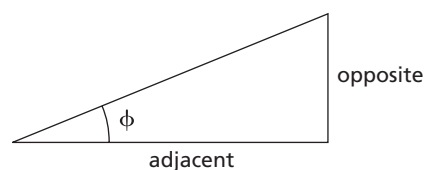
1 kip = 6.895 MPa

18.2 ROOF PITCH

The relationship between the pitch, fall or rise and the horizontal, is the relationship between the opposite and the adjacent sides of a right angled triangle.

This is known as the tangent of the angle. ($\tan \phi$) with the opposite side being the rise and the adjacent side the horizontal distance.

TAN .25°	=	.0044	approximating	1 in 225
TAN .5°	=	.0087	approximating	1 in 115
TAN 1°	=	.0175	approximating	1 in 60
TAN 1.5°	=	.0262	approximating	1 in 40
TAN 2°	=	.0349	approximating	1 in 30
TAN 2.5°	=	.0437	approximating	1 in 25
TAN 3°	=	.0524	approximating	1 in 20
TAN 4°	=	.0699	approximating	1 in 14
TAN 5°	=	.0875	approximating	1 in 12
TAN 6°	=	.1051	approximating	1 in 10
TAN 7°	=	.1228	approximating	1 in 8
TAN 8°	=	.1405	approximating	1 in 7
TAN 9°	=	.1584	approximating	1 in 6.5
TAN 10°	=	.1763	approximating	1 in 6
TAN 11°	=	.1944	approximating	1 in 5
TAN 12°	=	.2126	approximating	1 in 4.75
TAN 13°	=	.2309	approximating	1 in 4.5
TAN 14°	=	.2493	approximating	1 in 4
TAN 15°	=	.2679	approximating	1 in 3.75
TAN 16°	=	.2867	approximating	1 in 3.5
TAN 17°	=	.3057	approximating	1 in 3.25
TAN 18°	=	.3249	approximating	1 in 3
TAN 19°	=	.3443	approximating	1 in 3
TAN 20°	=	.3640	approximating	1 in 2.75
TAN 21°	=	.3839	approximating	1 in 2.5
TAN 22°	=	.4040	approximating	1 in 2.5
TAN 23°	=	.4245	approximating	1 in 2.5
TAN 24°	=	.4452	approximating	1 in 2.25
TAN 25°	=	.4663	approximating	1 in 2
TAN 30°	=	.5774	approximating	1 in 1.75
TAN 35°	=	.7002	approximating	1 in 1.5
TAN 45°	=	1	approximating	1 in 1
TAN 60°	=	1.732	approximating	1 in 0.6
TAN 75°	=	3.732	approximating	1 in 0.3



18.3 MATERIAL DENSITY, MELTING POINT, EXPANSION AND MODULUS

Material	Density kg/m ³	Melting point °C	Expansion mm/10m/100°C	Youngs modulus Gpa
Air	1.29			
Air acetylene		2500*		
Aluminium, rolled	2710	658	24	69
Brass	8330	900	18	
Carbon Dioxide 0°C	1.99			
Cement	1281			
Concrete, reinforced 2% steel	2420			
Copper	8938	1083	17	131
Glass	2787	850	9	
Gold	19290	1063	14	
Hydrogen 0°C	.0897			
Helium 0°C	.178			
Ice	913	0		
Iron, cast	7208	1530	12	179
Lead, rolled	11325	327	29	16
Nitrogen 0°C	1.25			
Oxygen 0°C	1.43			
Oxy acetylene		4400*		
Pinus Radiata	609			6
Polycarbonate	1244	133	64	
Polyester	1299	245	80#	
P.V.C.	1465	86	140	
Silver	10500	960	19	
Silver solder		735		
Easy-flo		630		
Solder Lead 50%/tin 50%	9302	210		
(Eutectic) Lead 33%/tin 67%	8615	180		
Snow: fresh	96	1		
wet compact	320			
Stainless Steel 304	8080	1425	17	193
Stainless Steel 316	8080	1385	16	193
Steel, low carbon	7850	1350	12	200
Tin	7280	231	27	
Water: fresh 4°C	1000			
Water: fresh 20°C	988			
Water: fresh 100°C	958			
Water: salt	1009-1201			
Zinc: rolled	7192	419	29	

* max flame temperature

glass reinforced polyester GRP expansion = 22

To convert Centigrade to Farenheit. $C^{\circ} = F^{\circ} - 32^{\circ} \times .56$

To convert Farenheit to Centigrade. $F^{\circ} = C^{\circ} \times 1.8 + 32^{\circ}$

18.3.1 THERMAL CONDUCTIVITY K

Material	W/mK	Material	W/mK
Copper	385	Water (20°C)	.56
Aluminium	205	Timber (Pine)	.14
Zinc	108	Snow	.1
Steel	50	Kraft building paper	.07
Lead	35	Fibreglass	.035
Stainless Steel	16	Rockwool	.035
Ice	2	Polystyrene	.035
Glass	1.05	Air (20°C)	.025
Concrete	.94	Polyurethane (Rigidised)	.016
Brick	.8		

Thermal conductivity values will vary with density, temperature and moisture content. (when applicable)

Electrical conductivity values generally follow thermal conductivity.

K = Kelvin = Absolute scale. i.e. 0° C = 273 K The degrees are equal i.e. 100° C = 373 K

18.4 DECADIC NUMBER SYSTEM

Symbol	Designation	Long Measure				Multiplier
T	Tera	Billion (Trillion USA)				10 ¹²
G	Giga	Milliard (Billion USA)				10 ⁹
M	Mega	Million				10 ⁶
ma	Myria	Ten thousand	mam	Myriametre		10 ⁴
k	Kilo	Thousand	km	Kilometre		10 ³
h	Hecto	Hundred	hm	Hectometre		10 ²
da	Deca	Ten	dam	Decametre		10
		One	m	Metre		1
d	Deci	Tenth	dm	Decimetre		10 ⁻¹
c	Centi	Hundredth	cm	Centimetre		10 ⁻²
m	Milli	Thousandth	mm	Millimetre		10 ⁻³
μ	Micro	Millionth		Micrometre (Micron)		10 ⁻⁶
n	Nano	Milliardth (billionth USA)	nm	Nanometre		10 ⁻⁹
p	Pico	Billionth (trillionth USA)	pm			10 ⁻¹²

18.4.1 INTERNATIONAL SYMBOLS**The Greek Alphabet**

Upper		Lower		Greek
A	Α	a	α	alpha
B	Β	b	β	beta
G	Γ	g	γ	gamma
D	Δ	d	δ	delta
E	Ε	e	ε	epsilon
Z	Ζ	z	ζ	zeta
H	Η	h	η	eta
Q	Θ	q	θ	theta
I	Ι	i	ι	iota
K	Κ	k	κ	kappa
L	Λ	l	λ	lambda
M	Μ	m	μ	mu
N	Ν	n	ν	nu
J	Ξ	j	ξ	xi
O	Ο	o	ο	omicron
P	Π	p	π	pi
R	Ρ	r	ρ	rho
S	Σ	s	σ	sigma
T	Τ	t	τ	tau
Y	Υ	y	υ	upsilon
F	Φ	f	φ	phi
X	Χ	x	χ	chi
C	Ψ	c	ψ	psi
V	Ω	v	ω	omega

18.5 GEOMETRY AND MENSURATION

a	= area
b	= base
d	= diameter
h	= height
l	= length
r	= radius
c	= circumference
π	= 3.1416
C	= $2\pi r$ or $22/7$ d

Areas

Circle	= πr^2 or $0.7854 d^2$
Square, rectangle, rhombus or rhomboid	= bh
Triangle	= .5 bh
Trapezoid	= .5 two parallel sides x h
Side of square of area equal to circle	= $0.8862 d$
Diameter of circle equal in area to square	= 1.1284 side of square
Parabola	= .66 bh
Ellipse	= $0.7854 d^1 d^2$

Area of any figure of four or more unequal sides is found by dividing it into triangles, finding areas of each and adding together.

Surface area

Cube	= $6b^2$
Sphere	= πd^2
Lateral surface area of regular figure	= .5 cbh (slant height)
Cylinder (Lateral surface area)	= πdh
Cylinder (Total surface area)	= $\pi dh + 2\pi r^2$
Cone (Total surface area)	= ab + c of base x .5h (slant height)

Volume

Cube	= b^3
Sphere	= $0.5236 d^3$
Pyramid or Cone	= .33 abh
Cylinder	= $\pi r^2 h$

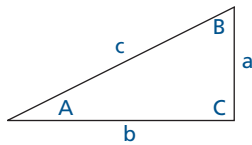
Table of polygons

S	= side of polygon.
R	= Radius of circumscribed circle.
r	= Radius of inscribed circle.
A	= Angle formed by the intersection of the sides.

Name	No of sides	Angle
Trigon	3	60°
Pentagon	5	108°
Hexagon	6	120°
Octagon	8	135°
Decagon	10	144°

Area of any regular polygon = Radius of inscribed circle x 1/2 number of sides x length of one side.

Right angle triangles



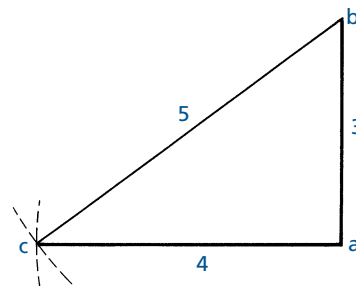
Find	Given	Solution
A	a, b	$\tan A = a / b$
	a, c	$\sin A = a / c$
	b, c	$\cos A = b / c$
B	a, b	$\tan B = b / a$
	a, c	$\cos B = a / c$
	b, c	$\sin B = b / c$
a	A, b	$b \tan A$
	A, c	$c \sin A$
	b, c	$\sqrt{c^2 - b^2}$
b	A, a	$a / \tan A$
	A, c	$c / \cos A$
	a, c	$\sqrt{c^2 - a^2}$
c	A, a	$a / \sin A$
	A, b	$b / \cos A$
	a, b	$\sqrt{a^2 + b^2}$
Area	a, b	$ab / 2$

To find a right angle:

Draw a line ab 3x long. At point a scribe an arc 4x long.

At point b scribe an arc 5x long to intersect a c.

Join ac and b, ac and ab are at 90°.



18.6 VELOCITIES

Unit	m/s	kms/h	mile/h
mile / hour	0.44704	1.60934	1
m/s	1	3.6	2.23694
km/h	0.277778	1	0.62137

Velocity is the distance travelled in one second (m/s).

The following speeds are approximate and are assumed to be constant and in a straight direction and therefore are also the velocity.

Description marked *R* are speed records.

	m/s	km/h	mile/hour	Beaufort Scale
Calm	0	<1	0	Smoke rises vertically
Light Air	0.8	3	2	1 Smoke rises on angle
Man walking	1.5	5.5	3.5	
Light breeze	2.5	9	5.6	2 Feel wind on face
Gentle breeze	4.5	16	10	3 Flags extend
Moderate breeze	7	25	15.5	4 Raises dust
Fresh breeze	10	35	22	5 Trees sway, waves
Runner 100m <i>R</i>	10	35	22	
Strong breeze	12.5	45	28	6 Telegraph wires whistle
Racehorse trotting <i>R</i>	15	54	33	
Moderate gale	15.5	56	35	7 Difficult to walk
Fresh gale	18.5	67	42	8 Branches break
Racehorse <i>R</i>	19	68	42.5	
Ostrich	20	72	45	
Racing cyclist <i>R</i>	22	79	49	
Strong gale	23	82	51	9 Slight building damage
Whole gale	26.5	96	60	10 Trees uprooted
N.Z. Road speed limit	28	100	62.5	
Skier downhill	28	100	62.5	
Storm	31	111	69	11 Widespread damage
Low wind speed NZS 3604	32	115	71	
Hurricane	33.5	120	75	12 Severe damage
Medium wind speed NZS 3604	37	133	83	
High wind speed NZS 3604	44	158	98	
AS/NZS 1170	45	162	101	
Swift - fastest bird	47	169	105	
Very high wind speed NZS 3604	50	180	111	
AS/NZS 1170 (Cook Strait)	51	184	114	
Moderate cyclone	55	198	153	
Tennis serve <i>R</i>	66	238	148	
Bullet train (Japan)	69	248	154	
Severe tropical cyclone	70	252	157	
TGV express train	77	277	172	
Wind <i>R</i>	103	371	230	

	m/s	km/h	mile/hour	
Boeing 747	256	920	572	
Sound in air	333	1199	743	
Land speed <i>R</i>	341	1228	763	
Rotation of earth at equator	465	1674	1040	
Concorde	649	2336	1452	
303 Bullet	792	2851	1772	
Lockheed Blackbird <i>R</i>	981	3529	2193	
Moon round the earth	1000	3600	2237	
Sound through steel	5100	18360	11408	
To escape earth's gravity	7823	28,163	17,500	
Fastest man has travelled	11,176	40,234	25,000	
Earth round the sun	29,700	106,920	66,437	
Pioneer space probe	66,720	240,192	149,248	
Light and electric waves	299,388,000	1,077,614,064	669,600,000	186,000 miles/sec

18.7 CONVERSION WIND SPEED TO PRESSURE

To convert metres a second into Pascals.

Dynamic pressure q (Pa)

V , m/s	0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0
10	61	74	88	104	120	138	157	177	199	221
20	245	270	297	324	353	383	414	447	481	516
30	552	589	628	668	709	751	794	839	885	932
40	981	1030	1080	1130	1190	1240	1300	1350	1410	1470
50	1530	1590	1660	1720	1790	1850	1920	1990	2060	2130
60	2210	2280	2360	2430	2510	2590	2670	2750	2830	2920
70	3000									

$$q_z = 0.6 V_{d(z)}^2 \times 10^{-3} \text{ kPa}$$

$$p_e = C_{pe} \pm C_{pi} k_1 q_z$$

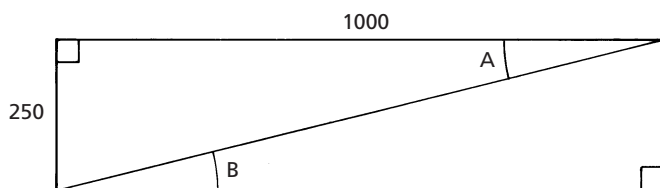
$$1 \text{ km/h} = .278 \text{ m/s}$$

$$1 \text{ m/s} = 3.6 \text{ km/h}$$

18.8 CRICKET PENETRATION PATTERNS

When cricket and diverter penetration flashings are used the pitch of the cricket valley will always be less than the pitch of the roof.

To find the pitch of a roof or valley, a simple method is to use a level measuring stick 1.000m long and measure the rise as shown in drawing 15.8.A. The relationship between the rise and the horizontal distance, is known as the tangent of the angle and is calculated by using $\tan \phi = O/A$ (being the opposite side divided by the adjacent side). (see section 18.2.)

**Drawing 18.8.A**

$$250/1000 = 0.25 = 14^\circ \text{ (1 in 4)}$$

N.B. Angles A and B are equal.

It is possible to obtain the length of the hypotenuse by using $\sqrt{a^2 + b^2}$

Cricket flashings as described in section 6 can be made to suit any penetration width, any cricket flashing depth to width ratio and roof pitch down to 3° . For simplicity three angles ϕ have been selected

$$\phi X = 45^\circ$$

$$\phi Y = 27^\circ$$

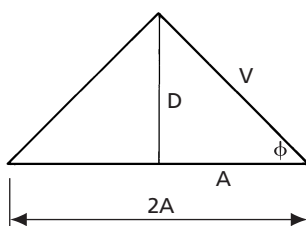
$$\phi Z = 18^\circ$$

VARIATION OF CRICKET VALLEY DESIGN DEPENDENT ON DEPTH AND ROOF PITCH

$$\text{Penetration Width} = 2A$$

$$\text{Depth} = D$$

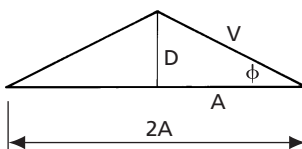
$$\text{Valley} = V$$



$$\phi X = 45^\circ$$

$$D = A$$

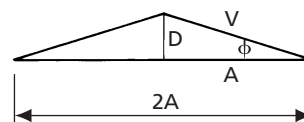
$$V = \sqrt{2} = 1.42$$



$$\phi Y = 27^\circ$$

$$D = 1/2A$$

$$V = \sqrt{1.25} = 1.118$$



$$\phi Z = 18^\circ$$

$$D = 1/3A$$

$$V = \sqrt{1.11} = 1.054$$

Drawing 18.8.B

To find the cricket valley pitch when the roof pitch is known, it is necessary to find the depth (D) of the cricket. If the depth of the cricket is half of the width of the penetration, as shown for 'Cricket X' the angles are at 45° and there is a defined relationship between the length of the valley of the cricket and the width of the penetration and also between the pitch of the valley of the cricket and the pitch of the roof.

This is $1 : \sqrt{2} = 1.42$ which means that to maintain the desired 3° fall in the cricket valley, the minimum roof pitch (4°) can be calculated using table 15.8.

If the depth of the cricket is a quarter or a sixth of the width of the penetration, there are also defined relationships between the pitch of the valley of the cricket and the pitch of the roof.

These are described in table 15.8 as 'Cricket Y' and 'Cricket Z'.

All figures comply with the minimum fall of 1.5°, but all the bold figures will provide a 3° cricket valley pitch.

This methodology is valid for all sizes of penetration, however there is a point at which, having a design with a wide penetration and a low pitch, it becomes uneconomic to pursue the ideal 3° fall in the cricket valley. When the roof pitch is known, the minimum allowable fall of the cricket valley pitch (1.5°) can then be read from table 15.8.

It is permissible to lower the valley pitch because 1.5° allows sufficient fall to clear debris from the valley and therefore qualifies as a warrantable flashing.

A diverter flashing without a cricket design only shifts the position of the cricket to the top overflashing of the penetration as shown on drawing 6.2.1.C, unless the penetration is rotated 45° as shown on drawing 6.3.D. (see section 6.0.)

ROOF PITCH	3°	4°	5°	6°	7°	8°	9°	10°
TANGENT	.0524	.0699	.0875	.1051	.1228	.1405	.1584	.1763
CRICKET X	2°	3°	3.5°	4.5°				
CRICKET Y	1.5°	1.75°	2.25°	2.75°	3.25°			
CRICKET Z	n/a	n/a	1.5°	2°	2.25°	2.5°	3°	3.5°

Table 18.8.

PROCEDURE TO MAKE A HALF PATTERN FOR A CRICKET PENETRATION FLASHING

Example:

A net penetration width is 550mm wide and gross width to the flat of the pans is 620mm (2A)

The back curb is required to have a fall of 3°.

The roof pitch is 7°.

From Table 15.8. select the cricket - Type Y

Given:

Half the width of the cricket $A = 310\text{mm}$

Depth of the Y cricket from drawing 15.8.B ($D=1/2A$) $D = 155\text{mm}$

Height of the side curb $H = 130\text{mm}$

Height to the top of the cricket $H_c = 70\text{mm}$

$H - H_c = H_r$ $H_r = 60\text{mm}$

From Drawing 15.8.C

Find length of V, S and R.

Right angle triangle therefore the length of V

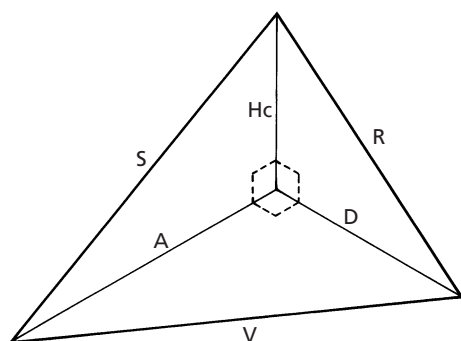
$$V = \sqrt{A^2 + D^2}$$
$$= 346 \text{ mm}$$

Right angle triangle therefore the length of R

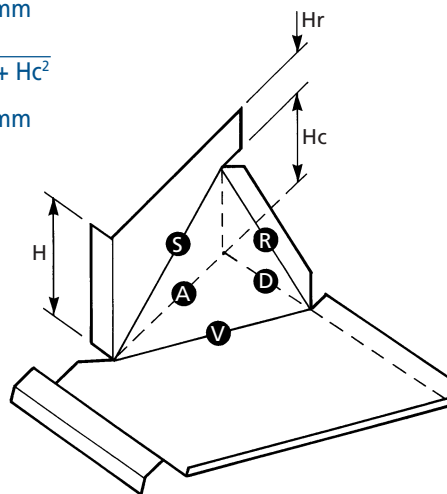
$$R = \sqrt{Hc^2 + D^2}$$
$$= 170 \text{ mm}$$

Right angle triangle therefore the length of S

$$S = \sqrt{A^2 + Hc^2}$$
$$= 318 \text{ mm}$$



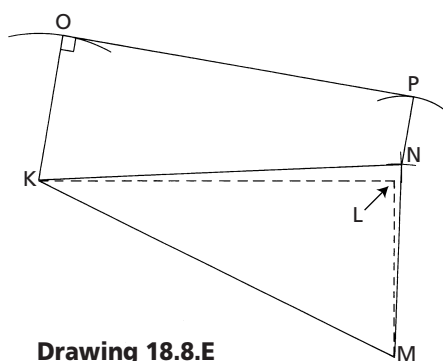
Drawing 18.8.C



Drawing 18.8.D

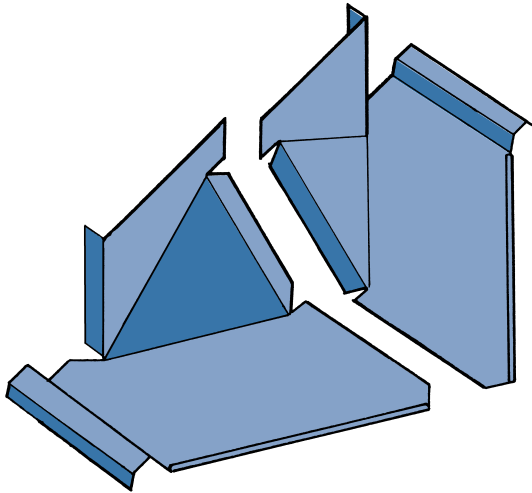
DRAW A HALF PATTERN

1. Draw a dotted line K - L length equal to A
2. From L draw a dotted line at right angles L - M length equal to D
3. Draw the line K - M (length equal to V)
4. With centre M scribe an arc length equal to R
5. With centre K scribe an arc length equal to S
6. From their point of intersection N draw a line to K and also to M
7. With centre K scribe an arc length equal to H.
8. With centre N scribe an arc length equal to Hr.
9. Draw a line as a tangent to the two arcs
10. From point K draw a line at right angles to intersect this line at O.
11. From O measure length A to a point P
12. The shape K-M-N-P-O is the net cricket pattern



Drawing 18.8.E

The back flashing and all tabs are added to this pattern, and then repeat the procedure for the other hand.



Drawing 18.8.F

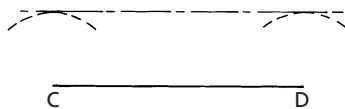
18.9 SHEET METAL WORK FOR ROOFING CONTRACTORS.

When forming various flashings in sheet-metal the Roofing Contractor is required to know how to cut his material in order to obtain the desired shape.

A basic knowledge of geometrical drawing and mensuration is required and this section explains the methods which are employed to ensure accurate results.

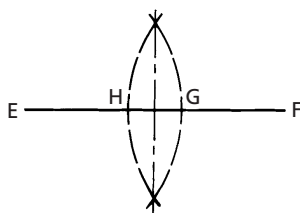
A straight line. A straight line is a line drawn in the shortest manner between two given points, so any other line between these points is a curved line.

Parallel lines. Parallel lines are lines which, when extended, do not touch. Given a line CD, to draw a parallel line set a compass to the required distance apart and with C and D as centres, describe two arcs. A line drawn as a tangent to both arcs will be a parallel line to CD.



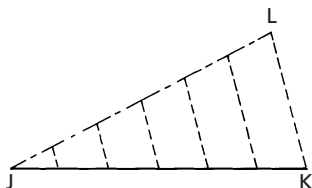
To draw a perpendicular line. Given a straight line EF, set a compass to any distance more than half the distance EF and, with E and F as centres, describe arcs of radius EG and FH.

A line drawn through the points of intersection of these arcs is perpendicular to EF, and bisects the distance EF.



To divide a line into any number of equal parts. Given a straight line J K, draw another line J L at any suitable angle and no particular length. Set off on J L, at any reasonable distance apart, a number of equal spaces similar in number to the parts into which J K is to be divided.

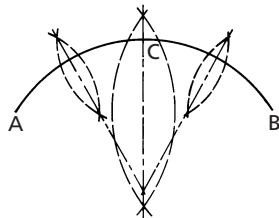
Connect L and K with a line, and parallel to this draw other lines through points on J L. These divide J K into the required number of equal parts.



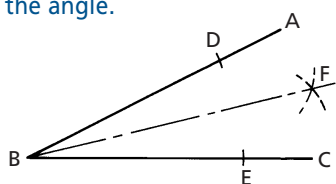
To bisect an arc. Given an arc AB, set a compass to a distance a little more than half that between the ends and with A and B as centres, describe arcs of equal radii.

A line drawn through the points of intersection will bisect AB. This method can be employed to divide the arc into any number of even parts by repetition. Further, the method may be used to find the centre of any given arc by further bisecting AC and CB.

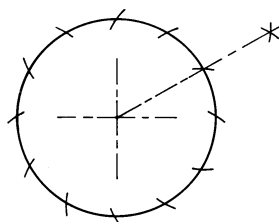
Lines taken through the intersecting points of these latter arcs, when produced, will intersect at the centre of the arc AB.



To bisect an angle. Given an angle ABC, set off equal distances BD and BE and with D and E as centres and a compass set at any reasonable radius, describe arcs to intersect in F. A line drawn through B and F bisects the angle.



To divide a circle into six equal parts. Set a compass to the radius of the circle and step this distance off along the circumference. Further division into 12 parts may be done by bisecting one part, and again stepping-off with the radius of the circle



Development of the frustrum of a true cone.

Draw the elevation X with base diameter AB, the vertical height CD to the desired cone angle and add the section line EF to the elevation. With centre D and radius DA describe a semicircle Y on the base, and divide the circumference of this into six equal parts.

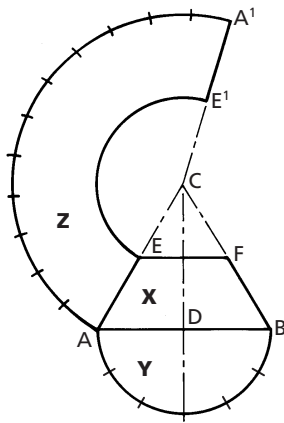
To draw the development Z:

With centre C and radius CB, describe an arc AA' whose length equals the circumference of cone base.

This may be obtained by marking off along the arc from A spaces equal to parts in the semicircle Y but double in number.(12)

With C as centre and radius CE, draw the arc EE' and add the line CA'.

The figure AA'E'E is the development Z of the frustrum.



Development of a square base to a circular top.

Draw the elevation X, making the base AB, vertical height CD, and diameter of top EF.

Draw a half plan Y on the base, drawing the semicircle E'F' and dividing one half of this into a number of equal parts, F'G, GH, HJ, and JK.

Through points F', G, H, J, and K, draw lines to B'.

Before proceeding to the development it is necessary to find the true lengths of B'K, B'J, B'H, B'G, and B'F'.

To do this, drop a perpendicular from F to F' and extend the base line AB.

An offset diagram is now made by measuring distances B'F', B'G, and B'H, setting these off from F' on base line AB and drawing lines to F.

The lengths FF', FG, and FH, etc., are now true lengths.

To draw the development Z:

Draw a centre line C'O. At right angles to C' draw A²B² equal to AB.

From C', set off distance C'F', equal to FB.

Join A² and B² to F'. With centre A² and radius F'G, draw a short arc to be cut by an arc of F'G radius struck from F' to obtain point G'.

Similarly, with A^2 as centre and radius FH , draw an arc, to be cut by an arc of GH radius struck from point G^1 , thus obtaining point H^1 .

Draw a line through, A^2 and H^1 and produce same to intersect the centre line C^1O at O .

Repeat the process with, B^2 as centre for long radii, thus completing one quarter of the whole development.

To complete the pattern, draw a curve through points $H^1G^1F^1$ and repeat in the other sections of the development.

