MODERN CONSTRUCTION ENVELOPES

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SECOND EDITION

MODERN CONSTRUCTION SERIES

AMBRA | V

CONTENTS

CONTENTS

MODERN CONSTRUCTION SERIES

The series is based around the Modern Construction Handbook. Topics from the Walls and Roofs chapters from the MCH are developed to provide more comprehensive information. Books in the series discuss material systems based on the primary material used. The series currently comprises Modern Construction Facades, Modern Construction Roofs and Modern Construction Envelopes.

AIMS OF THIS BOOK

Modern Construction Envelopes combines the earlier Modern Construction Facades and Modern Construction Roofs into a single book with updated illustrations and more exploded views of material systems. This is a textbook for students of architecture, as well as students of structural and environmental engineering who wish to broaden their study beyond the information provided in the Walls and Roofs chapters of the Modern Construction Handbook. It shows the principles of the main facade types used today and illustrates this through typical generic details. The six chapters examine envelopes from the standpoint of the primary material used in their construction, from metal to glass, concrete, masonry, plastics and timber. Each set of five double page spreads explains a specific form of construction which is accompanied by drawn and annotated details. The techniques described can be applied internationally.

METAL WALLS
Chapter 1

The Metals chapter explores the use of sheet metal from a material fully supported on a substrate to its use as a self-supporting material in the form of profiled decking and composite panels. The use of profiled decking in thicknesses normally used for shipping containers, rather than buildings, has led to the introduction of semi-monocoque construction with this material. Some composite panel systems are being manufactured without an outer facing of metal sheet to allow a separate waterproofing layer to be added.

GLASS WALLS
Chapter 2

The Glass chapter investigates the range from framed systems to point fixed glazing. Windows and shop fronts are discussed as separate systems which can be used as full glazing systems in their own right.

CONCRETE WALLS
Chapter 3

The Concrete chapter compares in-situ (cast-in-place) concrete, and its use of formwork on site, with precast concrete and its use of moulds in a factory away from the site. In the use of either technique, the constraints of the panel sizes imposed by casting methods influence the use of the material.

MASONRY WALLS
Chapter 4

In the Masonry chapter the construction methodology is classified by wall construction: loadbearing, cavity wall or cladding attached to a backing wall. Within each construction method, the use of materials is very similar from brick to stone and concrete block. The differences in the specific use of a particular material are shown in the details.

PLASTIC WALLS
Chapter 5

The Plastics chapter explores the range of plastics from cellular materials, such as polycarbonate, to composite materials such as GRP, which is a combination of a woven fibrous material and a polymer matrix. Newer composite materials combine the economy of plastic with the durability and stiffness of metal in composite sheet materials. The recent re-introduction of plastics into mainstream construction has been possible due to the improved quality and colour durability of these materials. An advantage of plastics in wall construction is that they can provide translucency, rather than the transparency associated with glass, combined with high levels of thermal insulation.

TIMBER WALLS
Chapter 6

The Timber chapter shows both recent developments in timber walls and developments in traditional techniques. The low levels of embodied energy in this material, particularly in locally grown timber, have helped to revive the use of this material. Traditionally shunned for large-scale applications due to its poor fire resistance, particularly in Europe, the use of timber is now better understood to reduce the spread of fire. Timber types are also discussed as their selection has considerable environmental impact.

METAL ROOFS
Chapter 7

The Metals chapter discusses the use of metal sheet in roofs both as a substrate and as a watertight covering. When used as a substrate, in the form of profiled metal decking or composite panels, a waterproof membrane can be formed in different materials. Used as a covering material, metal sheet can be employed in standing seams, profiled sheet and rainscreens. Solar shading devices formed from metal are also discussed.

GLASS ROOFS
Chapter 8

The Glass chapter sets out the use of the material as both rooflights and as large glass roofs. Stick framed rooflights and glazing systems are related to those used for walls, but are usually fixed with pressure plates on the two sides parallel with the line of slope. Bolt fixed glazing systems for rooflights and roofs follow principles used in wall construction. Bonded glass decks and rooflights are a development of glass block details, which are also discussed. Finally in this chapter, glazed canopies are discussed, focusing on those that use point fixings with a minimum of support structure.

CONCRETE ROOFS
Chapter 9

Roof decks constructed in concrete are covered with a variety of waterproof membranes and finishes. When the membrane is applied directly to the concrete, thermal insulation and finishes, such as planting, paving slabs or timber decking are applied. Construction can also be finished with another roofing system, such as metal standing seams or rainscreens in other materials. All these types are discussed in this chapter.

TIMBER ROOFS
Chapter 10

Timber roofs are a traditional form of construction that use mainly tiles, slates and shingles in housing projects. In recent years, the increased use of metal sheet on timber roofs has led to an increase in more complex geometries that do not need to follow the principles of those traditional lapped roofing materials. Flat timber roofs, thin planting and metal sheet, in addition to the more traditional single membrane finishes, are set out here.

PLASTIC ROOFS
Chapter 11

Polycarbonate panels have the advantage of providing well insulated translucent panels that are more economic than those in glass. They are much lighter than glass, allowing more visually delicate support structures to be used for these panels. Glass reinforced polyester (GRP) can produce opaque roof forms that are free of joints, forming continuous roof structures such as shells and domes composed of a monolithic, lightweight material with a watertight finish on its outside face. All these types are explained in this chapter.

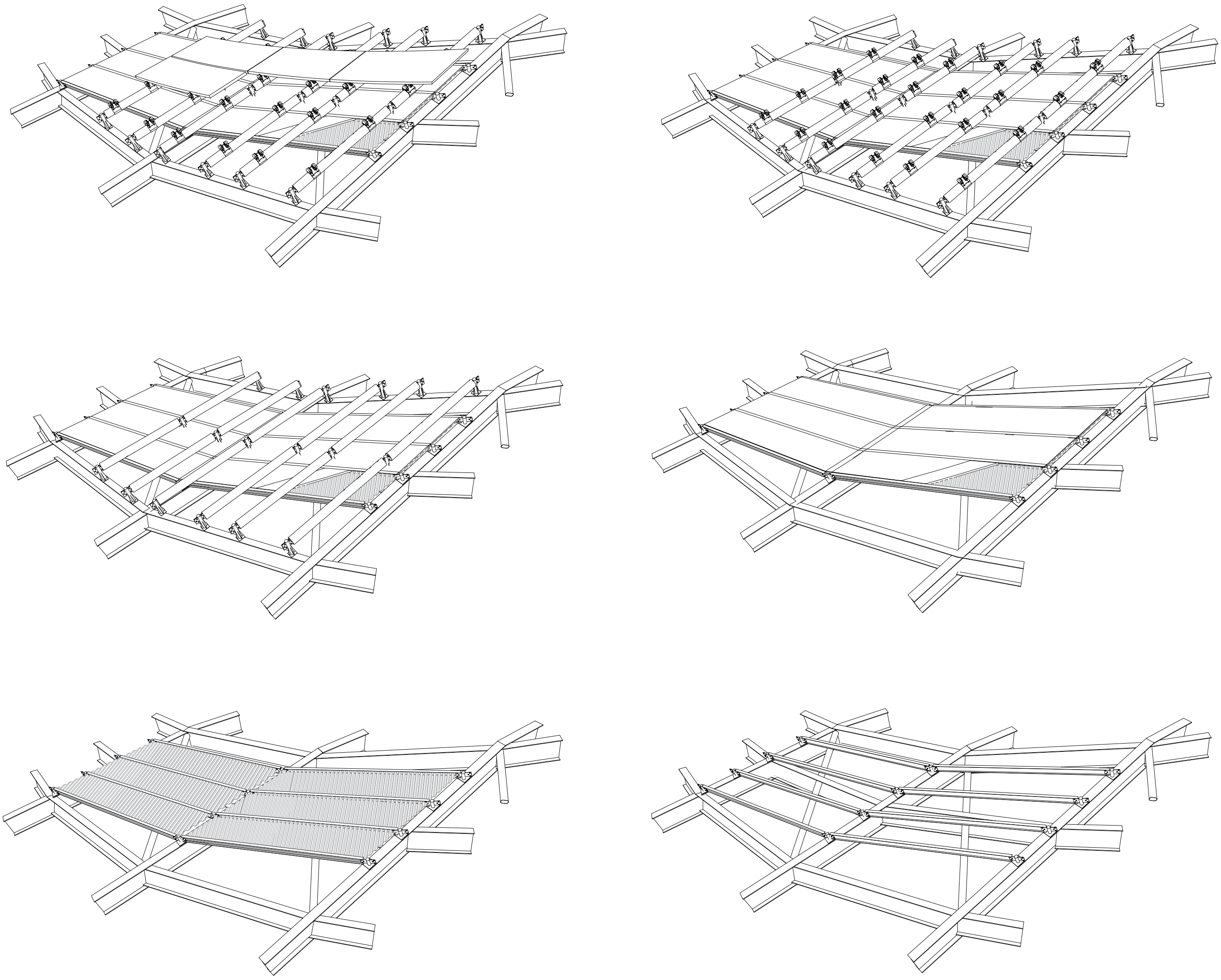
FABRIC ROOFS
Chapter 12

The Fabric chapter discusses tensile roof structures, air supported types and smaller scale canopies. PTFE membranes can be stretched over supporting structures, typically stainless steel cables with tubular steel supports. PTFE sheet is also used to form inflated 'air pillows' that are supported on an aluminium frame. Their advantage of high thermal insulation and lightness in weight makes them an increasingly preferred option for roof structures.

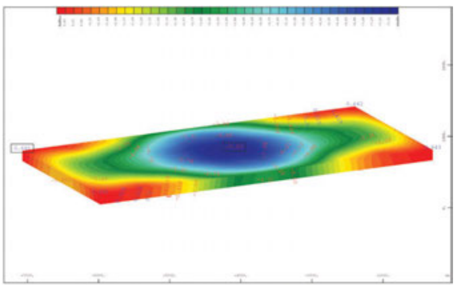
QUALIFYING COMMENTS

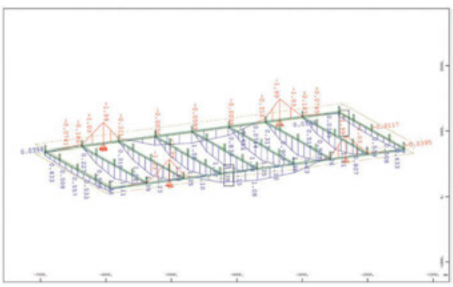
The building techniques discussed and the built examples shown are designed to last for an extended period with a relatively high performance. Consequently, buildings for exhibitions and for temporary use are excluded. For addressing an international readership, references to national legislation, building regulations, codes of practice and national standards have specifically not been included. This book explains the principles of accepted building techniques currently in use. Building codes throughout the world are undergoing increased harmonisation because of greater economic and intellectual globalisation. Building components and assemblies from many different countries are often used in a single building. Since building codes are written to protect users of buildings by providing for their health and safety, good construction practice will always uphold these codes as well as assist their advancement. The components, assemblies and details shown in this book describe many of the building techniques used by the building industry today, but this book does not necessarily endorse or justify their use since techniques in building are in a continual state of change and development. All details shown aim to demonstrate continuity in thermal insulation and waterproofing, together with two defences against rainwater penetration. Where specific items are not clearly present on drawings, these principles should still be followed.

From design concept to system design



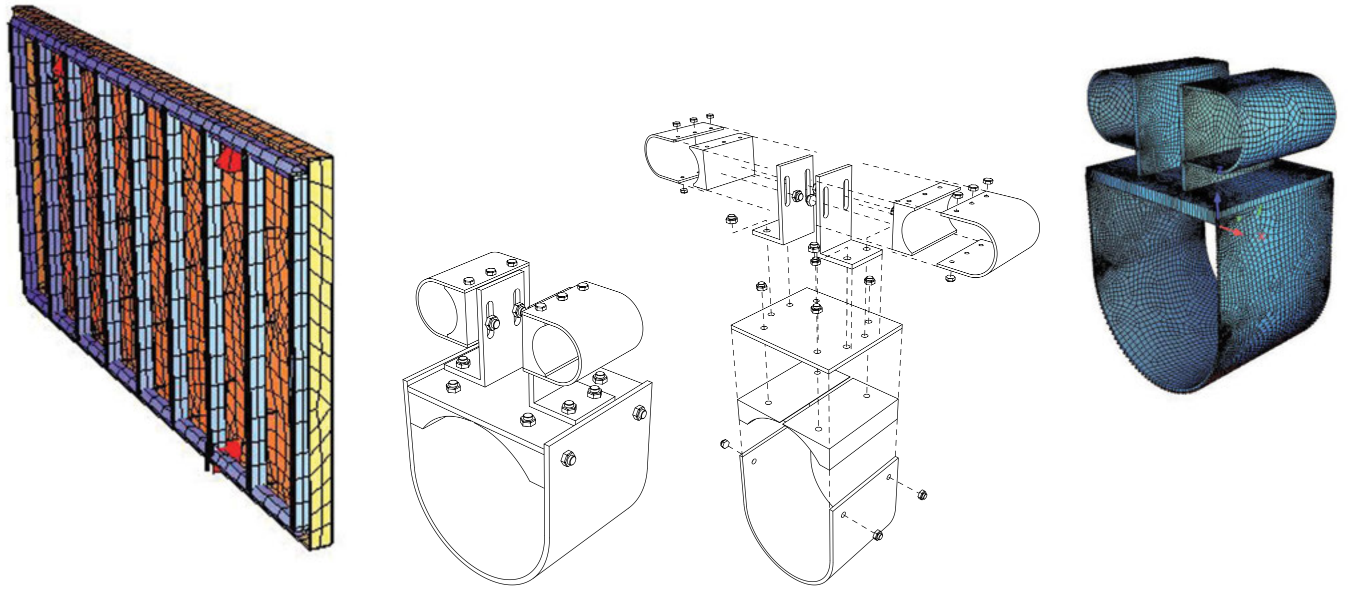
Build-up of a facade system showing the different layers required to provide supporting structure, thermal envelope, waterproofing, secondary structural support to facade panels, fixing brackets and facade panels.





Facade and roof systems can be developed from a sketch concept to a physical prototype through computer based 3D modelling and structural analysis. This design work is always supported by hand-based drawing and hand-based calculation methods, which allows the process to move through iterations towards a design which can can be manufactured from the 3D computer files. This approach allows the design team to provide information which can be inputted into machinery used by the fabricator or manufacturer.

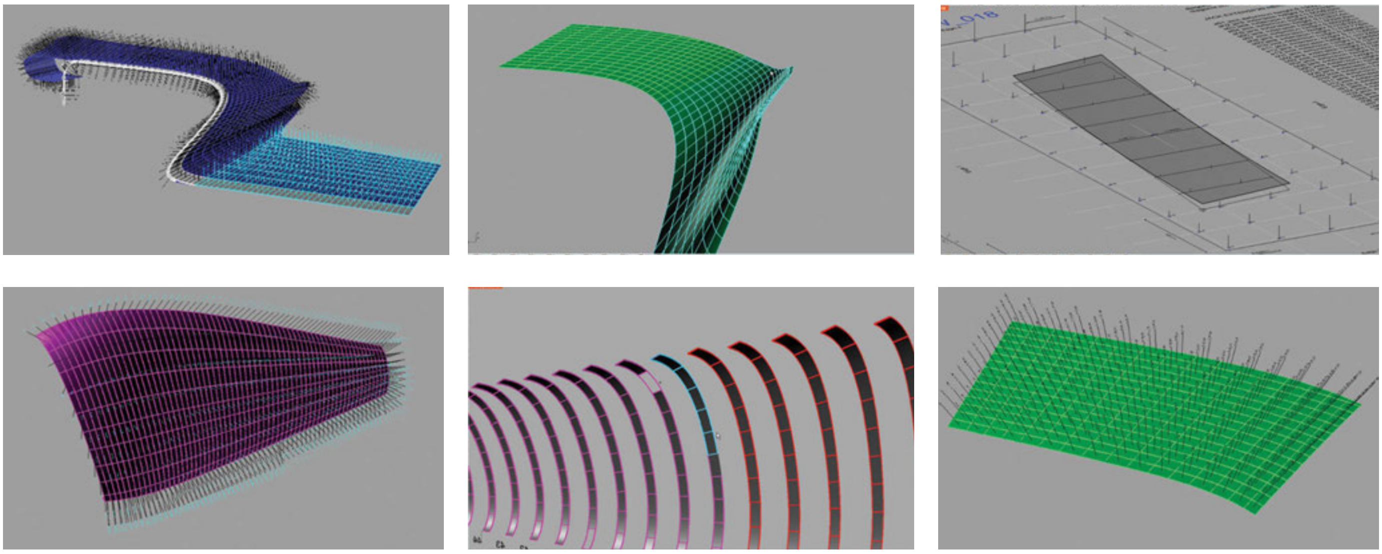
The ability of the design team to provide these files for direct use in fabrication avoids the need for a new set of detailed design proposals to be generated again from scratch. If a dialogue between designer and fabricator can be established during the design stage, then further time is saved in the procurement time of the prototype. A dialogue ensures that an optimised level of information is provided for the prototype: too much information can lead to the facade system becoming more expensive than would be the case if the fabricator were allowed to provided more economic methods of manufacture; too little information can result in the manufacturer being required to solve design issues that could have been addressed and resolved at a much earlier stage.



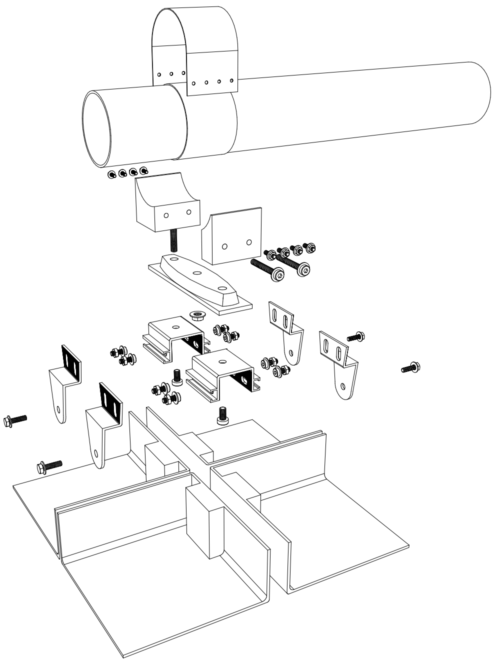
Structural analysis of the facade panel and support bracket. Analysis of deflection and stresses at an early stage of the design allows for the overall depth of a complex facade build-up to be established before the design of the building has progressed to the detailed stage.

Digital model of a physical prototype.

Physical prototype built from digital model.



Panelisation for manufacture, using 3-D parametric software.



Facades during completion

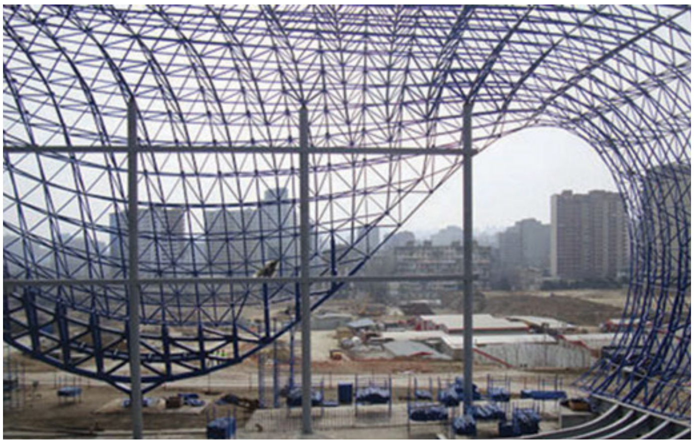
Fixing detail for panels using a minimum set of cast and extruded components.

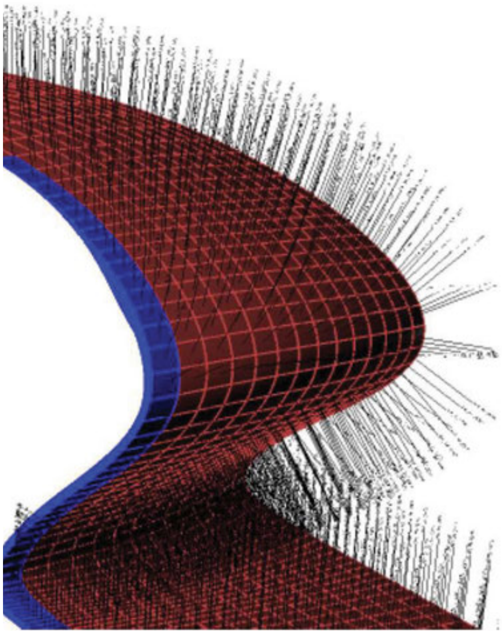
Facades during completion

While the building envelope systems described in this book are mostly described through rectilinear building forms, they can equally be applied to complex geometries and associated mass customisation techniques described in the introduction essays in the third edition of the Modern Construction Handbook.

An example is described here where the author, a director of Newtecnic, facade designers based in London, worked with the United Arab Emirates' based contractor, Arabian Profiles (APL) on an external envelope of complex geometry. The project was a cultural centre in Azerbaijan, which involved the manufacture of 16,000 cladding panels. These panels were either single curved or double curved to provide a continuously curved surface made from a combination of GRC (glass reinforced concrete) and GRP (glass reinforced polymer) types. The GRC is used mainly on surfaces that are walked upon in the plaza spaces around the building, while the GRP is used as roof cladding panels which are lighter in weight and have a comparable colour and surface finish. Panels were manufactured which followed the geometry required by the architect without the need for flat or facetted panels, while being economic in their method of manufacture. This outcome was achieved by translating the digital 3D model describing the geometry into individual panels with data that could be used in flexible moulding tables to fabricate the panels using a method of mass customisation. The moulding table was designed by the manufacturer of the panels, APL, who make envelope systems that focus on realising ambitious architectural designs using mass production or mass customisation techniques. The three dimensional form was described by a grid of points linked by regular curves that create the single curved forms with

Triangulated roof structure to which envelope system if fixed





Panelisation of geometry for manufacture.

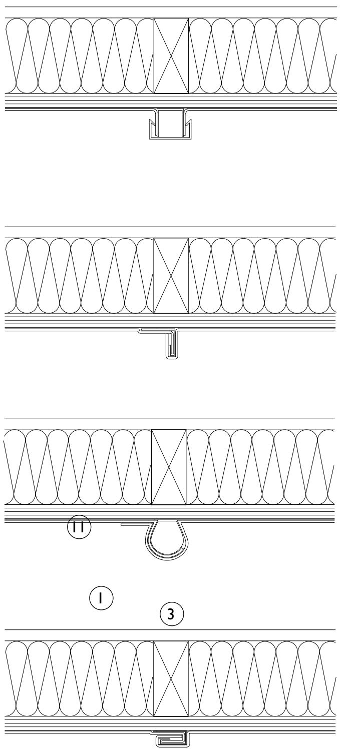
non-rectilinear edges. The flexible moulding tables use digital input to create visually complex forms without the need for hand-made components with their associated fabrication tolerances.

The use of a flexible moulding table allows complex panel shapes formed in single curved geometry to be manufactured quickly and economically to a high standard. Digitally controlled devices are used to adjust the shape of the panel with data provided by the 3D model. Information for edge returns for the panels, used to stiffen panels at their edges, was provided by 'developed', or unrolled, shapes offset from the curved shapes in the 3D model generated by the architect. This avoidance of purely hand crafted techniques ensures that the manufacture of systems for complex buildings can be applied to large-scale building envelopes.

Facades during completion

1

METAL WALLS



Horizontal section 1:10. Seam profile options

3-D view of folded metal sheet cladding with projecting joints. Type 1

3-D view of folded metal sheet with recessed seams. Type 1

Sheet metal is used for the rich surface textures that can be achieved with relatively soft materials applied to a continuous supporting substrate. This method does not provide the sharp lines and flat surfaces associated with rainscreen panels or composite panel construction. The most common metals used are copper, lead, zinc. More recently, stainless steel has come into use, but primarily as a roofing material. Copper sheet is a ductile material, but not as malleable as lead. Its characteristic green patina when fully weathered gives a consistent appearance. Lead sheet is extremely durable, and its softness allows it to be formed over complex geometries and panels with a high amount of surface relief. Zinc is durable, though more brittle than copper but is susceptible to corrosion from its underside if not ventilated. Stainless steel is a very durable material, but it still has an uneven surface when laid that provides a richness of reflection. The main disadvantage of working in stainless steel is its hardness, making it difficult to work when forming folds in jointing.

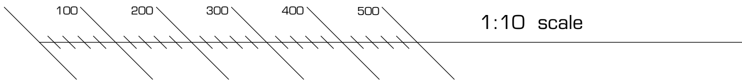
Fixing methods

There are three fixing methods for continuously supported sheet metal walls: continuous sheet, lapped tiles and recessed joints.

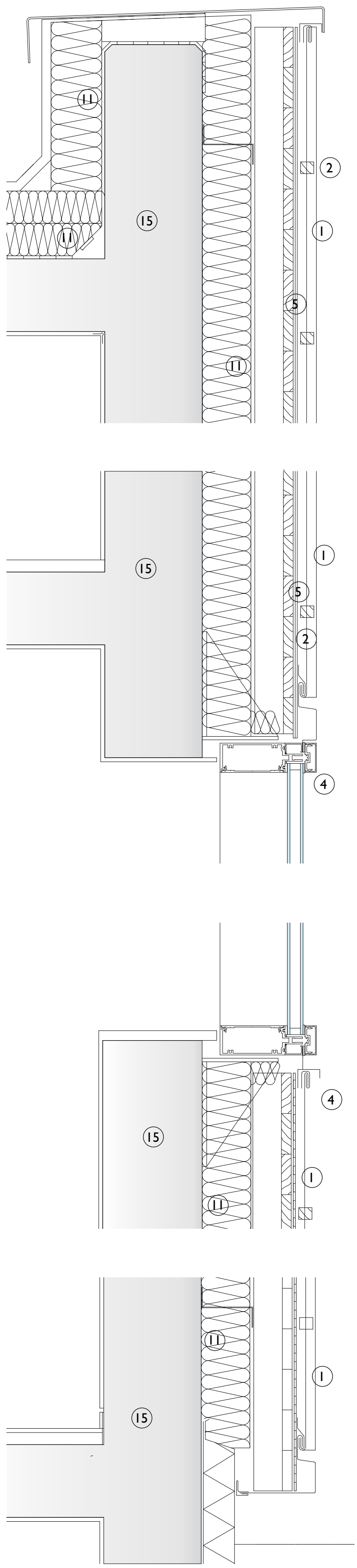
Continuous sheets are laid in varying widths with standing seams in vertical joints that run continuously from top to bottom of a wall. This gives the facade a characteristic striped appearance with strong shadows across the standing seam joints in sunlight. The sheet metal is fixed on the horizontal joints with flattened seams that allow rainwater to drain off easily. Horizontal joints are at distances to suit the visual appearance of the design but 12.0 metres (39ft 4in) to 17.0 metres (55ft 9in) is the maximum depending on the metal used. Vertical joints align with the edges of windows and door openings. Horizontal joints are usually staggered to form a pattern rather than try to achieve a continuous straight line which is difficult to keep completely straight and horizontal. This is because horizontal joints are broken between each vertical seam.

Lapped tiles are made approximately 450mm to 600mm (18inx24in) square and are set in either horizontal and vertical edges or at a 45° angle. Other angles can be used but are harder to co-ordinate with the edges of corners and openings. Window and door openings are usually enclosed in a metal strip around the reveal of the opening, with a shadow gap or projecting corner detail. Tiles are not folded into openings due to the complexity of jointing and the difficulty of getting them to fold neatly at half way across the panels. Shadows across the surface of a tiled wall have small strong lines which give a very textured appearance to the facade. Tiles are lapped on four sides to give a continuous watertight joint on all edges.

Recessed joints are formed in sheet metal laid over a specially formed substrate to produce recessed lines, which are usually horizontal. The material is occasionally recessed on four sides and set on a plywood background with projecting panels formed by the plywood. However, this technique is seldom used any more due to the increased use of metal rainscreen

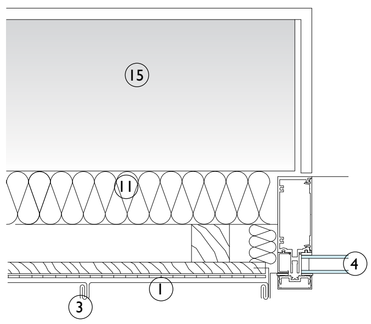


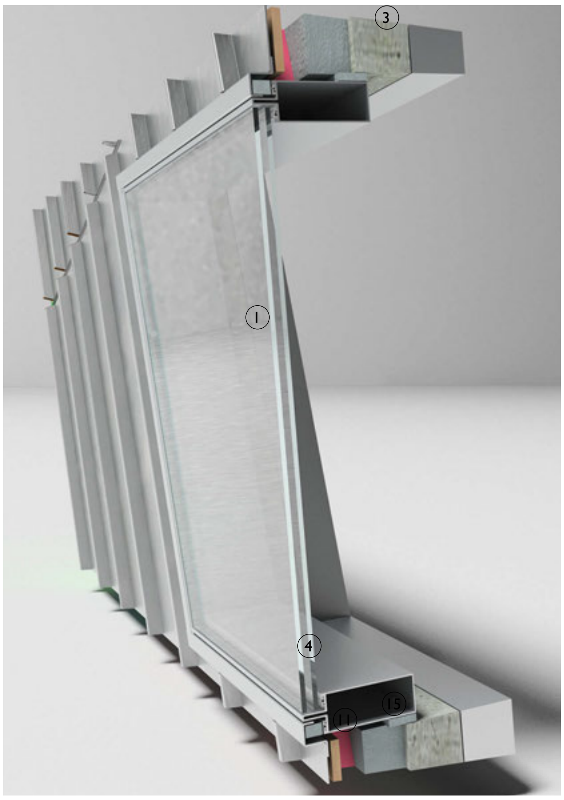
3-D views of folded metal sheet
with angled seam lines



Details

1. Folded metal sheet
2. Fixing battens
3. Standing seam joints
4. Window frame
5. Waterproof membrane, typically bitumen based paint
6. Internal finish
7. Metal clips fixed at centres
8. Timber window cill
9. Substrate in plywood or timber board
10. Folded metal coping
11. Thermal insulation
12. Backing wall - timber/metal frame with plywood facing
13. Vapour barrier
14. Ventilated metal drip
15. Structural concrete wall

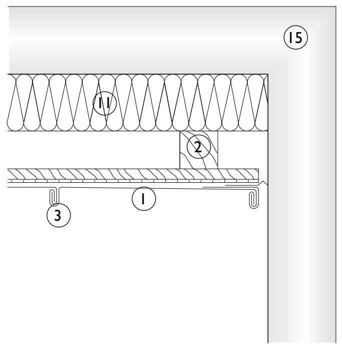




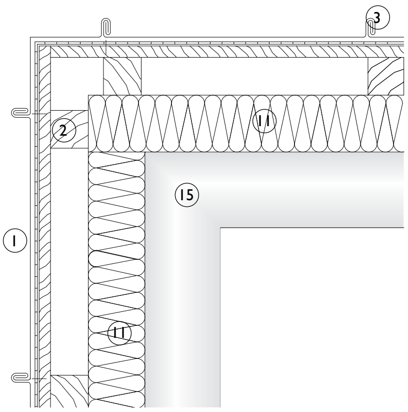
Horizontal section 1:10. Folded metal sheet connection to aluminium curtain wall type window

3-D view of aluminium window in folded metal cladding system

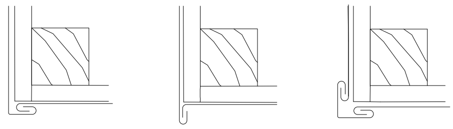
Vertical section 1:10. Folded metal sheet connection to aluminium curtain wall type window



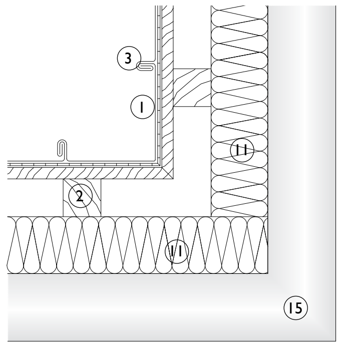
Horizontal section 1:10. Internal corner junction with wall



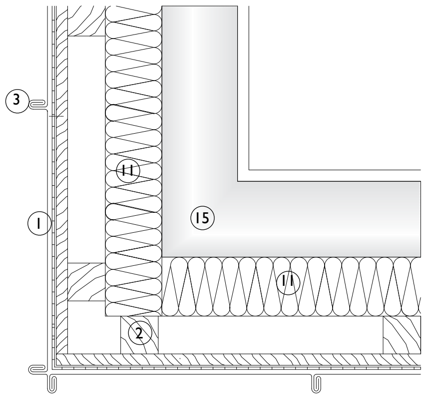
Horizontal section 1:10. External corner formed from folded metal sheet



Horizontal section 1:10. Simple seam details at corners



Horizontal section 1:10. Internal corner connection with folded metal sheet



Horizontal section 1:10. External corner with seam connection

Details
1. Folded metal sheet
2. Fixing battens
3. Standing seam joints
4. Window frame
5. Waterproof membrane, typically bitumen based paint
6. Internal finish
7. Metal clips fixed at centres
8. Timber window cill
9. Substrate in plywood or timber board
10. Folded metal coping
11. Thermal insulation
12. Backing wall - timber/metal frame with plywood facing
13. Vapour barrier
14. Ventilated metal drip
15. Structural concrete wall

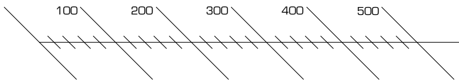
panels with their advantage of flatness of panel and close fixing tolerances, providing crisp lines at joints which are more difficult to achieve in a sheet metal continuously supported on a profiled background. However, this technique may find favour again due to its rich surface texture. Drips are incorporated at horizontal recessed joints to avoid staining occurring as a result of dirt being washed off the flat surfaces of these joints.

Openings

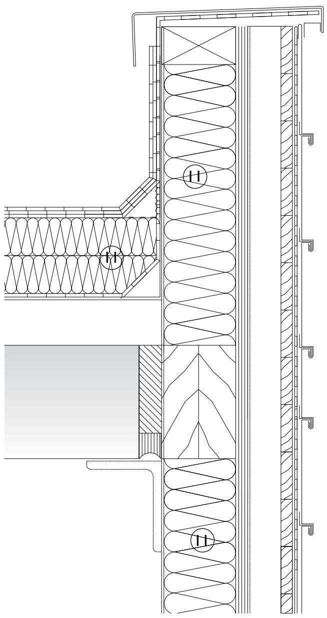
Where vertical jointed sheet metal is used, window and door openings are usually positioned so that a joint falls on the edge of an opening. This gives a clean, co-ordinated appearance to the facade, but openings that are set deliberately 'off grid' from the vertical joints also look visually dramatic. A recent development has been to use sheet metal with vertical joints inclined at angles up to 45º from the vertical so that they contrast with rectilinear window openings, giving the sheet metal the appearance of a continuous 'non-gridded' texture across a complete facade. For all orientations of sheet metal, window and door openings have separate metal sheets forming reveals on all sides. Although this can result in some awkward pieces of metal to form junctions around windows, in practice they are practical and economic to form on site due to the site-based nature of fixing metal sheet. Sheet metal cladding is ideally suited to the complex junctions associated with non-rectilinear geometries. Attempts to make the material appear too regular can produce disappointing results, particularly where a pure rectilinear grid is attempted. In this instance, metal rainscreen panels would probably be more suitable.

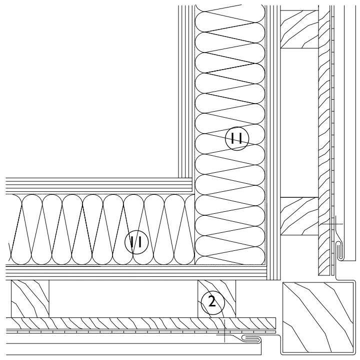
Windows and doors are glazed with almost any available technique, but the ever-increasing use of double glazed units both to conserve energy and avoid condensation on the window or door surface has led to thermally broken sections being used very commonly. Window frames are often clad in the same sheet metal as used in the adjacent facade, but this is expensive since the metal cladding will always be a decorative finish to a window that is designed for use without such a finish. The usual alternative is to use either a polyester powder coated or PVDF paint finish on aluminium to match the colour of the adjacent metal, or use a different material such as timber windows. A paint finish is obviously much easier to match if the sheet metal finish is pre-patinated (pre-weathered) so that its final colour will be very similar to the colour of the metal when installed. This is much more difficult in unweathered metals. The use of galvanised steel windows and doors with zinc is not so common due to the increased performance of paint coatings. However, galvanised finishes are ever-increasing in their durability and may eventually be used as a durable finish for window frames.

Buildings clad partly in sheet metal are beginning to use large-scale glazed openings using a completely different system such as bolt fixed glazing. Whereas these two systems previously seemed incompatible, with sheet metal as an economic system and bolt fixed glazing as an expensive system, the two are now used together increasingly where a deliberate

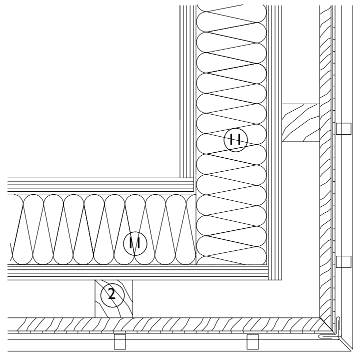


1:10 scale

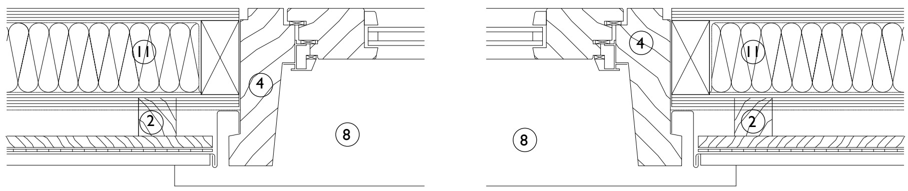




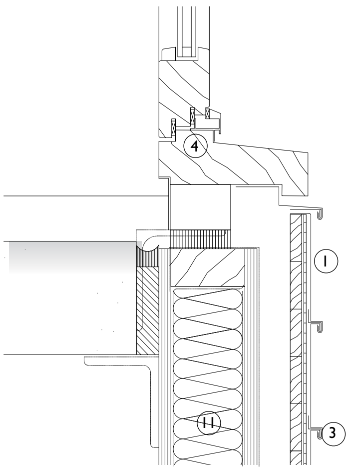
Horizontal section 1:10. External corner with seam connection

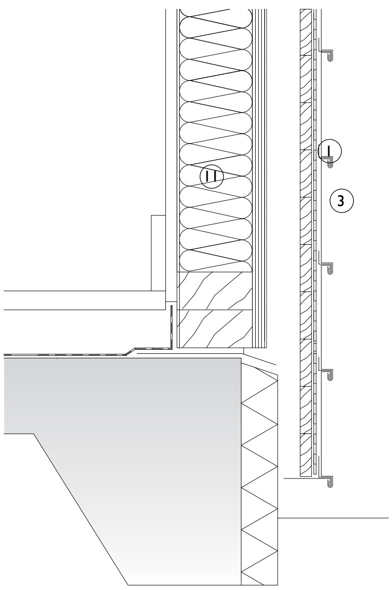


Horizontal section 1:10. External corner with seam connection



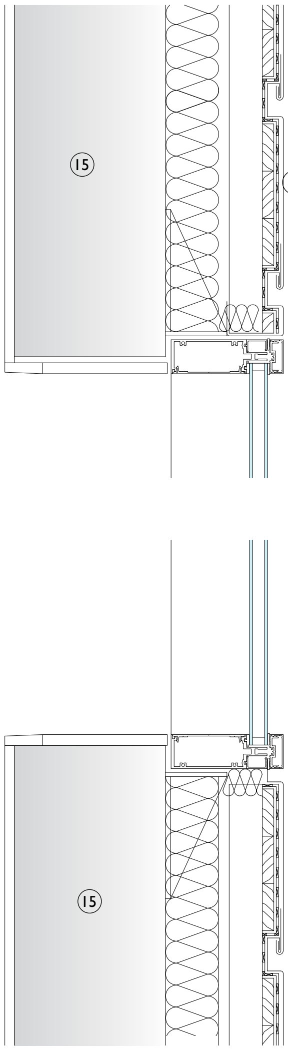
Horizontal section 1:10. Window detail in folded metal sheet with projecting joints



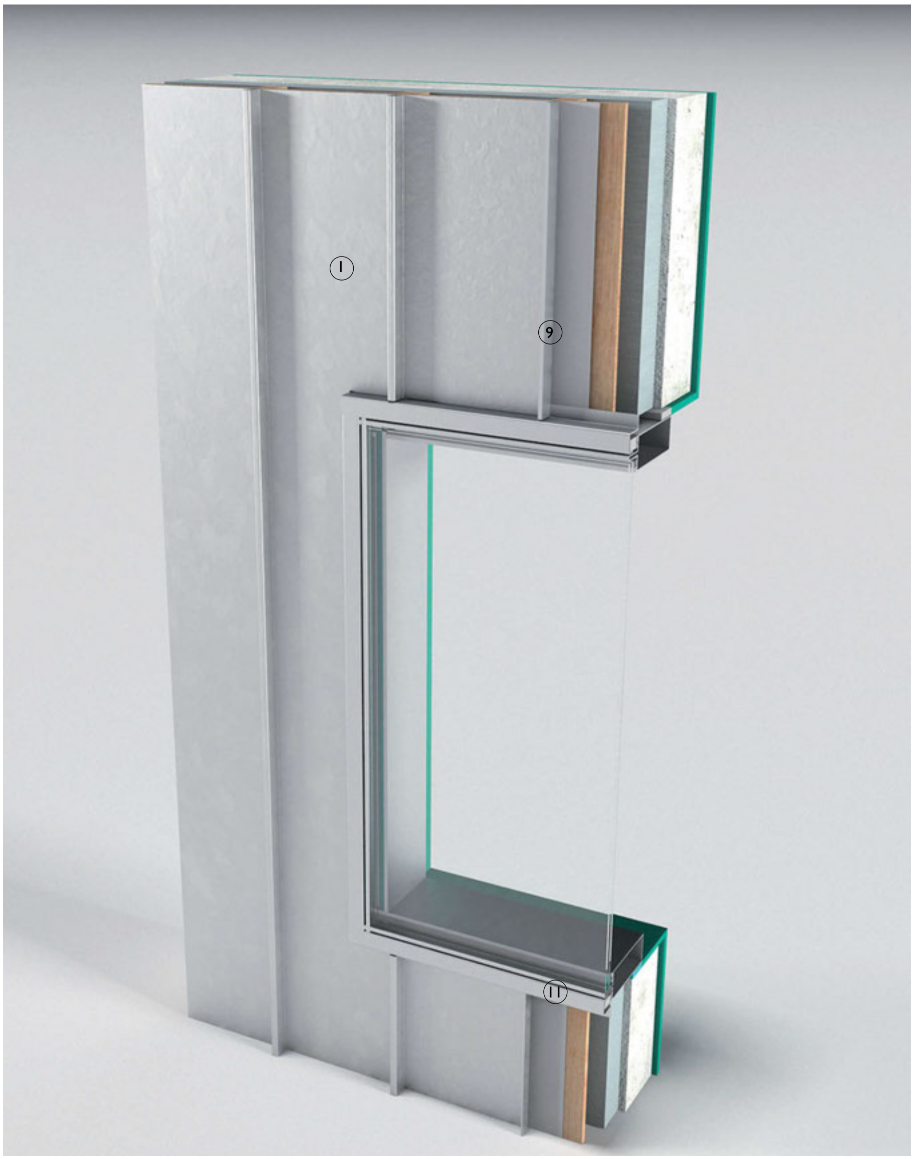


Vertical section 1:10. Ground level cill detail in folded metal sheet with projecting joints

3-D cut-away view of typical folded metal sheet cladding construction. Type 2



Vertical section 1:10. Aluminium curtain wall type window cill detail in folded metal sheet with recessed joints



3-D view of window inserted into folded metal facade. Type 2

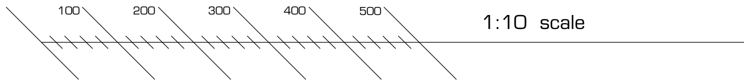
Details
1. Folded metal sheet
2. Fixing battens
3. Standing seam joints
4. Window frame
5. Waterproof membrane, typically bitumen based paint
6. Internal finish
7. Metal clips fixed at centres
8. Timber window cill
9. Substrate in plywood or timber board
10. Folded metal coping
11. Thermal insulation
12. Backing wall - timber/metal frame with plywood facing
13. Vapour barrier
14. Ventilated metal drip
15. Structural concrete wall

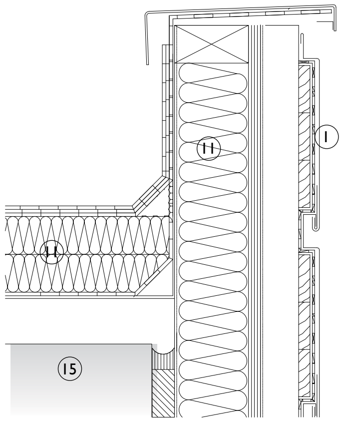
contrast of surface texture is sought. While bolt fixed glazing has a smooth, continuous surface uninterrupted by visible framing, sheet metal has joints in a direction at 400mm (1ft 4in) to 600mm (2ft) centres, with a comparatively uneven surface finish.

Substrates and supporting walls

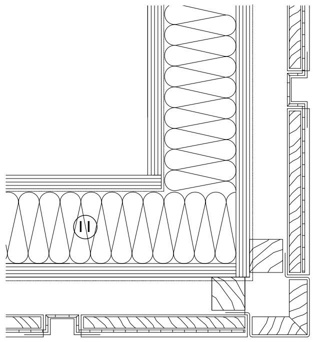
Sheet metals can be laid directly onto a substrate, typically plywood, with the exception of zinc, which needs ventilation on its interior face to avoid corrosion. Plywood is preferred for its durability, since if it becomes wet before a repair can be undertaken, the material can dry out without being damaged. Other materials such as particle boards are not resistant to moisture penetration and so are not used. Timber boards are used but are usually more expensive, as is profiled metal sheet. Where timber framing is used for the wall construction, the timber substrate forms an integral part of the external wall, providing diaphragm stiffness in the frame. Profiled metal sheet is increasingly used as a substrate for zinc, since zinc is more rigid than other metals such as copper or lead. Profiled metal sheet can span the gap between the peaks of the cladding, while providing a ventilated zone behind to avoid corrosion of the zinc. The addition of a ventilation mat provides a full gap between the zinc and the profiled metal.

Sheet metal is increasingly fixed to walls constructed in a wide range of materials: timber frames, precast concrete, concrete block and lightweight steel frames made in cold formed sections.

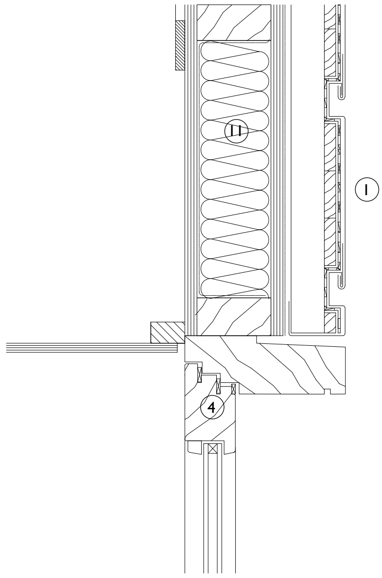


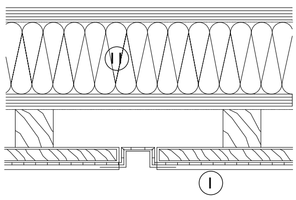


Vertical section 1:10. Parapet detail in folded metal sheet with recessed joints

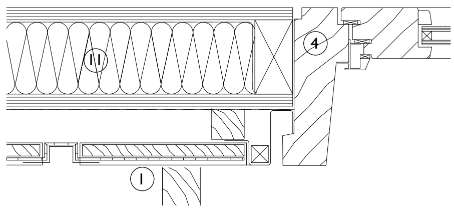


Horizontal section 1:10. External corner detail in folded metal sheet with recessed joints

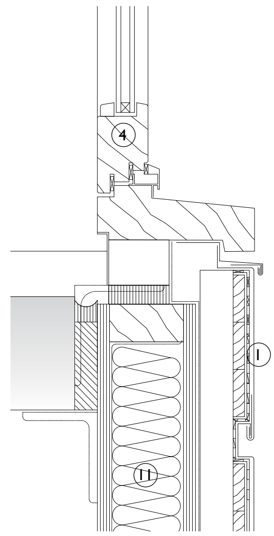


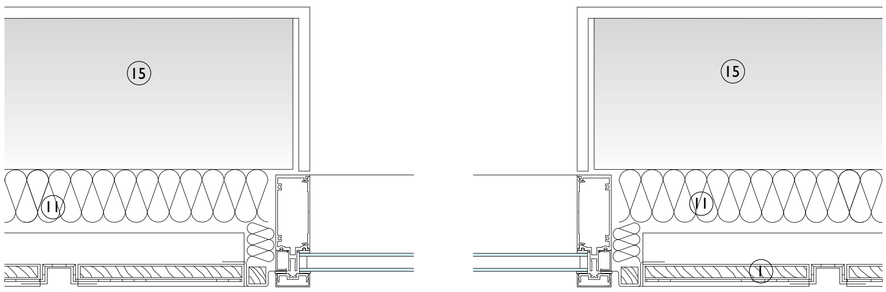


Horizontal section 1:10. Panel to panel junction with recessed joint



Horizontal section 1:10. Junction between timber window and folded metal sheets with recessed junctions



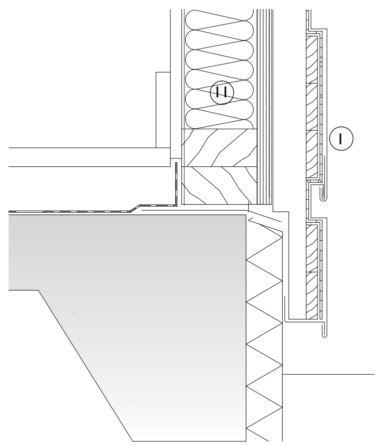


Horizontal section 1:10. Junction between curtain wall type window and folded metal sheets with recessed junctions

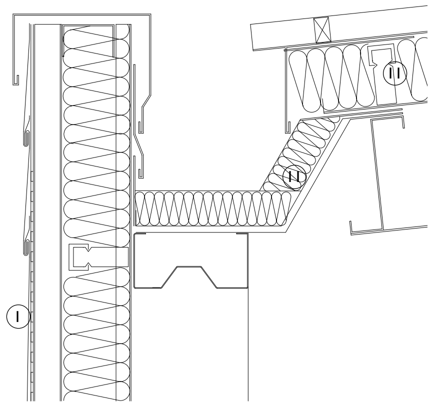
In Type 1, timber frames use sheet metal as a cladding in a fairly traditional form of construction, or as infill panels to a timber, concrete or steel frame. The overall cross section of the wall remains thin due to the inclusion of thermal insulation within the frame rather than on an outside face. A vapour barrier is needed on the warm-in-winter side (in a temperate climate) to avoid vapour reaching the insulation from inside. The vapour barrier is needed in the same place in Type 3, where pressed steel, or 'light gauge' steel sections are used. The all-metal construction of Type 3 is undergoing refinement for use in housing, where almost all its components can be either recycled or unbolted and modified with the same kit of parts during its lifetime. Its flatness of appearance combined with small-scale standing seam joints make it ideal for a sealed metal cladding where profiled metal sheet or composite panels have too 'industrial' an appearance. In Type 2, thermal insulation is set on the outside of the concrete structure in order to use its thermal mass as well as to keep the structure at as even a temperature as possible. The metal cladding is then set forward of the insulation. A new development is the use of profiled metal cladding as a substrate in Type 4. Where zinc is used the void formed by the profiled sheet provides a ventilation zone without the use of timber. A plastic-based drainage mat is set between the zinc and the profiled sheet to complete the ventilation.

Corners, parapets and cills

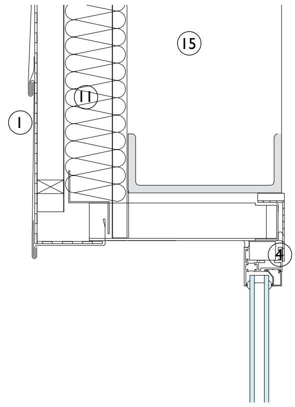
Sheet metal can be joined at corners in facades with either recessed or projecting coverstrips. The covers need a tim-

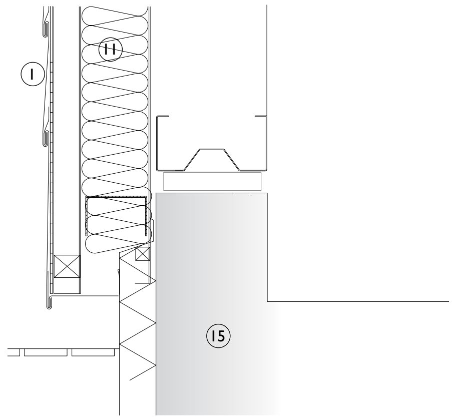


Vertical section 1:10. Ground level cill detail in folded metal sheet with recessed joints

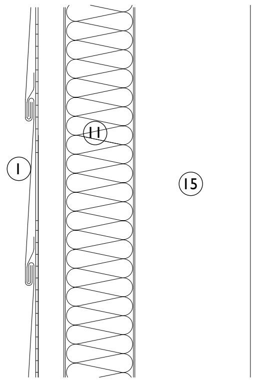


Vertical section 1:10. Parapet detail with interlocking folded metal sheets

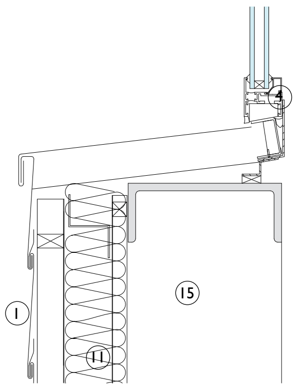




Vertical section 1:10. Ground level cill detail with interlocking folded metal panels. Type 3



Vertical section 1:10. Typical wall build-up with interlocking folded metal panels



Vertical section 1:10. Recessed aluminium window in interlocking folded metal facade

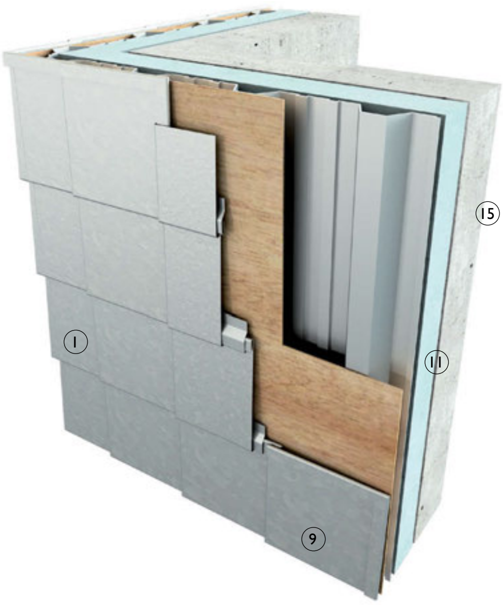
Details
1. Folded metal sheet
2. Fixing battens
3. Standing seam joints
4. Window frame
5. Waterproof membrane, typically bitumen based paint
6. Internal finish
7. Metal clips fixed at centres
8. Timber window cill
9. Substrate in plywood or timber board
10. Folded metal coping
11. Thermal insulation
12. Backing wall - timber/metal frame with plywood facing
13. Vapour barrier
14. Ventilated metal drip
15. Structural concrete wall

ber or plywood support under them to provide rigidity. Corners for vertically set metal sheet can also be formed by setting standing seam joints at the corner, or close to the corner on either side of the edge. With tiled sheets, corners usually wrap around, ignoring the corner like a continuous pattern folded around the corner. Alternatively, corners can have coverstrips that break the pattern from one facade to another. There is an increased use of pressed metal clips and rails, as used in profiled metal cladding, to support sheet metal substrates, typically plywood. Clips and rails are made as proprietary systems which can be fixed to the backing wall quickly and easily adjusted to correct vertical or inclined alignment.

An advantage of sheet metal is that parapet copings and cill drips at the base of walls at windows can be formed in the same material with an identical finish. This is unlike many other metal cladding systems, where extruded aluminium or pressed steel or aluminium are most commonly used for parapets and cills. The ability to form metal on site in junctions of sheet metal walls with parapet copings is used either to form a recessed joint, which allows the standing seam joint in the cladding to be tapered down to the line of the coping, or a projecting parapet coping which allows the standing seam to butt up to the underside of the coping. With either solution, an undercloak flashing or waterproof layer is needed underneath the coping to provide additional waterproofing.

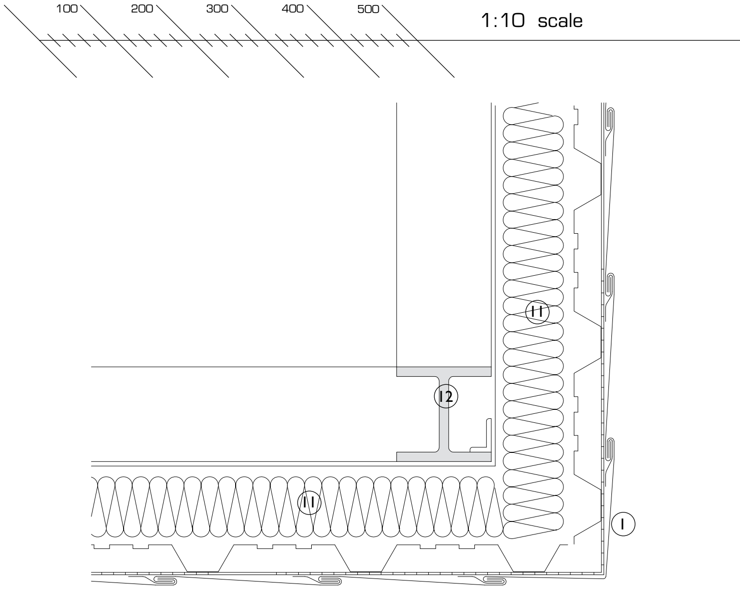
Cills are formed in a similar way, but with projecting or flush drips to throw water clear of the base of the cladding. Where unweathered metal is used, care should be taken that rainwater runoff from oxidising metal does not stain paved surfaces at the base of the wall. Slot drains or gravel edges can be used both to provide drainage and avoid visible staining. Drips are often reinforced with a steel or aluminium angle to create a strong, straight edge. Compatibility between the cladding material and support material must be ensured to avoid bimetallic corrosion. Where the void behind metal cladding is used for ventilation, parapets and cills are used to introduce fresh air. Insect mesh is introduced within the joint, but its presence does not alter air flow rates significantly.

3-D view of folded metal sheet with recessed seams.
Type 4

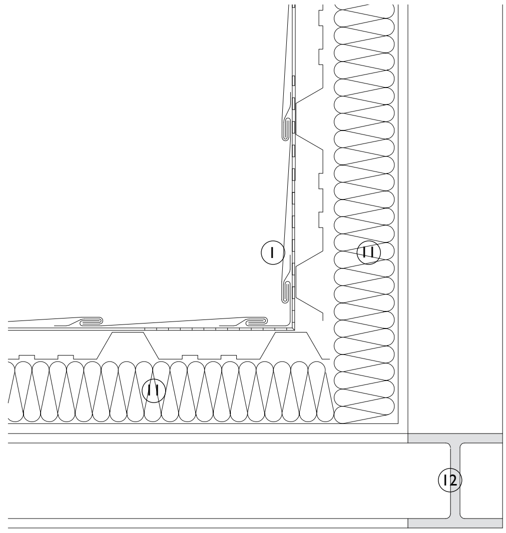


3-D view of folded metal sheet with recessed seams.
Type 4

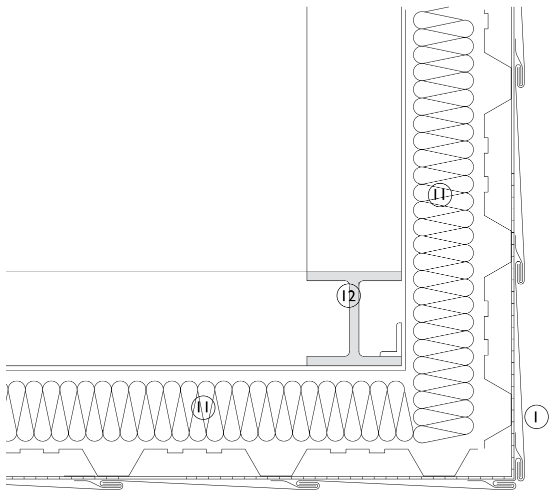
3-D view of folded metal sheet with recessed seams



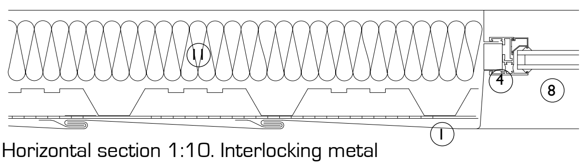
Horizontal section 1:10. Interlocking metal panels. External corner with metal fold



Horizontal section 1:10. Interlocking metal panels. Internal corner with joint

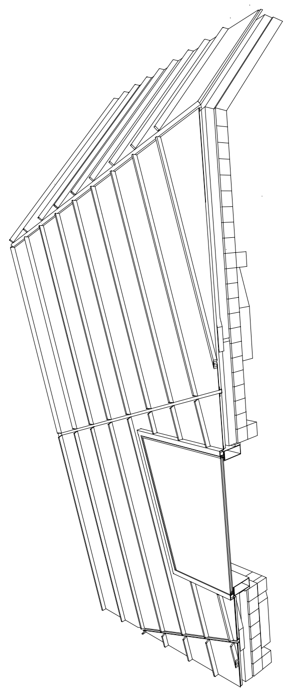


Horizontal section 1:10. Interlocking metal panels. External corner with joint

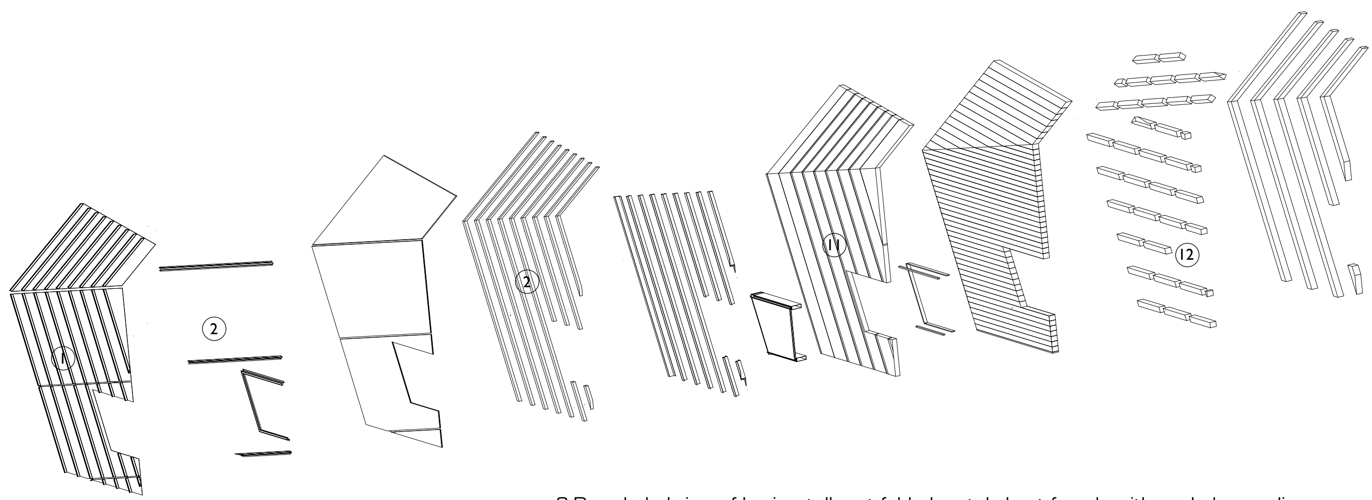


Horizontal section 1:10. Interlocking metal panels. Window junction

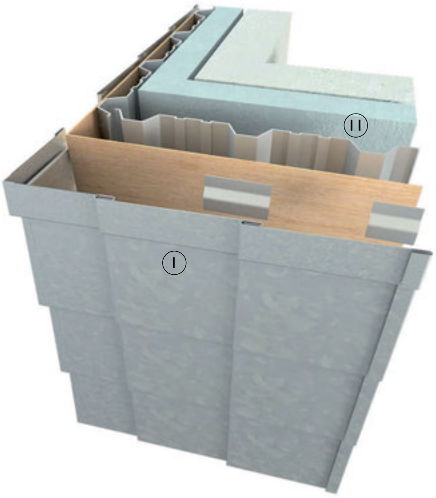
Details
1. Folded metal sheet
2. Fixing battens
3. Standing seam joints
4. Window frame
5. Waterproof membrane, typically bitumen based paint
6. Internal finish
7. Metal clips fixed at centres
8. Timber window cill
9. Substrate in plywood or timber board
10. Folded metal coping
11. Thermal insulation
12. Backing wall - timber/ metal frame with plywood facing
13. Vapour barrier
14. Ventilated metal drip
15. Structural concrete wall



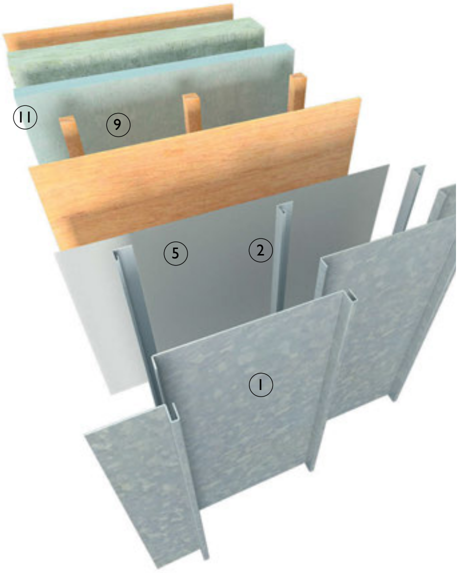
3-D exploded view of horizontally set folded metal sheet facade with angled seam lines



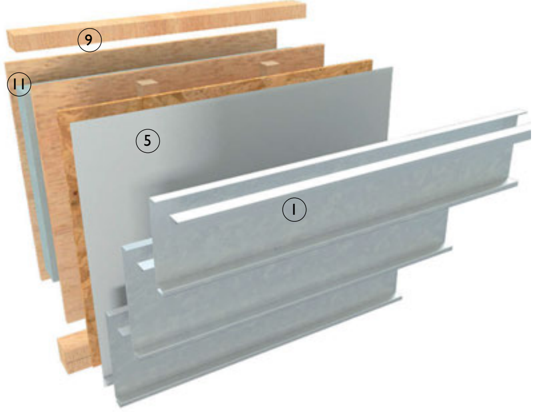
3-D exploded view of horizontally set folded metal sheet facade with angled seam lines



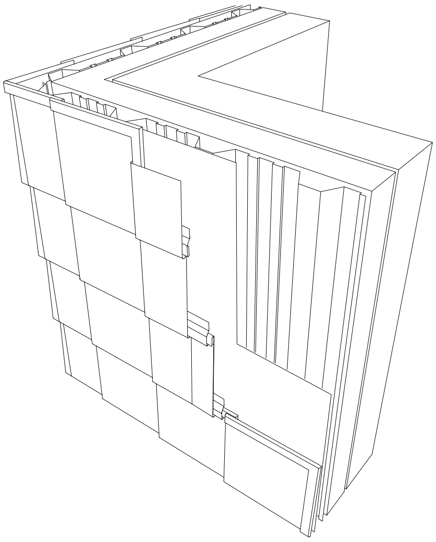
3-D exploded view of corner condition in tiled metal rainscreen system



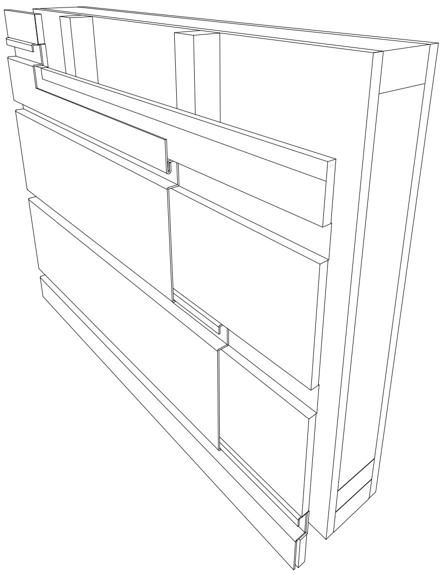
3-D exploded view of folded metal sheet with vertical recessed seams



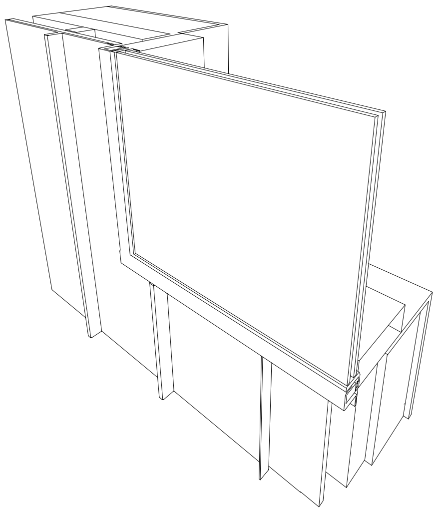
3-D exploded view of folded metal sheet with horizontal recessed seams



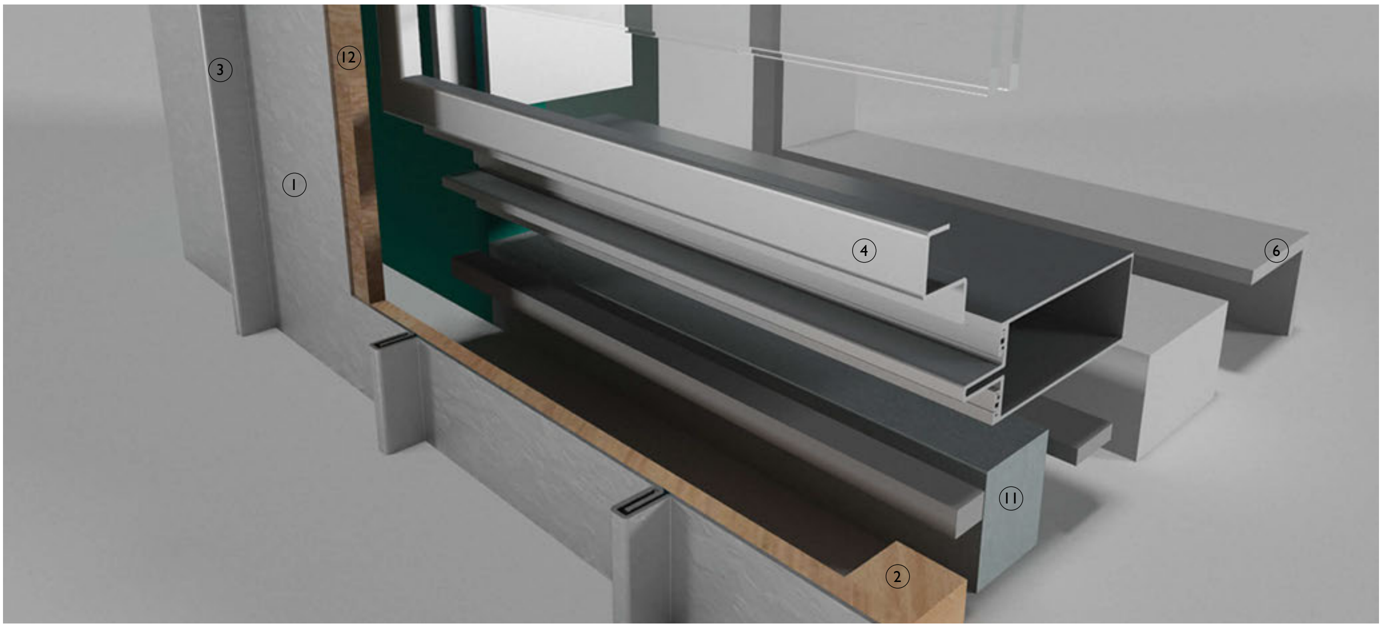
3-D exploded view of corner condition in tiled metal rainscreen system



3-D view of folded metal sheet with recessed seams



3-D view of folded metal sheet with recessed seams



3-D exploded view of construction of horizontally set folded metal sheet facade with angled seam lines

3-D view of horizontally set profiled metal sheet

3-D view of vertically set profiled metal sheet

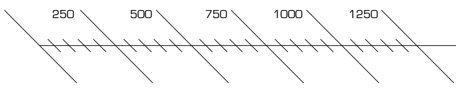
An advantage of profiled metal cladding is that it can be easily integrated with a similar system used for cladding the roof. Also, small areas of roof can be easily accommodated as steps within the facade with simple junctions between vertical and shallow pitch roofs. At the junction with the top of the roof an undercloak flashing is used to ensure water running off the wall is sent on down the roof and not into the joint at the base. At the bottom of the roof, either an exposed gutter or a concealed parapet gutter is used to collect the rainwater. Very small areas of roof can be drained without a gutter by projecting the roof beyond the cladding, allowing the rainwater to be thrown clear of the cladding and avoiding staining of the wall below. The effect of throwing water clear of the building needs to be integrated within the overall design.

Profiled metal cladding is most commonly used in large single storey buildings such as factories or warehouses where it spans vertically from ground to roof without the need for additional support. This makes it a very economical solution for enclosing these building types. Although profiled metal cladding is used mainly for industrial buildings in conjunction with a portal frame in either steel or concrete, it provides an economic cladding system for larger framed structures.

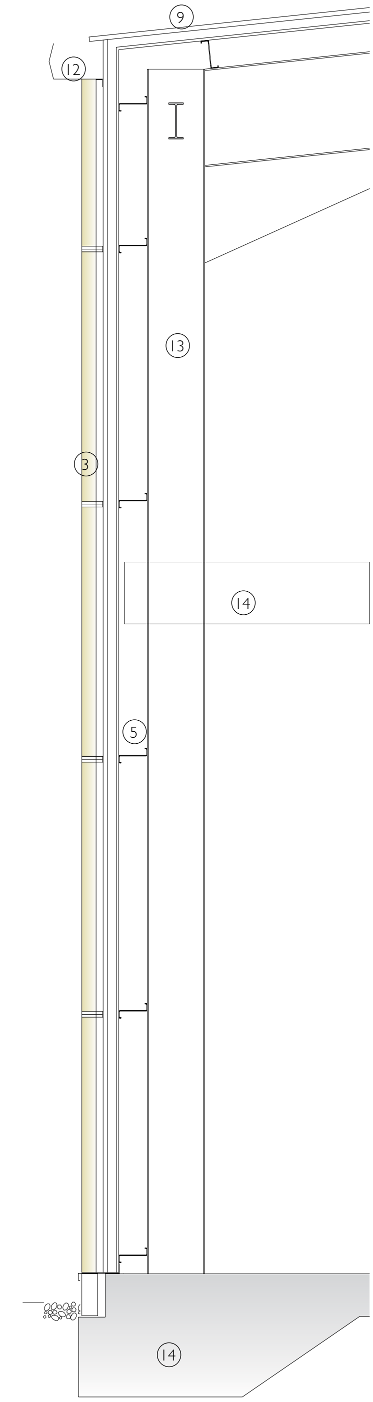
The material can be set either vertically or horizontally to suit the design.

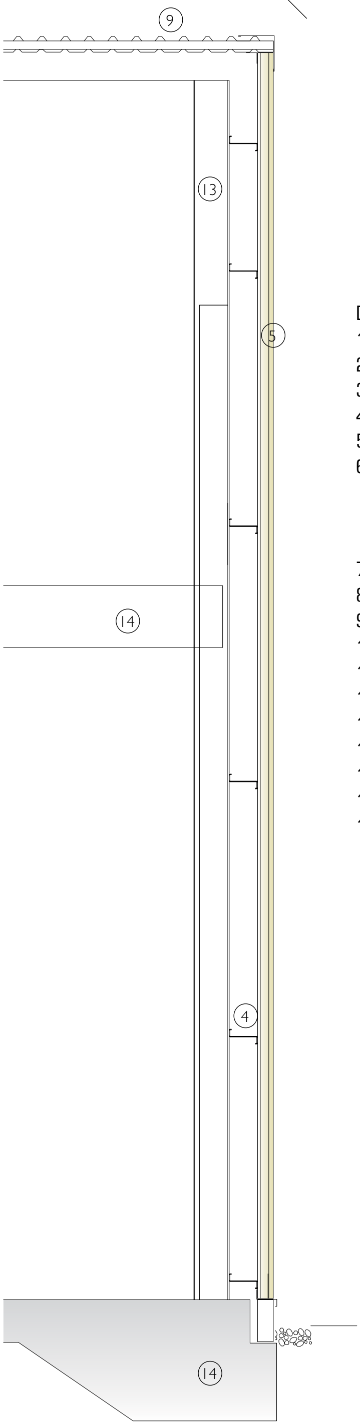
Horizontally-set cladding is used where its strong horizontal lines are used for linear emphasis. Like vertically-set cladding, the profiled sheet is supported at 3.0 to 5.0 metre (10ft to 16ft 6in) centres by posts or structural columns. This direction allows the material to enclose a building with a curved section. A useful aspect of profiled metal sheeting is its ability to be curved in one direction. This makes it an ideal cladding material for buildings with a curved vertical section. Slight irregularities in the surface finish or setting out of the curve are concealed by the profile itself. Polished stainless steel has been used for horizontally-set cladding in public buildings where its high cost is balanced by longer durability than coated aluminium or coated mild steel types.

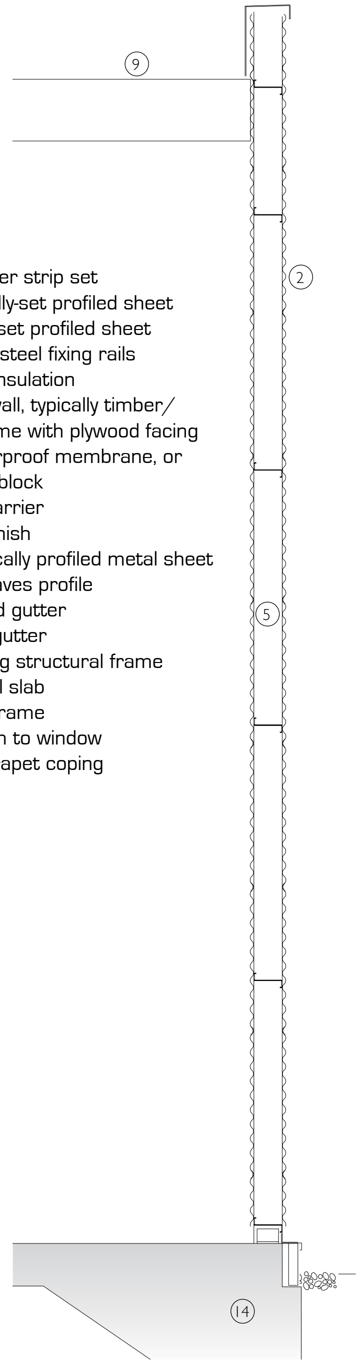
Vertically-set sheeting has horizontal cladding rails at 3.0 metre to 5.0 metre (10ft to 16ft 6in) centres, depending on the floor height. In buildings of more than one storey, an inner lining to the wall is usually added since the gap created between the cladding and the floor slab is difficult to seal economically at floor level in a way that will allow people to walk on it. The additional inner lining may extend up to 1.0 metres (3ft 3in) above the finished floor level and may be either a metal lining tray forming part of the proprietary cladding system, or be a concrete blockwork wall around 100mm (4in) thick. A smoke seal or fire barrier may be required between the floors enclosed by the cladding but this is very much dependent upon its particular application. Although horizontal rails can be set at wide centres, additional rails may be needed either to accommodate windows and doors or to increase the stiffness of the wall without using a much deeper profile, which would also increase stiffness.



1:25 scale





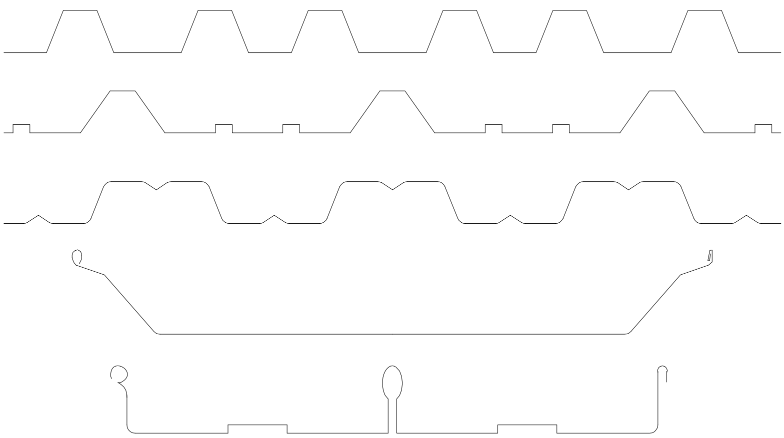


Details
1. Metal cover strip set
2. Horizontally-set profiled sheet
3. Vertically-set profiled sheet
4. Z section steel fixing rails
5. Thermal insulation
6. Backing wall, typically timber/metal frame with plywood facing and waterproof membrane, or concrete block
7. Vapour barrier
8. Internal finish
9. Roof, typically profiled metal sheet
10. Curved eaves profile
11. Concealed gutter
12. Exposed gutter
13. Supporting structural frame
14. Structural slab
15. Window frame
16. Metal trim to window
17. Metal parapet coping

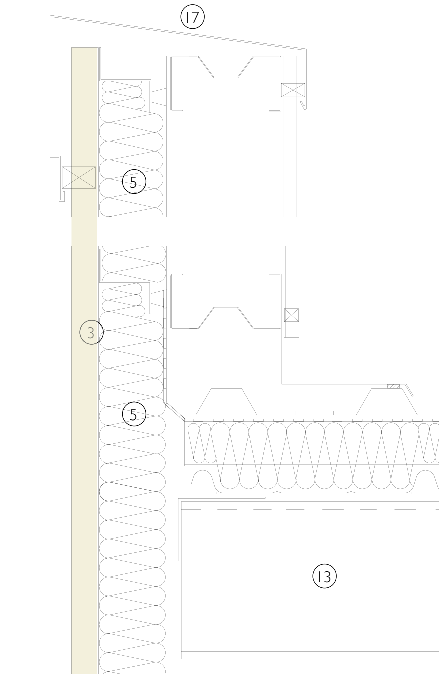
Vertical section 1:25. Vertically set profiled metal cladding with gutter

Vertical section 1:25. Vertically set profiled metal cladding with gable end

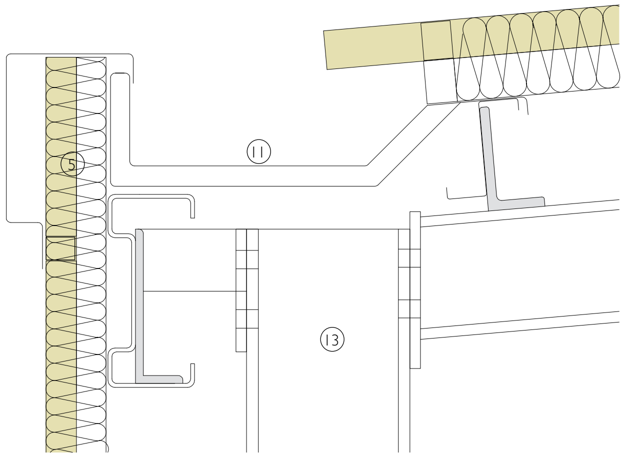
Vertical section 1:25. Horizontally set profiled metal cladding with parapet



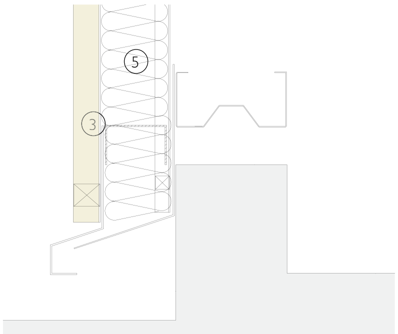
Typical profiled sheet profiles



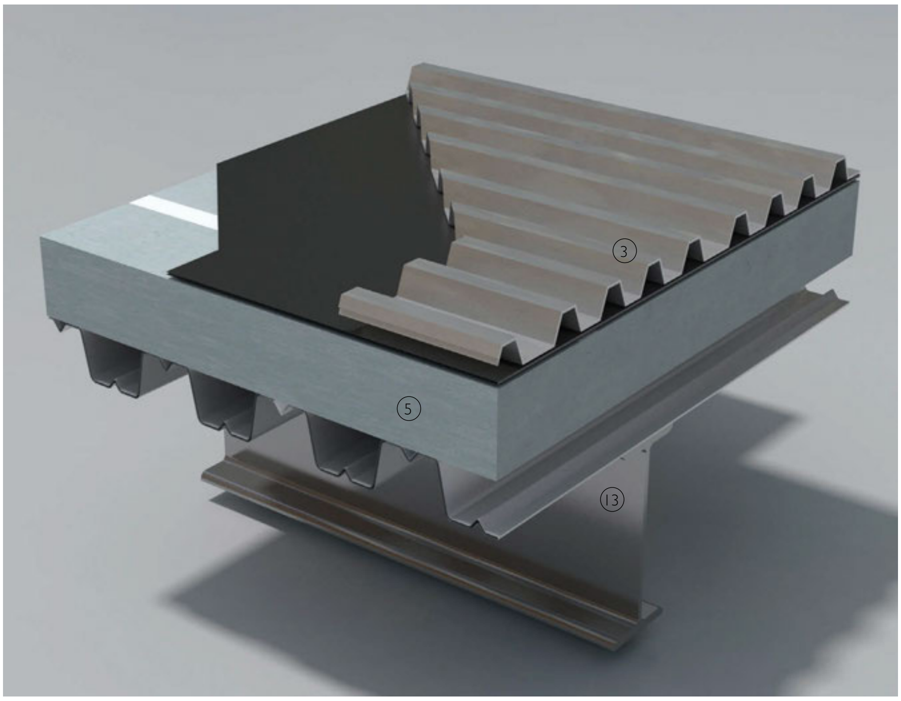
Vertical section 1:10. Parapet detail



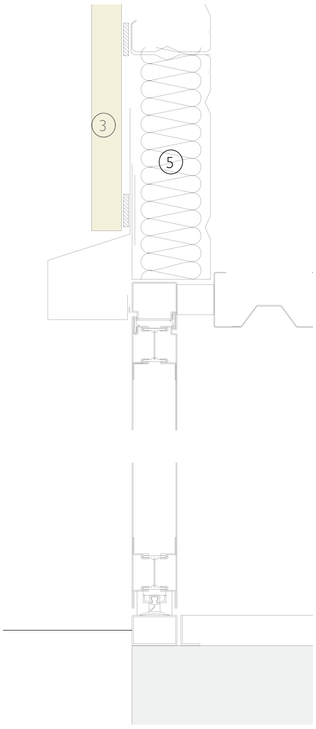
Vertical section 1:10. Gutter detail for large span enclosure



Vertical section 1:10. Ground level cill detail



3-D view of profiled metal sheet as roof material

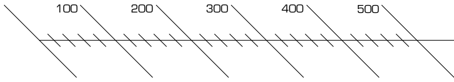


Vertical section 1:10. Metal door detail

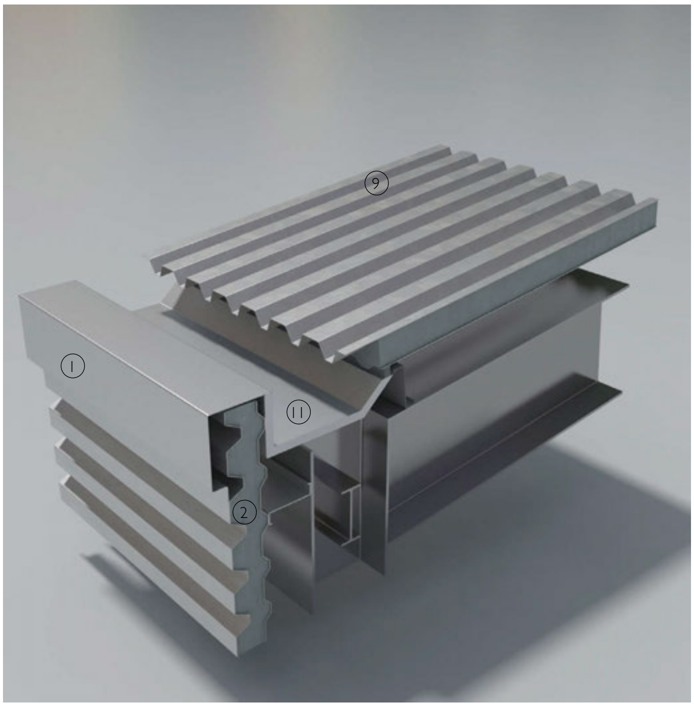
Junctions

When laid vertically, sheets are joined by lapping them by around 150mm (6in) at vertical joints. Horizontal joints are also lapped with the upper sheet set over the lower one in the traditional manner. When laid horizontally, horizontal joints are formed with laps as when laid vertically, but horizontal joints are not usually lapped in the same way. This is mainly because it is difficult to form a continuous straight line in a joint that moves in and out with the shape of the profile. Instead a recessed top hat section or projecting coverplate is used. The profiled sheet is butted up to the C-shaped section and sealed with silicone or mastic. The same principle is used for a projecting coverplate.

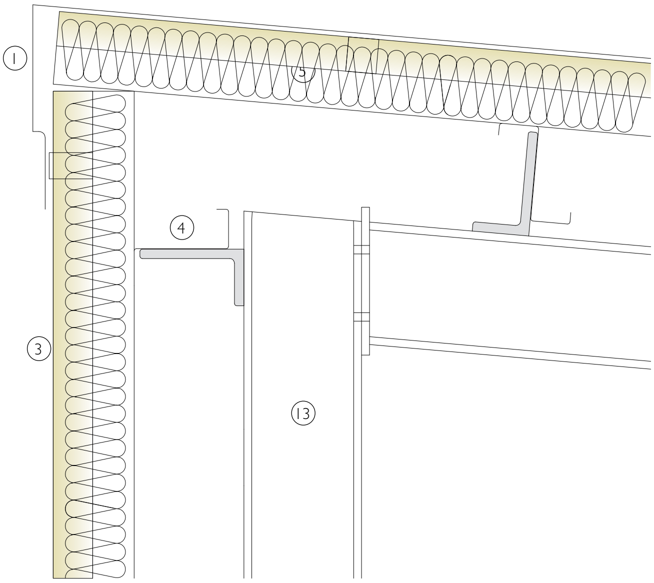
Corners are treated in a similar way. Corners to vertically- and horizontally-set cladding use projecting or recessed coverstrips. The profiled sheets that meet are lapped however, to provide a weathertight seal and the coverplate, provides both an additional seal along a potentially vulnerable joint as well as a crisp line to the corner. Regardless of sheet orientation, edging and jointing pieces are clearly visible, making them an important part of the design. Whereas profiled sheet can be lapped to give a continuous appearance on a large area of facade, the edging and jointing pieces of parapets, cills and corners are clearly visible. The visual impact of these junctions can be reduced with recessed joints. The use of curved eaves sheets and curved (in plan) corner sheets was developed to avoid the need for visible corner pieces. 90º corner sheets are now available, from some manufactur-



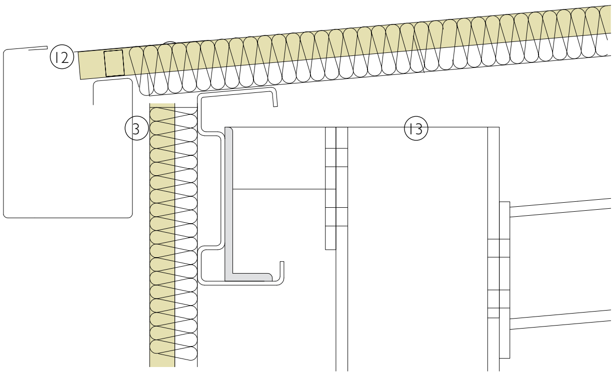
1:10 scale



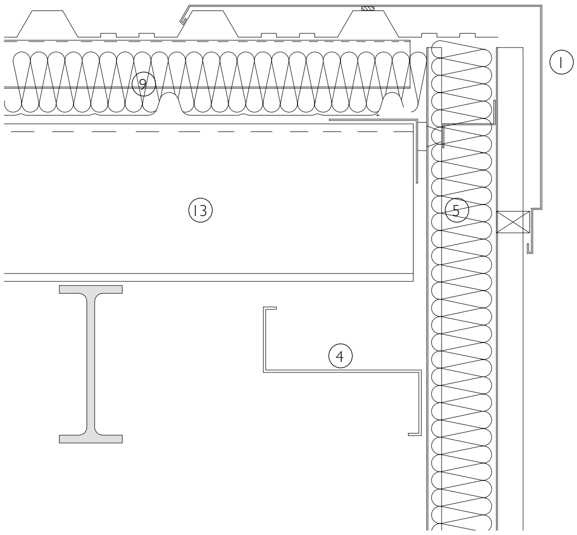
3-D view of gutter at connection between profiled metal wall and roof system



Vertical section 1:10. Sloping roof junction at gable end



Vertical section 1:10. Gable end with external metal gutter



Vertical section 1:10. Roof junction at gable end

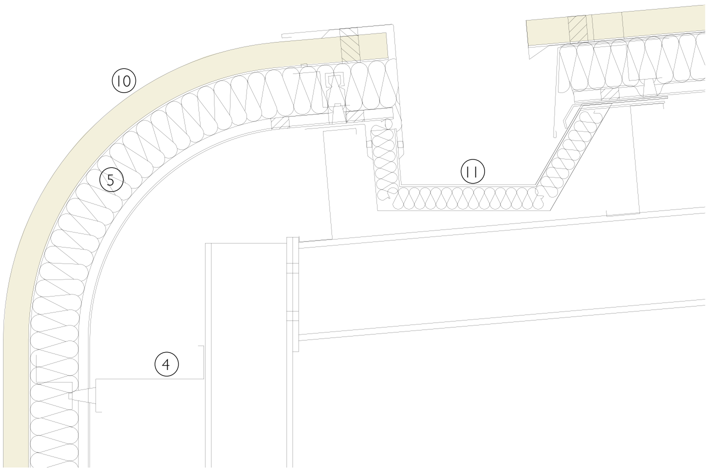
ers, that can be lapped smoothly over adjacent profiled metal sheets.

Parapets and gutters

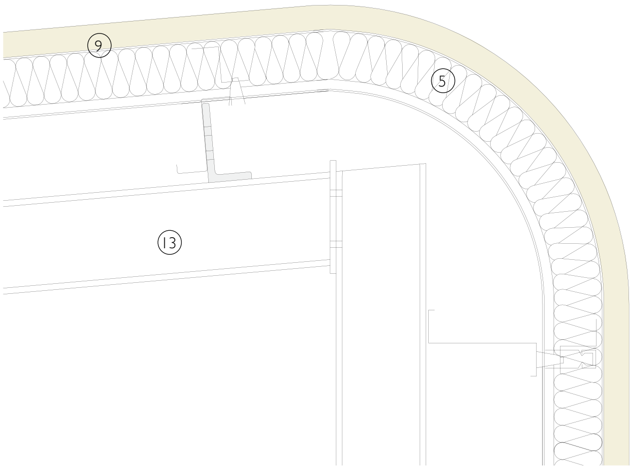
Parapets are usually formed by either projecting the profiled sheet above the roof line in order to conceal the roof completely, which is often in the same material in the case of industrial buildings. Alternatively, a low parapet is formed at the level of the intersection of wall and roof, with a recessed gutter set immediately behind the parapet. A variation on this latter solution is to use curved eaves to give the idea of complete continuity between walls and roof with only a recessed gutter creating a line between the two. The recessed gutter in any of these configurations is useful when a pitched roof is used. On the gable elevation the parapet can remain the same height while the roof rises and falls independently of the continuing line of the parapet on all sides. Curved eaves have mitred corner panels to allow a curved profile to be used continuously around a building.

Visible gutters are fixed on the outside face of the cladding. The roof projects over the top of the cladding in order to drain rainwater into the gutter, resulting in the roof visually projecting forward of the wall, unlike a parapet gutter. An advantage of this method is that rainwater is kept outside the building, avoiding the need to run vertical rainwater pipes within a building, then running rainwater back out through the foundations below ground level. Since gutters are needed only at the base of roof slopes, gutters are often not needed on all facadves, giving an uneven appear-

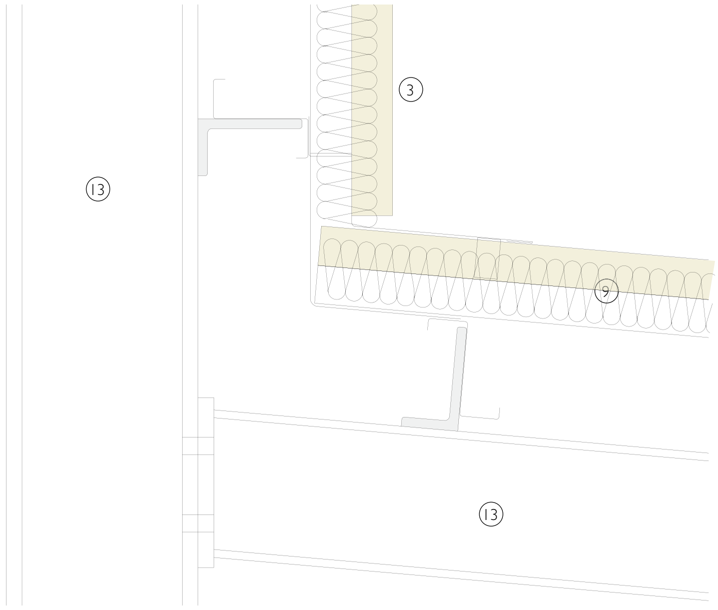
Details
1. Metal cover strip set
2. Horizontally-set profiled sheet
3. Vertically-set profiled sheet
4. Z section steel fixing rails
5. Thermal insulation
6. Backing wall, typically timber/ metal frame with plywood facing and waterproof membrane, or concrete block
7. Vapour barrier
8. Internal finish
9. Roof, typically profiled metal sheet
10. Curved eaves profile
11. Concealed gutter
12. Exposed gutter



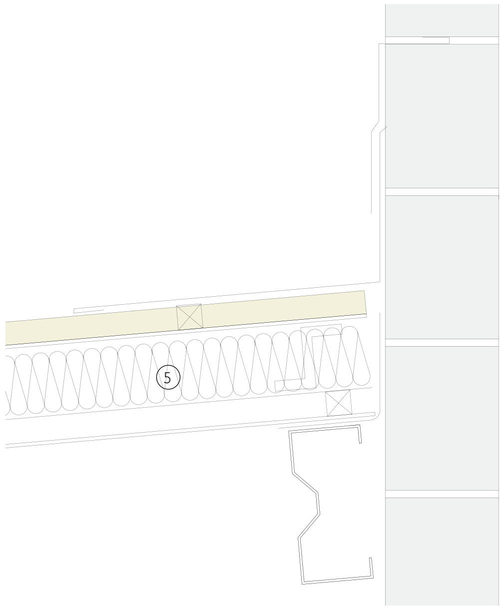
Vertical section 1:10. Curved eaves with hidden gutter



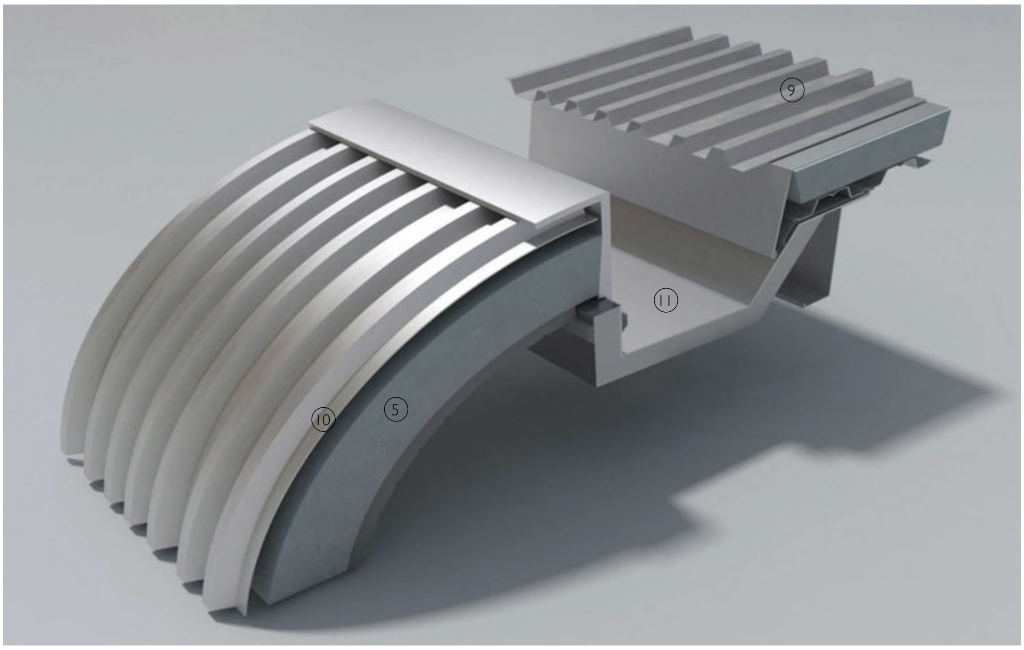
Vertical section 1:10. Curved eaves without gutter



Vertical section 1:10. Junction with roof



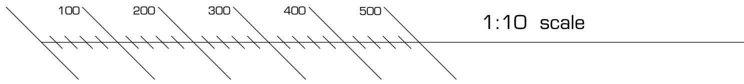
Vertical section 1:10. Roof junction at abutting wall

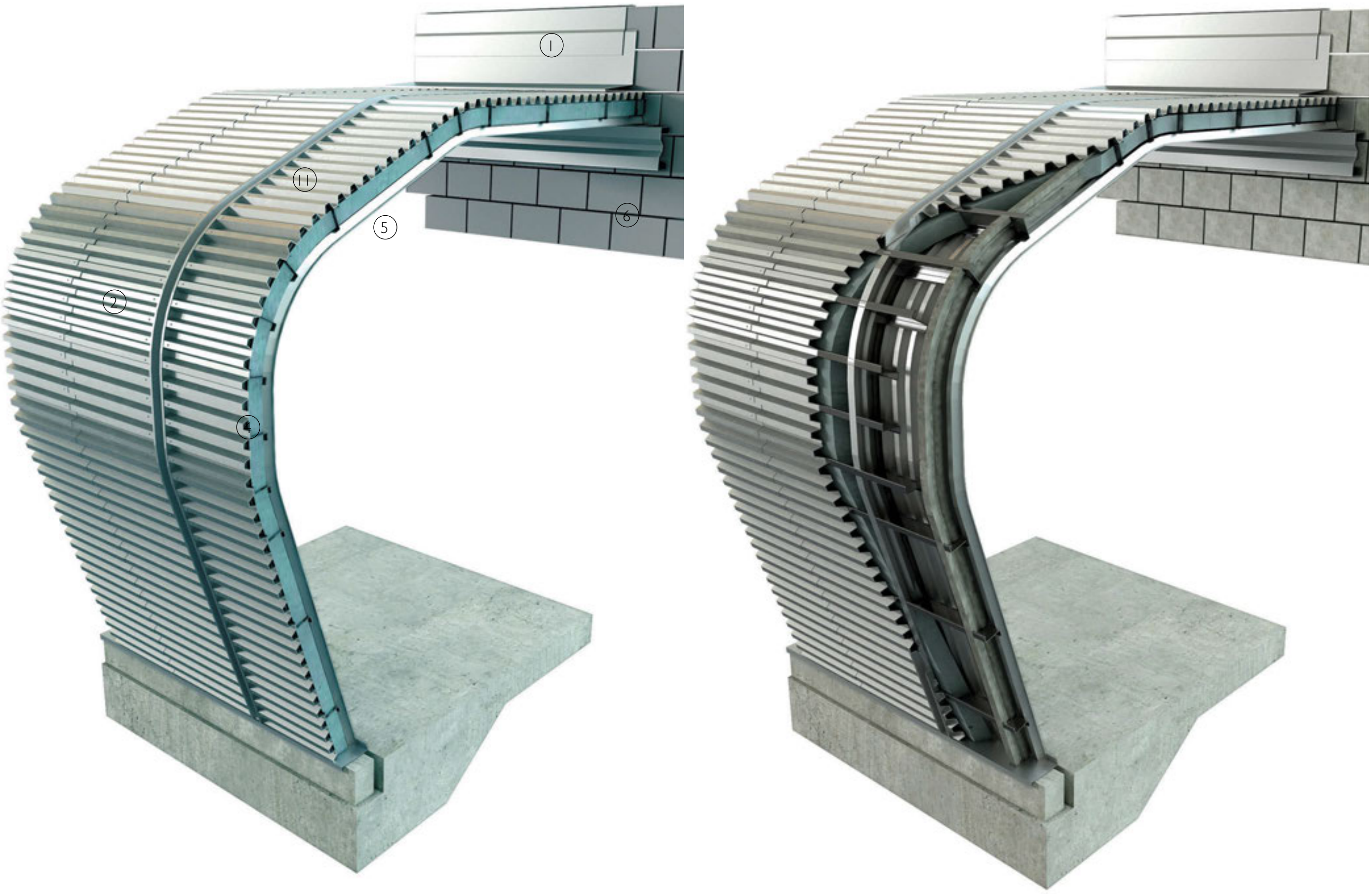


3-D view of curved eaves connection with hidden gutter

Details

1. Meal cover strip set
2. Horizontally-set profiled sheet
3. Vertically-set profiled sheet
4. Z section steel fixing rails
5. Thermal insulation
6. Backing wall, typically timber/metal frame with plywood facing and waterproof membrane, or concrete block
7. Vapour barrier
8. Internal finish
9. Roof, typically profiled metal sheet
10. Curved eaves profile
11. Concealed gutter
12. Exposed gutter
13. Supporting structural frame
14. Structural slab
15. Window frame
16. Metal trim to window
17. Metal parapet coping





3-D view and cut-away of profiled metal sheet assembly with gutter

ance to the building. A solution to making gutters work on all facades is to design a hipped roof that drains equally into all gutters, but this can complicate roof design. Gutters require support by brackets back to primary structure in order to support the weight of water when in use. The supporting brackets usually need to penetrate the cladding, requiring seals around the penetrations in order to make them weathertight. If the roof construction is required to be ventilated then the depth of the gutter will increase if the roof is intended to be hidden from view. Deep gutters have a strong visual presence on the facade.

Window and door openings

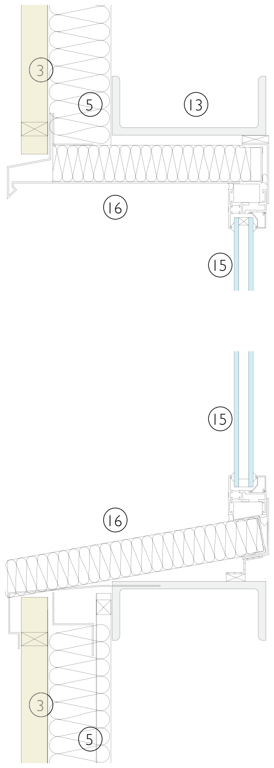
The reveals for windows and doors are formed in flat metal sheet, usually the same metal and same colour as the profiled sheeting. In practice the colour matching can be difficult if the coating (usually polyester powder coating or PVDF) is applied in different workshops or by different coating applicators. Contrasting colours are sometimes chosen for this reason. This is also true of window sections, which are usually supplied predated by a different manufacturer. Close co-ordination is needed between contractors to ensure a consistent colour throughout the project. An alternative approach is to reduce reveals to a small depth and use a colour for the windows different from that of the adjacent cladding. For example, with a silver metallic finish for cladding, a darker grey might be used for window frames without creating any contrast between the two colours used.

Cills are formed in pressed metal which is inclined to drain water from its horizontal surface and has a projecting drip to avoid dirt, washed off the cill, running onto the cladding below, which would cause staining. Some drips have rising edges at the sides to avoid water running off at the sides that causes streaking in lines below the edges of the openings. Cills at ground level or at the base of the cladding are either flush or projecting, to suit visual requirements. As with sheet metal cladding, the cill is usually reinforced both to ensure it lies in a straight line and protect it from accidental damage.

Insulation and liner trays

Although profiled metal sheet is capable of long vertical spans, the thermal insulation and internal finish material require additional support. The insulation cannot be fixed directly to the metal sheet without being bonded to it. Fixing brackets to the profiled sheet would involve penetrating the sheet, creating a possible point for water ingress. Welding a support bracket would be both expensive and easily distort the surface of the cladding. Bonding the insulation to the liner would be the next practical method, but this is done as a composite panel, which has constraints and is dealt with in the next section.

Flexible insulation quilt is fixed to intermediary sheeting rails that are also used to support an inner metal lining sheet. Sheeting rails are made from pressed steel sections. Since the lining sheets are usually flat, to create a smooth finish within the building, they do not span very far and require sheeting rails set at close centres.



Vertical section 1:10. Aluminium window recessed into profiled metal cladding system

3-D views of head and cill details of recessed aluminium window in profiled metal facade

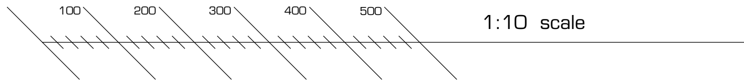
3-D view of recessed aluminium window in profiled metal facade

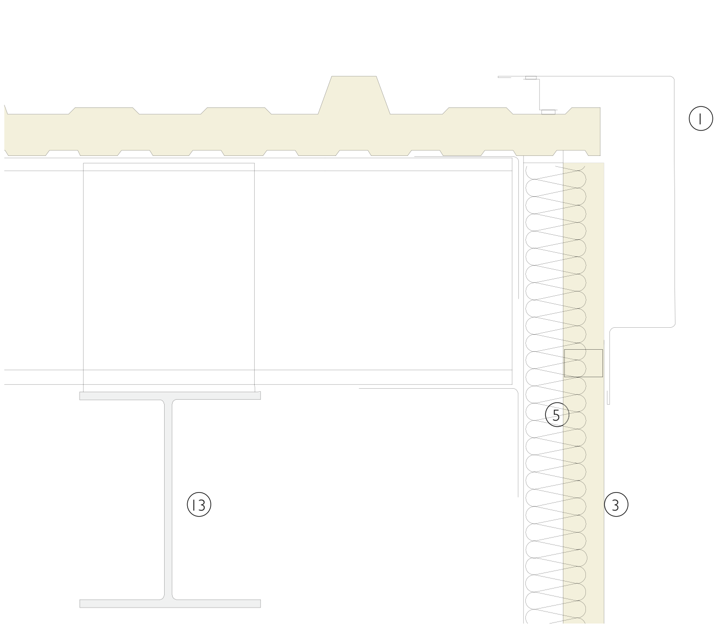
The rails can be used to give additional rigidity to the outer profiled sheet, but this requires penetrating the sheet with screw fixings which are sealed from the outside with plastic caps and washers.

An inner lining tray can also be formed from the same metal profiled sheet, as used in warehouse buildings where a smooth inner wall finish is not needed. Some intermediary sheeting rails are still required to support the thermal insulation. A more economic form of lining wall that does not interfere with the outer profiled cladding is concrete blockwork. In this instance, closed cell thermal insulation is fixed to the outside face of the wall.

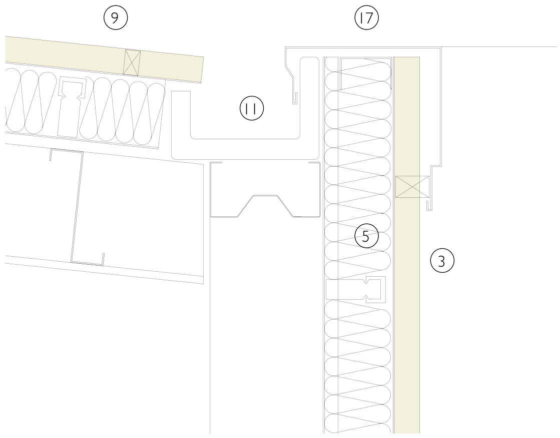
Developments

The range of profile types is steadily increasing, with wider, deeper profiles that were originally designed for use as roof decking being used as wall cladding. However, some of the interlocking types used on roofs are not suited to cladding since the standing seam joint, which is not designed to be tightly folded together, does not work when set in the vertical plane. This principle is also true of wall cladding types which are lapped and are not suited to use in roofs, where the seam is not high enough to be submerged under water during rain. A recent development has been the use of flat metal rainscreen panels fixed directly to a profiled sheet. This provides a smooth finish visually to the outside face of the cladding, while maintaining the economy and structural efficiency of the profiled sheet. Although the outer metal panel is fixed to the profiled sheet with screws or rivets that penetrate it, the pin jointed rainscreen configuration protects the fixings from the worst effects of windblown rain.

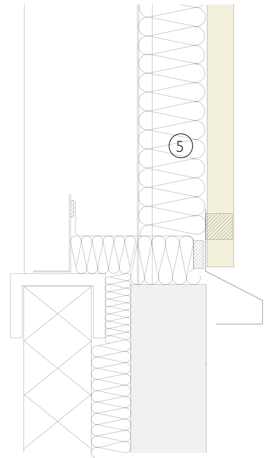




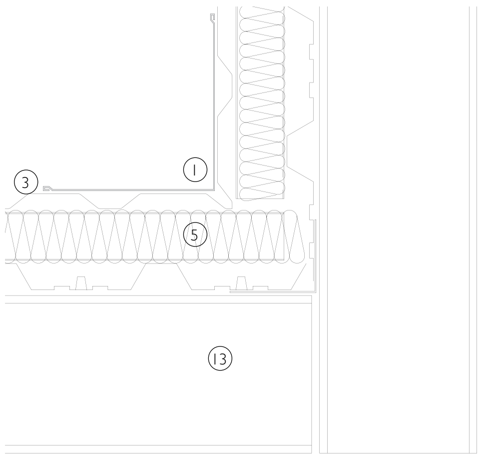
Vertical section 1:10. Roof connection to composite metal roof system



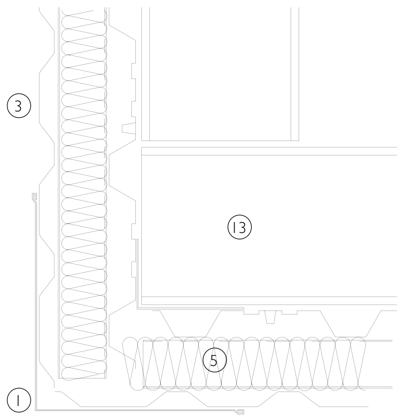
Vertical section 1:10. Gutter detail for small span enclosure



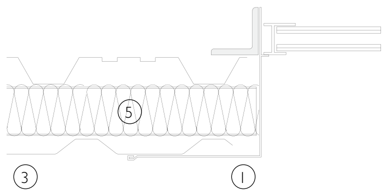
Vertical section 1:10. Cill connection to concrete upstand



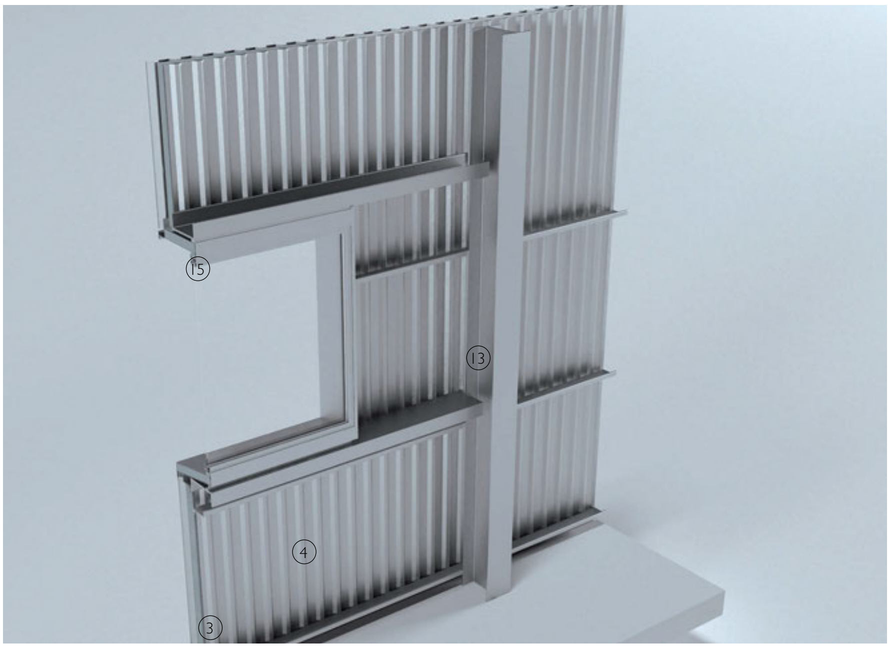
Horizontal section 1:10. Internal corner



Horizontal section 1:10. External corner



Horizontal section 1:10. Connection to metal door



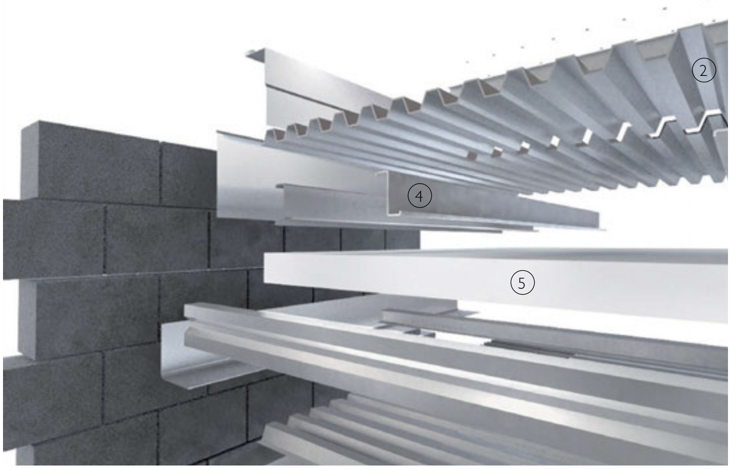
3-D view of rear of recessed aluminium window in profiled metal facade

Details
1. Metal cover strip set
2. Horizontally-set profiled sheet
3. Vertically-set profiled sheet
4. Z section steel fixing rails
5. Thermal insulation
6. Backing wall, typically timber/ metal frame with plywood facing and waterproof membrane, or concrete block
7. Vapour barrier
8. Internal finish
9. Roof, typically profiled metal sheet
10. Curved eaves profile
11. Concealed gutter
12. Exposed gutter
13. Supporting structural frame
14. Structural slab
15. Window frame
16. Metal trim to window
17. Metal parapet coping

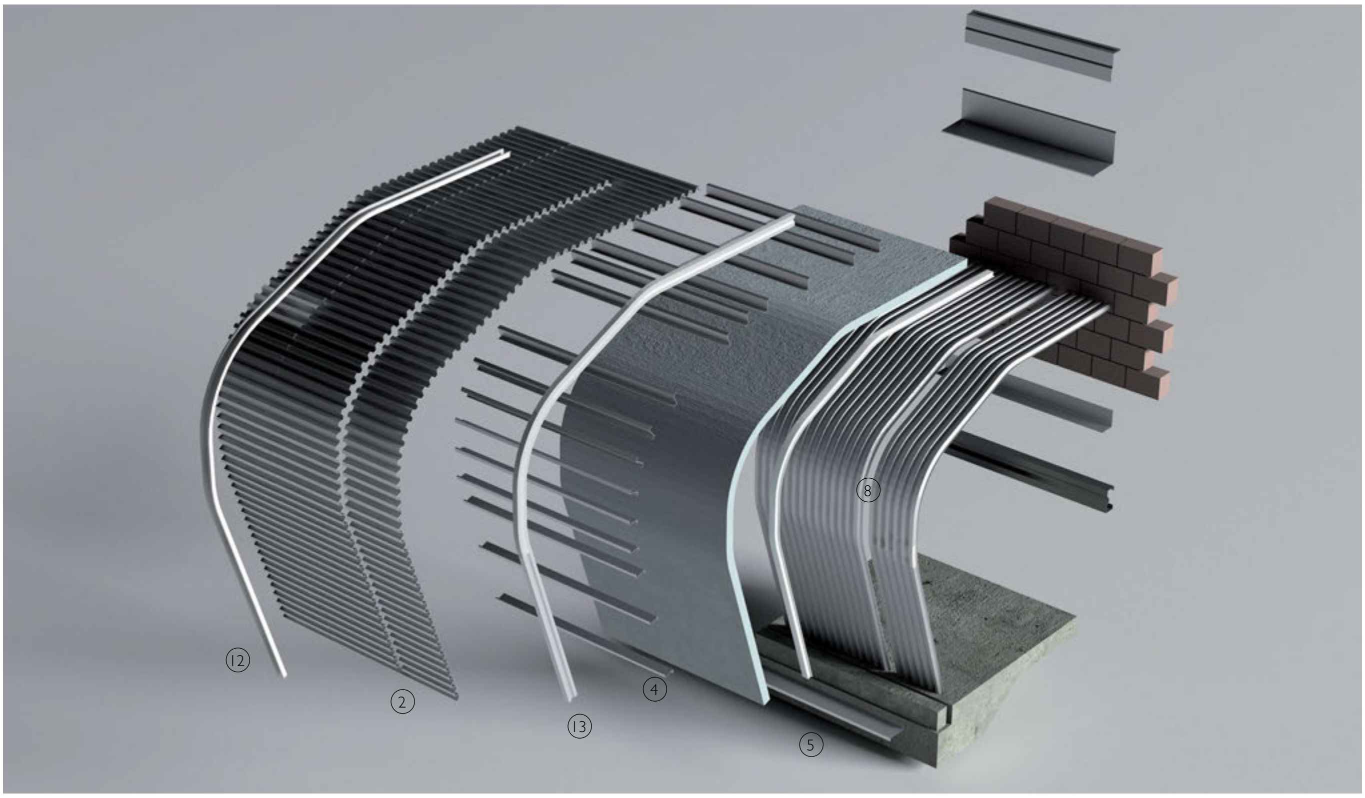
3-D detail view of profiled metal sheet connection to blockwork wall

Details
1. Metal cover strip set
2. Horizontally-set profiled sheet
3. Vertically-set profiled sheet
4. Z section steel fixing rails
5. Thermal insulation
6. Backing wall, typically timber/metal frame with plywood facing and waterproof membrane, or concrete block
7. Vapour barrier
8. Internal finish
9. Roof, typically profiled metal sheet
10. Curved eaves profile
11. Concealed gutter
12. Exposed gutter
13. Supporting structural frame
14. Structural slab
15. Window frame
16. Metal trim to window
17. Metal parapet coping

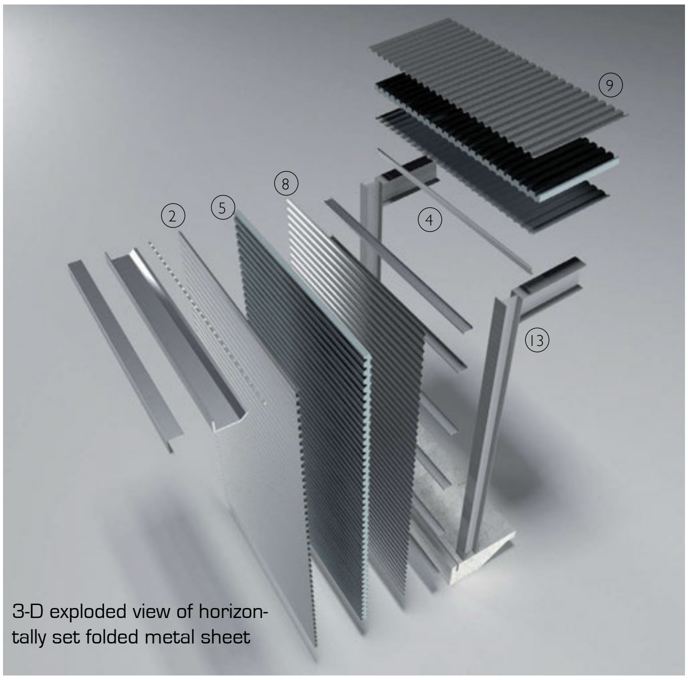
3-D detail view of profiled metal sheet with gutter



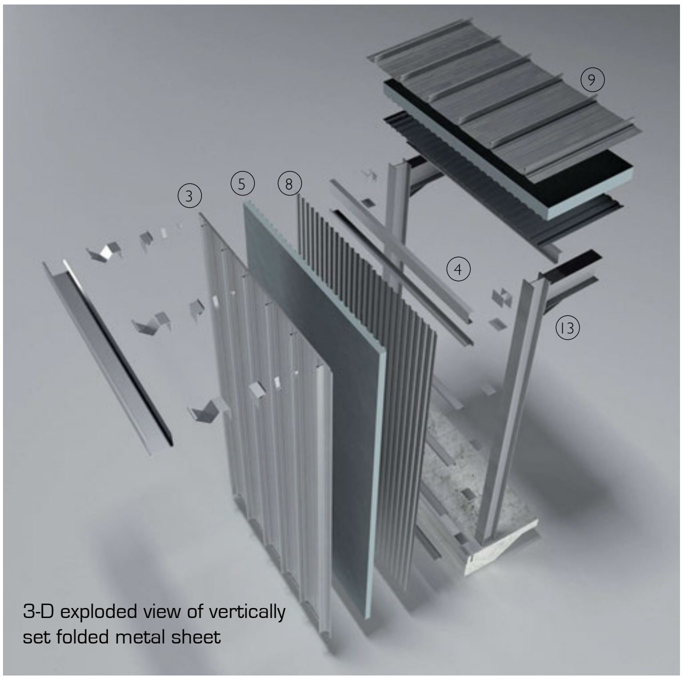
3-D exploded detail view of profiled metal sheet connection to blockwork wall



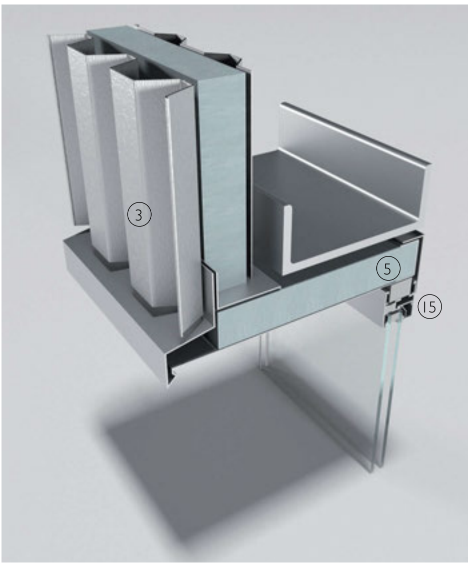
3-D exploded view of profiled metal sheet assembly with gutter

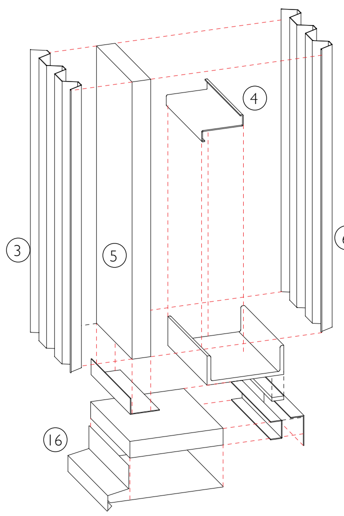


3-D exploded view of horizontally set folded metal sheet

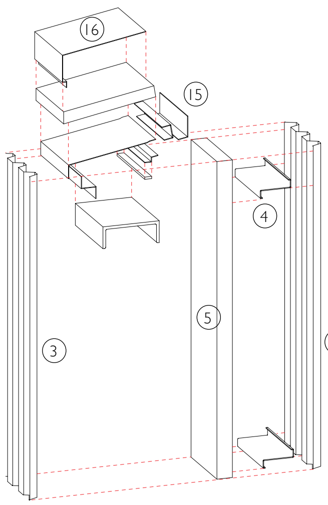


3-D exploded view of vertically set folded metal sheet





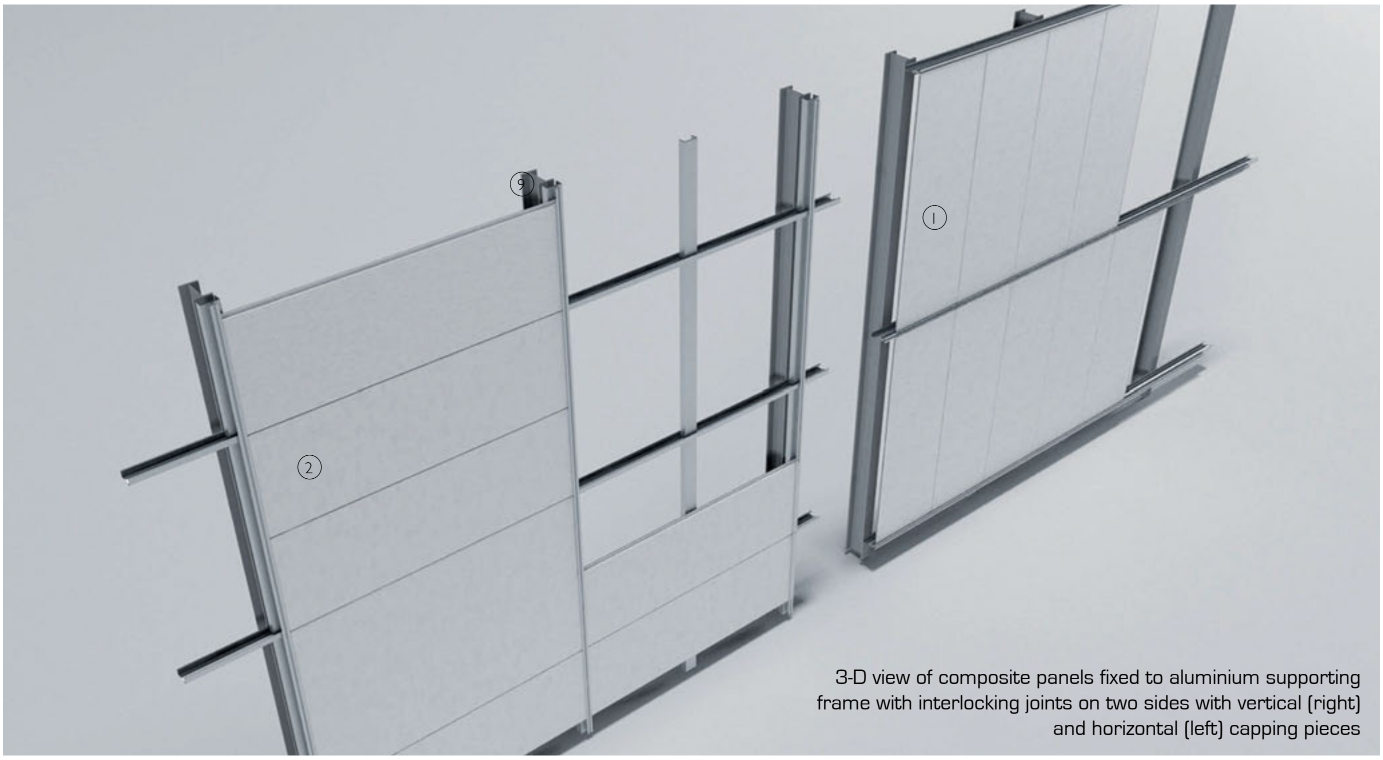
3-D view and exploded axonometric of window head detail



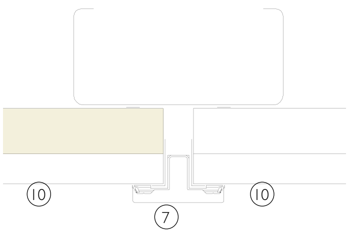
3-D section of recessed aluminium window in profiled metal facade

3-D section of recessed aluminium window in profiled metal facade

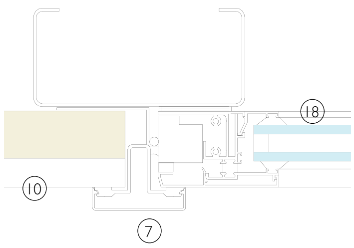
3-D view and exploded axonometric of window cill detail



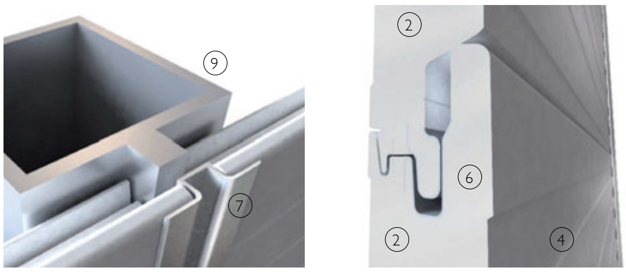
3-D view of composite panels fixed to aluminium supporting frame with interlocking joints on two sides with vertical (right) and horizontal (left) capping pieces



Horizontal section 1:5. Panel to panel connection with visible cap



Horizontal section 1:5. Panel to window connection with visible cap



3-D views of profiled composite panel fixed to steel and of horizontal interlocking joint between profiled composite metal panels.

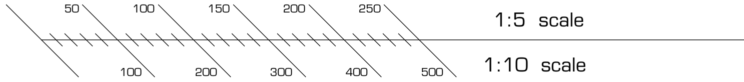
Composite metal panels require fewer components than for the 'kit of parts' used in the assembly of profiled metal cladding. Like profiled metal, panels are set either vertically or horizontally. Some panels interlock on two sides, while others interlock on four sides. Four-sided panels require no separate interface components for jointing but it is more difficult later to remove a damaged panel.

Horizontally-set composite panels can be easily integrated with ribbon windows and suit building facades covering several floors. Panels are stacked one above the other with their vertical joints closed by rubber-based gaskets, recessed channel sections in aluminium, or projecting coverstrips in aluminium. Panels are fixed back to the primary structure or on a secondary steel frame, typically box sections, fixed to the sides of floor slabs if columns are spaced too far apart or columns are not positioned on the edge of floor slabs.

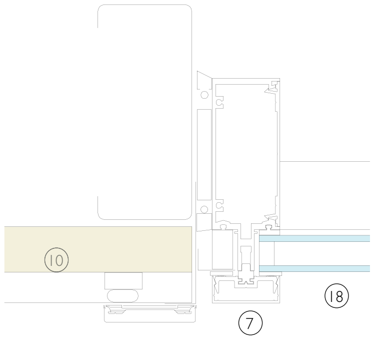
Where windows are used in a facade, additional support is needed to frame the opening. This is because windows are not supported by the composite panels except where made specifically as part of a proprietary system. In practice, windows are usually supplied by a specialist manufacturer.

The steel support framing is set on the face of the slab, making it easier to take up deflections in floor slabs. However, as is the case with curtain walling, the gap between composite panel and floor slab needs filling with a smoke seal or fire barrier. The floor finish usually has a metal angle to close off the gap at slab level and at the soffit level below. Four-sided interlocking panels use the same principle for fixing on all four sides. This also makes it easier to integrate windows within the system since a window panel is locked in like any other panel.

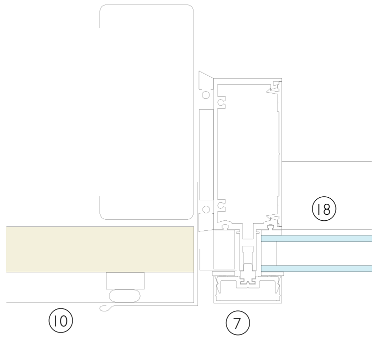
Vertically-set composite panels are more common in single storey applications, but multi-storey applications are used increasingly. Panels are interlocked at vertical joints, while horizontal joints are formed by using a cill-type detail similar to that used in a transition from vertical panel to low pitched roof. A cill in extruded or folded aluminium or steel (depending on which metal is used for the composite panel faces) is used. The front of the trim projects beyond the face of the cladding to throw water clear and prevent staining to panels below. The back of the drip projects up the back of the upper panel to prevent water from penetrating the joint. Panels are also supported on either an interlocking frame or occasionally they span between columns if panels are stiff enough to span unassisted. An additional method of fixing panels is to position them between floor slabs spanning from floor to ceiling when used as part of a rainscreen system. Panels sit on the floor slab with their outer face flush with the edge of the slab. The outer rainscreen is set forward of the composite panel, concealing both the panels and the edge of the floor slab.



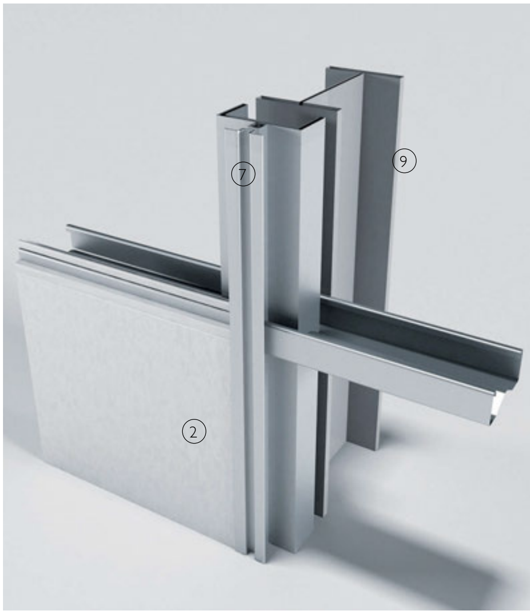
Details
1. Vertically-set composite panel
2. Horizontally-set composite panel
3. Silicone-based seal
4. Outer metal facing
5. Inner metal facing
6. Inner insulation core
7. Metal capping
8. Concealed fixing
9. Supporting structure
10. 4-way interlocking composite panel
11. Window frame
12. Sectional roller shutter formed from composite panels
13. Roof construction, composite panels are shown
14. Metal trim
15. Exposed gutter
16. Concealed gutter
17. Metal parapet coping
18. Stick glazed curtain walling
19. Door frame



Horizontal section 1:5. Connection between composite panel and curtain wall type glazing with cap

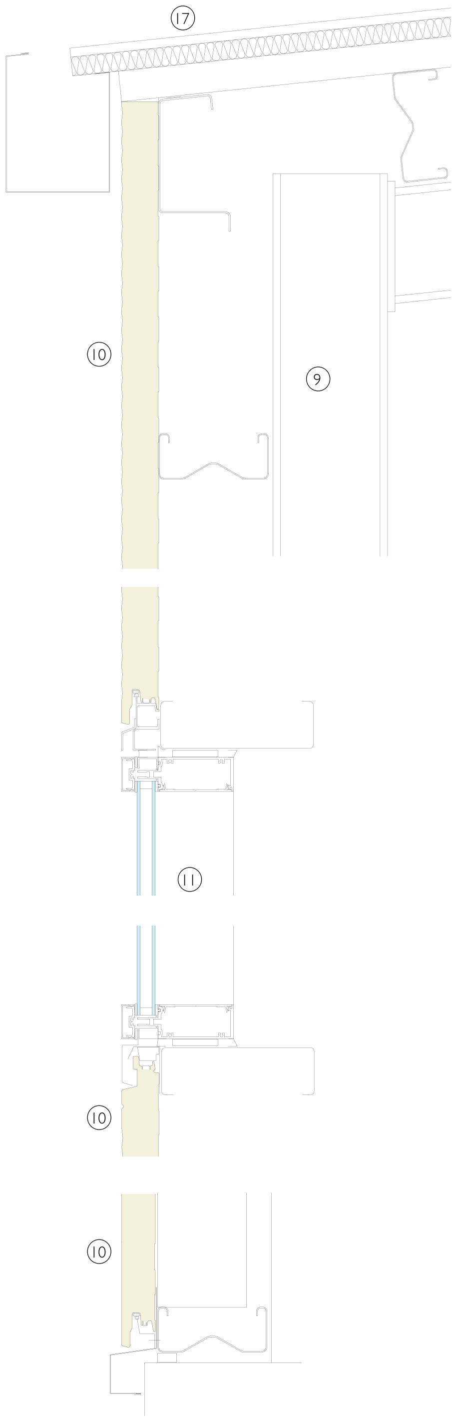


Horizontal section 1:5. Connection between composite panel and curtain wall type glazing with metal flashing

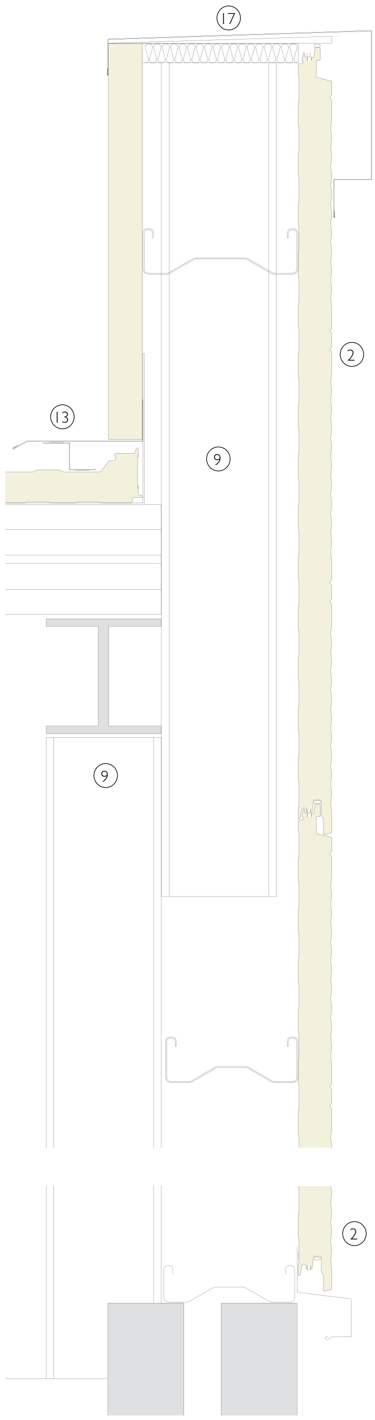


3-D view of framework supporting composite panels interlocking horizontally with vertical capping piece

3-D view of framework supporting composite panels interlocking horizontally with vertical capping piece



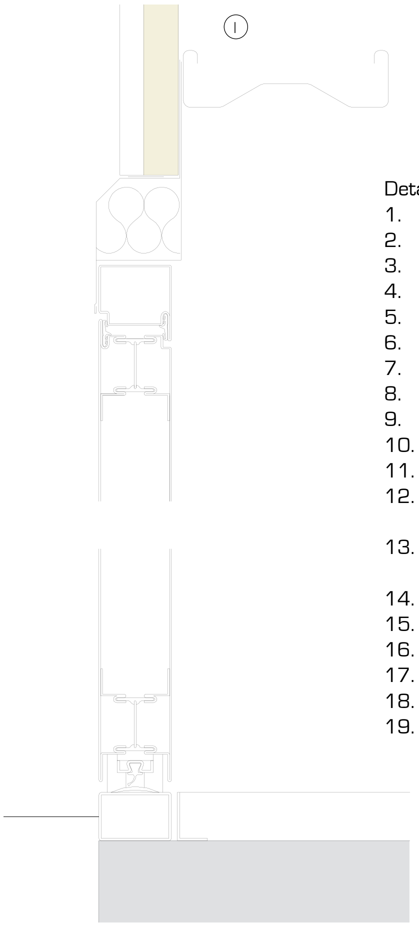
Vertical section 1:10. Parapet and cill with curtain walling type window set into cladding. Typical in industrial applications



Vertical section 1:10. Parapet and ground level cill

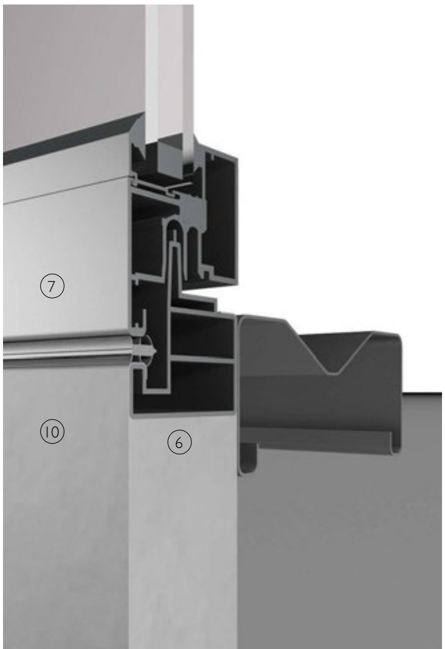
3-D view of concealed gutter detail

3-D view of junction with ground slab



Vertical section 1:5. Metal door set flush with face of composite metal panel

Details
1. Vertically-set composite panel
2. Horizontally-set composite panel
3. Silicone-based seal
4. Outer metal facing
5. Inner metal facing
6. Inner insulation core
7. Metal capping
8. Concealed fixing
9. Supporting structure
10. 4-way interlocking composite panel
11. Window frame
12. Sectional roller shutter formed from composite panels
13. Roof construction, composite panels are shown
14. Metal trim
15. Exposed gutter
16. Concealed gutter
17. Metal parapet coping
18. Stick glazed curtain walling
19. Door frame



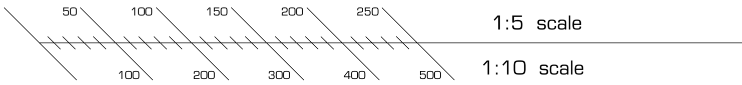
3-D view of junction with window frame

Interlocking vertically-set panels are of several types, unlike horizontally-set types, which have a stepped joint to avoid rainwater penetration. The most common type for vertical joints is also a stepped joint with a recess on the outer face. An alternative is to have projecting nibs on the sides of the panel to which a cover-plate is fixed over the gap between the two panels. Rubber-based seals are set into the depths of all these joint types. Another joint is a C-shaped channel profile which interlocks with the profile of the adjacent panel. The outside face of the panel has a slightly projecting edge instead of a recessed joint in the stepped joint types.

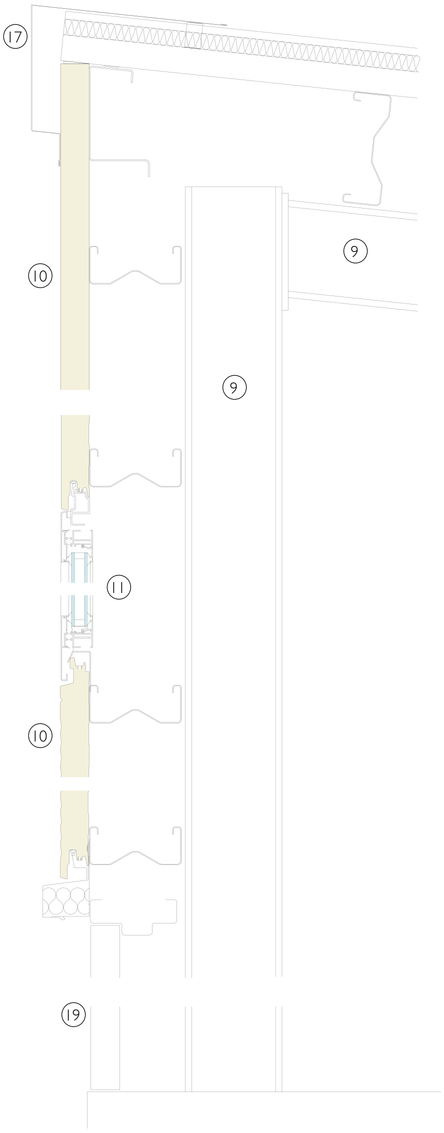
All these panel types use jointing methods that avoid thermal bridges. Drips often penetrate from outside but the low condensation risk is assessed during the design stage.

Parapets and cills

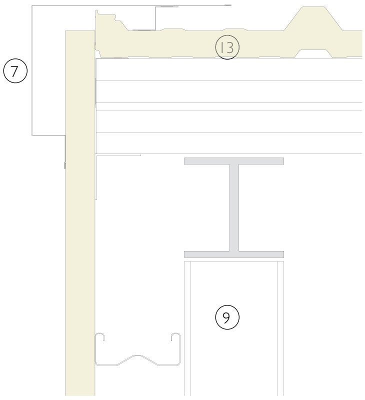
Parapet copings and drips at ground level can also be made as composite panels, forming an integrated part of a proprietary system. This can be an advantage when seeking a seamless effect across a facade, but sets limitations on the variety of junctions (in terms of width and height) at parapet and base due to the need for repetition in specially made panels. A large number of different panel types cannot be produced economically for a single project. Although folded metal flashings and extrusions can appear more visually intrusive than a specially made composite panel, this method is far more flexible for dealing with varied parapet and



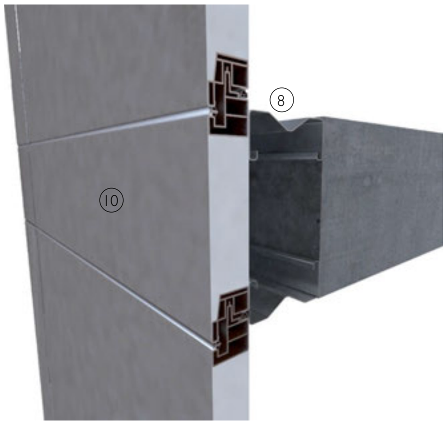
3-D view of composite panel facade assembly with flush glazing and concealed parapet



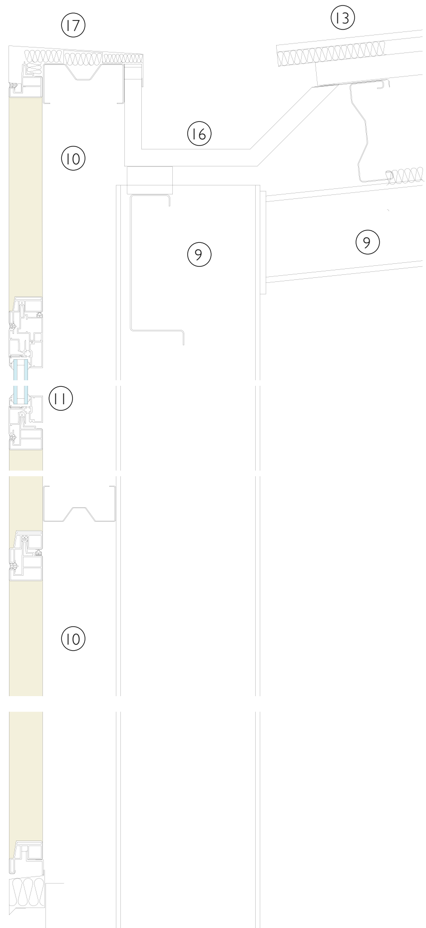
Vertical section 1:10. Integrated parapet, window and doors all flush with face of composite panels.



Vertical section 1:10. Cross section through roof with integrated parapet



3-D view of spandrel panel connection



Vertical section 1:10. Junction with roof including concealed gutter. Integrated windows flush with face of composite panels

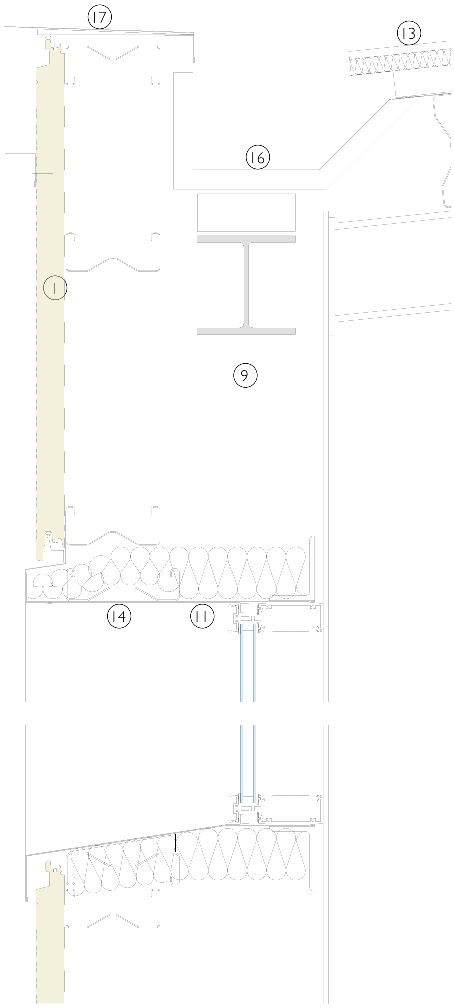
ground level junctions, particularly for complex junctions.

Like fully supported sheet metal facades, parapets can be set either level with the roof, to create a continuous smooth envelope, or be stepped to allow the roof profile to be concealed. The same principles apply as those for continuously supported sheet metal parapets and cills.

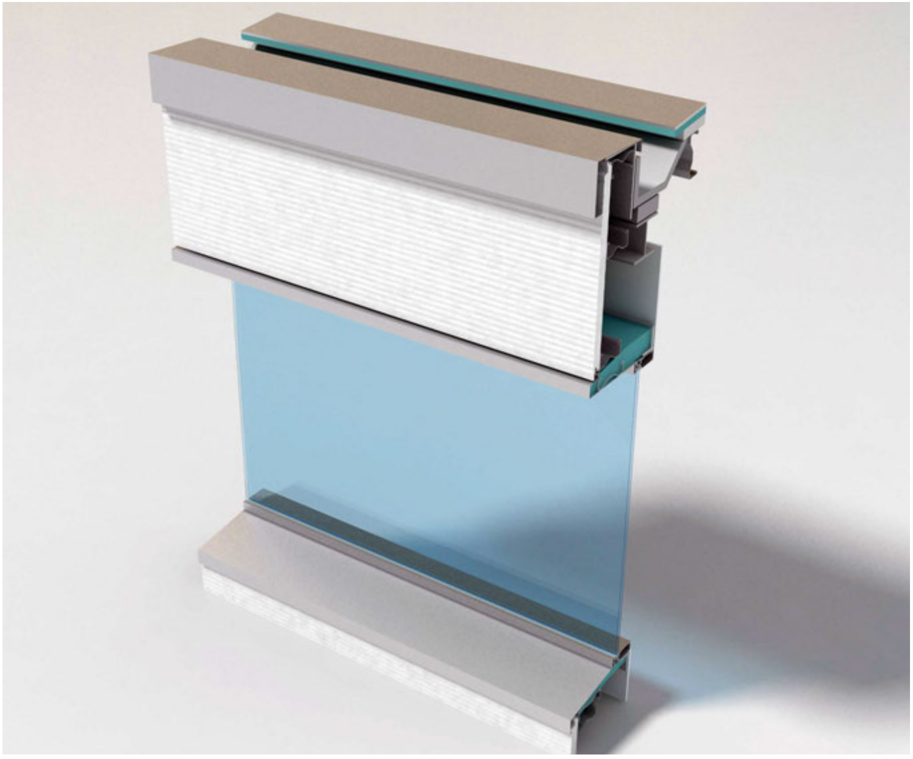
Windows and door openings

There are two methods of creating an opening in a composite panel for both horizontally- and vertically-set panels. The first method is a special reveal panel that interlocks with the composite panels. With vertically-set panels the window interlocks into vertical joints and has coverstrips on horizontal joints. Where horizontally-set panels are used, the window interlocks with the horizontal joints and has coverstrips applied on the vertical joints. The second method is to use metal sheet to form a reveal. A single sheet of metal, 1200 or 1500mm wide coil (4ft or 5ft), is fixed to a light gauge steel frame which is insulated. The inner framed wall has a vapour barrier and an inner metal sheet, usually matching the adjacent inner face of the panels.

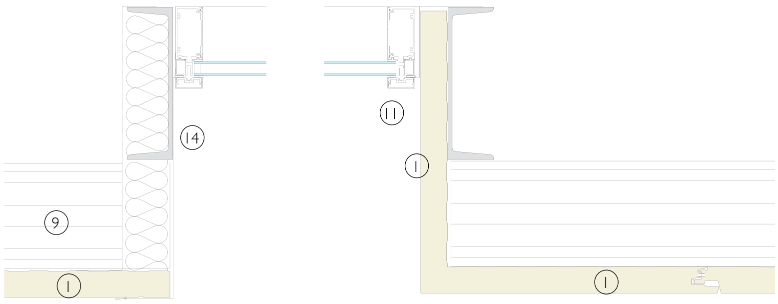
Heads and cills of openings are formed in the same way with either a purpose-made corner panel (the cill is an inclined surface) or with sheet metal and thermal insulation. However, the lightweight metal frame is not usually fixed back to the composite in order to avoid penetrating either outer or inner face of the panels. Instead it is fixed back to a floor slab or to the primary structure.



Vertical section 1:10. Parapet with concealed gutter and curtain wall type window recessed with deep metal reveal.



3-D view of composite panel curtain wall with recessed window with deep metal reveal, with cill and gutter detail



Horizontal section 1:10. Door jamb with metal sheet forming panel in door reveal.

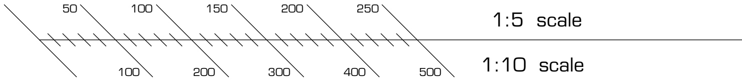
Details
1. Vertically-set composite panel
2. Horizontally-set composite panel
3. Silicone-based seal
4. Outer metal facing
5. Inner metal facing
6. Inner insulation core
7. Metal capping
8. Concealed fixing
9. Supporting structure
10. 4-way interlocking composite panel
11. Window frame
12. Sectional roller shutter formed from composite panels
13. Roof construction, composite panels are shown
14. Metal trim
15. Exposed gutter
16. Concealed gutter
17. Metal parapet coping
18. Stick glazed curtain walling
19. Door frame

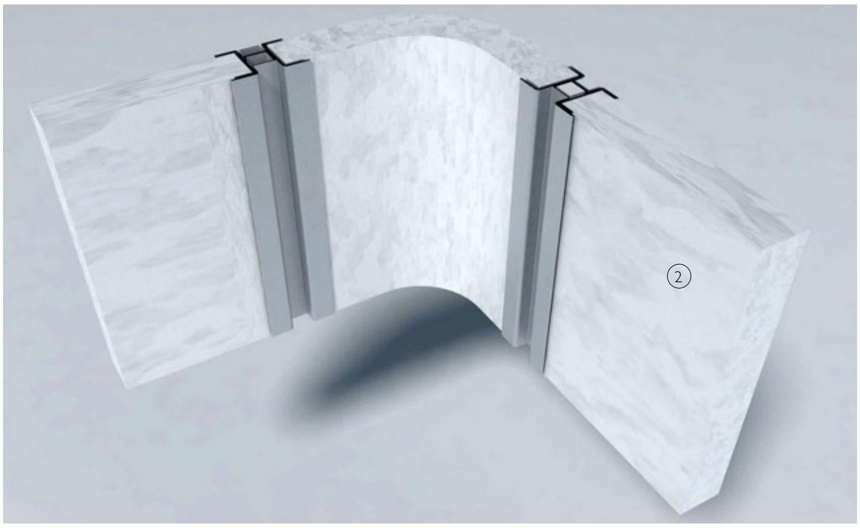
Since the inclusion of reveals is not really in the nature of composite panel detailing, and the wall has little depth, the additional frame is also used to support the window, typically aluminium framed with a thermal break and double glazed units. More often, windows and doors are fixed with the outer face of the glass or door aligned with the outer face of the adjacent composite panels. An alternative form of glazing to windows and doors is to use curtain walling. Thermally broken stick systems are fixed directly against the adjacent composite panels with a seal set against the primary structure forming the opening (typically vertical sheeting rails). If horizontally-set panels are used, then the curtain walling can be sealed against adjacent composite panels with a vertical cover strip used for all vertical joints.

Where many windows are required at a particular height on a facade, as when providing light into an upper floor, it is common to create a continuous ribbon of windows to avoid small infills of composite panels between windows. The continuous line of windows is fixed back to a secondary frame of steel box sections, which may be exposed in the building or be concealed behind an inner finish such as a plasterboard lining. Continuous windows can also be glazed into horizontally-set panels interlocking on two sides, or four-sided panels. This can avoid the need for additional support framing. In this instance the windows are braced back in the same way as the composite panels.

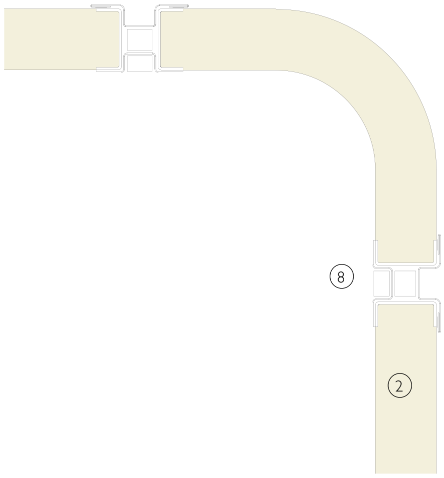
Developments

The use of composite metal panels is increasing into building types beyond

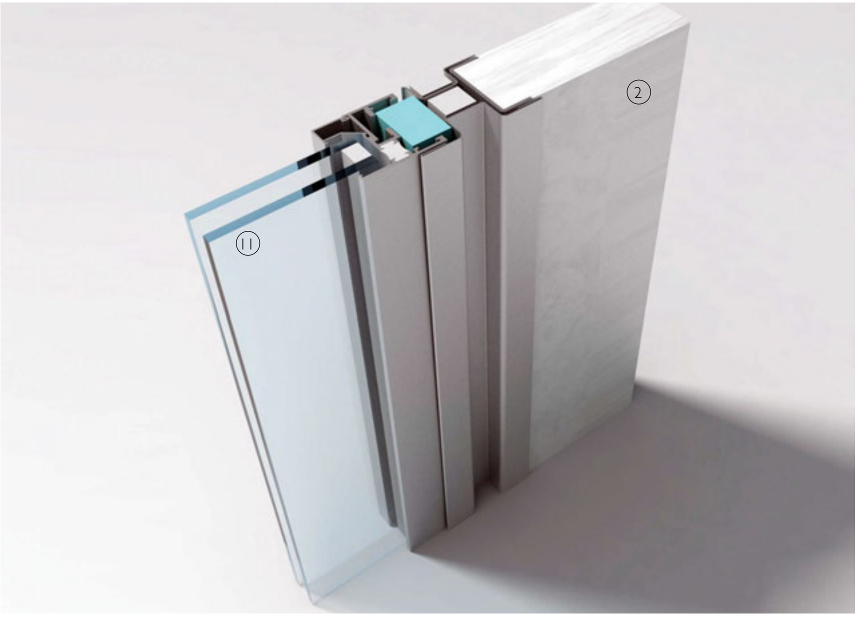




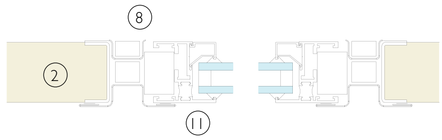
3-D view of curved internal corner panel with partially interlocking joints



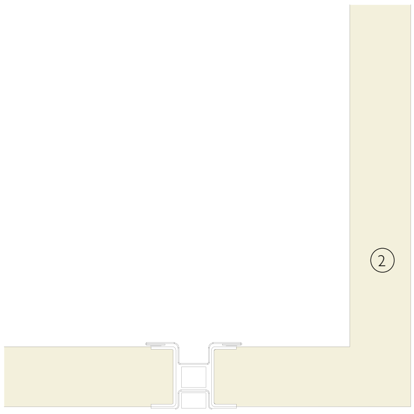
Horizontal section 1:5. Partially interlocking curved internal corner



3-D view of partially interlocking joint between composite panel and window



Horizontal section 1:5. Partially interlocking connection between composite metal panel and window

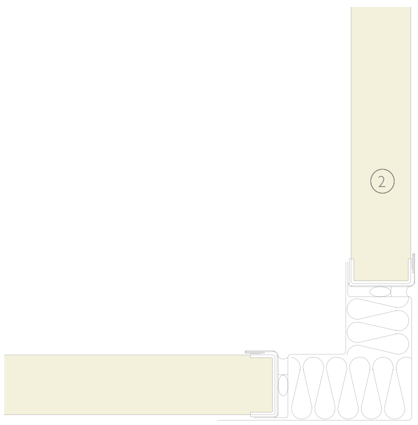


Horizontal section 1:5. Partially interlocking external corner

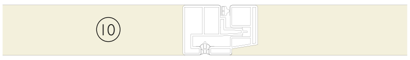
industrial buildings, into office buildings and sports facilities. In the case of office buildings, they provide an economic spandrel panel where curtain walling is not always effective. In sports facilities, composite panels enclose large indoor spaces with a durable, crisply-made and relatively economic cladding system. Although the appearance of the external face is smooth and gridded, the supporting structure is visible and usually set on the inside face to avoid penetrations to the outside through the joints between panels. If the exposed structure is enclosed with an economic lining wall concealing the structure, this additional element can add considerable cost to the cladding, making it much less economic.

For this reason, supporting structure that is designed to be seen, such as tubular steel posts, is increasingly used. The composite panels span between steel posts or trusses with little or no interlocking supporting structure. In order to keep the supporting structure as visually elegant as possible, trusses or posts are spaced as far apart as possible. This has led to panels getting longer, with a maximum length currently around 15 metres (49ft). Some proprietary systems include edges to panels which are deeper, making the continuous vertical joints and horizontal joints more rigid, allowing them to span greater distances, and thus reducing the amount of visible supporting structure needed.

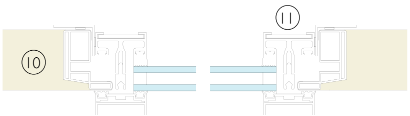
Increasingly, window openings need not be dictated by the direction in which panels are laid. Horizontally-set panels do not have windows arranged horizontally. Tran-



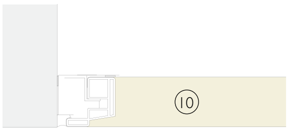
Horizontal section 1:5. Insulated corner connection detail



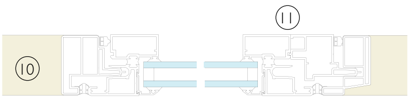
Horizontal section 1:5. Joint between composite panels with fully interlocking connection



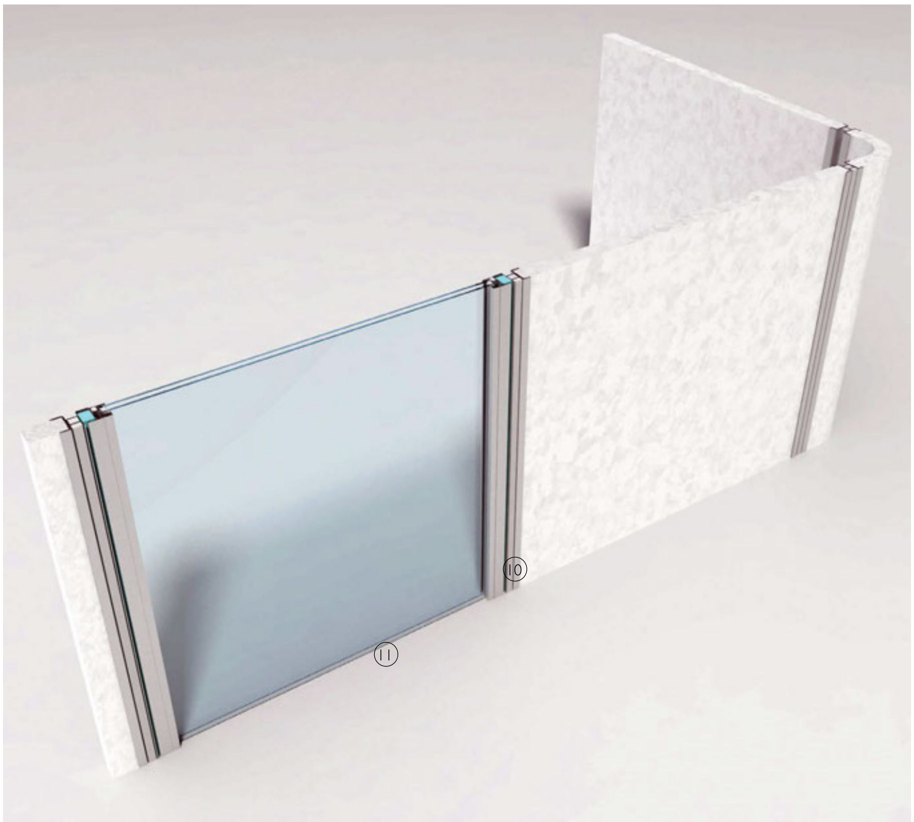
Horizontal section 1:5. Joint between composite panel and curtain wall type glazing with fully interlocking connection



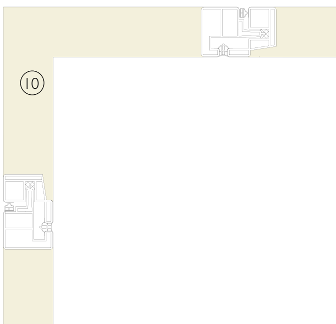
Horizontal section 1:5. Joint between composite panel and concrete wall with fully interlocking connection



Horizontal section 1:5. Panels interlocking on 4 sides spanning either vertically or horizontally



3-D view of partially interlocking panels with flush window and curved corner panel



Horizontal section 1:5. Fully interlocking internal corner panel

Horizontal section 1:5. Fully interlocking curved external corner panel

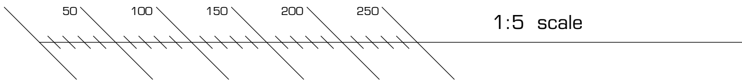
sitions between window openings and composite panels are becoming more economic with standard extrusions and rubber-based seals. This is ever-more the case with four-sided, interlocking panels, where window panels and metal panels are fixed in the same way. Increasingly, irregular facade grids are being developed in designs to create a richer mix of panel sizes in visual patchwork of different sizes of panels.

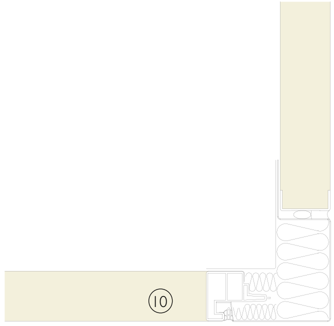
Corners

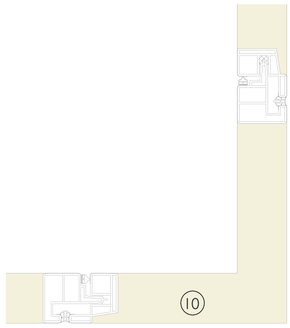
Composite panels are connected at corners by one of two methods. Either specially made corner panels are used (typically why 90º is standard) or a coverstrip is added to cover the junction where the panels meet. Corner panels are more suited to vertically-set arrangements, though panels for horizontally-laid panels are sometimes used for visual effect. Where corner coverstrips are used, their appearance resembles that of profiled metal cladding, which can give a facade an overall framed appearance. Metal trims at the parapet, base and corners can give this appearance. For this reason, the special corner panels and parapet panels are used increasingly.

Thermal bridges at cills

A weakness in composite panels systems has been the use of pressed metal sections or aluminium extrusions that pass from outside to inside without a thermal break. This is being remedied by the use of insulated cills, made in the manner of composite panels. This reduces the thermal bridge, in some cases a break in the section from outside to inside can be formed by turning the metal cill into the injected foam or polystyrene in the same way as a composite panel.





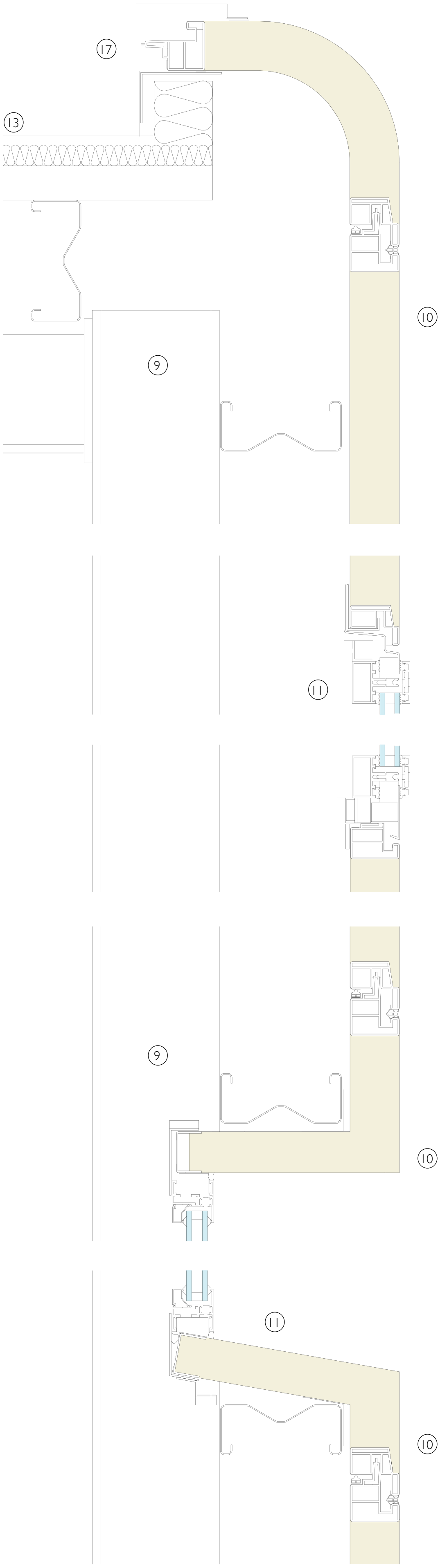


Horizontal section 1:5. Insulated corner connection between composite panels with fully interlocking connection

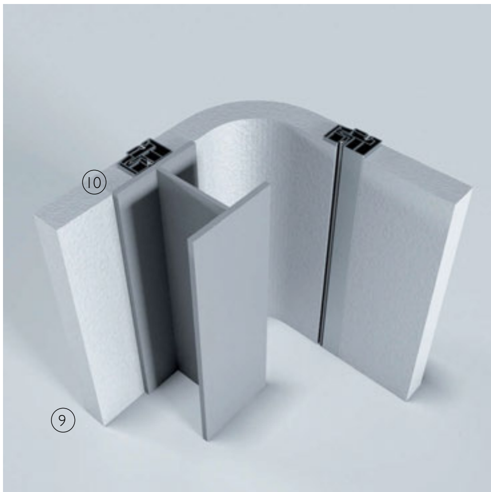
Horizontal section 1:5. Fully interlocking external corner panel

Details

1. Vertically-set composite panel
2. Horizontally-set composite panel
3. Silicone-based seal
4. Outer metal facing
5. Inner metal facing
6. Inner insulation core
7. Metal capping
8. Concealed fixing
9. Supporting structure
10. 4-way interlocking composite panel
11. Window frame
12. Sectional roller shutter formed from composite panels
13. Roof construction, composite panels are shown
14. Metal trim
15. Exposed gutter
16. Concealed gutter
17. Metal parapet coping
18. Stick glazed curtain walling
19. Door frame



Vertical section 1:10. Fully interlocking composite panels with curved cill and window set into reveal in cladding



3-D views of fully interlocking corner pieces with square and rounded corners

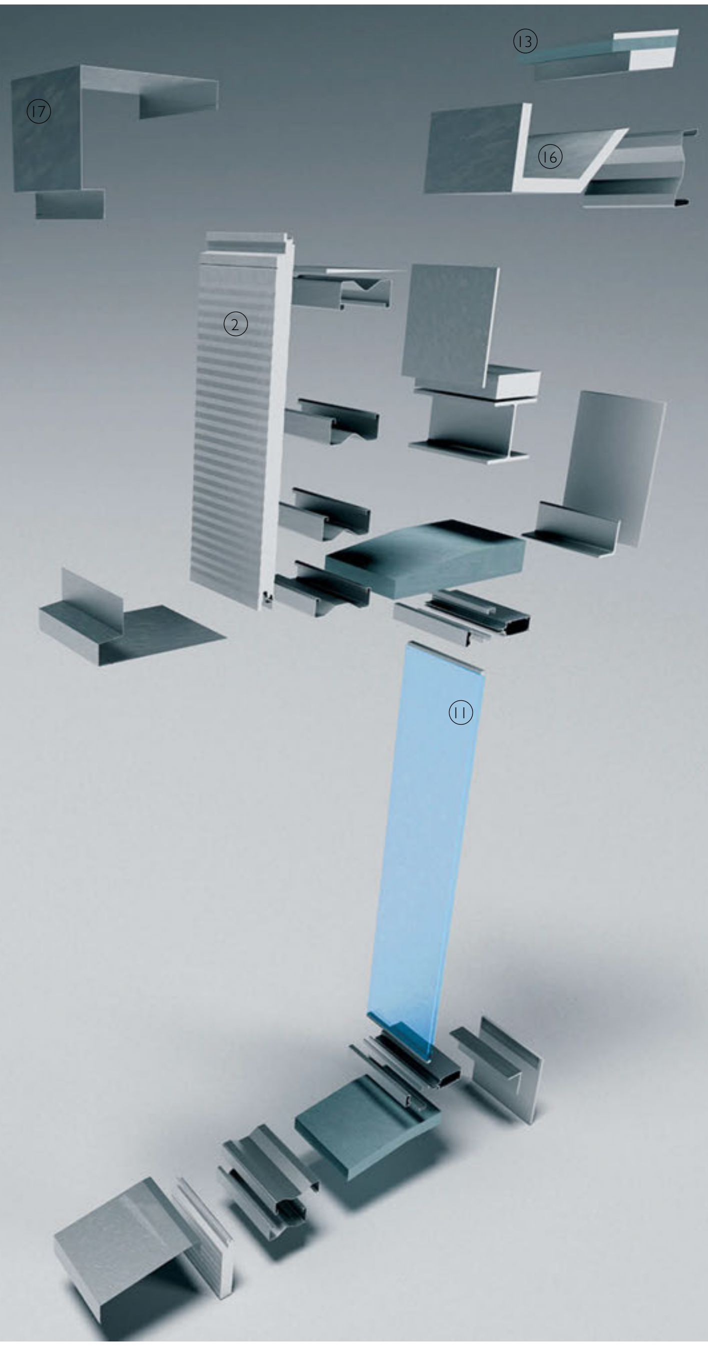
3-D views of fully interlocking corner pieces with square and rounded corners

3-D detail view of window frame
and supporting structure

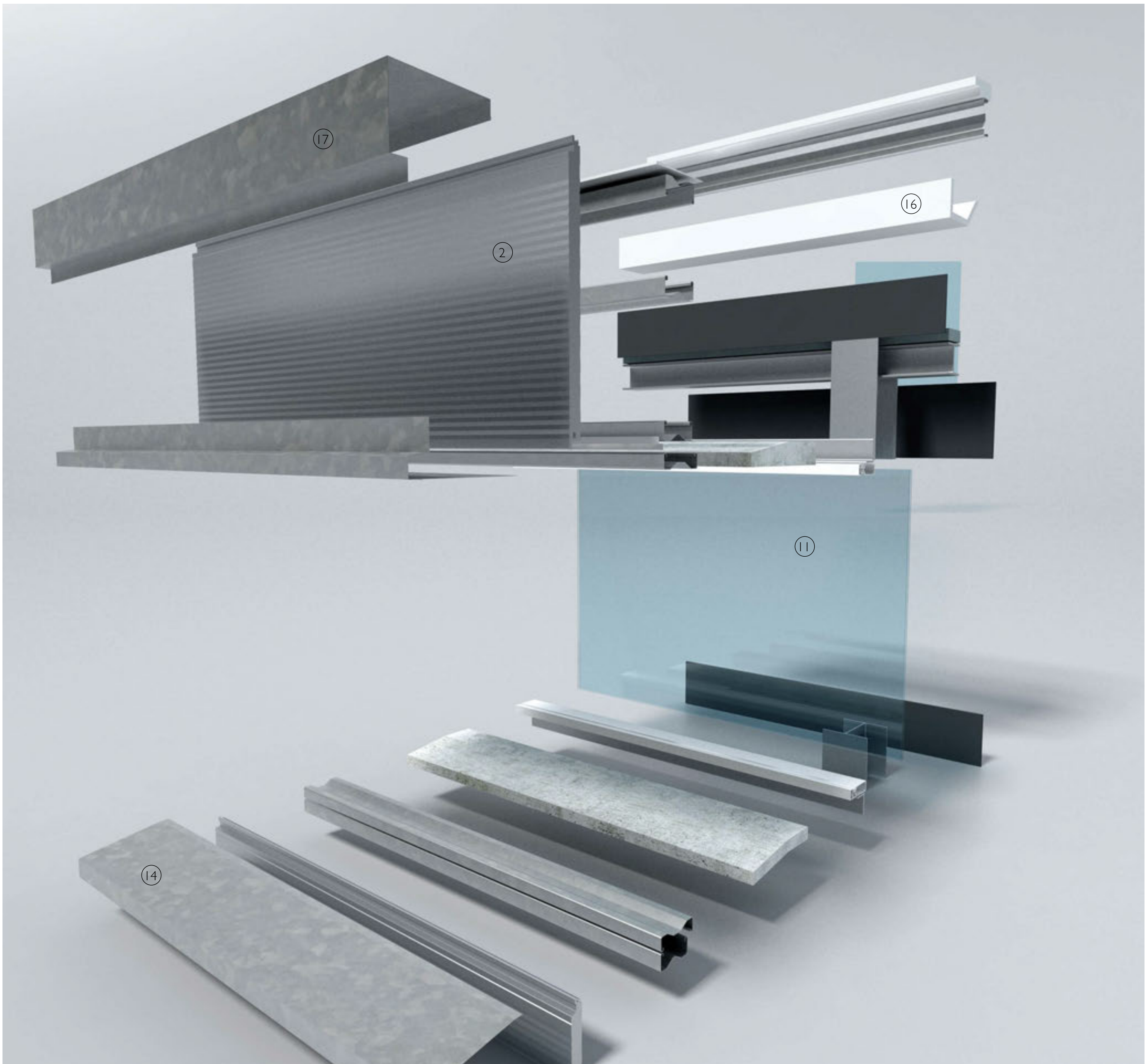
3-D detail view of gutter

Details

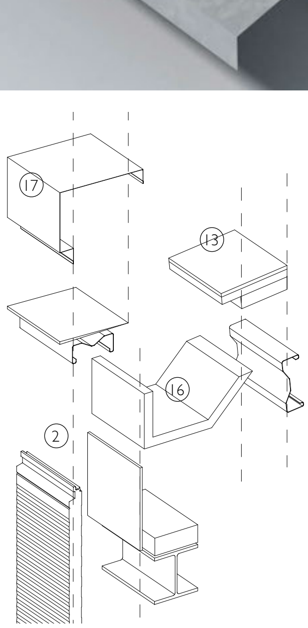
1. Vertically-set composite panel
2. Horizontally-set composite panel
3. Silicone-based seal
4. Outer metal facing
5. Inner metal facing
6. Inner insulation core
7. Metal capping
8. Concealed fixing
9. Supporting structure
10. 4-way interlocking composite panel
11. Window frame
12. Sectional roller shutter formed from composite panels
13. Roof construction, composite panels are shown
14. Metal trim
15. Exposed gutter
16. Concealed gutter
17. Metal parapet coping
18. Stick glazed curtain walling
19. Door frame



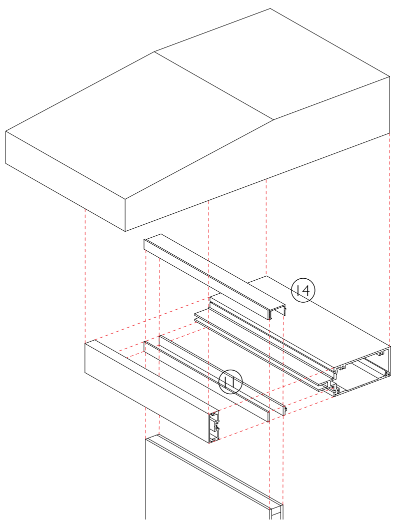
3-D view of composite panel facade with
flush glazing and concealed parapet



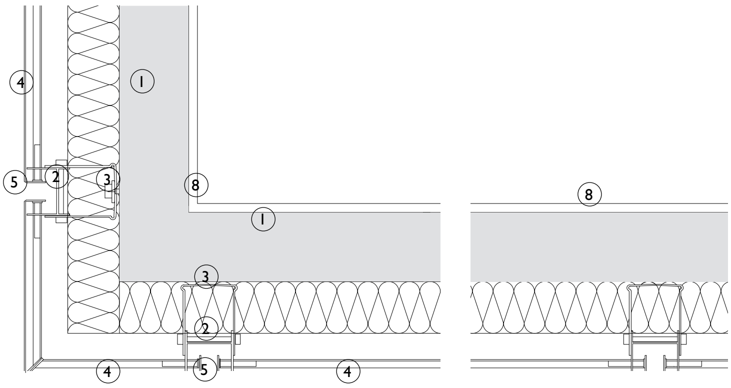
3-D exploded view of composite panel curtain wall with recessed window with deep metal reveal



Exploded axonometric gutter detail

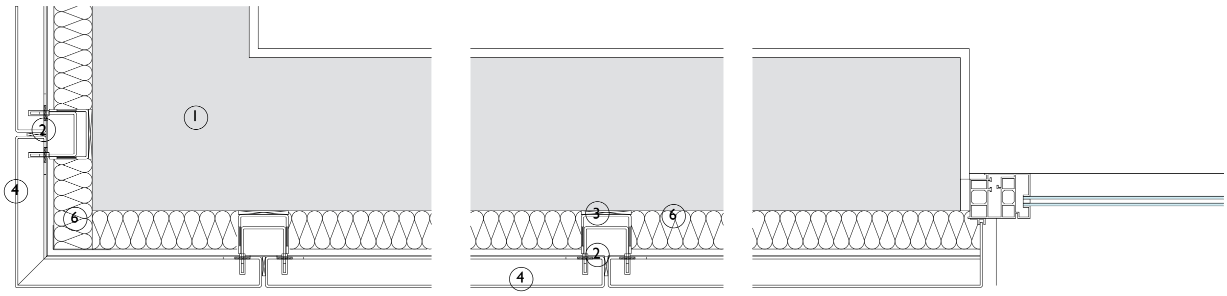


Exploded axonometric frame detail



Horizontal section 1:10. External corner connection between rainscreen panels

Details
1. Backing wall or structural wall supporting rainscreen
2. Supporting Frame
3. Support Bracket
4. Metal rainscreen panel
5. Open joint
6. Closed cell thermal insulation
7. Waterproof membrane
8. Internal finish
9. Supporting structure
10. Pressed metal cill
11. Pressed metal coping
12. Continuity of waterproofing layers of wall and roof



Horizontal section 1:10. External corner connection between rainscreen panels and junction with window

A much wider range of materials is used in rainscreens than was the case five years ago. Copper and zinc have the advantage of being easier to form than steel or aluminium, particularly where site-based construction methods are preferred for either economy or in dealing with complex or curved geometries. This method of fixing rainscreens avoids the need for off-site fabrication of a large number of different panel types with different curved geometries. They can be made economically on-site.

The 'tiling' or 'shingling' of panels in copper has been developed from sheet metal cladding. This departs from metal rainscreen designs in that the surface appearance has a deliberately uneven texture that emphasises the oil-canning effect that gives the appearance of a layered, tiled surface. The move away from the emphasis on flat metal panels in rainscreen construction includes an increased use of profiled and curved metal panels. A major advantage is that fixings can be concealed by semi-interlocking panels in the manner of sheet metal cladding or in the manner of traditional roof coverings.

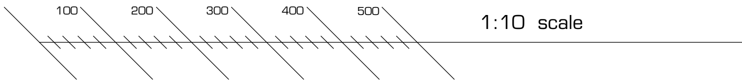
There has been a recent increased use of semi-lapped assemblies that conceal the void behind the metal cladding. These usually have visible fixings at panel joints but allow the joints between panels to be less in shadow than is the case with other fixing methods. There has been a gradual development of rainscreens as visual screens rather than as weather-excluding panels. For example, perforated metal screens in mild steel or aluminium are used to create both modelling to a facade and solar shading set forward of glazed walling. In such designs the back of the rainscreen panel is visually as important as the outer visible face where the panel is seen through glazed openings in a facade. Fixings for such rainscreen panels often have screws and bolts that are set into the fixing rather than having projecting threaded bolt and exposed nuts.

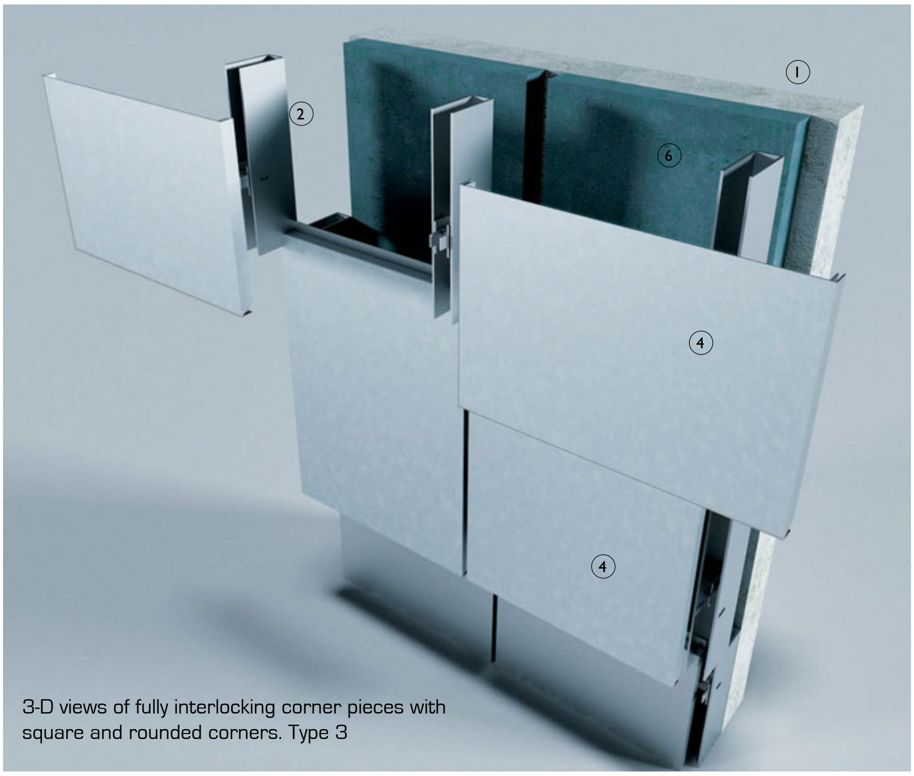
Materials

Rainscreen panels can have a flatness that is difficult to achieve with other methods. Panel flatness is achieved by either use of composites such as proprietary laminates where two sheets of aluminium are bonded on both sides of an inner core sheet of plastic of thickness 3-5mm (0.118in to 0.2in) or by a minimum 3mm (0.118in) thick aluminium sheet, or approximately 1mm thick steel sheet, depending on panel size. Honeycomb panels are also being used. A metal honeycomb layer, about 5mm (0.2in) thick, is bonded to thin metal sheets on either side. Aluminium is most commonly used. One of the outer sheets is factory paint coated from the rolled coil from which it is cut, giving the material a high level of colour consistency over large areas of panel.

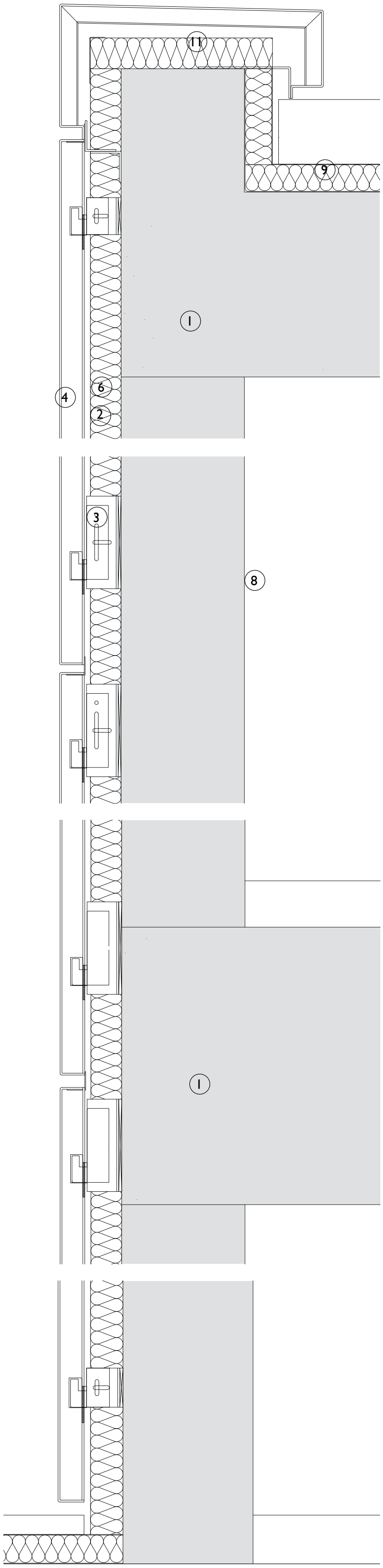
Fixing methods

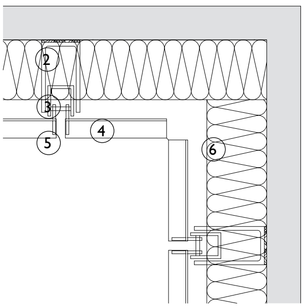
The three main fixing types used for metal rainscreens are (1) visible point fixed, (2) horizontal or vertical rails with partially exposed brackets (hung panels) and (3) vertical and horizontal rails with partially interlocking panels and concealed fixings. The choice of fixing method is often deter-



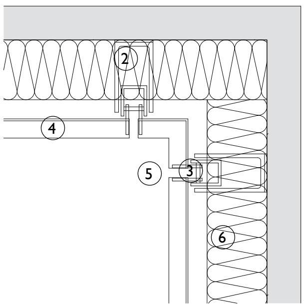


3-D views of fully interlocking corner pieces with square and rounded corners. Type 3





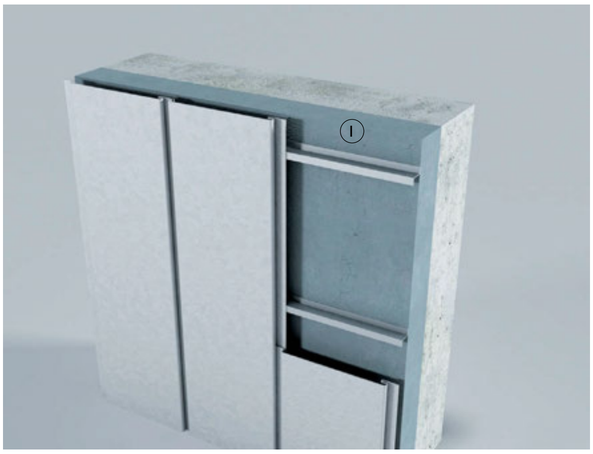
Horizontal section 1:10. Internal corner connection between rainscreen panels



Horizontal section 1:10. Internal corner connection between rainscreen panels

3-D views of fully interlocking corner pieces with square corners. Type 3

Vertical section 1:10. Metal rainscreen wall assembly



3-D views of semi interlocking rainscreen panels. Type 2
Left Above: Horizontal rails support cladding panels with vertical interlocking joints.
Left Lower: Vertical rails support cladding panels with horizontal interlocking joints.

mined by what is seen through the joint from the outside. If dark shadows are sought at the joint then the backing wall should have a consistent dark colour. In this case, short lengths of bracket may be sufficient to support the panels, since they will not be visible. If the backing wall is likely to be visible through the open joints, such as if the backing wall is clad in exposed polystyrene insulation board, then the joints will need to be screened by a continuous channel.

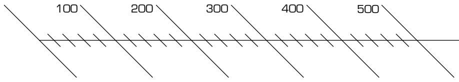
Panels which are point fixed have either countersunk screws set flush with the panel face, or dome headed screws which make a visible feature of them. The screws are fixed into rails set to suit their position. Vertical rails are often preferred since water can easily drain down them.
Hung panels are hooked onto supporting brackets. Panels are fixed by cutting slots into the sides of the rainscreen panel during manufacture and hooking them onto dowels projecting from C-shaped brackets. These brackets are in turn secured to vertical rails set at vertical joints between panels. The rails also act as screens to close off views into the cavity. Horizontal joints are formed by an upstand formed in the top or bottom edge of a panel.

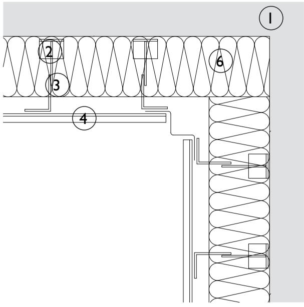
Semi-interlocking panels are fixed by screwing the top of the panel to horizontal rails to suit the orientation of the panels. The adjacent panel is lapped into the panel next to it, both to secure it and conceal the fixing. The joint in the other direction is either fixed with a similar semi-interlocking edge to form a tiled appearance, or has a cover strip.

Unlike masonry-based rainscreens such as terracotta or stone, metal rainscreen panels are lightweight in comparison and need to be mechanically fixed at a minimum of one or two points, usually at the bottom of the panel if the panel is hung from the top. Fixing screws are usually applied at the joint, unless it is fixed with exposed fixings through the panel itself. This means that part of the bracket is usually visible. Short lengths of brackets then become visible and need to be incorporated as a visible part of the design.

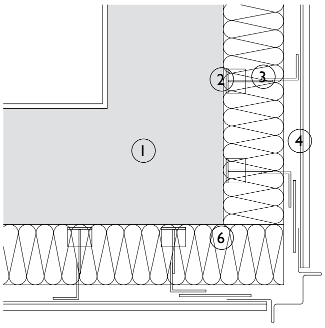
Backing walls
Supporting walls to rainscreen panels are usually concrete block, which allows supporting panels to be fixed at any point across its surface, or framed, where rainscreen fixings are secured to the framing members rather than the outer skin of the backing wall. In some cases, if the outer skin is thick enough, say 6mm (0.25in) aluminium sheet, rainscreens can be fixed directly to the sheet material rather than the frame. If a lightweight backing wall cannot accept additional loads from rainscreen cladding onto it (as with composite panels), then support rails span from floor to floor as posts.

With concrete block backing walls, the thermal insulation is usually set on the outside face in order to keep the structure either warm or cool, depending on the geographical location. The waterproof layer is set directly on the outside face of the concrete. The thermal insulation used is closed cell type in order for it not to absorb water which would drastically reduce its performance. The insulation is also used to protect the waterproof

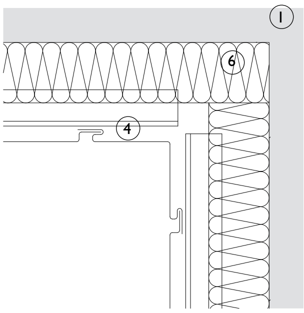




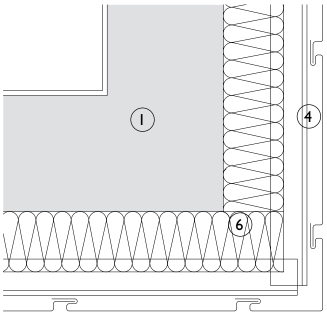
Horizontal section 1:10. Internal corner connection between metal rainscreen panels with interlocking horizontal joints and open vertical joints



Horizontal section 1:10. External corner connection between metal rainscreen panels with interlocking horizontal joints and open vertical joints

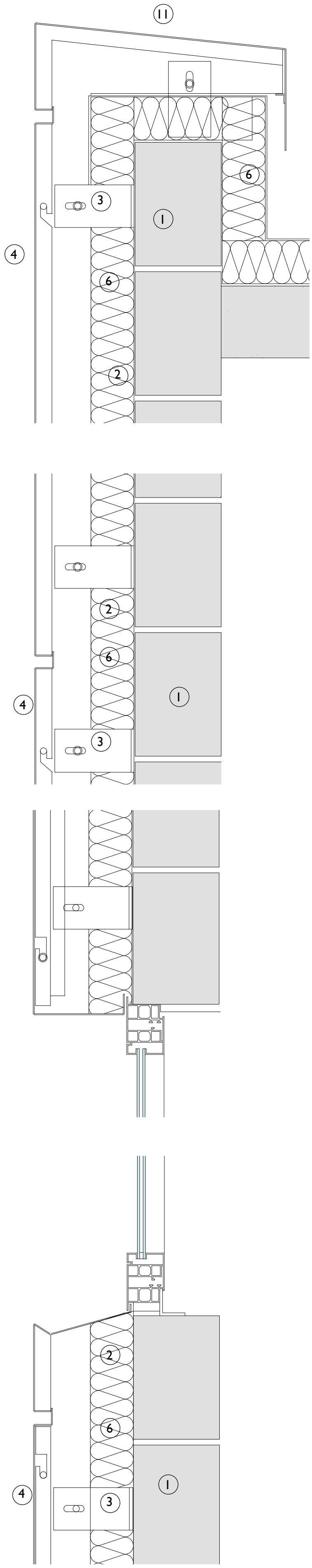


Horizontal section 1:10. Internal corner connection between metal rainscreen panels with open horizontal joints and interlocking vertical joints

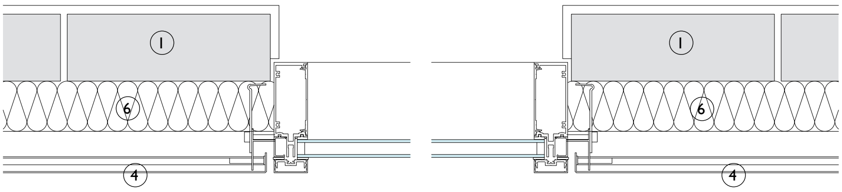


Horizontal section 1:10. External corner connection between metal rainscreen panels with open horizontal joints and interlocking vertical joints

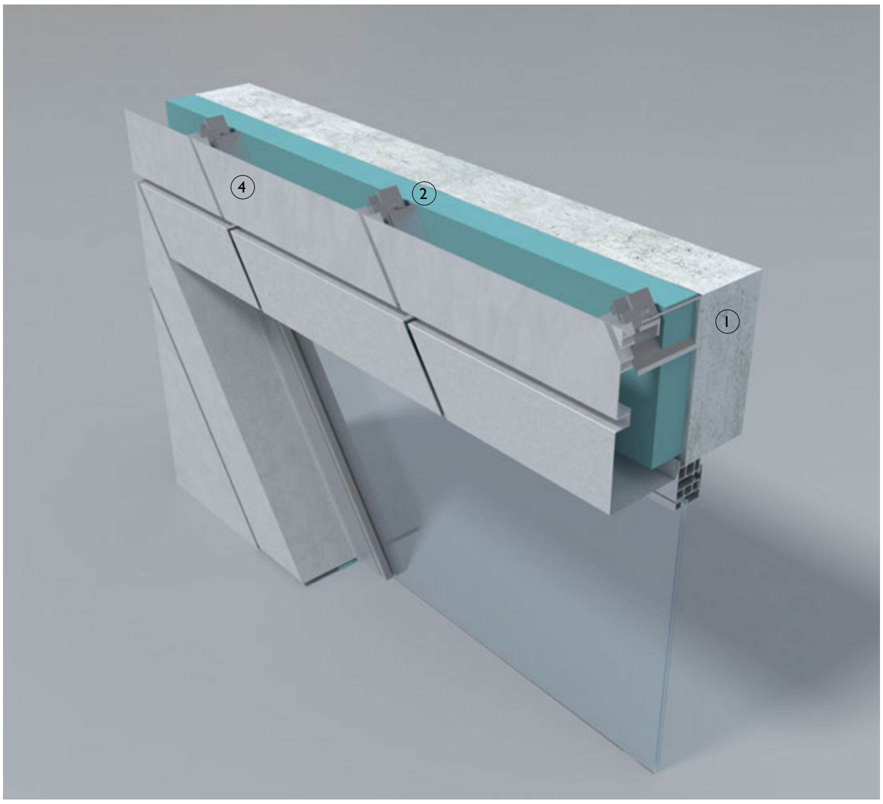
3-D view of semi interlocking metal rainscreen with angled joints and aluminium window recessed into the facade. Type 3



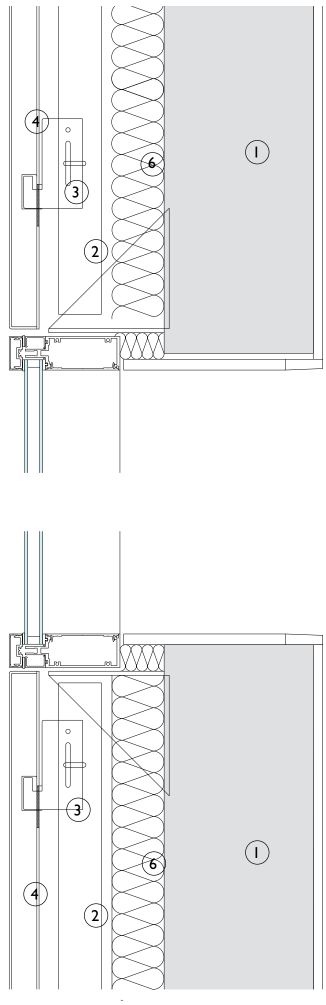
Vertical section 1:10. Metal rainscreen with interlocking horizontal joints, parapet and recessed window



Horizontal section 1:10. Connection between metal rainscreen and curtain wall type glazing with flush finish



3-D view of curtain wall type glazing set flush with metal rainscreen cladding. Type 3



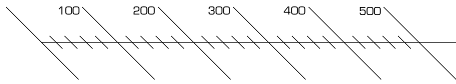
Vertical section 1:10. Metal rainscreen with curtain wall type glazing set flush with face of cladding.

Details
1. Backing wall or structural wall supporting rainscreen
2. Supporting Frame
3. Support Bracket
4. Metal rainscreen panel
5. Open joint
6. Closed cell thermal insulation
7. Waterproof membrane
8. Internal finish
9. Supporting structure
10. Pressed metal cill
11. Pressed metal coping
12. Continuity of waterproofing layers of wall and roof

membrane but this makes it necessary for support brackets to be fixed through the insulation to the supporting wall behind. Sometimes holes have to be cut in the insulation, which reduces its effectiveness, but it is always better if the fixings for support rails can be fixed at the same time as the insulation in order to co-ordinate them and avoid later cutting of the insulation.

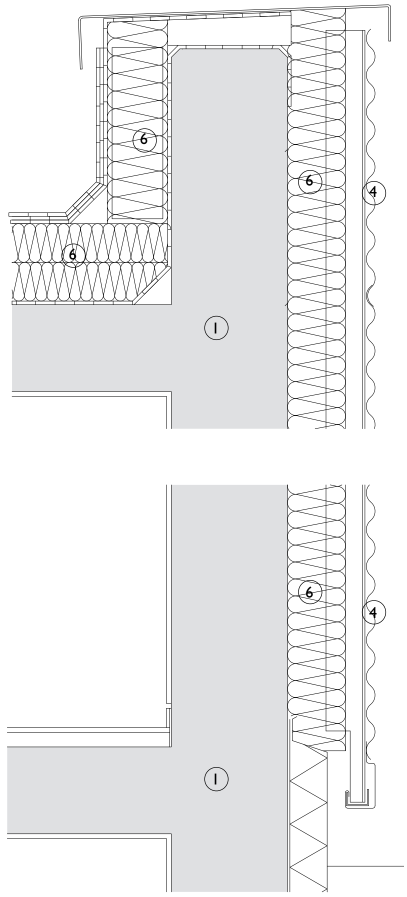
With lightweight backing walls in timber or pressed steel, thermal insulation is set within the frame. A waterproofing layer is set on the inside (warm in winter) face. An internal finish layer is then set in front of this vapour barrier. Rainscreen fixings for support rails are fixed directly to the outer waterproofing layer using sealing washers that avoid leaks through the fixing point. The framed backing wall is designed to receive fixing brackets at points which transfer loads down to the primary structure. The use of framed backing walls with rainscreens makes it necessary to co-ordinate the two elements of construction during the design rather than during the construction.

Construction sequence
An essential aspect of rainscreen construction is the sequence in which the various elements of the backing walls, windows, thermal insulation, waterproofing layer and rainscreen panel are brought together. Although the rainscreen principle is very effective and often very economic, its effectiveness can be reduced if seals are not properly applied or insulation is damaged because elements are assembled on site in the wrong order. Typically, windows are sealed against the

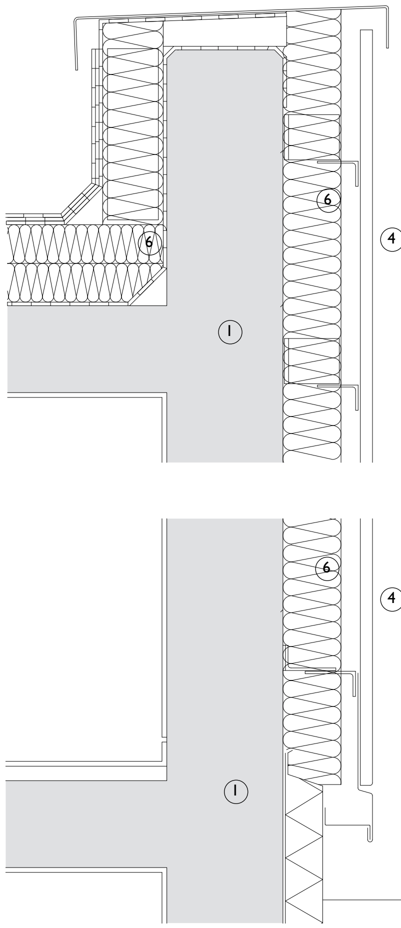


3-D view of vertical rail system with rain-screen panels spanning horizontally. Type 1

3-D view of horizontal rail system with rain-screen panels spanning vertically. Type 1



Vertical section 1:10. Horizontally spanning metal rainscreen panels with vertical rail system



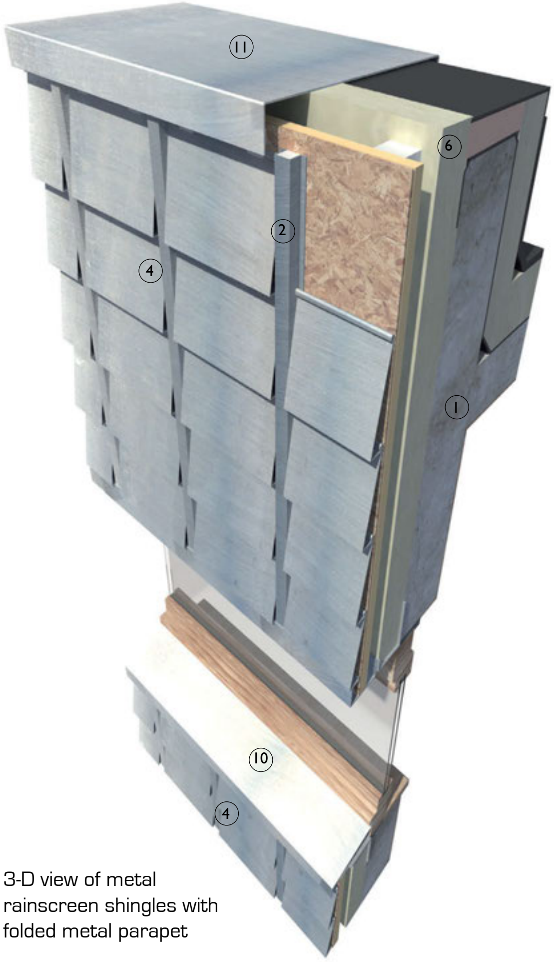
Vertical section 1:10. Vertically spanning metal rainscreen panels with horizontal rail system

backing wall before the rainscreen panels are set in place. An advantage of this form of construction is that the external wall can be made waterproof before the rainscreen panels are fixed.

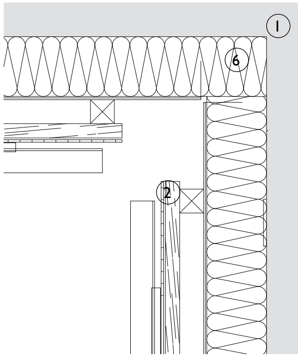
A typical construction sequence is to build the backing wall first and set the waterproofing layer and insulation in place. Windows are then set into the backing wall and are sealed against its waterproofing layer. Thermal insulation, if set outside the line of the waterproofing layer (as in in-situ concrete, precast concrete or concrete block) makes it easier to set the thermal insulation on the backing wall after the windows and doors have been fixed. Support rails for the rainscreen panels are then fixed to the backing wall, followed by the metal panels themselves. Panels are usually fixed in horizontal rows from the bottom up so that corner panels and panels at window openings can be fixed from the outside from the top of the panel. Metal panels can then be set in a correct alignment with the windows in terms of their position and in setting the required joint width. The open jointed nature of the construction usually dictates that the rainscreen panel is set in a way that avoids a view through the joint to the backing wall beyond.

Window and door openings

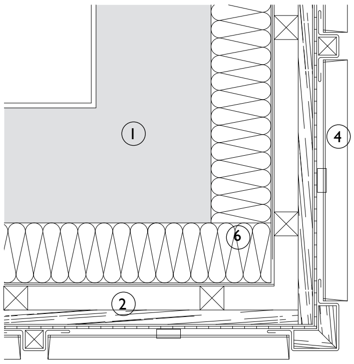
Because window and door openings are usually set into an opening before the rainscreen panels are set, reveals are sealed with either individual rainscreen panels or with sheet metal trims similar to those used for sheet metal construction. Unlike sheet metal construction however, a gap is usually maintained between the trim



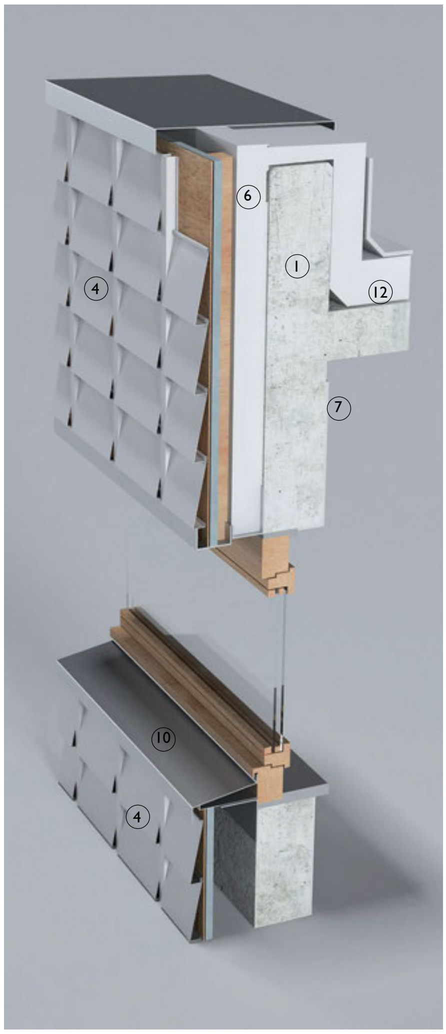
3-D view of metal rainscreen shingles with folded metal parapet



Horizontal section 1:10. Internal corner of metal rainscreen shingles



Horizontal section 1:10. External corner of metal rainscreen shingles

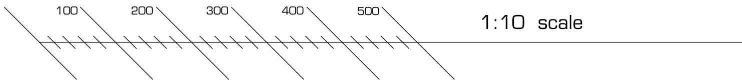


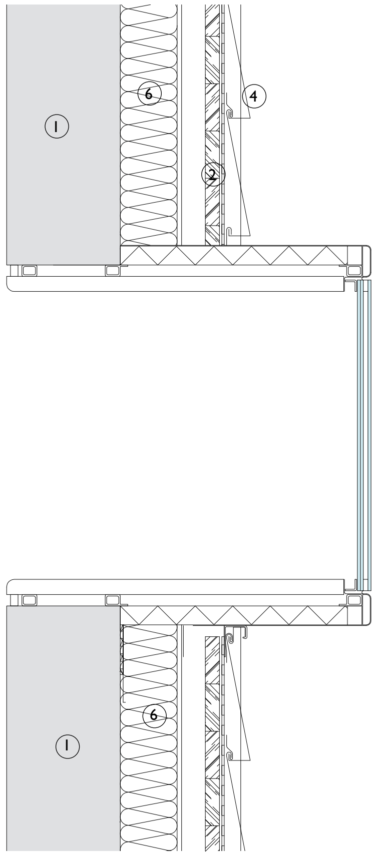
and the window in order to maintain the joint principle. Similarly gaps between reveal trims and adjacent wall panels are also separated by an open joint. Since windows and doors are sealed against the waterproofing layer behind the rainscreen panel rather than to the panel itself, these separations are straightforward to achieve. These open joints around openings are made in a way that conceals the waterproof layer behind, thus protecting it from both accidental damage from building users and from the possible effects from sunlight heating up the membrane or attacking it with UV light. Windows and doors are usually provided with an additional wider frame or trim at their edges in order to allow thermal insulation in the cavity to provide continuity at the opening and allow the rainscreen panel to lap against it.

Parapets and cills

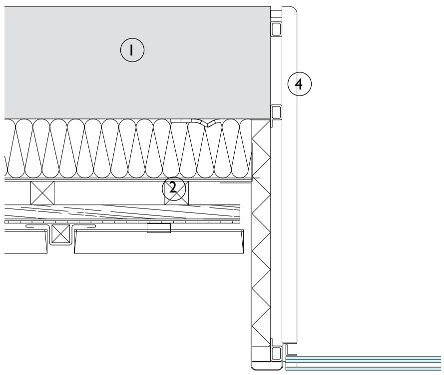
Parapets have an open joint between the parapet flashing and the panel below but horizontal joints between flashings are usually closed to protect the parapet from accidental damage to the waterproofing undercloak beneath or from the harmful effects of sunlight from above acting on its horizontal surface. Joints between flashings may be recessed to match the visual appearance of the rainscreen panels by providing a shadow or may be lapped in the manner of fully supported sheet metal cladding. The waterproofing layer will form a continuous seal with the adjacent roofing membrane. Cills at the base of the wall are detailed in a similar way with metal being continuous but with joints either recessed or lapped.

3-D views showing recessed timber window opening in metal rainscreen shingle cladding system





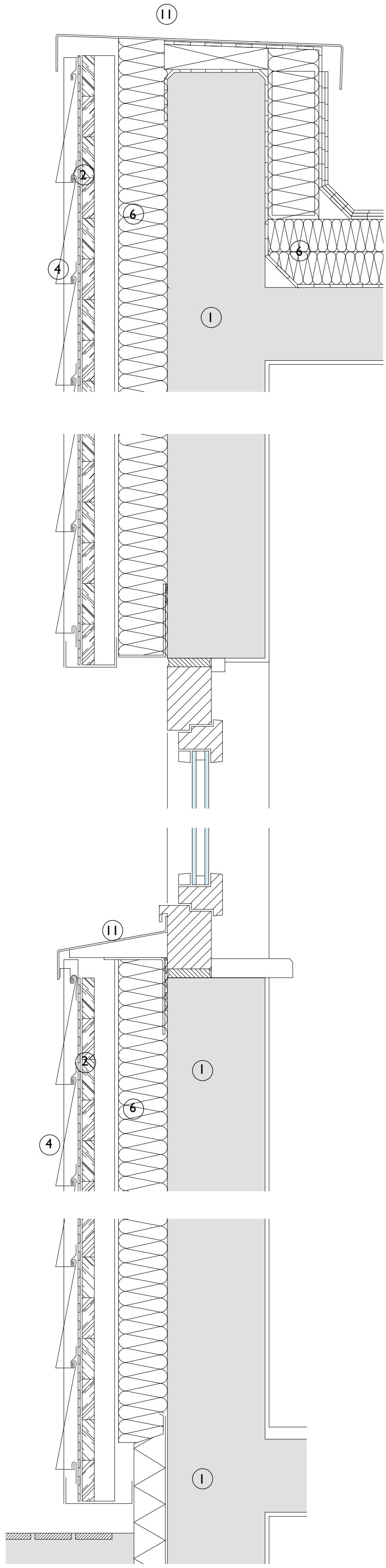
Vertical section 1:10. Connection between metal rainscreen shingles and timber window

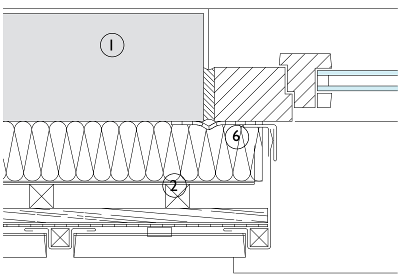


Horizontal section 1:10. Connection between metal rainscreen shingles and timber window

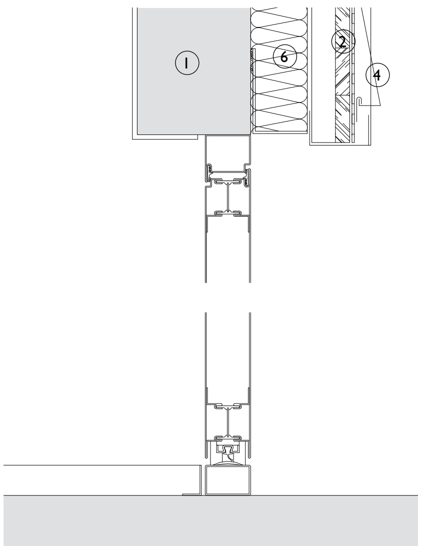
Details

1. Backing wall or structural wall supporting rainscreen
2. Supporting Frame
3. Support Bracket
4. Metal rainscreen panel
5. Open joint
6. Closed cell thermal insulation
7. Waterproof membrane
8. Internal finish
9. Supporting structure
10. Pressed metal cill
11. Pressed metal coping
12. Continuity of waterproofing layers of wall and roof





Horizontal section 1:10. Connection between metal rainscreen shingles and timber window



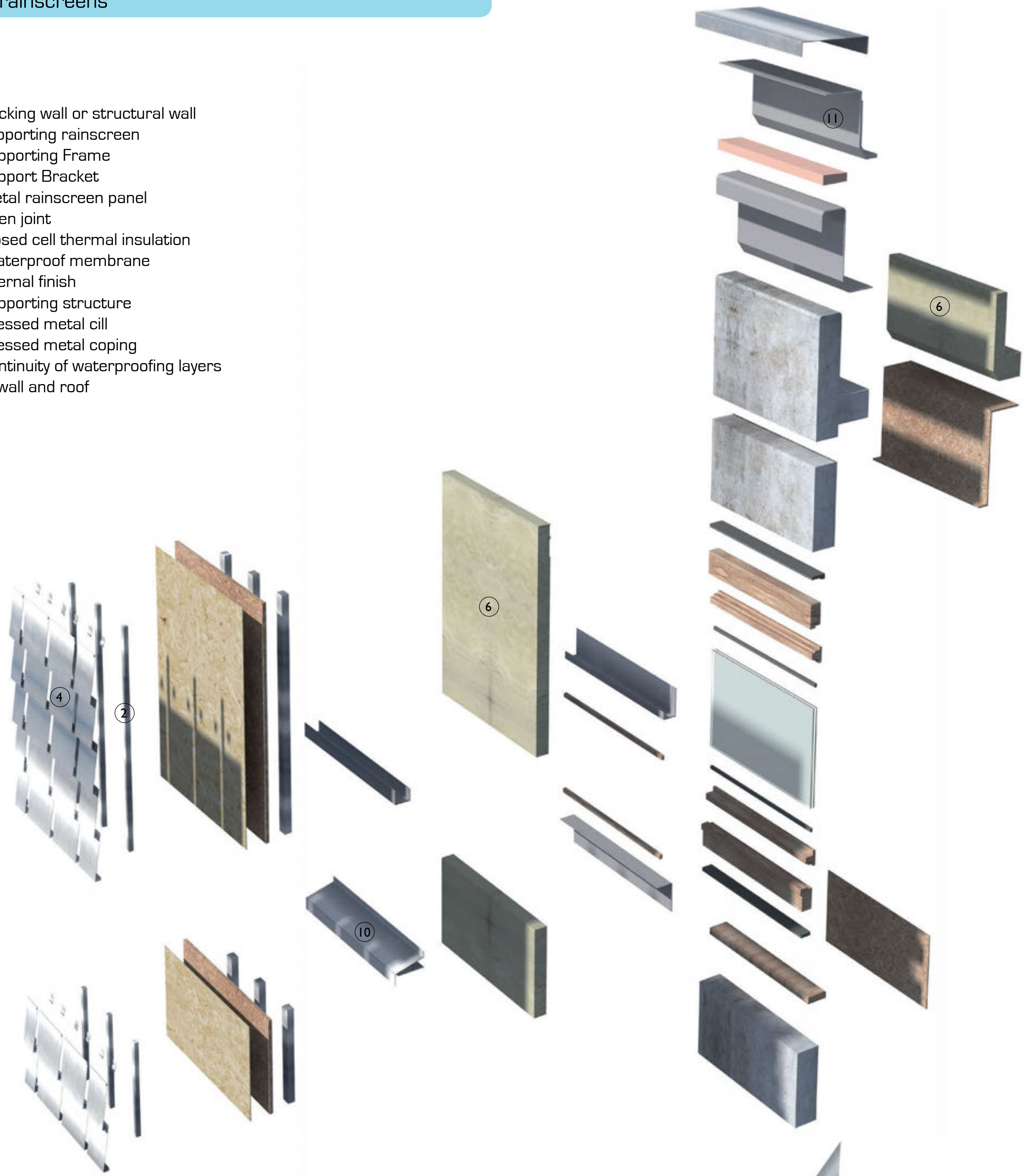
Vertical section 1:10. Metal door recessed into metal shingle rainscreen construction

3-D view recessed timber window in metal rain-screen shingle cladding system

Vertical section 1:10. Semi-interlocking metal rainscreen shingle system with parapet, timber window and finish at ground level

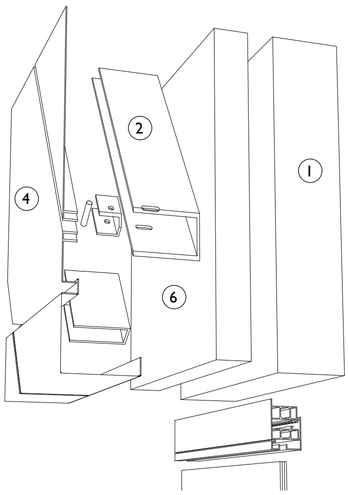
Details

1. Backing wall or structural wall supporting rainscreen
2. Supporting Frame
3. Support Bracket
4. Metal rainscreen panel
5. Open joint
6. Closed cell thermal insulation
7. Waterproof membrane
8. Internal finish
9. Supporting structure
10. Pressed metal cill
11. Pressed metal coping
12. Continuity of waterproofing layers of wall and roof



3-D exploded view of metal rainscreen panel system with overlapping tiles as panels

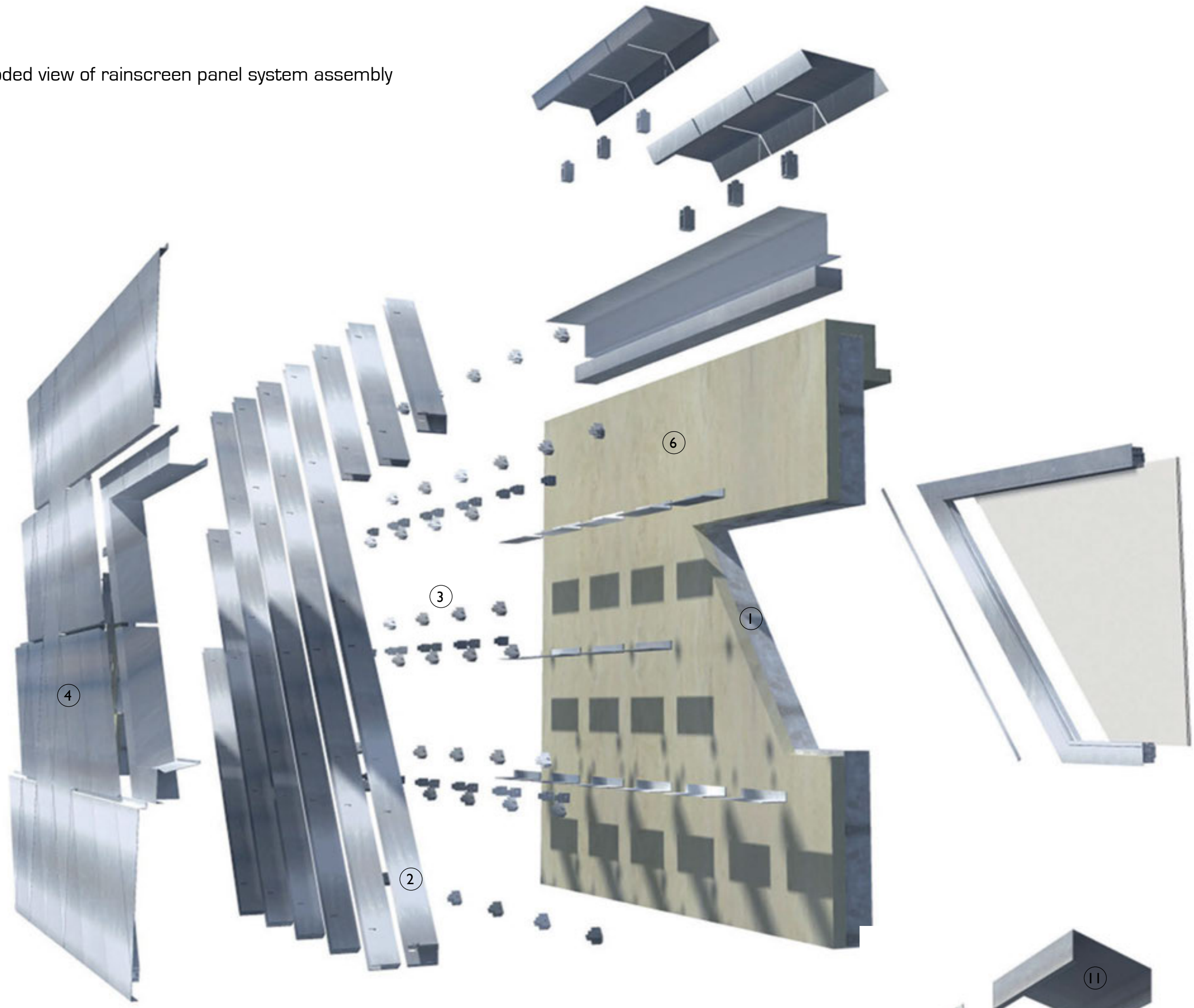
3-D exploded view of parapet condition

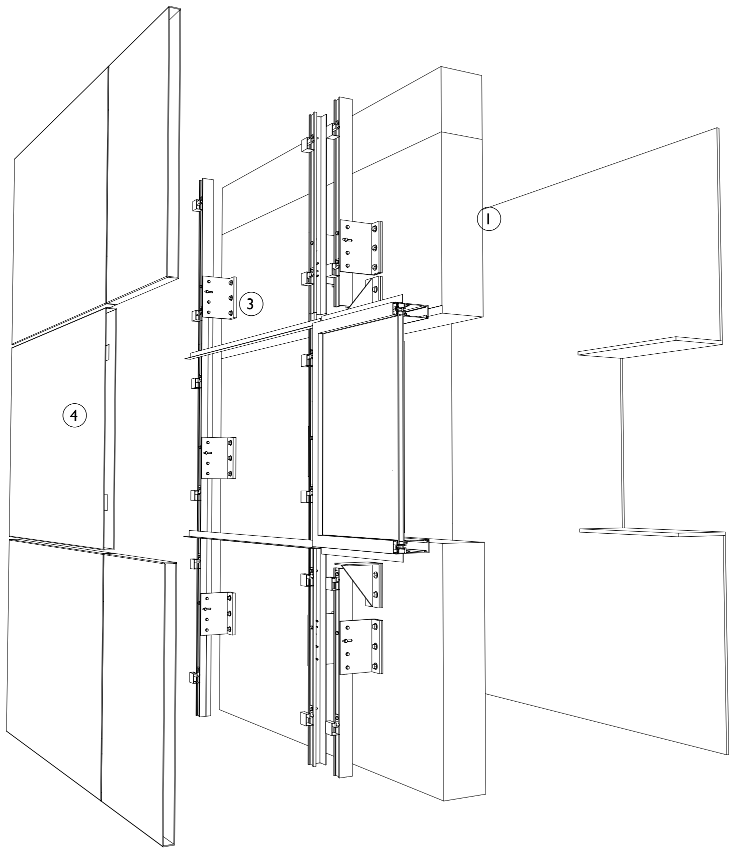


3-D exploded view of top of window opening

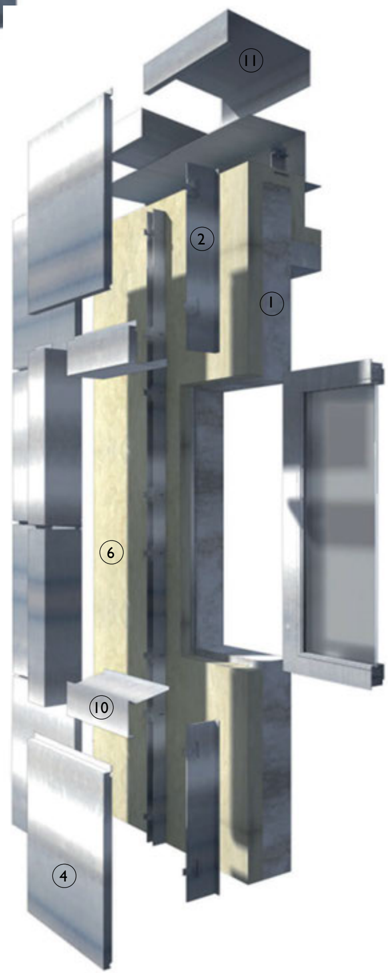
3-D exploded view of rainscreen panel system

3-D exploded view of rainscreen panel system assembly





3-D exploded view of opening in rainscreen panel system



3-D exploded view of typical window opening