

WALL TECHNOLOGY

Volume F

Glazing, curtain walls and overcladding



CONSTRUCTION INDUSTRY RESEARCH AND INFORMATION ASSOCIATION
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SUMMARY

The seven volumes of 'Wall Technology' provide guidance on the principles of design and construction of walls, based on the best available knowledge from authoritative UK sources. Volume F is in two parts, dealing with glazing and with curtain walls and overcladding. The first part considers the use of glass and plastics. New developments in the application of these materials may give rise to problems, on which guidance is given. The second part covers curtain wall and overcladding, including so-called 'rainscreen' applications. There are three different principles involved: sealed construction, rainscreen and pressure-equalised rainscreen. The technologies involved are described.

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FOREWORD

This set of seven volumes has been produced as an aid to Architects and others involved in the building industry. Research has shown that design errors are made more frequently than they might be because of difficulty in, or lack of time for researching and investigating the information which exists about the known performance of materials and the techniques of their application in building.

In some cases it is too difficult to find the source of information, in others there is such a surfeit of information from many different, or even, on occasion, conflicting sources as to confuse or lead to misjudgement. It is with these problems in mind that CIRIA has produced 'Wall Technology' an assembled survey of the best available knowledge in the UK on the subject.

A problem facing architects and other designers involved in building arises from the long timescale for the feedback of experience in the use of many materials and components available today. Often the lessons of experience come too late to prevent a repetition of defects. In many instances research can only achieve limited objectives and only by extensive experience in use will the adequacy of performance of new materials or techniques, or traditional materials used in new ways, be ascertained. There will continue to be a risk of some unanticipated problem arising when new materials or methods are used in building construction until there exists a record of satisfactory performance over a reasonably long timescale. There is a need for the component industries to invest more in testing materials to determine their longevity and the techniques of their application before putting them on the market.

Volume A, which deals with Performance Requirements, was produced by the Building Research Establishment, under a contract to CIRIA. This volume has relevance to all types of walling in the UK, having been assembled using the considerable resources and all the accumulated knowledge and experience of the BRE.

The six following volumes B to G contain within them various parts grouped according to a convenient classification arrangement. Each part has been drafted by the most appropriate research and development association, or, where no appropriate organisation existed or was able to contribute, by leading product or system manufacturers, or, for a very few, by the IoAAS at York. In all cases the texts have been appraised and amended by representatives of other organisations or competitor companies. The contributions have been further studied and amended by appropriate members of a steering group assembled by CIRIA which held regular meetings and which included architects, engineers and others representing a wide spectrum of the building industry and included a number of the contributors to the series.

Acknowledgements

The concept of the project was initiated by The Construction Industry Research and Information Association. The work to produce the seven volumes extended over almost 3 years and was funded by the Department of the Environment jointly with members of the construction industry.

The project was initially developed and structured by Dr Paul Stollard under the direction of Professor Douglass Wise, the director of the Institute of Advanced Architectural Studies at the University of York.

The management and research for the project together with the editing, rewriting and, for some parts, the writing were undertaken by retired practising architect and research fellow Basil Gillinson at the IoAAS York working with Mr Gordon Gray of CIRIA.

All the illustrations in volumes B to G and many in volume A were re-drawn by architect Noelle Houston.

As editor, Basil Gillinson acknowledges the word processing contribution of Angela Vickers and Linda Hetherington at York, the additional non-technical editing by Mr David Garner and the laser typesetting by Mr Ian Taylor and his colleagues of Computype, York.

CIRIA expresses its appreciation and thanks to all the members of the Steering Group which guided the project and in particular to those members who provided contributions in kind.

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**Part 2 Curtain walls and overcladding (including
rainscreen)**

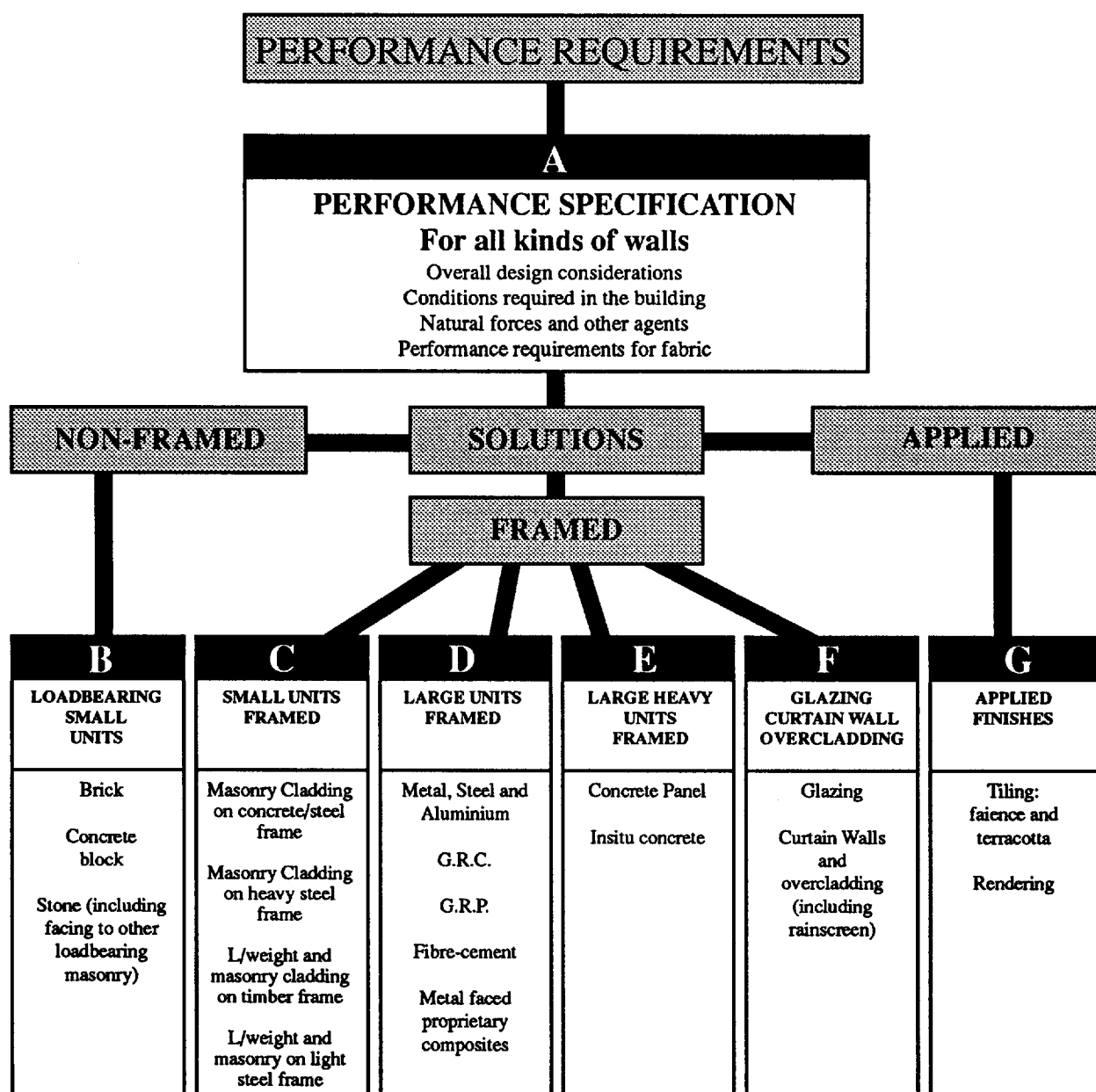
INTRODUCTION

This publication is one of a series that seeks to address the problem of lack of adequate suitable guidance in the field of 'Wall Technology'.

The aim of the series is to provide practitioners (architects, manufacturers, engineers, surveyors, quantity surveyors, etc) with a clear, concise, authoritative statement of the theory and practice of external wall construction.

Taken together, the 7 volumes of the series are relevant to every new building and every building in which walls are being upgraded. They are relevant in some degree to overseas, particularly where a similar climate to that of the UK exists.

The outline arrangement for the 7 volumes is shown below:



Objectives

The principal objectives of the project have been to:

1. Identify the fundamental principles governing the design and construction of walls having regard to their various functions and to show how these principles can be successfully applied for the wide variety of available materials and techniques, at the same time showing how many potential problems and defects are to be avoided.
2. Give authoritative, independent advice and guidance to good practice bringing together for the first time, in one set of documents, the best available knowledge gathered from the best authoritative sources in the industry.
3. Relate this guidance to underlying theory concerning the performance of walls. Because of continuous development and advances in technology it is intended that revisions of individual volumes will be made if and when it becomes necessary.

The technical frontiers are constantly being expanded by adventurous architects, engineers and industry in the pursuit of advancement and perfection. This CIRIA initiative does not attempt to embrace the most recent developments in advanced cladding technologies such as suspended structural silicone-bonded glass assemblies. These volumes do, however, deal comprehensively with most of the frequently used types of wall technology. They are each assessed against the performance requirements criteria set out in Volume A. The range of wall types covered is divided by a simple system of classification into six volumes, lettered B to G, each containing a number of related parts, dealing with particular materials and methods.

As well as developments in sophisticated new technologies applied to wall cladding, the future is likely to see a growth in demand for improved thermal performance and low energy use in the production of materials. Steps are being taken to improve the thermal performance of traditional types of wall construction. New concepts are exemplified by the practical experiment constructed in Denmark for their own offices by a major insulation material manufacturer using multiple layers and lamellas of mineral wool insulation, the recent 'Low energy' houses built at Milton Keynes or the 'Ecologically sound' self-build housing built by a foundation in north-east Scotland.

In a different direction there are new forms of lightweight cladding to curtain walls being developed using for example, thin ceramic, thin stone and marble, plastic laminates and super-compressed insulation materials. Double or triple glazing in thermally-broken frames and the development of low emissivity and reflective coatings permit imaginative and technically sophisticated possibilities for totally glazed walls where these are appropriate, such as for the terminal building at Stanstead airport, the hotel atrium at Heathrow airport Terminal 4, or the Financial Times printing works in London's docklands.

Overall arrangement

'Wall Technology' comprises a set of 7 volumes, designed for ease of use by relating the volumes, lettered A, B, C, D, E, F and G, to each other, with a similar structure.

Each wall type is comprehensively investigated with its characteristics and performance assessed against a set of 16 headings related directly to the same headings in Volume A Part 4, Performance requirements for fabric.

For this reason each technology or material classified is named and has its responses numbered 1 to 16 with appropriate sub-numbering to relate directly wherever possible to the same numbers in Volume A part 4 for cross-referencing.

Volume A Performance requirements deals with the subject in general and is divided into 4 parts:

1. Overall design considerations
2. Conditions required within the building
3. Natural forces and other agents.
4. Performance requirements for fabric.

Volumes B, C, D, E, F and G each deal with a wall type or a group of similar wall types according to a simple classification system.

Volume B Loadbearing small units, classified as:

1. Brick
2. Concrete block
3. Stone (including facing to other loadbearing masonry).

Volume C Small units on framed buildings, classified as:

1. Masonry cladding on concrete frame (including a steel frame encased in concrete)
2. Masonry cladding on uncased heavy steel frame (when varied from 1).
3. Lightweight and masonry cladding on timber frame.
4. Lightweight and masonry cladding on light steel frame.

Volume D Large lightweight units on framed buildings, classified as:

1. Metal: steel and aluminium
2. Glassfibre reinforced cement
3. Glassfibre reinforced polyester
4. Fibre-cement
5. Metal-faced proprietary composites

Volume E Large heavy units on framed buildings and in-situ concrete:

1. Concrete panel
2. In-situ concrete

Volume F Glazing, curtain walls and overcladding.

1. Glazing
2. Curtain walls and overcladding (including rainscreen)

Volume G Applied finishes

1. Tiling: faience and terracotta
2. Rendering

Volume F is in two parts dealing with glazing and with curtain walls and overcladding. The first looks at many types and techniques using glass and plastics. There are many new developments are taking place in the application of glazing techniques and some of these may give rise to potential problems. As a consequence there are a number of questions for which designers need a quick and objective reference concerning the application of glazing materials in their various forms.

Glazing now can be used as part of an 'intelligent' working facade with facilities to exercise an unprecedented degree of control over the internal environment of building including thermal and acoustic comfort and, where appropriate, view and sunshine. This volume does not, however, consider recently developed structural silicone and suspended frameless glazing systems since it was thought by the editor and steering group that advice on these technically advanced systems should be sought from appropriate manufacturers of the systems available.

The second part of this volume covers curtain wall and overcladding design and application including the 'Rainscreen' principle. There are three basic principles embodied in this technology which need to be understood by designers.

- **SEALED**, in which all panel or glazing edges and possible paths which might permit water penetration of the wall are totally sealed with the intention of forming a complete weather barrier to the elements. Sealed constructions employ vertical, and for multi-storey buildings, horizontal frameworks with the panels fixed to all edges with gaskets or by use of sealants. These systems rely for their success on the quality of materials and workmanship in the installation of the gaskets and/or sealants. It must be accepted, as a restraint, that these gaskets and/or sealants are likely to have a service life less than the other components forming the wall.
- **RAINSCREEN** adopts the principle that the majority of rainwater will be deflected from the outermost face but assumes a minimal penetration through joints into an inner zone where drainage and evaporation to external air can occur. These systems have panels with restricted open joints. Vertical support members are used to form uninterrupted ventilated cavities for the full height of the cladding behind the inner face of the panels. Protected inlet and outlet openings at the base and top will then allow drainage and induce air flow.
- **PRESSURE EQUALISED RAINSCREEN** exploits the use of the airspace behind the facing panels as a means of controlling the effects of wind action on the facade. This aims to limit the extent of rain penetration by incorporating openings protected by baffles, drips and other features in the cladding assembly so as to balance the wind-induced air pressure across the joints. This procedure avoids any use in the outer screen of gaskets or sealants.

Innovative new or modified designs for curtain walling and overcladding should always be tested thoroughly in conditions approximating to their potential site conditions in advance of their installation.

Reference should also be made to *Rainscreen cladding a guide to design principles and practice*, J M Anderson and J R Gill, CIRIA 1988.

Note regarding illustrations

Users of these volumes should particularly note:

1. The illustrations are only representative of different types of wall construction, and are not intended to be applied as standard answers. They are used only to show the principles which have to be observed when putting together an assembly of a similar type.
2. The sizing of the elements which make up the wall assemblies have, in general, been omitted. Actual sizing will depend upon the individual circumstances of the construction and/or, for instance, changes and development of the building regulations. The illustrations must not be translated directly into practice without first checking all the parameters involved in a particular project.
3. The details in illustrations are generalised and could be affected by decisions of designers to use particular proprietary components or elements. In many instances illustrations of components, elements and assemblies have been abstracted from manufacturer's literature, but are given only to demonstrate the principles involved.

Part 1 Glazing

First draft prepared by Mr Brian Pye, Pilkington Glass Consultants. Supplementary information supplied by Rohm Ltd Plastics division, GE Plastics Structured products, and the trade literature of manufacturers of materials and components. Edited by Mr Basil Gillinson, with added assistance from Dr W M Wolmuth of John Mowlem Construction plc and William J Marshall and Partners.

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1. General properties

Glass is the usual material chosen for glazing buildings but in certain circumstances and for particular locations more recently developed plastic materials may be selected.

Transparent glass for use in buildings is normally manufactured by the 'float' process. It can be produced either as a clear material or in a range of colours. In some processes a durable coating can be applied onto one surface during manufacture. Some glasses for building are also produced by a rolling process – typically patterned and wired glass – and have a translucent appearance. Most glasses can then be further processed, by toughening, laminating, texturing or (in the case of wired glass) polishing, or used in combination to produce sealed double- or triple-glazing units. Double-glazed units can have a coating applied and be filled with a special gas so as to significantly improve their thermal performance.

Glass is a useful and versatile material, largely taken for granted, which can be used in both vision and spandrel areas. There are, however, limitations to its use and advice should be sought by designers from glass manufacturers or specialist fabricators and installers for non-standard applications.

Plastic glazing sheet materials have different properties from those of glass and it is important that these are understood. Plastic materials are less brittle but softer than glass and may degrade with time and, although they are less easy to break and do not shatter, they are normally more readily affected by scratch marks and other surface damage. 'Longlife' coatings are available by which a transparent plastic sheet is provided with a co-extruded weather-coat for its outside face, improving protection against the effects of UV. Other coatings are available which prevents the formation of water droplets so that condensation becomes a water film on the surface, retaining high light levels, which can be useful for use in swimming pools and conservatories.

1.1 Appearance

1.1.1 Reflectivity and dazzle

Clear float glass reflects about 8% of the light falling on it perpendicular to its surface. As the angle of incidence increases the percentage reflected also rises, very rapidly when the angle is above 60°. Thus, a modern office-type building with a lot of glass in the facade will reflect both light and heat and may produce specific images of its surroundings for much of the time and from many viewing angles. With the increasing use of solar control reflective glasses, many of which have reflectivities of around 40% even at normal incidence, the likelihood of encountering bright reflections from windows is increased.

With care in design, potential problems can be anticipated and overcome by:

- The use of a glass with a lower reflectivity
- Higher internal illumination levels (but this may not be energy efficient)
- Tilting the glass in a facade
- Facetting the facade.

There has been no evidence of any problems being caused as a result of reflected heat energy from facades using reflecting glasses.

There will always be some possibility of distortion in a facade incorporating reflective glazing. The distortion of reflections will increase where there are long or oblique views of the building. The use of sealed double-glazed units is likely to increase the observable visible distortion. Consideration of the geometry, and angles between sun, buildings and 'viewer', at the design stage can minimize such problems.

The effects, which depend on the amount of energy reflected rather than the exact angle of reflection, such as overheating by reflected sunlight, are unlikely to occur with glass to any greater extent than with most other building surfaces.

References: Manufacturers' trade literature and Glass and Glazing Federation: *Glazing manual*

1.1.2 Colour

Glass for glazing purposes is generally of the soda-lime silica type with composition conforming to BS 952. During manufacture glass can be tinted to give a range of colours, typically bronze, green, blue and grey and/or coated to give a range of reflective metallic colours. Additional colours can also be achieved by off-line coating methods, typically green, bronze, grey, blue silver and gold. Alternatively colouring can be achieved by laminating with special interlayers or firing on of enamels.

The effect of using coloured, tinted or reflective glasses is to help in the control of solar radiation entering a building. The choice of glass can have a significant effect on the internal environment within the building by excluding unwanted solar gain and retaining internal warmth.

Plastic materials are available, clear, white and transparent, coloured and translucent or opaque. UV absorbent or UV transmitting grades and special high impact grades are also available, i.e. polycarbonate (PC), acrylic (Pmma) and polyvinylchloride (PVC).

1.1.3 Texture

Glass can also be supplied with a pattern or textured design of a decorative nature on one surface, and can be produced in a range of tints and colours. Wired glass manufactured by this method can be ground and polished to produce a clear transparent product. The surface texture of the glass can be further modified by etching or sand blasting or the application of a ceramic 'frit', dot matrix or other pattern as a shading device.

These various glasses can also be incorporated into double-glazing units for areas where insulation, either thermal or acoustic, is also be an important consideration.

Reference: Manufacturers' trade literature

Many of the available patterns can be toughened and/or laminated allowing the glass to be classified as a safety glazing material in accordance with BS 6206.

1.2 Geometry

1.2.1 Dimensional co-ordination

Glass should be glazed and fixed according to the general glazing advice given in BS 6262: 1982. Some glasses require special systems because of the function of the glass or the glass construction. These are:

- laminated glass
- security glass
- insulating glass.

Glass sheets are available in a range of thicknesses from 3 mm up to 25 mm and in sheet sizes typically up to 600 mm × 3210 mm. Plastics glazing is available in sheets varying in thickness from as little as 1.5 mm up to 25 mm. Depending on the grade, thickness, and whether in single, double or triple-skinned form, they can be supplied in sheet sizes ranging from 1200 mm × 1000 mm up to 10000 mm × 2050 mm.

1.2.2 Joints

Glazing may be fixed into frames made out of a variety of materials – timber, aluminium, unplasticised PVC, steel – or directly into concrete or masonry surrounds. The frame should be square and true and it must support the glass and be strong enough to prevent the creation of twisting stresses.

1.2.4 Tolerance and fit

The 'tight size' dimensions of glazing frames should be accurate to a tolerance of ± 1.5 mm and the diagonals should not differ by more than 3 mm. The frame members must be strong enough to limit the deflection under design loading to 1/175 of the span or 15 mm, whichever is the smallest.

1.2.5 Fixings

Frames should be plumb and be fixed or anchored so that loads due to structural movement cannot be transmitted into the frame. All glazing surfaces must be free of dirt or other contaminants and any protective lacquers or films must be removed. Precast concrete frames must be properly compacted and be fair-faced.

Drained and ventilated glazing systems must perform in practice according to the design of the frame manufacturer. The principle requirements for sealed doubled glazed units are:

1. A clearance of at least 6 mm on all edges to be kept free from unnecessary obstruction
2. The bottom glazing platform to slope at least 10° to the outside
3. Drainage outlets at least 5 mm high and 25 mm wide to be located about 30 mm from the corners and centred no more than 300 mm apart. They must not be blocked by setting or location blocks, glazing compound or dirt
4. A 'baffle' system to keep wind-driven rain out of the rebates
5. A recommendation that, ideally, ventilation slots should be provided in the top rebate at either end of the window opening, 20 mm × 3 mm, in exposed parts of the window. (Despite this recommendation, many frame manufacturers do not provide these ventilators and their appearance may often be unacceptable to designers).

Glazing with plastic sheet can be carried out using various systems:

- Glazing into rebates with beads. This is the most common method
- Over a nib with structural gaskets using a zipper strip to provide compression
- Using Y-section or ladder gaskets
- Fixing with bolts or screws to non-plastic material.

For plastic glazing the rebates must provide adequate edge cover and allow for the greater flexibility of the material. The beads may be of metal or wood, combined with a suitable sealant, either silicone or polysulphide, always the latter for edge lengths greater than 2 m.

Reference: Manufacturers' trade literature

Ethylene propylene diene modified and silicone gaskets are also suitable. Butyl sealants may only be used for panes with an edge length less than 500 mm. Fixing plastic sheets with bolts or screws should allow for the sheets to expand or contract without restraint, by the use of rubber grommets, oversize clearance holes or elongated slots in the sheet.

Refer to Figures F1.1 and F1.2 Typical glazing systems

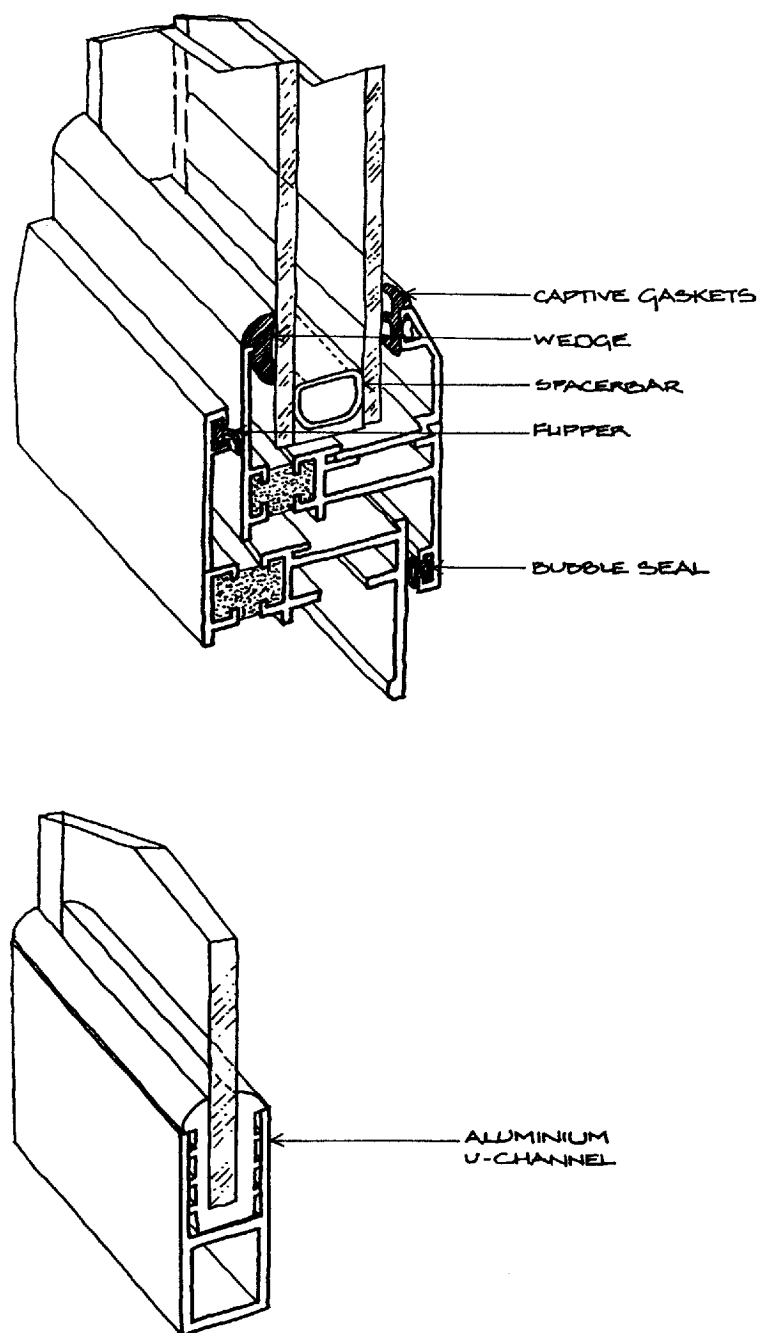


Figure F1.1 Typical gasket glazing system (above) and typical fully-bedded single glazing

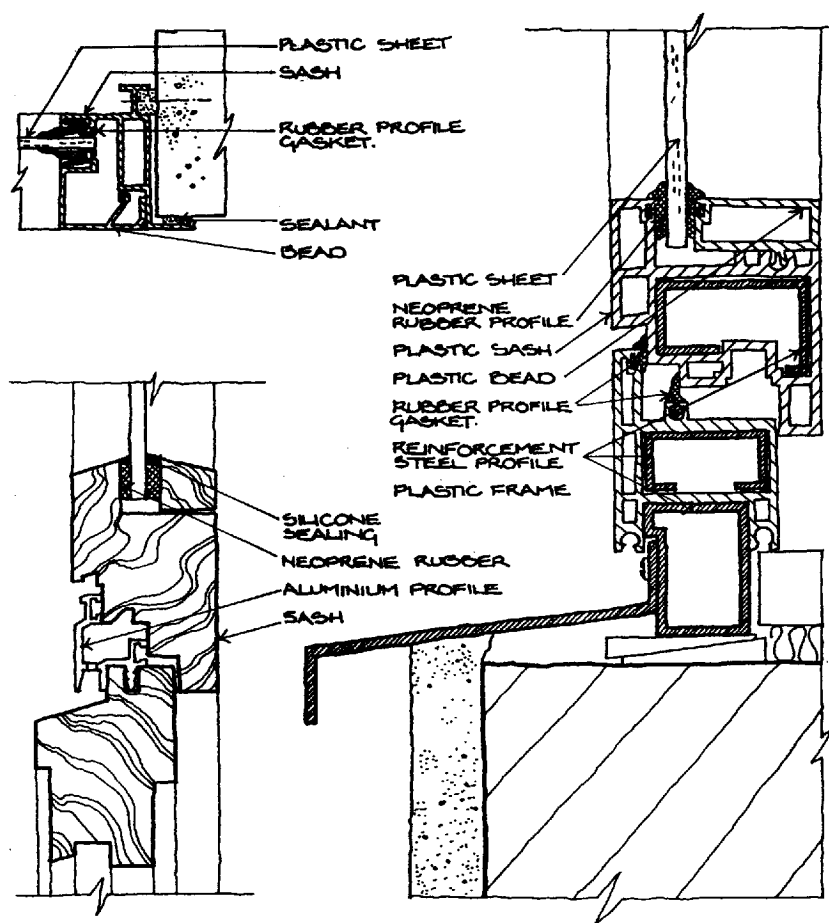


Figure F1.2 Typical glazing methods with plastic sheeting

1.2.6 Accommodation of structural, thermal, chemical and other movement.

Glass or plastics used in forming a part of exterior walling will be subject to movement due to the action of heat, moisture, imposed loading, or vibration. Some movements, such as those resulting from wind loads, may reach their maximum in seconds. Others may oscillate between maximum and minimum; for example atmospheric pressure changes will result in the glass of sealed double-glazed units deflecting marginally outwards or inwards. Failure to allow for movement leads to stressing of the glazing material and may produce one or more of the following results:

- Ingress of water to building due to glazing seal failures and possible breakdown of double glazing unit seals due to moisture penetration
- Breakage of glass
- Cohesive/adhesive failure of sealant or gaskets
- Deformation of adjacent components causing mechanical fracture of glass
- Bowing of plastic because insufficient allowance made for its greater coefficient of thermal expansion than that of glass.

Glass is an inorganic material and has a very low rate of thermal movement (0.076 to 0.080 mm/m/10 °C temperature change.) Glazing frames of plastic or steel have high or medium rates of thermal movement. It is essential that glazing follows the requirement of BS

6262 in order that these movements can be accommodated by allowing correct clearances and by using suitable glazing materials and seals.

Plastics have a higher thermal coefficient of thermal movement than glass, which should be checked from the manufacturer's trade literature.

Glass must be fixed so that any movement of components does not transfer any stress to the glass. Some glass or plastic movement will occur as deflections under the action of wind loading or atmospheric pressure changes. In either case, following the glazing recommendations of BS 6262 and of BS 5516 will prevent glass fracture due to any mechanical movement.

Refer to Section 4.1

2. Structure

2.2 Dead and applied loads

Deflection of a supported glass edge under design loads should not exceed the length of span of the glass edge divided by 175 or 15 mm, whichever is less. Vertical deflections of horizontal frame members should be limited to a maximum of 3 mm or 25% of the design edge clearance, whichever is the less.

Twisting of cill members due to dead loads of the glass should be limited to 1% between the ends and centre to minimise mechanical bending stresses at the glass edge. Any high concentrations of point pressures, or glass to metal contact can cause fracture of the glass.

For vertical glazing, snow loads can be ignored and only wind loads need to be considered, see BS 6262. When glass or plastic glazing sheet material is inclined then its self weight plus snow loads must also be taken into consideration. The self weight of glass is typically 2.5 kg/mm/m² and the self weight of plastics is typically 1.2 kg/mm/m². The likelihood of frame support bar deflections will be greater for inclined glazing and can impose a sustained load on the glass or plastics.

Refer to Figure F1.3 Patent glazing support bars

Reference: BS 5516: 1991
Code of Practice for patent
glazing and BS 6262.

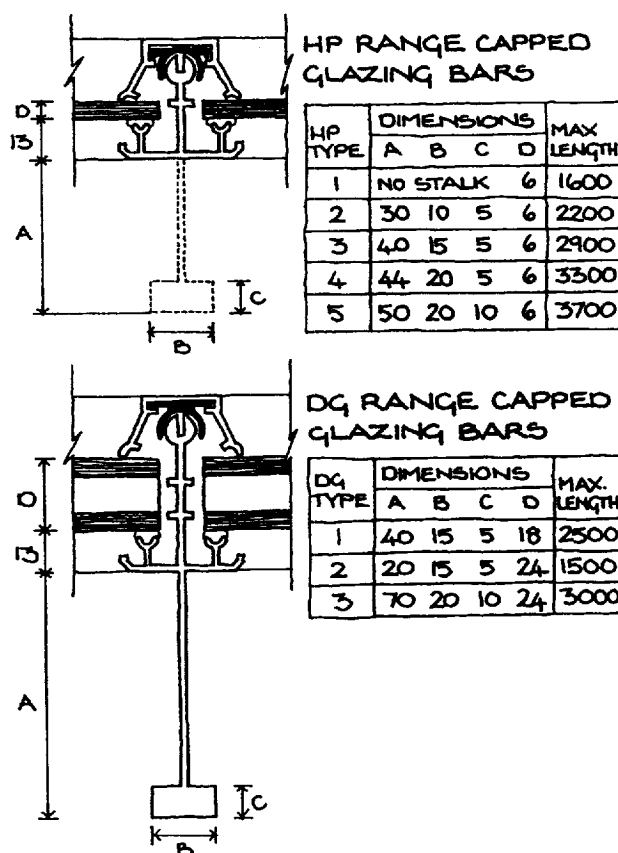


Figure F1.3 Glazing bars to sloped glazing

Wind loads

The calculation method for determining wind loads is described in Volume A Part 4 Section 2.4. When the maximum wind loading figure has been decided the minimum glass thickness can be ascertained from graphs supplied by glass manufacturers, and in accordance with BS 6262 and BS 5516. An example of a typical graph for vertical glazing in rectangular panes supported along all 4 edges and subject to a 3-second wind pressure is shown in Figure F1.4. This shows a band thickness, the lower edge to be used for aspect ratio 1:1, the upper for aspect ratio 3:1, with interpolation for intermediate values. As the aspect ratio of long to short edge increases for a given area, a rectangular plate will be able to withstand a greater load than a square plate. This is because the distance from the centre to the nearest supported edge is less. For inclined glazing BS 5516 should be consulted as self weight and snow loads will need to be considered together with the wind load.

Reference: BS 6262 and BS 5516

Refer to Figure F1.4 Typical wind-load graph

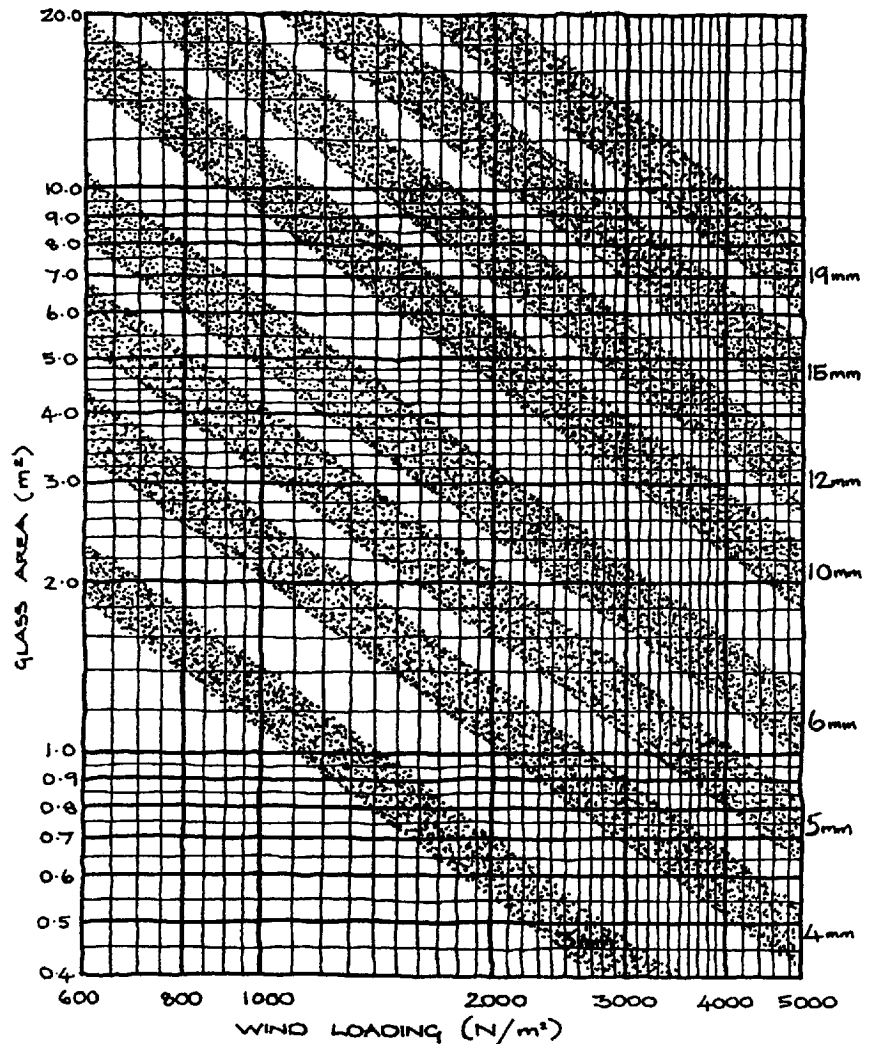


Figure F1.4 Annealed float glass – typical wind load graph

2.5 Accidental loads

The resistance to damage of glass from impact depends on the type of glass, its dimensions, thickness, how supported and the type of impacting body, mass, shape, speed, hardness and where impacted. Laminated glass is no more resistant to impact than ordinary float glass but if fractured the plastic interlayer holds the pieces together, whereas toughened glass can resist an impact 5 times greater than ordinary float. Wired glass has an impact resistance similar to float glass but when broken it is held together by the wire. The use of an adhered protective film also tends to hold the pieces of glass together after fracture.

Glass and plastic glazing sheet materials can be classified as to their resistance to accidental human impact according to BS 6206. A product meeting this standard is referred to as a Safety Glazing Material.

BS 6262 specifies various hazardous areas within a building and recommends minimum glazing solutions. For areas where ordinary glass is not recommended, the minimum performance level of Safety Glazing Material is referred to. For 2-edge supported glazing and inclined glazing BS 5516: 1991 makes appropriate recommendations.

Changes to Building Regulations may make the use of Safety Glazing Material mandatory for many locations.

Potential internal or external forces from explosions should be either dissipated or confined so as to limit damage to the essential structure or injury to the occupants and passers-by.

An enclosure which distorts and expands to absorb the blast without total disintegration may be advantageous if excessive forces are not to be transmitted to the essential structure, and may help to prevent personal injury. Framing, infill panels and glazing, should be chosen together with their fixings, to minimise the effect of flying debris on occupants or passers-by.

If glazing is essential in areas of high risk, plastics or laminated glass should be used with the provision of heavy net curtains to reduce the danger of personal injury due to flying splinters. Adequate framing and edge cover and the anchorage of window frames to the structure is necessary. It is essential to consult with manufacturers for specific advice.

2.7 Loads on fixings

Manufacturers or suppliers will advise and recommend the correct sealants for the framing surround and for glazing to ensure that excessive elongation or contraction of joints under loading does not occur, and that the sealants are compatible with the surrounding materials.

Refer to Section 1.2.5

Reference: BS 6262
Table 11.

3. Weathertightness

3.1 Permeability to air

Reference: BS 5368 Part 1

Glass is impermeable and plastic glazing sheets used for glazing have a very low permeability to air. Window systems can be tested for air penetration using the method described in BS 5368 Part 1.

3.2 Driving rain and water run-off

All glass and plastic glazing sheet elements must be installed in external walls so as to prevent the ingress of rain, wind, snow and dirt to the building or else be designed so that any water that penetrates the glazing rebate is drained from that area to the outside. It is necessary to make sure that none of the frame and glass seals will allow wind pressure to force water through into the interior of the building.

To ensure long life, it is important that the edges of sealed double-glazed units be so fixed that they cannot be affected by entrapped water.

3.3 Permeability to water, absorption, capillarity etc.

Glass is impervious to water as are plastic glazing sheet materials for all practical purposes.

When installing double-glazing units it is absolutely imperative to protect the edge seal of the unit from attack by water. The glazing system must be designed so that either the edge seal exists in an effectively dry environment or the penetration of rain and condensation to the edge seal is prevented.

There are basically two methods of glazing with sealed double-glazed units.

The first is the long established system of mastic glazing in which the edge of the unit is solidly bedded in a flexible sealant material.

The second are newer and preferred systems in which weatherproofing is by means of strips of foam material which have a sealant capping or gaskets which are pressed firmly into contact with the glass on both faces. This method allows an air space to be created round the edge of the unit which can be drained and ventilated by provisions incorporated into the framing or support system.

Refer to Figures F1.5 and F1.6

NOTE: It should be noted that in the opinion of some authorities concerned with the use and specification of double glazing that sealed systems will be unlikely to perform satisfactorily long term and may fail prematurely in the life of the building. This possibility can be considered in the 'life cycle costing' analysis,

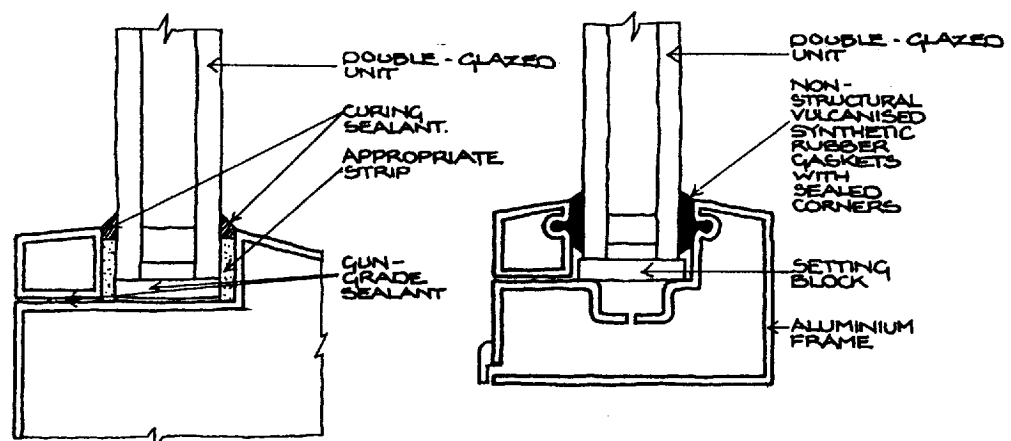


Figure F1.5 Fully-bedded-strip and capping (left) and drained glazing system

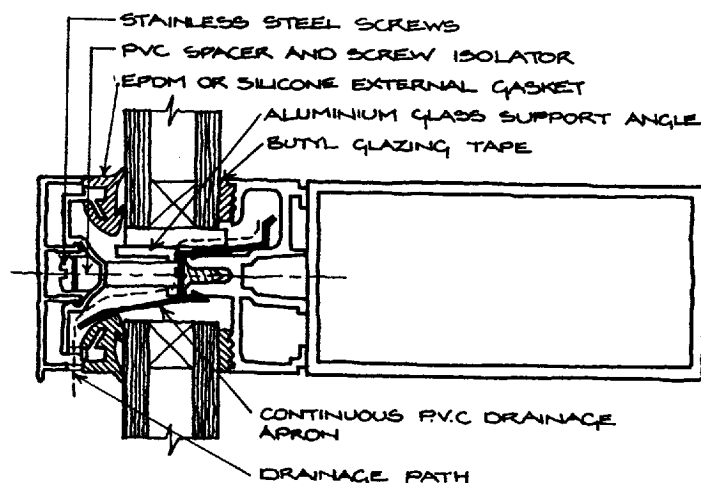


Figure F1.6 Typical drained curtain wall system

In 'drained' glazing, outlets in the bottom rebate and/or in the bottom glazing bead are arranged to allow any water that penetrates to the edge of the unit to drain away to the exterior. The theory is that both the external and the internal glazing seals should prevent the penetration of virtually all the water.

In 'drained and ventilated' glazing only the internal glazing seal needs to be watertight. Ventilation is used to dry the edges of the glazing unit. The space around the edges must be kept free of obstructions and careful siting of location blocks is necessary. Any water which penetrates is designed to be drained away.

In both 'drained' and 'drained and ventilated' systems, the drainage and ventilation holes or slots must be positioned or protected so that the wind cannot blow rain into the rebate and they must not be allowed to become blocked by dirt.

In 'fully-bedded' glazing, the spaces between the sealed double-glazed unit and the frame are completely filled with one or more glazing compounds so that, at least in theory, all water penetration is prevented. One-part silicone or 2-part polysulphide or silicone are the most commonly used bedding and sealing materials.

In the early days, after its introduction, the preferred method for sealed double-glazing unit installation was by fully-bedded systems, but doubts have been raised recently about this method. These have arisen because of the difficulties encountered in ensuring the application of sealant so that it is free of any voids which might hold water, and in carrying out regular maintenance. In the last five years (prior to 1991) the preferred installation method has been by means of a drained and ventilated system wherever appropriate.

3.4 Snow and hail

If the glazing satisfies the criteria set out under Section 3.3 above then there should be no additional problems caused by snow and hail.

Sloped glazing, however, needs very careful consideration. Severe hail storms have been known to cause glass breakages, so it becomes imperative to specify appropriate glass or plastic sheet glazing material in these locations. Similarly note should be taken of the potential weight of snow which may accumulate on sloped glazing if it is not rapidly

thawed. Further care must be taken to install snow-boards at the eaves of higher-level pitched roofs where there may be a potential danger from heavy snow-slides onto glazed roofs at a lower level.

4. Durability and compatibility

4.1 Modes of failure

Glass is very durable under normal conditions. Chemical deterioration of the surface can occur by the action of water-borne or deposited materials or presence of permanent condensation within unventilated spaces behind glass cladding. Where rainwater which has collected alkalis from surrounding construction may run down the surface of the glass, chemical attack or staining may occur. Particular care in this respect is needed when using plastic materials.

All glazing materials should be protected both internally and externally during building construction from the effects of plastering, weld splatter, cleaning chemicals etc.

The manufacture of sealed double-glazing units, although a straight forward process, involves a number of different operations, during any of which poor attention to detail can result in premature failure of the perimeter seals in service. Similarly a well-made sealed double-glazing unit if poorly installed, and/or using sealants incompatible with the perimeter seals, or in a system which allows water to collect adjacent to these seals, is also likely to fail prematurely.

Refer to Section 2.6 and Figure F1.7

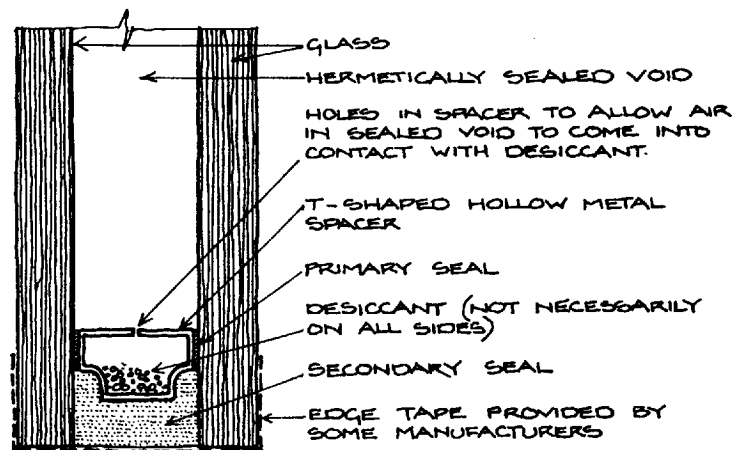


Figure F1.7 Typical section of double glazing at perimeter seal

As there are no performance standards available to the specifier by which life expectancy of sealed double glazed units can be predicted it is suggested that units specified are:

1. Tested to BS 5713 Specification for hermetically sealed flat double glazing units
2. Manufactured under BS 5750: 1979 Quality Systems and be checked for quality before fixing in particular for major building projects
3. Glazed wherever possible, in drained and ventilated framing systems following the recommendations of BS 6262 Code of Practice for glazing of buildings

Any further recommendations of the glazing unit manufacturer should also be accommodated in order that warranties of performance are not invalidated.

Refer to Section 2.6

4.2 Compatibility

To ensure compatibility of adjacent materials, the durability of the glass or plastic glazing sheet materials and the possibility of interaction between adjacent materials both in the glazing system itself and between it and the surround must be carefully considered.

Plastic glazing materials may be attacked by certain substances. To avoid crazing, only compatible gaskets, clamps, sealants and cleaning materials etc. should be used. Information should be obtained from the material supplier. It is imperative that contact with plasticised PVC paint solvents, insecticide sprays, impregnating agents, powerful industrial cleaning agents and other aggressive materials and media is avoided.

4.3 Corrosion

The corrosion of metals which are in close proximity to glass surfaces may cause glass breakage as a result of induced localised high stress.

5. Sound insulation

The weakest point for sound transmission through an external wall is usually the windows. This is due, mainly, to air gaps round the frame, and to the fact that conventional single glazing offers relatively low sound insulation. Windows that are openable to allow for natural ventilation cause total loss of sound insulation when open regardless of glass thickness. In air conditioned buildings, however, sound insulation is usually good because windows are sealed so that noise problems are avoided.

The three main factors which affect the characteristics of sound transmitted through a closed window are:

- The size of the window
- The thickness of the glass and
- The width of the air space in the case of double windows.

Doubling the area of glass will double the amount of energy admitted and this will increase the level of transmitted sound by approximately 3 decibels (dB). Similarly, halving the area of window will reduce sound levels by approximately 3 dB. 3 dB can be described subjectively as a just-noticeable difference only, therefore reducing the window area is not the most significant factor in improving the sound insulation of a building.

There are three effects dependent on glass thickness.

- The 'mass law' effect. For a given frequency, doubling the mass and therefore the thickness of a piece of glass will theoretically increase its sound insulation by 6 dB.
- Panel resonances. A glass panel can resonate at certain frequencies depending on its size, stiffness and mounting as well as its mass. The effect of resonance can be to impair sound insulation at low frequencies e.g. traffic noise. The thinner the glass the lower will be the frequency at which fundamental resonance occurs.
- The coincidence effect. At a certain frequency the wavelength of sound will be the same as that of natural oscillation of the glass and consequently the transmission loss through the glass is reduced. This gives a characteristic 'coincidence dip' in the insulation spectrum. The greater the thickness of the glass, the lower will be the frequency at which the coincidence dip occurs. The overall sound insulation of laminated glass is marginally better than that of a monolithic glass of similar thickness, mostly occurring in the coincidence region.

In multiple glazing systems the width of the air space between panes is the most important factor. The wider the air space the better. A separation of 150 to 200 mm, with the glasses in separate frames, may be necessary when insulating against severe noise sources. Additional benefit can be obtained by lining the reveals between the two windows with an acoustic absorbent and which is not in contact with the frame. Tight fitting windows are essential, small gaps having a marked influence on overall efficiency. The ventilation of rooms should be by means other than opening windows. If ventilation has to be provided by the windows, some sound insulation can be achieved by using sliders and opening the inner and outer windows at opposite ends. This provides a baffle to give sound insulation similar to closed single-glazed windows.

Refer to Figure F1.8 Typical noise spectra

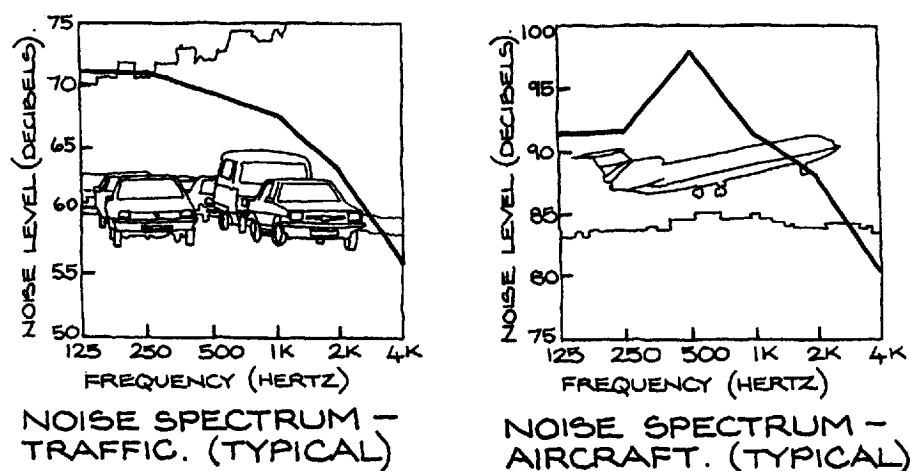


Figure F1.8 Typical noise spectra

This means that different glass substances having different insulation spectra could be represented by the same single figure for insulation. These single figures should be regarded as an approximate rather than an exact indication of performance. A more satisfactory way of describing the noise reducing properties of glass is to list the complete insulation in spectrum. In this way, and by knowing the spectrum of the noise source, a designer will be able to decide which glass types will be most effective. In particular he can check that the coincidence does not occur at the same frequencies at the predominating frequencies of the noise source.

Reference: BS 2750

A single figure, in decibels, is often given when describing the sound insulation of a particular window. Such a figure is the arithmetic mean of the values of insulation measured in each of fifteen third-octave bands according to BS 2750.

It has been determined by the Building Research Establishment that the type of window frame material, makes no significant difference to sound insulation, other than that the frame should be of good quality and be adequately sealed.

6. Heat and moisture

6.1 Thermal insulation

The thermal transmittance (U-value) for clear float glass is $5.6 \text{ W/m}^2\text{K}$ but this can be improved appreciably by double glazing. The improvement is derived by enclosing a layer of air or gas between the two glasses and is dependent on the air space width, the emissivity of the glass surface and the thermal conductivity of the gas.

When standard surface conditions are defined, a Standard Thermal Transmittance is obtained and a range of these are shown graphically in Figure F1.9.

Refer to Figure F1.9

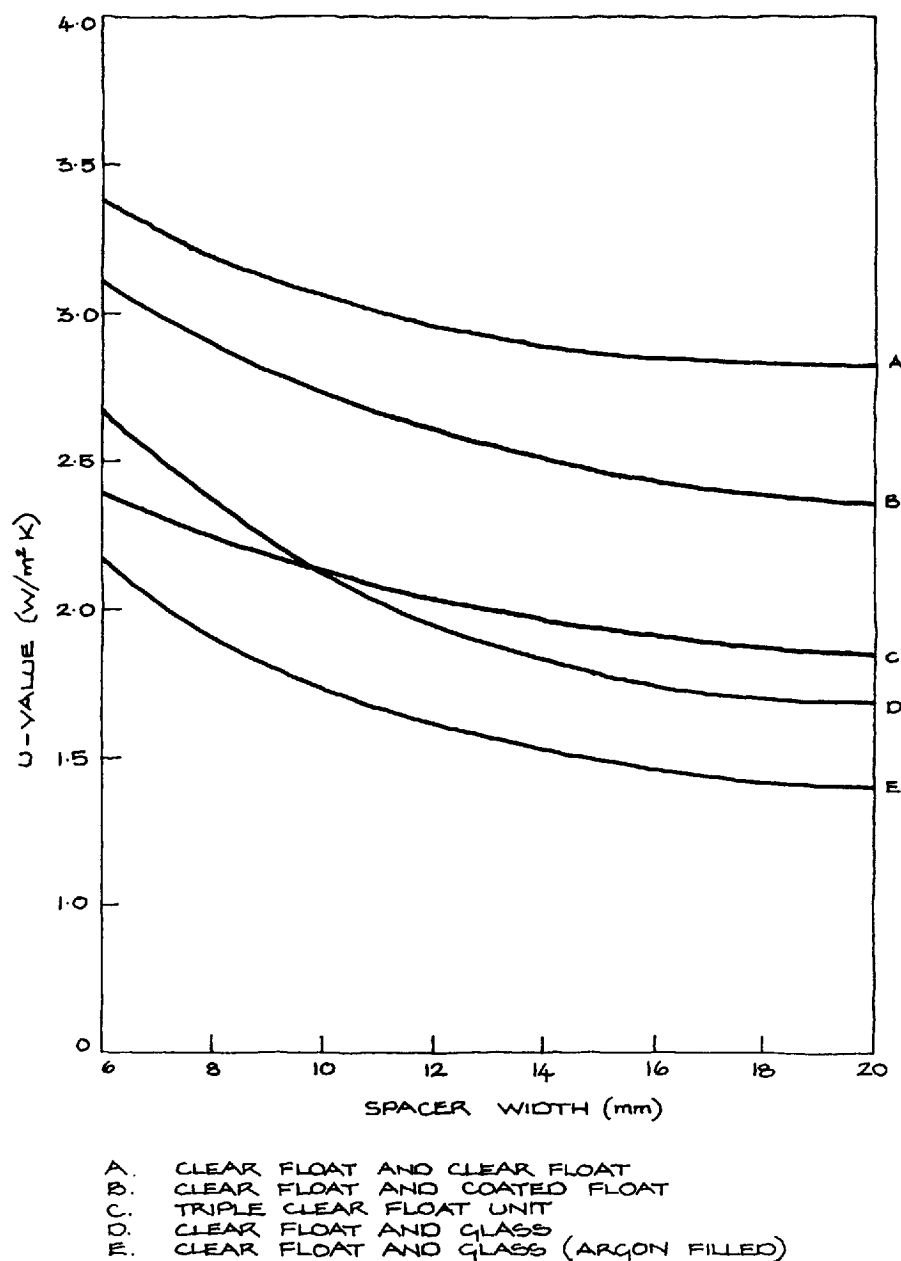


Figure F1.9 Standard U-values

The thermal transmittance improves as the air space width is increased. It can be seen that the U-value improves, i.e. decreases in numerical value, as the air space width is increased up to 20 mm. For air space widths greater than 30 mm, however, convection within the airspace increases and this leads to a corresponding reduction in U-value. Further improvements may be expensive because of the increased cost of units and special frames to accommodate them. It is usually better to improve the insulation using a glass with a low emissivity coating and/or by changing the enclosed gas type.

In spandrel areas both single and double glazed toughened glass units can achieve U-values of between 0.42 and 1.15 W/m²K, depending on the construction, if glass fibre or rigid foam board is attached to the back.

The emissivity of a surface is a measure of its infra-red reflectivity – the lower the emissivity, the more infra-red energy is reflected and so not transmitted through the surface. An untreated glass surface has a high emissivity (0.85-0.9), whilst low emissivity glass measures less than or equal to 0.2 as defined in building regulations. The beneficial effect of using low emissivity glasses in sealed double glazed units, and of replacing the enclosed air by an inert gas such as argon are illustrated in Table F1.A.

Sealed double-glazed unit Specification	Thermal transmittance (W/m ² K) Spacer width (mm)					
	6	8	10	12	16	20
Clear float and clear float	3.4	3.2	3.1	3.0	2.9	2.8
Clear float and float 20/34 (silver)	3.1	2.9	2.7	2.6	2.4	2.4
Clear float and coated low emissivity glass	Not recommended			2.0	1.7	1.7
Clear float and coated low emissivity glass (argon filled)	Not recommended			1.6	1.5	1.4

NOTES U-value for single Float glass is 5.6 W/m²K. Thermal resistances of glass not included.

Table F1.A Standard U-values of some sealed double glazed units, for standard exposure conditions and based on the methods in the CIBSE Guide

The standard U-values that are effective in comparing one structure with another must be modified in practice to take account of the effects of the outdoor wind exposure conditions. In the case of windows the effect of the window frame and the levels of wind exposure: sheltered, normal and severe, are used. The effect of these on the U-value of some framed windows are shown in Table F1.B.

Frame type	Percentage of window area used by frame	U-value (W/m ² K) for stated exposure					
		Single			Double		
		Sh	N	Se	Sh	N	Se
Wood	10	4.7	5.3	6.3	2.8	3.0	3.2
	20	4.5	5.0	5.9	2.7	2.9	3.2
	30	4.2	4.7	5.5	2.7	2.9	3.1
Aluminium	10	5.3	6.0	7.1	3.3	3.6	4.1
	20	5.6	6.4	7.5	3.9	4.3	4.8
	30	5.9	6.7	7.9	4.4	4.9	5.6
Aluminium with thermal barrier	10	5.1	5.7	6.7	3.1	3.3	3.7
	20	5.2	5.8	6.8	3.4	3.7	4.0
	30	5.2	5.8	6.8	3.7	4.0	4.4

Sh = sheltered; N = normal; Se = severe

Table F1.B U-values of framed windows for three exposures

Sealed double glazing offers the most convenient method of thermally insulating new buildings. The fitting of secondary sashes is useful to improve the performance of existing windows.

The optimum gap for thermal insulation is around 20 mm, for sound insulation 100 mm or more may be required. It is sometimes thought that thermal and sound insulation are incompatible properties. This may be because the effect of convection on the heat transfer through the window has been exaggerated. Wide air space windows having good sound insulation will also have good thermal insulation.

6.2 Thermal capacity

All types of glazing have a minimal thermal capacity which must be disregarded in any thermal calculations.

6.3 Permeability to water vapour, risk of interstitial condensation

Glass is impermeable. It is the seals at joints and with frames that control the passage of water vapour.

Multiple glazing reduces the heat flow through the window, leading to an increased inside surface temperature which lessens the incidence of surface condensation. The four parameters which govern the formation of surface condensation are:

1. Internal air temperature
2. External air temperature
3. Relative humidity
4. Thermal transmittance of the glazing.

As an example, when the internal air temperature is 20°C and the relative humidity is 60%, condensation will not form on double glazing, of U-value 3.0 W/m²K, until the external temperature falls below -3°C. Under the same internal conditions condensation would form on single glazing, of U-value 5.6 W/m²K, when the external temperature fell below 8°C.

If the relative humidity of a space is 100% and the internal temperature is higher than the external temperature, no amount of thermal insulation can prevent condensation forming on the walls and windows. Under these extreme conditions the moisture should be extracted as close to the source as possible to prevent it dispersing through the building.

Condensation within the air space of double-glazing units is prevented by ensuring that there is not enough water vapour present for condensation to occur under practical conditions. Windows with secondary glazing (not sealed units) should have the air space ventilated to the outdoors to minimise the chance of air space condensation.

A breathing space can be made in dual glazing by having a loose-fitting outside frame. Even narrow slits, however, will seriously reduce sound insulation. A preferable method of ventilating the air space is to have two or three small holes, about 6 mm in diameter, drilled through the external part of the frame. To keep out dirt and small insects the holes should be lightly packed with mineral fibre. Venting the air space to the outside gives only a slight reduction in thermal efficiency but helps to reduce condensation and retain a clear view.

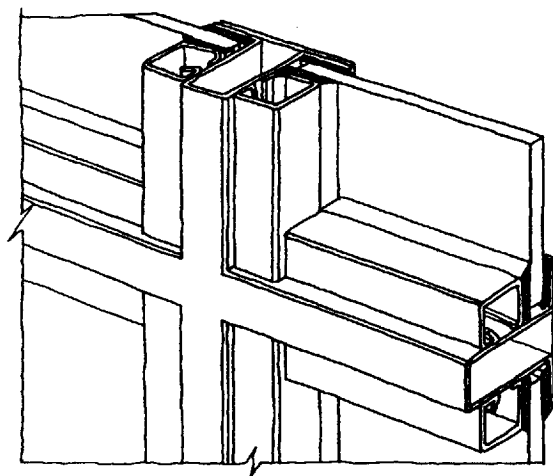
Moisture in an unsealed air space can be initially absorbed within the space, but the dessicant eventually becomes saturated and it can, in direct sunshine, sometimes release the moisture previously absorbed. Windows that are not hermetically sealed will allow dirt to enter into the space between the panes so provision must be made for cleaning the inner surfaces.

7. Fire

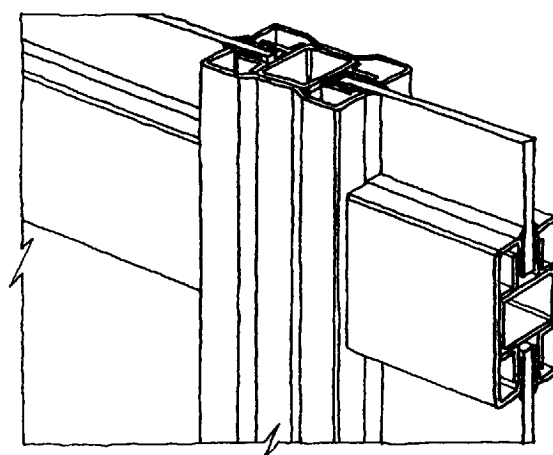
The fire performance of glass depends on the type, size, shape, number of panes, orientation, method of retention and performance required. Performance requirements relate to the size and position of openings, the internal arrangements of the building, its height, purpose and distance from the boundary.

Designers should obtain local advice relevant to that part of the country in which the building is to be located. General guidance on the fire performance of glass for various test conditions can be obtained from PD 6512: Part 3: 1987. For elements of construction, the fire performance which may be achieved depends upon the glazing system used. This level of performance can only be ascertained with any certainty by extensive and thorough testing.

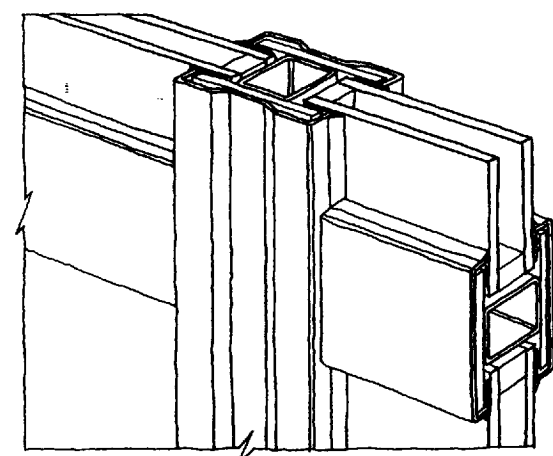
Refer to Figure 1.10



PROFILED STEEL
SECTIONS AND
BEADS



PROFILED STEEL
SECTIONS AND
BEADS



ALUMINIUM
CLADDING

Figure F1.10 Typical fire resistant glazing systems

NOTE: Prior consultation should be made with both fire prevention officers or advisers as well as with material manufacturers and component suppliers wherever there may be a potential hazard.

7.1

Fire safety

Certain acrylic glazing materials should not be specified for areas where their use might constitute a fire hazard. Some of these materials have an ignition temperature of as low as 430 °C . Some PVC materials produce large amounts of toxic smoke in certain fire conditions which could constitute a dangerous potential hazard.

8. Safety

8.1 Means of escape in case of fire

Specially designed frames of metal and timber incorporating insulating fire resisting glasses are available from specialist suppliers which are suitable for use to protect fire escape routes and be used in doors on such routes in certain classes of buildings. Prior agreement to their use must always be obtained from the local fire and building control authorities.

The principle usually employed uses multiple layers of specially treated glass interleaved with layers of intumescent material framed in appropriate fire resistant material with extra large rebates and other special design features. The behaviour in fire may, when appropriate, maintain transparency for the first few minutes of the fire to allow occupants to escape and firefighters to evaluate the extent of the fire.

As the heat increases, the intumescent layers expand and the glass becomes opaque thus indicating a severe fire but obscuring it from vision, which may help to prevent panic during an evacuation of the building.

It is possible with some systems to maintain a relatively low temperature of around 100°C on the side of the glazing away from the fire thus greatly reducing the risk of heat transfer leading to fire spreading to and igniting combustible materials thus assisting in the containment of a fire.

Refer to Figure F1.11 Typical details of fire resistant glazing

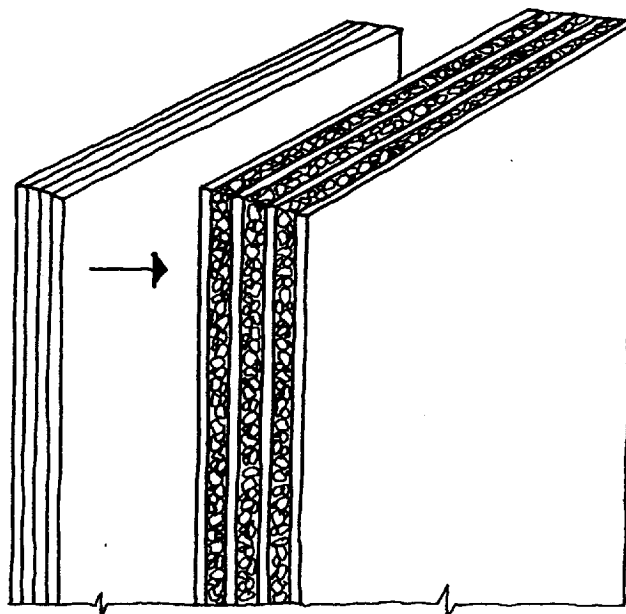


Figure F1.11 The characteristics of typical fire resisting glazing under fire conditions

8.2 Protection of the person against falling

Glass and plastic glazing materials are suitable for use as protective barrier walls in or on the outside of buildings provided the design meets the requirements of BS 6180. There are two distinct types of glass or plastic protective barriers; those in which the glass or plastic glazing sheet material acts as an infill panel and those in which they act as a structural element. Where plastic material is framed it is important to ensure that the rebates are sufficiently wide to ensure that the material, which will be more flexible than the equivalent glass, is held in place by the beads when subjected to exceptional pressures. Laminated and toughened glasses are both recognised safety glazing materials which may be suitable for protective barriers as defined in BS 6180: 1982.

Wired glass is not a recognised safety glass but may be used for certain protective barriers provided the glass is fully framed and no dimension exceeds 300 mm.

Reference: BS 6180: 1982

NOTE: Design details for infill panels can be found by reference to BS 6180: 1982.

8.3 Comfort including tactile properties

Glass and plastic glazing materials, even when they have textured or modelled surfaces, are essentially smooth to touch and do not emit deleterious substances.

8.4 Safety during construction

Glass can be a very dangerous material when being moved about or if improperly or carelessly stacked on a building site. Great care, therefore needs to be taken in handling and storing the material. When fitted in an incomplete building, glass panes should be marked clearly to obviate breakages due to accidents or carelessness. Glass breakages can cause serious or even fatal injuries.

Refer to Section 16.1

9. Security

Security glazing is used in situations where a high degree of protection is required either to persons or property.

When glass is used for anti-bandit purposes, it is normally formed from multiple layers of glass and plastics. Thick polycarbonate plastics are also suitable in certain circumstances subject to manufacturers recommendations.

Normally, laminated glasses designed to provide any specified degree of resistance to penetration or thick plastics are used. The precise constituent of the laminated glass will depend on the level of security required and the specification and glazing technique should be decided after detailed discussions with the supplier.

There are, typically, three considerations:

- Manual attack
- Firearms attack
- Explosion resistance.

For design guidance relating to security glazing see BS 5051: Part 1; BS 5357 and BS 5544.

10. Daylight and sunlight

10.1 Daylight

Refer to Volume A Part 4, Section 10.1 of this series.

10.2 Sunlight

10.2.1 Solar gain

Windows are transparent to sunlight and it is often as important to control the admission of solar heat as it is to limit heat loss from the building. Control of solar gain improves comfort and reduces air conditioning costs.

Radiation falling on a glass surface is partially reflected from the front surface of the glass: the rest passes into the body of the glass where a portion is absorbed and a small portion reflected from the back surface. The remainder passes through the glass as radiant energy with visible and non-visible components dependent on the spectral quality of the incident radiation, the composition of the glass and the nature of the glass surface.

The proportion of radiation reflected at the glass surface is dependent on the angle of incidence and the nature of the glass surface. At right angles to the surface the reflection is at a minimum; at glancing incidence a maximum. Radiation reflected from the outer surface of the glazing will not become part of the heat gain of the building. The proportion absorbed is dependent on the composition and the glass thickness. The radiation absorbed will cause the glass temperature to rise and the glass itself will then become a heat source. Some of the heat in the glass will be lost to the outside of the building: the remainder becoming part of the heat gain inside.

The amount of radiation reflected by solar control glasses can be altered by introducing traces of certain elements into the glass composition. With solar control glasses thermal stress must be minimised, therefore the edges of panes must be clean cut. Glass with nipped or damaged edges must not be used, because cracks start from edge flaws. Manufacturers' literature should be consulted for methods of reducing the risks of thermal breakage with particular reference to the combining of heat absorbing and wired glass in double-glazing units.

Refer to Section 6.1

10.2.2 Shading devices

There are many different possible ways to shade glazing taking into account both light transmission and heat radiation.

- A reflective light-coloured and diffusive interlayer of glass fibre or other similar material may reduce the total heat flow into the building. The radiation passing through will be diffused, reducing localised heating effects. Diffuse glazing may appear very bright when sunlit, and care must be taken to avoid discomfort. The thermal safety of such systems must also be considered.
- Glass can be screen-printed with a 'dot matrix' or a 'ceramic frit'. These treatments can be used to aid the control of both heat and light transmission through the glazing in walls. The extent of the ceramic coverage, which can be graded, will control the shading coefficient. For example a 40% 'ceramic frit' cover on to clear float glass will reduce the light transmission to 62% and the shading coefficient to 0.76.

- Diffusing glasses, including patterned and wired glasses may only reduce by a small amount the total amount of solar heat entering through the glazing, but they do have the effect of spreading the radiation and reducing intense localized heating.

- Other screening methods:

Blinds or louvre screens should preferably be controllable but some are permanent fixed installations, whilst others may be installed for the summer season. The blinds or screens, when fixed externally, should be of light colour to be more effective in excluding solar heat and to minimise the build up of thermal stress in the glazing system.

When using tinted or reflective glazing care must be taken to calculate the thermal stress across the glass which may be caused by overhangs or shadows, internal blinds or heat sources which might cause excessive heating of the glazing. In some circumstances it will be necessary to consider glass whose resistance to thermal stress is greater, i.e. toughened or heat-strengthened glass, or to reconsider design parameters.

11. Maintenance including acceptable wear on moving parts

All glazing systems are subject to some degradation with time by the action of the elements and building movement. Periodic inspection and maintenance work should be carried out systematically. The frequency of this depends on the nature of the glazing materials; their conditions of exposure and the location on the building. The inspection should check that the integrity and performance of the glazing system is not impaired. Water lodged in the neighbourhood of a double-glazed unit edge-seal will shorten its life.

Inspection should be carried out at least annually to check the integrity of sealant cappings and that drainage paths in drained systems are unobstructed and to check on seal integrity of compression glazing systems. With compounds and sealants where no cracking and no loss of adhesion has taken place, no maintenance is necessary. With slight surface cracks or slight adhesion loss, the compound should be taken out, or sealant cut back to a depth of 6 mm, and replaced with a similar fresh product.

Glazing materials and systems will not necessarily require maintenance or repair at every inspection. Generally, curing sealants and vulcanised rubber sections should not need frequent rectification.

The requirements for maintenance should be set out and handed over on completion of the glazing, as part of a building maintenance manual. This will ensure awareness of the need to comply with the maintenance procedure for the satisfactory performance of the glazing system in the years to follow.

11.1 Cleaning

Adequate provision for cleaning, care and replacement should be incorporated in the design of the building.

The selection of glazing systems (including materials and surrounds) should be influenced by:

- The provision of suitable and safe access for cleaning and maintenance, including consideration of any possible inconvenience caused to the building occupants
- The ease and cost of replacement of materials
- The cleaning costs.

Glass and plastic should be cleaned regularly. Failure to do this may result in discolouration and deterioration of the surface. Warm water with soap or a mild domestic detergent, followed by a clean water rinse, is generally adequate for routine cleaning.

For transparent glass, but not for plastics, polishing with whiting in water or methylated spirits may be found to be successful. Corrosive cleaning liquids are also sometimes employed, but care should be taken to ensure proper protection of the operative, and they should be sluiced away with an excess of clean water as soon as possible after use to avoid damage to the glass or fixing materials and window frames. Organic solvents are also useful for special purposes, e.g. for removing tar, paint that has not dried hard, or grease from glass, but again, must not be used on plastics. Any organic solvent is likely to have toxic properties and the operative should be suitably protected particularly against inhalation and skin contact. In some instances fire risk may need to be guarded against during use. The solvents should always be carefully cleaned off the glass afterwards. Plaster or mortar splashed on to glass may be removed with a razor blade.

If glazing in sunny situations is allowed to become very dirty, either internally or externally, the dirt will absorb solar heat. This may result in glass breakage. Toughened glass is not subject to the same risk, as it can withstand larger temperature differentials.

12 Repair and replacement

12.1 Life cycle costing

Consideration should be given during the design stages of the building to the replacement of large glass or plastic panes. Adequate lifting equipment in the form of roof mounted cradles, hoists or mobile cranes, if access is available, should be provided and precautions taken to avoid damage or injury by falling debris or breakages. Depending on the glazing method re-glazing may only be possible from inside the building which may necessitate the dismantling of interior components of the building.

12.2 Replacement of damage

Although glass and certain plastics are very durable, the sealants, gaskets and other components used to hold them in position have, in some cases, proved to be much less durable and short-lived. There have, for example, been instances of failure of sealed double-glazed units within a few years of manufacture and installation. Failures of the perimeter seals of units have been attributed both to faulty unit manufacture and imperfect installation.

Reference: BRE Digest 262
*Selection of windows by
performance*

It is therefore necessary to assume that glass or unit failures may occur and the design of buildings and the method of access to individual units needs to take into account facilities for ease of access in order to replace units. Replacement should be fabricated from site measurements and not original production drawings.

14. **Buildability, handling and workmanship**

While in transit from the store to the opening in which it will be glazed, glass is vulnerable to both bending fracture and impact damage. The method to be used to transfer the glass can be selected from a wide range of techniques, or combinations of techniques, to ensure that the glass can be moved without being bent or impacted. Some important techniques are discussed here.

14.2 **Handling**

The extent to which the glass can be carried by hand will depend upon its weight, size and the distance or height that it has to be carried. When ladders are in use for glazing from the outside, pieces of glass that are larger than can be carried under the arm should be taken up inside the building and passed through the frame to the glazier on the ladder.

Double-glazing units are about twice as heavy as single glass of the same size so the size of unit that can be carried is less than of single glass. The risk of strong, gusty winds must be assessed because glass is difficult to control under such conditions.

Straps or slings are used for handling large pieces of glass. They are passed under the bottom edge of the glass so that several carriers can share the load, taking care that the tops of tall plates are adequately supported. Carrying handles can be attached to the glass surface by suction pads. Each handle is attached to two or three pads that are placed on the glass surface and actuated by a small lever.

There is a great variety of trucks and glass-carriers. They should be easily moveable, and equipped to hold the glass securely. Glazing contractors often have their own mechanical methods of moving glass safely into position and the site conditions must be arranged so that the apparatus, such as crane-operated vacuum-suckers, can be used to the best advantage.

14.4 **Weather interference**

Adverse weather, in particular high wind conditions, will make glazing of large panes difficult and dangerous and can be the cause of site erection delays.

When mastics are used for jointing and bedding, they may be affected by wet weather or extreme heat or cold. Many mastic applications cannot be satisfactorily carried out in wet conditions.

15. Services

Building services will not normally be expected to have a direct bearing on the design and installation of glazing in external walls.

16. Site handling and storage

Before any glass is delivered to the site the supplier, the general contractor, framemaker and the glazier (or any other interested sub-contractor) should agree on the location of the storage area, make sure that there is good access to it for the supplier's vehicles and see that the glass can be transferred safely from the store to the building.

The size, type and quantity of glass will influence the choice of the method of handling on the site which in turn will influence the way the glass is packed or loaded on the lorries.

16.1 Method of delivery, storage and stacking

The storage area should be clean, dry, level, firm and able to support the weight of the stacked glass – each cubic metre of glass weighs about 2.5 tonnes. The glass should be stored on its edge, the choice of long or short edge depending upon the size and thickness of the glass and the availability of space.

The glass should be supported as evenly as possible. It is usually better for the base support to be of separate timbers running across the edge of the glass than to be a single flat surface.

Water must not be allowed to reach the edges of stacked glass as it could be drawn between the sheets by capillary attraction. Unless it could be dried out quite soon it would leach alkaline substances from the glass and damage the surfaces. So the glass must be dry when put into store and must be kept dry, protecting it not only from rain and driven snow but also from water on the ground. Adequate ventilation to the open air is needed to keep the storage space dry, and if some heating can be provided to stop the glass from getting too cold it will help prevent any condensation.

The glass must also be shielded from direct sunshine to avoid the possibility of a build-up of heat within the stack that could cause enough thermal stress to break the glass. This is especially important for solar control glasses. The close covering of stacks with tarpaulin is not adequate protection because there must be free ventilation to keep the glass cool.

Refer to Section 8.4

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- | | |
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| Part 3 | <i>Sound insulation</i> |
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| BS 6206 | <i>Impact performance of safety glass and plastics</i> |
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Building Research Establishment

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Part 2 Curtain walls and overcladding

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1. General properties

Curtain walling is the general description used for the construction of external walls of buildings using a prefabricated framework with an infilling of glazing and/or panels of other materials supported by the structural frame of the building.

Overcladding is the general description used when a curtain wall light framing system with panels, sheeting or glazing is superimposed over an existing facade, with the objective, usually, of improving the performance of the wall.

The design of curtain walling and overcladding systems can take any of the following forms:

- a. Separate vertical and horizontal members fixed to the structure, which support intermediate members inserted between them on site
- b. Separate vertical and/or horizontal members fixed to the structure which support a framed infill
- c. Horizontal and vertical members which are assembled into units on site prior to being fixed to the structure
- d. Factory assembled units.

There are three basic optional techniques which can be used in the design of a wall to achieve weathertightness:

- Fully sealed or front sealed systems
- Drained and back ventilated systems
- Pressure equalised rainscreen systems.

These options are explained in detail in Section 3. Weathertightness.

Reference: CIRIA. Book 5.
*Rainscreen Cladding: A
guide to design principles
and practice.*

1.1 Appearance

A wide range of materials can be used to form curtain walling and overcladding. A key factor to be taken into account when considering the design is the positioning of window and door units relative to the plane of the cladding assembly. If a flush appearance is required either a fully sealed system or a pressure equalised rainscreen, should be used, the latter with well designed labyrinth joints minimising leakage into the air space behind the rainscreen.

1.1.1 Reflectivity and dazzle

When choosing the material and considering the layout of the building it must be appreciated that some materials which may be used for curtain walling and overcladding can cause a degree of glare and dazzle. These include glass, glazed ceramics, anodised aluminium and polished stainless steel.

1.1.2 Colour

Materials used as cladding can be of any colour but rain streaking and dirt accumulation is likely to be more noticeable on light coloured surfaces, particularly when horizontal profiling is used. Dark coloured cladding assemblies will attain much higher surface temperatures than light. Light colours are, therefore, to be preferred, thus reducing thermal expansion and contraction of the assembly and, other factors being equal, assisting in extending the life of the cladding assembly. Colour fading and colour matching must also be taken into account.

1.1.3 Texture and scale

Face fixings, surface irregularities and panel bowing will be less noticeable when textured surfaces are used, but these may be more difficult to clean if non-uniform weathering occurs. Graffiti on untreated panels may also be more difficult to remove. Smooth surfaces are easy to clean, but rain streaking, face fixings, surface irregularities and panel bowing are likely to be much more noticeable on smooth panels.

1.1.4 Effects of joints

The layout, type and width of joints has a significant effect on appearance but must be based primarily on functional requirements. A careful balance must be arrived at between the criteria for the desired appearance and the functional constraints. Sealed joints must not be too narrow otherwise movement may cause the strain capacity of the sealant to be exceeded. Similarly, with pressure equalised rainscreen design, joints which are too narrow will prevent the intended pressure equalisation taking place.

1.2 Geometry

1.2.1 Dimensional co-ordination

Curtain wall and overcladding will be undertaken using manufacturers standard or specifically designed components. All of these will be fabricated using, to some degree, standard components or components manufactured from materials produced in standard range of sizes. Consequently curtain wall projects will need to be designed within a disciplined and regular dimensionally co-ordinated grid.

1.2.2 Joints

Like and unlike components

Particular care needs to be taken at interfaces between different components e.g. windows in large panel construction, curtain walling and brick work. The selection of the correct type of gasket for joints will be of critical importance.

Refer to Section 3. Weathertightness

Key joints

A section drawing illustrating some typical joints are shown in Figures F2.1 and F2.2.

Refer to Figures F2.1 and F2.2.

Reference should be made to
BS 6093:1981 *Joints and
jointing* and BS 6213:1982.
*Guide to selection of
constructional sealants.*

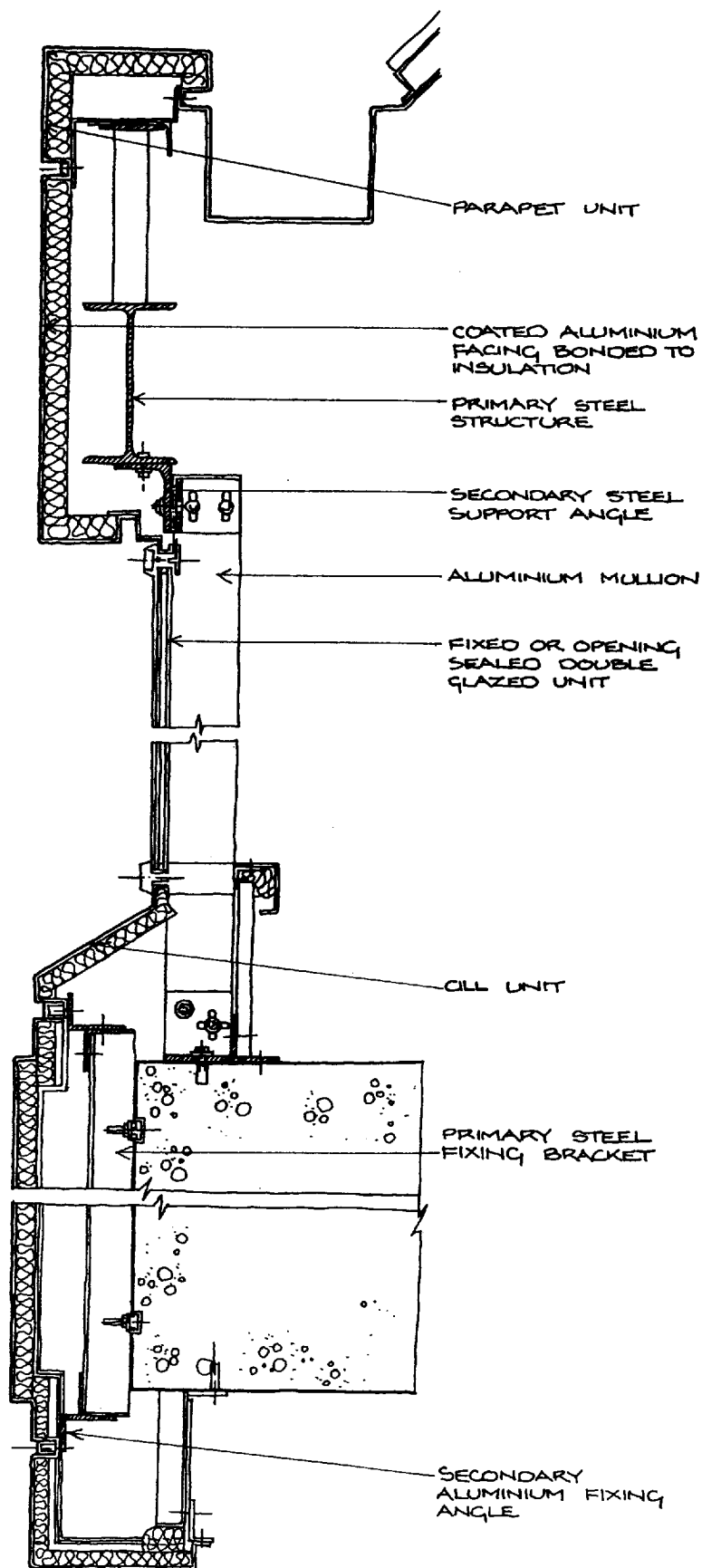


Figure F2.1 Typical section using aluminium panels

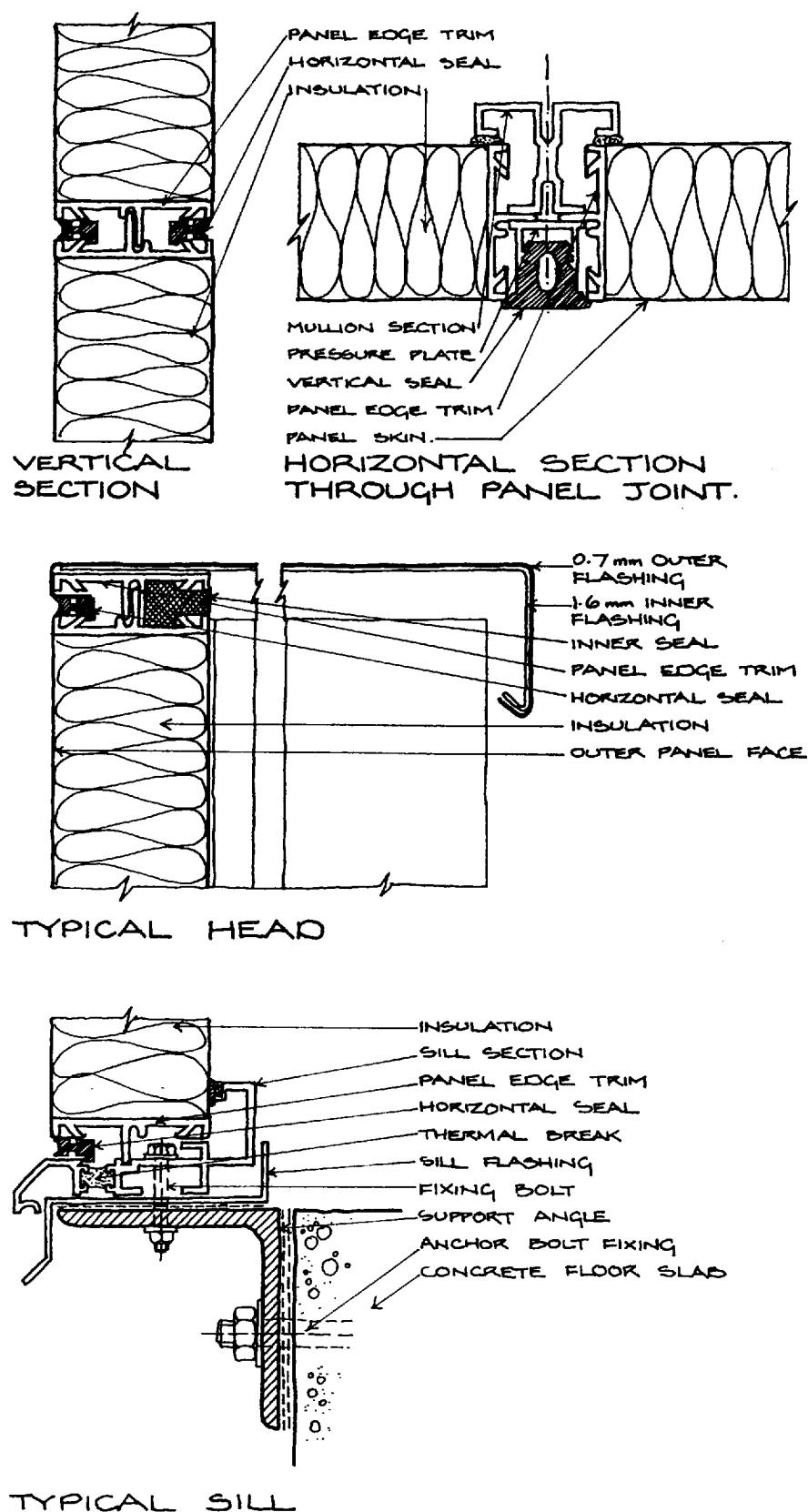


Figure F2.2 Curtain wall / cladding panel systems

1.2.4 Tolerance and fit

Refer to Volume A, Part 1.2.4 and to Part 1.1.4 above and Part 1.2.5 below.

1.2.5 Fixings

Fixings must be designed to provide three-way adjustment without relying on the use of an excessive thickness of packing shims. With overlcladding the adjustment range normal to the plane of the cladding must be sufficient to accommodate significant variations in the position of the inner leaf. On large overlcladding projects a geometric survey of the building structure should be carried out to establish the adjustment range needed to accommodate these variations. With new works a range of at least plus or minus 30 mm is recommended.

Fixings must be able to accommodate structural, thermal and other movements by the provision of sliding adjustments which will accommodate the maximum anticipated movements throughout the life of the building. In order that accidental slippage under maximum design load does not occur, all adjustable fixings must be equipped with provision for the restoration of positive fixity following adjustment during installation.

Refer to Section 2.7

Refer to Figures F2.3 and F2.4.

References: BS 7307: Part 2 1990 and BS 7308: 1990.

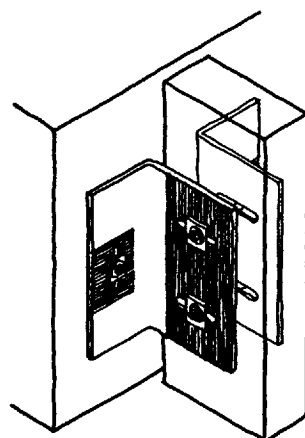


Figure F2.3 Typical curtain wall fixing bracket

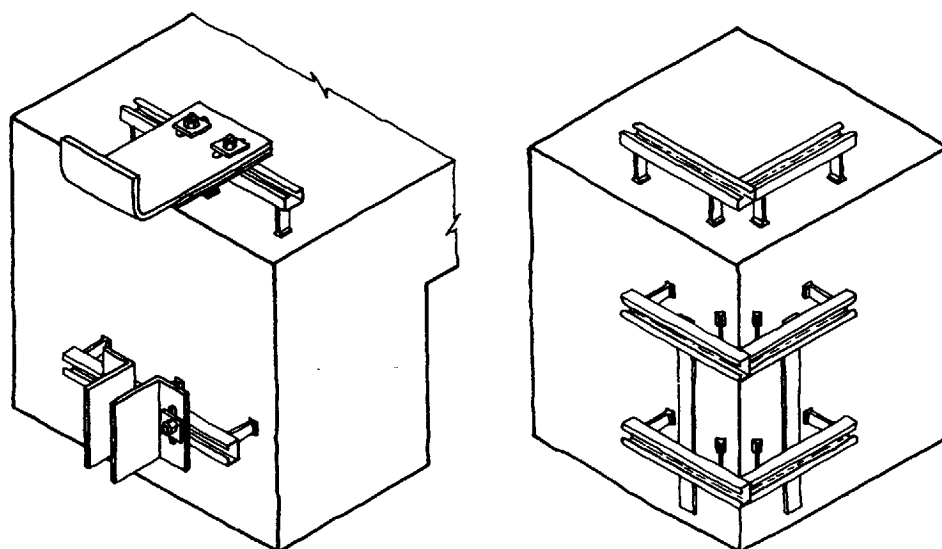


Figure F2.4 Typical fixings for curtain wall mullions (left) and typical welded corner channels

NOTE: For constructions using large panels which have few joints, then the movements to be accommodated will become a significant factor in the overall cladding design.

Particular attention needs to be paid to the design of large panel systems. Off-site manufacture precludes the possibility of making adjustments on site to the panels. Any discrepancies in the structure have to be taken up in the joints. Care must be taken to avoid joints becoming impracticable i.e. too narrow (low strain capacity) or too wide (joint sealant slumps).

References: BS 7307: 1990
and BS 7308: 1990.

The number of fixing methods for curtain walling and overcladding is constantly increasing with new developments. These include new procedures for secret fixing including such concepts as 'double-sided' acrylic tape for use as a means of fixing panel stiffeners and for mounting sheet materials into framed assemblies.

1.2.6 Accommodation of structural, thermal, chemical and other movements

Allowance must be made for deformations and movements in the building structure. These movements can be caused by:

- shrinkage and creep
- elastic deformations
- differential settlement
- live load deflection of floor slabs and beams
- wind sway.

The likely extent of such movements should be estimated in advance of the cladding design. Adequate allowance must also be made to accommodate movements caused by thermal expansion and contraction, due to solar and clear night radiation. The surface temperature extremes to be assumed will be determined by the colour, surface texture and orientation of the cladding panels; the thermal characteristics of the construction and the efficiency of the cavity back-ventilation process. In the absence of specific design data, temperature extremes of -25°C and $+80^{\circ}\text{C}$ are commonly used as the criteria for the UK.

2. Structure

It is recommended that the structural design of curtain walls and overcladding always be undertaken by a qualified structural engineer.

2.2 Dead and applied loads – framed, lightweight

Generally curtain walls and rainscreen cladding systems are required only to support their own dead weight, wind loads and impact loads plus seismic loads where relevant. These loads are then transferred to the main structural building frame.

Dead loads are generally taken to the structure via fixings at each floor level or, if the cladding is a unitised system with units more than one storey in height, at the base or head of each unit. The fixings must also be able to accommodate lateral movements due to thermal expansion and contraction. Refer to Volume A of this series for notes concerning the likely magnitude of these movements.

Fixings and joints must also be able to accommodate deformations and movement of the structure. For example with 'stick' curtain walls it is the usual practice to accommodate vertical movements in the mullions at the point of minimum bending.

2.4 Wind loads

Reference: Volume A of this series. Part 4, Section 2.4.

Reference: ASTM
(American Society for
Testing and Materials) for
details of test programme.

NOTE: Little is known
(1991) about the wind
response characteristics of
open-joint rainscreen
cladding, when used in
curtain walls or for
overcladding. In the absence
of adequate research into
this technology no account
should be taken of the
possible favourable effects
of cavity pressurisation.

Curtain walls and overcladding must be designed with sufficient strength and stiffness to transmit the resulting wind loads and other forces back to the fixings. Design stresses for the various materials used can be obtained by reference to the appropriate British Standards or in the absence of such standards, to manufacturers' data, e.g. composite materials as used in some overcladding systems.

Where stone in a thin veneer form, 25-30 mm thickness, is employed in a curtain wall, it is recommended that a test programme be undertaken to establish its properties, i.e. modulus of rupture, compressive strength, modulus of elasticity etc. at its proposed thickness. The thickness of the stone and of its fixings is then determined on the basis of an allowable working stress calculation using the test results.

Structural testing can normally be carried out as a part of series of weathertightness tests and is described in detail in Section 4 Durability and compatibility.

All closers around perforations such as window and door openings should be designed to resist the most extreme anticipated combination of external and internal wind pressures. All cavity closers and smoke stops should be designed to withstand the air pressure differentials acting across them. Those at the top and corners of the building will be subjected to higher wind pressures than those in other parts of the elevation.

Refer to Figure F2.5.

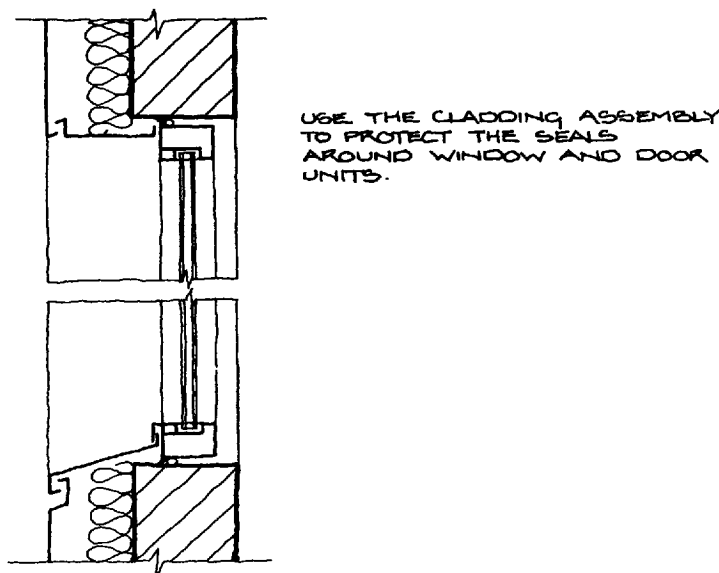


Figure F2.5 Fixing and sealing window and door units to the inner leaf

Reference: BS CP 118 *The structural use of aluminium.*

2.4.4 Fatigue

Fatigue testing of whole curtain wall and overcladding assemblies is rarely undertaken at the present time, because of the cost involved and the time needed. Testing of fixings is often carried out both in relation to the main fixings retaining the cladding to the structure in particular and of those used for retaining thin stone or other materials to the cladding framework.

2.5 Accidental loads

Normal curtain wall framing and the range of lightweight materials used for panels cannot be expected to accommodate impact damage from vehicles etc. In locations where there is the probability or even the possibility of the wall being subject to such damage then it should be protected by such devices as a barrier, by bollards, a dry or wet moat or by planting.

Reference: BS 8200: 1985.

Curtain walls and overcladding should be designed and tested to meet the requirements set out in BS 8200: 1985.

2.7 Loads on fixings

Fixings must be able to withstand all the dead and imposed loads to which they are or may be subjected. All fixings should be checked for the worst potential design load/adjustment combination.

NOTE: A minimum level of testing for frame fixings should be established prior to commencement of a contract for curtain walling, followed by an ongoing test sampling regime.

In selecting bolt anchors account must be taken of the strength and variability of the materials into which fixings are to be made. Specialist manufacturers should be consulted on such matters as anchor selection, factors of safety, vibration, self-locking devices and the need for pull-out tests. In particular account should be taken of the innate variability of the performance of anchors when fixed into materials such as concrete or masonry which may be variable in quality.

3. Weathertightness

Curtain walls and overcladdings can be categorised in one of three different systems to deal with their weathertightness.

- First are fully-sealed walls which are constructed using relatively impervious materials, such as metal and glass designed to drain off water at their outermost surface. If constructed with single stage joints the rain and wind barrier is the same, so the film of water which flows across the wall is immediately influenced by the wind pressures. Since the joints are required to prevent the passage of both rain and air, they must be able to resist the combined effects of heavy wetting and wind-induced air-pressure differentials. This requires the complete absence of rain leakage paths necessitating a very high level of workmanship in the application of sealing materials which must have the ability to accommodate movement and the effects of ultra-violet degradation etc.

NOTE: The probable life span of the materials used for gaskets and sealants will be less than that of the other wall elements.

The long-term performance of fully-sealed walls can be improved by introducing an air space immediately behind the sealed outer face. The single-stage joints are still subjected to the combined effects of heavy wetting and wind-induced air-pressure differentials but, in the event of a primary seal failure, the cavity provides a space which can

be drained to the exterior. Many metal and glass curtain walls systems incorporate a secondary defence system complete with an internal drainage mechanism.

Refer to Figure F2.6.

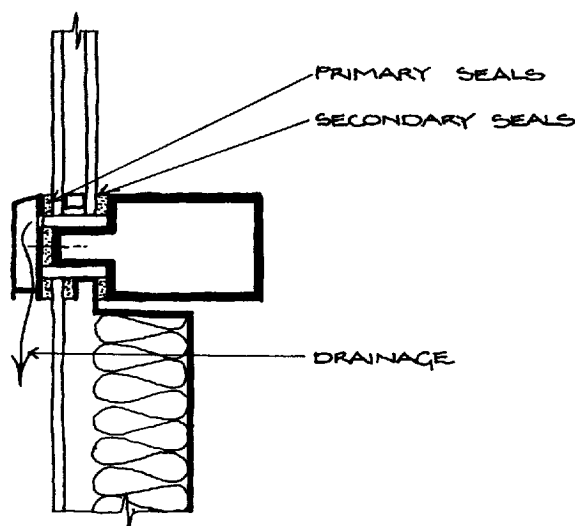


Figure F2.6 Internal drainage mechanism

Overcladding systems, are not normally designed to be fully-sealed but are generally designed either as drained and back-ventilated or pressure-equalised rainscreens.

- Second, both curtain walls and overcladding can be designed as drained and back-ventilated rainscreens. In their simplest form they consist of a series of thin impervious composite sheets or metal panels fixed to vertical support rails. Joints are designed to provide protection against the kinetic energy of wind-driven rain by incorporating baffles or by stringently controlling the width of narrow open joints. Such joints obstruct the passage of wind-driven droplets of rainwater but do not prevent leakage due to the effects of gravity and wind-induced air-pressure differentials. Rainwater can penetrate the joints and run down the reverse, hidden face of the cladding assembly: the design should prevent this water from reaching the inner leaf so as to cause heavy wetting.

The fundamental concept of the drained and back-ventilated approach is that the cladding is allowed, or assumed, not to be 100% watertight, and no deliberate attempt is made to minimise the effects of wind by means of pressure equalisation. Instead, the cavity behind the cladding is drained, and positive back ventilation is used to promote the rapid evaporation of any rainwater deposited on the inner face of the outer leaf.

- The third category is the pressure-equalised rainscreen. This is a well accepted and widely used technique for a variety of curtain wall and overcladding constructions, where the presence of an air space is exploited as a means of controlling the effects of wind action.

NOTE: For rainscreen designs with open joints it is essential the width of the joints is sufficient to allow pressure equalisation to take place.

In this technique, the effects of kinetic energy, surface tension, gravity and pressure assisted capillarity are controlled by incorporating baffles, labyrinths, drips and upstands in the joints in the cladding assembly. Rain penetration caused by wind-induced air-pressure differentials is attenuated by pressure equalisation, which is achieved by incorporating protected openings of adequate size within the rainscreen. The nature of wind-flow patterns around buildings make the ideal condition of full pressure equalisation impossible to achieve with certainty. A compromise has therefore to be adopted, which entails minimising the wind-induced air-pressure differentials across the joints in the rainscreen, while controlling any other leakage process which may be at work.

The main design principal of the pressure-equalised rainscreen approach is that, without relying on the use of sealants or gaskets, every effort is made to minimise or eliminate water penetration through the joints in the cladding assembly. No cladding system is likely to be 100% watertight so, therefore, a precautionary drainage mechanism is necessary. Positive back-ventilation is also used to promote the rapid evaporation of residual rainwater. For pressure equalised rainscreens the minimum width of joint is recommended to be 20 mm.

Refer to Figure F2.7.

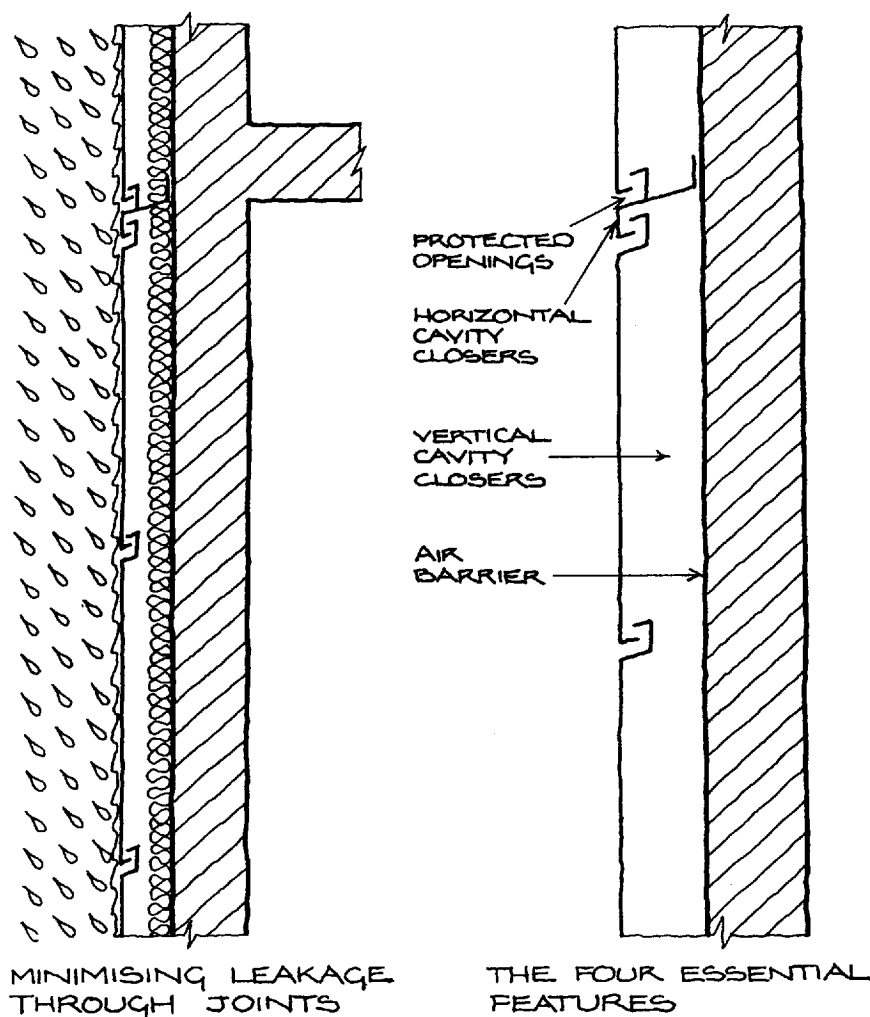


Figure F2.7 Pressure-equalised rainscreen

The successful application of the pressure equalised technique requires:

1. Joints within the cladding assembly designed to give a high degree of resistance to rain penetration caused by kinetic energy, surface tension, gravity and pressure-assisted capillarity.
2. An effective and continuous barrier against air infiltration on the internal side of the cavity.
3. The air space sub-divided into a series of compartments so that air pressure can be equalised.
4. The protection of openings within the cladding assembly, to minimise the wind-induced air-pressure differentials which act across the rainscreen.

3.1 Permeability to air

Reference: BS 5368: Part 1: 1976.

The recommended maximum rate of air permeability of a curtain walling system is 1 m³/m²/hr, when determined in accordance with the requirements of BS 5368: Part 1:1976. For opening lights the recommended maximum rate is 2 m³/hour/metre length.

For overcladding which is designed to be permeable to air, reliance must be placed on the inner leaf to provide the necessary resistance to air permeability. In new construction incorporating overcladding it is recommended that testing be carried out with a sample of the inner leaf installed in the test chamber.

Cavity closers such as those around window openings need to be relatively airtight with overcladding systems if they are to be effective.

3.2 Driving rain and water run-off

Curtain walling and overcladding are generally constructed of impervious materials with little or no absorption, so a substantial film of water flows across the surface of the cladding. Much of this becomes concentrated at joints, particularly if they are recessed, where the flow of water is much higher than the average flow over the whole surface. Textured or modelled surfaces will break-up the flow thus reducing the pressure on joints. Wind may also force rain water upwards into horizontal joints, particularly near the top of windward elevations.

3.3 Permeability to water, absorption, capillarity etc.

There are five processes which tend to force water through joints:

- **Kinetic energy**
Droplets of rainwater driven by wind often have sufficient momentum to carry through open joints. Even if the joints are narrow and the raindrops shatter upon impact, smaller droplets of the water will still be driven inwards. The simple way to counteract this process is to incorporate a form of baffle or labyrinth in the joint design

Refer to Figure F2.8

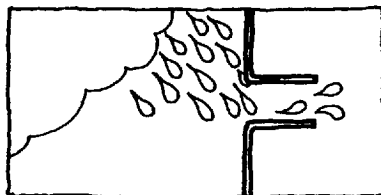


Figure F2.8 Kinetic energy

- **Surface tension**
Surface tension can cause water to adhere to and run across the underside of horizontal surfaces. The conventional and most effective way of preventing this is to incorporate some form of drip along the leading edge of horizontal joints.

Refer to Figure F2.9

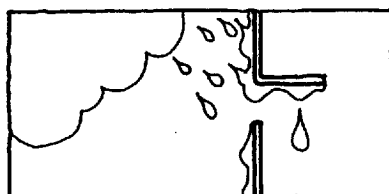


Figure F2.9 Surface tension

- **Gravity**
The force of gravity will pull rainwater through any opening or large capillaries which lead inwards and downwards. If there is an air space within the wall, the water will tend to run downwards within this space until it reaches a horizontal stop along which it can be fed and expelled.

Refer to Figure F2.10



Figure F2.10 Gravity

- **Capillarity**

The effect of capillarity is to draw water into narrow passages which are bounded by wettable surfaces. For it to take place a force such as gravity or wind pressure must be applied. The degree of penetration will be determined by the magnitude of the applied force and the pore size of the capillary passage. This effect can be overcome by incorporating an air space, either within the joints, or within the wall itself.

Refer to Figure F2.11

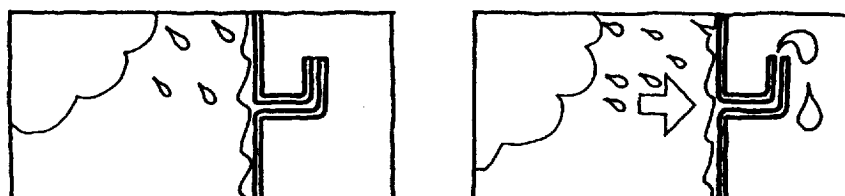


Figure F2.11 *Capillarity (left) and pressure assisted capillarity*

- **Air-pressure differentials**

The most common form of leakage, which is also the most difficult to combat, is due to wind-induced air-pressure differentials. If the air pressure on the outer face of a wall or wall cladding is greater than that acting on its reverse face, rainwater will be forced inwards through unprotected openings or through joint seal imperfections in the soaked outer face. If the air pressures on either side of the openings can be equalised, water will not be forced inwards by this means alone. This concept of equalising the air pressures on either side of the joints in walls and wall claddings is known as 'pressure equalisation'. It is an essential criteria that there is a 'confined air space' behind the outer panel rather than a simple ventilated cavity.

NOTE: For pressure-equalised rainscreens the recommended minimum width of open joint is 20 mm.

Refer to Figure F2.12



Figure F2.12 *Air pressure differentials*

3.4 **Snow and hail**

Fine powdered snow may possibly enter through openings. If this happens then frozen snow may temporarily inhibit the pressure equalisation behaviour of the wall.

4. Durability and compatibility

4.1 Modes of failure

Most problems with curtain walling are due to water penetration. Care is required in the design and installation to ensure that watertightness is achieved and subsequently maintained. Joints, in particular, require very careful detailing and execution.

The only satisfactory way to validate a new or amended design or an established design to be used in a potentially harsher environment is by means of a testing programme.

For full details of recommended testing programme refer to the Appendix to this Volume F, Testing .

4.2 Compatibility

There are many more potential causes of failure in sealants including failure of adhesion or cohesion, by excessive extrusion, slumping, folding, intrusion, chemical attack and displacement. The most common of these is adhesion failure due to the failure of the bond between the sealant and the sub-strate.

The life of sealants can only be estimated on the basis of experience of their performance in use and on the assumption that the joints have been properly designed and the material properly applied in strict accordance with the manufacturer's instructions.

Types of sealant	Expected service life
Oleo-resinous Bitumen and rubber/bitumen Butyl	Up to 10 years
Acrylic (solvent) Acrylic (emulsion)	Up to 15 years
1-part polysulphide 1-part polyurethane Silicone 2-part polysulphide 2-part polyurethane	Up to 20 years

Table F2.A Expected service life of sealant types
(Reproduced from BS 6213: 1982).

4.3 Corrosion

Metals deteriorate primarily by corrosion. This can take the form of either self-corrosion or bi-metallic corrosion. Steel, other than stainless steel, is unacceptable unless suitably treated by galvanising. Galvanised steel can have a long life in certain relatively benign environments i.e. dry internal conditions.

Aluminium will also corrode but unlike steel the oxide is stable and protective. However, the oxide spoils the appearance of the metal and it is recommended therefore that a surface treatment be provided. This can take the form of anodising, which is the implantation of an artificial

oxide on the surface achieved by electrochemical treatment, or more commonly the application of an organic paint based on polyester or fluorocarbon. Acceptance test auditing of these coatings should always be carried out.

Stainless steel forms a protective chromium oxide film which is very stable even in aggressive environments and is thus particularly suitable for use in fixings.

Bi-metallic corrosion results when different metals are in contact one of which is more corrodible than the other. The problem is particularly acute in an environment where water can contact both metals simultaneously. The risk of bi-metallic corrosion is discussed in BS 6682: 1986. The most practical solution is to provide insulation between the contacts, for example, by means of neoprene washers.

It is therefore very important to avoid rain penetration or interstitial condensation through or within the cladding, or wetting by run-off. For example, water washing from a copper roof onto aluminium will cause serious corrosion of the aluminium. The effect of bi-metallic contact is to enhance the corrosion rate of an already corroding metal to the benefit of the other metal in contact.

By following basic rules this potential problem can be avoided.

- Select metals which are protected from corrosion in the environments in which they are used
- Avoid contact by fixing insulation materials between different metals
- Eliminate the possibility for water to bridge the points of contact
- Ensure that external water wash-off from one metal to another does not create a bi-metallic corrosion risk.

Reference: BS 6682: 1986

5 Sound insulation

Both external walls using curtain walling and overcladding systems may be required to protect occupants from exterior noise. Reference should be made to Volume A Part 4 Section 5 for detailed information on how to determine the sound control rating of a cladding system. Testing of a construction may be necessary to demonstrate compliance with specified requirements.

An example of a successful application at an airport hotel is shown.

Refer to Figure F2.13 and F2.14 for sound control wall details.

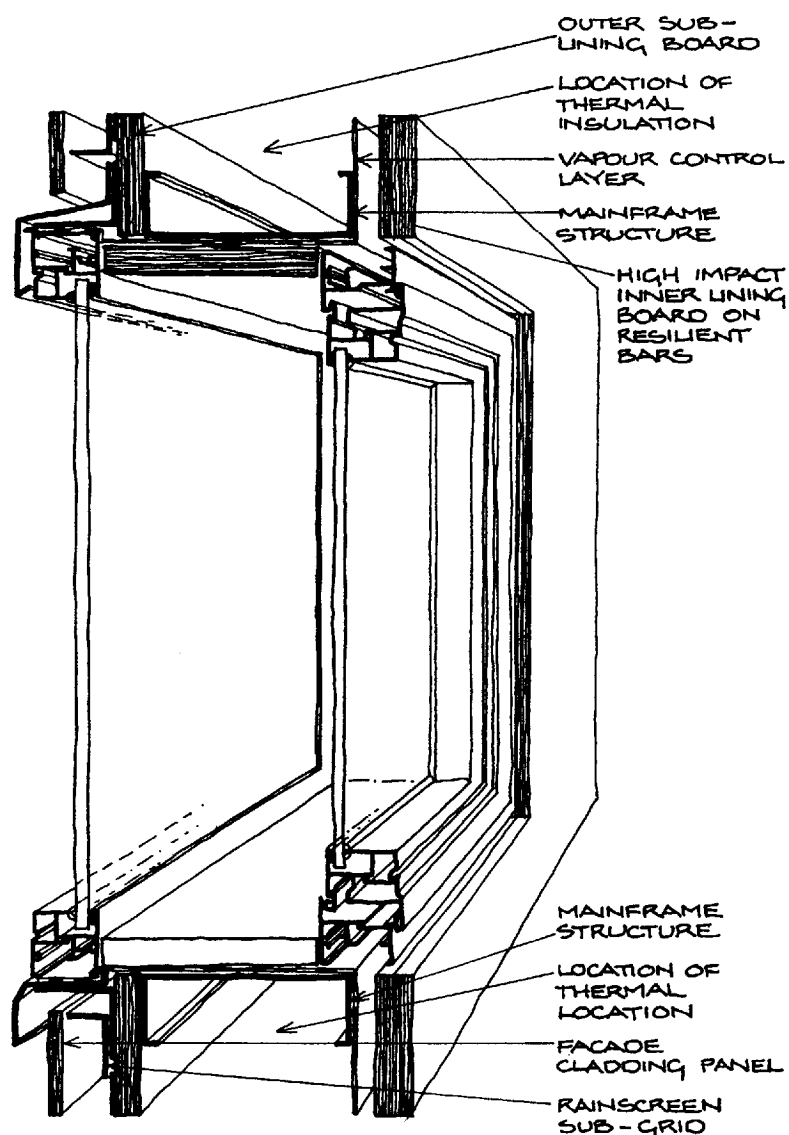


Figure F2.13 Section through glazing module; airport hotel

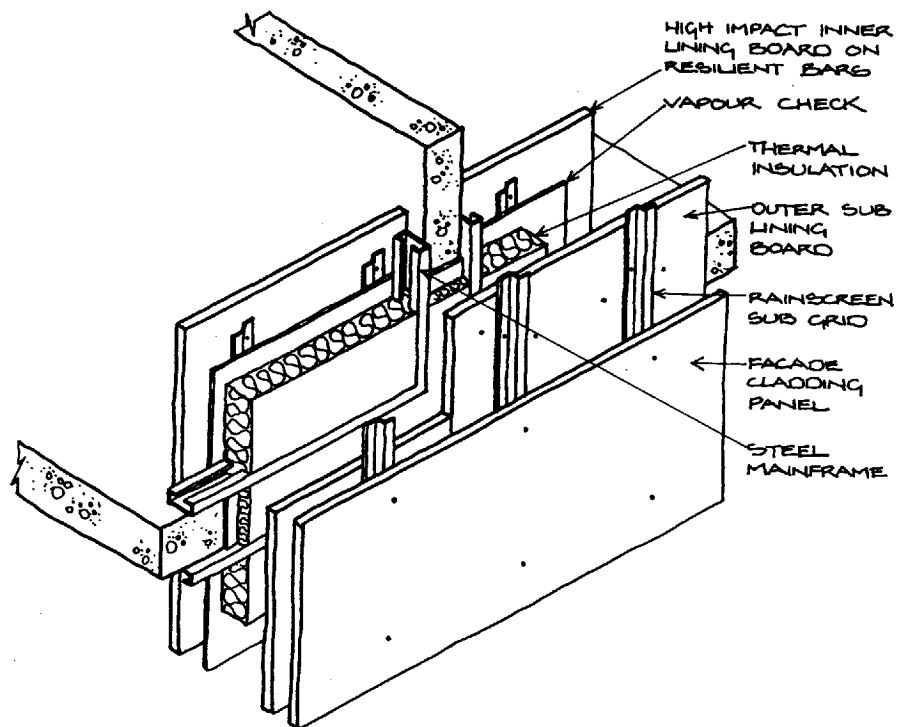


Figure F2.14 Typical sectional detail showing construction build up

For all curtain walls and for overcladding systems in particular:

- Check that the inner leaf will provide the requisite standard of sound insulation, since it must be assumed that lightweight, air-permeable cladding will provide little resistance to the transmission of airborne sound.
- Ensure that all closers around window and door openings which penetrate through the cavity achieve the required standard of sound insulation.
- If thin metal sheets are used, an internal coating of anti-drumming compound may be helpful in reducing noise caused by rain. Flexible waterproof compounds can be sprayed or painted onto the inside face of the cladding panels. Bonded membranes should be used only with caution as they may cause crevice corrosion or become detached and partially block the air space gaps.
- Non-metallic slip pads should be incorporated on all primary movement joints if noise due to stick and slip movements is considered a potential problem.

6 Heat and moisture

6.1 Thermal insulation

Virtually all forms of curtain walling and overcladding systems need to incorporate added insulation material in their construction in order to achieve the required levels of thermal insulation. This insulation can be located in various positions in the construction of a curtain wall, but with overcladding systems it should be located on the outer face of the inner leaf and not on the back of the cladding panels. The insulation used should be non-combustible, vapour-permeable, rot and vermin-proof and be water-repellant.

Reference: For the thermal performance characteristics of glazing refer to Part 1 of this Volume.

Cold bridging can create a problem in curtain walling construction not only by reducing the overall thermal performance of the wall, but also by creating conditions where the inside surface temperature drops below the dewpoint of the air, causing condensation. In extreme conditions this may even result in the formation of ice. The use of thermally broken mullions and transoms is recommended as the best means to avoid this. Care is needed, to determine the effect of this on their structural adequacy.

Refer to Figure F2.15.

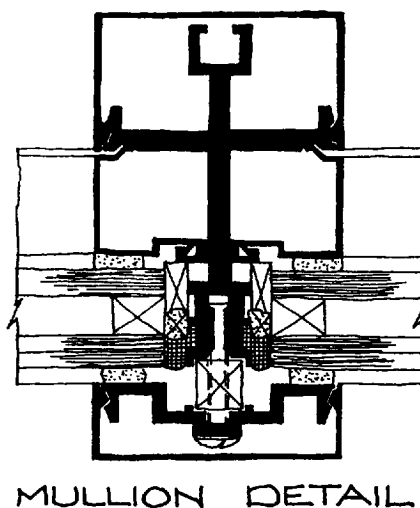


Figure F2.15 Typical thermal break details (proprietary)

6.2 Thermal capacity

Curtain wall assemblies in themselves usually have a very low thermal capacity and consequently these forms of construction generally respond very quickly to changes in heating and cooling and rely on the inner wall or other elements of the building to provide a thermal capacity if this is needed.

6.3 Permeability to water vapour, risk of interstitial condensation

Refer to Section 3.3

6.4 Vapour control layers

Refer to Section 3.3

7 Fire

7.1 Fire safety

It must be appreciated that the design of overcladding needs to take into account social as well as technical considerations. There is a need to discuss proposals with all the parties involved including tenants associations, estate managers as well as the relevant local authority and fire officer.

In particular, for overcladding it should be noted that walls need to satisfy building regulations in relation to means of escape in case of fire, as well as internal and external fire spread, but these requirements do not cover the potential problems created by fires from an external source. Such fires whether started accidentally or intentionally can have very severe consequences. Overcladding systems are particularly vulnerable in this respect and as a result of experiences gained in real fires it is recommended that some or all of the following measures are considered:

- Construct the first storey of cladding in masonry or other non combustible material
- Provide suitable street furniture bollards or landscape features so as to prevent vehicles being parked adjacent to the wall
- Provide an external sprinkler system designed, if the need arises, to be turned on by the fire brigade.

The fire performance of curtain walling and overcladding materials, their relationship to each other and to the main fabric and structure of the building must always be given the most careful consideration. Account must be taken of the behaviour of materials in fire conditions not only in respect of the safety of the buildings or occupants and contents but also of fire-fighting personnel.

7.2 Fire spread

Insulation materials, particularly those used in overcladding systems, should be of a non-combustible type such as mineral wool. Mineral wool insulation has a pronounced 'grain'. The fire performance of the insulation will be much improved if the individual panels are fixed with the 'grain' alternately at right angles. The insulation should be attached with metal fixings, because most plastic alternatives can melt.

If a building paper is required it is recommended that this be specified to be of the woven thermoplastic type.

7.3 Cavity barriers

The need for and location of cavity barriers in curtain walling and overcladding is dependent not only on how the system is designed to function from a weathertightness aspect. A drained and back-ventilated system requires the minimum of barriers to work effectively whereas with a pressure-equalised design, barriers are required at frequent intervals.

It is necessary to consider each project on its merits and to discuss it fully with all relevant parties in order to arrive at an acceptable layout. As a guide it is recommended that horizontal and vertical cavity closers should be installed at no more than 8 m centres when the surface finishes in the air space are less than class 'O'. With class 'O' surfaces the space of closers may be increased to not more than 20 m centres.

Reference should be made to Approved Document B (B/2/3/4 – Fire spread) for guidance. The performance requirements for walls are defined by BS 476: Part 7 (Surface spread of flame) and BS 476: Part 8.

Care should be taken at locations where there is the possibility of the overall depth of overcladding exceeding the general depth as designed (e.g. splayed corners). The need for extra fire protection to supports at these locations must be considered.

Refer to Figure F2.16

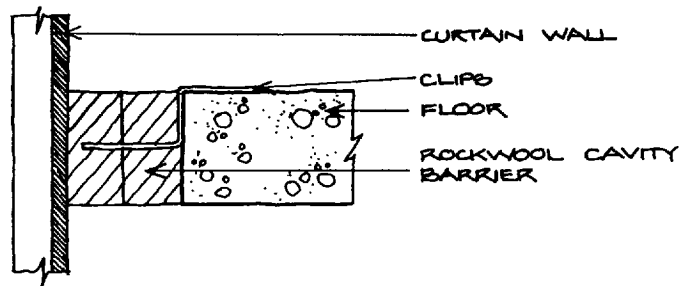


Figure F2.16 Typical firestop detail in curtain wall

All cavity closers around window and door openings must satisfy the appropriate standards of fire resistance. In curtain walling systems support plates should be provided for fire stops.

The risk of vertical fire spread will be minimised if non-combustible mineral fibre such as rockwool or similar incombustible insulants are used as fire stops and cavity barriers. Cavity closers should be installed at no more than 8 m centres or at every alternate floor level horizontally and at approximately 8 m centres vertically. All cavity closers around window and door openings must satisfy the appropriate standards of fire resistance.

7.5 Lightning protection

Guidance on protection against lightning is provided in BS 6651: 1990.

Care must be exercised when overcladding to an existing building is carried out because the continuity of conductors fixed to the existing facade cannot be easily checked after the overcladding has been installed.

Reference: BS 6651: 1990

8. Safety

8.1 Means of escape in case of fire

The requirements for means of escape will vary according to the building use, number of storeys etc. and need to be discussed with the appropriate Fire Prevention Authority. Walls, including curtain wall systems, bounding means of escape will need to have the appropriate fire performance. Smoke vents, when provided in a curtain wall, should not impair performance in terms of air permeability, watertightness and wind resistance.

8.2 Protection of the person against falling

Curtain walls, where they are located adjacent to escape routes or balconies, should be designed to prevent persons from falling through. Areas of particular concern include those providing means of escape, where there is the risk of crowd loading.

8.3 Comfort including tactile properties

A wide range of materials can be used in the construction of curtain walls and overcladding. Care should be taken to ensure that the finished surfaces within 1.5 m of an access level do not have any irregularities or sharp arrises which could damage the skin. Also they should not emit substances which can mark clothing.

8.4 Safety during construction

Careful consideration needs to be given to the dangers involved in handling when specifying very large panels for curtain walling systems on exposed sites or on very high buildings. Although there may be merit in some circumstances or to suit particular design parameters in the use of very large panel components, it should be remembered that site assembly and erection may be dangerous or be delayed on windy days.

9. Security

Having assessed the risks according to the building type and its location, decisions need to be taken as to vulnerability, e.g. in relation to the accessibility of the walls and concerning the selection of materials.

9.2 Security requirements

When choosing the cladding material in a curtain wall it will be necessary to consider its security against break-in, if it is to be used in a vulnerable location. The building can only be as secure as the weakest elements which form part of the external fabric. Doors and windows will nearly always be the most vulnerable elements.

Buildings with external lightweight curtain walls which might in themselves be considered to be at risk can be made more secure by the provision of masonry or reinforced concrete back-up inner walls where necessary.

Overcladding is most usually applied to buildings which already have masonry, concrete or similarly secure walls.

10. Daylight and sunlight

Reference should be made to the *CIBSE Applications Manual: Window design* 1987 for further information on shading devices.

Consideration should be given to designing and specifying different and more appropriate types of walling for different elevations of a building. For south, east, and west elevations, for example, it may be appropriate to have horizontal overhangs and louvres for sunlight control but the north elevation might have smaller areas of glazing, without shading. The danger of future global warming should accelerate the desirability of adopting this energy efficient approach.

11. Maintenance including acceptable wear on moving parts

11.1 Cleaning

The effective cleaning of buildings with curtain walling or overcladding is best achieved by means of properly designed exterior building maintenance equipment. This is essential if the walls are sealed and without openable windows.

The designer should involve all interested parties, including the building owner, cleaning company, equipment manufacturer, cladding manufacturer and structural engineer, in considering the most appropriate means of cleaning and maintaining the facade. It may for major buildings be pertinent to employ a specialist consultant to take responsibility for this task.

Factors which need to be taken into account when deciding on cleaning and maintenance equipment selection include building height, building shape, relevant codes and standards. Platforms are available which are self-powered, roof-pressured and automatic. These systems have advantages and disadvantages and their suitability to individual buildings should be investigated.

Buildings over 30 m in height must be provided with vertical window washing guides. These can be in the form of:

- indented mullions
- external 'T' elements
- button guides
- intermittent tie-in bolts or pins.

Specialist cleaning cradle equipment manufacturers should be consulted.

Reference: BS 6037: 1990, BS 5974 and BS 2830

NOTE: A detailed review of external access for maintenance aspect of wall technology is contained in the paper on the subject by L B Herzog presented to the symposium on Exterior Claddings on High Rise Buildings in Chicago in November 1989.

12. Repair and replacement

12.1 Life cycle costing

Curtain wall assemblies are available in a very wide range of designs and employing an equally wide range of assembly methods, cladding materials and technologies. There is consequently a very wide variation in both the quality and the cost of the numerous systems and methods available. It will be particularly significant for this type of cladding that a comprehensive evaluation should be undertaken of the nature of the project with its initial capital cost balanced by its anticipated 'Cost in use' over a predetermined length of life.

Very high quality, high initial cost wall cladding, carefully evaluated and with a good long-term maintenance programme may often prove, when evaluated on a long term basis, to have a lower life span cost than a relatively low capital cost system which will involve continuous maintenance costs and may need replacing or significant repairs after a relatively short lifespan. As stated, however, in Volume A of this series, the long-term life-cycle cost considerations affecting the curtain wall or overcladding cannot be considered in isolation from all the other parts of the building and its anticipated use.

12.2 Replacement of damage

It must be accepted that some form of repair or replacement is likely to be needed during the life of a building. For example sealants have a life of at most twenty years, whereas the cladding might be expected to last at least sixty years. The need to be able to replace such materials, as well as inspect and maintain them, must be considered at design stage, as must the ability to be able to remove and replace complete cladding panels.

Consideration also needs to be given to replacing glazing units at various times during the life of the building. If installed from the inside then it must be ensured that no permanent obstructions have been fitted after initial glazing, e.g. heater casings, partitions or balustrades, which prevent or make this difficult.

13. Health and hygiene

13.1 Presence of deleterious materials

The metals and composite materials normally used and the finishes applied to them when used as panels in curtain walls or for overcladding are not generally known to contain any deleterious material which could adversely effect health. These facing and infill materials do not normally utilise any non-sustainable raw materials other than those which produce the energy used during their manufacture.

Care should be exercised, however, in the choice and specification of insulating materials which are used as part of or in conjunction with the external wall system. The majority of available materials now commonly used are now considered not to constitute any risks for health or hygiene and those insulants whose manufacture involved the use of CFCs have now or are rapidly being phased out.

13.2 Control of insects, vermin and other animal and plant life

This is not normally a problem with this form of construction but particular care needs to be taken in detailing to prevent the ingress of insects and vermin to cavities.

There will be essential openings in rainscreen and overcladding systems so there will always be some possibility for infestation by vermin or insects and care should be taken in detailing to minimise these risks.

14. Buildability, handling and workmanship

14.1 Buildability

Volume A sets out the parameters that generally need to be provided for in the design of walls for buildability. All of these to some measure are important and some are critical in the design of curtain walling and overcladding.

Particular attention needs to be paid to the design of large panel systems. Off-site manufacture precludes the possibility of making adjustments on site to the panels. Any discrepancies in the structure have to be taken up in the joints. Care must be taken to avoid joints becoming impracticable i.e. too narrow (low strain capacity) or too wide (joint sealant slumps).

The samples used for large scale weathertightness testing, as described in the Appendix on Testing, can also be useful as a means of evaluating the buildability of a system, in particular for a custom designed curtain wall which may have new designs of extrusions, gaskets, panels or other components.

14.2 Handling

Because curtain wall and overcladding elements, including framing where exposed, panels and glazing, are always decorative as well as being functional elements, careful site handling is imperative to avoid distortion and damage.

14.3 Workmanship

Curtain walling systems require for their success a high standard of workmanship for manufacture and assembly both on and off site.

For all major contracts, a sample assembly should be constructed for testing purposes and when approved, it should be retained and protected, not as a prototype but as a reference for quality control purposes.

14.4 Weather interference

Large elements made up in factory conditions off-site may require moving and placing in position on the building with the use of cranes and cradles. Inclement weather, in particular gusty wind conditions, may hamper work or cause delays. These factors should be taken into account when deciding the scale of assembly operations on or off site.

15. Services

Services will normally only be influenced by the performance rather than the proximity of the curtain wall. The exception will be the incorporation of louvres for ventilation or inlets or exhausts to serve air conditioning or ventilation plant.

In these situations particular care needs to be taken to avoid providing flanking routes for sound transmission or differential movement due to extremes of thermal stress.

15.6 Electro-magnetic compatibility

Metal framed curtain wall systems have the potential to facilitate the installation of screening systems to prevent electronic eavesdropping and to protect sensitive electronic equipment within a building from external electrical interference.

Reference: BRE Digest 335

16. Site handling and storage

16.1 Method of delivery, storage and stacking

The size of units and whether they are pre-assembled totally on or off site will effect the choice of method of handling on site.

Ideally pre-assembled units will be delivered to site and be immediately lifted off the vehicles or trailers and fixed in their final locations, thus avoiding double handling.

Where this is not possible, due to site access restrictions, materials need to be carefully handled and stored under cover in dry and dust-free conditions. Panels and framing should be stored according to the fabricators' instructions and preferably be under their control on site until fixed in position.

Glazing should be handled according to the recommendations and advice in Part 1 of this Volume.

Appendix: Testing

Recommended testing programme for a new or a significantly amended design for a curtain wall or overcladding system.

Reference: BS 5368: 1975:
Part 1 and American Society
for Testing Materials E283/4

Reference: This test is
described in U.S. ASTM
test method 501.1-83.
(Dynamic pressure)

1. An air permeability test of curtain walling (but not overcladding) aimed at minimising air infiltration through the cladding to check for high rates of air change which could lead to inordinately high air losses, as well as draughts. Both the ASTM or BS Tests are acceptable with a maximum test pressure of not less than 600 Pa for an air conditioned building and 300 Pa for naturally ventilated.
2. A watertightness test for all types of curtain wall in accordance with the requirements of BS5368 Part 2, or the equivalent ASTM E331-86. Additionally, drained and ventilated or pressure equalised systems, in which only the inner skin is subject to a pressure differential in the previously mentioned 'static' test, should also be subjected to a dynamic water penetration test. To simulate wind action this test involves applying a turbulent airflow against the test surface whilst exposed to water spray.

The recommended specified test pressure in the static test should not be less than 600 Pa or 20% of the design wind pressure whichever is the greater. For the dynamic test the pressure produced should be such that the deflections obtained in the sample are equal to those due to the equivalent static water pressure.

3. A wind resistance test designed to evaluate the structural performance of the cladding system in relation to both its stiffness and strength. This test method is based on BS 5368: Part 3 with the test sample being subjected to a series of positive and negative wind gusts up to the equal of the designed pressure. Current practice is for the maximum allowed deflection to be as follows:
 - For a storey height assembly, $L/200$
 - For a framing member containing a single pane of glass, $L/125$
 - For a framing member containing a single double glazed unit, $L/175$
 - For an infill panel (not including a panel made of annealed, tempered or laminated glass) related to the nature of the material.
 - For multiple glazing units with 3 or more panes of glass, the limits to be agreed with the manufacturer.

The maximum deflection of any glazed unit should not exceed 15 mm.

4. A structural safety test is also advisable where the sample is subjected to one positive and one negative pulse equal to 1.5 times the design wind pressure. This test might result in undue permanent deformation so it is carried out after all other tests have been completed.
5. A thermal cycling test, for which there is no standard, is a useful means of establishing the performance after limited thermal working and fatiguing. It is also helpful in exposing a possible condensation risk. It is not generally carried out on open jointed overcladding systems. The outer face of the test panel is normally temperature cycled six times from -20°C to $+80^{\circ}\text{C}$ whilst the interior is maintained at a constant temperature and humidity.

Refer to Figure F2.17. Typical curtain-wall test rig.

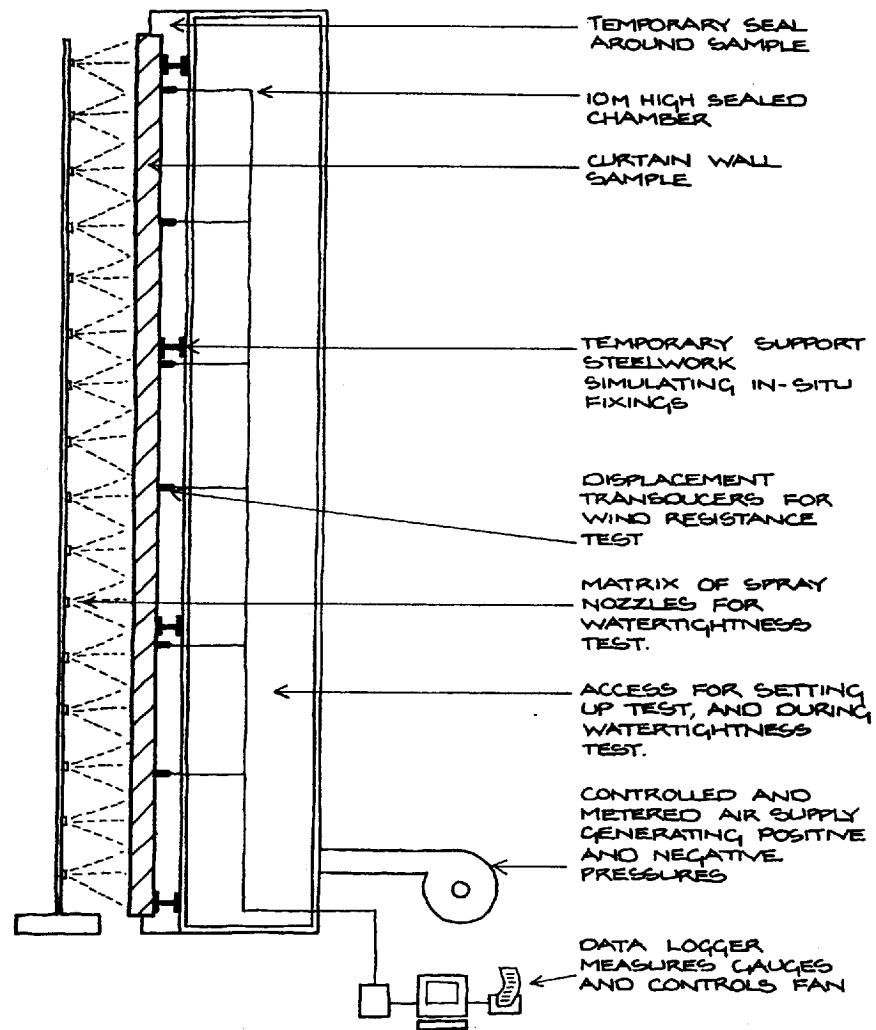


Figure F2.17 Typical curtain wall test rig

It is recommended that these various tests be carried out in the order:

- 1 Air permeability
- 2 Watertightness
- 3 Wind resistance
- 4 Repeat air permeability
- 5 Repeat watertightness
- 6 Thermal cycling
- 7 Repeat air permeability
- 8 Repeat watertightness
- 9 Dynamic water penetration
- 10 Structural safety

Consideration should also be given to the simulation of potential building movements arising from structural flexibility or thermal changes in the test programme.

Refer to Figure F2.18.

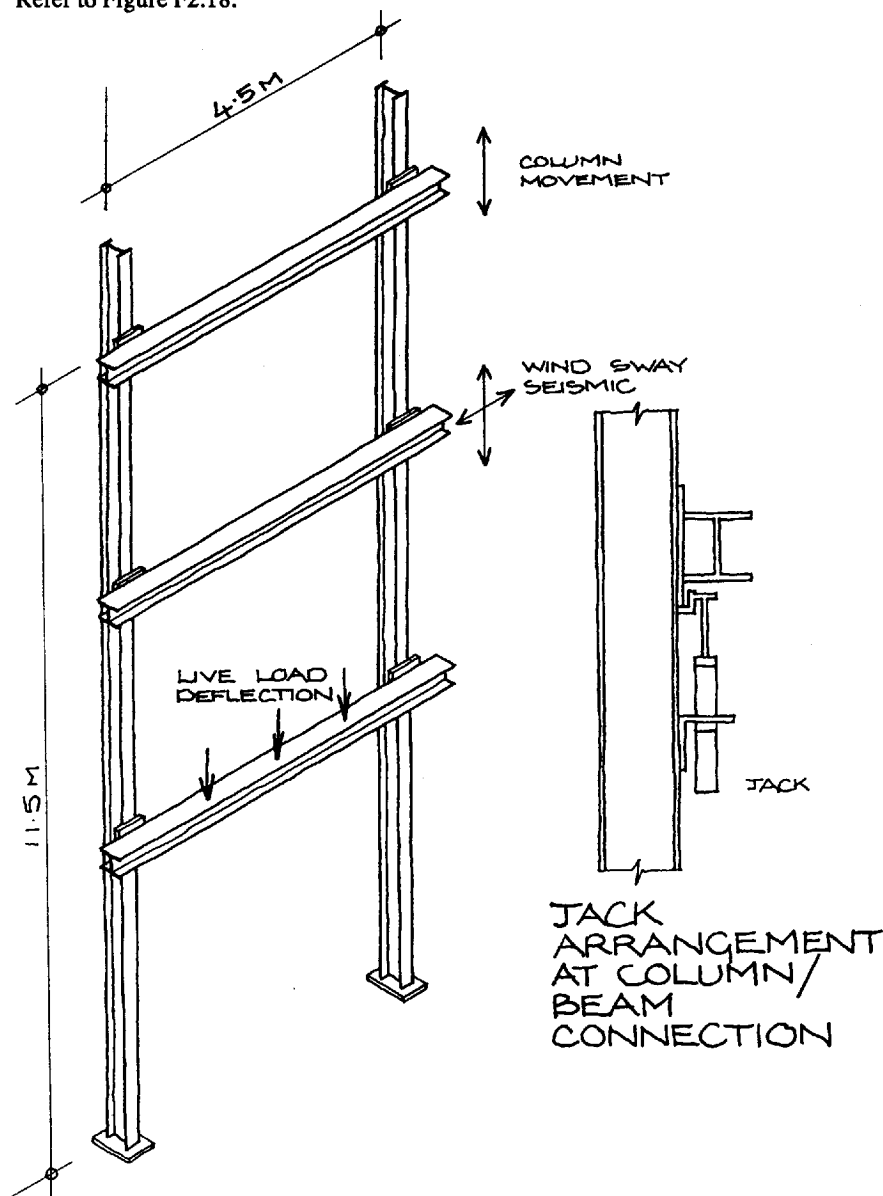


Figure F2.18 Support frame for testing building movement effects on cladding

To check on the workmanship of curtain walling during installation, a programme of on-site water testing can be carried out as construction progresses. This can be done either by means of a simple high pressure nozzle, as described in ASTM A 501.2-83, or a test with pressure differentials employing the methods in ASTM A 501.3-83 or BS5368 Part 2. These latter methods will involve boxing in either an inside or outside section or an area of the facade and applying a positive pressure outside, or a reduced pressure inside, whilst water is sprayed via nozzles on to the outside.

Refer to Figure F2.19.

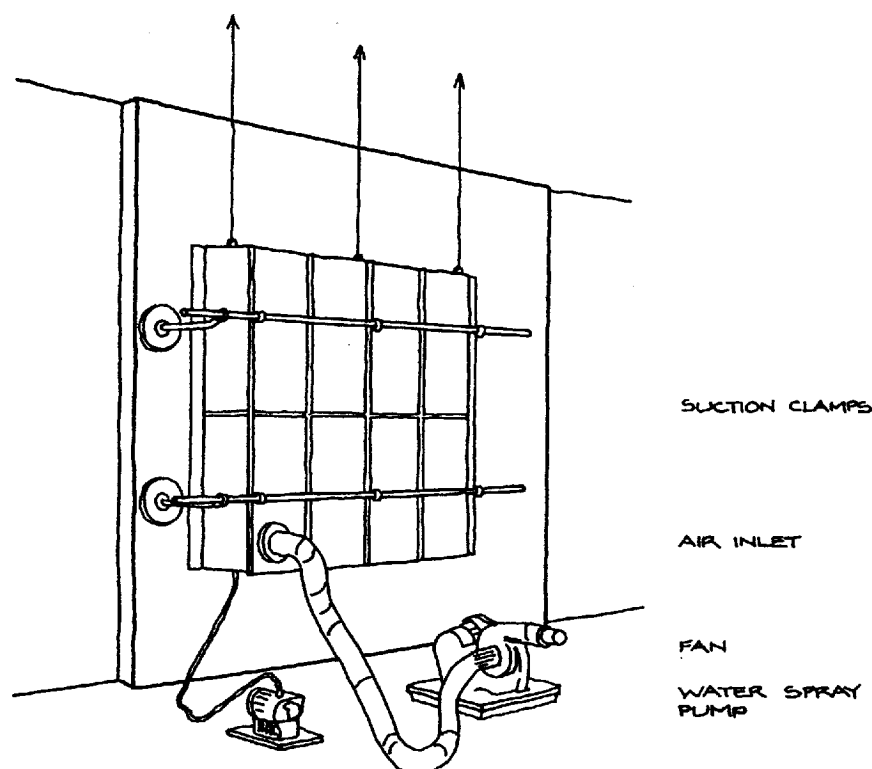


Figure F2.19 *Lightweight in-situ testing chamber*

References

British Standards Institution

BS CP 118	<i>Structural use of aluminium</i>
BS 476	<i>Fire tests on building materials and structures</i>
Part 4 1970	<i>Non combustibility test for materials</i>
Part 5 1979	<i>Methods of test for ignitability</i>
Part 7 1987	<i>Classification for surface spread of flame</i>
Part 8 1972 and	<i>Tests for fire resistance of elements</i>
Part 20 1987	<i>of building construction</i>
Part 10 1983	<i>Principles for application of fire testing</i>
Part 13 1987	<i>Measuring ignitability</i>
Part 22 1987	<i>Determination of fire resistance of non-loadbearing elements</i>
BS 1470: 1987	<i>Specification for wrought aluminium and aluminium alloys</i>
BS 2830: 1973	<i>Specification for suspended safety chains and cradles</i>
BS 3734: 1978	<i>Specification for dimensional tolerances of solid moulded and extruded rubber products</i>
BS 4255: 1986	<i>Rubber in gaskets. Specification for non-cellular gaskets</i>
BS 5368: 1985 (3 Parts)	<i>Methods of testing windows</i>
BS 5821: 1984	<i>Method for rating airborne sound insulation in buildings</i>
BS 5964: 1990	<i>Measurement methods for building. Setting-out and measurement</i>
BS 5974: 1982	<i>Code of Practice for temporarily installed suspended access equipment</i>
BS 6037: 1981	<i>Code of Practice for permanently installed suspended access equipment</i>
BS 6093: 1981	<i>Code of practice for design of joints and jointing in building construction</i>
BS 6213: 1982	<i>Guide to selection of construction sealants</i>
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BS 8200: 1985	<i>Design of non-loadbearing external vertical enclosures of buildings</i>
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