Patent glazing and sloping glazing for buildings —

Part 2: Code of practice for sloping glazing

ICS 81.040.20; 91.060.50

British Standards

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Association of Building Engineers

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Contents

Foreword

This part of BS 5516 has been prepared under the direction of Technical Committee B/520. This part of BS 5516, together with BS 5516-1, supersedes BS 5516:1991, which is withdrawn. It revises all or part of Clauses **6**, **7**, **10.3** to **10.5**, **10.6.2**, **10.6.3**, **10.8**, **12**, **14** to **19**, **20.1**, **20.3**, **20.4**, **21** to **24**, **25.1**, **25.2**, **25.4**, **25.6**, **25.8**, **25.9**, **26** to **29**, and Annex A to Annex F and Annex J to Annex K of BS 5516:1991.

BS 5516:1991 has been revised and restructured to simplify its use and will be published in three parts covering the following areas:

— *Part 1: Code of practice for design and installation of sloping and vertical patent glazing*;

— *Part 2: Code of practice for sloping glazing*;

— *Part 3: Special applications*.

Requirements for standards of workmanship for glazing have been published separately as BS 8000-7 and, therefore, this subject is not dealt with in this standard.

Since the correct selection of materials to be used in glazing for buildings depends on many factors, attention is drawn to the other parts of this standard.

As a code of practice, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and iv, pages 1 to 83 and a back cover.

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1 Scope

This part of BS 5516 gives recommendations for design, properties and maintenance of sloping glass and plastics glazing sheet materials in overhead situations in the envelope and interiors of buildings. It includes those situations where the sloping glazing extends down to floor level.

These recommendations apply only when the glass is installed in an appropriate glazing system.

These recommendations do not apply to:

a) vertical glazing (see BS 6262);

b) glazing for commercial greenhouses (see BS 5502-21);

c) glazing for domestic greenhouses;

d) sloping glazing which is to be used as a walking surface (see BS 5516-3);

e) profiled plastics sheets.

NOTE There are occasions, as with some curved glazing, where parts of a pane might be vertical, while other parts might be sloping. In this case, attention is drawn to both BS 6262 and BS 5516.

Requirements for standards of workmanship for glazing have been published separately as BS 8000-7 and, therefore, this subject is not within the scope of this standard.

Since the correct selection of materials to be used in glazing for buildings depends on many factors, attention is drawn to the recommendations in the other parts of this standard.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the reference cited applies. For undated references, the latest edition of the referenced document (including any amendments).

BS 476-3:1958, *Fire tests on building materials and structures — Part 3: External fire exposure roof test.*

BS 476-4, *Fire tests on building materials and structures — Part 4: Non-combustibility test for materials.*

BS 476-6, *Fire tests on building materials and structures — Part 6: Fire tests on building materials and structures. Method of test for fire propagation for products.*

BS 476-7, *Fire tests on building materials and structures — Part 7: Method of test to determine the classification of the surface spread of flame of products.*

BS 476-20, *Fire tests on building materials and structures — Part 20: Method for determination of the fire resistance of elements of construction (general principles).*

BS 476-22, *Fire tests on building materials and structures — Part 22: Methods for determination of the fire resistance of non-loadbearing elements of construction.*

BS 952-1, *Glass for glazing — Part 1: Classification.*

BS 4254, *Specification for two-part polysulphide-based sealants.*

BS 4255, *Rubber used in preformed gaskets for weather exclusion from buildings.*

BS 5215, *Specification for one-part gun grade polysulphide-based sealants.*

BS 5357, *Code of practice for installation of security glazing.*

BS 5368, *Methods of testing windows.*

BS 5516-1:2004, *Patent glazing and sloping glazing for buildings — Part 1: Code of practice for design and installation of sloping and vertical patent glazing.*

BS 5713, *Specification for hermetically sealed flat double glazing units.*

BS 5889, *Specification for one-part gun grade silicone-based sealants.*

BS 6180, *Barriers in and about buildings — Code of practice.*

BS 6206, *Specification for impact performance requirements for flat safety glass and safety plastics for use in buildings.*

BS 6262 (all parts), *Code of practice for glazing for buildings.*

BS 6262-4, *Glazing for buildings — Part 4: Safety related to human impact.*

BS 6375, *Performance of windows.*

BS 6399-2:1997, *Loading for buildings — Part 2: Code of practice for wind loads.*

BS 6399-3, *Loading for buildings — Part 3: Code of practice for imposed roof loads.*

BS 8213-1, *Windows, doors and rooflights — Part 1: Code of practice for safety in use and during cleaning of windows and doors (including guidance on cleaning materials and methods).*

BS EN 356, *Glass in building — Security glazing — Testing and classification of resistance against manual attack.*

BS EN 572-2, *Glass in building — Basic soda lime silicate glass products — Part 2: Float glass.*

BS EN 572-3, *Glass in building — Basic soda lime silicate glass products — Part 3: Polished wired glass.*

BS EN 572-5, *Glass in building — Basic soda lime silicate glass products — Part 5: Patterned glass.*

BS EN 572-6, *Glass in building — Basic soda lime silicate glass products — Part 6: Wired patterned glass.*

BS EN 673, *Glass in building — Determination of thermal transmittance (U value) — Calculation method.*

BS EN 1063, *Glass in building — Security glazing — Testing and classification of resistance against bullet attack.*

BS EN 1096 (all parts), *Glass in building — Coated glass.*

BS EN 1279 (all parts), *Glass in building — Insulating glass units.*

BS EN 1363-1:1999, *Fire resistance tests — Part 1: General requirements.*

BS EN 1364-1:1999, *Fire resistance tests for non-loadbearing elements — Part 1: Walls.*

BS EN 1364-2:1999, *Fire resistance tests for non-loadbearing elements — Part 1: Ceilings.*

BS EN 1634-1:2000, *Fire resistance tests for door and shutter assemblies — Part 1: Fire doors and shutters.*

BS EN 1634-3:2001, *Fire resistance tests for door and shutter assemblies — Part 3: Smoke control doors and shutters.*

BS EN 1863 (all parts), *Glass in buildings — Heat strengthened soda lime silicate glass.*

BS EN ISO 10077-1, *Thermal performance of windows, doors and shutters — Calculation of thermal transmittance — Part 1: Simplified method.*

BS EN 12056, *Gravity drainage systems inside buildings. Roof drainage, layout and calculation.*

BS EN 12150 (all parts), *Glass in building — Thermally toughened soda lime silicate safety glass.*

BS EN 13501-1, *Fire classification of construction products and building elements — Classification using test data from reaction to fire tests.*

BS EN 13541, *Glass in building — Security glazing — Testing and classification of resistance against explosion pressure.*

BS EN 13823:2002, *Reaction to fire tests for building products — Building products excluding floorings exposed to the thermal attack by a single burning item.*

BS EN ISO 1182:2002, *Reaction to fire tests for building products — Non-combustibility test.*

BS EN ISO 1716:2002, *Reaction to fire test for building products — Determination of the heat of combustion.*

BS EN ISO 9239-1:2002, *Reaction to fire tests — Horizontal surface spread of flame on floor-covering systems — Part 1: Determination of the burning behaviour using a radiant heat source.*

BS EN ISO 11600, *Building construction — Jointing products — Classification and requirements for sealants.*

BS EN ISO 11925-2:2002, *Reaction to fire tests — Ignitability of building products subjected to direct impingement of flame — Part 2: Single flame source test.*

BS EN ISO 12543 (all parts), *Glass in building — Laminated glass and laminated safety glass.*

3 Terms and definitions

For the purposes of this part of BS 5516, the following terms and definitions apply.

3.1
aspect ratio
ratio of the longer side of a pane to its shorter side

3.2
conservatory
construction which has not less than three-quarters of the area of its roof and not less than one half of the area of its external walls made of translucent material, and which is attached to and has direct access from a building

3.3
coupled glazing
two panes of glazing spaced apart in an opening, either in the same frame or glazed separately, to form an unsealed cavity

3.4
edge cover
distance between the edge of the glass and the sight line

NOTE See Figure 1.

3.5
fire resistant glass
glass that can resist the passage of flames and smoke through the glass for a period of time (normally 30 min or longer), when tested in accordance with BS 476-22 or BS EN 1364-1 or BS EN 1364-2

NOTE Fire resistant glass which can also resist the passage of heat through the glass for a period of time (normally 30 min or longer), when tested in accordance with BS 476-22 or BS EN 1364-1 or -2, without the unexposed surface temperature exceeding a specified limit is known as insulated glass. Fire resistant glass that does not have this resistance to heat is known as integrity only glass.

3.6
frame
member which continuously supports and retains the edge of the glazing

3.7
glazing
glass or plastics glazing sheet material for installation into a building

3.8
glazing bar
member, incorporating drainage channels, that supports and retains the edges of the glazing in patent glazing

3.9
glazing material
product or substance used as an intermediary to separate the glazing from the frame which supports and restrains it

NOTE Glazing materials might also restrict air and water ingress and might play an active part in restraining the glazing sealants; gaskets and glazing strips are the commonest types.

3.10
insulating glass unit
i.g.u.
two or more panes of glass manufactured to size and shape, spaced apart and then hermetically sealed in a factory, ready for glazing

NOTE The individual panes might be of different sizes and/or thicknesses.

3.11
nominal
<of dimensions> design size excluding tolerances

3.12
pane
single piece of glass or plastics glazing sheet material, in a finished size ready for glazing

3.13
pane size
dimensions of a pane

NOTE See Figure 1.

3.14
patent glazing
self draining and ventilated system of dry glazing, which does not rely entirely for its watertightness upon external seals. It consists essentially of a series of continuous longitudinal glazing bars with an infilling of glass or other suitable material

3.15
plastics glazing sheet material
plastics materials in the form of a single sheet, or a combination of sheets laminated together, or an extruded multi-wall sheet

3.16
sight size
dimensions of the opening which, when glazed with a transparent or translucent pane, admits light

NOTE See Figure 1.

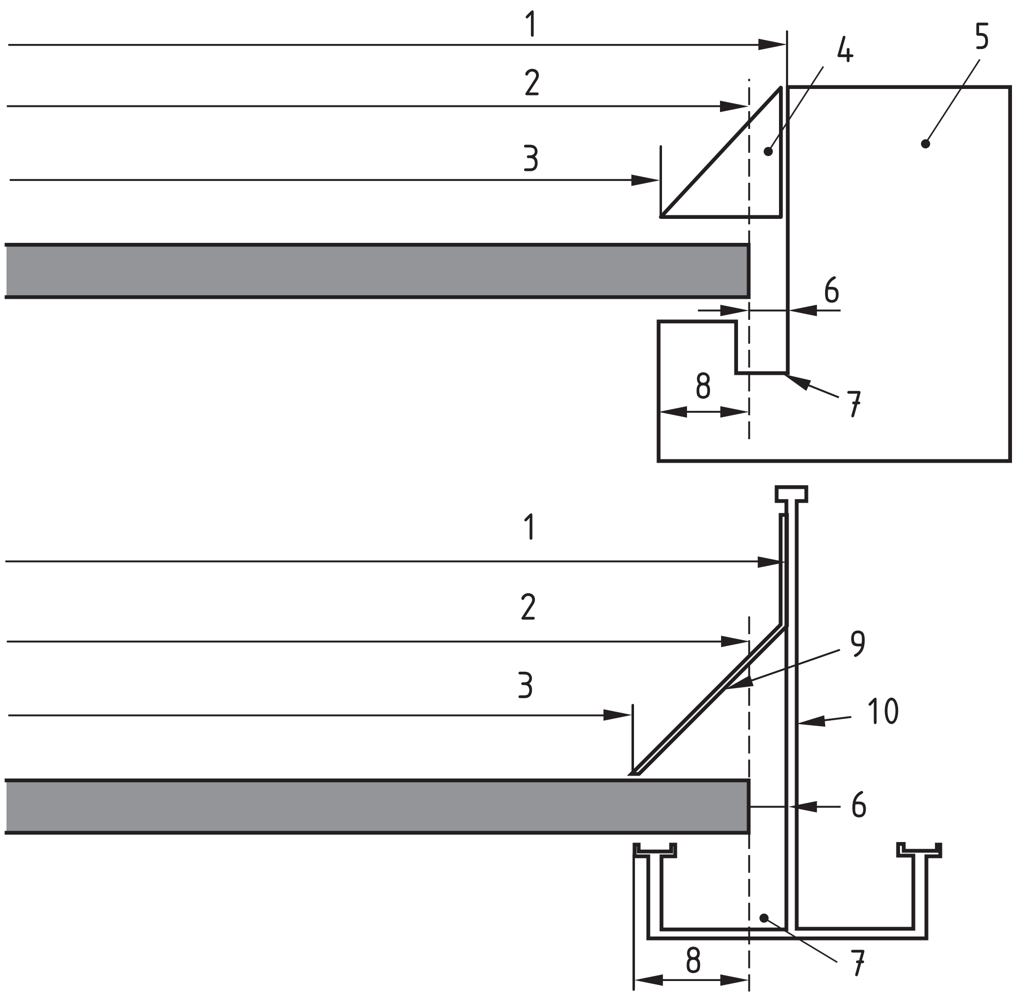
3.17
sloping glazing
glazing which is horizontal or having a slope of 75° or less

NOTE Slopes are measured from the horizontal; thus a slope of 75° is 15° from true vertical.

3.18
tight size
rebated size
dimensions of the rebated opening

NOTE See Figure 1.

3.19
vertical glazing
glazing which is vertical, or within 15° of vertical



Key

1	Tight size	6	Edge clearance
2	Pane size	7	Drainage
3	Sight size	8	Edge cover
4	Bead	9	Wing
5	Frame	10	Glazing bar

Figure 1 — Definition of sizes

4 Symbols

A Area of glazing

A_e Effective area of glazing

a Longer dimension of four edge supported glazing

b Span between supports for two edge supported glazing, or smaller dimension of four edge supported glazing

C Sound reduction index modification factor

C_p Combined pressure coefficient for calculating wind loads

C_{tr} Sound reduction index modification factor for traffic noise

d_{all} Maximum deflection of the glass or plastics glazing sheet material

f_c Critical resonance

F Shape factor

F_A Altitude factor

F_T Topographical factor

g_i Dead weight per unit area of the glazing

h Depth of valley in a valley roof

h_1 Height of abutting structure above roof or canopy

h_2 Height of abutting structure above roof or canopy

H_A Altitude of the site

L Unsupported length of glazing

p_{di} Dead load, including self weight

$p_{g;f}$ Working pressure for glass strength calculation

$p_{g;y}$ Working pressure for glass deflection calculation

p_p Working pressure for plastics glazing sheet material

p_s Design snow load

p_w Design wind load

q Site dynamic wind pressure

q_0 Site dynamic wind pressure equivalent at sea level

r Aspect ratio a/b of the glazing

R Sound reduction index

R_m Mean sound reduction index

R_{TRA} Weighted sound reduction index against traffic noise

R_W Weighted sound reduction index

s_0 Site snow load

s_{alt} Snow load altitude factor

s_b Basic snow load

s_d Snow load

S Span of a glazing bar between its support points

t Glass thickness

α Slope of the glazing

5 Glazing

5.1 Glass

Glass for glazing should conform to the classification of BS 952-1. The availability and viability of the glass should be checked with the manufacturer. The following are the types of glass normally used in sloping glazing.

— Float glass, clear or body tinted, which should conform to BS EN 572-2.

— Polished wired glass, which should conform to BS EN 572-3.

— Patterned glass, clear or body tinted, which should conform to BS EN 572-5.

— Wired patterned glass, which should conform to BS EN 572-6.

— Insulating glass units, which should conform to BS 5713 (or BS EN 1279).

— Coated glass, which should conform to BS EN 1096.

— Heat strengthened glass, which should conform to BS EN 1863.

— Thermally toughened glass, which should conform to BS EN 12150.

— Enamelled thermally toughened, which should conform to BS EN 12150.

— Heat soaked thermally toughened glass.

— Laminated glass, which should conform to BS EN ISO 12543.

NOTE A European Standard, prEN 14179, is being developed for heat soaked thermally toughened glass.

5.2 Plastics glazing sheet materials

Plastics glazing sheet materials are of various basic polymer types. The types marketed vary because of differences in their chemical composition or form, i.e. solid or hollow section. Whilst different types are normally available under their proprietary brand names, the basic types most commonly used in sloping glazing are generically:

— polycarbonate (PC);

— unplasticized polyvinyl chloride (PVC-U);

— polymethylmethacrylate (PMMA), commonly referred to as “acrylic”;

— glass reinforced plastic (GRP).

PC, PVC-U and PMMA are thermoplastics, available in both solid sheet and hollow section forms. In addition to being available as clear transparent form, some of them are available as transparent colours, as opal whites and with patterned surfaces.

GRP is a glass-reinforced thermoset, available only in translucent form, which may be coloured.

For further information on plastics glazing sheeting materials, see Annex A.

6 Glazing systems

6.1 General

Many types of glazing systems can be used for supporting sloping glazing. These include patent glazing (see BS 5516-1), slope glazed curtain walling, rooflights, sloping roof windows, structural sealant glazing and structural bolted systems.

In all of these systems, attention should be paid to weather resistance (see Clause **15**), which is more difficult to achieve in sloping glazing than it is in vertical glazing, and appropriately dimensioned components should be used to adequately support and protect the glazing.

6.2 Patent glazing

Patent glazing should conform to the requirements of BS 5516-1.

6.3 Glazing systems using beaded frames or pressure plates with caps

This includes slope glazed curtain walling, rooflights, etc.

The rebate depth should be designed to give a nominal edge clearance of 6 mm all round the glazing and a nominal edge cover of at least 10 mm and not less than the thickness of the single pane or the thicker pane of an insulating glass unit.

To protect the edge seal of insulating glass units from the effects of UV exposure, the nominal edge cover should be at least 12 mm and preferably 16 mm, unless the edge seal is of a type (e.g. silicone dual seal) that can resist exposure to UV light. It is possible to enhance the effective edge cover by using chamfered gaskets. The frame should also be designed to drain any water that gets into the frame away from the edges of insulating glass units.

For plastics glazing sheet materials, the minimum edge cover should be 15 mm.

Glazing materials should be compatible with the glazing and the frame. Particular attention should be paid to compatibility with edge seal of insulating glass units and with plastics glazing sheet materials.

Transoms should be designed to avoid local ponding of water on the sloping glazing. This can be either by having a sufficiently low, chamfered profile or by incorporating a drainage mechanism.

6.4 Structural sealant glazing

This method of glazing uses the adhesive qualities of silicone sealants to retain glass in the frame by adhesion, without the necessity of any mechanical retention such as beads, clips or bolt fixings (although some specifiers insist on augmenting the system with retaining clips or other mechanical devices). The system can be either a two edge or four edge system. In a two edge system, two opposite edges are retained in a traditional frame with bead retention (see **6.3**).

The glazing should be prepared in the factory by mounting a structural seal support frame onto the glass, complete with any appropriate setting blocks, location blocks and distance pieces. On site, the support frame is attached to the building structure by mechanical means and the gaps between the glazing are sealed (see Figure 2).

The inner pane of an insulating glass unit should not be manufactured from monolithic toughened glass, since, if this is accidentally fractured, there is a possibility that the rest of the unit will become detached from the adhesive.

The glass selection should take into account the likely loading, be appropriate for safety requirements and be appropriate for environmental factors, e.g. thermal insulation, solar control and sound insulation.

The adhesive sealant is the only or the main means of retaining the glazing in position, so the type of sealant is important. Only sealants recommended by the manufacturer for this purpose should be used.

The sealant bite should be determined from the design loads on the glass and the allowable stress in the sealant. With an insulating glass unit, both the unit hermetic seal and the structural seal serve a structural purpose in retaining the glass in position and the sealant bite for both of these should be not less than the calculated figure.

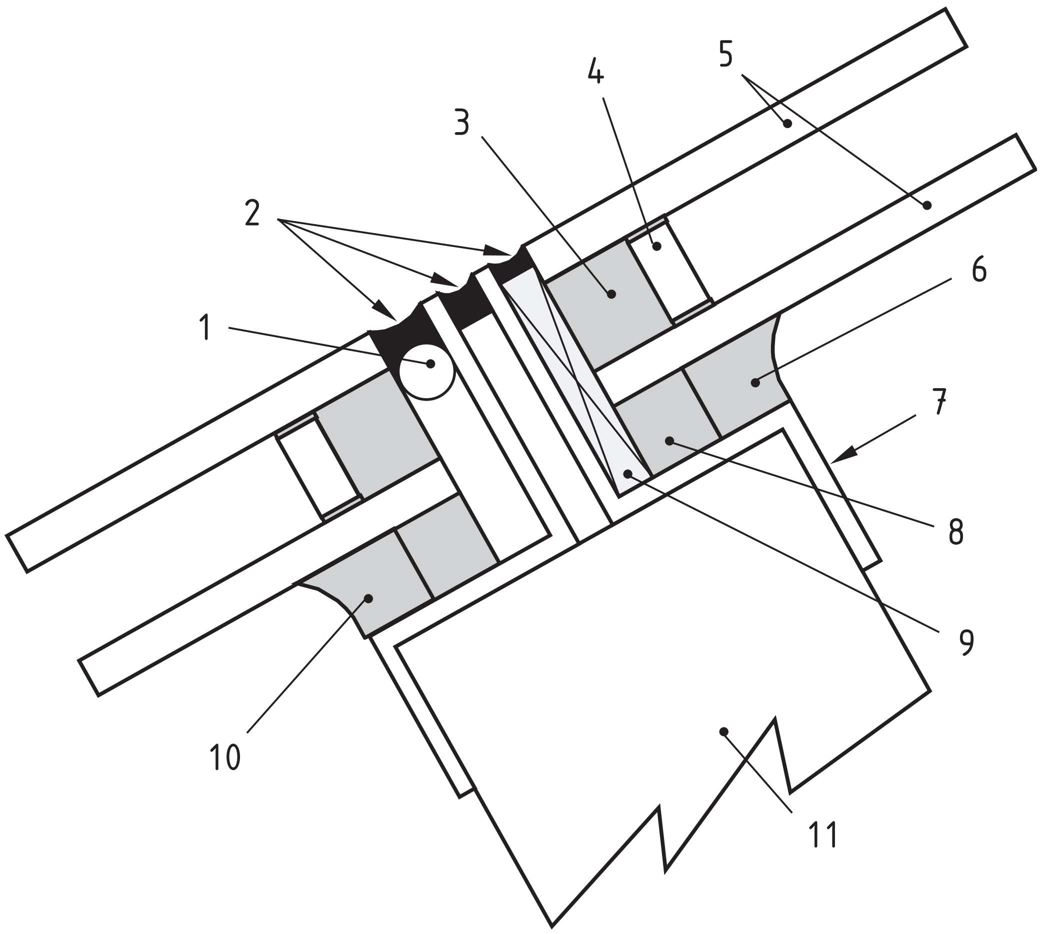
The glazing should be designed in such a way that the sealant is only subjected to short duration tensile forces, e.g. wind suction or live loads. Dead loads or sustained loads, such as snow, should be supported by the sealant in compression or by other means, e.g. setting blocks to carry the glass weight, unless the sealant is shown to be capable of sustaining the loads.

The design of the glazing should eliminate shear stresses on the structural sealant, unless it has been specifically designed for this purpose.

The sealant will only perform its function if the adhesive bonds between the sealant and the surfaces of the glass and the support frame are adequate and durable. The sealant supplier should perform tests on the adhesion at all the interfaces of the proposed products to ensure that the joint is capable of developing the required strength and that this can be maintained for the expected life of the glazing, assuming regular inspection.

Adhesion is product and surface specific. Once the adhesion tests have been completed satisfactorily, the specification for the glass, the support frame, the adhesive sealant and any primers should not be changed. If any changes are made, the full range of tests should be repeated.

Assembly of the glass and the support frame should be performed in controlled factory conditions, working to a prepared method statement. The adhesive qualities of the joint can be adversely affected by changes in temperature and humidity or the presence of moisture, so structural glazing adhesive joints should not be made on site.



Key

1 Backer rod
2 Weather seals
3 i.g.u. edge sealant
4 Spacer bar
5 Glass
6 Structural sealant
7 Structural sealant support frame
8 Spacing material
9 Setting block
10 Structural sealant
11 Building structure

Figure 2 — Structural sealant glazing

6.5 Structural bolted glazing

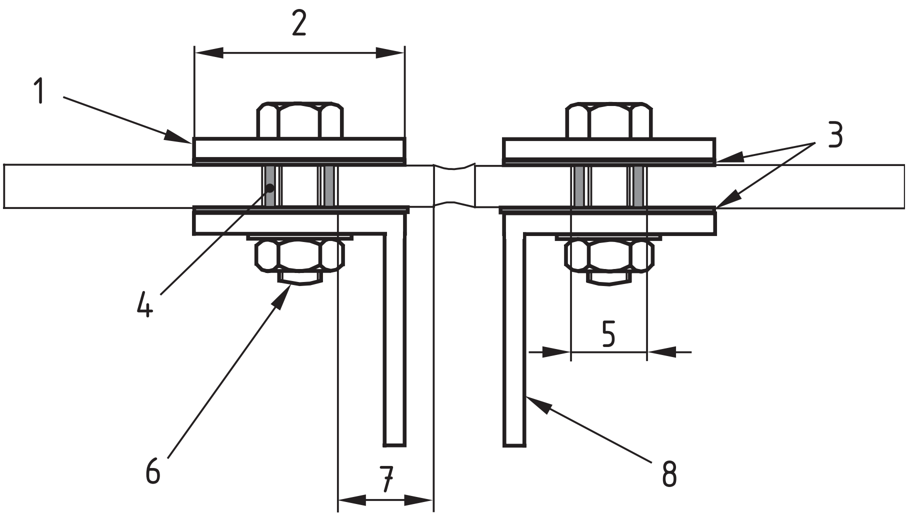
This method of glazing uses bolted fixings through glass to retain the glass in position. The panes are butt jointed to each other and weather sealing is achieved by using sealant, usually silicone, between the edges of the panes. At the edges of the glazing system, a rebated and beaded frame or a channel may be used.

For bolted fixings, toughened glass should be used for the main load bearing glazing, although heat strengthened glass may be used for non load bearing components with holes or cutouts. Annealed glass should never be used with bolted connections through holes or cutouts.

The fixings should be designed to limit the local bearing stress generated by the bolted connection, by having adequate bearing area and having suitable gaskets and bushes to prevent glass to metal contact and spread the loads. A fixing that can perform this function is shown in Figure 3.

Other types of fixing, such as countersunk bolted systems, may be used. The manufacturer should be consulted.

Where bolted fixings are used away from the corners of the glass, or with complex shapes, or with intermediate fixings, care should be taken to take into account the stress concentrations generated around holes and notches by bending the glass across them.



Key

1 Minimum 6 mm thick metal plate
2 Plate diameter = glass hole diameter + 30 min
3 1 mm incompressible fibre gaskets
4 Nylon bush, 2 mm to 3 mm thick
5 Glass hole diameter = bolt diameter + 10 mm
6 Bolt tightened to maximum torque
7 Minimum 2 × glass thickness
8 Minimum 6 mm thick metal angle fixed to structure

Figure 3 — Example of a simple bolted fixing

7 Mechanical design

7.1 Loading

Sloping glazing is not normally designed to withstand loads imposed by the structure to which it is attached. The loads that normally have to be resisted by sloping glazing are combinations of those due to the following:

— wind pressure exerted on the surface of the sloping glazing, which can act either inwards (positive pressure) or outwards (negative pressure or suction) or both: negative and positive pressures are not necessarily equal in magnitude;

— snow acting inwards on the surface of the sloping glazing;

— self-weight, usually acting inwards: the weight should also be considered as a load acting downward in the plane of the glazing;

— maintenance, if required, which should be taken as acting inwards.

7.2 Assessment of design loads

7.2.1 *Wind load*

The design wind loads, both positive and negative, for the particular situation of the sloping glazing should be determined at the initial design stage.

Wind loads for external walls and roofs of normal, rectangular, clad buildings and for canopy roofs should be determined by the method described in BS 6399-2:1997. A summary of this procedure is given in Annex B, together with an approximate method for low rise buildings.

For buildings of unusual geometric shape or site location not covered by BS 6399-2:1997 and for problems involving consideration of the excess pressure near ground level that can, in some circumstances, be generated by downdraught from tall buildings or high speed air currents such as can occur in narrow paths between buildings, expert advice should be sought, e.g. from the Building Research Establishment.

7.2.2 *Snow load*

The design snow loads on roofs for the particular situation of the sloping glazing should be determined at the initial design stage.

Snow loads on roofs should be determined by the method described in BS 6399-3. A summary of this procedure is given in Annex C.

Exceptional local effects such as shelter from the wind or local configurations which funnel the snow can give rise to increased loading. If there might be unusual local conditions that might need to be taken into account then the nearest meteorological office or informed local sources should be consulted.

Where there is a risk of damage by impact from large masses of snow sliding off an adjoining roof at higher level, snow guards should be fitted and BS EN 12056 should be referred to for detailed advice.

7.2.3 *Self-weight*

Dead loads for the glazing should be calculated from the actual known mass of the glazing.

Self-weight should also be considered as a dead load acting downwards in the plane of the glazing (see Annex D).

7.2.4 *Maintenance load*

Safe and efficient means of access should be considered for the maintenance, including cleaning, of sloping glazing, both inside and outside.

NOTE Attention is drawn to the requirements of the Construction Design and Management Regulations and the HSE Book *Health and Safety in Roof Work*, HSG33 [1].

Maintenance loads should not be applied directly to the glazing, but to the frame, glazing bars or other supporting elements by means of crawler boards, spreaders, or through specifically designed attachments for maintenance. Where direct access by temporary ladder or crawling boards is intended, the frames or glazing bars should, if required, be capable of supporting the loads imposed by their use. If the glazing is required to carry maintenance loads directly, it should be designed specifically for this purpose.

NOTE BS 5516-3 is in preparation.

Access systems which are independent of the sloping glazing system are preferred, especially for the maintenance of sloping glazing at high level.

7.2.5 *Other loads*

Where loads other than those mentioned in **7.2.1**, **7.2.2**, **7.2.3** and **7.2.4** are anticipated, for example any permanent imposed loads or suspended loads, expert advice should be sought. These loads should not normally be applied directly to the glazing or the glazing bars, but to the supporting structure.

7.3 Determination of working pressures

7.3.1 *General*

In determining working pressures for sloping glazing, account should be taken of the most adverse combination of design loads that is likely to occur in service in the particular situation of the glazing. Examples of this procedure are given in Annex E.

7.3.2 *Glass*

Glass is appreciably weaker when subjected to a sustained load such as snow and dead loads than to a load of short duration and, in determining working pressures for glass, it is essential that account should be taken of the effect of the duration of the various loads under consideration. The flexural strength of glass on which thickness computations, such as are given in **7.5.1**, are based is that for a uniform, short duration (e.g. wind gust) load and the relative strength for a sustained load is approximately ⅜ of that for a short-term load. When considering snow load and dead load in conjunction with wind load these sustained loads should be multiplied by a factor of 2.6 so that their effect on the strength of the glass may be considered in terms of a short duration load. This factor is not applied to the dead load where it merely reacts against a negative wind pressure since the weight counters the wind suction only when the suction occurs.

For the purpose of calculating deflections, the values of the longer duration loads need not be factored up. Extended duration of loads on glass does not lead to creep (i.e. increased deflection).

Applying this adjustment for sustained loads to combinations of design loads considered in Annex B, Annex C and Annex D, the following expressions are obtained.

a) Stress calculations:

— for positive (downward pressure) p_w: the higher of either: $+ 0.6p_w + 2.6(p_s + p_{di})$

or: $+ p_w + 2.6(0.6p_s + p_{di})$

— for negative (wind suction) p_w: $- p_w + p_{di}$

b) Deflection calculations:

— for positive (downward pressure) p_w: the higher of either: $+ 0.6p_w + p_s + p_{di}$

or: $+ p_w + 0.6p_s + p_{di}$

— for negative (wind suction) p_w: $- p_w + p_{di}$

To take account of wind-free conditions, zero should be substituted for $+ p_w$.

Each load case should be considered and whichever of the resultant values is numerically the greater for stress, $p_{g;f}$, and deflection, $p_{g;y}$, calculation should be taken as the operative working pressures for glass for the particular situation of the glazing. The values thus obtained should be used with the graphical data given in **7.5.1** for determining the recommended minimum thickness for glass.

The expressions apply to glass in single glazing and to insulating glass units.

With systems of coupled glazing comprising two or more separate and mechanically independent layers of glass, assuming some degree of air permeation between the panes, each pane should be designed to resist the full wind load, both positive and negative, in addition to its own weight. With such systems of coupled glazing, only the outer pane of glass needs to be capable of carrying the snow load.

7.3.3 *Plastics glazing sheet materials*

Under long-term, sustained loads, such as snow and dead loads, plastics glazing sheet materials can undergo a slight permanent deformation known as creep. This can manifest itself as a visible sagging of the glazing. In determining working pressures for plastics glazing sheet materials, it is essential that account should be taken of the effect of the duration of the various loads under consideration. The performance of plastics glazing sheet materials on which data given in **7.5.2** are based is that for a uniform, short duration (e.g. wind gust) load. When considering snow load and dead load in conjunction with wind load, these sustained loads should be multiplied by a factor so that their effect on the performance of plastics glazing sheet materials may be considered in terms of a short duration load. Based on experience and experimental knowledge, a factor of 2 is recommended. This factor is not applied to the dead load where it merely reacts against a negative wind pressure since the weight counters the wind suction only when the suction occurs.

Applying this adjustment for sustained loads to the combination of design loads considered in Annex B, Annex C and Annex D, the following expressions are obtained.

For positive (downward pressure) p_w: the higher of either $+ 0.6p_w + 2(p_s + p_{di})$

or $+ p_w + 2(0.6p_s + p_{di})$

For negative (wind suction) p_w: $- p_w + p_{di}$

To take account of wind-free conditions, zero should be substituted for $+ p_w$.

Each load case should be considered and whichever of the resultant values is numerically the greater should be taken as the operative working pressure for plastics glazing sheet materials, p_p, for the particular situation of the glazing. The values thus obtained should be used with the data given in **7.5.2** for determining the recommended minimum thickness for solid sheet or the form of hollow section sheet, of the plastics glazing sheet materials.

The expressions apply to solid plastics glazing sheet materials in single glazing and to hollow section plastics glazing sheet materials. With systems of coupled glazing comprising two separate and mechanically independent layers of plastics glazing sheet materials, assuming some degree of air permeation between the panes, each pane should be designed to resist the full wind load, both positive and negative, in addition to its own weight. With such systems of coupled glazing, the outer pane should be capable of carrying the snow load but the inner pane need not.

7.4 Strength and stiffness

7.4.1 *Glass*

The strength of glass to withstand uniform loading is based on the safe tensile stress it can carry and depends on the load duration, the type, size and thickness of the glass, the manner and the number of edges by which the glass is fully supported and, in the case of glass fully supported along all four edges, the aspect ratio of pane.

When glass is fully supported along two opposite longitudinal edges only, transverse bending of the glass creates stress at the mid-span and this is controlled by limiting the unsupported span of the glass. However, the adoption of the strength of the glass as the criterion might result in excessive deflection and this should be taken into account when determining the spacing of glazing bars.

When glass is fully supported along all four edges, up to an aspect ratio of pane of 3:1, the stress in the centre of the glass is controlled by limiting the area of the pane.

For an aspect ratio of pane greater than 3:1 the glass is considered to be effectively fully supported along two opposite long edges only.

Deflection in the glass should be limited to an amount likely to be visually acceptable and not impair its performance or weather resistance at flashings and other weatherings. Greater flexural strength does not indicate greater stiffness.

In the absence of any specified deflection limits, the glass deflection relative to its supports should be limited to $L/65$ when the glass is subjected to the working pressure determined from **7.3.2**, where L is an appropriate unsupported length, e.g. the span, b, of two edge supported glazing, or the length, a, of four edge supported glazing.

7.4.2 *Plastics glazing sheet materials*

The strength of plastics glazing sheet materials to withstand uniform loading is based on adequate resistance to flexing and depends on the size and thickness of the plastics glazing sheet material and, in the case of hollow section sheets, the geometry of their structure. It also depends on the manner and number of edges by which the plastics glazing sheet material is fully supported, the edge cover provided by the glazing bars and, in the case of plastics glazing sheet materials fully supported along all four edges, the aspect ratio of pane.

Failure of a pane of plastics glazing sheet material under mechanical load is more likely to be by displacement than by breakage. Deflection of the plastics glazing sheet material should be limited to an amount likely to be visually acceptable and not impair its performance or weather resistance at flashings or other weatherings (see Annex A). Deflection of the plastics glazing sheet material results in reduction of edge cover. When the plastics glazing sheet material is supported along two opposite longitudinal edges only, adequate edge cover is maintained by limiting the unsupported span of the pane. In the case of plastics glazing sheet materials fully supported along all four edges, having an aspect ratio of pane of not more than 3.5:1, adequate edge cover is maintained by limiting the area of the pane. Panes fully supported along all four edges having an aspect ratio of pane greater than 3.5:1 are considered to be supported along two opposite long edges only. In the case of a hollow section plastics glazing sheet material fully supported along all four edges, account should be taken of the different stiffness properties parallel to and perpendicular to the geometric profile which characterizes the sheet and reference should therefore be made to the manufacturer for design information.

7.5 Determination of recommended minimum thickness for glazing

7.5.1 *Glass*

Working pressures for glass determined on the basis of a short duration load, taking account of sustained loading effects, as described in **7.3.2**, should be used to calculate the minimum thickness or maximum size of pane by a graphic technique. The procedure given is for rectangular panes of annealed and processed flat glass, as described in BS 952-1, used in a glazing system with an appropriate edge cover and which does not deflect under maximum design load by more than the appropriate limits given in **7.6**. The procedure applies to glass in single glazing, to each pane of glass in coupled glazing comprising two separate and mechanically independent layers of glass and to insulating glass units.

The graphs should be used to determine the recommended minimum thickness of glass type for a given unsupported span or area of glass, according to the number of edges by which the glass is fully supported, using the procedures given in Annex F.

Figure 4a) to Figure 4f) are for glass which is fully supported on two opposite edges only and for glass which is fully supported on all four edges having an aspect ratio of pane greater than 3:1.

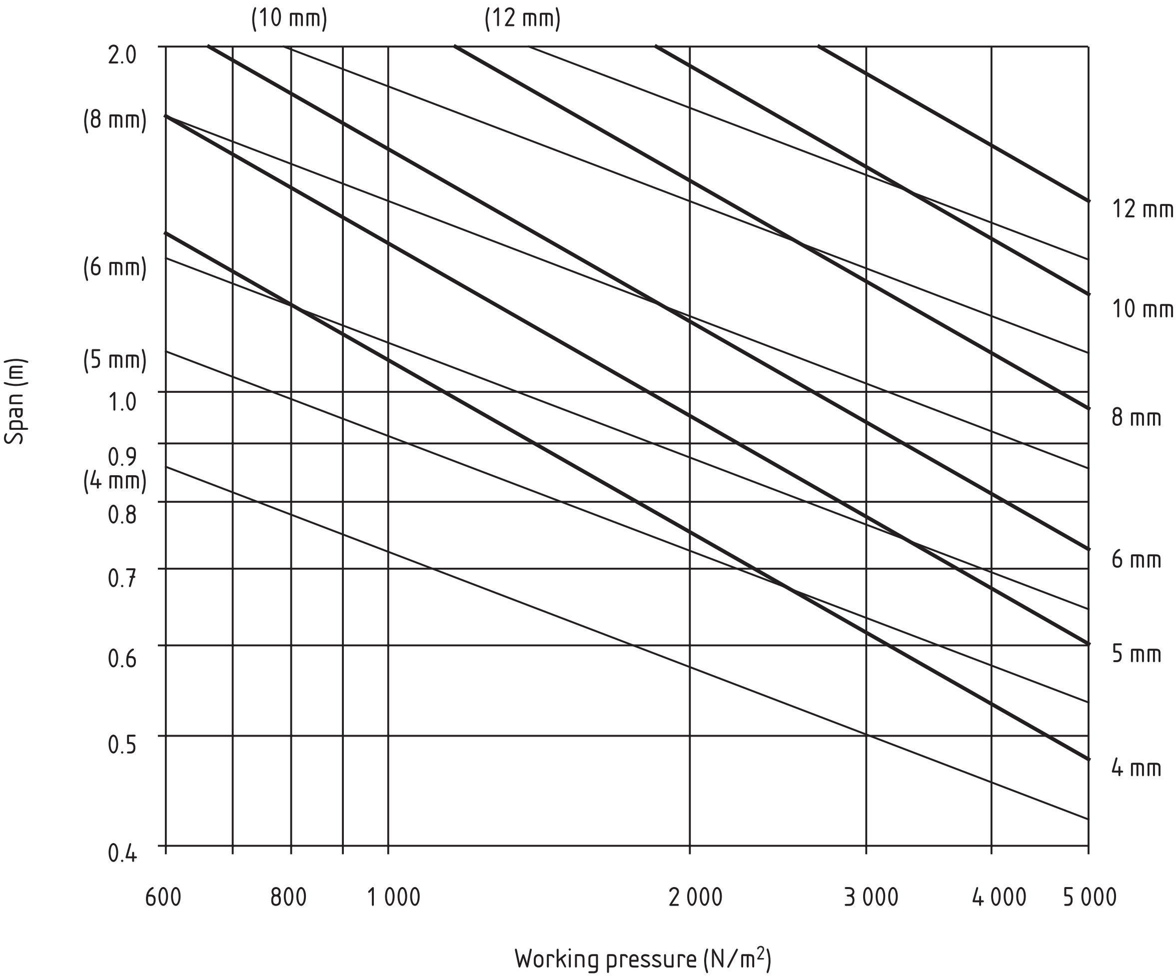
Figure 4g) to Figure 4l) are for glass which is fully supported on all four edges having an aspect ratio of pane not greater than 3:1. The effective area of the glazing is determined by the method in Annex F. As noted in **7.3.2**, if the aspect ratio of pane is greater than 3:1 the glass is considered to be fully supported on two opposite long edges only, the length of the shorter side being treated as the unsupported span of glass for use in Figure 4a) to Figure 4f). For glass to be considered as fully supported on all four edges, up to an aspect ratio of pane of 3:1, the deflection of each glazing bar or frame should not exceed the appropriate limits given in **7.6**. For other support conditions and for non-rectangular panes, the glass manufacturer should be consulted.

In the graphs, the minimum tolerances on glass thicknesses given in BS 952-1 have been used together with design stresses based on experience, experimental knowledge and statistical methods of analysis. Compliance of a glass design with working pressure does not imply suitability of use; other recommendations of this standard and other design requirements might also need to be followed. Glass having to withstand only low working pressure, notably in sheltered situations or used internally, might need to be increased in thickness or reduced in size in order to avoid excessive deflection under hand pressure, e.g. during cleaning operations. For design purposes, therefore, it is recommended that a minimum working pressure for glass of 600 N/m^2 is used.

The figures containing information on toughened glass are based on the design stress for fully toughened glass. This may lead to a glass design which, although mechanically safe, has large and possibly visually disturbing deflections under maximum load. The figures for two edge supported glass or insulating glass units also contain information on the thickness required to limit the deflection to the value suggested in **7.4.1**.

The laminated glasses referred to are three-ply laminated glass incorporating an interlayer of polyvinylbutyral. Thicknesses shown are nominal and based on the total glass thicknesses only.

For other glass types and thicknesses, for other constructions of laminated glass and for other glass combinations in insulating glass units, reference should be made to the glass manufacturer for recommendations.



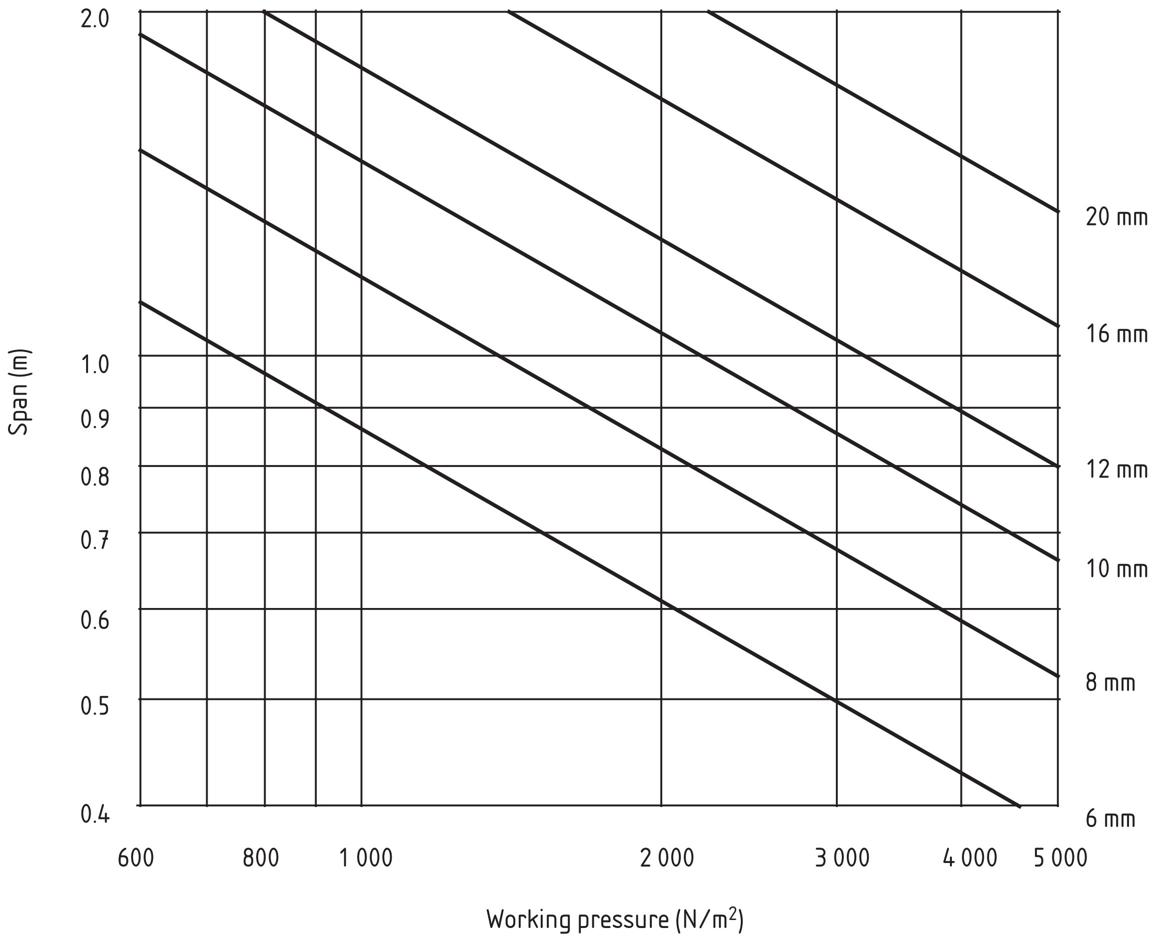
a) Toughened glass supported on two opposite edges only

Key

Stress limited ▬▬

Deflection limited ——

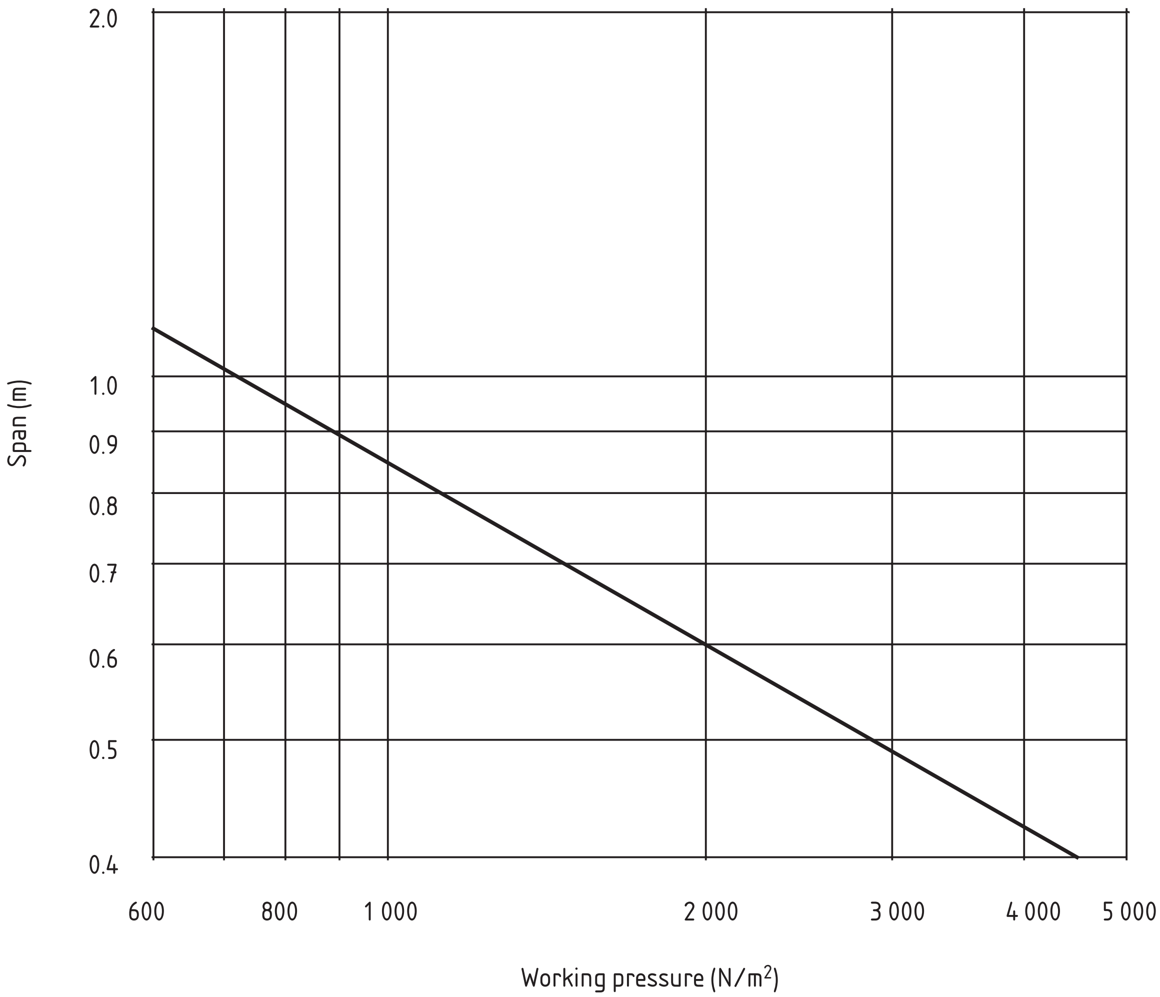
Figure 4 — Glass thickness selection chart



b) Laminated glass supported on two opposite edges only

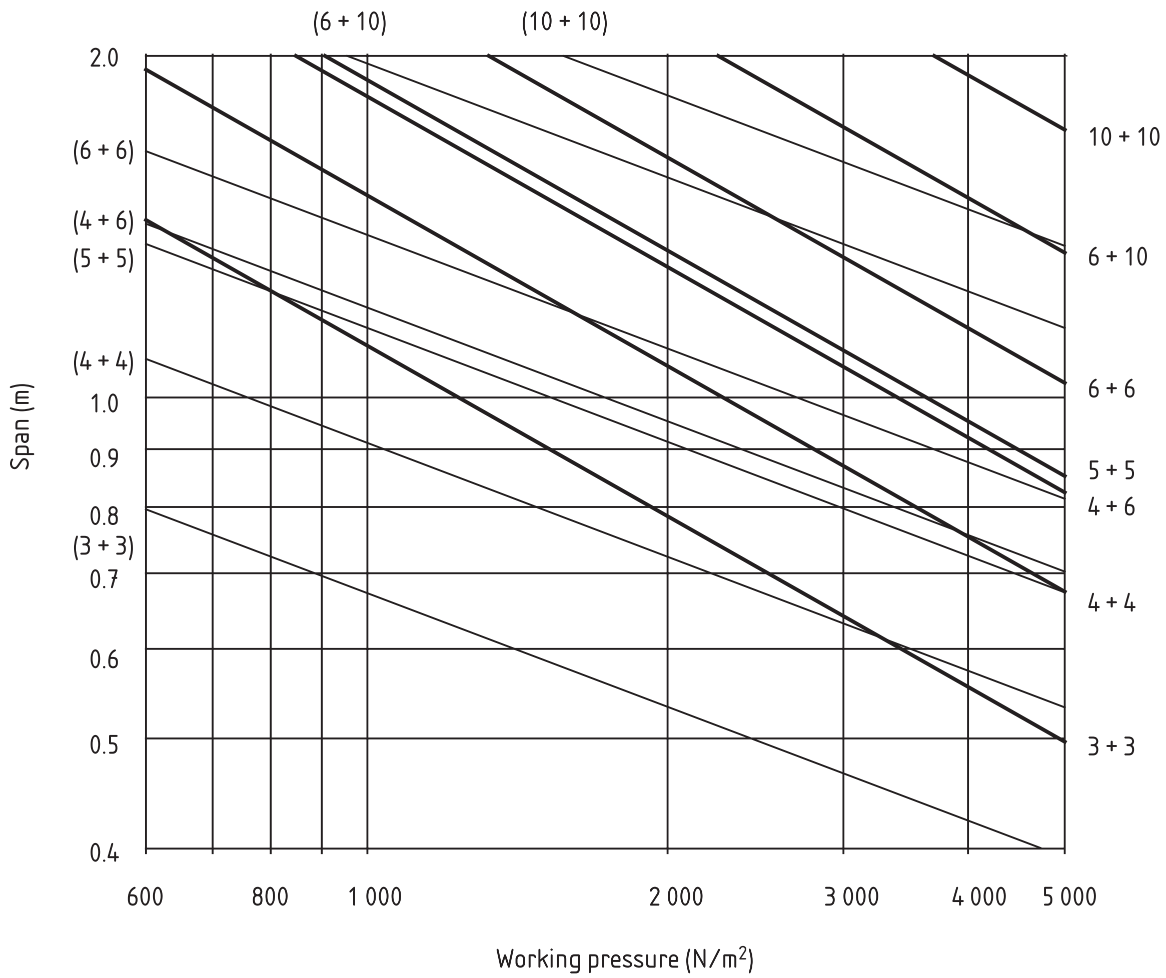
NOTE The thickness of laminated glass given in the figure is the sum total of the nominal glass thicknesses within a three-ply laminate made from float glass and PVB, irrespective of the laminate construction and discounting the thickness of the interlayer.

Figure 4 — Glass thickness selection chart (*continued*)



c) 6 mm polished wired glass or 7 mm wired patterned glass supported on two opposite edges only

Figure 4 — Glass thickness selection chart (*continued*)



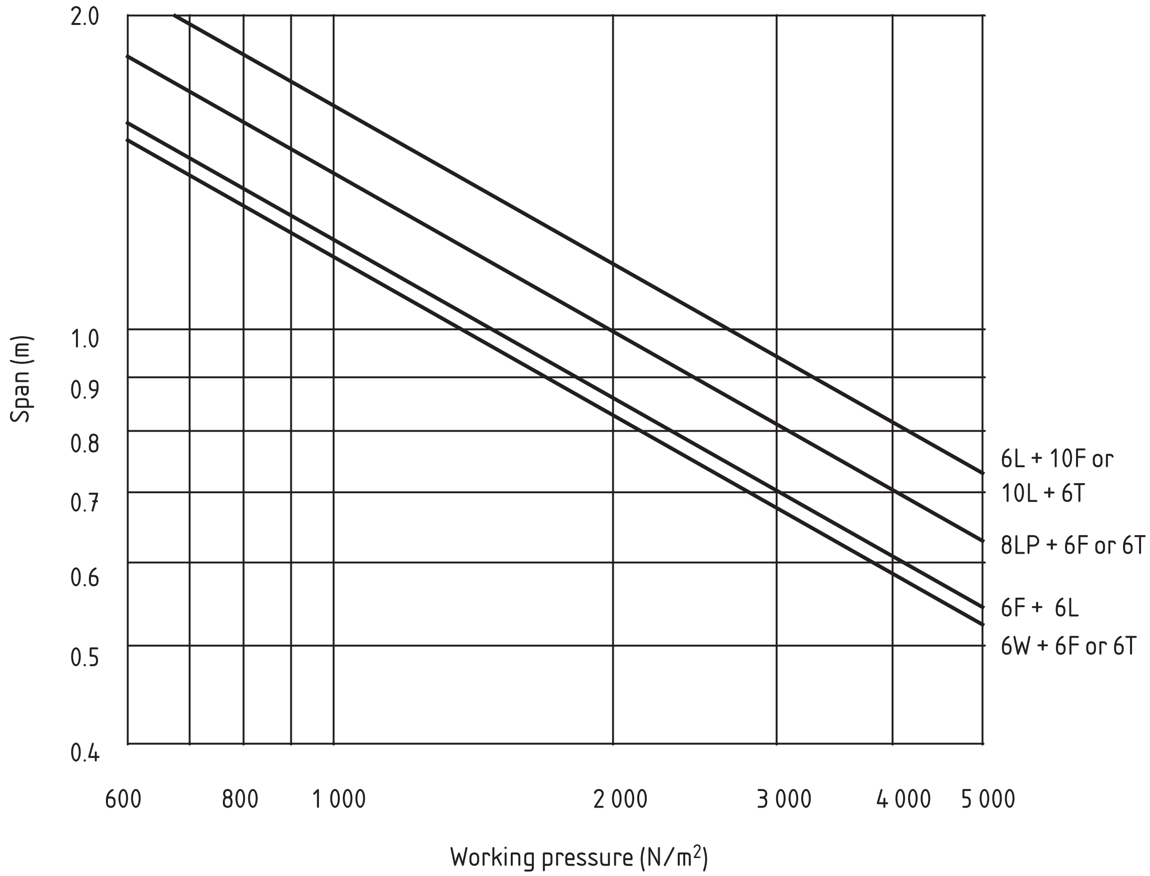
d) Toughened glass insulating glass units supported on two opposite edges only

Key

Stress limited

Deflection limited

Figure 4 — Glass thickness selection chart (*continued*)



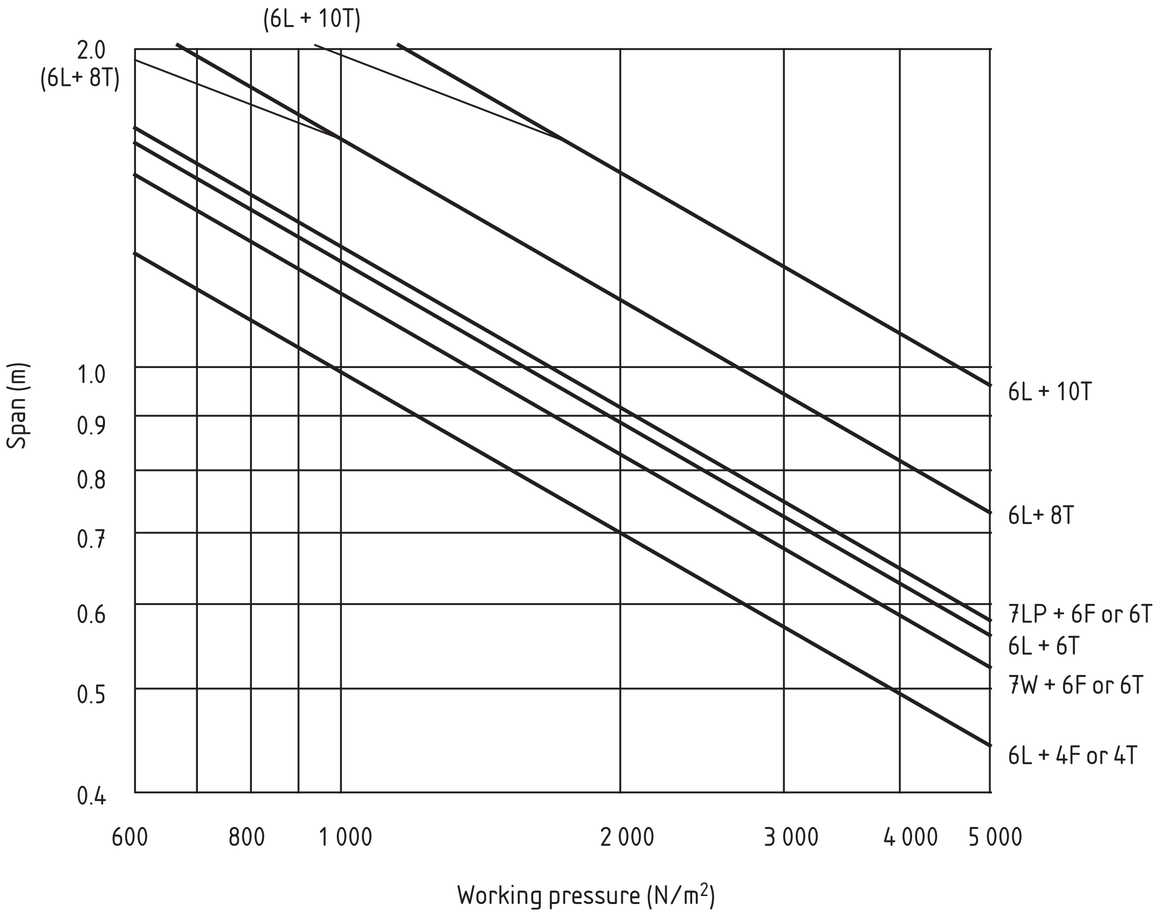
e) Various insulating glass units supported on two opposite edges only

Key

F – Float glass
P – Patterned glass
L – Laminated glass
T – Toughened glass
W – Wired glass
LP – Laminated glass

NOTE The thickness of laminated glass given in the figure is the sum total of the nominal glass thicknesses within a three-ply laminate made from float glass and PVB, irrespective of the laminate construction and discounting the thickness of the interlayer.

Figure 4 — Glass thickness selection chart (*continued*)



f) Various insulating glass units supported on two opposite edges only

Key

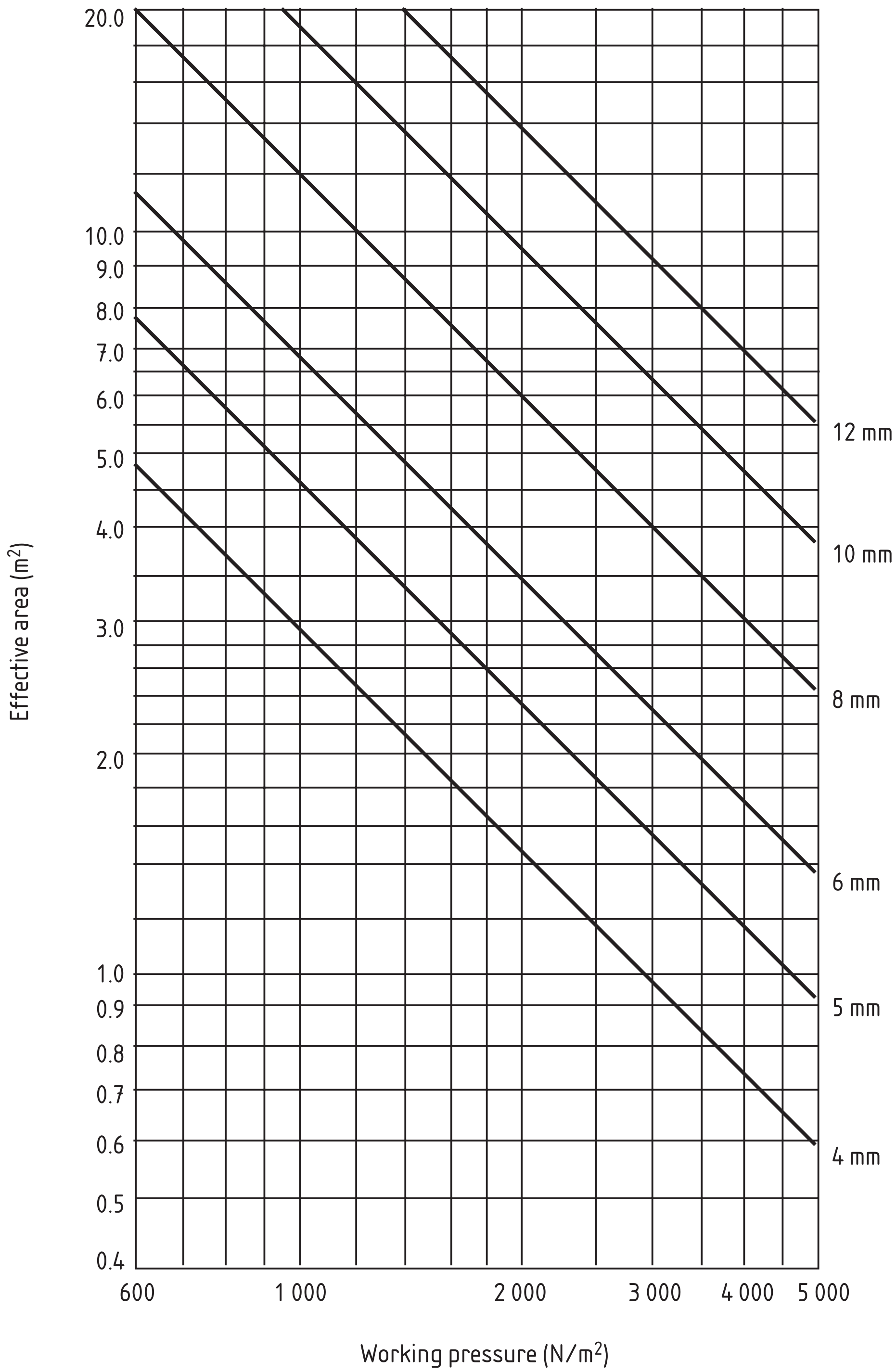
Stress limited

Deflection limited

F – Float glass
P – Patterned glass
L – Laminated glass
T – Toughened glass
W – Wired glass
LP – Laminated glass

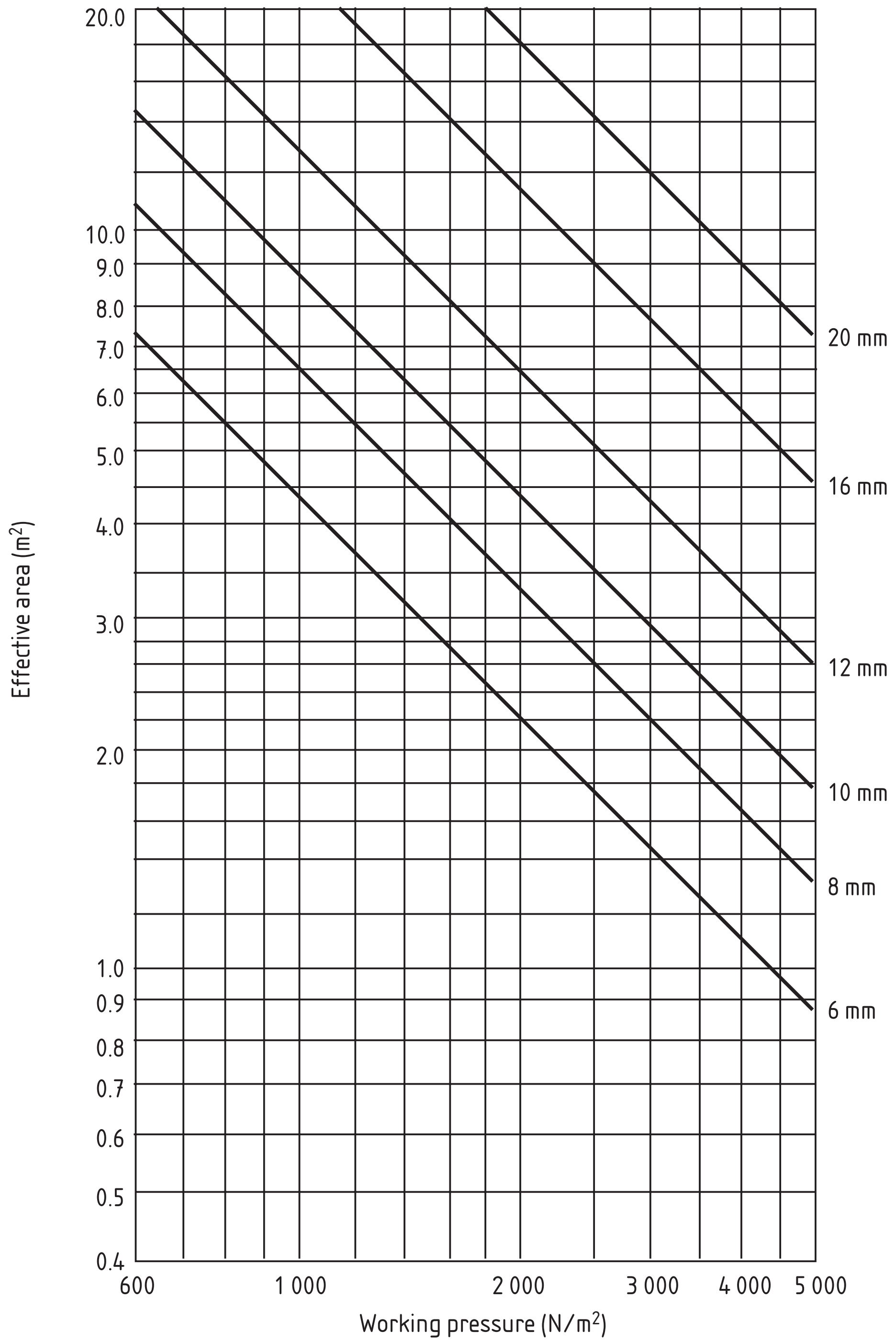
NOTE The thickness of laminated glass given in the figure is the sum total of the nominal glass thicknesses within a three-ply laminate made from float glass and PVB, irrespective of the laminate construction and discounting the thickness of the interlayer.

Figure 4 — Glass thickness selection chart (*continued*)



g) Toughened glass supported on all four edges

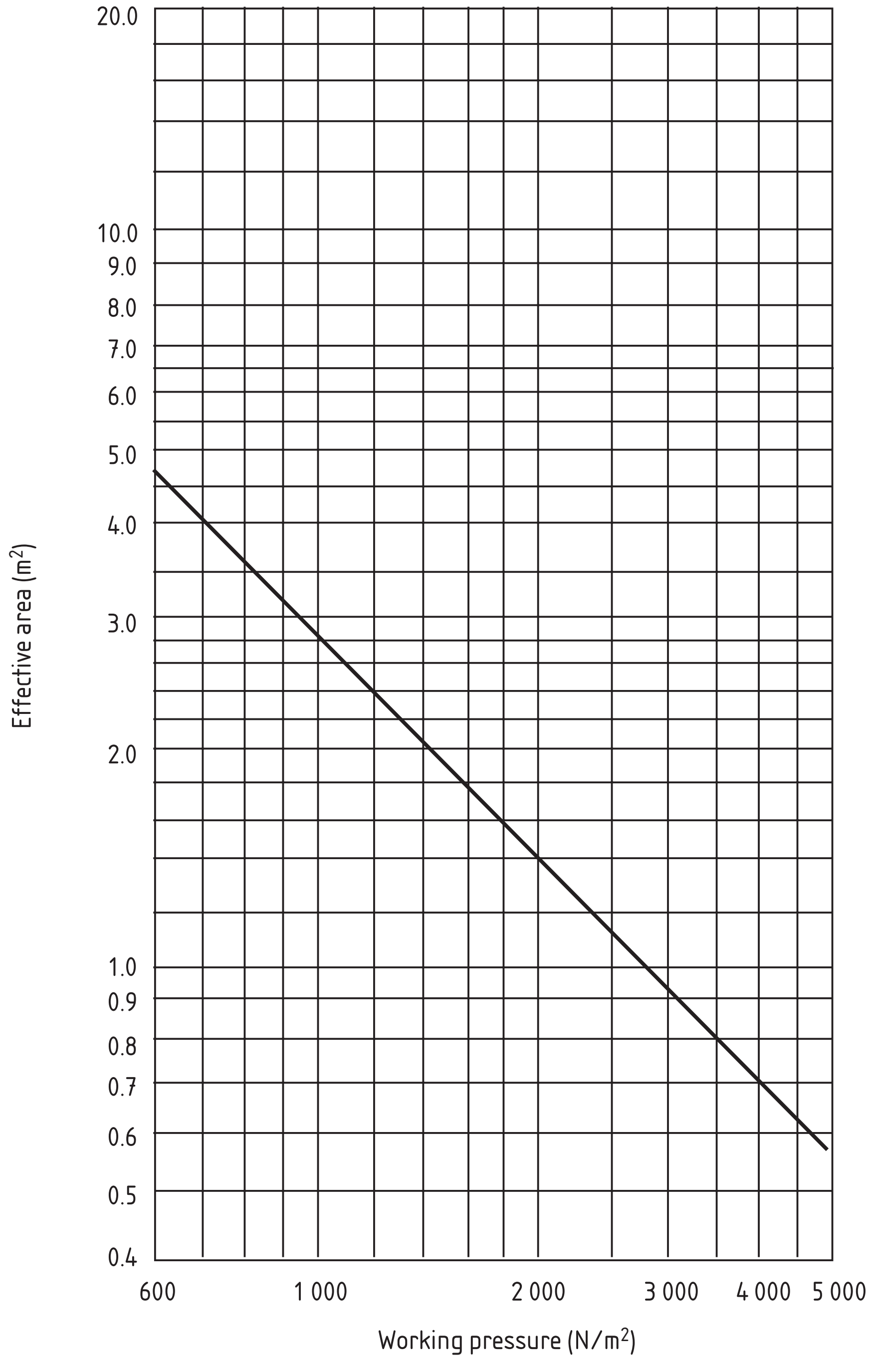
Figure 4 — Glass thickness selection chart (*continued*)



h) Laminated glass supported on all four edges

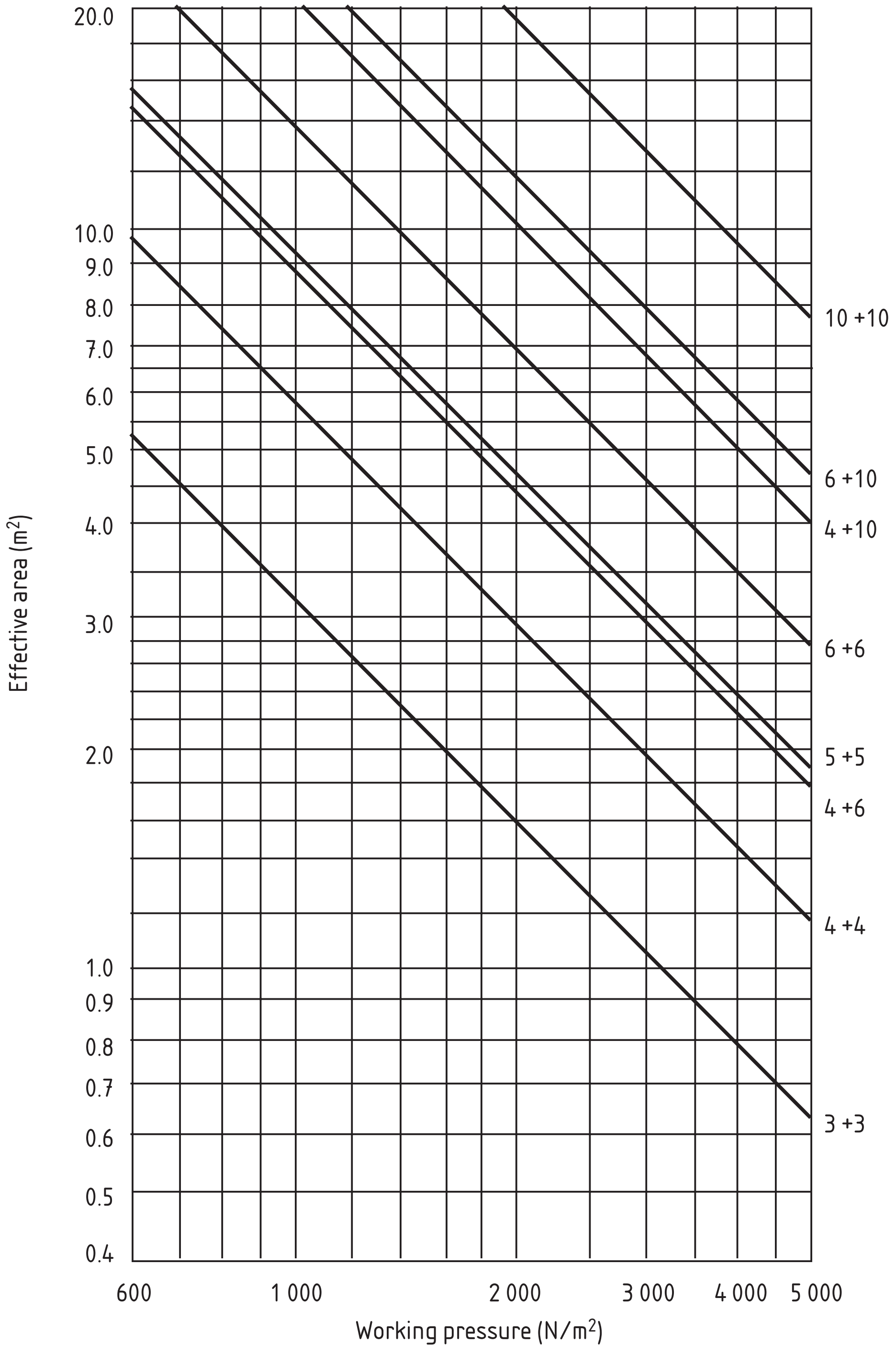
NOTE The thickness of laminated glass given in the figure is the sum total of the nominal glass thicknesses within a three-ply laminate made from float glass and PVB, irrespective of the laminate construction and discounting the thickness of the interlayer.

Figure 4 — Glass thickness selection chart (*continued*)



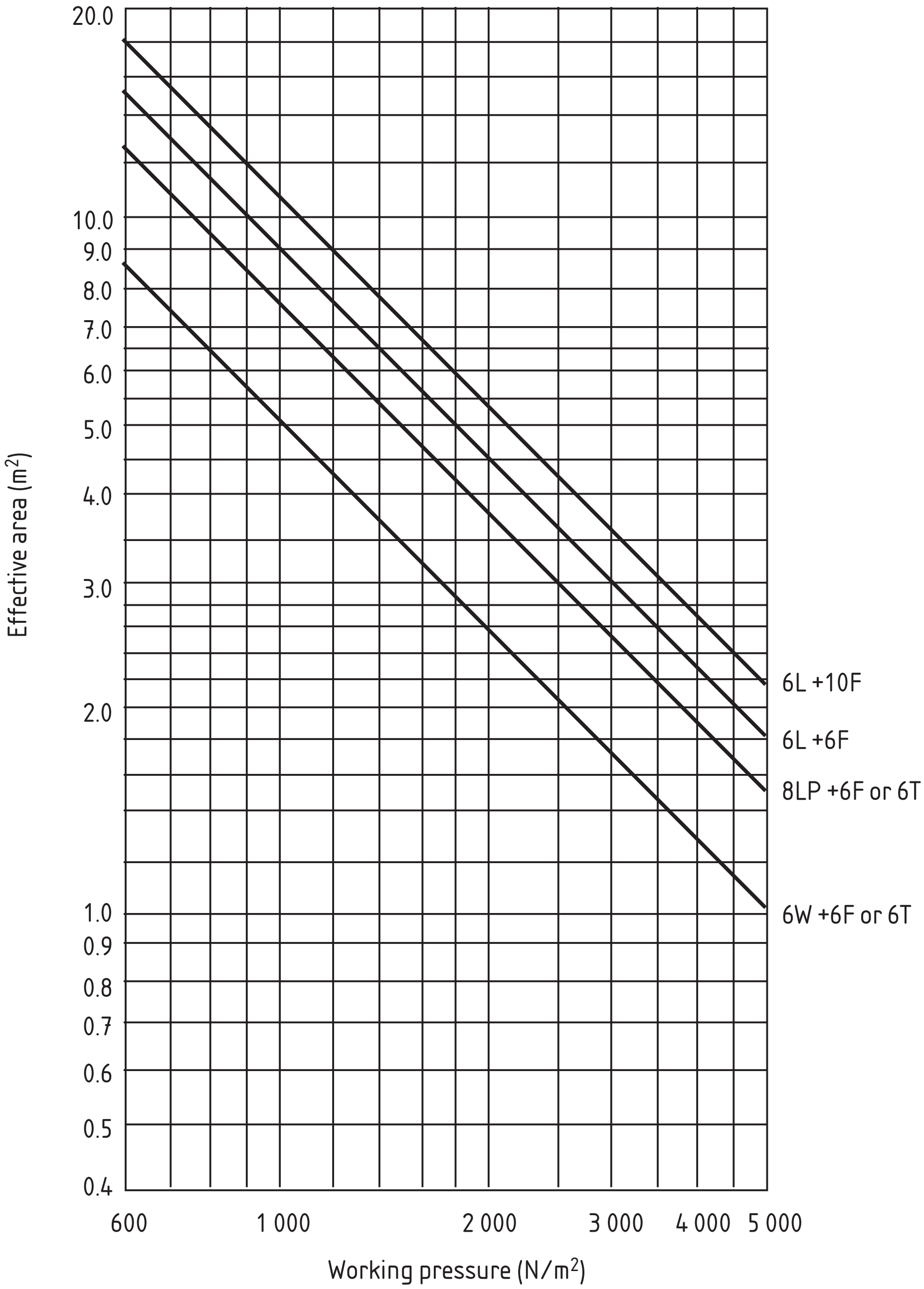
i) 6 mm patterned glass or 6 mm polished wired glass or 7 mm wired patterned glass supported on all four edges

Figure 4 — Glass thickness selection chart (*continued*)



j) Toughened glass insulating glass units supported on all four edges

Figure 4 — Glass thickness selection chart (*continued*)



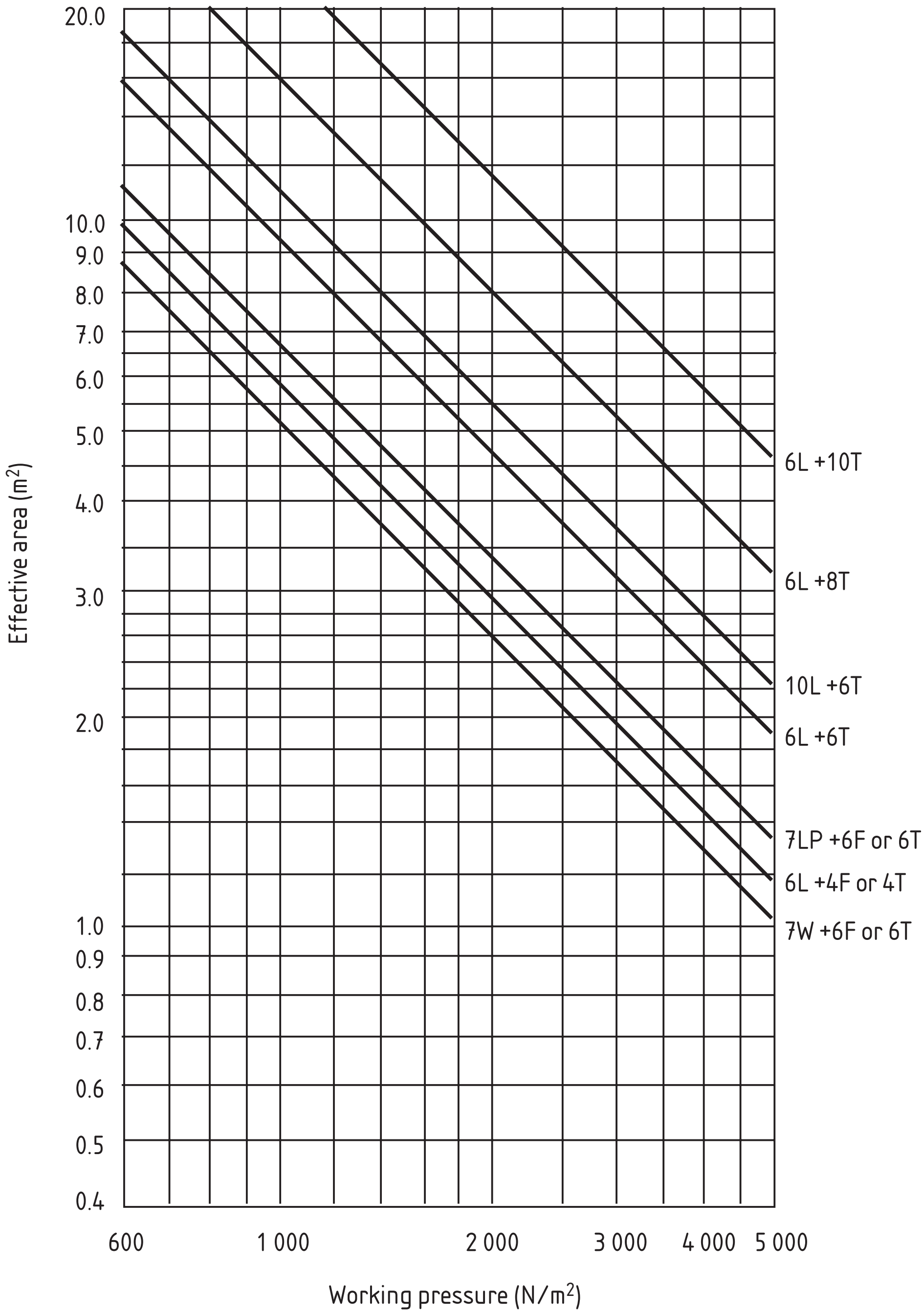
k) Various insulating glass units supported on all four edges

Key

F – Float glass	P – Patterned glass
L – Laminated glass	T – Toughened glass
W – Wired glass	LP – Laminated glass

NOTE The thickness of laminated glass given in the figure is the sum total of the nominal glass thicknesses within a three-ply laminate made from float glass and PVB, irrespective of the laminate construction and discounting the thickness of the interlayer.

Figure 4 — Glass thickness selection chart (*continued*)



l) Various insulating glass units supported on all four edges

Key

F – Float glass P – Patterned glass
L – Laminated glass T – Toughened glass
W – Wired glass LP – Laminated glass

NOTE The thickness of laminated glass given in the figure is the sum total of the nominal glass thicknesses within a three ply laminate made from float glass and PVB, irrespective of the laminate construction and discounting the thickness of the interlayer.

Figure 4 — Glass thickness selection chart (*continued*)

7.5.2 *Plastics glazing sheet materials*

7.5.2.1 *General*

Working pressures for plastics glazing sheet materials, determined on the basis of a short duration load, taking account of sustained loading effects as described in **7.3.3**, should be used to calculate the minimum thickness or maximum size of pane by a graphic technique in the case of solid plastics glazing sheet materials. In the case of hollow section plastics glazing sheet materials, these working pressures should be used to determine the required form of hollow section sheet by reference to the plastics glazing sheet material manufacturer.

The recommendations given as follows are applicable to rectangular panes of plastics glazing sheet materials used in a glazing system in which the glazing bars do not deflect under maximum design load by more than the appropriate limits given in **7.6**. These recommendations apply to single glazing or each pane in double glazing made up of two separate and mechanically independent layers.

Compliance of a plastics glazing sheet material design with working pressures does not imply suitability of use. Other recommendations of this standard as well as other design requirements, such as vandal resistance, might also need to be satisfied.

7.5.2.2 *Solid sheets*

Figure 5a) is for solid plastics glazing sheet material which is fully supported along two opposite, longitudinal edges only and for solid plastics glazing sheet material which is fully supported on all four edges having an aspect ratio of pane greater than 3.5:1.

Figure 5b), Figure 5c) and Figure 5d) are for solid plastics glazing sheet material which is fully supported on all four edges having aspect ratios of pane in the ranges 1.0:1 to 1.5:1, 1.5:1 to 2.5:1 and 2.5:1 to 3.5:1 respectively.

As noted in **7.3.3**, if the aspect ratio of pane is greater than 3.5:1, the solid plastics glazing sheet material should be considered to be fully supported on two opposite long edges only, the length of the shorter side being treated as the unsupported span for use in Figure 5a). For solid plastics glazing sheet material to be considered as fully supported on all four edges, up to an aspect ratio of pane of 3.5:1, the deflection of each glazing bar should not exceed the appropriate limits given in **7.6**. For other support conditions and for non-rectangular panes the manufacturer of the plastics glazing sheet material should be consulted.

In the graphs in Figure 5, the minimum recommendations for edge cover of plastics glazing sheet material have been used (see Annex A). If these recommendations cannot be fully satisfied, other methods of glazing may be employed and the manufacturer should be consulted.

7.5.2.3 *Hollow section sheets*

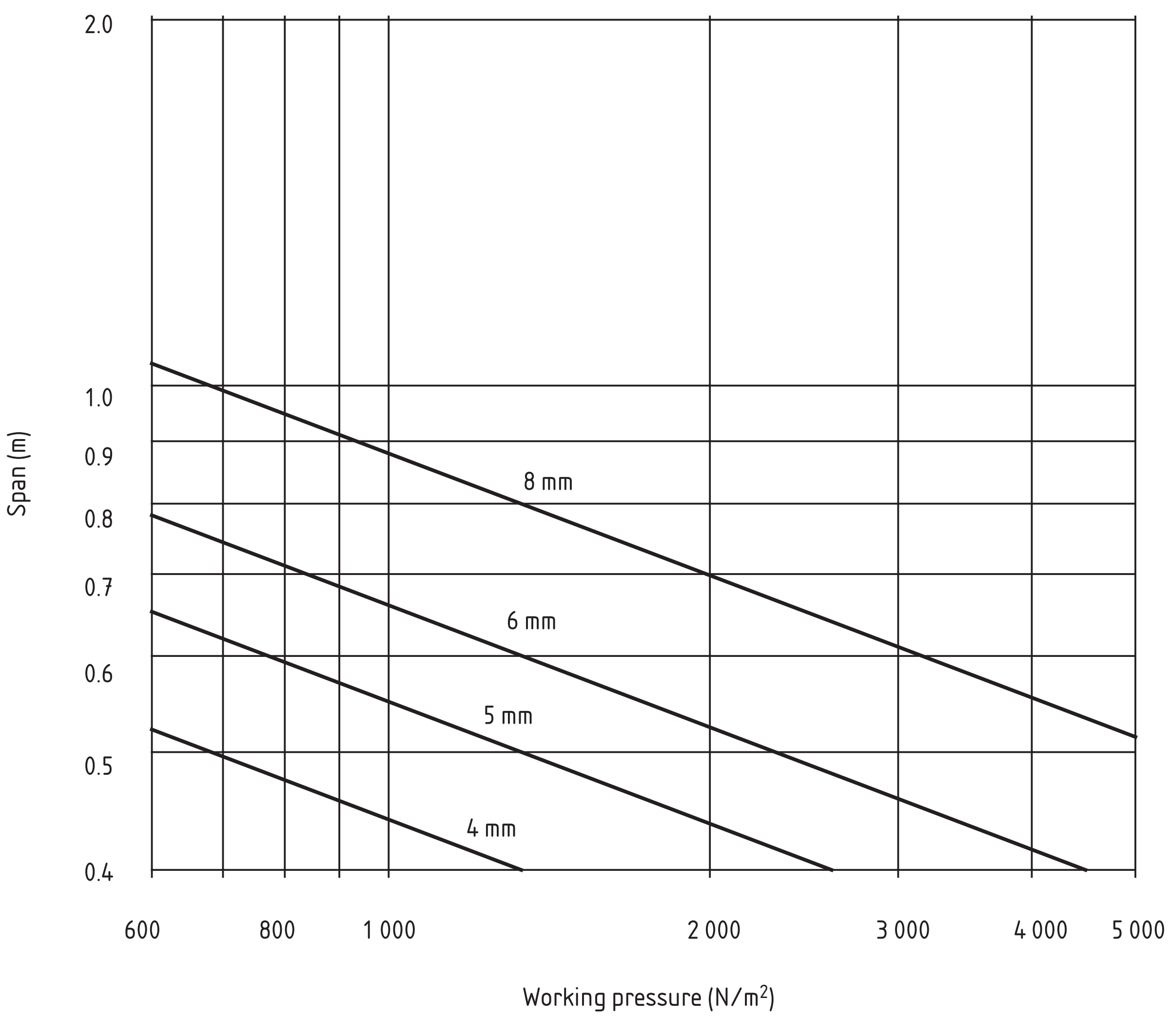
The stiffness of a hollow section plastics glazing sheet material is determined by the material from which it is made, the overall thickness and geometry of the sheet. In addition, in a system in which the of glazing is fully supported on all four edges, the deflection characteristics of a particular hollow section plastics glazing sheet material vary according to which direction the webs run in relation to the long edges of the pane. It is not practical, therefore, to produce a set of graphs relating working pressures to hollow section sheets because of the variety of profiles and thicknesses in existence, and the possibility of more to come. In the case of hollow section plastics glazing sheet materials fully supported on all four edges, advice should therefore be obtained from the manufacturer.

In a two-edge glazing system, transverse bending of the plastics glazing sheet material is a function of the working pressure p_p, the unsupported span L, and the permissible bending moment for the form of hollow section sheet.

For rectangular panes of hollow section plastics glazing sheet materials which are fully supported on two opposite, longitudinal edges only, the calculated value $(p_p L^2)/8$ N·m/m should not exceed the permissible bending moment. This expression assumes that the pane is simply supported along its edges and does not take account of any clamping effect which might be produced by the glazing bars at the edges of the pane. Advice should be obtained from the manufacturer.

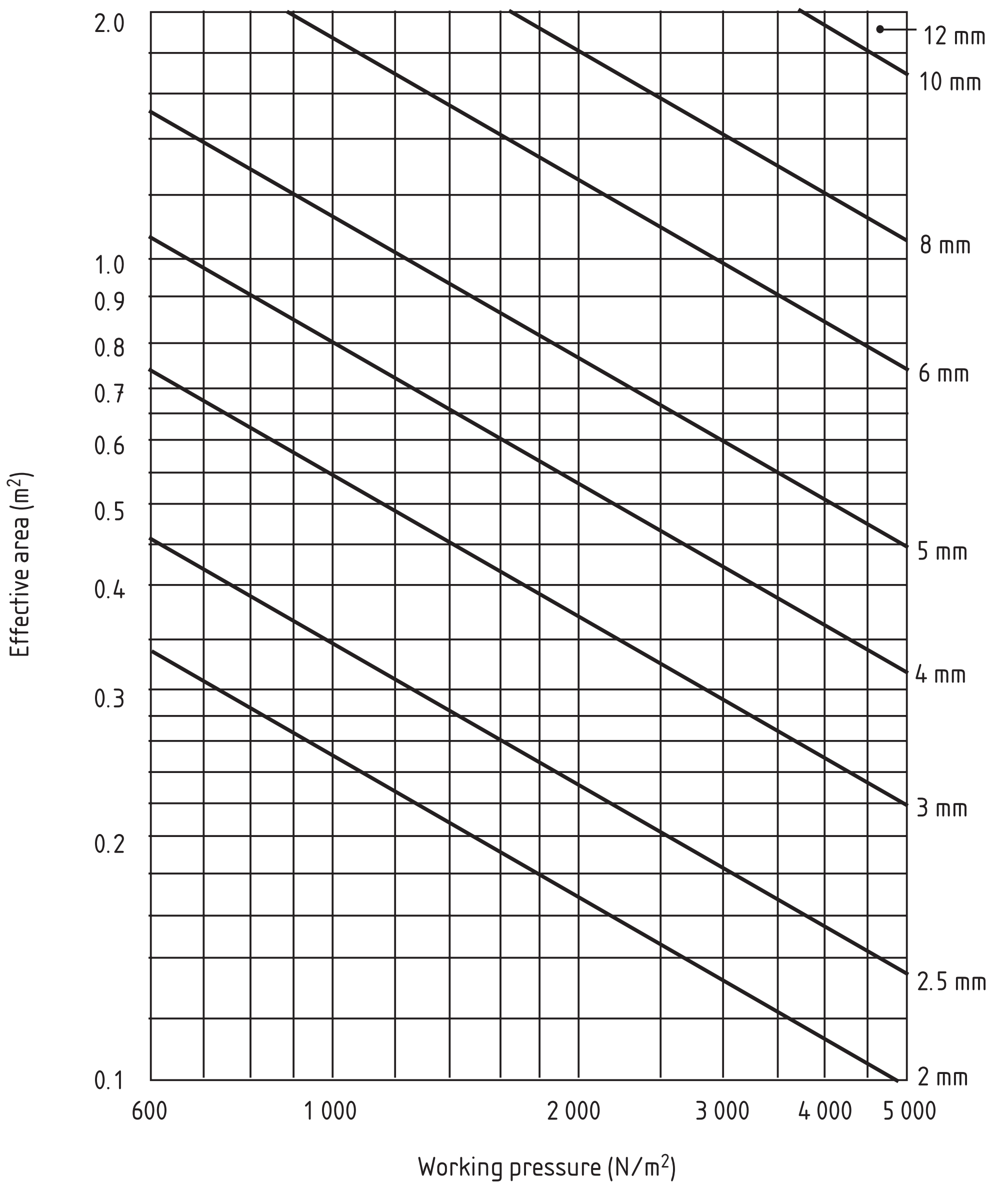
For external glazing, rectangular panes of hollow section plastics glazing sheet materials are normally installed with the webs parallel to the frames or glazing bars, i.e. in the direction of the slope or the flow of water. Therefore for hollow section plastics glazing sheet materials which are fully supported on two opposite, longitudinal edges only, the manufacturer should provide a value for the permissible bending moment for the particular hollow section sheet, supported parallel to the webs. In the case of hollow section plastics glazing sheet material with a non-symmetrical profile, i.e. with different permissible bending moments according to the direction in which the load is applied, only the lower value should be used.

In all cases, the minimum requirements for edge cover should be satisfied (see Annex A). Information supplied by the manufacturer should also satisfy these requirements. If these requirements cannot be fully satisfied, other methods of glazing may be employed and the manufacturer should be consulted.



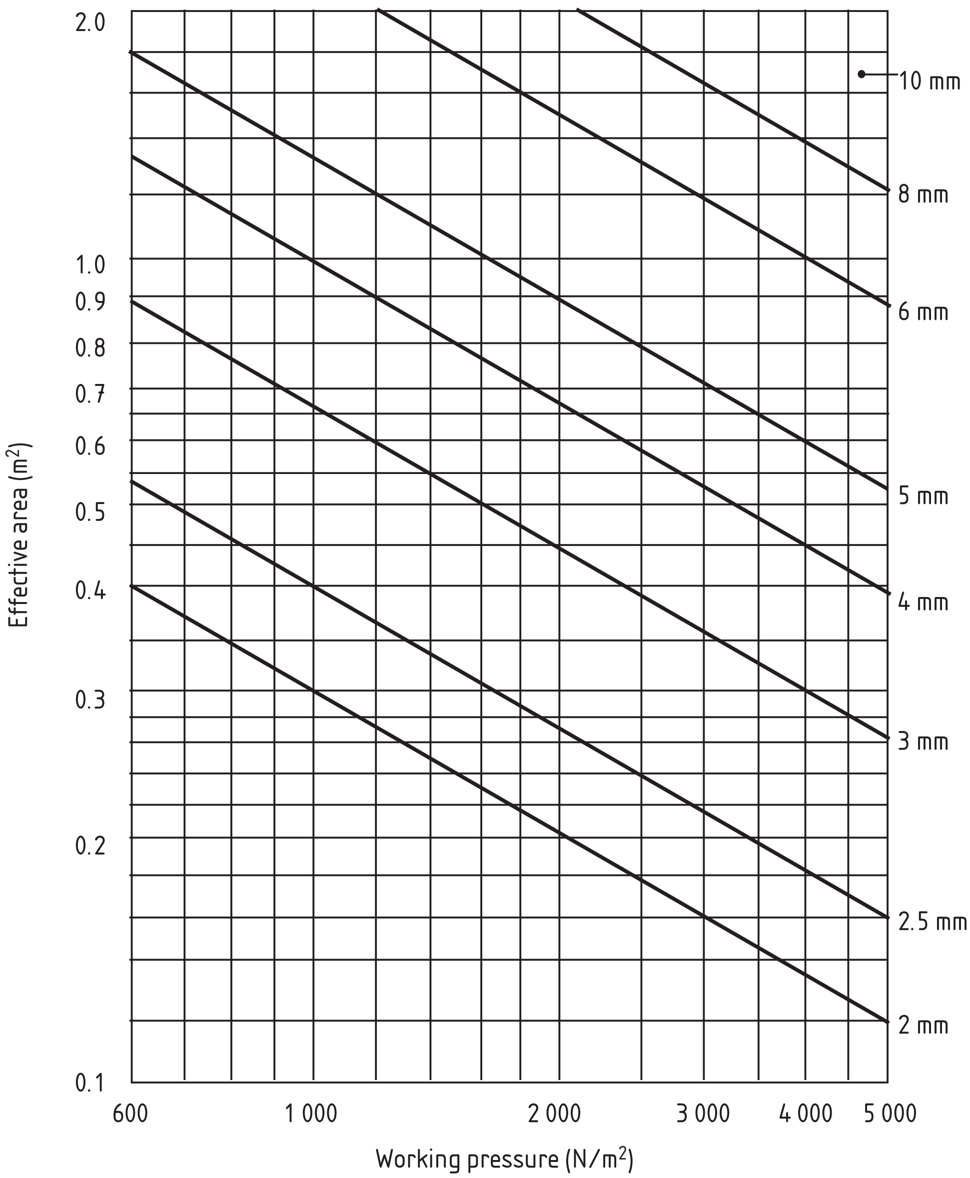
a) Two edge supported plastics glazing sheet materials, 15 mm edge cover

Figure 5 — Working pressure graph for solid plastics glazing sheet materials



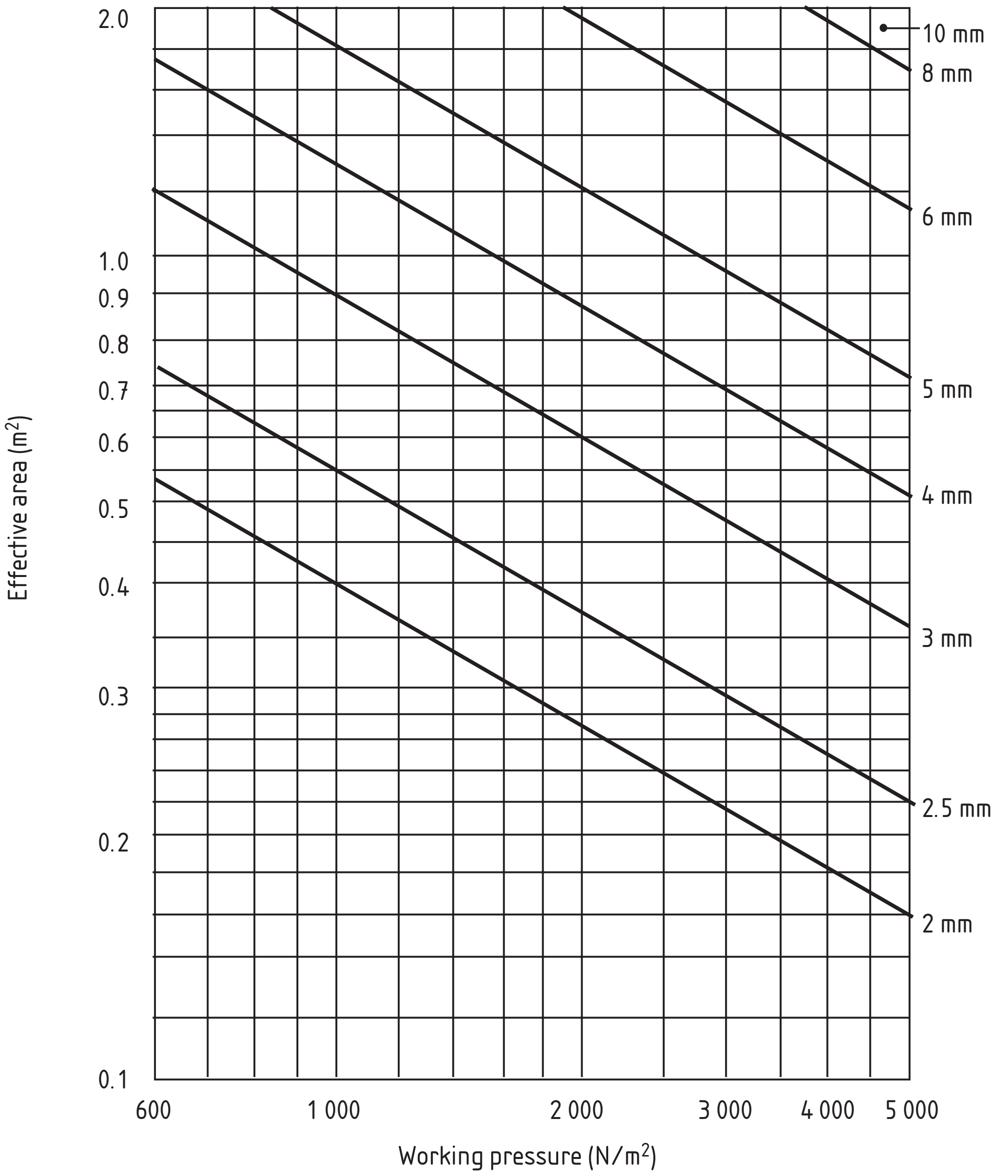
b) Four edge supported plastics glazing sheet materials, 15 mm edge cover, aspect ratio 1.0 to 1.5

Figure 5 — Working pressure graph for solid plastics glazing sheet materials (*continued*)



c) Four edge supported plastics glazing sheet materials, 15 mm edge cover, aspect ratio greater than 1.5 up to and including 2.5

Figure 5 — Working pressure graph for solid plastics glazing sheet materials (*continued*)



d) Four edge supported plastics glazing sheet materials, 15 mm edge cover, aspect ratio greater than 2.5 up to and including 3.5

Figure 5 — Working pressure graph for solid plastics glazing sheet materials (*continued*)

7.6 Limiting deflections of glazing bars

7.6.1 *Out-of-plane deflections*

7.6.1.1 *General*

For glazing bars carrying glass and other similar infill material, the maximum allowable deflection normal to the plane of the glazing is often determined by considerations of appearance as well as to ensure the glazing bars give adequate support to the glazing. To restrict stresses in the infill material, the following deflection limits (in millimetres), determined from the glazing bar span, S (in metres), should not be exceeded.

7.6.1.2 *Two-edge systems*

For single glazing and for coupled glazing:

$$d_{all} = \frac{S^2}{180} \times 10^3$$

or

$$d_{all} = 50$$

whichever is the less

where

d_{all} is the deflection.

For insulating glass units:

$$d_{all} = \frac{S^2}{540} \times 10^3$$

or

$$d_{all} = 20$$

whichever is the less.

7.6.1.3 *Four-edge systems*

For single glazing and coupled glazing when the span is less than or equal to three metres:

$$d_{all} = \frac{S}{125} \times 10^3$$

For single glazing and coupled glazing when the span is greater than three metres:

where

d_{all} is the deflection.

For insulating glass units:

$$d_{all} = \frac{S}{250} \times 10^3 + 12$$

or

$$d_{all} = 40$$

whichever is the less.

For insulating glass units:

$$d_{all} = \frac{S}{175} \times 10^3$$

or

$$d_{all} = 20$$

whichever is the less.

7.6.1.4 *Point supported systems*

The deflection of any support point relative to the adjacent support points on any individual pane or insulating glass unit should not be more than:

$$d_{all} = \frac{L}{200}$$

or

$$d_{all} = 20$$

whichever is the less.

where

L is the unsupported span between the support point being assessed and the nearest support point.

When designing to these maximum values, account should be taken of the magnitude of deflection under sustained loading and of the possible effect on adjacent materials and finishes. If lower deflection limits are required, these should be specified and the necessary information should be provided at the design stage.

7.6.2 *In-plane deflections*

Maximum recoverable deflection in the plane of the glazing of a transverse transom when carrying its full design load should not be such as to reduce design edge clearance between that member and the edge of the glazing or any other part immediately below it by more than 25 % and generally should not exceed 1/400 of the span of the member or three millimetres whichever is the less.

8 Safety

8.1 General

The risk of human injury arising from fracture and/or penetration of the glazing should be considered. Hazard categories might be limited to areas of sloping glazing from which people might be at risk in the course of the normal use of the building. An appropriate risk assessment should be made, taking into account the likely hazards and consequences.

Consideration should be given to the type of glazing for use in the following six areas of hazard which might be associated with sloping glazing:

— *roof or canopy glazing*, where there is normal access to areas below the glazing;

— *low level glazing*, where the glazing might be subject to accidental human impact;

— *bathing areas*, where the glazing is adjacent to or surrounding private or public swimming pools;

— *special risk areas*, where the planned activity generates a special risk;

— *inwardly sloping glazing*, where the glazing might be subjected to inadvertent head impact;

— *barriers which provide guarding*, where there is a difference in level as defined in BS 6180.

Glazing of a suitable type, thickness and size should be selected to provide an appropriate degree of human safety, taking into account the intended use of the building. In addition the following criteria should be taken into account: loading, i.e. wind, snow, maintenance, self-weight and any other imposed loads, (see Clause **7**) and fire (see Clause **9**).

The recommendations in **8.3** are based on the following main criteria.

a) The characteristics of the glazing under human impact and the mode of fracture.

Depending on the location, the glazing should have one of the following properties:

— *no break*, the glazing remains undamaged and serviceable;

— *break safe*, fracture of the glazing gives either relatively harmless pieces or insufficient penetration to allow serious injury.

These characteristics should be determined for single panes of glazing or for the individual panes of insulating glass unit, by testing by the methods given in BS 6206.

When it is required that the glazing, on impact, should remain in position and be unbroken/unpenetrated the manufacturer should be consulted.

b) The building and its use.

The number and likely behaviour pattern of the people expected to be in close proximity to the glazing is particularly important.

8.2 Fracture characteristics of glazing

8.2.1 *General*

The energy required to cause fracture and penetration varies with the type, thickness and composition of the glazing.

The behaviour of glass and plastics glazing sheet materials under impact and their fracture characteristics are given in **8.2.2** and **8.2.3**.

8.2.2 *Glass*

8.2.2.1 *Annealed glass (e.g. float glass, patterned glass)*

If annealed glass is broken and penetrated the resulting glass edges will be sharp.

8.2.2.2 *Wired glass*

If wired glass is broken after impact, it will be held together by the wires and penetration is unlikely except under impacts that break the wires. If penetrated, the characteristics of the edges are similar to those of annealed glass. Safety wired glass is capable of obtaining Class C to BS 6206.

8.2.2.3 *Laminated glass*

The fracture characteristics of laminated glass will be similar to those of its component glasses, but the pieces will remain substantially adhered to the plastics interlayer. The glass, when containing an interlayer of 0.38 mm polyvinylbutyral (PVB), is normally capable of obtaining Class B to BS 6206. Much greater penetration resistance may be given with thicker interlayers. For the impact safety performance of laminated glass with other interlayer materials, the manufacturer should be consulted.

8.2.2.4 *Filmed annealed glass*

Annealed glass covered with a film of organic materials intended to hold the glass together after breakage will, when broken, be difficult to penetrate providing the film is applied over the whole of one surface of the glass in accordance with the manufacturer's recommendations. For the impact safety performance of filmed glass, the manufacturer of the film should be consulted.

8.2.2.5 *Toughened glass*

Thermally toughened soda lime silicate glass is difficult to penetrate but, if broken, it fragments into small, relatively harmless pieces. Correctly toughened glass is normally capable of obtaining Class A to BS 6206. When broken, the fragments of toughened glass have no significant residual strength and can fall out. This is particularly likely in sloping applications.

8.2.2.6 *Heat soaked toughened glass*

Heat soaked thermally toughened soda lime silicate glass conforming to prEN 14179 has the same breakage characteristics as toughened glass (see **8.2.2.5**), but has a much lower risk of fracture from nickel sulfide inclusions.

8.2.2.7 *Heat strengthened glass*

Heat strengthened glass is stronger than annealed glass, but if it is broken and penetrated, the resulting glass edges will be sharp.

8.2.3 *Plastics glazing sheet materials*

8.2.3.1 *Polycarbonate:*

Polycarbonate is virtually impossible to break. In extreme and exceptional cases, panes can be dislodged from glazing bars, but fracture should not occur.

8.2.3.2 *Polyvinyl chloride*

If polyvinyl chloride is broken after impact, penetration is unlikely, except under extreme impact conditions when some pieces can be dislodged.

8.2.3.3 *Acrylic*

Acrylic will exhibit similar characteristics to polyvinyl chloride, but at lower impact levels.

8.2.3.4 *GRP*

GRP is difficult to break and tends to break in a pseudo ductile manner into pieces which do not generally have sharp cutting edges. Penetration is unlikely, except under extreme impact conditions when some pieces can be dislodged.

8.3 Risk areas

8.3.1 *General*

Not every accident is avoidable, but injuries can be due to failure to provide adequate protection at vulnerable points. A reasonable standard of human behaviour for appropriate age groups is assumed. In most buildings, glazing not in areas defined in **8.3.2**, **8.3.3**, **8.3.4** and **8.3.5** does not usually give significant risk.

8.3.2 *Roof or canopy glazing*

The risk of injury from glazing in roofs or canopies should be considered under three categories:

a) risk of injuries sustained from broken glazing falling;

b) risk of injuries sustained from objects falling through the glazing;

c) risk of falling through the glazing while standing on it.

Category b) is not considered here as there is no single method for designing against such loads, and specialist advice should be sought. Category c) is dealt with in Part 3 of this standard.

The risk of injury from falling fragments of glazing can be reduced by the following methods:

— using glazing that is very unlikely to fracture under any circumstances, e.g. plastics glazing sheet materials;

— using glazing that is likely to remain in position even if fractured, e.g. wired glass, laminated glass or plastics glazing sheet materials;

— using glazing that shatters into relatively harmless fragments after fracture, e.g. toughened glass, and limiting the height or quantity of falling material or both.

NOTE The risk of fracture of toughened glass due to nickel sulfide inclusions may be reduced by specifying heat soaked toughened glass to prEN 14179.

Recommendations for the types of glass suitable for use in roof or canopy glazing in or around non-agricultural buildings are as follows.

a) *Glazing at a height up to five metres above floor level* (this covers single storey buildings, conservatories, etc.):

1) *single glazing*: This should be toughened glass, heat soaked toughened glass, laminated glass, or wired glass;

2) *insulating glass units*: The lower pane should be one of the types of glass given in a). If the lower pane is toughened glass or heat soaked toughened glass, then the upper pane should also be one of the types of glass given in 1);

b) *Glazing at a height over 5 m and up to 13 m above floor level (this covers intermediate height atria, larger conservatories, etc.)*:

1) *single glazing*: This should be laminated glass or wired glass. Alternatively, heat soaked toughened glass or toughened glass, provided it is not more than six millimetres thick and not more than 3 m2 in area, may be considered;

2) *insulating glass units*: The lower pane should be one of the types of glass given in 1) including the size and area restriction on heat soaked toughened glass and toughened glass. If the lower pane is toughened glass or heat soaked toughened glass, then the upper pane should also be one of the types of glass given in 1);

c) *glazing at a height over 13 m above floor level*:

1) *single glazing*: This should be laminated glass or wired glass;

2) *insulating glass units*: The lower pane should be one of the types of glass given in 1).

8.3.3 ***Low level glazing***

The glazing should conform to the requirements of BS 6262-4.

8.3.4 ***Bathing areas***

Any glazing likely to be subjected to accidental human impact should conform to the requirements of BS 6262-4.

Attention is specifically drawn to swimming pools, where small particles of broken glazing falling into water can be difficult to locate and remove.

8.3.5 ***Areas of special risk***

The glazing should conform to the requirements of BS 6262-4.

8.3.6 ***Inwardly sloping glazing***

Where sloping glazing is used with glazing less than 2.1 m above the floor level and where the glazing also slopes towards that area of floor, there is a risk of inadvertent impact on the glazing from the head of persons using that area of the floor.

In such locations, for those areas which are wholly or partially between a height of 800 mm and 2.1 m above floor level, glazing conforming to BS 6206 class C or better should be used.

Consideration should be given to manifestation of the glass in these areas or to provision of barriers to restrict access.

8.3.7 ***Barriers which provide guarding***

Where sloping glazing separates a significant difference in levels, as defined in BS 6180, either:

— the glazing should be protected by a barrier designed in accordance with BS 6180; or

— the glazing should be designed in accordance with BS 6180.

9 Fire

9.1 Regulations and test standards

Structural fire precautions, in which the performance of glass and plastics might need to be considered, are controlled by Building Regulations and bylaws for new building work and by other fire safety legislation for occupied premises.

For new buildings, control is exercised separately in England (excluding Inner London) and Wales, Inner London, Scotland and Northern Ireland. The extent of control depends on the type of glass or plastics glazing sheet material and the method of specification, the particular location and the regulations applicable thereto.

In determining the appropriate fire properties of glazing, the tests given in Table 1 apply. Both European Standards and British Standards are accepted, but these should not be mixed and matched.

Generally, regulations are written in terms of performance under the standard fire tests but BS 5588 and other codes of practice dealing with means of escape in case of fire make specific mention in connection with the use of glass when fire resistance is required.

Table 1 — British and European Standards

British Standards	European Standards
Tests for roofing materials	
BS 476-3:1958. This test determines whether the roofing material is susceptible to burning brands and radiation from adjacent burning buildings that will burn through or melt the roof material. NOTE Although the 1958 version is obsolete and Part 3 has been revised several times since 1958, the revised versions cannot be used to test glass, so both the Building Regulations and this standard still refer to the 1958 version for classification of glass in roofs.	There is no direct equivalent to this standard in the set of European Standards. NOTE DD ENV 1187 currently has three alternative test methods, none of which are equivalent to BS 476-3. However, a fourth test is being included for UK purposes.
Reaction to fire	
BS 476-4:1970. This test determines whether building materials are non-combustible within the meaning of the definition. Determination of combustibility is made by reference to the duration of any flaming or the increase in the temperature of the sample or furnace above a defined limit. *BS 476-6:1989*. The tests provide a means of comparing the contribution of building materials to the growth of a fire by measuring the rate of heat evolution. The performance is expressed as a numerical index from 0 to 100 or more, low values indicating a low rate of heat release. *BS 476-7:1987*. The tests are used to determine the tendency of materials to support the spread of flames across their surfaces and specifies a method of classification. The performances are expressed as four classes, class 1 representing the best performance. NOTE For Class 0, Tp(a) and Tp(b), see the appropriate building regulations.	According to European Commission Decision 96/603/EC (consolidated 2003/424/EC), glass, including heat strengthened, chemically toughened, laminated and wired glass, has been classified as reaction to fire Classes A1 and $A1_{FL}$ as provided for in European Commission Decision 2000/147/EC without the need for testing. For plastics glazing sheet materials, reaction to fire is determined and classified in accordance with *BS EN 13501* based on the results of the following tests. *BS EN ISO 1182* to test for combustibility. *BS EN ISO 1716* to test for contribution to the growth of fire. *BS EN 13823*, *BS EN ISO 11925-2* and BS *EN ISO 9239-1* to test for surface spread of flame.
Fire resistance	
BS 476-20:1987 and *BS 476-22:1987*. These tests determine whether elements of construction retain their integrity against the passage of hot gases and provide, where necessary, resistance to heat transmission and heat radiation. Performances are expressed in minutes to failure by appropriate criteria.	*BS EN 1363*, *BS EN 1364* and *BS EN 1634*. These tests determine whether elements of construction retain their integrity against the passage of hot gases and provide, where necessary, resistance to heat transmission and heat radiation. Performances are expressed in minutes to failure by appropriate criteria.

9.2 Information

Glass and plastics glazing sheet materials in sloping glazing may need to satisfy requirements for:

a) external fire exposure; and

b) surface spread of flame over room linings; and

c) the fire performance of external cladding; and

d) external fire spread, including cladding and unprotected areas.

NOTE The information in the rest of Clause **9** relates to fire performance of glass in relation to BS 476, since there is insufficient information to generalise performance in relation to the new European Standards.

Where glass is incorporated within elements of escape routes, etc., the glazed installation should satisfy the necessary period of fire resistance in terms of the criteria in BS 476-22.

The ability of elements to conform to fire resistance requirements will depend on the type of material, its thickness, size, height to width ratio of pane, glazing slope, type of frame, method of fixing, the form of the construction surrounding the glazed area, and whether or not the element consists of a single pane.

Only certain types of glazed installations are able to satisfy fire resistance requirements specified in terms of BS 476-22. Periods up to two hours are obtainable for integrity and insulation, or integrity only, depending on the glazed elements and the frame design, but most of the test results are for vertical glazing. Information on sloping glazing is limited and the manufacturers should be consulted. No restrictions are made on the use of glazed systems meeting the full fire resistance performance in terms of both integrity and insulation, but those systems not providing adequate insulation might be limited under BS 5588 and Building Regulations dealing with compartmentation, the protection of escape routes, etc.

Reference to Clause **8** should be made when impact safety requirements need to be taken into account in addition to fire resistance.

Information on the fire performance of glass and plastics and on glazed systems (e.g. fire-resisting doors and partitions) should be obtained from the manufacturers of the material, component or system.

9.3 Glass

9.3.1 *Reaction to fire*

Monolithic glass is not combustible and will generate no heat and make no contribution to the spread of a fire. On the other hand, it is thin and transparent and heat from a fire can quickly transmit through it, either by radiation or conduction.

Laminated glass can contain plastics materials which in themselves are combustible. Being a relatively small proportion of the product and being encapsulated by the glass, these plastics do not produce significant amounts of heat, so laminated glass also makes no contribution to the spread of fire.

Soda lime silicate glass is classified as non-combustible when tested according to BS 476-4. Laminated products in which the outer layers comprise soda lime silicate glass will have non-combustible exposed surfaces, and as such should be acceptable in any wall lining.

The fire performance properties of various types of glass are given in Table 2.

9.3.2 *Fire resistance*

9.3.2.1 *Annealed glass (e.g. float glass, patterned glass)*

Annealed glass will crack and tend to fall from its frame. In very small panes, the cracked pieces can remain in position, depending on the framing system and glazing method, and provide limited integrity only.

9.3.2.2 *Wired glass*

Wired glass will crack, but the presence of the wires tends to hold it together. Depending on the framing system and glazing method, wired glass can give considerable periods of integrity only.

9.3.2.3 *Laminated glass*

The individual panes of laminated glass will behave in the same way as described elsewhere in this clause.

If the interlayer material is plastics not specifically designed for fire resistance, it will quickly break down and make no effective contribution to fire resistance.

If the interlayer is specially formulated to contribute towards fire resistance, the laminated glass, depending on the framing system and glazing method, can give considerable periods of integrity and insulation.

9.3.2.4 *Toughened glass and heat soaked toughened glass*

Thermally toughened soda lime silicate glass is very resistant to thermal breakage, but cannot normally be expected to survive fire conditions. It will break and fall from its frame. Modified toughened glass (highly toughened soda lime silicate glass with specially treated edges glazed in specially designed glazing systems) can give considerable periods of integrity only.

Thermally toughened borosilicate glass is extremely resistant to thermal breakage and, depending on the framing system and glazing method, can give considerable periods of integrity only.

9.3.2.5 *Heat strengthened glass*

Heat strengthened soda lime silicate glass will perform in the same way as annealed glass.

Heat strengthened borosilicate glass is extremely resistant to thermal breakage and, depending on the framing system and glazing method, can give considerable periods of integrity only.

Only certain types of glazed installations have performed adequately under BS 476-22: 1987 test conditions or have been permitted under deemed-to-satisfy provisions in codes of practice and bye-laws.

Table 3 and Table 4 indicate the potential fire resistance of some types of glass, assuming they are glazed in an appropriate manner. However, the information given in these tables should be used with caution when considering sloping glazing. Most fire tests on glazing are performed in the vertical position. Since glass tends to soften with heat and is subject to more adverse gravitational forces when used in sloping situations, most products perform less well, if at all, in sloping glazing. The manufacturers should be consulted.

9.4 Plastics glazing sheet materials

Table 5 gives a brief summary of the fire performance of plastics glazing sheet materials. Manufacturers should be consulted regarding the detailed performance of specific products.

Where regulations and requirements specify materials used for glazing in terms of their fire resistance performance careful note should be taken of the following points when using plastics glazing sheet materials.

a) Different plastics glazing sheet materials can have different properties. The basic types of plastics glazing materials (see **5.2** and Annex A) can have surface spread of flame classifications under BS 476-7:1987.

b) Some regulations have specific and arbitrary systems of classification of thermoplastics materials that might not relate with the classifications given in **5.2**. Under these circumstances the mandatory (i.e. legislative) requirements should be carefully followed.

c) Where regulations have as part of their requirements reference to BS 476-4:1970 for non-combustibility (and Part 22 for fire resistance), it should be noted that thermoplastics glazing sheet materials do not meet this requirement.

It is essential that fire test information be obtained from manufacturers of plastics glazing sheet materials in a form and type compatible with and mandatory regulations for these materials.

Where plastics glazing sheet materials are specified because of other design parameters described in this standard, authorization for its use might require waivers or relaxations in respect of fire performance.

Table 2 — Fire properties of glass (excluding fire resistance[a])

Type	External fire exposure[b] (BS 476-3:1958)	Non-combustibility (BS 476-4:1984)	Fire propagation index (BS 476-6:1989)	Surface spread of flame (see Note 1) (BS 476-7:1987)
Annealed (non-wired)	AA	Non-combustible (see Note 2)	$I < 12$ and $i_1 < 6$	Class 1
Wired	AA	Non-combustible (see Note 2)	$I < 12$ and $i_1 < 6$	Class 1
Toughened	AA	Non-combustible (see Note 2)	$I < 12$ and $i_1 < 6$	Class 1
Laminated				
a) PVB (polyvinylbutyral) interlayer	AA	Combustible	$I < 12$ and $i_1 < 6$ (see Note 2)	Class 1 (see Note 2)
b) intumescent interlayer	AA	Non-combustible (see Note 2)	$I < 12$ and $i_1 < 6$	Class 1
c) Gel interlayer	AA	Non-combustible (see Note 2)	$I < 12$ and $i_1 < 6$	Class 1
d) Resin interlayer	See Note 3	See Note 3	See Note 3	See Note 3
Borosilicate	AA	Non-combustible (see Note 2)	$I < 12$ and $i_1 < 6$	Class 1
Glass blocks	AA	Non-combustible	$I < 12$ and $i_1 < 6$	Class 1

NOTE 1 The performance might be different where adhesive films have been applied.

NOTE 2 That is to say, it satisfies the requirements for class 0 combustible materials.

NOTE 3 The performance of laminated glass constructed with resin interlayers has not been tested.

[a] See Table 3 and Table 4.
[b] Thickness: 4 mm nominal or thicker.

Table 3 — Fire properties of *integrity only* glass when tested in accordance with BS 476-22:1987 and glazed in suitably designed systems

Type	Nominal thickness mm	Type of system[a]	Comments	Test results[b] Integrity only
Annealed (non-wired)	6	Small panes for Copper light panels		30 min
Wired	6 and 7	Timber or steel frames, single or multiple panes		up to 2 h
Modified Toughened	5 to 12	Special glazing systems[c]	This should not be confused with normal toughened glass	up to 1 h
Laminated	7 to 13	Timber or steel frames, single or multiple panes		up to 1 h
Borosilicate	6	Steel frames, single or multiple panes	Glass with a low coefficient of expansion	up to 2 h
Ceramic	5 to 10	Steel frames, single or multiple panes	Glass with a zero coefficient of expansion	up to 2 h
Glass Blocks	80			up to 1 h

[a] The detailing of the glazing system and its fixture to the building structure plays a critical part of the fire performance of glazed walls. Glazing systems which have test-proven fire resistance with appropriate glass types should be used. The manufacturer's recommendations should be followed.
[b] This table is based on publicly available data. The levels of performance given do not represent the maximum that can be achieved, but indicate levels of performance which have been achieved using specific glazing systems and which can be substantiated with test evidence from either the glass or frame manufacturer.
[c] The edge cover can affect the fire resistance.

Table 4 — Fire properties of *insulated* glass when tested in accordance with BS 476-22:1987 and glazed in suitably designed systems

Type	Nominal product thickness mm	Type of system[a]	Comments	Test results[b] Integrity and Insulation
Intumescent interlayer	12 to 50	Timber or steel frames, single or multiple panes		up to 2 h
Gel interlayer	22 to 74	Steel frames, single or multiple panes		up to 90 min

[a] The detailing of the glazing system and its fixture to the building structure plays a critical part of the fire performance of glazed walls. Glazing systems which have test-proven fire resistance with appropriate glass types should be used. The manufacturer's recommendations should be followed.
[b] This table is based on publicly available data. The levels of performance given do not represent the maximum that can be achieved, but indicate levels of performance which have been achieved using specific glazing systems and which can be substantiated with test evidence from either the glass or frame manufacturer.

Table 5 — Fire properties of plastics glazing sheet materials

Type	BS 476-6	BS 476-7	Class O[a]	TP(a)[a]	TP(b)[a]
Solid sheet					
Polycarbonate	Some forms, with satisfactory results	Most class 1	Some forms	⩾3 mm[b]	N/A
PVC-U	Some forms, with satisfactory results	Most class 1	Some forms	All	All
Acrylic	—	Class 3	—	N/A	All
Hollow section sheet					
Polycarbonate	Some forms, with satisfactory results	Some forms, class 1	Some forms	Some forms, if they meet Class 1 to BS 476-7	All
PVC-U	—	Some forms, class 1	—	Some forms, if they meet Class 1 to BS 476-7	All
Acrylic	—	—	—	—	All

NOTE Some plastics glazing sheet materials have been classified to BS 476-3:1958, including certain forms as AA rated.

[a] See Building Regulations England & Wales, Approved Document B.
[b] For smaller thicknesses, consult the manufacturer.

10 Light

10.1 Daylighting

Daylighting prediction for interior spaces is usually based on the "daylight factor" concept. The daylight factor is the ratio, expressed as a percentage, between the illuminance at a point in the building compared with the illuminance that would occur at that point if the building (walls and roof) and any other shading was removed.

Sloping glazing will admit more daylight to the interior than vertical glazing. Care should be taken that sloping glazing does not become a source of glare. Glare results from excessive contrast of illumination, or from an excess of illumination in the field of view. Reaction to it is subjective. When correctly designed, natural lighting does not usually give a glare problem. Overhead glazing is one of the better positions for glazing to ameliorate potential glare problems.

Glare can be reduced by some form of mechanical shading, e.g. an external louvre system or internal louvres or blinds. It might also be possible at the design stage to orientate the glazing to avoid entry of direct solar radiation, e.g. as north lights. Alternatively, the interior layout might be suitably designed to eliminate glare.

Integration of daylight and artificial light is important to the energy efficiency of buildings and should be considered carefully. Glazed areas should not be used excessively, as this can give rise to solar overheating (see Clause **11**).

Further information on the subject of daylighting and on the calculation of daylight factors can be found in BS 8206-2.

10.2 Light transmission properties of glazing

Light transmission is defined as the fraction of visible light at normal incidence transmitted through the glazing. Typical light transmission properties of glass are given in Table 6, Table 7 and Table 8. For plastics glazing sheet materials, the manufacturer should be consulted.

Glazing with light transmission lower than 50 % can ameliorate discomfort glare. These products decrease the sky luminance components but permanently reduce the admission of daylight. Alternatively, shading devices, internal or external, movable or fixed, can be used.

10.3 Diffusion and obscuration

The nature of some glazing products (for example patterned or acid etched glass) can cause the direct incident solar beam to be scattered diffusely. Hence the glazing can assume an uncomfortably high brightness and become a discomfort glare source in its own right. Diffusing glazing used within the normal field of view should be used with caution.

10.4 Fading

Most materials can fade when subjected to either daylight (particularly direct sunlight) or artificial light. Fading is a complex phenomenon, involving many chemical reactions, initiated or accelerated by light of different wavelengths. Generally, the better quality dyes and pigments fade relatively slowly and react only to the shorter wavelengths (ultraviolet and the blue end of the visible spectrum). Other materials can fade quickly and can do so under light of much longer wavelengths. It is the combination of wavelength, available light and transmission which determines glass selection to minimize fading, not simply the UV transmission.

In order to minimize fading the following precautions should be taken.

— Overall levels of illumination, both daylight and artificial should be reduced and in particular direct sunlight should be avoided. Shading (curtains or blinds) should be used and the glazing, artificial lighting and orientation controlled.

— The time for which the object is exposed to the light should be reduced. Halving the time of exposure has the same effect as halving the light intensity.

— The temperature should be reduced. All changes involved in fading proceed more rapidly at higher temperatures.

— Transmission of the UV and blue end of the spectrum should be reduced by fitting appropriate glazing and artificial light sources.

Significant reduction in UV transmission can be achieved by using plastics glazing sheet materials or an appropriate interlayer in the construction of laminated glass. Reflective and tinted solar control glass can also aid in reducing fading. The manufacturer should be consulted on appropriate values of UV transmittance of the various types of glass or plastics glazing sheet materials.

11 Energy

11.1 General

The role of sloping glazing with respect to energy is viewed in several ways:

— thermal comfort (see **11.2**);

— solar energy gain (see **11.3**);

— energy loss (see **11.4**);

— condensation (see **11.5**);

— energy balance (see **11.6**);

— thermal stress (see **11.7**);

— thermal movement (see **11.8**).

11.2 Thermal comfort

Energy transmission through glazing can significantly influence occupier comfort by raising or lowering room air temperatures. For example, hot sunny weather can give rise to excessive heat gains; and heat losses can occur through the glazing during cold weather, or at night. Thermal comfort can also be influenced by direct radiation through the glazing and/or by radiation exchange between the glazing and the occupants.

11.3 Solar energy gain

11.3.1 *General*

Factors that can influence the amount of solar gain through the glazing include:

a) slope and direction;

b) glazed area;

c) shading devices, both internal and external;

d) properties of the glazing.

11.3.2 *Total solar energy transmittance*

Total solar energy transmittance is the proportion of solar radiation at normal incidence transferred through the glazing. It is composed of the direct transmittance, (short wave component) and the part of the solar absorptance dissipated inwards by long wave radiation and convection (long wave component).

NOTE Total solar energy transmittance may also be referred to as “g value” or “solar factor”.

The total solar energy transmission properties of solar control glazing can be described by its shading coefficient. The shading coefficient is derived by comparing the properties of the solar control glazing with a clear float glass having a total solar energy transmittance of 0.87 (i.e. equivalent to a clear glass between three millimetres and four millimetres thick).

11.3.3 *Solar control glass*

11.3.3.1 *General*

Solar control glass can be manufactured in several forms (see **11.3.3.2**, **11.3.3.3**, **11.3.3.4** and **11.3.3.5**). The function of solar control glass is to reduce the total solar energy transmittance, which usually leads to a decrease in the transmission of the visible part of the solar spectrum. However some tints and coatings are able to preferentially attenuate non-visible solar radiation, leaving the transmission of the greater proportion of the visible radiation largely unchanged.

The relationship between light transmission and total solar energy transmission is referred to as the light/energy ratio. Some manufacturers use this as a descriptive code, quoting a light transmission figure followed by a total solar energy transmission figure.

NOTE The performance of typical glass products showing the relationship between light transmission and total solar energy transmission is illustrated in Figure 6 (the shaded area represents the envelope enclosing most practically available architectural glass products).

There is no optimum light/energy ratio. The selection of an appropriate product depends on the requirements of the building. Solar gain can be relatively high, for making use of passive solar gains, or low, to reduce air-conditioning loads. Light transmission will depend on the extent to which daylight is used to obviate artificial lighting.

11.3.3.2 *Body tinted glass (increased absorption)*

Solar control properties and colour vary with the thickness of the glass. When used in insulating glass units, body tinted glass should be positioned as the outer pane where the heat from the absorbed radiation is more easily dissipated to the outside.

Performances of a typical range of body tinted glass products are shown in Table 6, with the properties of clear float for comparison.

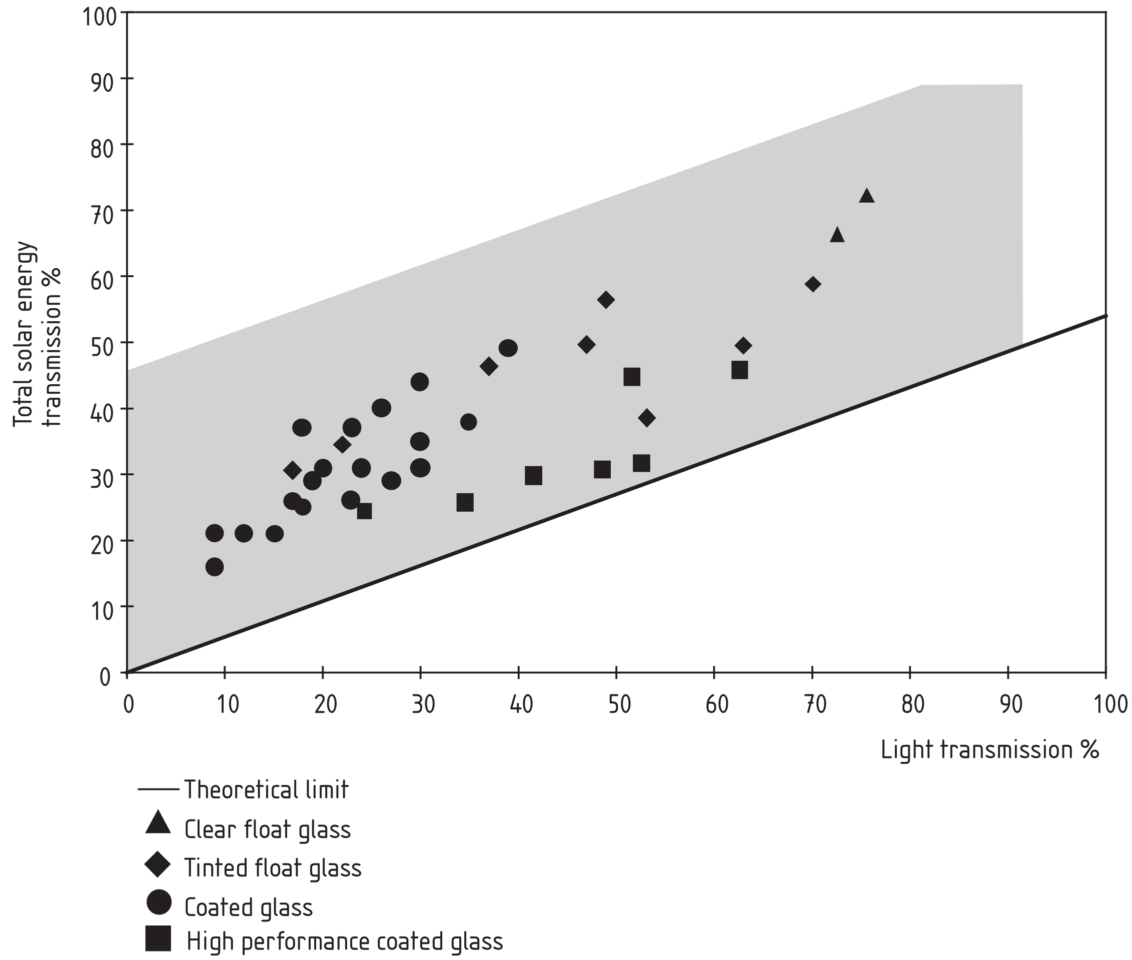


Figure 6 — Performance of different glass products showing relationship between light transmission and total solar energy transmission

11.3.3.3 *Reflective coated glass*

Reflective coated glass uses the principle of increasing the direct reflection to maximize solar energy attenuation. In comparison with clear glass its absorption of solar energy is also increased. The advantages of such glass types are:

a) greater performance range than body tinted glass;

b) higher performances (greater solar energy attenuation);

c) light/energy ratios nearer to the theoretical limit;

d) a range of colour appearances in transmission and reflection.

Performance data in comparison to clear glass are shown in Table 7.

The reflective coatings may be placed on to body-tinted glass to extend the range of performances.

11.3.3.4 *Screen printed glass*

The application of ceramic frit fired into the surface of the glass can also be used to modify the energy and light transmission of the glass. The effect can be varied across a pane depending on the screen print pattern. The manufacturers should be consulted for specific details.

Table 6 — Properties of a typical range of body-tinted glass products

Glass type and thickness	Light		Solar radiant energy				Shading coefficients		
	Transmittance	Reflectance	Direct transmittance	Reflectance	Absorptance	Total transmittance	Short wave	Long wave	Total
4 mm clear	0.89	0.08	0.82	0.07	0.11	0.85	0.94	0.04	0.98
6 mm clear	0.87	0.08	0.78	0.07	0.15	0.82	0.90	0.04	0.94
10 mm clear	0.84	0.07	0.70	0.07	0.23	0.76	0.80	0.07	0.87
4 mm green	0.78	0.07	0.58	0.05	0.37	0.68	0.67	0.11	0.78
6 mm green	0.72	0.06	0.46	0.05	0.49	0.59	0.53	0.14	0.67
10 mm green	0.61	0.06	0.29	0.04	0.67	0.46	0.33	0.20	0.53
6 mm blue	0.54	0.05	0.46	0.05	0.49	0.59	0.53	0.14	0.67
4 mm bronze	0.61	0.06	0.58	0.05	0.37	0.68	0.67	0.11	0.78
6 mm bronze	0.50	0.05	0.46	0.05	0.49	0.59	0.53	0.14	0.67
10 mm bronze	0.33	0.04	0.29	0.04	0.67	0.46	0.33	0.20	0.53
4 mm grey	0.55	0.05	0.55	0.05	0.40	0.65	0.63	0.12	0.75
6 mm grey	0.42	0.05	0.42	0.05	0.53	0.56	0.48	0.16	0.64
10 mm grey	0.25	0.04	0.25	0.04	0.71	0.43	0.29	0.21	0.50

Table 7 — Properties of a typical range of reflective coated glass products

Glass type and thickness	Light		Solar radiant energy				Shading coefficients		
	Transmittance	Reflectance	Direct transmittance	Reflectance	Absorptance	Total transmittance	Short wave	Long wave	Total
6 mm clear	0.87	0.08	0.78	0.07	0.15	0.82	0.90	0.04	0.94
6 mm silver	0.32	0.13	0.29	0.11	0.60	0.43	0.33	0.16	0.49
6 mm silver	0.20	0.23	0.16	0.18	0.66	0.31	0.18	0.17	0.35
6 mm silver	0.10	0.38	0.08	0.32	0.60	0.20	0.09	0.14	0.23
6 mm blue	0.40	0.10	0.32	0.10	0.58	0.46	0.37	0.16	0.53
6 mm blue	0.30	0.16	0.21	0.18	0.61	0.35	0.24	0.17	0.41
6 mm blue	0.20	0.20	0.15	0.21	0.64	0.29	0.17	0.17	0.34
6 mm bronze	0.26	0.17	0.20	0.14	0.66	0.35	0.23	0.18	0.41
6 mm bronze	0.10	0.19	0.06	0.21	0.73	0.21	0.07	0.17	0.24
6 mm grey	0.32	0.12	0.21	0.10	0.69	0.44	0.33	0.18	0.51

NOTE Compared with a float glass surface, these reflecting coatings (owing to their composition) exhibit lower levels of emissivity which improves their U value. See **11.4.1**.

11.3.3.5 *Laminated glass*

Laminated glass is commonly constructed with clear glass and clear interlayers, but solar control properties can be incorporated into laminated glass by including either solar control glass or tinted interlayers or both.

Laminated glass with clear interlayers and solar control glass exhibits similar properties to the solar control glass from which it is made.

Laminated glass with a tinted interlayer acts in a similar manner to body tinted glass, by absorbing the solar radiation, but with a different range of colours and performances.

Performances of a typical range of laminated glass products with clear glass and tinted interlayers are shown in Table 8, with the properties of clear laminated glass for comparison.

11.3.4 ***Solar control plastics glazing sheet materials***

Various coloured plastics glazing sheet materials are available that reduce the transmission of solar radiation. The manufacturers should be consulted for specific details.

11.3.5 ***Blinds and louvres***

The use of blinds or louvres in glazing affects the glazing shading coefficient. This depends upon the solar optical properties of the glazing and the material of the blind, on the coefficients of heat transfer at the glazing surfaces, on the geometry and location of the blind, and the angular position of the sun. The manufacturer should be consulted for specific advice.

11.4 Energy loss

11.4.1 ***General***

Energy loss is quantified by the thermal transmittance or U value ($W/m^2 \cdot K$). For a full definition of thermal transmittance and its method of calculation, reference should be made to BS EN 673. Glass and thin plastics glazing sheet materials readily conduct heat and so are poor insulators. To improve resistance to energy loss, insulating glass units or coupled glazing should be used, since the air cavities provide extra thermal resistance.

Increasing the thickness of the glass or plastics glazing sheet material makes little or no difference to the U value of the glazing.

11.4.2 ***Methods for improving thermal insulation***

11.4.2.1 *Use of low emissivity coatings*

Low emissivity (low-E) coatings have surface emissivities of less than 0.2 (see BS 952-1:1995). The use of such a coating on glass improves the thermal insulation. They are most efficient when used on the cavity surfaces of insulating glass units.

11.4.2.2 *Increasing the width of the cavity*

Enhanced thermal insulation can be achieved by increasing the width of the airspace. However, there is a practical upper limit of about 16 mm. Above this width no extra thermal benefit is obtained due to convection within the cavity.

NOTE The 16 mm optimum cavity width applies to air or argon filled cavities. For denser gases such as xenon or krypton, the optimum cavity width is lower.

11.4.2.3 *Using gases of lower thermal conductivity*

Replacing the air in the cavity with argon, krypton or xenon can improve the thermal insulation.

11.4.2.4 *Inhibiting convection within the air space*

Filling the cavity with cellular material reduces convection and makes the cavity a more efficient insulator. However, this usually results in loss of vision, since the materials are, at best, translucent.

11.4.2.5 *Evacuation of the air space*

In theory, a vacuum will eliminate energy transfer by conduction and convection. However, a vacuum puts high demands on the glass from the external air pressure.

NOTE Evacuation of the air space is currently considered to be technically impractical.

Table 8 — Properties of a typical range of reflective coated glass products

Laminated glass colour and thickness	Light		Solar radiant energy				Shading coefficients		
	Transmittance	Reflectance	Direct transmittance	Reflectance	Absorptance	Total transmittance	Short wave	Long wave	Total
6.4 mm clear	0.87	0.08	0.77	0.07	0.16	0.81	0.89	0.04	0.93
6.4 mm brown	0.28	0.04	0.32	0.04	0.64	0.49	0.37	0.19	0.56
6.4 mm bronze	0.52	0.05	0.54	0.05	0.41	0.65	0.62	0.12	0.74
6.4 mm grey	0.44	0.05	0.51	0.05	0.44	0.62	0.59	0.13	0.72
6.4 mm marine	0.60	0.06	0.63	0.06	0.31	0.71	0.72	0.10	0.82
6.4 mm blue-grey	0.37	0.05	0.43	0.05	0.52	0.56	0.49	0.16	0.65
6.4 mm blue-green	0.73	0.07	0.69	0.07	0.24	0.75	0.79	0.07	0.86
6.4 mm white translucent	0.57	0.05	0.54	0.05	0.41	0.65	0.62	0.12	0.74

11.4.3 *Typical U values of glass products*

Table 9 gives typical centre-pane U values.

Table 9 — Typical U values for glass

Pane or unit	Airspace width	U value W/m²·K		
	mm	Vertical	45° slope	Horizontal
4 mm	—	5.8	6.7	7.5
6 mm	—	5.7	6.6	7.4
10 mm	—	5.6	6.4	7.2
12 mm	—	5.5	6.3	7.1
4 mm + 4 mm	12	2.9	3.2	3.5
6 mm + 6 mm	12	2.8	3.1	3.5
10 mm + 6 mm	12	2.8	3.1	3.4
6 mm + 6 mm	6	3.2	3.5	3.7
6 mm + 6 mm	16	2.7	3.1	3.5
6 mm + 6 mm	20	2.7	3.1	3.4
6 mm + 6 mm	16 (argon fill)	2.6	2.9	3.2
4 mm + 4 mm low E (ε = 0.15)	12	1.9	2.2	2.6
6 mm + 6 mm low E (ε = 0.15)	6	2.6	2.8	2.9
6 mm + 6 mm low E (ε = 0.15)	12	1.9	2.2	2.6
6 mm + 6 mm low E (ε = 0.15)	16	1.7	2.2	2.5
6 mm + 6 mm low E (ε = 0.15)	20	1.7	2.2	2.5
6 mm + 6 mm low E (ε = 0.15)	16 (argon fill)	1.5	1.9	2.1
4 mm + 4 mm low E (ε = 0.10)	12	1.8	2.1	2.4
6 mm + 6 mm low E (ε = 0.10)	6	2.5	2.7	2.8
6 mm + 6 mm low E (ε = 0.10)	12	1.8	2.0	2.4
6 mm + 6 mm low E (ε = 0.10)	16	1.5	2.0	2.4
6 mm + 6 mm low E (ε = 0.10)	20	1.6	2.0	2.3
6 mm + 6 mm low E (ε = 0.10)	16 (argon fill)	1.3	1.7	1.9
4 mm + 4 mm low E (ε = 0.05)	12	1.7	1.9	2.3
6 mm + 6 mm low E (ε = 0.05)	6	2.5	2.6	2.7
6 mm + 6 mm low E (ε = 0.05)	12	1.6	1.9	2.3
6 mm + 6 mm low E (ε = 0.05)	16	1.4	1.9	2.2
6 mm + 6 mm low E (ε = 0.05)	20	1.4	1.9	2.2
6 mm + 6 mm low E (ε = 0.05)	16 (argon fill)	1.1	1.5	1.8

NOTE 1 The U values given are calculated according to BS EN 673:1997 using the following external and internal heat transfer coefficients:

— vertical external 23.0 W/m²·K, vertical internal 8.0 W/m²·K, 45° slope external 28.75 W/m²·K,

— 45° slope internal 7.7 W/m²·K, horizontal external 34.5.0 W/m²·K, horizontal internal 7.4 W/m²·K.

NOTE 2 The use of argon in the cavity will typically reduce the U values by 0.2 to 0.4 W/m²·K.

NOTE 3 ε is the normal emissivity of the coated surface.

NOTE 4 Part L of the Building Regulations (England & Wales) gives U values for windows (glass and frames) with a correction factor for non-vertical glazing which takes into account the combined effects of slope on the glass and frames.

11.4.4 ***U values of plastics glazing sheet materials***

Table 10 gives typical U values of some plastics glazing sheet materials. For detailed information on specific products, the manufacturer should be consulted.

Table 10 — Thermal transmittance (U values) of single and double plastics glazing sheet materials

Sheet or unit	Airspace width	U value W/m²·K		
	mm	Vertical	45° slope	Horizontal
Single 3 mm	—	5.5	6.3	7.1
5 mm	—	5.3	6.1	6.8
Double	3	3.6	3.7	4.5
3 mm + 3 mm, or	6	3.2	3.5	3.7
3 mm + 2 mm, or	9	3.0	3.2	3.5
2.5 mm + 2.5 mm	12	2.8	3.1	3.5
	16	2.7	3.1	3.5
	20	2.7	3.1	3.4

11.4.5 ***Recommendations for U values***

In the interests of energy efficiency, insulating glass units or coupled glazing should be used in all new buildings and in all replacement glazing in existing buildings. An exception may be made for listed and historic buildings.

Consideration should be given to the installation of glazing with improved thermal insulation, which can be achieved by incorporating low emissivity glass.

11.4.6 ***Effect of frames***

The other major criterion to take into consideration when designing low U value glazing is the frame. The type of frame can have a considerable effect on the overall U value of glazing, particularly when glazing with good thermal insulation (low U value) is used. Calculations should be made using BS EN ISO 10077-1.

11.5 Condensation

11.5.1 ***Room side condensation***

As thermal insulation of the glazing improves, the susceptibility to condensation on the room face of the glazing is reduced.

NOTE Condensation can occur after single glazing is replaced by insulating glass units due to the reduction in ventilation (see BS 5250).

11.5.2 ***Interstitial condensation***

In insulating glass units, condensation in the cavities is minimized by hermetically sealing and dehydrating the cavity.

In coupled glazing and hollow plastics glazing sheet materials, interstitial condensation problems can be reduced in the UK by venting the cavity to the outside.

NOTE Hollow plastics glazing sheet materials are normally glazed with the cavities running from ridge to eaves so any interstitial condensation will drain away.

11.5.3 ***Exterior condensation***

On rare occasions, condensation can occur on the outermost glass surface of highly insulating glazing, e.g. low E glass, as a result of the reduction of heat conduction to the outside. This effect will only be prevalent at low sky temperature, i.e. a clear sky, when there is a heavy dew, and is more likely to occur on sloping glazing than on vertical glazing, since a larger proportion of the sky is able to cool the glazing.

11.6 Energy balance

The magnitude of solar energy gain through clear insulating glazing facing South, East and West can be much greater than the energy losses over the duration of the heating season. The glazing acts as a passive solar collector. This idea is encapsulated in the concept of “effective U value”, whereby the additional useful energy gain is offset against the energy loss. Manufacturers should be consulted about the effective U value of their products

NOTE BS EN ISO 14438 describes how to obtain the effective U value.

11.7 Thermal stress

11.7.1 *Glass*

Glass should be checked for its susceptibility to breakage initiated by thermal stress. Although thermal stress in glass and the need for its assessment is described below, the question of thermal safety related to particular circumstances is not considered, such detail being the subject of glass manufacturers’ literature.

Knowledge of the solar radiation to which the glass is to be subjected and the thermal capabilities of the glass are necessary for the assessment of the thermal safety of glass. One method of assessment is by determining the solar radiation intensity on the glass surface and the air temperature range applicable to the location of the building. These, together with the heat transfer coefficients and the glass absorption allow determination of the appropriate basic temperature difference between the central area of the glass and its edge. The difference is related to the thermal stress and then modified for the type of glazing system, taking account of extraneous effects resulting from blinds, back-up walls, proximity to heaters and the like, to derive a stress for actual service conditions. High air temperatures, low rates of air movement, and the insulation provided by blinds, back-up walls and insulating glass units tend to reduce the loss of heat and uphold the centre temperature.

In roof glazing, the slope affects the solar radiation intensity on the glass, and special attention should be paid to the effect of local back-ups produced where the glazing passes over supporting structure. Low temperatures at the edges are maintained by conduction from the glass through the frame to a cold building structure with a large thermal capacity.

The resultant stress should then be compared with the design stress for the glass. If on comparison the stress is less than or equal to the design stress, the glass and glazing system can be accepted as thermally safe provided that the edges of the glass are of sufficient quality.

Insulating glass units have different temperature distribution patterns from those of single glazing because each glass, having absorbed its share of solar energy, transfers some of its heat to other glasses in the system.

Where the application of a solar control film is being considered to a glass already glazed in a building, advice should be sought from the manufacturer on the effect of any additional thermal stress likely to be induced in the glass.

The materials used to support the glass vary widely in their thermal properties and the details of the frame design are therefore important in determining the temperature gradients near the edges of the glass.

If the frame is in good thermal contact with a heavy masonry structure it will lose heat rapidly to the masonry and stay relatively cool. Blinds and other shading devices interfere with the free movement of air over the glass and they reflect, absorb and reradiate solar radiation. Edge cover is instrumental in causing stress in the edge of sunlit glass but, within the practicable limits consistent with the safe retention of the glass in conventional glazing, changes in the width of edge cover alter the edge stress so little that their effect on the thermal safety of the glass is negligible.

Because the normal mode of thermal breakage of glass is by the action of tensile stress located in and parallel to an edge, the breaking stress of the glass is mainly dependent on the extent and position of flaws in the edges. The condition of the glass edge is therefore extremely important.

Solar control glasses should not be nipped to size and any panes with shelled or vented edges should not be accepted for glazing in orientations subject to direct sunlight. Although a wheel-cut edge is the most satisfactory, laminated glasses may be supplied with worked edges. Where clean cut edges are not possible, arrisses should be created by a wet process, working parallel to the edge and not across the thickness, and the design implications of such an action should be examined. For wired glass, the manufacturer's recommended cutting techniques should be adopted. Care should also be taken to reduce the risk of wire rusting.

It is important to remember that the thermal safety assessment is based on the behaviour of glass in good condition and properly glazed. Even if the glass is shown to be thermally safe, that thermal safety depends on close adherence to the recommended glazing procedures. All necessary precautions should be taken to see that only glass with edges of an acceptable condition is glazed. The glass should be stored and handled so that no contact with hard bodies can damage the edges and each pane should be carefully examined immediately before glazing.

Most solar control glasses can be toughened or heat strengthened and this gives a means of raising the design stress and ensuring safety from thermal fracture.

Thermal safety checks should be performed on sloping glazing exposed to solar radiation whenever a solar control glass or wired glass is used.

11.7.2 *Plastics glazing sheet materials*

In general, when plastics glazing sheet materials are used for glazing thermal safety need not be considered. However, plastics glazing sheet material is subject to thermal stress when the temperature of all or part of the pane exceeds its maximum continuous service temperature. The two principal situations in which this can occur are as follows.

— When a dark tinted plastics glazing sheet material, having a low maximum continuous service temperature, is exposed to high levels of direct solar radiation, such as in south facing sloping glazing: in such a case, the solar energy absorbed by the pane can raise its temperature to a point where mechanical distortion of the pane occurs.

— When a transparent plastics glazing sheet material possessing a high solar energy transmission value is exposed to high levels of direct solar radiation in a glazing system which includes dark coloured component parts close to or in contact with the plastics glazing sheet material, particularly the inner surface: such components will absorb the transmitted solar energy, converting it into heat energy, which will be radiated back to the inner surface of the sheet and can lead to localized stress cracking.

Localized stress cracking resulting from thermal stress may be minimized by ensuring that components in positions likely to absorb solar energy transmitted through the plastics glazing sheet material are light coloured on the side facing the sheet.

Contact with chemically incompatible substances (e.g. unsuitable sealing and glazing materials) can also add to any problems resulting from thermal stress (see Annex A).

Plastics glazing sheet materials have high coefficients of thermal expansion and the appropriate allowances for sizing should be made (see Annex A). Mechanical distortion of a pane can result from thermal movement if the pane is incorrectly glazed.

NOTE Polycarbonate has a high maximum continuous service temperature and is much less at risk from thermal problems than other plastics glazing sheet materials. Advice should be sought from manufacturers.

11.8 Thermal movement

11.8.1 *Glass*

The coefficient of linear expansion of all the soda-lime silicate glass types (see BS EN 572-1) referred to in this code, whether clear or tinted, annealed, laminated or toughened, is approximately 9×10^{-6} K^{-1}.

11.8.2 *Plastics glazing sheet materials*

Movement caused by temperature changes should be allowed for in the edge clearance when cutting the plastics glazing sheet material pane to fit into its frame. The coefficient of linear expansion for most plastics sheet materials is around of 6.0×10^{-5} K^{-1} to 8.0×10^{-5} K^{-1} (see also Annex F). Special consideration might be needed when using screws or bolts to fix plastics glazing sheet material.

12 Acoustic performance

12.1 Introduction

The slope of the glazing has no effect on its acoustic performance.

Noise, i.e. unwanted sound, can be attenuated by employing thick glazing, insulating glass units, secondary glazing, laminated glass or any combinations of these. In order to maximize the acoustic benefits of the glazing, special consideration should be given to the actual frequency spectrum of the noise source.

The presence of large areas of glass surfaces reflects sounds and can enhance or detract from the acoustics inside or immediately adjacent to the building. For further information, expert advice should be sought. Guidance can be found in BS EN 12758.

12.2 Source of noise

12.2.1 *Road traffic noise*

Road traffic noise is very common problem, particularly in urban areas, where low frequency (125 Hz to 250 Hz) noise from engine and exhaust systems predominates. Tyre noise, which is of higher frequency, depends on the road surface and becomes more important as speeds increase.

12.2.2 *Railway noise*

Railway noise has a similar spectrum to road traffic except that more middle frequency components are present. However this noise is generally more tolerable than road traffic noise since the peaks are of short duration. It is generally accepted that railway noise can exceed road traffic noise by 10 dB for a similar level of disturbance.

12.2.3 *Aircraft noise*

Aircraft noise changes significantly with altitude, climatic conditions, type and load utilization of aircraft, and whether it occurs at landing or take off. Take off noise is dominated by low frequencies whereas landing noise contains strong high frequency components.

12.2.4 *Speech*

The important frequencies of speech lie between 500 to 2 000 Hz (middle frequency dominated).

12.3 Specification of acoustic performance

Because the noise level produced by most noise sources and the sound reduction provided by building elements varies with frequency, this has to be taken into account when specifying acoustic performance. Usually the noise level or sound reduction is specified in frequency bands.

For general building acoustics, the octave frequency bands are 125, 250, 500, 1 000, 2 000 and 4 000 Hz. However, for some critical applications it is useful to extend the range down to 50 Hz and/or up to 5 000 Hz.

When more detailed analysis is appropriate, these octave bands may be subdivided into 3 (except for the 4 000 Hz band) to give 16 one-third-octave bands at 100, 125, 160, 200, 250, 315, 400, 500, 630, 800, 1 000, 1 250, 1 600, 2 000, 2 500 and 3 150 Hz.

12.4 Acoustic indices

12.4.1 *General*

Although the levels of noise and the amounts of sound reduction are usually measured in frequency bands, it is often convenient to reduce the information to single number quantities or indices (see **12.4.2**, **12.4.3** and **12.4.4**). The indices R_W, C and C_{tr} describe sound reduction should be determined in accordance with BS EN ISO 717-1.

NOTE Of the previously used sound reduction indices (R_m, R_W and R_{TRA}), R_m is no longer required, R_W is effectively unchanged and R_{TRA} can be approximated by $R_W + C_{tr}$.

12.4.2 *Weighted sound reduction index,* R_W

The weighted sound reduction index is a single number rating used to describe the sound reduction of a building element when measured in a laboratory. It is calculated from the measured values in each one-third-octave band, which are known as the sound reduction indices R. The rating method described in BS EN ISO 717-1 should be used. The measurement method is described in BS EN ISO 140-3.

As with all single figure indices of acoustic performance, the ranking order is not always the same when applied to real noise exposure. Hence the introduction of the adaptation terms C and C_{tr}.

12.4.3 *Sound reduction against specific noises,* $R_W(C;C_{tr})$

The noise level in a room resulting from outside noise intrusion depends mainly on the level and frequency spectrum of the noise and the sound reduction characteristics of the glazing. The weighted sound reduction index cannot be used directly to estimate the noise level in the room. To facilitate such calculations, BS EN ISO 717-1 describes the calculation of two spectrum adaptation terms, C and C_{tr}. These can be added to R_W to give an indication of the sound reduction in dB of the glazing (or other building element) against typical noise sources which are listed in the standard, including motorway and urban road traffic.

This information is presented as in the following example:

$R_W(C;C_{tr})$ = 41(0;–5) dB

where

R_W = 41 dB
C = 0 dB
C_{tr} = –5 dB

If an extended frequency range has been specified, it is denoted as in the following examples:

$C_{50\text{-}3150}$, $C_{50\text{-}5000}$, $C_{100\text{-}5000}$, $C_{tr;50\text{-}3150}$, $C_{tr;50\text{-}5000}$ and $C_{tr;100\text{-}5000}$.

12.4.4 *Mean sound reduction index,* R_m

The mean sound reduction index is no longer required, but there might be historical reasons which need its use, so values for glass have been included in Table 11 and Table 12. For some materials the mean sound reduction index is the only available information, e.g. plastics glazing sheet materials (Table 13 and Table 14).

12.5 Sound reduction of a single glass pane

12.5.1 *General*

Glass has a very low sound absorption. Table 11 shows the sound reduction properties for different types of single glazing. Several factors affect the overall acoustic performance. These include the mass, coincidence resonance, gaps in frames, edge support conditions, lamination and pane dimensions (see **12.5.2**, **12.5.3** and **12.5.4**).

12.5.2 *Effect of mass*

Doubling the glass thickness, and therefore the mass, improves the sound reduction figures by about 4 dB.

12.5.3 *Coincidence resonance*

Coincidence resonance is characterized graphically by a "dip" in the sound reduction at a certain frequency. The frequency, f_c (in hertz), at which this occurs is inversely proportional to the glass thickness, determined from the formula

$$f_c = \frac{12\ 000}{t}$$

where

t is the glass thickness, in millimetres.

12.5.4 ***Lamination***

Instead of using ordinary solid (or monolithic) glass the thickness may be split up into thinner components, each separated, but bonded together, by a softer interlayer material to form a laminated glass. This is common in safety and security applications and such lamination can also have acoustic benefits, particularly in the suppression of the coincidence resonance.

There are many different interlayer materials and their effect on sound reduction depends on the type and thickness. Stiffer interlayer materials or thinner interlayers have less effect as they couple the individual glass plies together. With softer or thicker interlayers, the individual plies of glass tend to act as if they were separate entities, so the residual resonances occur at frequencies that correspond closely with the individual glass components of the laminate. These resonances are shifted to higher frequencies where, generally, they play a less important role in relation to common noises.

12.6 Sound reduction of insulating glass units and secondary glazing

12.6.1 ***General***

In addition to those factors determining the sound reduction of single glass, there are additional factors with insulating glass units and secondary glazing. These include the use of different glass thicknesses, cavity width and gas filling (see **12.6.2**, **12.6.3** and **12.6.4**). Table 12 shows typical sound reduction properties for insulating glass units and secondary glazing.

12.6.2 ***Different glass thicknesses***

The individual resonances of the panes can be offset by ensuring that the component panes differ in thickness by at least 30 % (e.g. 10 mm + 6 mm, or 6 mm + 4 mm). Lamination of one pane produces a further small improvement and this is achieved regardless of which pane is laminated.

12.6.3 ***Cavity width***

Over the usual cavity range of 6 mm to 20 mm for insulating glass units, there is little variation of acoustic performance. Where higher sound reduction of glazing is required, cavity widths of greater than 100 mm, which are not available in insulating glass units, might be needed. Sound absorbing lining of the reveals improves performance. Beyond 200 mm, significant further improvement is gained only by resorting to very large gaps.

12.6.4 ***Gas filling***

For applications where middle frequency acoustic performance is critical (e.g. speech), insulating glass units might benefit from being filled with sulfur hexafluoride (SF_6) gas mixtures. However SF_6 introduces a significant resonance at 200 to 250 Hz and, for noise dominated by low frequency components, such as traffic noise, this might be detrimental. Argon filled units, used for improving thermal insulation, exhibit exactly the same acoustic performances as standard air-filled units of the same glass combination.

12.7 Sound insulation of plastic glazing sheet materials

The sound insulation properties of plastics glazing sheet materials relate to mass. Table 13 gives the mean sound reduction index for various thicknesses of single plastics glazing sheet materials and Table 14 gives an estimation of the probable mean sound reduction index of double glazed plastics glazing sheet materials.

NOTE Further information might be available from the manufacturer.

Hollow section plastics glazing sheet materials can give improved sound reduction against some forms of airborne noise.

Table 11 — Typical sound reduction properties of single glazing

One-third-octave band centre frequency Hz	Sound reduction (dB) for glass thickness (mm)							
	4	**6**	**6.4 PVB laminate**	**7 PMMA laminate**	**10**	**12**	**13 PMMA laminate**	**13.5 PVB laminate**
100	17	16	21	23	24	24	27	25
125	18	19	20	26	21	29	30	28
160	16	20	21	25	25	31	30	27
200	19	22	20	26	23	28	31	27
250	20	24	24	27	28	29	33	31
315	22	25	25	28	28	31	33	31
400	25	28	27	30	31	29	35	33
500	27	30	29	32	33	33	37	35
630	28	32	32	33	34	32	38	37
800	30	34	34	35	33	31	40	37
1 000	32	35	34	36	31	32	40	36
1 250	33	35	35	38	29	32	41	35
1 600	34	32	34	39	30	36	40	37
2 000	34	26	31	40	33	39	38	41
2 500	31	27	31	40	36	42	41	44
3 150	24	30	35	38	37	45	45	47
4 000	26	33	39	36	40	47	51	50
R_W	29	31	32	36	33	34	39	37
C	–2	–2	–1	–1	–2	0	0	–1
C_{tr}	–3	–3	–3	–4	–3	–2	–2	–3
R_m	26	27	28	32	30	33	36	35

NOTE The values are based on float glass. Toughened, coated, wired and patterned glass are acoustically the same as float glass of the same thickness.

Table 12 — Typical sound reduction properties of insulating glass units and secondary glazing

One-third-octave band centre frequency	Sound reduction (dB) for glass/cavity width/glass (mm)								
Hz	4/12/4	6/12/4	6/12/6	10/12/4	10/12/6	10/12/6.4 PVB	6/100/4	6/150/4	10/200/6
100	21	18	18	24	26	27	25	27	32
125	21	23	23	24	25	24	27	30	37
160	20	23	20	25	24	23	27	30	39
200	18	18	15	19	22	24	33	34	45
250	15	21	18	22	29	30	33	34	46
315	19	23	23	25	30	30	37	39	46
400	22	25	26	30	31	32	41	42	47
500	25	24	29	32	34	35	46	46	45
630	29	32	33	35	36	37	50	50	45
800	33	36	37	36	39	40	54	54	44
1 000	36	39	39	37	39	41	57	57	45
1 250	38	41	39	39	37	40	59	58	50
1 600	40	40	37	40	39	40	58	58	53
2 000	39	36	33	44	37	40	52	52	58
2 500	34	36	32	45	39	43	51	49	58
3 150	28	37	36	41	43	47	48	47	64
4 000	31	40	40	42	46	52	57	52	64
R_W	29	32	31	35	36	38	46	47	49
C	–1	–2	–-1	–2	–1	–1	–2	–2	–1
R_{tr}	–4	–4	–4	–5	–3	–5	–7	–6	–4
R_m	27	29	29	32	33	35	44	44	47

NOTE The values are based on float glass. Toughened, coated, wired and patterned glass are acoustically the same as float glass of the same thickness.

Table 13 — Sound reduction: single plastics glazing sheet material

Thickness mm	Mean sound reduction index dB
3	18
4	20
5	22
6	23
8	25
10	26
13	28

Table 14 — Sound reduction: double glazing, both panels the same thickness of plastics glazing sheet material

Thickness	Estimated improvement in sound reduction index compared with single glazing of the same thickness for an air space of:				
mm	50 mm dB	100 mm dB	150 mm dB	200 mm dB	250 mm dB
3	9	12	13	14	15
4	9	12	14	15	15
5	9	13	14	15	16
6	10	13	14	16	16
8	10	14	15	16	16
10	11	14	15	16	17
13	12	14	15	17	17

13 Security

13.1 General

Security glazing is used in situations where a high degree of protection either to persons or property is required, either against violent, malicious manual attack, or the use of firearms, or against the effect of explosions. Specialist advice should be sought on the appropriate class to be used for particular risk situations.

13.2 Manual attack

Glazing resistant to manual attack should conform to BS EN 356, which specifies performance requirements and test methods.

13.3 Firearm attack

Bullet-resistant glazing for interior use should conform to BS EN 1063, which specifies performance requirements and type tests for various classes.

13.4 Explosion resistance

Glazing resistant to explosion loads should conform to BS EN 13541, which specifies performance requirements and test methods.

Special glass types and fixing systems are available and specialist advice should be obtained. Most explosion resistant glazing systems are designed to allow the glazing to crack, but to retain it in place after fracture. The self weight of sloping glazing makes it more difficult than with vertical glazing to retain the glazing after fracture.

13.5 Installation

Bullet-resistant glazing and glazing resistant to manual attack should be installed according to the recommendations of BS 5357.

For explosion resistant glazing and also for security glazing intended for use in external situations, advice should be sought from the manufacturer.

13.6 Glass

Laminated glass can be designed to provide any specified degree of resistance to penetration. The composition of the laminated glass will depend on the level of protection required. The manufacturer of the laminated glass should be consulted on the design of the glazing system and the fixing procedures required.

13.7 Plastics glazing sheet material

Different types of plastics glazing sheet materials can provide varying degrees of resistance to breakage and penetration. The manufacturer of the plastics glazing sheet materials should be consulted on the design of the glazing system and the fixing procedures required. In some situations it might also be necessary to take account of the fire properties of such materials in addition to the security aspect.

13.8 Means of escape

Particular care should be taken when designing and installing security glazing systems that the means of escape from the buildings in emergency situations, e.g. in the case of fire, is not prejudiced by the enhanced security. In such cases, specialist advice should be sought and the provision of additional means of escape might be necessary.

14 Glazing materials

14.1 General

There is a wide range of glazing materials available for fixing glazing into its frame, weather sealing the joints in sloping glazing, and weather sealing between the glazing and the frame or other adjacent materials. Glazing materials should be of a resilient nature, capable of accommodating any likely movements, and be compatible with the substrates to which they are applied or with which they are in contact. Care should be taken in the selection of glazing materials, particularly sealants (see BS EN 11600) to ensure that they are sufficiently resistant to climatic effects, especially ultraviolet light and atmospheric pollution in the conditions in which they are to be used (see also Annex A).

Correctly positioned setting blocks of adequate size, with or without other glazing materials, should be used to prevent direct contact between the bottom edge of glass and any metal component, continuous or otherwise. Suitable materials for use as setting blocks in sloping glazing include plasticized polyvinyl chloride and extruded unplasticized polyvinyl chloride. However, plasticized polyvinyl chloride setting blocks are not recommended for use with plastics glazing sheet materials.

Location blocks should be used where necessary to space glass away from the surrounding frame.

14.2 Material types

14.2.1 *Preformed glazing materials*

Preformed glazing materials are usually substantially dry and non-viscous, commonly in reel or strip form, and include mastic tapes, greased cords, synthetic rubbers and plastics sections and gaskets, either solid or cellular. Such materials, which do not normally undergo a physical or chemical change, might require to be used under compression.

Preformed rubber gaskets should conform to the appropriate Part of BS 4255.

14.2.2 *Other glazing materials*

These are viscous materials for application by hand, knife or gun and include bulk mastics, glazing compounds and sealants. Such materials can undergo a physical or chemical change after initial placing and might also have adhesive properties.

BS 6213 gives advice on the selection of sealants.

One-part gun-grade polysulfide-based sealants should conform to BS 5215.

Two-part polysulfide-based sealants should conform to BS 4254.

Silicone-based sealants should conform to BS 5889.

15 Weather resistance

15.1 General

The degree of exposure and the particular situation of the glazing system should be taken into account when considering weather resistance and the type of glazing system to be employed.

Consideration should also be given to the intended use and occupancy of the building, together with any specific performance criteria. The necessary information should be provided at the initial design stage.

15.2 Air permeability

Resistance to air permeation will depend upon several factors including the type of glazing system employed.

In view of the large variety of designs available it is not practical to give quantified information. If a specific level of performance is required in respect of air permeability, this should be specified at the design stage.

15.3 Water penetration

The glazing system should be so designed and constructed as to not allow the penetration of water, due to rain or snow, into any part of the interior of the building, which would be adversely affected by such water.

Discharges from downpipes or other concentrations of rainwater should not be allowed to flow over sloping glazing. Separate drainage gutters should be provided.

15.4 Means of achieving weather resistance

15.4.1 *General*

The principal factors affecting the weather resistance of sloping glazing systems are as follows.

15.4.2 *Slope*

To avoid ponding on the glazing, the slope should be not less than 5° to the horizontal.

For shallow slopes, exposed situations or long down-slopes, special considerations might be required to prevent ingress of water.

The glazing system should be designed to discourage the accumulation of standing water on transverse frame members. This is particularly important with shallow glazing slopes.

15.4.3 *Drainage*

It should always be assumed when designing a sealing system for sloping glazing that, with the possible exception of very simple butt joints between adjacent panes, it will be impossible to obtain a perfect seal.

Water channels or drainage pathways should be provided within frames to collect and drain away to the outside of the building, either directly or indirectly, any water that might penetrate beyond the wings, caps, beads, gaskets, seals or other external weathering details. Outlets from water channels should be of adequate size to ensure proper drainage and should be free of obstruction so as not to provide places for silt to lodge.

Where excessive dust, grit or dirt is likely to silt up the water channels or drainage pathways, suitable precautions should be taken.

15.4.4 *Seatings*

All supported edges of the glazing should be properly seated on appropriately resilient glazing material (e.g. gasket, glazing tape or sealant) throughout their full lengths.

All support points of the glazing should be properly seated on appropriately resilient glazing material over the whole contact area.

15.4.5 ***Flashings***

Flashings which provide the weathering at the top of sloping glazing should overlap the infilling by a nominal 75 mm (see Figure 7). With flashings, which are likely to produce a capillary path for water, the path should be broken by incorporating an air space or otherwise effectively sealed.

Site formed flashings should be properly dressed down and secured as necessary.

15.4.6 ***Weather bars***

On two-edge supported systems of sloping glazing, weather bars or seals should be provided between the frames at the bottom edge of the glazing to prevent the penetration of windblown water, snow and dust.

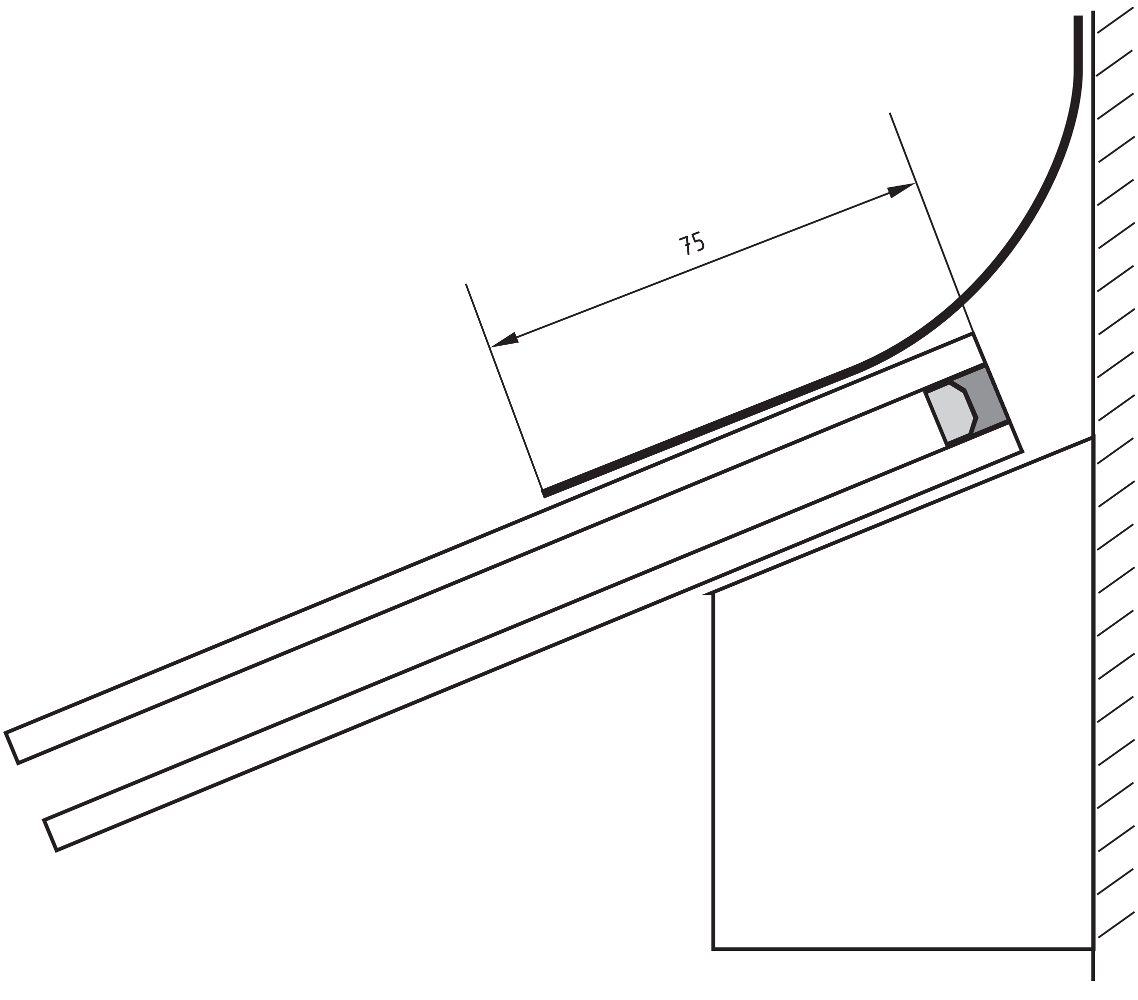


Figure 7 — Flashing at the top edge of glazing

15.4.7 *Bottom overhang*

On two-edge supported systems of sloping glazing, the bottom edge of the glazing should overhang at least 75 mm beyond the weather bar or weather seal (see Figure 8). In conditions of extreme exposure or when the slope of the glazing is less than 15°, the overhang should be increased.

Overhangs up to 150 mm are unlikely to be overstressed by the applied loads. Above 150 mm, the overhang should be assessed for its resistance to the applied loads.

When the glazing incorporates an insulating glass unit, only the upper pane should overhang the weather bar or seal and the insulating glass unit seal should preferably be inside the weather bar or seal to protect it from exposure to the weather.

15.5 Testing

Sealed glazing systems, e.g. slope glazed curtain walling and sloping bolted structural systems, should be assessed for weather resistance to BS 5368 and BS 6375.

Open drained glazing systems, e.g. patent glazing, should be assessed for weather resistance by the method described in BS 5516-1.

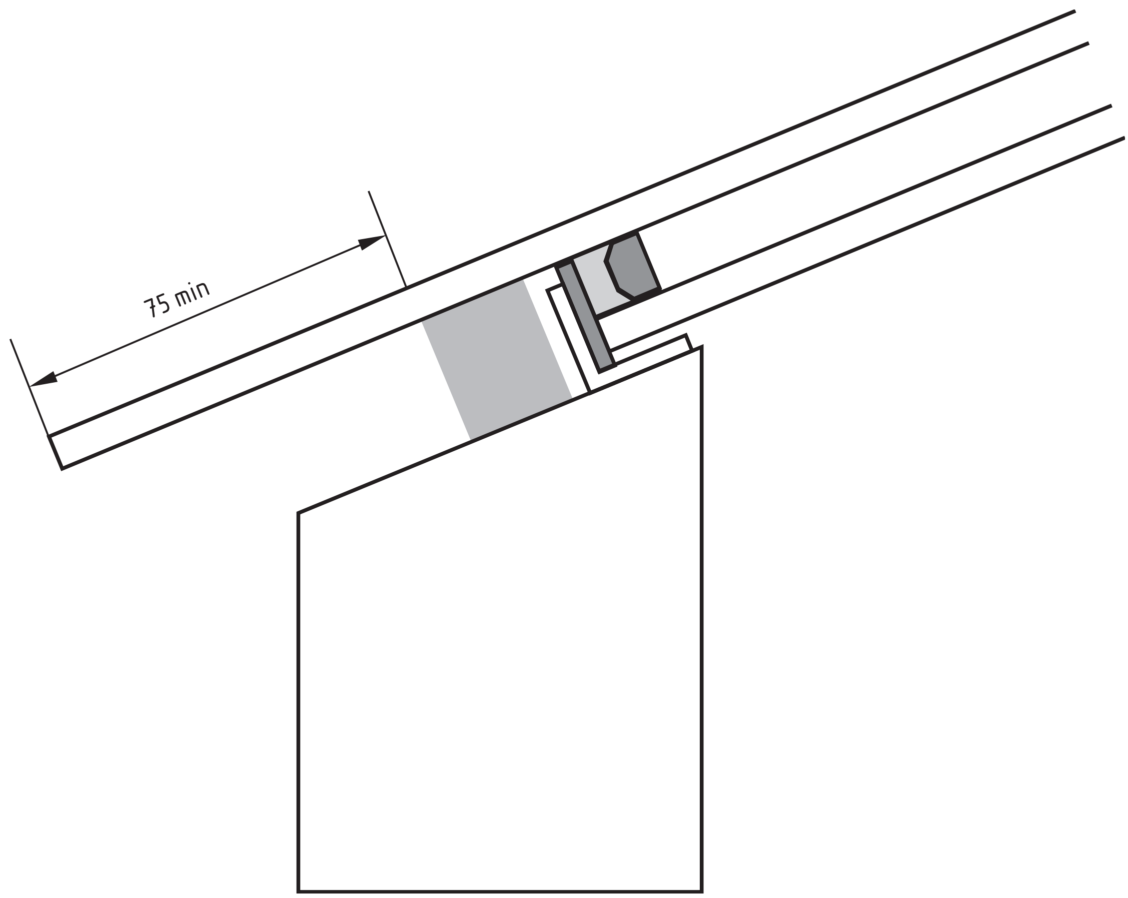


Figure 8 — Schematic bottom overhang for insulating glass units

16 Storage and handling

Glazing should always be stored and handled correctly to avoid damage.

- — Glazing should be stacked upright, leaning back at around 6°, fully supported at the back.
- — The bottom edge of glass should stand on wood, felt or other material softer than glass.
- — Glazing should be stored dry and out of direct sunlight at all times.
- — The glazing should be protected from impact or stored in a location where it is unlikely to be impacted.
- — Contamination of the glazing by cementitious material, plaster, adhesives and solvents should be avoided.
- — Appropriate personal protective equipment should always be used when handling glass, e.g. gloves, safety glasses, safety shoes, safety helmet.
- — The correct handling equipment for the weight and size of the glazing should be used.
- — No attempt should be made to move glazing, unless there is adequate room to manoeuvre it.
- — Contact should be avoided between glass and any hard material, e.g. concrete, stone, brick, metal, glass.
- — Only one pane at a time should be handled unless the glazing is securely packed.

Further advice can be obtained from BS 8000-7. The Glass and Glazing Federation and the Laminated Glass Information Centre both publish booklets on the subject. Manufacturers' recommendations should also be followed.

17 Maintenance

17.1 General

For safety reasons, maintenance should not be carried out in strong winds or when there is snow or ice on the sloping glazing. The clearing of snow from roofs containing fragile or non-loadbearing materials, especially glass, is not recommended. Partial removal of snow can adversely affect the structural stability of the roof.

17.2 Access for maintenance and cleaning

17.2.1 *General*

Those engaged on maintenance work should use suitable equipment (see BS 8213).

NOTE Attention is drawn to the Construction Design and Management Regulations, the Construction (Working Places) Regulations 1966 [3], the NBS specification *Access for cleaning and maintenance* [4] and the HSE booklet *Health and safety in roof work* [1].

Experienced operatives should be employed. Glazing should never be stood or walked upon, unless it is specifically designed as a floor (see BS 5516-3). Crawling boards should be used to transfer the maintenance loads directly to the frames or supports.

17.2.2 *Temporary access systems*

Temporary access, if required, may be attained by the use of ladders, crawling boards and scaffolding of various forms suitable for the particular type of building and the location of the glazing. Such forms of access should be removed shortly after use.

Ladders and crawling boards may be used safely without imposing any loading on the glazing provided that they are supported at a purlin or other structural member. Spreader boards should be properly secured and should rest on at least two frames or glazing bars. Stops might need to be provided on the frames to locate crawling boards, etc. and to prevent them from slipping. Maintenance loads should never be carried directly by the glazing, unless it is specifically designed as a floor (see BS 5516-3).

Temporary access may also be gained through the use of specialist systems, such as manual or powered cradles or gantries. Motorized working platforms are particularly useful on the inside of a building provided that there is good access and sufficient room to manoeuvre. They may also be effectively used outside. Care should always be exercised to ensure that firm and level areas are provided from which to operate.

17.2.3 ***Permanent access systems***

Systems of permanent access might be either fixed or moving platforms on some form of tracking, re-locatable within a pre-set pattern.

Walkways or platforms might be designed as an integral part of the glazing system, but preferably should be completely independent of it.

17.3 Inspection

Periodic inspection of glazing and its seals and supports should be carried out by those responsible for the maintenance of the building.

Particular attention should be given to:

— the tightness of bolts and other fasteners;

— joint seals and junctions between different materials;

— moving parts such as ventilators, etc.

The frequency of inspections/cleaning for a particular component or finish may also be determined by the requirements of the terms and conditions of a manufacturer's warranty.

Where it is known that there is a particular risk from atmospheric pollution, e.g. from certain production processes, or close proximity to the sea, more frequent inspection might be necessary.

17.4 Cleaning

17.4.1 ***General***

Glazing should be cleaned regularly and at time intervals depending upon the accumulation of dirt.

Regular cleaning to remove atmospheric grime and pollution will maintain the appearance, durability and performance of glazing. Cleaning therefore contributes considerably to the effective life of the glazing. The frequency of cleaning of internal as well as external surfaces depends upon the following:

— the current use being made of the building;

— the particular situation of the glazing on the building;

— the building location and the local environmental conditions;

— the type of glazing, its surface texture and finish;

— the materials used for frames, flashings, ancillary components and their surface texture and finish;

— the attitude of the client/owner to the general appearance and maintenance of the building.

If excessive dirt is allowed to accumulate, this could lead to:

— reduction of light transmission leading to an unsatisfactory level of illumination which can affect occupants and their safety;

— increase in the absorption of solar radiation which, with glass, may cause an unacceptable increase in the thermal stress.

17.4.2 ***Cleaning materials***

A solution of mild detergent in water, applied with a clean soft non-abrasive cloth, followed by a thorough clean water rinse should be used for routine cleaning. Care should be exercised to avoid rubbing dirt into any surface.

The removal of stains and marks, other than those which are removed by the method described above, should be discussed with the manufacturer of the material to be cleaned.

17.5 Other maintenance

Any damaged or missing components located during periodic inspection should be replaced as soon as possible and any loose items secured as necessary.

Where replacement or repair work is necessary, the glazing contractor responsible for the original installation should preferably carry this out.

Annex A (normative)
Plastics glazing sheet materials

A.1 General

The properties of plastics glazing sheet materials differ considerably from glass materials in a number of significant ways. These properties affect the following aspects of sloping glazing:

— allowances for expansion and contraction of the pane (affected by the coefficients of expansion due to temperature change and moisture absorption);

— edge cover provided by glazing bars (affected by the flexing of the pane under load, coefficients of expansion and, in the case of hollow section sheets, the profile of the sheet);

— double glazing (affected by gas and water vapour permeability properties);

— sealing and glazing materials (affected by the need for chemical compatibility with parts of the system in contact with the pane);

— flashings and other weatherings (affected by the flexing of the pane under load and the coefficients of expansion).

A.2 Allowances for expansion and contraction of the pane

Plastics glazing sheet materials possess high coefficients of thermal expansion. In addition, acrylic based materials can have high coefficients of expansion due to moisture absorption. Taking these coefficients into account, the potential dimensional changes over a temperature variation of 40 °C for plastics glazing sheet materials are as follows:

a) polycarbonate, 3 mm/m;

b) polyvinyl chloride, 3 mm/m;

c) acrylic, 5 mm/m;

d) GRP, 2 mm/m.

Plastics glazing sheet materials should only be incorporated in systems of sloping glazing designed for their use.

Having thus calculated the expansion allowances required, the exact pane size to be cut may be calculated given the temperature at which the material will be cut to size and the range of temperatures anticipated for the sloping glazing once installed and in use.

Typically, for panes cut to size indoors, a temperature in the range 18 °C to 20 °C may be assumed. Normal air temperature variation in the UK may be assumed to be 10 °C to 30 °C. It is essential that these temperature differences are taken into account during the design of the sloping glazing.

If plastics glazing sheet materials are cut to size or trimmed on site, they should always be clamped firmly to a flat surface to prevent juddering during the cutting operation. The manufacturer should be consulted for guidance on which type of cutting equipment, e.g. saw blades, should be used.

A.3 Edge cover and edge clearance

A.3.1 *Solid plastics glazing sheet materials*

The graphs in Figure 5 should be used to determine the minimum thickness of a rectangular pane of solid plastics glazing sheet material for a given working pressure. Aspect ratio and area should be used in the case of panes supported on four edges and unsupported span should be used in the case of panes supported on two opposite longitudinal edges only.

All the graphs in Figure 5 assume a minimum edge cover of 15 mm. It is essential that edge clearance should also be provided in the glazing bars for the pane. A frame or glazing bar designed for plastics glazing sheet materials should therefore incorporate sufficient edge cover and edge clearance, during all normal flexing and movement of the pane.

For example, in Figure A.1, a pane of width 600 mm is shown between two patent glazing bars with edge cover and edge clearance at each side totalling 25 mm. The distance between the stalks or webs of the glazing bars is shown as 610 mm, thus allowing for expansion of the pane and for any other required tolerances. When the pane is centrally located, as in the upper diagram of Figure A.1, a gap of 5 mm exists at each edge of the pane. However, should the pane move over to one side, as in the lower diagram of Figure A.1, and completely close the gap at one edge, a gap of 10 mm will now exist at the opposite edge. Even in the latter case, the minimum edge cover of 15 mm is maintained at both edges.

Similar consideration should be made for the design and layout of four-edge systems of sloping glazing.

Dimensions in millimetres

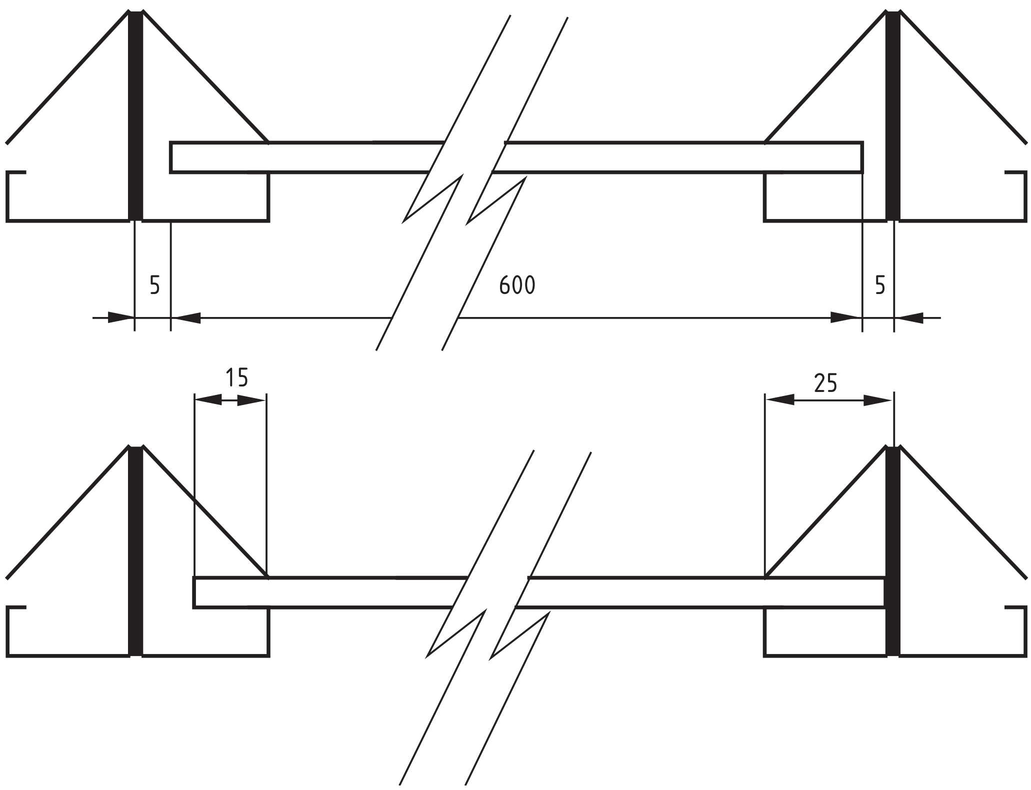
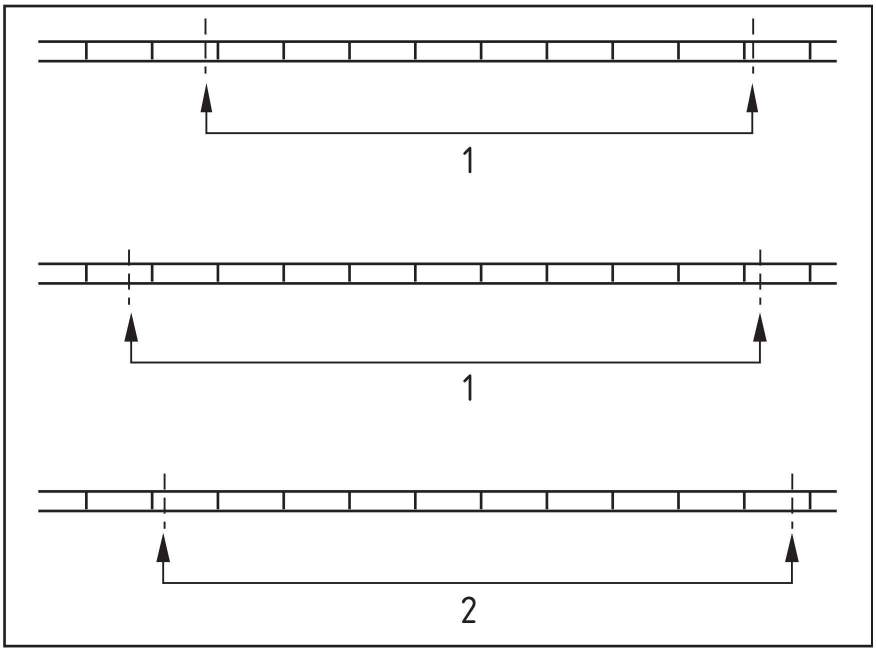


Figure A.1 — Minimum edge cover of plastics glazing sheet material

A.3.2 ***Hollow section plastics glazing sheet materials***

Frames used with hollow section plastics glazing sheet materials will often be of the same design as those used with solid sheets. However, the spacing of the webs in the sheet can affect the minimum requirements for edge cover and advice should therefore be sought from the manufacturer concerning acceptable designs of frames for the particular sheet considered.

Care should be taken when cutting hollow section panes to width. It is possible to cut the sheet just inside one of the supporting webs in the sheet thus leaving unsupported skins at the edge of the pane which make no contribution to the integrity of the glazing. This is a particular problem with hollow section sheets with wide web spacing. Figure A.2 illustrates the acceptable and unacceptable cutting of hollow section panes.



Key

1 Acceptable

2 Unacceptable

Figure A.2 — Acceptable and unacceptable positions for cutting hollow section plastics glazing sheet material

A.4 Multiple glazing with plastics glazing sheet materials

Double or multiple glazing systems, which include at least one pane of plastics glazing sheet materials, should be installed as vented coupled glazing. Hermetically sealed units should not be manufactured using plastics glazing sheet materials. Plastics glazing sheet materials allow the diffusion of gases and vapours, including water vapour, in minute amounts. Desiccants used in hermetically sealed units will therefore eventually be unable to cope with the increase in humidity resulting from this diffusion.

Hollow section plastics glazing sheet materials are effectively multiple glazing sheets and should be installed as vented glazing.

Advice should be sought from the manufacturer concerning the correct method and materials to employ in preparing vented units with a particular plastics glazing sheet material. Failure to design and construct units correctly can lead to permanent internal condensation and possibly the growth of algae where there is insufficient airflow. Where there is too much air flow, the inside surfaces of the sheet will become soiled. It is usually impossible, or at best very expensive, to remedy such conditions.

In the design of multiple units including one or more panes of plastics glazing sheet materials, the following rules should be followed unless there are specific overriding reasons not to, in which case advice should always be sought from the manufacturer.

— Where clear transparent and tinted panes are used together, the tinted pane should always be to the outer side of the glazing to minimise solar heat gain in the cavity between the panes.

— Where panes of different material are used, the pane of material with the lowest moisture diffusion rate should go to the side with the highest ambient air moisture content. This is usually the side to the interior of the building.

— The design of the vented glazing and choice of materials in contact with the panes should take account of any differing expansion coefficients and chemical compatibility requirements of both materials.

— The choice of gasket materials and spacer should take account of the fact that high temperatures can be produced in the system as a result of solar heat gain combined with the insulation provided by the pane.

A.5 Sealing and glazing materials

Some types of sealing and glazing material are chemically incompatible with plastics glazing sheet materials. The effect of this can be short term or long term. The detrimental effect can occur on either the plastics glazing sheet material or the sealing/glazing material, or both. Increased temperature due to solar energy gain or the imposition of relatively high stress on the plastics glazing sheet material can result in an adverse chemical effect that would not otherwise occur. Some coatings used on gaskets to lubricate them and ease installation can also be chemically incompatible with plastics glazing sheet materials.

Consideration should also be given to the design of the gasket taking into account the fact that, under load, plastics glazing sheet materials flex more than glass. They also exhibit more reversible movement than glass due to temperature change and, in the case of acrylic materials, moisture absorption also. Gaskets should therefore be designed to accommodate movement of the pane without consequential loss of integrity or weather resistance properties.

Advice should be sought from the manufacturer concerning suitable design of gasket and suitable composition of gasket, sealant or mastic.

A.6 Flashings and other weatherings

Flashings and weatherings should be chemically compatible with plastics glazing sheet materials and be designed to allow expansion and contraction of the pane while retaining their weather performance.

Because plastics glazing sheet materials flex more under load than some other glazing, preformed rigid flashings, which are not permanently deflected by flexing panes, should be used. In addition, the pane should be supported on the opposite side from the flashing to prevent deflection of the pane away from the flashing when under load.

Annex B (normative)
Wind load

B.1 Summary of BS 6399-2

The maximum one hour mean wind speed likely to be exceeded on average only once in 50 years at a height of 10 m above ground in open, level country is determined for the district where the building is located. This basic wind speed is multiplied by appropriate factors to take account of altitude, topography, building life and wind direction to give the site wind speed.

The site wind speed is then multiplied by a terrain and building factor, relating to the height of the building and the distance of the site from the sea and from the edges of towns, to give the effective gust wind speed.

The effective wind speed is then converted to a dynamic pressure, expressed in N/m^2, from the standard relationship given in SI units. The maximum inward (positive) pressure and the maximum outward (negative) pressure exerted at any point on the surface of the sloping glazing are obtained by multiplying the resulting dynamic pressure by appropriate pressure coefficients based on the combination of the sloping glazing being subjected simultaneously to positive pressure on one surface and negative pressure on the other.

For external walls and roofs of clad buildings the value of these pressure coefficients is the difference between an external pressure coefficient which is dependent on the shape and size of the building, wind direction and the position of the sloping glazing under consideration, and an internal pressure coefficient evaluated on the basis of the size and distribution of openings in the building. For roofs of freestanding, open-sided canopies combined overall pressure coefficients are used depending on the shape of the roof, the degree of obstruction under the canopy and the position of the sloping glazing under consideration.

A negative sign prefixing a pressure coefficient indicates a suction (negative pressure) as distinct from a positive pressure and the design wind loads p_w thus derived, which can be both positive and negative, act in a direction normal to the surface of the sloping glazing.

NOTE Extremes of internal pressure can arise when a building is only partially clad during its construction. This should be considered so that the most vulnerable conditions of partial cladding and dangerous structural shapes are avoided.

B.2 Abbreviated method of determination of design wind load for low rise buildings

To find the design wind loading, select:

a) the basic wind speed from Figure B.1;

b) the site terrain category from Table B.1,

then use these to obtain the dynamic wind pressure at sea level equivalent from Table B.2.

Table B.1 — Site terrain categories

Description	Category
Open country up to 10 km from open sea	A
Open country more than 10 km and up to 50 km from open sea	B
Open country more than 50 km from open sea	C
Town areas up to 10 km from open sea	D
Town areas more than 10 km and up to 50 km from open sea	E
Town areas more than 50 km from open sea	F
NOTE For sites less than 0.3 km from the edge of town, the site terrain category should be taken as open country.	

To obtain the dynamic wind pressure, q, for the site, multiply the dynamic wind pressure at sea level, q_0, by the factor $F_A = \left(1 + \frac{H_A}{1\,000}\right)^2$, where H_A is the altitude of the site in metres, and also by the topographical factor F_T from Table B.3.

$$q = q_0 F_A F_T$$

Select the appropriate net pressure coefficients, C_p, both suction (upward) and pressure (downward), from Table B.4. Multiply the dynamic wind pressure for the site by the pressure coefficients to obtain the design wind pressures acting downwards and upwards on the glazing.

$$p_W = qC_p$$

The limitation of the abbreviated method is that the buildings are not more than 15 m in overall height.

If this limitation is not valid, then the method described in BS 6399-2:1997 should be used.

An example of the abbreviated calculation method is given an Annex E

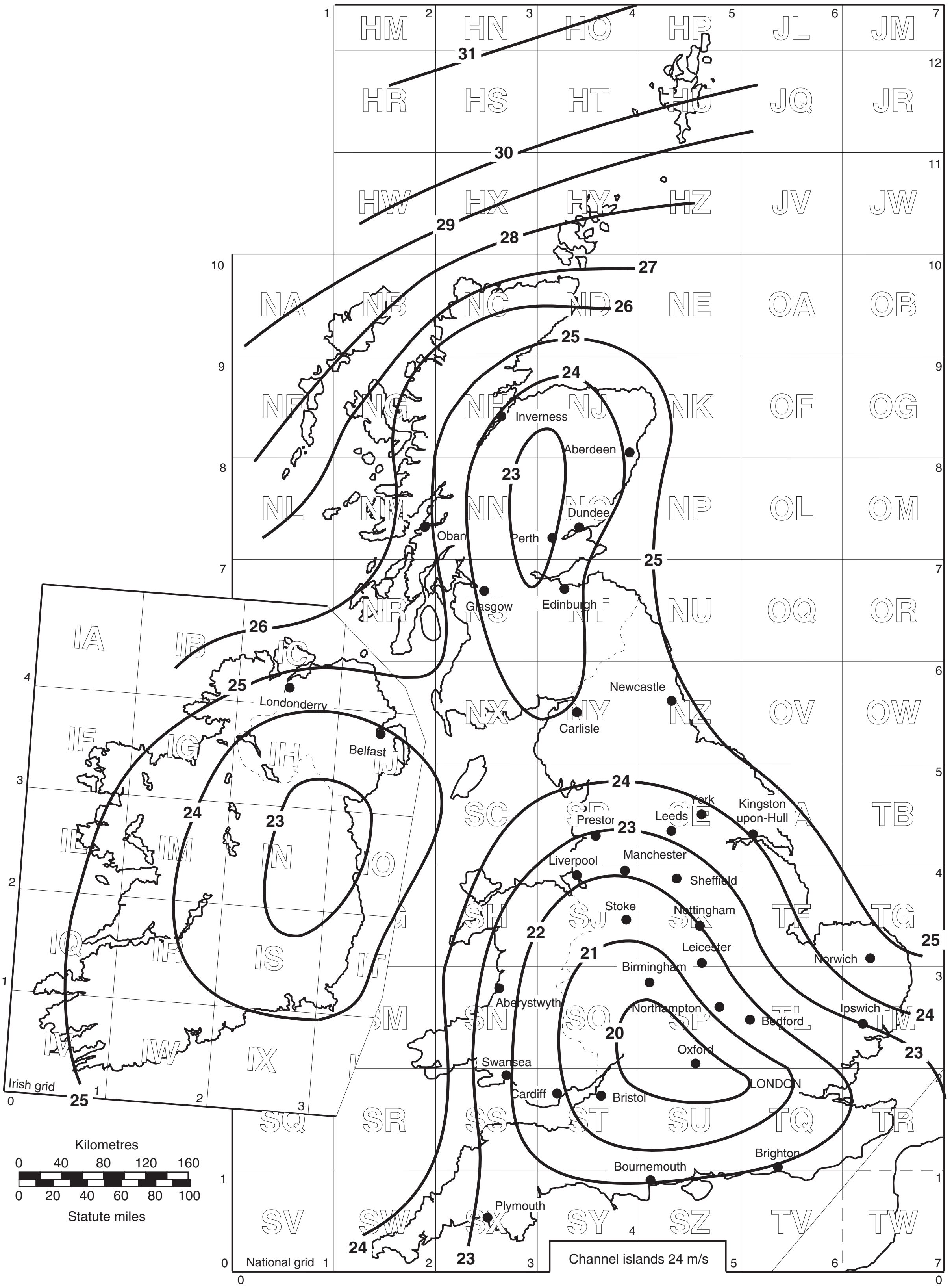


Figure B.1 — Basic wind speed map (from BS 6399-2:1997)

Table B.2 — Dynamic wind pressure

Basic wind speed m/s from Figure B.1	Height of building m	Dynamic wind pressure (N/m²) for site terrain category (see Table B.1)					
		A	B	C	D	E	F
20	⩽ 5	668	604	567	501	440	408
	> 5 and ⩽ 10	786	734	692	659	612	574
	> 10 and ⩽ 15	848	821	768	725	684	651
21	⩽ 5	736	666	625	553	485	450
	> 5 and ⩽ 10	866	809	763	727	675	633
	> 10 and ⩽ 15	935	905	847	800	754	718
22	⩽ 5	808	731	685	607	533	494
	> 5 and ⩽ 10	951	888	837	798	741	695
	> 10 and ⩽ 15	1 026	994	930	878	827	788
23	⩽ 5	883	799	749	663	582	540
	> 5 and ⩽ 10	1 039	971	915	872	810	759
	> 10 and ⩽ 15	1 122	1 086	1 016	959	904	862
24	⩽ 5	961	870	816	722	634	588
	> 5 and ⩽ 10	1 131	1 057	997	950	881	827
	> 10 and ⩽ 15	1 222	1 182	1 106	1 045	985	938
25	⩽ 5	1 043	944	885	783	688	638
	> 5 and ⩽ 10	1 228	1 147	1 081	1 030	956	897
	> 10 and ⩽ 15	1 325	1 283	1 200	1 133	1 068	1 018
26	⩽ 5	1 128	1 021	957	847	744	690
	> 5 and ⩽ 10	1 328	1 240	1 170	1 115	1 034	970
	> 10 and ⩽ 15	1 434	1 388	1 298	1 226	1 156	1 101
27	⩽ 5	1 217	1 102	1 032	914	802	744
	> 5 and ⩽ 10	1 432	1 337	1 261	1 202	1 116	1 046
	> 10 and ⩽ 15	1 546	1 497	1 400	1 322	1 246	1 187
28	⩽ 5	1 308	1 185	1 110	983	863	800
	> 5 and ⩽ 10	1 540	1 438	1 356	1 293	1 200	1 125
	> 10 and ⩽ 15	1 663	1 609	1 506	1 422	1 340	1 277
29	⩽ 5	1 404	1 271	1 191	1 054	926	858
	> 5 and ⩽ 10	1 652	1 543	1 455	1 387	1 287	1 207
	> 10 and ⩽ 15	1 784	1 726	1 615	1 525	1 438	1 370
30	⩽ 5	1 502	1 360	1 275	1 128	991	918
	> 5 and ⩽ 10	1 768	1 651	1 557	1 484	1 377	1 291
	> 10 and ⩽ 15	1 909	1 848	1 728	1 632	1 539	1 466
31	⩽ 5	1 604	1 452	1 361	1 205	1 058	980
	> 5 and ⩽ 10	1 888	1 763	1 663	1 584	1 471	1 379
	> 10 and ⩽ 15	2 038	1 973	1 846	1 743	1 643	1 565

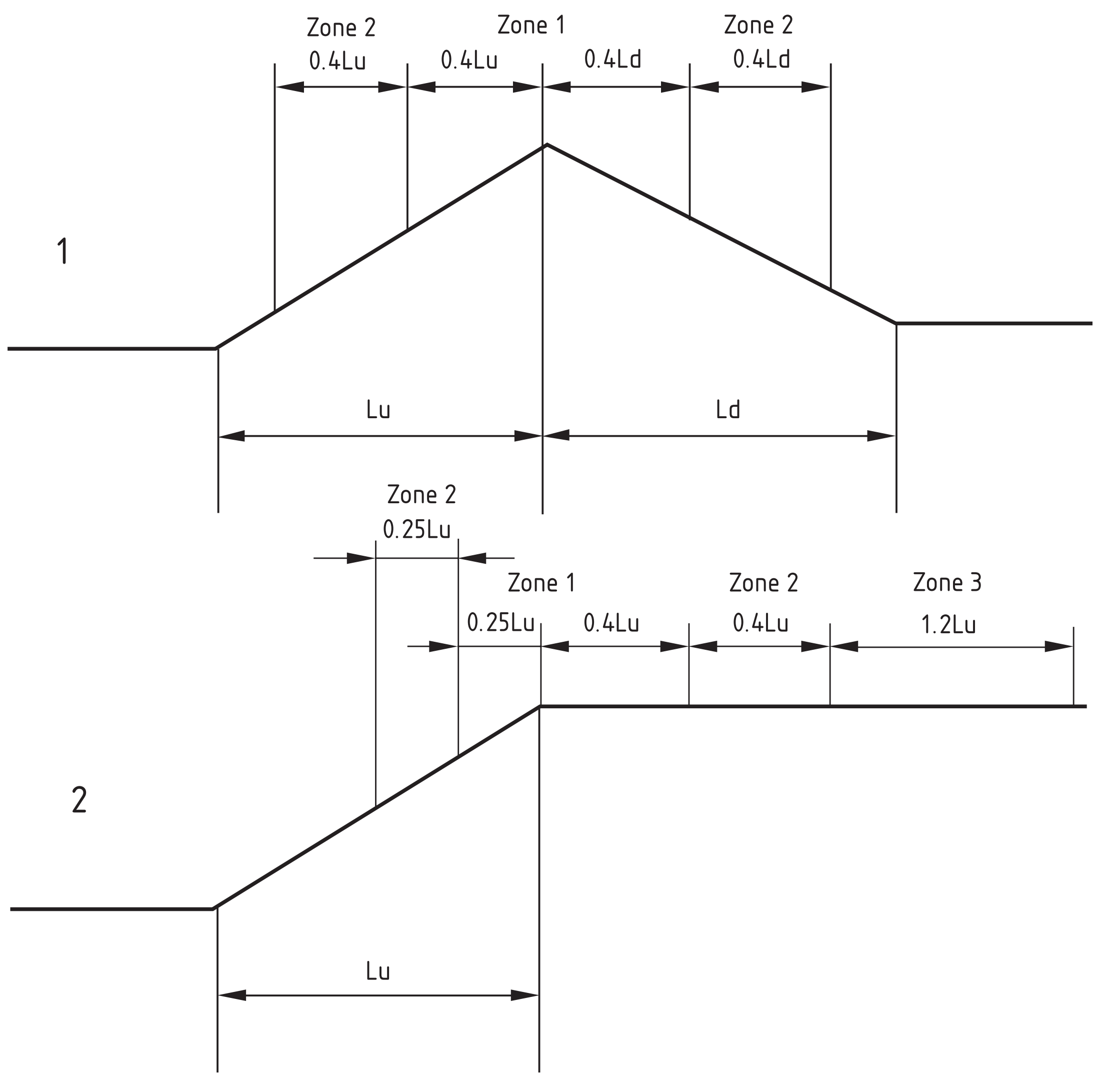
NOTE 1 The values are rounded.

NOTE 2 N/m² = Pa.

NOTE 3 The derivation of this table is shown in **B.3**.

Table B.3 — Topographical factor

Topographical category and description	Factor F_T according to zone from Figure B.2			
	Zone 1	Zone 2	Zone 3	Elsewhere
Category 1: Nominally flat terrain ground slope <1/20	1.0	1.0	1.0	1.0
Category 2: Moderately steep terrain ground slope ⩽1/5	1.54	1.28	1.21	1.0
Category 3: Steep terrain ground slope >1/5	1.85	1.44	1.32	1.0



Key
1 Hills and ridges
2 Cliffs and escarpments

Figure B.2 — Topographic zones

Table B.4 — Net pressure coefficients

Glazing position[a]		Mono pitch roofs[b]		Duo pitch roofs[b]	
Pressure direction		**Suction**	**Pressure**	**Suction**	**Pressure**
Roof pitch in degrees	–45°	—	—	–1.2	0.5
	–30°	—	—	–1.4	0.5
	–15°		—	–2.4	0.5
	–5°	—	—	–2.0	0.5
	0°	–1.7	0.5	–1.7	0.5
	5°	–2.0	0.5	–1.7	0.5
	15°	–2.5	0.5	–1.3	0.5
	30°	–2.0	1.0	–0.9	1.1
	45°	–1.2	1.0	–0.9	1.1
	60°	–0.9	1.0	–0.9	1.1
	75°	–0.9	1.0	–0.9	1.1

Glazing position[a]		Mono pitch canopies			Duo pitch canopies		
Pressure direction		**Suction**		**Pressure**	**Suction**		**Pressure**
		No blockage	**Fully blocked**		**No blockage**	**Fully blocked**	
Roof pitch in degrees	–20°	—	—	—	–1.6	–2.7	1.7
	–10°	—	—	—	–1.6	–2.5	1.5
	0°	–1.4	–2.2	1.8	–1.4	–2.2	1.8
	10°	–2.1	–2.7	2.4	–1.5	–2.0	1.8
	20°	–2.9	–2.9	2.9	–2.0	–1.7	1.9
	30°	–3.8	–2.5	3.2	–2.0	–1.6	1.9

[a] For the purposes of this table, a roof is glazed into a closed building with relatively impermeable walls on all sides. A canopy is the roof of a structure with at least one wall mainly absent.

[b] The net pressure coefficients given for roofs are based on the assumption that all the external walls of the building have similar permeability, i.e. similar numbers and sizes of opening doors and windows etc. If external walls do not have similar permeability, or if in doubt, then increase the suction values by –0.5.

B.3 Derivation of the dynamic wind pressure in Table B.2

The values of dynamic wind pressure are derived from BS 6399-2:1997. The symbols and terminology below are described in BS 6399-2:1997.

Basic wind speed, V_b, is obtained from Figure 6 of BS 6399-2:1997 (reproduced as Figure B.1 in this standard).

Effective wind speed, $V_e = V_b S_a S_d S_s S_p S_b$

where $S_a = 1.0$ $S_d = 1.0$ $S_s = 1.0$ $S_p = 1.0$

Three building heights, H, of up to 5 m, up to 10 m and up to 15 m high have been considered. Effective height, H_e, depends on the surroundings

Open country: $H_e = H$ i.e. H_e = 5 m or 10 m or 15 m

Town (with buildings around): $H_o = 0.6H$ i.e. H_e = 3 m or 6 m or 9 m

From Table 4 of BS 6399-2:1997, for components of dimension 5 m or less, the following terrain and building factors, S_b, were calculated.

The reference wind speed, $V_e = V_s S_b$

The dynamic wind pressure at sea level, $q_0 = 0.613 V_e^2$

Table B.5 — Building factors

Site terrain category from Table B.1	S_b for building height		
	5 m	10 m	15 m
A	1.65	1.79	1.86
B	1.57	1.73	1.83
C	1.52	1.68	1.77
D	1.43	1.64	1.72
E	1.34	1.58	1.67
F	1.29	1.53	1.63

Annex C (normative)
Snow load

C.1 Summary of BS 6399-3

The load intensity of undrifted snow at ground level likely to be exceeded on average only once in 50 years at an altitude of 100 m in a sheltered area is determined for the district where the building is located. This basic snow load on the ground is adjusted on a regional basis for locations whose altitude is above 100 m and to take account of building life to give the characteristic snow load on the ground.

The snow load on the sloping glazing is obtained by multiplying the characteristic snow load on the ground by an appropriate shape coefficient based on the worst load case applicable. The value of this shape coefficient is dependent on the external shape of the roof, the position and height of any surrounding roofs and the position of the sloping glazing under consideration. Two primary loading conditions should be considered: that resulting from a uniform layer of snow and that resulting from an uneven distribution of snow. Uneven distribution can result from the transport of snow by the wind from one side of a roof to the other side or from the accumulation of drifted snow against vertical obstructions and in valleys.

The resultant snow load on the sloping glazing is assumed to act vertically and refer to a horizontal projection of the area of the glazing. For the derivation of the design snow load p_s (in N/m^2) the component of the snow load on the sloping glazing perpendicular to and measured in the plane of the glazing is required. This may be found from the following equation:

$$p_s = s_d \times 10^3 \cos^2\alpha$$

where

s_d is the snow load (in kN/m^2).

NOTE It is recommended that load cases involving local drifting of snow be treated as exceptional snow loads because of the rarity with which they are expected to occur. In such cases, the value obtained for the snow load on the roof, s_d, may be multiplied by a factor of 0.8 when deriving the design snow load, p_s for use in calculations involving the strength of sloping glazing.

C.2 Abbreviated method of determining the snow load

To determine the design snow load, select the basic snow load, s_b, in kN/m^2 from the map in Figure C.1.

Determine the altitude factor for the site from the altitude of the site, A, in metres:

$$s_{alt} = 0.1s_b + 0.09$$

Determine the site snow load, s_0, in kN/m^2:

— For site altitudes lower than 100 m: $s_0 = s_b$

— For site altitudes above 100 m: $s_0 = s_b + s_{alt}\frac{A - 100}{100}$

Determine the design snow load, s_d, in kN/m^2 as follows.

$$s_d = 0.8s_0$$

Where there is a possibility of drifting, the following design snow loads should also be considered.

a) For roofs with valleys of depth h, in metres, drift loads which are the lesser of:

$s_d = 2h$ and $s_d = 5s_0$

b) For canopies and lower roofs, extending outwards up to five metres, abutting a structure of height h_1, in metres, above the level of the canopy or roof, drift loads which are the lesser of:

$s_d = 2h_1$ and $s_d = 5s_0$

c) For canopies and lower roofs, extending outwards more than five metres, abutting a structure of height h_2, in metres, above the level of the canopy or roof, drift loads which are the lesser of:

$s_d = 2h_2$ and $s_d = 5s_0$

NOTE Drift loads can decrease rapidly away from the maximum load calculated. For the glazing bars, frames or other supporting structure, advantage of this may be taken by using the calculation methods in BS 6399-3. For glass or plastics glazing sheet material, the maximum drift load should be assumed to be applied as a uniformly distributed load over the whole surface of each pane.

This method should not be used for sites at altitude above 500 m.

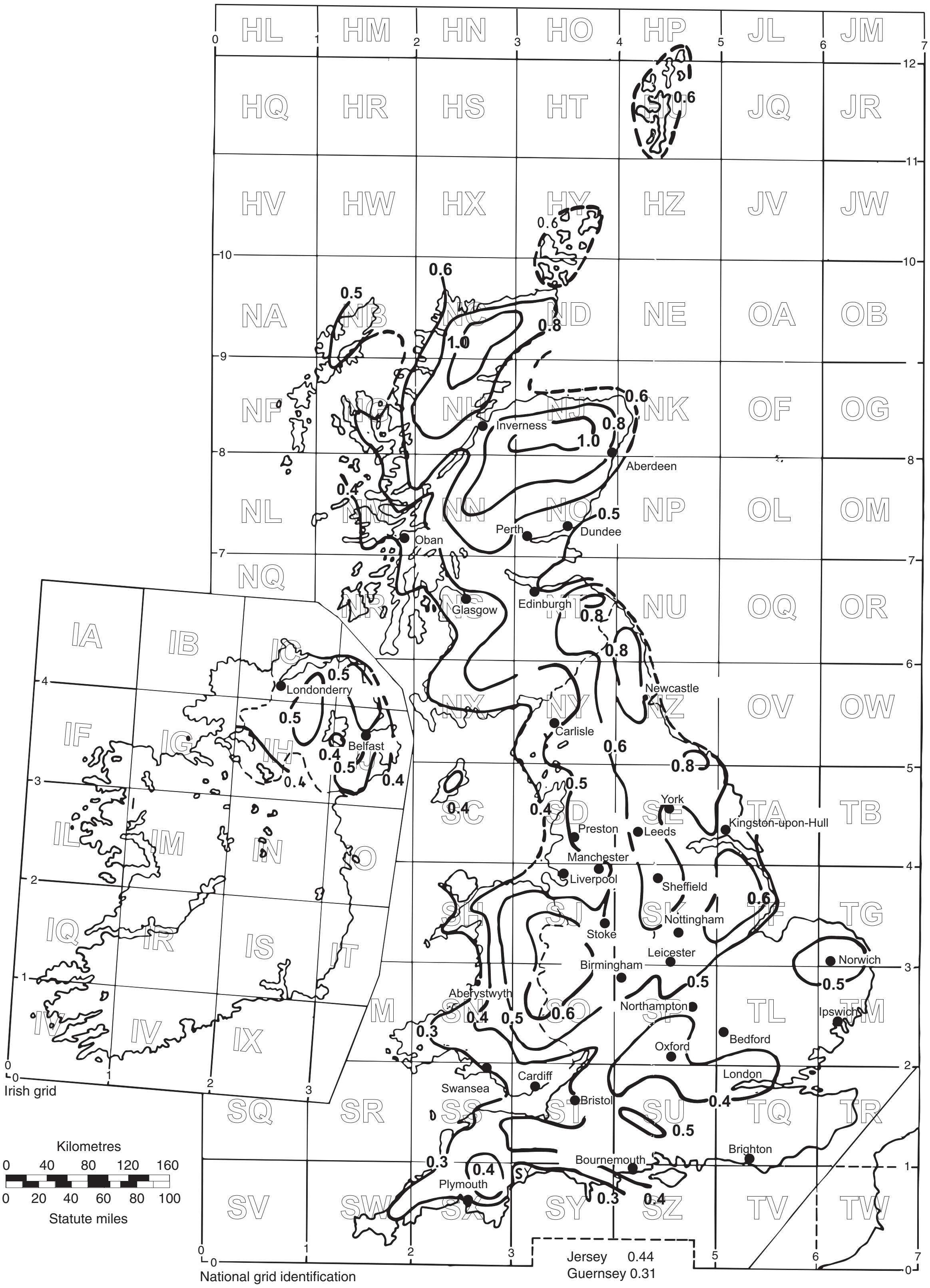


Figure C.1 — Basic snow load map (from BS 6399-3:1997)

Annex D (normative) Self-weight

Dead load for the sloping glazing should be based on the mass of the glazing only. The mass of hermetically sealed double glazing units and of laminated glass should be taken as the sum of the nominal mass of the individual glasses.

For the derivation of design dead load for the sloping glazing, p_{di} (in N/m^2), the component of the weight perpendicular to the plane of the glazing is required and use may be made of the following equation:

$$p_{di} = g_i \cos\alpha$$

where

g_i is the weight per unit area of the glazing (in N/m^2).

NOTE (Kilogram mass per square metre) × 9.81 = weight per unit area (N/m^2).

For glass, g_i = 25 N/m^2 for every millimetre thickness of glass.

For monolithic plastics glazing sheet material, g_i = 15 N/m^2 for every millimetre thickness of plastics glazing sheet material. For hollow section plastics glazing sheet materials, the manufacturer should be consulted.

Annex E (informative) Examples of working pressures for sloping glazing

E.1 General

The following example is based on the following site information.

Basic wind speed (from Figure B.1)	23 m/s
Snow load	0.6 kN/m^2
Site altitude	75 m
Site terrain category (from Table B.1)	E
Topography nominally flat	
Building height	5 m
Glazing slope	15°
Glazing is in a mono pitch roof	

E.2 Wind pressures

From Table B.2, for a basic wind speed of 23 m/s, building height 5 m and site terrain category E, the dynamic wind pressure:

$$q_o = 582 \text{ N/m}^2$$

The altitude factor:

$$F_A = \left(1 + \frac{75}{1\,000}\right)^2 = 1.156$$

The topography factor from Table B.3 is:

$$F_T = 1.0$$

The dynamic wind pressure is

$$q = 582\ 1.156 \times 1.0 = 673 \text{ N/m}^2$$

From Table B.4 for a mono pitch roof at 15°, the pressure coefficients are:

Suction: $C_p = -2.5$

Pressure: $C_p = 0.5$

giving design pressures:

Suction: $p_w = 673 \times (-2.5) = -1682\ \text{N/m}^2$

Pressure: $p_w = 673 \times 0.5 = 336\ \text{N/m}^2$

E.3 Snow load

The snow load has been given as:

$$s_d = 0.6\ \text{kN/m}^2$$

From Annex B, the design snow load is:

$$p_s = s_d \times 10^3 \cos^2(15) = 560\text{N/m}^2$$

E.4 Self weight

The self weight component of the load depends on the thickness of glazing being assessed. for the purposes of this example, the glazing will be taken as:

Glass 6 mm toughened glass upper pane, 6.4 mm laminated glass lower pane.

The nominal total thickness is 12 mm (interlayer thicknesses can be ignored), so the weight per unit area from Annex D is:

$$g_i = 25 \times 12 = 300\ \text{N/m}^2$$

From Annex D the design dead load is:

$$p_d = 300 \times \cos(15) = 290\ \text{N/m}^2$$

Plastics glazing sheet material Single glazed 4 mm

The nominal thickness is 4 mm, so the weight per unit area from Annex D is:

$$g_i = 15 \times 4 = 60\ \text{N/m}^2$$

From Annex D, the design dead load is:

$$p_{di} = 60 \times \cos(15) = 58\ \text{N/m}^2$$

E.5 Working pressure

E.5.1 ***Glass***

The working pressure is calculated in accordance with **7.3.2**.

Stress calculations

Pressure load: $0.6p_w + 2.6(p_s + p_{di}) = 0.6 \times 336 + 2.6(560 + 290) = 2\ 412\ \text{N/m}^2$

or: $p_w + 2.6(0.6p_s + p_{di}) = 336 + 2.6(0.6 \times 560 + 290) = 1\ 964\ \text{N/m}^2$

Suction load: $-p_w + p_{di} = -1\ 682 + 290 = -1\ 392\ \text{N/m}^2$

The highest numerical value is 2 412 N/m^2,

so: $p_{g;f} = 2\ 412\ \text{N/m}^2$

Deflection calculations

Pressure load: $0.6p_w + (p_s + p_{di}) = 0.6 \times 336 + (560 + 290) = 1\ 052\ \mathrm{N/m^2}$

or: $p_w + (0.6p_s + p_{di}) = 336 + (0.6 \times 560 + 290) = 962\ \mathrm{N/m^2}$

Suction load: $-p_w + p_{di} = -1682 + 290 = -1\ 392\ \mathrm{N/m^2}$

The highest numerical value is 1 392 $\mathrm{N/m^2}$,

so: $p_{g;y} = 1\ 392\ \mathrm{N/m^2}$

E.5.2 ***Plastics glazing sheet materials***

The working pressure is calculated in accordance with **7.3.3**.

Pressure load: $0.6p_w + 2(p_s + p_{di}) = 0.6 \times 336 + 2(560 + 58) = 1\ 438\ \mathrm{N/m^2}$

or: $p_w + 2(0.6p_s + p_{di}) = 336 + 2(0.6 \times 560 + 58) = 1\ 124\ \mathrm{N/m^2}$

Suction load: $-p_w + p_{di} = -1\ 682 + 58 = -1\ 624\ \mathrm{N/m^2}$

The highest numerical value is 1 624 $\mathrm{N/m^2}$,

so: $p_p = 1\ 624\ \mathrm{N/m^2}$

Annex F (normative) Methods of calculating glazing thickness

F.1 Strength of glass to withstand uniform loading

F.1.1 ***General***

The procedure given in **F.1.2** is for glazing with four-edge fully supported rectangular panes of glass, as described in BS 952-1. The procedure applies to single glazing, to insulating glass units and to all other forms of double glazing, whether sealed, openable or permanently ventilated.

If the aspect ratio of the glass is more than 3, then the glass should be designed as two edge supported with the shorter dimension as the span.

The procedure given in **F.1.3** is for glazing with two-edge fully supported rectangular panes of glass, as described in BS 952-1. The procedure applies to single glazing, to insulating glass units and to all other forms of double glazing, whether sealed, openable or permanently ventilated.

For glass to be considered as supported along an edge, the deflection of each supported edge should be restricted to the limits given in **7.6**.

Calculated examples are given in **F.3**.

F.1.2 ***Use of working pressure graphs to determine the thickness of four-edge supported glass***

The design working pressures, for both deflection and strength calculation, should be determined from **7.3.2** using design loads obtained by the abbreviated methods in Annex B, Annex C and Annex D or by the full methods from BS 6399.

For four-edge fully supported panes, Figure 4g) to Figure 4l) should be used for the appropriate glass type, and the procedure should be as follows.

a) Calculate the area $A = ab$, and the aspect ratio, $r = a/b$, where a is the longer dimension and b is the shorter.

NOTE If r is greater than three, the Figure 4g) to Figure 4l) do not apply; the glass should be designed as two edge supported, according to **F.1.3**, with the shorter dimension as the span.

b) Calculate the shape factor for effective area $F = 4r/(r + 1)^2$. Some values are given in Table F.1.

c) Calculate the effective area of the glass $A_e = F_A$.

d) On the appropriate graph from Figure 4g) to Figure 4l), determine the point where the vertical line for the required downward working pressure for strength calculation intersects the horizontal line for the effective area.

e) If the point of intersection is above the solid line for the glass type being considered, then a stronger glass is required.

f)) If the point of intersection is on or below the solid line for the glass type being considered, then the glass is adequate to resist the downward working pressure.

g) If the graph has dotted lines indicating a deflection limitation, then repeat d) to f) using the working pressures for deflection calculation.

Table F.1 — Shape factors

r	*F*
1.0	1.000
1.25	0.988
1.5	0.960
1.75	0.926
2.0	0.889
2.5	0.816
3.0	0.750

F.1.3 ***Use of working pressure graphs to determine the thickness of two-edge supported glass***

The design working pressures, for both deflection and strength calculation, should be determined from **7.3.2** using design loads obtained by the abbreviated methods in Annex B, Annex C and Annex D or by the full methods from BS 6399.

For two-edge supported panes, Figure 4a) to Figure 4f) should be used for the appropriate glass type, and the procedure should be as follows.

a) On the appropriate graph from Figure 4a) to Figure 4f), determine the point where the vertical line for the required downward working pressure for strength calculation intersects the horizontal line for the span of the glass.

b) If the point of intersection is above the solid line for the glass type being considered, then a stronger glass is required.

c) If the point of intersection is on or below the solid line for the glass type being considered, then the glass is adequate to resist the downward working pressure.

d) If the graph has lines indicating a deflection limitation, then repeat a) to c) using the working pressures for deflection calculation.

F.2 Strength of plastics glazing sheet material to withstand uniform loading

F.2.1 *General*

The recommendations given in **F.2** are for flat, plane, solid plastics glazing sheet materials of uniform thickness, in rectangular shapes.

Failure of a pane of plastics glazing sheet material under load is most likely to be by displacement of the pane rather than by breakage. The recommendations on thickness for plastics glazing sheet material is related to the minimum size of edge cover needed to prevent a pane of specified thickness from springing out under loading in normal glazing conditions. The design considerations are based on this.

The procedure given in **F.2.2** is for glazing with four-edge fully supported rectangular panes of solid plastics glazing sheet material.

The procedure given in **F.2.3** is for glazing with two-edge fully supported rectangular panes of solid plastics glazing sheet material.

For plastics glazing sheet material to be considered as supported along an edge, the deflection of each supported edge should be restricted to the limits given in **7.6**.

Calculated examples are given in **F.3**.

F.2.2 ***Use of working pressure graphs to determine thickness of four-edge supported solid plastics glazing sheet materials***

The design working pressure should be determined from **7.3.3** using design loads obtained by the abbreviated methods in Annex B, Annex C and Annex D or by the full methods from BS 6399.

For four-edge fully supported panes, Figure 5b) to Figure 5d) should be used for the appropriate aspect ratio, and the procedure should be as follows. For panes having an aspect ratio greater than 3.5:1 or when they are non-rectangular, the manufacturer should be consulted.

In order to limit the deflection for larger panes, the manufacturer should be consulted where areas of individual panes exceed 2 m^2.

a) Calculate the area of the pane, $A = ab$ and the aspect ratio, $r = a/b$, where a is the longer dimension and b is the shorter.

b) On the appropriate graph for the aspect ratio from Figure 5b) to Figure 5d) determine the point where the vertical line for the required working pressure intersects the horizontal line for the required area.

c) If the point of intersection does not coincide with a thickness line, the recommended thickness for use with the corresponding size of edge cover is indicated by the line above.

F.2.3 ***Use of working pressure graphs to determine the thickness of two-edge supported plastics glazing sheet material***

The design working pressure should be determined from **7.3.3** using design loads obtained by the abbreviated methods in Annex B, Annex C and Annex D or by the full methods from BS 6399.

For two-edge supported panes, Figure 5a) should be used, and the procedure should be as follows.

a) On Figure 5a), determine the point where the vertical line for the required downward working pressure for strength calculation intersects the horizontal line for the span of the plastics glazing sheet material.

b) If the point of intersection is above the solid line for the plastics glazing sheet material thickness being considered, then a thicker plastics glazing sheet material is required.

c) If the point of intersection is on or below the solid line for the plastics glazing sheet material thickness being considered, then the plastics glazing sheet material is adequate to resist the downward working pressure.

F.2.4 ***Design of hollow section plastics glazing sheet materials***

The stiffness of a hollow plastics glazing sheet material is determined by the material from which it is made, the overall thickness and the geometry of the sheet. The deflection characteristics of a particular hollow section plastics glazing sheet material vary according to which direction the webs run in relation to the long edges of the pane. It is not practical, therefore to produce a set of graphs relating wind loading to hollow section sheets because of the variety of profiles and thicknesses. Advice should be obtained from the manufacturer.

F.3 Calculation examples

F.3.1 ***Four edge supported glass***

The glass type (6 mm toughened outer pane, 6.4 mm laminated inner pane) and working pressure for stress calculation (2 412 N/m^2) are taken from the example in Annex E. The pane size is 1 400 mm × 2 400 mm. The procedure is described in **F.1.2**.

a) $A = 1.4 \times 2.4 = 3.36$ m^2, $r = 2\,400/1\,400 = 1.714$

b) $F = 4r/(r + 1)^2 = 0.931$

c) $A_e = FA = 3.36 \times 0.931 = 3.13$ m^2

d) The appropriate graph is Figure 4l).

e) and f): The point of intersection for a working pressure of 2 412 N/m^2 with an effective area of 3.13 m^2 lies below the line labelled $6L + 6T$.

The glass is able to resist the working pressure. This does not necessarily mean the glass is suitable for the purpose – there are other criteria which might also need to be considered.

F.3.2 ***Two edge supported glass***

The glass type (6 mm toughened outer pane, 6.4 mm laminated inner pane) and working pressure for stress calculation (2 412 N/m^2) are taken from the example in Annex E. The pane size is 850 mm × 2 400 mm, supported on the long edges. The procedure is described in **F.1.3**.

a) The appropriate graph is Figure 4f).

b) and (c): The point of intersection for a working pressure of 2 412 N/m^2 with a span of 0.85 m lies above the line labelled 6*L* + 6*T*.

The glass is inadequate to resist the working pressure. A different, stronger, glass product should be selected and the calculation performed again. Note that the design load will need to be recalculated if the total glass thickness changes.

F.3.3 ***Four edge supported plastics glazing sheet material***

The plastics glazing sheet material thickness (4 mm) and working pressure (1 624 N/m^2) are taken from the example in Annex E. The pane size is 570 mm × 1 160 mm. The procedure is described in **F.2.2**.

a) A = 0.57 × 1.16 = 0.66 m^2, r = 1 160/570 = 2.04

b) The appropriate graph is Figure 5c). The point of intersection for a working pressure of 1 624 N/m^2 with an effective area of 0.66 m^2 lies below the line labelled 4 mm.

4 mm single plastics glazing sheet material is able to resist the working pressure. This does not necessarily mean the plastics glazing sheet material is suitable for the purpose – there are other criteria which might also need to be considered.

F.3.4 ***Two edge supported plastics glazing sheet material***

The plastics glazing sheet material thickness (4 mm) and working pressure (1 624 N/m^2) are taken from the example in Annex E. The pane size is 570 mm × 1 160 mm, supported on the long edges. The procedure is described in **F.2.3**.

a) The appropriate graph is Figure 5a).

b) and c): The point of intersection for a working pressure of 1 624 N/m^2 with a span of 0.57 m lies above the line labelled 4 mm.

4 mm plastics glazing sheet material is inadequate to resist the working pressure. The calculation will need to be performed again for 6 mm or 8 mm thick plastics glazing sheet material. Note that the design load will need to be recalculated to accommodate the thickness change.

Bibliography

Standards publications

BS 5250:2002, *Code of practice for control of condensation in buildings.*

BS 5516:1991, *Code of practice for design and installation of sloping and vertical patent glazing.*

BS 5516-3 (in preparation), *Patent glazing and sloping glazing for buildings — Part 3: Special applications.*

BS 5502-21:1990, *Buildings and structures for agriculture — Part 21: Code of practice for selection and use of construction materials.*

BS 5588 (all parts), *Fire precautions in the design, construction and use of buildings.*

BS 6213:2000, *Selection of construction sealants — Guide.*

BS 8000-7:1990, *Workmanship on building sites — Part 7: Code of practice for glazing.*

BS 8206-2:1992, *Lighting for buildings — Part 2: Code of practice for daylighting.*

BS EN 572-1:1995, *Glass in building — Basic soda lime silicate glass products — Part 1: Definitions and general physical and mechanical properties.*

BS EN 12758:2002, *Glass in building — Basic soda lime silicate glass products — Definitions and general physical and mechanical properties.*

BS EN ISO 140-3:1995, *Acoustics — Measurement of sound insulation in buildings and of building elements — Part 3: Laboratory measurement of airborne sound insulation of building elements.*

BS EN ISO 717-1:1997, *Acoustics — Rating of sound insulation in buildings and of building elements — Part 1: Airborne sound insulation.*

BS EN ISO 14438:2002, *Glass in building — Determination of energy balance value — Calculation method.*

DD ENV 1187:2002, *Test methods for external fire exposure to roofs.*

prEN 14179 (all parts), *Glass in building — Heat soaked thermally toughened soda lime silicate safety glass.*

Other publications

[1] *Health and safety in roof work*. HSG33 ISBN 0-7176-1425-5 (1980) HS. HSE Books. PO Box 1999. Sudbury, Suffolk. CO10 2WA.

[2] GREAT BRITAIN. Building Regulations England & Wales, Approved Document B.

[3] GREAT BRITAIN. Construction Design and Management Regulations, the Construction (Working Places) Regulations 1966, SI 64.

[4] National Building Specification (NBS). *Access for cleaning and maintenance*. NBS National Building Specification Subscription Service. Work Section N25: Permanent Access and Safety Equipment, August 2002.

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