MALAYSIAN STANDARD

DMS 2753-1:2025

Use of glass in building – Code of Practice Part 1 – Selection of glass

ICS: 81.040.20

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Department of Standards Malaysia (Secretariat)
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Universiti Teknologi Malaysia

The Working Group on Code of Practice for Glass (NSC 04/TC 9/WG 6) which developed this Malaysian Standard consists of representatives from the following organisations:

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Federation of Malaysian Manufacturers
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Safety Glass Processor Association of Malaysia
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Foreword

This Malaysian Standard was developed by the Working Group on Code of Practice for Glass (NSC 04/TC 9/WG 6) under the authority of the National Standards Committee on Building and Civil Engineering Works (NSC 04).

MS 2753 consists of the following parts, under the general title Use of glass in building – Code of Practice

Part 1: Selection of glass
Part 2: Design and analysis

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

CONTENTS

Use of glass in building – Code of Practice – Part 1: Selection of glass

1 Scope

This document provides guidelines on the design, construction, testing, quality assurance and installation of glass structures or elements in buildings.

1.1 Design considerations

1.1.1 Aim of glass design

The limit state design principle is adopted for structures using glass with the aim to achieve the following:

i) Overall stability and buckling resistance against the design loads;

ii) Strength against collapse under the design loads and the imposed deformations of supporting structures;

iii) Integrity and robustness against progressive collapse under the design loads;

iv) Serviceability under the design loads and the imposed deformations of supporting structures;

v) Water and air tightness;

vi) Durability

vii) Quality; and

viii) Maintainability during its design working life.

1.1.2 Design references

The document has made references to various international standards in Annex A. Where an alternative method or a performance-based approach is adopted, adequate information, including proposals on compliance testing, must be provided to demonstrate that the aim of glass design specified in clause 1.1.1 can be achieved.

2 Normative references

The following documents are referred to in the text in such a way that some or all their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

MS 832, Aluminium alloy windows – Specification

MS 1017, Aluminium framed sliding glass doors – Specification

MS 1057, Specification for adjustable louvre windows

MS 1135, Float glass – Specification

MS 1498, Safety glass in building – Specification

MS 1553, Code of practice on wind loading for building structure

MS 2397, Coated glass in building – Specification

MS 2666, Glass in buildings - Insulating Glass Unit (IGU) - Performance and evaluation

MS 2676, Wired glass – Specification

MS EN 1991-1-4, Eurocode 1: Actions on structures - Part 1-4: General actions - Wind actions

BS 8206-2, Lighting for buildings – Part 2- Code of practice for daylighting

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
bite
width of structural sealant used to bond the glass to supporting members.

3.2
buckling resistance
limit of force or moment that a member can withstand without buckling failure.

3.3
curtain wall
non-load-bearing enclosure fixed onto the load-bearing structure with its dead loads, imposed loads and wind loads transferred to the structure through fixings.

3.4
ultimate design strength
ultimate design strength obtained by applying partial material factor to the specified minimum yield strength or tensile strength of the material.

3.5
gasket
plastic-like solid material used to separate glass and other brittle materials from contact with each other or supporting frames.

3.6 Glass

3.6.1
annealed glass
sheet, plate, float or rolled glass that is processed to allow residual internal stresses to be relaxed so that it can be freely cut shall comply with MS 1135.

3.6.2
decorative glass
clear or tinted glass processed by craftsmen for decorative effect. Sand-blasted, acid-etched, embossed, fritted and printed glass fall into this category. Decorative interlayers may also be incorporated in laminated glass.

3.6.3
heat strengthened glass
glass which has been subjected to a special heat treatment so that the residual surface compression stresses lie between 24 MPa to 52 MPa.

Note 1 to entry: Monolithic heat strengthened glass is not suitable for the safety glazing application.

3.6.4
Insulating Glass Unit (IGU)
an assembly consisting of at least two panes of glass, separated by one or more spacers, hermetically sealed along the periphery, mechanically stable and durable.

Note 1 to entry: Systems are available where the spacer and hermetic seal are included within a single edge sealing system.

3.6.5
laminated glass
glass consisting of two or more sheets of glass permanently bonded together by one or more sheets of plastic interlayer. Plastic interlayer can consist of polyvinyl butyral (PVB), thermoplastic polyurethane (TPU), ethyl vinyl acetate (EVA), polyethylenes, polycarbonates, polyurethanes and other plastics.

3.6.6
patterned glass
glass having a pattern impressed/embossed on one side or both sides.

3.6.7
safety glass
glass or glass assemblies that are “break safe” such as laminated or tempered glass.

3.6.8
tempered glass
glass of any shape that has been subjected to a thermal treatment process characterised by uniform heating followed by rapid uniform cooling to produce comprehensively stressed surface layers.

3.6.9
tinted glass
glass to which a small amount of colour has been added consistently through the glass batch which reduces glare and absorbs heat.

3.6.10
wired glass
a single sheet of glass with wire completely embedded in the glass. The wired glass shall comply with MS 2676.

3.7
glass wall
wall mainly formed by structural glass elements spanning between floors.

3.8
heat soak process
quality control process to heat up tempered glass for a period of time to reduce the possibility of spontaneous breakage in service.

3.9
instability
inability to carry further load due to vanishing stiffness.

3.10
interlayer
layer or multiple layers of material acting as an adhesive between glass panes which enhance the performance of the finished assembly, for example, composite action, impact resistance, solar control, acoustical insulation, etc.

3.11 Load

3.11.1
dead load
any permanent structural or non-structural loads that remain throughout the service life of a structure as stated in the Uniform Building By Law (UBBL).

3.11.2
dynamic load
part of an imposed load resulting from motion.

3.11.3
factored load
specified load multiplied by the relevant partial safety factor.

3.11.4
imposed load
applied load, with the exception of dead and wind loads, likely to arise during the service life of a structure as stated in the Uniform Building By Law (UBBL).

3.11.5
wind load
applied load as calculated in accordance with the Code of Practice on Wind Loading for Building Structure in Malaysia.

3.12
linear analysis
analysis based on elastic stress and the original geometry prior to deformation for stress computation.

3.13
local stability
stability of element or part of element against local buckling.

3.14 Members

3.14.1
glass beam
one-dimensional load-bearing element predominantly subject to bending.

3.14.2
glass column
vertical load-bearing element predominantly carrying axial force and possibly moments.

3.14.3
glass fin
vertical or sloping glass beam used to support façade and glass wall which are predominantly subject to wind load and other lateral load.

3.14.4
transom
horizontal member in curtain wall or glass wall system that directly supports a glass/ cladding element.

3.15 Restraints

3.15.1
lateral restraint for a glass fin
restraint that prevents lateral movement of the compression edge.

3.15.2
torsional restraints
restraint that prevents rotation of a member about its longitudinal axis.

3.16
nonlinear analysis
structural analysis that allows for nonlinear effects such as large deflection effect and membrane action. Nonlinear analysis can be second-order direct and second-order indirect analysis of which the former does not require effective length for flexural buckling check and the latter still requires effective length for flexural buckling check.

3.17
overall stability
stability of overall structure against buckling, overturning, uplift and sliding.

3.18
setting block
block of resilient non-absorbent material placed between the bottom edge of the glass and frame to support the dead load of the glass to the frame at specific points to limit deformation of the supporting member.

3.19
single glazing
single glazed window is constructed using a single pane of glass, or a laminated glass.

3.20
monolithic/single pane
single homogeneous piece of glass as opposed to laminated glass or insulating glass unit.

3.21
slenderness
effective length divided by the radius of gyration.

3.22
stability
resistance to failure by buckling or loss of static equilibrium.

3.23
wardrobe doors
doors that provide access to built-in storage areas excluding those fitted to pieces of furniture that are not built into the building.

3.24
window
framed glazing in an opening of an external wall to allow natural light and/or ventilation through the building.

3.25
window wall
windows spanning between floor slabs of the building.

4 Symbols

A	Cross-sectional area of the member
E	Modulus of elasticity
G	Shear modulus
L	Span between end supports or Length
M_d	Ultimate design moment obtained from loading
M_w	Working design moment obtained from loading
M_{cr}	Critical elastic buckling moment
M_e	Elastic moment capacity
M_u	Ultimate moment capacity
R	Factored design pressure
b_i	Minimum structural sealant bite
c	Strength coefficient
k_{pane}	Load sharing factor of glass pane
t	Minimum thickness of glass pane
t_{eq}	Equivalent laminated glass thickness
C_t	Tensile stress (lateral load) of secondary (structural) sealant
I_{eq}	Equivalent second moment of area due to composite action in laminated glass
I	Second moment of area of monolithic glass with total thickness equal to sum of individual glass
p_b	Permissible design bond strength for structural sealant
p_y	Ultimate design strength
p_{yf}	Ultimate design strength of glass fin
γ_d	Strength reduction factor
γ_f	Partial load factor
γ_s	Glass surface treatment reduction factor
γ_m	Partial material factor
λ	Degree of composite action in terms of stiffness
ρ	Density of glass pane
δ	Deflection of glass pane or Deflection due to member curvature and loads
υ	Poisson's ratio

5 Energy, light and sound

5.1 Energy

5.1.1 General

Glazed areas in buildings should be designed so that account is taken of the overall energy balance in relation to the effects on the thermal comfort of occupants and the total annual energy implications of solar gain and energy loss.

These should be examined separately, since factors affecting one aspect of performance might have no effect on the other. Energy gain is due to transmission of solar radiant energy through the glass into the building. Solar energy is all at relatively short wavelengths and is controlled by using the glass to absorb or reflect the energy. Energy loss is due to the transfer of energy by conduction, convection and long wavelength radiation and can be influenced by a number of factors, e.g. incorporating air cavities, including gases of low thermal conductivity and/or low emissivity glass.

5.1.2 Thermal comfort

Energy transmission through glazing can significantly influence occupier comfort by raising or lowering room air temperatures. For example, hot sunny weather can increase heat gain, while heat loss can occur through 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.

5.1.3 Solar energy gain

a) Orientation;

b) Glazed area;

c) Shading devices, both internal and external;

d) Properties; and

e) Others

5.1.4 Total solar energy transmittance

5.1.4.1 General

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

The total solar energy transmission properties of solar control glazing can be described by their shading coefficients. 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, clear glass 3 mm thick)

NOTE: Total solar energy transmittance is also known as g value.

5.1.4.2 Solar control glass

5.1.4.2.1 General

Solar control glass can be manufactured in several forms (see 5.1.4.2.2, 5.1.4.2.3 and 5.1.4.2.4). 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 attenuate preferentially non-visible solar radiation, leaving the transmission of the greater proportion of the visible radiation largely unchanged.

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.

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.

5.1.4.2.2 Body tinted glass

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 because the energy due to the absorbed radiation is more easily dissipated to the outside.

5.1.4.2.3 Coated glass

5.1.4.2.3.1 Solar reflective glass

Solar reflective 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 complied with MS 2397.

Note: Compared with a float glass surface, soft coated solar reflective glass (owing to their composition) exhibits lower levels of emissivity which improves their U value.

The advantages of such glass types are:

a) Greater performance range than body tinted glass;

b) Higher performances (greater solar energy attenuation); and

c) A range of colour appearances in transmission and reflection.

5.1.4.2.4 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.

5.1.4.2.5 Insulating glass units

Insulating glass units, whilst used primarily for improved thermal transmittance (U value), can also improve the total solar energy transmittance. This improvement is a result of the incorporation of a second pane of glass together with the hermetically sealed airspace. The second glass panes can be any glass type. The main glasses used as the inner pane are clear glass, hard coat low emissivity glass or soft coat low emissivity glass.

Note: Soft coat low emissivity glass must be used with the hermetically sealed airspace to protect the coating.

5.1.5 Blinds and louvres

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

5.2 Light

5.2.1 Daylighting

5.2.1.1 Daylighting prediction

Daylighting prediction for interior spaces is usually based on "daylight factor" concepts. The daylight factor is a ratio, expressed as a percentage of the illuminance at a point on a given internal plane due to light received directly and indirectly from a sky of known or assumed luminance distribution, to the illuminance on a horizontal plane from an unobstructed hemisphere of the sky.

Windows which have a view of the high altitude (overhead) areas of the overcast sky, with corresponding high luminance, will admit more daylight to the interior. Caution should be exercised that these windows do not become a source of glare, because of the higher luminance. With a clear sky the opposite should be considered, together with orientation. Integration of daylight and artificial light is important to the energy efficiency of buildings and should be considered carefully. Since the CIE (Commission Internationale de l'Eclairage) overcast sky (see Annex A) assumes no orientation effects, the estimates of daylight contribution can be in error. To correct this, orientation factors have been derived to be applied to the daylight factors.

NOTE: Further information on the calculation of daylight factors can be found in BS 8206-2.

5.2.2 User requirements from daylight

5.2.2.1 Task lighting

Standards of daylight provision for task lighting are set out in BS 8206-2 based on the provision of illumination on the working plane.

NOTE: Task lighting cannot be provided by daylight alone for the entire working day throughout the year, and some form of artificial lighting is required to supplement available daylight. Glazed areas should not be used excessively as a means to admit more daylight, as this might give rise to solar overheating.

5.2.2.2 Energy conservation

Good window design can, by reducing reliance on artificial lighting, be one of the largest single means of saving energy and should be carefully considered.

Account should be taken of room shape, window orientation, occupancy patterns and tasks, together with the relationship of windows to surrounding buildings and other obstructions. As with task lighting, possible solar overheating might result and similar precautions should be taken.

5.2.3 Light transmission properties of windows

Light transmission is defined as the fraction of visible light at normal incidence transmitted through the glazing. Visible light has a spectral distribution corresponding to the CIE Standard Illuminant D65, approximately the same as daylight.

Dirt on glazing reduces the light transmission, often by an appreciable extent before becoming noticeable. To ensure daylighting levels are adequate, an allowance for the reduced light transmission should be made in daylighting calculations by introducing a "dirt factor" between 0.7 and 1.0. Glass should be cleaned regularly.

5.2.4 Glazing properties and their influence on daylight quantity and quality

5.2.4.1 Light transmission for task lighting

The level of task lighting is determined principally by the light transmission of the glazing and the extent and size of the glazed area. The quality of the lighting and its distribution depend on the shape of the glazing, its position and orientation, and the nature of the internal space.

Clear glass, with a light transmission of 87%, when correctly positioned in a window wall, with little obstruction and light-coloured interior decoration, will provide adequate daylighting to a depth of about 6 m from the window.

NOTE: Reducing the height of the window reduces the depth of daylight penetration and changing its shape and distribution influences the lighting levels and quality.

5.2.4.2 Light transmission for amenity lighting

Judgement of acceptability of an interior, where recreation and social contact predominate, is based on the appearance of the furnishings and the other occupants. This is determined by the areas of light and shade giving shape and detail. Thus, special attention should be paid to the "flow" of light within the interior and its intensity and distribution. The visual success of the overall lighting system should be judged by the balance between "directional" light, which flows over and around the interior and its contents, and the "non-directional" diffuse light reflected from the walls, floor and ceiling.

5.2.4.3 Light transmission for energy conservation

Four distinct situations should be considered:

a) Interiors where the average daylight factor is greater than 5%;

b) Rooflit interiors where the average daylight factor is less than 2%;

c) Rooflit or shallow sidelit interiors having average daylight factors of 2% to 5%; and

d) Deep sidelit rooms

Where the average daylight factor exceeds 5%, natural lighting should be adequate for most purposes during daylight hours. In rooflit areas with average daylight factors less than 2%, permanent supplementary lighting is usually required. Lighting controls should be arranged to switch or dim individual luminaries at fixed steps of illumination. When the average daylight factor is between 2% and 5%, the supplementary lighting should be planned to take full advantage of available daylight. The provision of automatic controls for switching should result in significant energy savings. The position of luminaries should be carefully arranged in relation to the position of windows in order to preserve the daylit character. In deep sidelit spaces the supplementary lighting should be carefully zoned.

Note: It is often advantageous to use local artificial task lighting and to use daylight to provide general background lighting. Before any lighting system is satisfactorily specified, either as a totally daylit system or as an integrated daylight/artificial system, the amount and distribution of natural light should be predicted, using one of the many methods currently available (e.g. BS 8206-2).

5.2.5 Glare

5.2.5.1 General

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 should not be a glare problem.

NOTE: Contrasts in excess of 10:1 in illumination in different parts of the field of view might give rise to glare in some form.

5.2.5.2 Disability glare

Reducing the light transmission of glazing from 87 % to 60 % produces a just perceptible reduction in disability glare caused by direct sunlight. Even when the light transmission of the glazing is as low as 10 %, some 10 000 lux can still be experienced and glare will almost certainly occur.

Glare can be reduced by some form of mechanical shading, e.g. a canopy, an overhanging floor, a balcony, or a louvre system. Alternatively, internal screening can be provided by louvres or blinds.

NOTE: Any fixed shading system reduces the amount of natural light entering the building throughout the year, irrespective of whether there is a glare problem at any particular time. It might also be possible to reorientate the glazing to avoid entry of direct solar radiation. Alternatively, the interior layout can be suitably designed to eliminate glare.

5.2.5.3 Discomfort glare

Glazing products 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, may be used.

Other methods of reducing the problems of glare should be considered, including:

a) Installation of windows in more than one wall to raise the general background illumination and, in so doing, to reduce the contrast between a window and its surrounding surfaces;

b) Use of light-coloured matt finishes for the window frames and the surrounding surfaces;

c) Splayed reveals, to assist in reducing the contrast between the window and its surroundings;

d) Use of slender glazing bars and transoms of high reflectance; and

e) Lowering windowsills to allow increased illumination to enter, which increases the adaptation level and reduces the likelihood of discomfort glare.

5.2.6 Diffusion and obscuration

The nature of some glazing products (e.g., patterned or acid etched glass) can cause the direct incident solar beam to be scattered diffusely. Hence the window might 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.

5.2.7 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 might 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:

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

b) 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;

c) The temperature should be reduced. All changes involved in fading proceed more rapidly at higher temperatures; and

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

NOTE: Significant reduction in UV transmission can be achieved by using 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.

5.2.8 One way vision

Effective one way vision may be provided by suitably adjusting the amounts of reflection on each surface of the glazing and controlling the lighting levels on both sides of the glazing.

NOTE: It is very difficult to obtain one way vision through external windows, as daylight cannot be controlled. Venetian strip silvered glass or a reflective coated glass are two common materials used to achieve one way vision.

5.3 Sound

5.3.1 Introduction

Noise, i.e. unwanted sound, can be attenuated by employing thick glazing, insulating 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.

NOTE: Further information on the performance of glass can be obtained from BS EN 12758.

5.3.2 Source of noise

5.3.2.1 Road traffic noise

Road traffic noise is a very common problem, particularly in urban areas, where low frequency noise from engine and exhaust systems predominates. On faster roads, tyre noise (which is of higher frequency) becomes more important.

5.3.2.2 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 up to 10 dB for a similar level of disturbance.

5.3.2.3 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.

5.3.2.4 Speech

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

5.3.3 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 should 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 Hz, 250 Hz, 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz. However, for some critical applications it is useful to extend the range down to 50 Hz and/or up to 5000 Hz.

When more detailed analysis is appropriate, these octave bands may be subdivided into three (except for the 4 000 Hz band) to give 16 one-third-octave bands at 100 Hz, 125 Hz, 160 Hz, 200 Hz, 250 Hz, 315 Hz, 400 Hz, 500 Hz, 630 Hz, 800 Hz, 1000 Hz, 1250 Hz, 1600 Hz, 2000 Hz, 2500 Hz and 3150 Hz.

5.3.4 Acoustic indices

5.3.4.1 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 7.4.2, 7.4.3 and 7.4.4). The indices Rw, C and C describe sound reduction.

NOTE: Of the previously used sound reduction indices (R Rw and R) R is no longer required, Rw is effectively unchanged and RTRA can be approximated by Rw + Cu.

5.3.4.2 Weighted sound reduction index, Rw

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 is described in BS EN ISO 717-1 and BS EN ISO 717-2, 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.

5.3.4.3 Sound reduction against specific noises, Rw(C;C)

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 windows. 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 and BS EN ISO 717-2 describe the calculation of two spectrum adaptation terms, C and Cr. These can be added to Rw to give an indication of the sound reduction in dB of the window (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:

$$Rw(C:C) = 41(0;-0.5)\ dB \qquad (1)$$

where

Rw = 41 dB;

C = 0 dB;

Ctr = -5 dB

If an extended frequency range has been specified, it is denoted as in the following examples: C50-3150, C50.5000, C100-5000, Ctr.50-3150, Ctr.50-5000 and Cr100.5000.

5.3.5 Sound reduction of a single glass pane

5.3.5.1 General

Glass has a very low sound absorption. Several factors affect the overall acoustic performance. These include the mass, coincidence resonance, gaps in frames, edge support conditions, lamination and pane dimensions (see 5.3.5.2, 5.3.5.3 and 5.3.5.4).

5.3.5.2 Effect of mass

Doubling the glass thickness, and therefore the mass, results in about 4 dB increase in sound reduction.

5.3.5.3 Coincidence resonance

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

$$Fc = 12000/d \qquad (2)$$

where

d is the glass thickness (mm)

5.3.5.4 Lamination

Instead of using ordinary solid (or monolithic) window 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. Two main types of interlayer material may be used, polyvinylbutyral (PVB) and polymethylmethacrylate (PMMA).

There are important differences in the acoustic performances of these two kinds of interlayer. Polyvinylbutyral generally offers a smaller acoustic effect as it couples the individual glass plies together. With PMMA, the individual plies of glass tend to act as if they were separate entities, so the residual resonances occur at frequencies which correspond closely with the individual glass components of the laminate. Thus, the PMMA shifts these resonances to higher frequencies where, generally, they play a less important role in overall attenuation of common noises.

NOTE 1: PMMA is a generic name for a wide variety of resins. The acoustic performance of these resins can vary considerably with type.

NOTE 2: There are special types of PVB available with enhanced acoustic performance. The manufacturer of the interlayer or laminated glass should be consulted for more information.

5.3.6 Sound reduction of insulating glass units and secondary glazing

5.3.6.1 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 5.3.6.2, 5.3.6.3 and 5.3.6.4).

5.3.6.2 Different glass thickness

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.

5.3.6.3 Cavity width

Over the usual cavity range of 6 mm to 16 mm for insulating glass units, there is little variation of acoustic performance. Where higher sound reduction of windows is required cavity widths of greater than 100 mm 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.

5.3.6.4 Gas filling

For applications where middle frequency acoustic performance is critical (e.g. speech), insulating glass units can benefit from being filled with sulfur hexafluoride (SF) gas mixtures. However SF_6, introduces a significant resonance at 200 Hz to 250 Hz and, for noise dominated by low frequency components, such as traffic noise, this might be detrimental.

Note: SF_6 is a potent greenhouse gas and its use is discouraged.

Argon filled units, used for improving thermal insulation, exhibit exactly the same acoustic performance as standard air-filled units of the same glass combination.

6 Glass

6.1 General

Glass is a brittle material and normally fails in a sudden and catastrophic manner. Glass is weak in tension because of the nature of its atomic structure and the resulting susceptibility to flaws and inability to resist crack propagation. When glass is loaded in tension it behaves purely elastically until it fails suddenly at the ultimate tensile strength, unlike structural steels, aluminium alloys and even reinforced concrete that can accommodate plastic deformation after yield point (Figure 1). Stress or moment re-distribution does not occur in glass and local failure commonly leads to global failure. Glass strength is highly statistical in nature in common with other brittle materials. Highly stressed and larger stressed area results in a higher probability of failure.

In most structural applications of glass, it is necessary for the components to sustain mechanical stress. When a material is stressed, it deforms, and strains are created. At a low level of stress, most materials obey Hooke's law, that is, strain is linearly proportional to stress. For ductile materials such as metals and plastics; after they reach their yield point, they undergo a significant portion of plastic deformation. On the other hand, brittle materials such as glasses and ceramics, can accommodate very little, if any, plastic deformation and fail suddenly (Figure 1).

Glass at normal temperatures does not creep or "flow" and does not undergo fatigue in the metallurgical sense. Rather, there is slow growth of micro-cracks under sustained or cyclical loads. Once the cracks have reached a critical size, the glass may fail suddenly in a brittle manner.

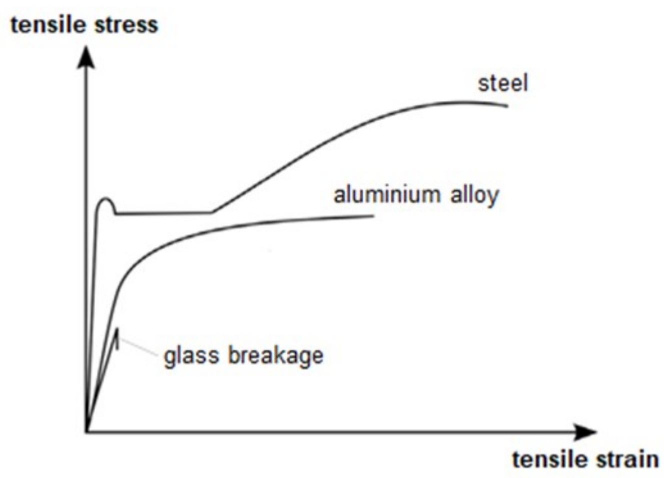


Figure 1 – Stress-strain behaviour of glass, steel and aluminium

6.2 Glass materials

Glass is an inorganic solid with a non-crystalline (amorphous) atomic structure and is produced from a wide variety of constituent materials. This clause applies to soda lime silicate glass commonly used in buildings.

The typical composition and physical properties of soda lime silicate glass are shown in Table 1 and Table 2 respectively.

Table 1 – Glass chemical composition

Chemical		Float Glass	
Element	**Composition (%)**	**Except Ultra-Clear**	**Ultra-Clear**
Silicon dioxide (SiO_2)	69 to 74	√	√
Calcium oxide (CaO)	5 to 12	√	√
Sodium oxide (Na_2O)	12 to 16	√	√
Magnesium oxide (MgO)	≤ 6	√	√
Aluminium oxide (Al_2O_3)	1.1 to 3	√	√
Ferric oxide (Fe_2O_3)	≤ 0.02	N/A	√

NOTE: The float glass that will be coated during production shall comply to all the above specification except for Al_2O_3 which are 0% to 3%

Table 2 – Typical physical properties of glass

Property	Symbol	Value
Modulus of elasticity	E	70,000 N/mm^2
Shear modulus	G	E / [2(1 + v)]
Poisson's ratio	υ	0.22
Coefficient of thermal expansion	α	9 × 10^{-6} /°C
Density	ρ	2,650 kg/m^3

6.3 Glass types

6.3.1 Annealed glass

Annealed glass, also known as sheet, plate, float or rolled glass that is processed to allow residual internal stresses to be relaxed so that it can be freely cut. Annealed glass breaks into large jagged shards and in an extremely dangerous manner.

Annealed glass is relatively susceptible to impact, bending stress, thermal stress and imposed strains. Fracture of annealed glass depends on the flaws in the glass, the stress level, the stressed surface area and the duration of the load. The flaws in the glass may be inherent or may result from the cutting, grinding or drilling of the glass and from the environment to which the glass has been subjected (e.g. humidity promotes crack growth).

6.3.2 Heat treated glass

Heat treated glass products, whether heat strengthened or tempered, are produced in a very similar fashion using the same processing equipment. The glass is heated to approximately 650ºC and then force cooled to create surface and/or edge compression in the glass. It is by controlling the rate of cooling that determines if the glass is either heat strengthened or tempered.

6.3.2.1 Heat strengthened glass

Heat strengthened glass is produced from annealed glass by first cutting to shape and put under a thermal cycle. This cycle involves heating the glass to a temperature slightly above the annealing point followed by air quenching of the glass surface. This process cools and solidifies the surface first. As the interior starts to cool, the glass tries to shrink inside and goes into tension and with the stresses balanced by the compressive stresses at the surface. This heat treatment results in a fracture characteristic that produces fragments smaller but still like annealed glass. After the heat treatment process, the surface compressive stress is to be greater than 24 MPa but less than 52 MPa.

Surface compression shall be measured by light refraction methods with the light source of semiconductor laser 635 nm or similar methods as stated in ASTM C1279.

The surface compressive stress could also be measured by Grazing Angle Surface Polarimeter (GASP) or Differential Stress Refractometer (DSR) on the "tin side" of flat, soda-lime float glass. Tin side is the side of glass that was in contact with the molten tin bath in the float process. The GASP or DSR is based on a non-destructive photoelastic test method, using light rays traveling along the glass surface.

The inherent benefit of the heat strengthening process is that, unlike annealed glass, surface cracks do not easily propagate as the heat strengthened glass is under compressive stress.

6.3.2.2 Tempered glass

Tempered glass, also known as "fully tempered" or "thermally toughened" glass, is produced in the same way as heat strengthened glass, except that it is quenched more rapidly. This heat treatment results in a larger variation between the compressive stress at the surface and tensile stresses at the interior, as shown in Figure 2. After the heat treatment process, the surface compression stress shall comply with MS 1498. When tempered glass breaks, it will fracture into small, roughly cubic fragments.

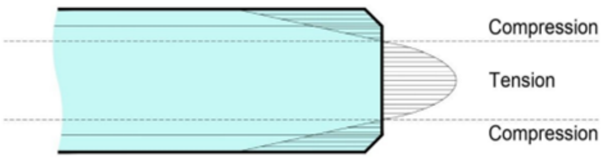


Figure 2 – Stress profile in tempered glass

Surface compression shall be measured by light refraction methods with the light source of semiconductor laser 635 nm or similar methods as stated in ASTM C1279.

The surface compressive stress of tempered glass could also be measured by the GASP or DSR. Tempered glass exhibits high values of bending strength because of the locked-in compressive surface stresses. In some cases, the design is controlled by deflections and the strength of tempered glass may not be fully exploited.

Bolt holes do not cause large changes in surface stress, as long as their diameter is at least equal to the thickness of the glass. This enables cooling air to pass readily through the holes so that glass edges along the bolt holes cool at a similar rate as the parent glass pane. All cutting and drilling and grinding of glass must be carried out before the glass is tempered, in order to avoid glass shattering. Tempered glass has a better resistance against stress concentration at openings.

Tempered glass is susceptible to “spontaneous breakage” due to Nickel Sulphide (NiS) inclusions inside the high tensile zone at the interior. The process causing breakage occurs when α-NiS particles are trapped in the tensile zone of the glass during production and transformed to the larger volume β-NiS phase. As the transformation continues the volume eventually increases and induces stresses in the glass pane causing spontaneous breakage. To minimize spontaneous breakage, tempered glass should go through heat soak process based on EN 14179 Part 1 and Part 2, during its production as tempered glass containing NiS inclusions will break during the process and would not be put in use. Requirement and quality assurance of heat soak process are given in clause 9.2 of MS 2753-2.

6.3.3 Laminated glass

Laminated glass is formed by two or more glass panes bonded by means of an interlayer. The principal materials for the interlayer described in clause 7.4 of MS 2753-2 are films such as polyvinyl butyral (PVB), resin or equivalent. The interlayer usually ranges from 0.38 mm to 6.0 mm in thickness. As described in clause 6.3.3 of MS 2753-2, laminated glass shall be designed with no composite action unless otherwise justified by tests.

Laminated glass can incorporate any of the different glass types and panes with different thicknesses. However, it is recommended to use same glass type and the difference of glass thickness not greater than one thickness grade. The flexibility in the selection of the individual glass panes allows a range of products to be produced with mechanical and optical properties tailored to suit particular applications.

Heat strengthened glass and tempered glass have different amplitude waves on the surface caused by rolling process. In this connection, precaution should be taken to address the risk of separation and delamination by providing sufficient thickness of interlayer. For glass panes with surface treatment applied on the inner surface of the laminated glass, durability tests may be required to examine the quality and durability of lamination.

Laminated glass is considered as a safety glass with high reliability, suitable for glass balustrade, as the glass debris is adhered to the interlayer even after breakage. Replacement of damaged laminated glass should be carried out as soon as possible because the entire glass pane may still fall from height. To ensure the lamination quality and minimise the risk of delamination, adequate quality control measures as described in clause 9.1.4 of MS 2753-2 should be implemented. Besides, it is a good practice if the edges of laminated glass are to be protected from direct exposure to weather.

6.3.4 Insulating glass units

The insulating glass unit (IGU) is formed by two or more panes of glass spaced apart and hermetically sealed to form a single-glazed unit with an air space between glass panes as shown in Figure 3. IGU provides better performance in sound and heat insulation. It can further be made to become reflective and low-emissivity (low-E) glass, however the soft coated low-E at the edge of IGU should be removed to avoid coating oxidation and to ensure the adhesion of secondary seal. The common form of IGU incorporates spacer bar with desiccant filled, primary seal and secondary seal. Spacer bar shall be made of material compatible with seals and desiccant filled to ensure seal durability to MS 2666. Primary seal is of low permeability and serves to minimise water vapour and gas permeating the air cavity between the glass panes of IGU. Secondary seal shall be two-part structural sealant which completely covers spacer with no gaps or voids, continuously bonded to glass. The gap between the two or more panes of glass provides relatively good insulation compared to the normal glass. The gap can be filled by gas, such as hexafluoride, which is a good sound insulator. Tin side of the glass panes should be located on the outermost surfaces of IGU for future surface stress measurement.

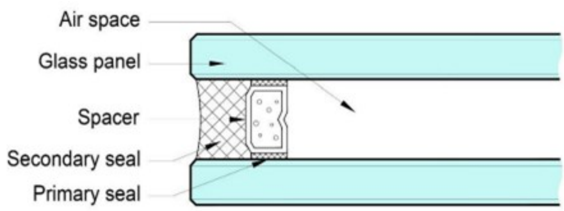


Figure 3 – Edge of typical IGU

6.3.5 Coated glass

Coated glass has a coating or treatment applied that tunes the performance of glass to reduce energy consumption. The low- E glass surface does not absorb radiation heat and reflects it so the thermal insulation properties can be improved. The effect of using coated glass may not be on structural aspect, except that the surface temperature may have some effects on the surface thermal stress and it is in general insignificant for heat strengthened or tempered glass complied with MS 2397.

6.3.6 Fire-rated glass

Glass is generally non-combustible. However, when exposed to the effects of heat, normal glass products shatter easily because of their low tensile bending strength in conjunction with their relatively high coefficient of thermal expansion.

Fire-rated glass commonly uses a clear intumescent interlayer “gel” in a laminated or multi-laminated glass assemblies. At elevated temperature, the intumescent interlayer turns into a rigid and opaque fire shield. The higher the fire resistance rating requirement, the thicker the glass assembly and the greater the number of interlayers. Durability tests for fire-rated glass such as high-temperature test, humidity test and radiation test should be carried out.

6.3.7 Decorative glass and fritted glass

A wide variety of techniques may be employed to apply decorative treatments to glass surface. The most common methods include coating, acid etching, sand blasting, fritting, screen printing, ink-jet printing, body tinting, embossing and abrading. Decorative interlayers may also be incorporated in laminated glass. The purpose of these treatments is to confer aesthetic benefits. It is possible that some of these treatments, such as fritting and engraving, may reduce the strength and durability of the glass, the effect of which on the ultimate design strength of glass pane is given in clause 6.4 of MS 2753-2, Ultimate limit state design. The surface stress and fragmentation shall be comply with MS 1498 requirement.

6.4 Strength of glass

The strength of glass varies greatly depending on the particular heating and cooling cycle(s) (heat treatment) that are applied in its production resulting in different types of glass. The types of glass commonly used for construction are outlined in clauses 6.3.1 to 6.3.2.2.

Breakage of glass is due to the stress concentrated at the micro cracks on its surface. The ultimate design strength of glass is defined as the strength at which not more than 8 out of 1000 glass panes would fail.

The ultimate design strength (py) of glass under short-term load duration is given in Table 3. As the strength of glass depends on load duration, a strength reduction factor (γd) should be applied to py for medium and long-term load duration for different glass types as given in Table 4. Definition of load duration is given in clause 5.5 of MS 2753-2

Also, as the strength of glass depends on different glass surface treatment, a glass surface treatment reduction factor (γs) should be applied to py as given in Table 5. Design strength of glass with surface treatment should be verified by bending test.

Table 3 – Ultimate design strength (p_y) for different glass types under short- term load duration

Type of glass	Ultimate design strength (p_y) under short-term load duration (MPa)
Annealed	20
Heat strengthened	40
Tempered	80

Table 4 – Strength reduction factor (γ_d) applied to p_y for different load durations and glass types

Type of glass	Strength reduction factor (γ_d)		
	Short-term load duration	Medium-term load duration	Long-term load duration
Annealed	1.00	0.53	0.29
Heat strengthened	1.00	0.73	0.53
Tempered	1.00	0.81	0.66

Table 5 – Glass surface treatment reduction factor (γ_S) for different glass types

Type of glass	Glass surface treatment reduction factor (γ_s)
Flat clear, tinted or coated glass	1
Ceramic fritted or enamelled painted glass	0.625
Patterned (embossed), sand blasted or acid etched glass	0.5

7 Criteria for human impact safety

7.1 Scope

Where any glazing is within 2000 mm above the ground level of all buildings it is considered likely to be subjected to human impact and, hence, shall comply with the human impact safety requirements of this clause.

Where reference is made to floor or ground level this shall mean the highest abutting finished floor or ground level.

NOTE 1: In some circumstances the requirements of other clauses of this standard can exceed the requirements of this clause.

NOTE 2: Accident statistics show that glazing in some locations in buildings is more vulnerable to human impact than in others. These critical locations, some of which are shown in Figure 4 including the following:

a) In and around doors (particularly in side panels which may be mistaken for doors);

b) Panels mistaken for a doorway or opening;

c) Bathrooms and toilets;

d) Buildings associated with special activities, e.g., gymnasia, enclosed swimming pools, etc;

e) Schools and child care facilities; and

f) Retirement villages, nursing homes, and aged care facilities.

NOTE 3: Locations not listed in Note 2 above, where injury can occur, are addressed in this section of the standard.

NOTE 4: Precautions should be taken to reduce the risk of injuries that can result from glass breakage by:

a) Selecting glass of a suitable type, thickness and size in accordance with the requirements of this clause;

b) Enhancing a person's awareness of the presence of glass by making glass visible (manifestation, see Clause 7.15); or

c) Minimizing manual handling of large pieces of glass during installation.

NOTE 5: Glass is a brittle material. The application of this clause requiring the use of either safety glass or thicker annealed glass will reduce the risk of injury from human impact. However, this does not assume that the glass will not be broken under all human impact conditions, but rather it will not be broken under the most likely forms of human impact. When broken, the likelihood of cutting or piercing injuries will be minimized by virtue of the protection given to the glass, or by the limited size or increased thickness, or by the fracture characteristics of the glass.

Note 6: The safety glass classification shall be based on performance specification and Table 8 requirement of MS 1498.

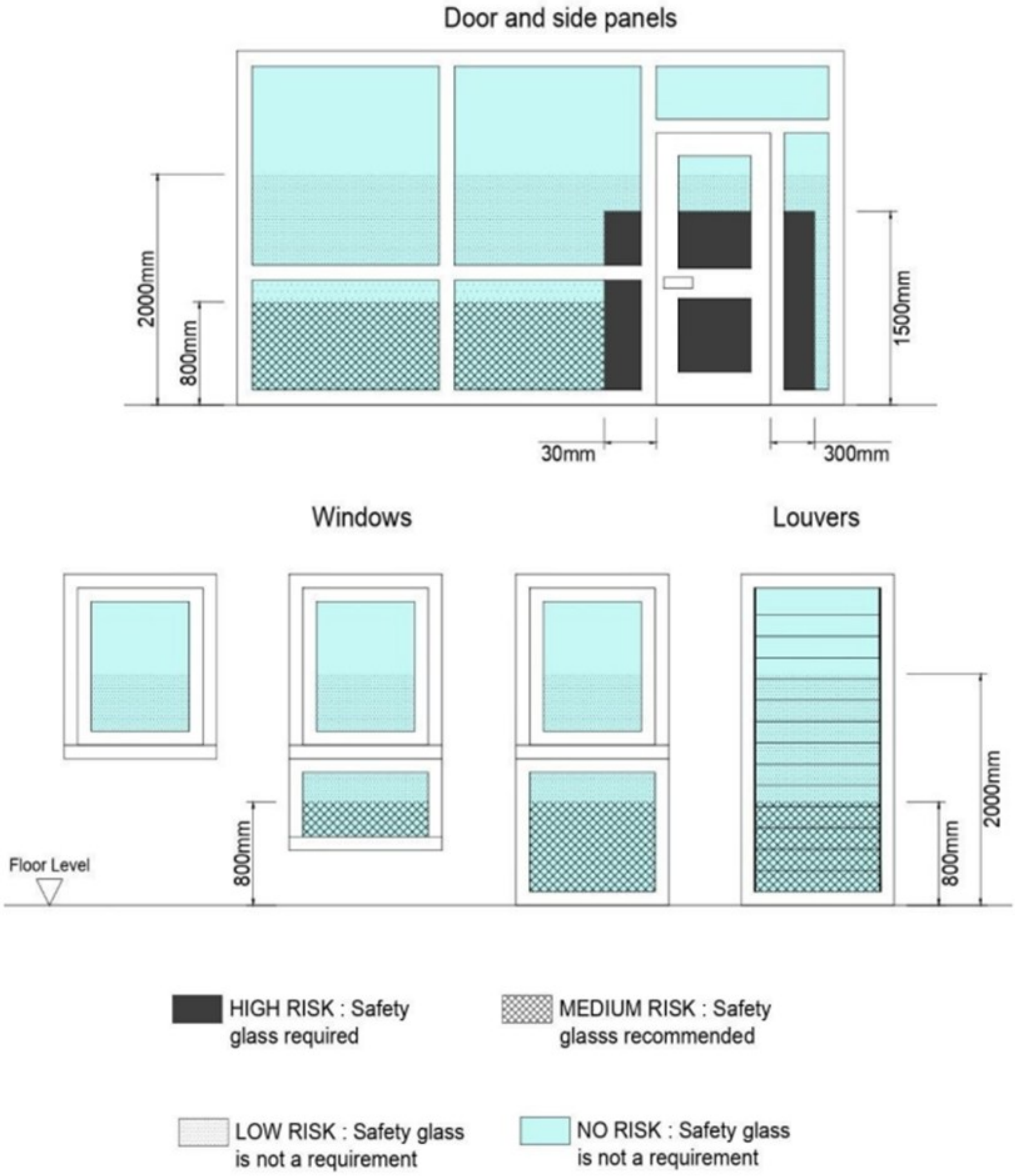


Figure 4 – Critical locations

7.2 Doors

7.2.1 General

Glazing in doors shall be Class 1 - Safety glass that complies with the maximum areas of safety glazing as set out in Table 7.

The following are specific requirements or exceptions:

a) Wardrobe doors with mirror, as defined in Clause 3.23 where the mirror is not completely adhered to a solid backing, shall be Class 1 safety organic-coated mirror (e.g., vinyl-backed) in accordance with Table 6;

b) Doors in bathrooms, ensuites and spa rooms shall be in accordance with Clause 7.8;

c) Unframed doors other than those incorporated into shower screens or bath enclosures shall comply with the following requirements:

   i) To be glazed with tempered glass with a minimum nominal thickness of 10 mm, or laminated tempered glass with a minimum total thickness of 10 mm; and

   ii) All exposed edges shall be polished

d) Roller doors, tilting doors, roller panel sliding glass doors complying with MS 1017. Casement windows shall comply with MS 832; doors shall comply with MS 1017 and glazing provisions herein. Casement door may use ordinary annealed glass which shall be in accordance with Column 1 of Table 7.

e) For annealed and annealed decorative glass panels in doors the following applies:

   i) For 3 mm and 4 mm annealed glass, the maximum area shall not exceed 0.1 m^2 with a maximum panel width of 125 mm; and

   ii) For 5 mm and 6 mm annealed glass, the maximum area shall not exceed 0.26 m^2 with a maximum panel width of 300 mm

f) For annealed glass in fully framed panels with a thickness of 10 mm or greater, with or without bevelled edges, the maximum area shall not exceed 0.5 m^2.

NOTE 1: The requirements for the glazing of doors are the same for residential and non-residential use.

NOTE 2: Doors of all operational types are included, e.g, hinged, sliding, folding and stacking, etc.

7.3 Side panels

7.3.1 General

Glazing in side panels, with the nearest vertical sightlines less than 300 mm from the nearest edge of the doorway opening shall be glazed in accordance with the following:

a) Fully framed side panels

   All fully framed glazing in side panels, wholly or partially within 1500 mm from floor or ground level, shall be of Class 1 Safety glass in accordance with Table 8, with the following exceptions:

   i) A minimum of 5 mm ordinary annealed glass may be used up to a maximum area of 0.3 m^2.

   ii) For decorative glass the following applies:

   For 3 mm and 4 mm annealed glass, the maximum area shall not exceed 0.1 m^2 with a maximum pane width of 125 mm.

   iii) For annealed glass with a thickness of 10 mm or greater with or without bevelled edges, the maximum area shall not exceed 0.5 m^2.

b) Unframed and partly framed side panels:

   i) Without exposed edges

All unframed or partly framed glazing in side panels, without exposed edges, wholly or partially within 1500 mm from the floor or ground level, shall be Class 1-Safety glass in accordance with Table 8.

Note: An example of unframed glass side panel without exposed edges would be flat or curved panels silicone butt-jointed and the assembled panels contained in a perimeter frame.

ii) With exposed edges

All unframed glazing in side panels with exposed edges shall be tempered glass with a minimum nominal thickness of 10 mm or laminated tempered glass with a minimum total thickness of 10 mm in accordance with Table 8. Exposed edges shall be polished.

Note: The values for tempered glass in Table 8 are also applicable to laminated tempered glass.

iii) Louvres in side panels

Louvres in side panels shall be glazed in accordance with Clause 7.11.

NOTE 1: A side panel may or may not be in the same plane as the doorway.

NOTE 2: The requirements for glazing side panels are the same for residential and non-residential buildings.

7.4 Glazing capable of being mistaken for a doorway or opening

7.4.1 General

Glazing, excluding doors and side panels glazed in accordance with Clauses 7.2 (Doors) and 7.3 (Side panels), which may be capable of being mistaken for:

a) A doorway:

b) An opening that could provide access to, or egress from one part of a building to another; or

c) An opening between inside and outside of a building and can result in human impact shall be Class 1 Safety glass in accordance with:

   i) Table 6 for framed glazing; or

   ii) Table 8 for unframed glazing.

7.4.2 Exceptions

Glazing that conforms to any one of the following shall not be considered to be capable of being mistaken for a doorway or opening:

a) The sight size width is less than or equal to 500 mm;

b) The sight size height is less than or equal to 1000 mm;

c) The lowest sightline of the opening, as shown in Figure 13 – Size and Rebates, is 500 mm or greater above the floor or ground level;

d) The glazing is opaque and patterned;

e) Where a crash/chair rail, handrail or transom is provided and located with its upper edges not less than 700 mm or its bottom edge not more than 1 000 mm above the floor level;

f) The panels are louvres with a blade width (i.e., shortest side) not greater than 230 mm; and

g) The glazing protects a difference in level of 1000 mm or more.

7.5 Low-level glazing in residential buildings

Low-level glazing, where the lowest sightline is less than 800 mm from the floor or ground level, shall be:

a) Class 1 Safety glass in accordance with Table 6; or

b) For fully framed glazing, annealed glass not less than 5 mm minimum nominal thickness up to a maximum area of 1.2 m^2. Larger areas of ordinary annealed glass are not permitted regardless of glass thickness.

7.6 External shopfronts

This clause shall apply to all glazing in external shopfronts that are not:

a) Doors (see clause 7.2);

b) Side panels (see clause 7.3);

c) Fins less than 500 mm in width; or

d) Capable of being mistaken for a doorway or opening (see clause 7.4)

Glazing in external shopfronts shall be Class 1 safety glass in accordance with Table 6 with the following exceptions:

a) Fully framed glazing, including fin-jointed glazing, in accordance with Column 2 of Table 7 with a minimum thickness of 10 mm.

b) Partly framed glazing, with the top and bottom edges framed and one or more side edges unframed, shall be glazed in accordance with Table 7.

7.7 Internal shopfronts and internal partitions

7.7.1 General

This clause shall apply to all internal shopfronts and partitions that are not doors or side panels (see Clauses 7.2 and 7.3), in all buildings.

7.7.2 Fully framed glazing

Fully framed glazing shall be Class 1 safety glass in accordance with Table 6. For panels that cannot be mistaken for a doorway or opening, as defined in Clause 7.4, they may be glazed with ordinary annealed glass in accordance with Column 2 of Table 7.

7.7.3 Partly framed glazing

7.7.3.1 Side edges, unframed

Partly framed glazing, with the top and bottom edges framed and one or more side edges unframed, shall be glazed in accordance with Table 8. For panels with a lowest sightline greater than 1500 mm above floor level and a panel height not exceeding 1000 mm, they may be glazed in annealed glass in accordance with Column 2 of Table 7, with a minimum nominal thickness of 6 mm.

7.7.3.2 Top edges, unframed

Partly framed glazing framed on three sides but not on the top edge shall be glazed with Class 1 safety glazing material in accordance with Table 6. Partly framed glazing where the top edge is 1500 mm or greater above the highest abutting finished floor level, which cannot be mistaken for a doorway or unimpeded path of travel, as defined in Clause 7.4, may be glazed with annealed float glass in accordance with Column 1 of Table 7.

7.7.3.3 Other unframed glazing

All other unframed glazing shall be tempered or laminated safety glass in accordance with Table 8.

7.8 Bathroom, ensuite and spa room glazing

7.8.1 General

Glazing, including mirrors, within 2000 mm above the floor level in bathrooms, ensuites, and rooms or enclosures containing bathtub or spa pools shall be Class 1 safety glass or Class 2 safety glass in accordance with the requirements of Table 6.

Annealed glass, including mirror, may be used provided it is fully backed by and completely adhered to a solid material in such a way that all pieces will remain bonded to the backing in the event of glass breaking.

Annealed glass including mirrors, may be used provided a fixed vanity or bench having:

a) a height of not less than 760 mm, and

b) a depth of not less than 300 mm, and

c) extends the full width of the glass or mirror is located in front of the glass or mirror

NOTE. For further information on shower screen installation, see Annex C.

7.8.2 Fully framed glazing

Fully framed glazing shall be Class 1 safety glazing material or Class 3 in accordance with Table 6.

7.8.3 Partly framed glazing

Partly framed glazing, with one unframed edge or two opposite unframed edges, shall be glazed with Class 1 tempered glass or tempered laminated safety glass in accordance with Table 9. Class

1 tempered glass with a minimum thickness of 5 mm may be used for a maximum area not exceeding 2.2 m^2.

7.8.4 Frameless glazing

Frameless shower doors or panels shall be glazed with Class 1 tempered or tempered laminated safety glass with a minimum thickness of 6 mm, in accordance with Tables 9.

7.9 Balustrades

Glazing for balustrades shall be in accordance with Clause 10.

7.10 Mirrors and other types of glass subject to risk of human impact

7.10.1 General

Where mirrors and other types of glass are required to be Class 1 safety glass, annealed glass may be substituted when the panel is fully backed by and completely adhered to a solid material.

NOTE 1: Examples of where full backing is provided include walls, timber cupboards or wardrobe doors.

NOTE 2: Examples of other types of glass include mirror tiles and painted or ceramic frit glass.

NOTE 3: It should be noted that tempered glass mirrors are likely to distort because of the tempering process.

7.11 Glass blade for louvre subject to risk of human impact

Where Class 1 safety glass is required and louvres are used, louvres shall be Class 1 tempered glass with a nominal thickness not less than 5 mm up to 230 mm in blade width (i.e., shortest side) and 1 000 mm in blade length. Blade widths or lengths in excess of these dimensions shall be subject to specific design. The edge for glass blade louvre should be polished.

For glass blade and fixing details refer to MS 1057.

NOTE. For determining the appropriate glass thickness for wind loading, see Clause 6.4.2 and Table 2 of MS 2753-2 for wind load factors and Clause 6.4.3 for partial material factors.

7.12 Operable windows

Glazing in operable windows shall meet the requirements of this clause in all possible operable positions.

7.13 Two-edge unframed glazing

Glazing with two horizontal edges unframed (also known as sashless windows and doors), which is subject to human impact shall be Class 1 safety glass, and shall comply with the following minimum requirements:

a) 5 mm tempered .... 1000 mm max. span

b) 6 mm tempered .... 1200 mm max. span

c) 6 mm laminated .... 750 mm max. Span

7.14 Curved glass

Curved glass shall be acceptable if a flat panel of the same type and thickness conforms to the human impact requirements of this clause.

7.15 Making glass visible (Manifestation)

If the presence of glass in a door, side panel or a panel capable of being mistaken for a doorway or opening is not made apparent by transoms, colonial bars, other components of the glazing system, or other decorative treatment, such as being opaque, or patterned, the glass shall be marked to make it visible.

Refer to Figure 5, the marking shall be in the form of an opaque band not less than 20 mm in height and located so that the vertical distance from the floor level is:

a) not less than 700 mm from the upper edge of the band; and

b) not more than 1200 mm to the lower edge of the band.

The band shall be readily apparent. This may be achieved either by ensuring that the band contrasts with the background or by increasing the height of the band. Making glass visible by marking is not a substitute for the use of safety glazing where it is a requirement of this clause.

A band or marking is not required where any one of the following applies:

i) The height of the glazing is no greater than 1000 mm at any part.

ii) The width of the glazing is no greater than 500 mm at any part (with faceted glazing this applies to the overall panel assembly-not individual glass pieces).

iii) There is no glazing within 500 mm of the floor level.

iv) The glazing is provided with at least one fixed glazing bar, firmly attached to the styles to locate and protect each face of the glass. At least one glazing bar shall be located with its upper edge not less than 700 mm, and its bottom edge not more than 1 200 mm above the floor level. The glazing bar shall have a face width not less than 20 mm.

NOTE 1: A broken line or patterns using company logos may be acceptable form of marking provided it meets the other criteria set in this Clause.

NOTE 2: Glazing in buildings where the MS Standard/UBBL requires access for people with disabilities, should be marked in accordance with MS 1184 - Universal design and accessibility in the built environment - Code of practice.

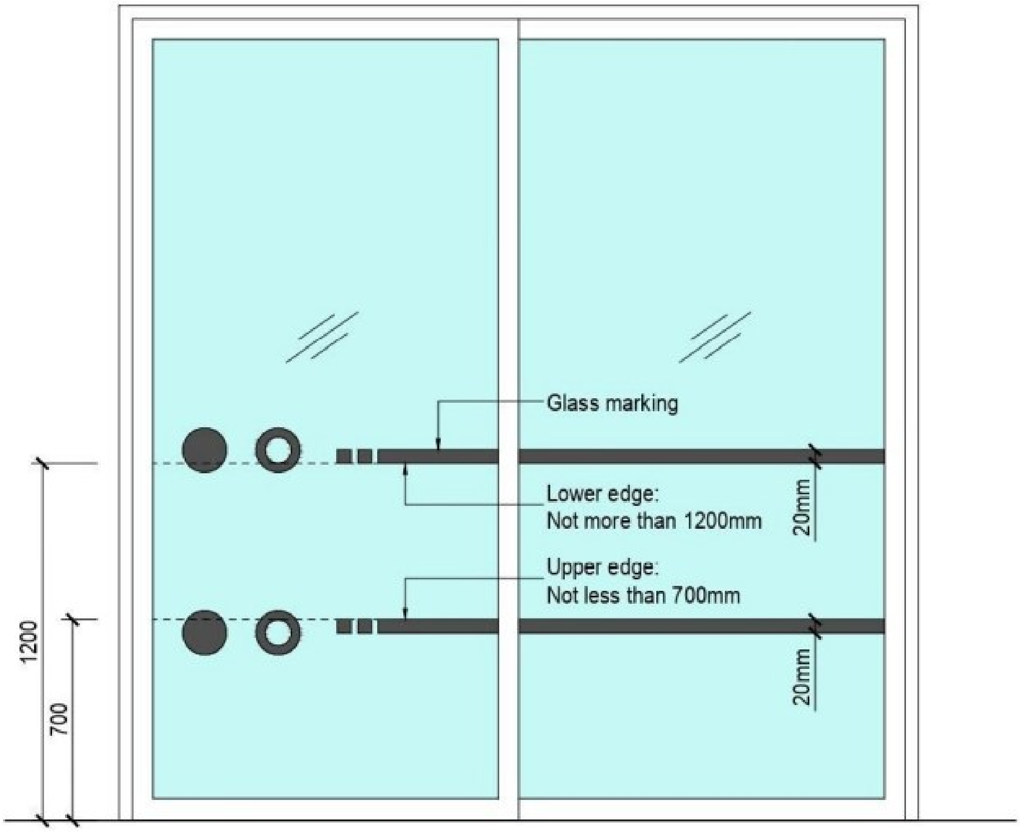


Figure 5 – Safety marking locations on glass doors

7.16 Areas subject to high risk of breakage

In all those parts of buildings where the planned activity can generate a high risk of breakage from human impact, such as in or about gymnasiums, swimming pools and spa pools and enclosures, part of schools, halls, public viewing galleries in stadiums and the like, Class 1 safety glazing material in accordance with Table 6 or Table 8 shall be used.

All the safety glazing material shall be legibly marked in accordance with MS 1498.

NOTE: Parts of schools referred to in the requirements of this Clause include glazing situated within 5000 mm of areas where activities such as those in relation to playgrounds, courts or marked out playing fields occur, unless otherwise protected by a permanent barrier.

7.17 Fire doors

All glazed elements in fire-resisting enclosures and doors shall conform to relevant by-laws, regulations and requirements by Fire and Rescue Department of Malaysia (BOMBA).

Table 6 – Maximum areas of safety glass

Class	Type of glazing	Nominal thickness (mm)	Maximum area (m^2)
Class 1 Safety Glass	Tempered Glass	4	2.2
		5	3
		6	4
		8	6
		10	8
		12	10
		> 12	Extrapolate
		8	6
		10	8
		12	10
		> 12	Extrapolate
	Laminated Glass *	6	3
		8	5
		10	7
		12	9
		> 12	Extrapolate
	Heat-strengthened laminated glass *	6	3
		8	5
		10	7
		12	9
		> 12	Extrapolate

Class 1 Safety Glass	Safety organic-coated mirror	4	3
		5	3.5
		6	4
	Safety organic-coated glass	3	2
		4	2
		5	2.2
		6	3
		8	5
		10	7
		12	9

* Safety glazing material Class 1 or Class 2 to MS 1498. Based on total glass thickness only (interlayer thickness not included and should be added). This area may not be readily available.

Table 7 – Maximum area of annealed glass

Nominal Thickness (mm)	**Maximum areas (m^2)**	
	Column 1	**Column 2**
	Roller shutter, top edge, unframed	Fully framed glazing, partly framed glazing, window seat glazing, external shop front
5	0.3	1.2
6	0.9	2.1
8	1.8	3.2
10	2.7	4.4
12	4.5	6.3
15	6.3	8.2
19	8.5	10.3
25	12.0	13.5

*This is equivalent to span (see Clause 1.4.5.1 for definition of span)

NOTE 1: For curved glass the butt joint and maximum panel width limits may not apply.

NOTE 2: The values for tempered glass are also applicable to tempered laminated glass.

Table 8 – Glazed panels with unframed side edges

Height of glass*	Type of glass	Minimum nominal thickness	Maximum number of vertical butt joints	Maximum panel width (m)
≤ 1.2	Annealed	6	No limit	No limit
	Heat Strengthened	6	No limit	No limit
	Tempered	6	No limit	No limit
	Laminated	6	No limit	No limit
> 1.2 ≤ 1.6	Annealed	8	No limit	No limit
	Heat Strengthened	8	No limit	No limit
	Tempered	6	No limit	No limit
	Laminated	6	No limit	No limit
> 1.6 ≤ 2.0	Annealed	10	No limit	No limit
	Heat Strengthened	10	No limit	No limit
	Tempered	6	2.0	1.2
	Tempered	8	No limit	No limit
	Laminated	6	2.0	1.2
	Laminated	8	No limit	No limit
> 2.0 ≤ 2.5	Annealed	10	1.0	1.0
	Heat Strengthened	10	1.0	1.2
	Tempered	8	2.0	1.2
	Tempered	10	No limit	No limit
	Laminated	8	2.0	1.2
	Laminated	10	No limit	No limit
> 2.5 ≤ 2.8	Tempered	10	2.0	1.2
	Tempered	12	No limit	No limit

Height of glass*	Type of glass	Minimum nominal thickness	Maximum number of vertical butt joints	Maximum panel width (m)
	Laminated	10	2.0	1.2
	Laminated	12	No limit	No limit
> 2.8 ≤ 3.2	Tempered	12	2.0	1.2
	Tempered	15	No limit	No limit
	Laminated	12	2.0	1.2
	Laminated	16	No limit	No limit
> 3.2 ≤ 3.6	Tempered	15	2.0	1.2
	Tempered	19	No limit	No limit
	Laminated	16	2.0	1.2
	Laminated	20	No limit	No limit

Table 9 – Maximum areas of tempered glass or laminated tempered glass for use in frameless shower screen doors

Type of glazing	Glass thickness (mm)	Unframed maximum panel area (m^2)
Class 1	8	2.0
Tempered or tempered laminated glass	10	3.0
	12	4.5

8 Sloped overhead glazing

8.1 General

This clause applies to glass that is glazed overhead and sloped with an angle less than 75° to the horizontal, and operable roof light windows. It does not apply to glass louvres or vertical operable windows that are inclined at 75° or more to the horizontal in the closed position.

Glazing inclined at angles equal to or greater than 75° to the horizontal shall be designed in accordance with AS 1288 – Accordance with Section 3 and other relevant action, as applicable.

NOTE. Refer to Annex D for the sloped overhead glazing fracture characteristics. The selection process should include a risk assessment based on the risk of injury to persons who might fall through the glazing in the event of breakage.

Where the requirements of other sections exceed the requirements of this clause, they shall be followed.

8.2 Loads and load combinations

The design of sloped overhead glazing for stability, ultimate strength and serviceability limit states shall account for the action effects directly arising from the following loads:

a) Imposed wind actions specified in MS 1553. Dead loads include glass weight and actions specified.

b) Live loads (concentrated point loads) in accordance with MS EN 1991-1-1 applied as a uniformly distributed load over a-circular area of 0.01 m2 for glazed panels inclined at less than 30° to the horizontal.

   For glazed panels inclined at greater than or equal to 30° to the horizontal, use a live load of 0.5 kN (concentrated point load) applied normal to the glass.

   For IGUs, apply the point load separately to the uppermost pane.

c) Other specific loads, as required.

NOTE: Other loads may include imposed live loads for maintenance and cleaning not covered above, which the designer may require.

9 Glass element design

9.1 Glass wall

There are many variations in glass wall systems using glass fins, tension rods, cables, etc, in vertical, sloped and horizontal manner.

The use of glass fin requires analysis to determine the buckling resistance under combined in-plane and out-of-plane loads. Side wind effect at the corner of glass wall should be considered simultaneously. The column or the glass fin at the corner should be designed to resist the induced moments and forces.

Structural sealant or point-supporting bolt systems can be used for the connections between glass panes. However, special care is needed to consider the effects of local stress concentration and the stability. Tempered glass has a better resistance against stress concentration at openings.

For point supported systems, simple bolt, patch and countersunk bolt can be used. Clearance, distances from edges, movement, stability and stress concentration around openings require careful consideration during design and fabrication. Direct contact between hard materials should be avoided.

Structural spider fixing is commonly used as fixing device in glass wall systems. The design of structural spider can be verified by means of proof load test. The mechanical properties, dimensions, load capacities and specific proprietary model number/series of a spider should be provided in the design report. In addition, attention should be made to its detailing at the interface connection with the glass panes, which should be designed such that the structural glass in contact with the spider fixing should not cause high stress concentration greater than the design strength of glass. The interface connection should be filled up with resilient gasket made with a less stiff material.

Where glazing is supported by a structural system using stainless steel tension rods or cables, special attention should be paid to the geometrically nonlinear behaviour, differential temperature change, possible creep effect under long-term load and support movement, in addition to conventional loads. A comprehensive consideration of all possible load cases should be given in the design.

In addition to a full-scale mock-up test, performance-based design approach with rigorous design and advanced nonlinear analysis may be required for glass wall system or glass supporting system, depending on the complexity in the interaction and load transfer between various components.

9.1.1 Design of glass fin/glass beam

The use of glass in structural applications may require analysis to determine buckling resistance under combined in-plane and out-of-plane loads. Glass fins and glass beams can become unstable if they are not adequately restrained. Glass fins and glass beams should be restrained from rotation and held in position to ensure stability.

When glass fins / glass beams subject to bending about its major axis, the ultimate design strength should be reduced by 40% (e.g. 80 MPa to 48 MPa for tempered glass fins). Apart from the rigorous nonlinear finite element analysis approach in equation 6 the following simplified equations 3 to 5 can be used for checking the glass fin / glass beam.

9.1.1.1 Local buckling

The free edge of a glass fin should be checked against local buckling:

$$\frac{Et^3}{6\,(1+v)} > Mw \qquad (3)$$

where

M_w = working design moment in the glass fin (in-plane moment) with load factor γ_f equal to 1.0

E = Modulus of elasticity

v = Poisson's ratio

t = Minimum thickness of glass pane being checked

9.1.1.2 Lateral torsional buckling

The formulae in Annex C for glass fins could be used to check the critical elastic buckling moment (M_{cr}). It should be at least 1.7 times the ultimate design moment (M_d).

$$M_{cr} > 1.7\, M_d \tag{4}$$

where

Mcr = Critical elastic buckling moment given in Annex C

Md = Ultimate design moment in the glass fin

9.1.1.3 Elastic moment capacity

The elastic moment capacity of glass fin should not be less than the ultimate design moment.

$$M_e = \gamma d \text{ x } \gamma s \text{ x } p_{yf} \text{ x } Z > M_d \tag{5}$$

where

Me = Elastic moment capacity

Md = Ultimate design moment in the glass fin (in-plane moment)

pyf = Ultimate design strength of glass fin as described in clause 9.1.1

Z = Elastic section modulus of glass fin

γd = Load duration factor

γs = Glass surface treatment reduction factor

9.1.1.4 Non-linear finite element analysis

A geometrically nonlinear finite element analysis by shell element with imperfection equal to 0.5% of the length of the glass fin should be carried out to determine the ultimate moment capacity Mu of the glass fin. Ultimate moment capacity Mu refers to the minimum moment, accounting for geometrically nonlinear effects that caused the maximum stress in the glass fin equals to its design glass strength.

$$M_u > M_d \tag{6}$$

where

M_u = Ultimate moment capacity evaluated from non-linear finite element analysis

M_d = Ultimate design moment in the glass fin with appropriate load factor γ_f given in Table 2 of MS 2753-2

Alternatively, in finite element analysis by shell element, the maximum principal stress (s_1) of the glass pane should be smaller than the ultimate design strength of glass fin (p_{yf}).

9.1.2 Deflection of glass fin/glass beam

The deflection limit of glass fin/glass beam should be taken as the smaller of 1/180 of the span or 20 mm for the span not greater than 7.2 m. For span greater than 7.2 m, the deflection limit of glass fin/glass beam should be taken as 1/360 of the span.

9.1.3 Design of glass column

Glass column is the primary structural element supporting glass beams or glass floors. Glass column should therefore be adequately restrained from rotation and held in position to ensure stability. Glass columns are typically slender and therefore governed by the tensile forces arising from buckling stress and out-of-plane bending. Moreover, the design of glass columns should have sufficient structural redundancy.

The design of glass columns or glass fin under compression buckling should be referred to relevant literature with adequate design justification. The design of glass columns may also be needed to deal with the design of such miscellaneous systems. A performance-based design approach derived from first principles should be adopted together with component and system testing in order to ensure the structural adequacy and safety.

9.2 Curtain wall, windows and window wall

A system that incorporates glazing must be designed to safely sustain and transmit the combined dead loads, imposed loads and wind loads to the load-bearing structure without excessive deflection or deformation that causes damage to the system or impairs its stability.

Design of glass supporting frames should follow relevant codes of practice for steel, aluminium and stainless steel.

Owing to the complexity in the interaction and load transfer between various components in a system such as curtain wall system, a full-scale mock-up test as specified in Clause 8, Testing and Measurement of MS 2753-2 should be carried out to verify if the performance of the system satisfies the limit states.

Design, fabrication and installation of curtain wall, window and window wall systems should achieve the required safety standard. Attention should be given to the requirements on horizontal imposed loads, protection of openings, function of glass balustrades, corrosion protection, quality control of materials and protection against the spread of fire and smoke between floors.

There are numerous types of curtain wall systems, broadly as stick and unitised systems. They all need to be designed for possible building movements, displacement due to lateral load, thermal expansion and against water and air leakage, durability and corrosion, in addition to general consideration for structural safety.

9.3 Tensioning structure system

Stainless steel tension rods and cables provide aesthetic supports to glass with maximum transparency. These tension rods and cables are very slender and buckle easily when in compression, but they are strong and stiff in tension. To ensure that these structural elements are always in tension, they can be pre-tensioned or pre-stressed as such that they are always in tension under all load combinations by limiting the compression induced loads smaller than the pre-tensioned forces.

Where a glazing is supported by a structural system using stainless tension rods or cables which is deflection sensitive, the geometrically nonlinear behaviour, differential temperature change, possible creep effect under long-term load or imposed load, and support movement of the system should be considered, in addition to the wind loads on the system. Therefore, in this respect, a detailed consideration of all possible load cases should be given in the design of tensioning structural system.

10 Balustrade

10.1 General

For the purposes of this clause, glass balustrade panels shall be classified as:

a) structural balustrade panels; or

b) infill balustrade panels.

NOTE: Balustrade infill panels are not required to resist line loads along their top edge as the handrail provides this resistance.

10.2 Loads and other actions

10.2.1 Loads

The design of balustrades for the stability, ultimate strength and serviceability limit states shall account for the action effects directly arising from the following loads:

a) Imposed live and wind load actions specified in MS EN 1991-1-1 and MS 1553; and

b) Accidental load, as required.

10.2.2 Load combinations

The design combinations for the stability, ultimate strength and serviceability limit states shall be those specified in MS EN 1991-1-1.

The actions due to wind need not be assumed to act concurrently with the loads in MS EN 1991-1-1; however, the loads causing the worst actions shall be used for design.

10.2.3 Handrails

Handrails shall be classified as follows:

a) Load-supporting handrails

The handrail is mechanically fixed to the structure, independent of the glass, but the glass can be connected to it. The handrail supports the loads defined in Clauses 10.2.1 and 10.2.2.

NOTE: Normally these are used with infill balustrades.

b) Non-load-supporting handrails

Either the top edge of the glass acts as the handrail or the glass supports a handrail that is fixed to the glass and relies on the glass for structural support. The glass supports the loads defined in Clauses 10.2.1 and 10.2.2

c) Interlinking handrail

The handrail is non-load-supporting, unless a panel breakage occurs, and is connected to adjacent panels of glass, or the building, where the adjacent panels are at least 1 000 mm wide and three or more panels of glass form the balustrade. If anyone panel fails, then the remaining panels and handrail shall be capable of resisting the loads defined in Clauses 10.2.1 and 10.2.2.

10.3 Selection of balustrade glass

10.3.1 General

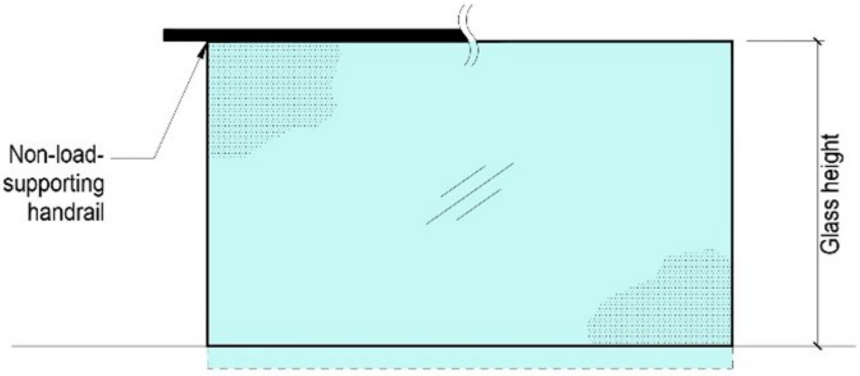
Class 1 safety glass shall be used in all balustrades. The standard nominal thickness of glass for a given situation of use shall be determined in accordance with Clause 6, MS 2753-2.

Balustrades designed to Clauses 10.3.2 to 10.3.6, as appropriate, are deemed to comply with or are an acceptable solution for the resistance of the live load actions in accordance with AS 1170.1 or AS/NZS 1170.1 and MS EN 1991-1-1.

10.3.2 Structural balustrades - Cantilevered glass - Protecting a difference in level less than 1 000 mm

Heat strengthened laminated glass, or tempered laminated glass shall be used with a minimum 10 mm standard nominal glass thickness in accordance with Table 10 (see Figure 6).

Cantilevered glass protecting a difference in level less than 1 000 mm, handrail is not required. Non load supporting handrail is optional.



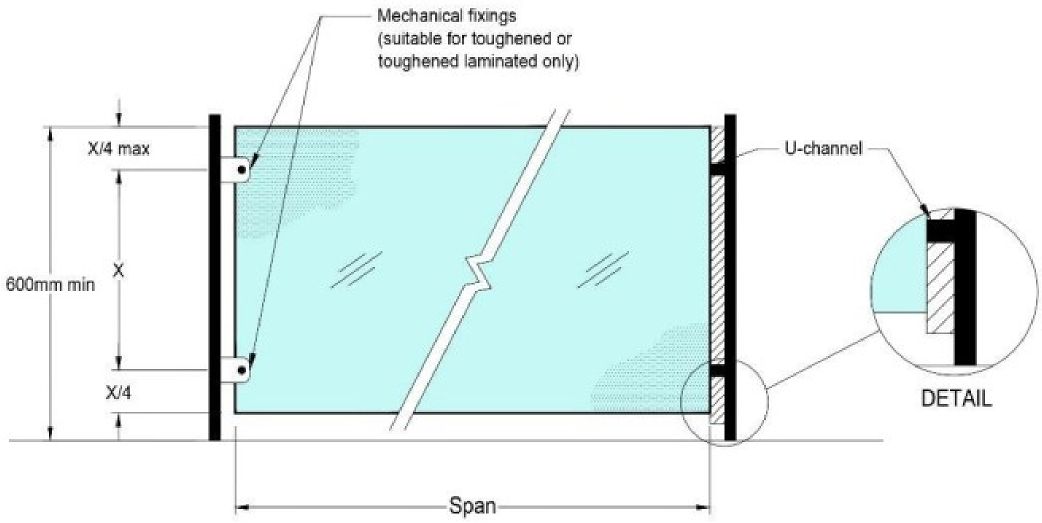
NOTE: This requires the bottom of the panels to be fully and rigidly fixed for the full length of the panel, usually into a grouted channel. Mechanical fixing method is not covered under this clause.

Figure 6 – Structural balustrades - Cantilevered glass protecting a difference in level less than 1 000 mm

10.3.3 Structural balustrades - Two-edge support (two opposite edges) - Protecting a difference in level less than 1 000 mm

Heat strengthened laminated glass or tempered laminated glass shall be used with a minimum 6 mm standard nominal glass thickness in accordance with Table 11. The supported edges shall be more than 600 mm long (see Figure 7).

Two-edge support (two opposite edges) protecting a difference in level less than 1 000 mm, handrail is not required. Non load supporting handrail is optional.



NOTE: The glazing panels are supported in a channel or by fixings to vertical posts at each side

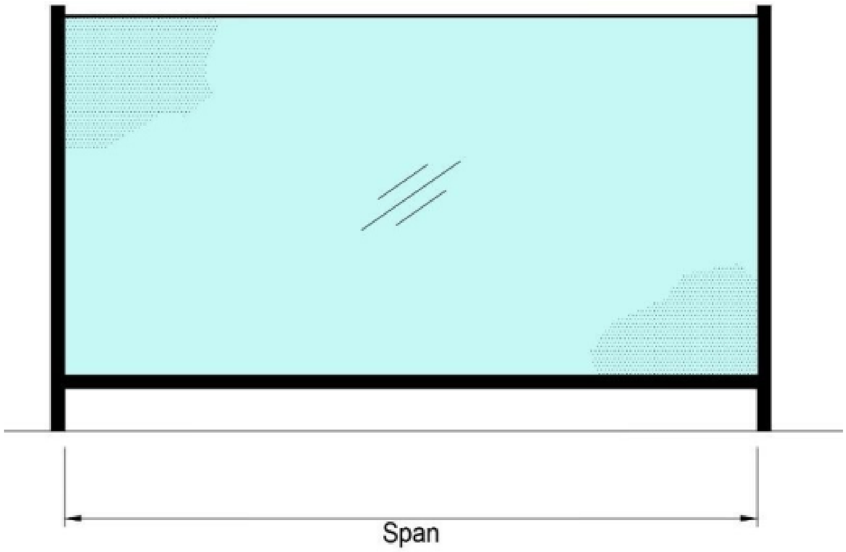
Figure 7 – Structural balustrade – Two-edge support

10.3.4 Structural balustrades - Three-edge support (bottom and two sides) - Protecting a difference in level less than 1 000 mm

Laminated glass, tempered glass, heat strengthened laminated or tempered laminated glass shall be used with a minimum 6 mm standard nominal glass thickness in accordance with Table 11(see Figure 8).

Three-edge support (bottom and two sides) protecting a difference in level less than 1 000 mm, handrail is not required. Non load supporting handrail is optional.

The base and two vertical ends are supported in channels or by fixings.



NOTE: For mechanical fixing, tempered or tempered laminated glass only is to be used

Figure 8 – Structural balustrades – Three-edge support

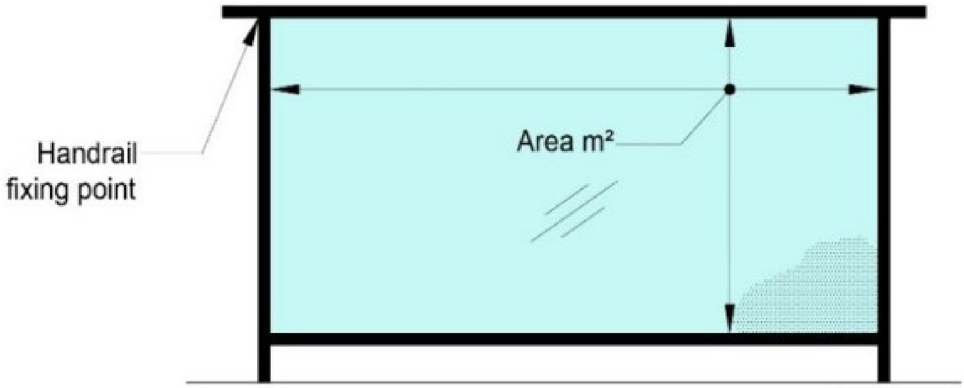
10.3.5 Structural balustrades - All types, protecting a difference in level, equal to or greater than 1 000 mm, interlinking handrail is required

If an interlinking handrail is used in accordance with Clause 10.2.3(c), laminated glass, tempered glass, heat strengthened laminated or tempered laminated glass shall be used in accordance with Table 10 or 11, as applicable.

10.3.6 Infill balustrades - Protecting any difference in level

10.3.6.1 Four-edge support

Class 1 safety glass, in accordance with Table 6 shall be used with a minimum nominal thickness of 8 mm (see Figure 9). The infill balustrade panels shall also comply with the requirements of the loading code MS EN 1991 or AS/NZS 1170, as appropriate. Glass in accordance with Table 12, with the maximum glass span taken as the smaller dimension, shall be deemed to comply with this requirement.

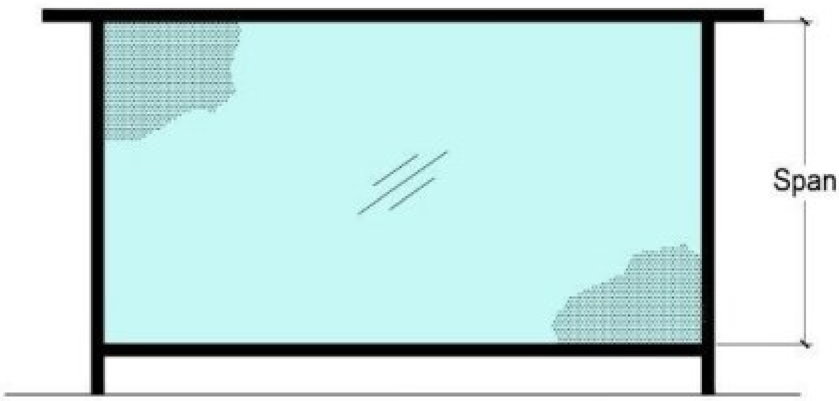


NOTE: This infers that there is a handrail supporting the design loads and the glass. The design tables apply for infill panel loads.

Figure 9 – Infill balustrades – Four-edge support

10.3.6.2 Two-edge support

Laminated glass, tempered glass, heat strengthened laminated glass or tempered laminated glass in accordance with Table 12 shall be used. Full edge support shall be provided on two opposite edges (see Figure 10)



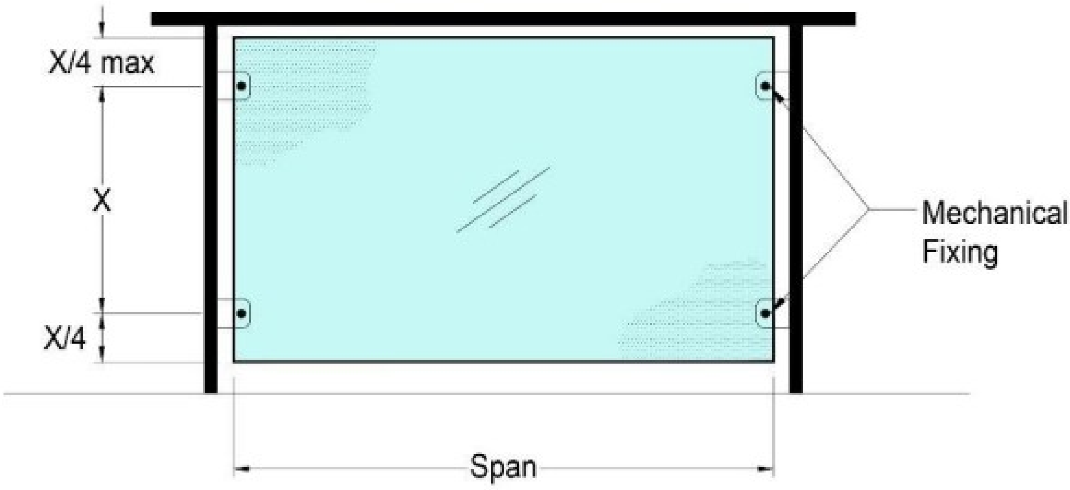
NOTE: This infers that there is a handrail supporting the design loads, which may not be connected to the glass. The design tables apply for infill panel loads

Figure 10 – Infill balustrades – Two-edge support

10.3.6.3 Two-edge support – Mechanical fixings

Tempered glass, heat strengthened laminated glass or tempered laminated glass shall be used in accordance with Table 12. There shall be a minimum of four fixings per pane. The panes shall be positioned not more than $X/4$ from the corner, where X is the span between fixings (see Figure 11).

NOTE. The fixing design is not covered in this Standard. Fixings should be suitable for clamping the glass into position and capable of withstanding design loads and vibration. As a guide they are normally minimum 50 mm x 50 mm and 6 mm thick plates depending on the glass thickness and bolt/screw size. Direct glass to metal contact should be avoided by the use of rubber, nylon or fibre pads and a nylon bush in the glass hole. Refer to fitting suppliers for proprietary design information.



NOTE: This infers that there is a handrail supporting the design loads, which may not be connected to the glass. The design tables apply for infill panel loads.

Figure 11 –Infill balustrades – Two-edge support (mechanical fixings)

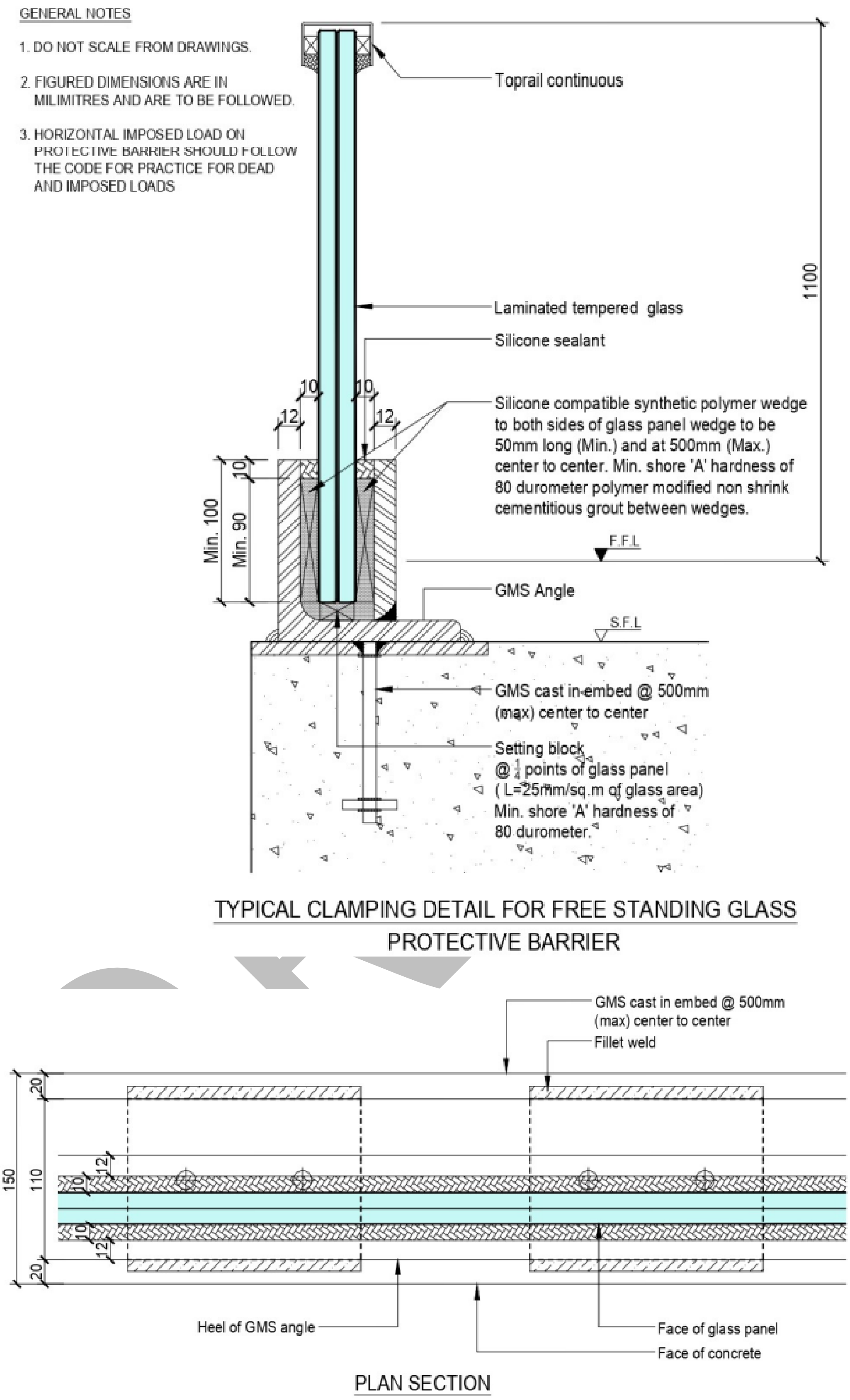


Figure 12 – Typical glass balustrade detail

Table 10 – Structural balustrade - Cantilevered glass

Design load (kN/m)	Maximum glass height for tempered laminated glass (mm)			
	10	12	16	20
0.35	1070	1320	1750	2210
0.75	820	1 020	1 360	1710
1.5	460	630	1040	1360
3	230	310	520	780
0.60kN*	640	1020	1490	2060

* Point load

Notes:

1. Height is from base of channel to top of glass or handrail with the handrail centred on top edge of the glass.
2. For trapezoid-shaped panels on the sides of stairways, the height is the vertical height above the fixing points.
3. The heights have been calculated for short-term live loads applied along the top edge.
4. Deflection is limited to height/30 or 30 mm maximum.
5. Glass thicknesses are nominal thickness and can be used for tempered laminated glass excluding the interlayer thickness.
6. Table 10 is calculated for the handrail live design load.
7. The design loads applicable arc to be in accordance with MS EN 1991-1-1/MS EN 1991-1-4

Table 11 – Structural balustrade – Two and three-edge support

Design load kN/m	Maximum glass span (mm)													
	Laminated glass (mm)			Tempered glass (mm)						Tempered laminated glass (mm)				
	8	10	12	6	8	10	12	15	19	8	10	12	16	20
0.75	820	1020	1200	1240	1540	1830	2100	2470	2910	1430	1810	2090	2590	3080
1.5	580	720	850	870	1160	1460	1760	2080	2450	1140	1440	1750	2180	2590
3	410	510	600	690	910	1130	1330	1620	1960	910	1140	1350	1720	2110
0.60kN*	180	270	400	540	930	1630	2170	2690	3350	900	1590	2150	2860	3600

* Point load

Notes:

1. The spans have been calculated for medium-term live loads applied along the top edge.
2. Deflection is limited to span/60 or 30 mm maximum.
3. Glass thicknesses are nominal thickness and can be used for tempered laminated glass excluding the interlayer thickness.
4. In some exposed situations, the wind load may exceed the infill design load and thicker glass may be required by the design live load.

Table 12 – Infill balustrade

Balustrade infill design load	Maximum glass span (mm)									
	Laminated glass (mm)			Tempered glass (mm)				Tempered laminated glass (mm)		
	8	10	12	8	10	12	15	10	12	16
0.50 kPa	1210	1490	1770	1640	2000	2300	2700	1980	2290	2830
1.0 kPa	850	1050	1250	1300	1650	1930	2270	1630	1920	2380
1.5 kPa	690	860	1020	1140	1430	1730	2050	1420	1720	2150
0.25 kN	450	670	1250	1860	2410	2910	3610	2390	2880	3800
0.5 kN	210	330	470	1070	1860	2310	2860	1830	2290	3040
1.5 kN	70	110	150	360	540	990	1910	530	930	2110

Notes:

1. The spans have been calculated for medium-term live loads.
2. Deflection is limited to span/60 or 30 mm maximum.
3. Glass thicknesses are nominal thickness and may be used for tempered laminated glass excluding the interlayer thickness.
4. In some exposed situations, the wind load may exceed the infill design load and thicker glass may be required by the design live load.

11 Installation

11.1 General

This clause sets out the basic installation requirements for glass.

NOTE 1: This clause does not preclude the use of other methods or systems for glazing, provided the alternate method or system can be demonstrated to satisfy the requirements for correctly supporting the glass within the frame, or glazing system.

NOTE 2: Patent and other proprietary systems are not described in this clause.

11.2 Site working and damage of glass

Heat strengthened and tempered glass shall not be cut or worked after heat treatment. All necessary cutting, drilling, notching, and edge working shall be carried out to correct dimensions prior to heat treatment.

Glass damaged during or prior to installation shall not be installed.

11.3 Dimensional requirements

11.3.1 General

The dimensions for edge clearance, edge cover, and front and back clearance, as defined in Figure 13 shall be not less than the values given in Table 13 and 14 for different thicknesses of glazing materials.

11.3.2 Dimensions of rebates and grooves

Dimensions of rebates and grooves shall accommodate the requirements of Table 11.1 and allow for the appropriate setting and location blocks as illustrated in Figures 10 to 13 of MS 2753-2.

11.3.3 Glass dimensional tolerance

The glass dimensional tolerance shall meet the requirements of MS 1498.

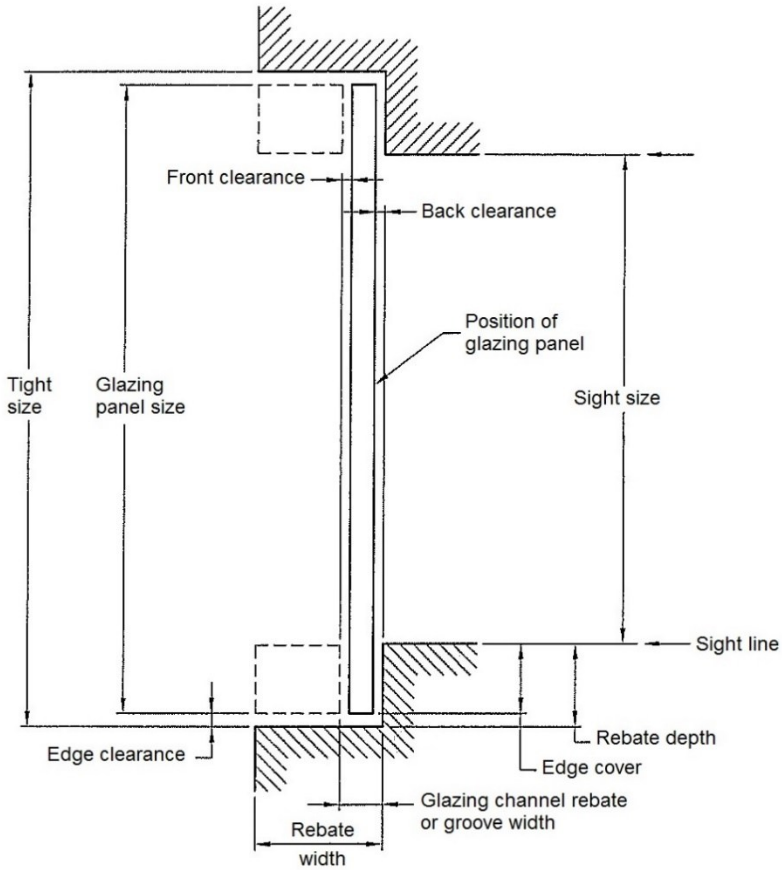


Figure 13 – Sizes and rebates

Table 13 – Minimum glazing dimensions for monolithic and laminated glass

Nominal thickness	Front and back clearance		Edge clearance	Edge cover	Rebate depth
	Sealant (see Note 1)	Gaskets (see Note 2)			
3 ≤ 0.1 m²	-	-	2	4	6
3 > 0.1 m²	-	-	3	6	9
3	2	1	3	6	9
4	2	1	3	6	9
5	2	2	4	6	10
6	2	2	4	6	10
8	3	2	5	8	13
10	3	2	5	8	13
12	3	2	6	9	15
15	5	4	8	10	18
19	5	4	10	12	22
25	5	4	10	15	25

Table 14 – Minimum glazing dimensions for insulating glass units

<table>
<tr><th rowspan="2">Nominal thickness</th><th colspan="2">Front and back clearance</th><th rowspan="2">Edge clearance</th><th rowspan="2">Edge cover</th><th rowspan="2">Rebate depth</th></tr>
<tr><th>Sealant (see Note 1)</th><th>Gaskets (see Note 2)</th></tr>
<tr><td>4+A+4</td><td rowspan="3">5</td><td rowspan="3">3.5</td><td rowspan="3">15</td><td rowspan="3">5</td><td rowspan="3">20</td></tr>
<tr><td>5+A+5</td></tr>
<tr><td>6+A+6</td></tr>
<tr><td>8+A+8</td><td rowspan="3">7</td><td rowspan="3">5</td><td rowspan="3">17</td><td rowspan="3">7</td><td rowspan="3">24</td></tr>
<tr><td>10+A+10</td></tr>
<tr><td>12+A+12</td></tr>
</table>

Notes:

1. Sealant applies to non-setting glazing compounds, plastic glazing compounds, two-part rubberizing compounds, sealants and preformed strip materials.
2. Gasket applies to gaskets made from extruded materials such as butyl strip, ethylene-propylene-diene-monomer (EPMD), neoprene and thermoplastic vulcanizate (TPV) held in position by pressure upon the glass.
3. For non-standard glass thicknesses the nearest values of nominal thickness, shall be used.
4. Timber and PVC frames may not require the specified front and back clearances provided the waterproofing performance requirements are met.
5. A is air spacer. Available thickness: 6 mm, 9 mm, 12 mm, 15 mm, 16 mm.

Annex A
(informative)

References

A.1 Referenced standards

Table A.1 – Referenced standards

Code of standards	Title of standards
AS 1288	Glass in Buildings - Selection and Installation (Incorporating Amendment Nos. 1 and 2)
AAMA 501.1	Standard Test Method for Water Penetration of Windows, Curtain Walls and Doors Using Dynamic Pressure
AAMA 501.2	Quality Assurance and Diagnostic Water Leakage Field Check of Installed Storefronts, Curtain Walls and Sloped Glazing Systems
AAMA 501.3	Field Check of Water and Air Leakage Through Installed Exterior Windows, Curtain Walls, and Doors by Uniform Air Pressure Difference
ASTM C719-14	Standard Test Method for Adhesion and Cohesion of Elastomeric Joint Sealants Under Cyclic Movement (Hockman Cycle)
ASTM C794-15	Standard Test Method for Adhesion-in-Peel of Elastomeric Joint Sealants
ASTM C920-14a	Standard Specification for Elastomeric Joint Sealants
ASTM C1087-00	Standard Test Method for Determining Compatibility of Liquid-Applied Sealants with Accessories Used in Structural Glazing Systems
ASTM C1036-11e1	Standard Specification for Flat Glass
ASTM C1048-12e1	Standard Specification for Heat-Strengthened and Fully Tempered Flat Glass
ASTM C1172-14	Standard Specification for Laminated Architectural Flat Glass
ASTM C1184-14	Standard Specification for Structural Silicone Sealants
ASTM C1249- 06a(2010)	Standard Guide for Secondary Seal for Sealed Insulating Glass Units for Structural Sealant Glazing Applications
ASTM C1279-09	Standard Test Method for Non-Destructive Photoelastic Measurement of Edge and Surface Stresses in Annealed, Heat-Strengthened, and Fully Tempered Flat Glass
ASTM C1369-14	Standard Specification for Secondary Edge Sealants for Structurally Glazed Insulating Glass Units

Referenced Standards (Continued)

Code of standards	Title of standards
ASTM C1651-11	Standard Test Method for Measurement of Roll Wave Optical Distortion in Heat-Treated Flat Glass
ASTM C1401-09a	Standard Guide for Structural Sealant Glazing
ASTM C1464-06	Standard Specification for Bent Glass
ASTM D638-10	Standard Test Method for Tensile Properties of Plastics
ASTM D5026-06	Standard Test Method for Plastics: Dynamic Mechanical Properties: In Tension
ASTM E283-04	Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen
ASTM E330-14	Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference
ASTM E331-00(2016)	Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure
ASTM E547-00(2016)	Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Cyclic Static Air Pressure Difference
ASTM E1300-12ae1	Standard Practice for Determining Load Resistance of Glass in Buildings
ASTM E2190-10	Standard Specification for Insulating Glass Unit Performance and Evaluation
ANSI Z97.1	Glazing Materials Used in Buildings – Safety Performance Specifications and Methods of Test
BS 952-1	Glass for Glazing. Part 1: Classification
BS 952-2	Glass for Glazing. Part 2: Terminology for Work on Glass
BS 5516-1	Patent Glazing and Sloping Glazing for Buildings. Code of Practice for Design and Installation of Sloping and Vertical Patent Glazing
BS 5516-2	Patent Glazing and Sloping Glazing for Buildings. Code of Practice for Sloping Glazing
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

Referenced Standards (Continued)

Code of standards	Title of standards
BS 6213	Selection of Construction Sealants. Guide.
BS 6262	Glazing for Buildings
BS EN 572	Glass in Building - Basic Soda Lime Silicate Glass Products
BS EN 1279-1	Glass in Building - Insulating Glass Units Part 1: Generalities, Dimensional Tolerances and Rules for the System Description
BS EN 1288-3	Glass in Building - Determination of the Bending Strength of Glass. Part 3: Test with Specimen Supported at Two Points (Four Point Bending)
BS EN 1863-1	Glass in Building. Heat Strengthened Soda Lime Silicate Glass. Definition and Description
BS EN 1863-2	Glass in Building. Heat Strengthened Soda Lime Silicate Glass. Evaluation of Conformity. Product Standard
BS EN 12600	Glass in Building - Pendulum Test. Impact Test Method and Classification for Flat Glass
BS EN 13022-2	Glass in Building. Structural Sealant Glazing. Assembly Rules
BS EN 14179-1	Glass in Building - Heat-soaked Thermally Toughened Soda Lime Silicate Safety Glass. Part 1: Definition and Description
BS EN 14179-2	Glass in Building - Heat-soaked Thermally Toughened Soda Lime Silicate Safety Glass. Part 2: evaluation of conformity / product standard
BS EN 15434	Glass in Building. Product Standard for Structural and/or Ultra-violet Resistant Sealant
BS EN ISO 12543	Glass in Building. Laminated Glass and Laminated Safety Glass
CAN/CGSB-12.20-M89	Structural Design of Glass for Buildings
GB 15763-2	Safety Glazing Materials in Building. Part 2: Tempered Glass
GB 15763-3	Safety Glazing Materials in Building. Part 3: Laminated Glass
GB 15763-4	Safety Glazing Materials in Building. Part 4: Heat Soaked Thermally Tempered Glass
SUG	Code of practice for the structural use of glass 2018

Annex B
(informative)

Recommendations for shower screen installation

The following recommendations are provided for the benefit of screen fabricator and installer, and the homeowner/user:

a) Shower screen installation shall comply with MS 1498 and MS 1017.

b) To ensure stability and safe performance of frameless shower screens, glass gussets, braces and supports at the head of the frame less glass may be necessary.

c) While patch fittings provide required strength and appearance, the fixed glass panels in a frameless shower screen may be attached to the wall and floor with a securely fixed channel. The glass should be anchored firmly to the channel with glazing wedges or structural grade silicone.

d) The hardware design should be such that the 'cut-outs' or fixing holes in tempered glass anchor the glass to the fittings thus reducing the potential for a hinged frameless door to sag, which can result in glass to glass and glass to floor contact. The hardware design should also include gaskets to prevent glass to metal contact.

e) Unframed doors should be installed in such a manner as to avoid the edge of the glass, which is the part of glass most vulnerable to breakage, from coming into contact with the stile or floor.

f) A frameless glass wall panel up to 2 100 mm high should have a minimum of two mechanical fixings to the wall at 1 700 mm maximum spacing. Panels exceeding 2 100 mm high require additional fixings at 1 700 mm maximum spacing. This is in addition to silicone, which provides some stability to the glass as well as sealing of glass to wall tiles, etc. Screens can be attached to the floor allowing for minimum 3 mm clearance with either structural silicone or minimum 2 mechanical fixings at a maximum spacing of 1700 mm.

It is recommended that homeowners regularly inspect the following aspects of the operation of a frameless shower screen:

i) Ensure a minimum of 3 mm clearance is maintained between all edges of a frameless glass door and the fixed panel and or wall and the floor.

ii) Check the tightness of the screws and clamp/patch and hinge fittings.

iii) Check the operation of the hinges to ensure that they hinge freely and are not bound.

iv) Replace scratched or damaged glass.

v) Ensure that, when making alterations to a shower area, frameless shower screen glass door/s do not make contact with objects that may cause the frameless glass door to fracture.

When reglazing or replacing glass it is recommended that Class 1 safety glass be used.

Annex C
(informative)

Basis for determination of fin design to prevent buckling

C.1 Introduction

In glass facades that use glass stiffening fins located on the inside to provide the necessary support for the facade panels, it is necessary to ensure that buckling of the fin will not occur when it is subjected to the design loads.

Since there are many possible configurations for glass stiffening fins, it is not practicable to provide a simplified design approach. Consequently, each design must be analysed in accordance with accepted engineering principles.

The analysis requires a knowledge of the critical elastic buckling moment (M_{CR}), and values for particular situations can be obtained from standard texts on structural analysis. However, as an aid to design, some values of the critical elastic moment are presented in this Annex.

The design moment for a particular structural situation must not exceed the critical elastic buckling moment (M_{CR}) divided by a factor of safety of 1.7.

The following recommendations are applicable to end-supported beams of bisymmetrical cross-section for which the contribution of warping stiffness to the buckling strength may be neglected.

The ends at supports are assumed to be effectively restrained against twisting. This condition will be satisfied if the supports possess a torsional stiffness in excess of 20 GJ/L, where GJ is the torsional rigidity of the beam and L is its length.

Note: For information on more general- sections, including the effects of warping stiffness, refer to NETHERCOT, D.A. AND ROCKNEY, K.C. Unified Approach to the Elastic Lateral Buckling of Beams, The Structural Engineer, Vol. 49, No. 7, July 1971, pp. 321-30. (For erratum, see Vol. 51, No. 4, April 1973, pp. 138 - 9.)

C.2 Beams with intermediate buckling restraints

The critical elastic value of the maximum moment between two buckling restraints may be taken as:

$$M_{CR} = (g_1/L_{ay})\left[(E1)_y(GJ)\right]^{1/2} \quad \text{(C.1)}$$

where

M_{CR} = critical elastic buckling moment;

gi = constant obtained from Table C.1;

L_{ay} = distance between effectively rigid buckling restraints;

$(E1)_y$ = effective rigidity for bending about the minor axis; and

(GJ) = effective torsional rigidity.

In computing the effective torsional rigidity of beams of solid rectangular cross-section, the value of torsional moment of inertia (J) may be taken as:

$$J = \frac{db^3}{3}\left(1 - 0.63\,\frac{b}{d}\right) \qquad \text{(C.2)}$$

where

d and b are the depth and breadth of the fin respectively.

The value of torsional elastic modulus (G) may be taken as 28.7 GPa for glass fins.

The value of the linear elastic modulus (E) may be taken as 70.0 GPa for glass fins.

Table C.1 – Coefficients for slenderness factor of bisymmetrical beams with intermediate buckling restraints

Moment parameter (β) (see Figure C.1(c))	Slenderness factor (g_1)	
	Free restraint condition*	Fixed restraint condition*
1.0	3.1	6.3
0.5	4.1	8.2
0.0	5.5	11.1
-0.5	7.3	14.0
-1.0	8.0	14.0

* The buckling restraints must prevent rotation of the beam about the z-axis. The terms 'free' and 'fixed' restraint condition refer to the possibility for rotation of the beam about y-y axis at the restraint locations, as shown in Figure C.1.

C.3 Beams with no intermediate buckling restraints

The critical elastic value of maximum moment of beams with no intermediate buckling restraints may be taken as:

$$M_{CR} = (g_2/L_{ay})[((EI)_y)(GJ)]^{1/2}\left[[1 - g_3(y_h/L_{ay})][(EI)_y/GJ]^{1/2}\right] \qquad \text{(C.3)}$$

where

M_{CR} = critical elastic buckling moment;

g_2, g_3 = constants obtained from Table C.2;

L_{ay} = distance between effectively rigid buckling restraints (span of beam);

$(EI)_y$ = effective rigidity for bending about the minor axis;

(GJ) = effective torsional rigidity; and

y_h = height above centroid of the point of load application.

Note:. In Table C.2 the values of the coefficients g_2 and g_3 apply to beams with lateral restraints only at their end points. However, these coefficients may be used for any other beam load system that has a similar shape of bending moment diagram between points of lateral restraint.

C.4 Continuously restrained beams

For beams of bisymmetrical cross-section continuously restrained against lateral displacement at a distance y0 from the neutral axis, the critical elastic moment M_{CR} may be taken as:

$$M_{CR} = \frac{\left((\pi/L_{ay})^2/(EI)_y\left[\left[\frac{d^2}{12}\right]yo^2\right] + (GJ)\right)}{(2y_0 + y_h)} \quad \text{(C.4)}$$

where

M_{CR} = critical elastic buckling moment

LL_{ay} = distance between points of effective rigid rotational restraints

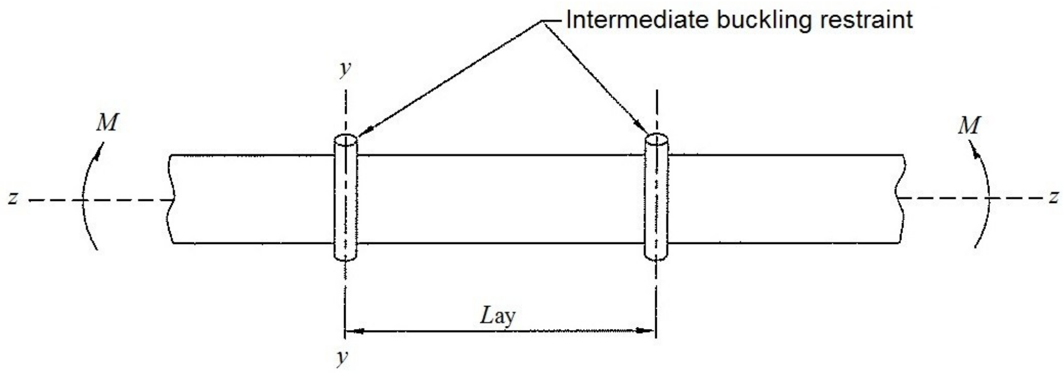
$(EI)_y$ = effective rigidity for bending about the minor axis

d = depth of beam

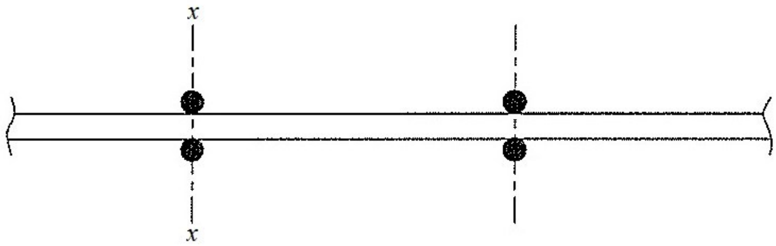
(GJ) =effective torsional rigidity

y_h = location from the neutral axis of the loading point [see Figure C.2(a) and C.2(b)].

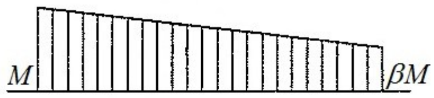
NOTE. The parameter y_h may take on negative values, subject to the direction of the applied load and the position of the restraint.



a) Side view of beam



b) Top view of beam



c) Diagram of bending moment between buckling restraints

Figure C.1 – Notation for beams with intermediate buckling restraints

C.5 Buckling restraints

For most design situations no check need be made on the effectiveness of buckling restraints. However, for an unusually light restraint system being used for a critical (i.e non-load-sharing) engineered structure, it may be advisable to assess the effect and the capacity of the restraints.

For a design of slender beams having equally spaced buckling restraints, the restraint system is considered a lateral one as shown in Figure C.2 where the restraint stiffness (KA) is defined as follows:

$$P_R = K_A \, \Delta_A \tag{C.5}$$

Where

P_R = restraint force

K_A = restraint stiffness

Δ_A = beam displacement

The restraint force (P_R) occurs when the point of attachment of the restraint to the beam undergoes a displacement (Δ_A). It is assumed that the ends of beams are effectively restrained against torsional rotation.

For members of rectangular section and for box beams, the design force (P_R) on the lateral restraints is given by the following equation:

$$P_R = \frac{0.1 M_a}{d \, (n + 1)} \, g_4 \tag{C.6}$$

where

M_a = the applied bending moment on the beam

g_4 = constant

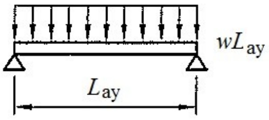
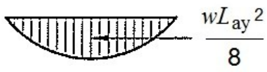
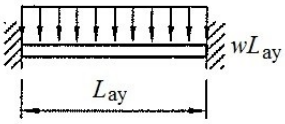
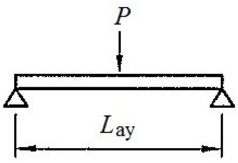
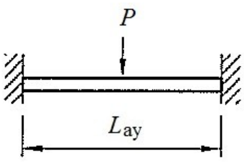
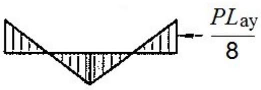
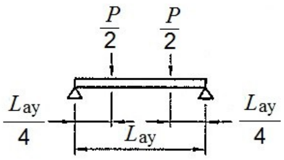
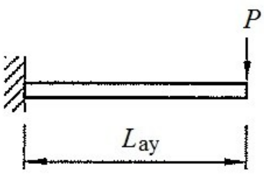
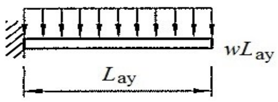
= lesser of (m + 1)/2 and 5

d = depth of beam

n = number of equally spaced intermediate restraints

m = number of members supported by each restraint system

Table C.2 – Coefficient for slenderness factors of bisymmetrical beams with no intermediate buckling restraints

Loading	Bending moment (M)	Condition of end restraint against rotation about y-y axis*	Slenderness factor	
			g_2	g_3
		Free Fixed	3.6 6.1	1.4 1.8
		Free Fixed	4.1 5.4	4.9 5.2
		Free Fixed	4.2 6.7	1.7 2.6
		Free Fixed	5.3 6.5	4.5 5.3
		Free Fixed	3.3 -	1.3 -
		Free Fixed	4.0	2.0
		Fixed	6.4	2.0

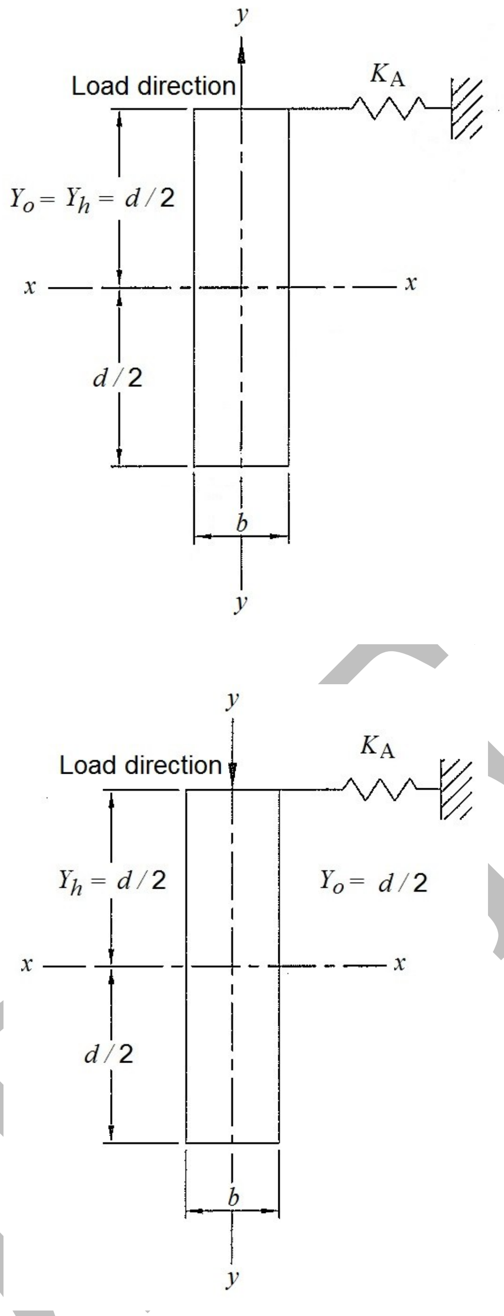


Figure C.2 – Beam lateral restraints

Annex D
(informative)

Sloped overhead glazing fracture characteristics

D.1 Introduction

This annex supports Clause 8.1 and 8.2, providing supplementary guidance for the selection and performance assessment of glazing subjected to inclined or overhead conditions.

D.2 Safety when accessing sloped overhead glass

Glass in sloped overhead glazing may be susceptible to impact damage from people walking or falling on the glass or from falling objects. If the building has human access space directly beneath the sloped glazing, then the safety of the occupants beneath the glazing should be considered as well as the safety of the workers above the glazing who may make contact with the glazing. For this reason, only safety glazing material is permitted to be used in s loped overhead glazing. However, different types of safety glazing materials have different breakage characteristics, and it is therefore important to choose the most appropriate glass type for the particular conditions applicable to the building in question.

D.3 Laminated safety glass

In the event of glass breakage, laminated safety glass tends to adhere to the plastic interlayer and not to fly or fall apart. The likelihood of glass falling out in large pieces is limited provided that the glass is fully framed and the impact that causes the breakage is not great.

The post-breakage performance of laminated glass may be improved by increasing the thickness of the plastic interlayer.

D.4 Heat strengthened laminated safety glass

Heat strengthened laminated safety glass has a similar performance to laminated safety glass as the breakage pattern of heat-strengthened glass is close to that of ordinary annealed glass. Heat strengthened laminated glass has a strength advantage over ordinary laminated glass and will be Jess susceptible to accidental and thermal breakage.

Bibliography

[1] MS 1525, *Energy efficiency and use of renewable energy for non-residential buildings – Code of practice*

Acknowledgement

Members of Working Group on Code of Practice for Glass (NSC 04/TC 9/WG 6)

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