Working Draft Standard

GLAZING SYSTEMS IN BUILDINGS – CODE OF PRACTICE

FOREWORD

Foreword will be provided after the committee discussion and decision on working draft.

Working Draft Standard

GLAZING SYSTEMS IN BUILDINGS CODE OF PRACTICE

1 SCOPE

1.1 This standard covers provisions relating to glazing systems such as selection, design, fabrication, installation, testing, and maintenance. This standard covers the glazing system used in the following areas of building Curtain Wall, Skylights and Canopy, and Doors and Windows.

1.2 This Standard does not cover patent glazing, glass for furniture; glazing for commercial and domestic green house.

> NOTE – The provision of this Standard pertains to glass and installation thereof. However, parties, as per their mutual agreement, may appropriately utilize the relevant provisions for installation of alternative sheeting materials used for similar purposes such as plastic glazing sheets/polycarbonate sheets taking also into account requirements of safety issues as applicable with the specific material.

2 REFERENCES

The standards listed in Annex A contain provision which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreement based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated therein.

3 TERMINOLOGY

For the purpose of this Standard, the definitions given below and those in IS 14900 shall apply.

3.1 Annealed Glass (*see Glass*) – Also known as 'normal' glass, which has not been subjected to toughening, lamination and heat strengthening. It is the product obtained from the process of slow and steady cooling of hot glass in order to relieve internal stresses or thermal induced stresses.

> NOTE – This term is most commonly used for flat glass.

3.2 Annealed Fire Resistant Glass – Type of glass which is made out of annealed glass combination and is tested for the required duration and satisfies the intended criteria of fire resistance. These types of glasses may not possess the best of the impact resistance characteristics and may be used as vision panels.

3.3 As-Cut Finished Sizes – Finished panes of flat glass cut from stock/standard sizes. They may be subject to further processing, such as edge working drilling, face decoration, etc.

3.4 Aspect Ratio – The ratio of a longer side of glass pane to its shorter side.

3.5 Balustrade – A low barrier forming a parapet to a stair, ramp, balcony, raised level or a change in level.

3.6 Beads or Glazing Beads – A strip of wood, metal or other suitable material attached to the rebate to retain the glass in position in the frame.

3.7 Bite – The minimum distance by which the inner edge of a frame (or a stop) overlaps the edge of the glass panel.

3.7.1 *Glazing Bite* – The dimension by which the framing system overlaps the edge of the glazing infill.

3.8 Block (Setting Block) – A small piece of wood, plastic, rubber or other suitable material used between the edges of the glass (generally the bottom edge only) to centralize the glass in the frame (frequently called a setting block).

3.9 Chair Rail – A fixed rigid bar that provides protection from human impact.

3.10 Clear Glass – A transparent glass with neutral/near colourless appearance.

3.11 Coefficient of Linear Expansion – It is expressed as the strain (change in length per unit length) per unit variation of temperature of a material.

3.12 Combustible Material – The material which when burnt adds heat to a fire when tested for combustibility in accordance with IS 3808.

3.13 Corridor – A common passage or circulation space including a common hall.

3.14 Coupled Glazing (also known as Secondary Glazing) – Two panes of glazing spaced apart in an opening, either in the frame or glazed separately, to form an unsealed cavity.

3.15 Curtain Wall – Non-load bearing structure/partition of glass attached to the building frame, usually on the exterior face. Curtain wall vertical framing members run past the face of floor slabs, and provision for anchorage is typically made at vertical framing members only.

> NOTE – In contrast to combination assemblies and composite units, curtain wall systems often need to meet additional performance requirements for inter-story differential movement, seismic drift, dynamic water infiltration, etc. Operating vents and entrance doors are provided as separate inserts.

3.16 Distance Piece – A small piece of wood or other suitable material used to locate the glass between the bead and the back of the rebate to prevent lateral movement.

3.17 Door or Shutter Assembly Door-Set – A pedestrian door-set or industrial type door-set including any frame or guide, door leaf or leaves, rolling or folding curtain, etc, which is provided to give a fire resisting capability when used for the closing of permanent openings in fire resisting separating elements, which includes any side panel(s), vision panel(s), flush over panel(s) and/or transom panel(s) together with the building hardware and any seals (whether provided for the purpose of fire resistance or smoke control or for other purposes such as draught or acoustics) which form the assembly.

3.18 Double Glazed Fire Resistant Glass – A fire resistant glass that is used in a double glazed unit.

> NOTE –These shall be tested as a complete Double Glazed Unit (DGU) or other multiple glazed units as the case may be. Double glazed fire resistant glass can be a combination of intumescent laminated fire rated or tempered fire resistant glass. Fire resistant glass cannot be combined with another glass and used as a DGU unless the combined double glazed or multiple glazed units are also tested.

3.19 Double Glazing – Glazing formed by an assembly of two glass panes separated by a spacer and the gap may be filled by vacuum, air or inert gases and hermetically sealed along the periphery to improve the thermal insulation.

3.20 Edge Deterioration – The discolouration of the reflective coating at the edge of the silvered glass.

3.21 Edge Faults – The faults that affect the as-cut edge of the glass. They may include entrant/emergent faults, shelling, corners on/off and vents.

3.22 Edge Polished – It is usually applied to flat glass, the edges of which have been polished after cutting.

3.23 Edging – Grinding the edge of flat glass, to a desired shape or size.

3.24 Exposed Edge – A glass panes' edge that is not covered.

3.25 Facade – It is the front or face of the building which is part of framed or frameless system.

3.26 Faceted Glazing – It is a type of glazing in which flat panes of glass are installed vertically at an angle to each other to form a faceted surface.

3.27 Fenestration – All area (including frame) in the building envelope that let in light, including window, plastic panels, clerestories, skylight, fanlight and glass doors that are generally more than one-half the floor height, and glass block walls.

3.28 Fin – A piece of glass positioned and fastened to provide lateral support.

3.29 Fire Separation – The distance, in metres, measured from the external wall of the building concerned to the external wall of any other building on the site, or from other site, or from the opposite side of street or other public space for the purpose of preventing the spread of fire.

3.30 Float Glass – Flat, transparent, clear or tinted soda-lime silicate glass having parallel and polished surfaces obtained by continuous casting and floatation on a metal bath.

> NOTE - Flat glass is a general term covering sheet glass, float glass and various forms of rolled and plate glass in which shape of the glass is flat and commonly used for windows, glass doors, transparent walls and other architectural applications.

3.31 Flush Over Panel – A panel which is incorporated within a door-set or openable window and fitted above the leaf or leaves within the frame head and the jambs and with no transom.

3.32 Frame – An element made of timber/metal/aluminium or other durable material/combinations of materials, such as glass fins and structural sealant, supporting the full length of a glazed panel edge.

3.33 Frameless Glazing – An unframed glazing which maintains the integrity through pointed support structures.

3.34 Front Putty – The compound forming a triangular fillet between the surface of the glass and the front edge of the rebate.

3.35 Fully Framed Glazing – The glazing whose panels have all its four edges framed.

3.36 Gap – A clearance between two adjacent surfaces and/or edges, for example between the edge of the leaf and the reveal of the frame or between the face of the leaf and the frame stop.

3.37 Glass – An inorganic product of fusion which has cooled to a rigid condition without crystallizing. It is typically hard and brittle, and has a conchoidal fracture. It may be colourless or tinted and transparent to opaque. The term glass refers to monolithic glass unless specified otherwise.

3.38 Glass Appearance Faults – Faults such as spot and/or linear and/or enlarged area faults which alter the visual quality of glass.

3.39 Glazing – Act of securing of glass or other glazing material into a building in prepared openings in windows, door panels, partitions, etc.

3.40 Guard Rail – A permanent physical barricade used to prevent human impact on glass/glazing.

3.41 Hairline Scratch – Very fine scratch that can hardly be seen with naked eye and is associated with glass cleaning techniques.

3.42 Halo – It is the distortion zone around a spot fault.

3.43 Heat Soaking – It is done on toughened/tempered glass by reheating to a temperature of 290 °C and keeping it at this temperature for 8 h and cooling it gradually. The glass can break spontaneously and without provocation due to possible impurity of nickel sulphide in basic glass used for toughening/tempering. This risk of spontaneous breakage can be minimised by heat soaking process by forcing such glasses to break during the test itself.

3.44 Heat Strengthened Glass – Glass within which a permanent surface compressive stress has been induced by a controlled heating and cooling process in order to give it increased resistance to mechanical and thermal stress and prescribed fracture characteristics.

3.45 Hermetic Seal – A complete seal (especially against the escape or entry of air which is impervious to outside interference or influence) done on insulating glass units.

3.46 High Activity Area – An area where multiple and major human activity takes place.

3.47 High Risk Area – An area prone to human injury and causality.

3.48 Infill Balustrades – The balustrades in which the supported glass resists an infill pressure and/or point load applied to the glass panel.

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

3.50 Interlayer – Layer or material acting as an adhesive and separator between plies of glass and/or plastic glazing sheets.

> NOTE – It can be designed to give additional performance to the finished product, for example impact resistance, fire resistance, solar control and acoustic insulation.

3.51 Internal Partition – An interior dividing wall or such portion of an interior dividing wall that is not a door, side panel, shop front or atrium wall.

3.52 Laminated Safety Glass – It is a glass made of two or more pieces of glass which are held together by an interleaving layer or layers of plastic materials.

3.53 Light Transmission – It is the measure of light passing through a transparent or a translucent material.

3.54 Light Transmittance – It is the measure of percent of visible light transmitted through glass pane which depends on type of body substrate and coating done on glass.

3.55 Linear Defects – They are the scratches and extended spot faults on the glass.

3.56 Manifestation – Any technique for enhancing a person's awareness of the presence of transparent glass.

3.57 Maximum Thickness – The thickness of a pane of glass at the maximum thickness tolerance.

3.58 Minimum Thickness – The thickness of a pane of glass at the minimum thickness tolerance.

3.59 Modulus of Elasticity (*Young's Modulus*) – This modulus expresses the tensile force that theoretically has to be applied to a glass specimen to stretch it by an amount equal to its original length. It is expressed as a force per unit area (for glass, E = 0.7 x 10^5 N/mm^2 = 70 GPa).

3.60 Monolithic Glass – A single sheet of flat glass which could be either annealed, toughened or heat strengthened.

3.61 Mullion – Vertical framing member separating and supporting two adjacent panes of glass or panels.

3.62 Nominal Thickness – A numeric designation that indicates the approximate thickness of glass.

3.63 Non-Combustible Material – A material not liable to burn itself or to add heat to a fire when tested for combustibility in accordance with IS 3808.

3.64 Organic Coated Glass – A sheet of glass coated on one or both sides with an applied organic coating or sheeting.

3.65 Pane – A single piece of glass or plastic glazing sheet material in a finished size ready for glazing.

3.66 Panel – An assembly containing one or more panes of glass.

3.67 Partition – It means an interior non-load bearing divider, one storey in height or part.

3.68 Partly Framed or Unframed Glazing – The panels that have one or more edges unframed.

3.69 Passive Solar Gain – The solar radiation in the form of energy and light which is transmitted through the glazing into the building and which can be utilized as a source of energy to reduce the need for artificial lighting.

3.70 Patterned Glass – A rolled glass having a distinct pattern on one or both surfaces.

3.71 Protective Coating(s) Faults –The faults where the metallic layer is exposed. They can be scratches or loss of adhesion of the protective coating(s).

3.72 Rebate – The part of a surround; the cross-section of which forms an angle into which the edge of the glass is received.

3.73 Reflective Coated Glass – It is a glass with reflective coating which 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.

> NOTE – In comparison with float glass surface, these reflecting coatings (due to their composition) exhibit lower level of emissivity which improves their U-value.

3.74 Reflective Silver Coating Faults – It is the fault on reflective silver layer which shall alter the appearance of the silvered glass. They consist of scratches, stains, colour spots and edge deteriorations.

3.75 Residual Protection – It is the protection provided to avoid the human impact on glass. It is provided on the side of glass where there are chances of human impact. It can be achieved by providing a sill structure or a grill inside.

3.76 Shading Coefficient – The ratio of the rate of solar heat gain through a specific unit assembly of glass to the solar heat gain through a single light of 3 mm clear glass in the same environment.

3.77 Sheet Glass – Glass made in large sheet directly from furnace or by making a cylinder and then flattening it.

> NOTE – These transparent glass have a glossy, fire-finished, apparently plane and smooth surfaces, but having a characteristic waviness of surface.

3.78 Skylight – A fenestration surface having a slope of less than 60˚ from the horizontal plane. Other fenestration, even if mounted on roof of a building is considered as either a vertical glazing or sloped glazing depending upon the angle of the glazing.

3.79 Sloped Overhead Glazing – A glazing that is inclined at less than 75º to the horizontal and located, wholly or partially, directly above an area that may be used by people.

3.80 Solar Energy Absorption – The percentage of the solar spectrum energy (ultraviolet, visible, and near infrared) from 300 nm to 2 500 nm that is absorbed by a glass product.

3.81 Solar Energy Transmittance (Direct) – The percentage of energy in the solar spectrum, ultraviolet, visible, and near-infrared energy, 300 nm to 2 500 nm, that is directly transmitted through the glass.

3.82 Solar Heat Gain Coefficient (SHGC) – The SHGC is the fraction of incident solar radiation admitted through a fenestration, both directly transmitted, and absorbed and subsequently released inward through conduction, convection and radiation.

3.83 Spandrel – A non-vision portion of the exterior wall of a building.

3.84 Spot Faults – The nuclei (solid or gaseous inclusions), deposits, crush marks, etc, in the glass. In certain instances spot faults are accompanied by a distortion zone called 'halo'. The nucleus of the spot fault is measurable.

3.85 Stain – An alteration of the reflective coating characterized by a more or less brownish, yellowish or greyish colouration of zones which can sometimes cover the whole reflective surface.

3.86 Stock/Standard Sizes – The panes of flat glass such as coated, mirror, enamelled glass, etc, supplied with as-cut edges which are intended for further processing. These are generally corresponded with manufacturer’s production size.

3.87 Tempered or Toughened Glass – Flat glass within which a permanent surface compressive stress has be induced by a controlled heating and cooling (quenching) process in order to give it greatly increased resistance to mechanical and thermal stress and prescribed fragmentation characteristics.

3.88 Tempered Fire Resistant Glass – A single piece of specially thermally-treated or chemically treated glass, tested for fire resistance for the required duration and having such a stress pattern that the piece when fractured, it reduces to numerous granular fragments, with no large jagged edges.

3.89 Thermal Transmittance (U) – Thermal transmission through unit area of the given building unit divided by the temperature difference between the air or other fluid on either side of the building unit in steady state conditions. It is also called as U-value. Its unit is W/m^2K.

NOTES:

1 Thermal transmittance differs from thermal conductance insofar as temperatures are measured on the two surfaces of a building unit in the latter case and in the surrounding air (or other fluid) of the material on the two sides, in the former case. Thermal conductance is a characteristic of the building unit whereas thermal transmittance depends on conductance and surface coefficients of the building unit under the conditions of use.
2 In the case of glazing, thermal transmission is taken through the central part of the glazing, that is, without edge effects.

3.90 Through Component/Connection – The internal spacer or fixing that either penetrates through the door-set or openable window from one face to another or directly connects the faces of one to the other.

3.91 Tinted Glass – A normal flat glass to which colourants (normally metal oxides) are added during manufacturing process to achieve tinting and solar radiation absorption properties. It is also referred to as body tinted glass.

3.92 Toughened Safety (Tempered) Glass – A single piece of specially heat-treated glass, with a stress pattern such that the piece when fractured reduces to numerous granular fragments, with no large jagged edges.

3.93 Transom – A horizontal cross bar connecting two vertical members in a glazing frame.

3.94 Unframed Glazing – A glazing with one or more edges unframed.

3.95 UV Transmittance – The percentage of energy in the ultraviolet (UV) spectrum from 300 nm to 380 nm that is directly transmitted through the glass.

3.96 Vertical Fenestration – All fenestration other than skylights. Trombe wall assemblies, where glazing is installed within 300 mm of a mass wall are considered walls and not fenestration.

3.97 Wired Glass – It is a type of glass into which a wire mesh is embedded during production. Wired glass has an impact resistance similar to that of normal glass, but in case of breakage, the mesh retains the pieces of glass.

SECTION 2: SELECTION OF MATERIALS

2.1 Types of Glazing system:

Glazing System includes all components of façade which include Glass, Frames, Supporting Structure, Sealants, Gaskets, Hardware and other associated accessories. Glazing systems can be generally classified into framed and frameless system.

- Framed Systems
- Frameless Systems

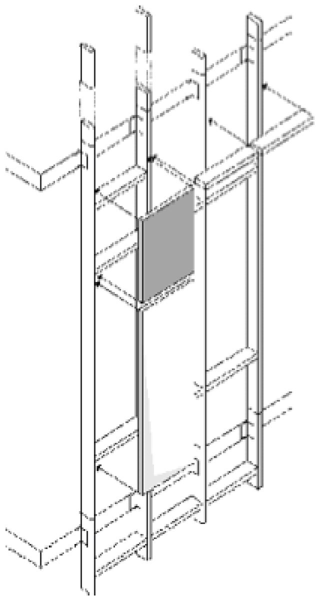
Framed Systems

Framed systems are facades where structural loads are taken by frames and the glass just acts as filling material. Framed systems are used extensively. The most common type of framed system is the structural curtain wall floor-to-ceiling glazing. Views of such a system can be enhanced using larger panel sizes.

The three most common types of framed systems are,

a) Stick systems
b) Unitized systems
c) Semi-unitized systems

2.1.1 Stick System



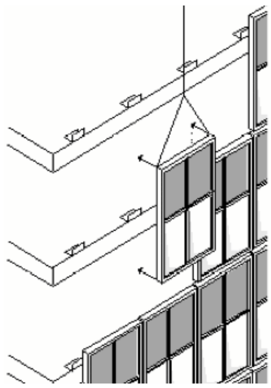
The term "stick" refers to the factory-cut mullions and transoms which are transported to site as loose bars or sticks. However, it is possible to assemble them into a ladder frame often referred to as "ladders" for quicker site assembly. Glass is then fixed to the frames at the site. Here glass acts as a panel that is fixed in the openings of the frames. Stick system may be defined as non-load bearing walls, usually suspended in front of structural steel or concrete framing. The deadweight of the stick system with environmental forces acting upon them is transferred back to the main structure through the fixing points of the stick system.

This system is mainly made from extruded hollow aluminium profiles which are finished in either polyester powder coated or anodized finishes and available in a wide choice of colors.

One of the main advantages of this system is the wide availability of system choice on the market at very competitive prices and short lead-in times. The connections between the vertical mullions and transoms must be sealed correctly with the correct type of sealant. The joints of the inner gaskets must be cut and glued successfully if inner vulcanized frames are not used. A further sub-division of SCW is the choice of system drainage, there being two types

1. Zone or Field Drainage – horizontal pressure plates and capping must be machined to allow air in and to allow water drain out successfully from the wall after heavy rainfall.
2. Mullion Drainage – water travels across all transoms and collects at the mullion connections and runs downwards, similar to water downpipe.

2.1.2 Unitized System



This system consists of manufactured and pre-glazed story high units or panels normally constructed from aluminium profiles or steel framework that are fully completed at the factory, prior to going on site, including all fenestration choices from glass, stainless metal panels, insulated spandrels to the stone cladding. Adjacent units are attached by sliding the next unit to the already installed unit.

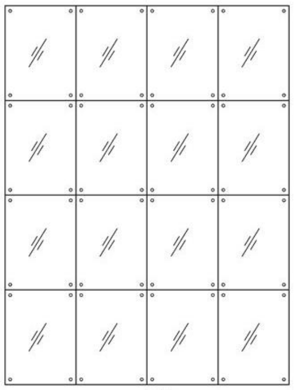
The widespread use of this system is largely attributed to factors such as the increase in building height, the demand for recladding of older buildings and the ever-increasing drive to reduce onsite construction.

2.1.3 Semi-unitized system

A Semi-unitized curtain wall is a type of curtain wall which has the combined features of stick curtain wall and unitized curtain wall. In the semi-unitized system, the framing is done at the site itself and the glass is then bonded. The glass is structurally glazed to the sub-frame, which is bolted to the main frame, and weather silicone is filled with two glasses. All components of semi-unitized curtain wall except main keels are fabricated and assembled into unitized panels at the production facilities and then delivered to construction sites to be fixed on main keels for installation. Glazing sequence is not restricted unlike in unitized systems.

2.1.4 Frameless Systems

Frameless systems are known as bolted systems. One example of frameless systems is the spider glass system, which is a bolted glass assembly that secures the glazing by means of articulated point fixing. Frameless systems provide an unrestricted vision of interiors and offer contemporary designs.



Frameless systems can be of the following types:

- Lightweight Tension Truss System
- Glass Fin System
- Cable Net System
- Conventional Shell Framed System
- Patch Fixing System

MULLION

Vertical framing member in facades is known as mullion. The mullions go from floor to floor and are fixed to these by the anchoring points. In general, the anchoring should be left longitudinally free in the lower profile (so as to accommodate the expansion of the metal), thus ensuring that the vertical forces always produce stretching (tensile stresses) in the profiles, and never compression. The mullion is mainly subjected to the horizontal pressure of the wind, uniformly distributed along its length, and to the vertical forces of its own weight and the load of the glass and panels, as shown in the figure below.

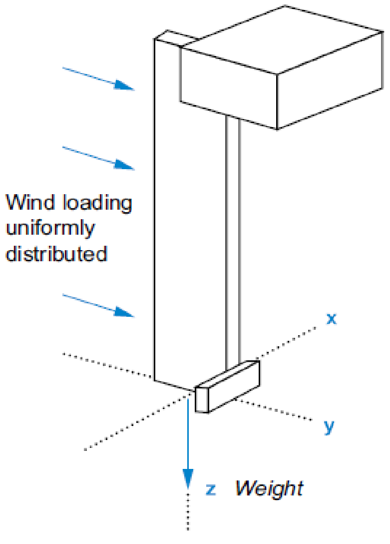


FIG: LOADS ACTING ON A MULLION.

Transoms

The horizontal framing member in the façade is known as transom. It is present between two mullions and act similar to the secondary beams in a building frame. In actuality, the transom is subjected to bi-axial bending. Firstly, by the forces acting in the vertical plane produced by its own weight and the weight of the panes or panels it has to support. Secondly, by the forces acting in the horizontal plane produced by the pressure of the wind.

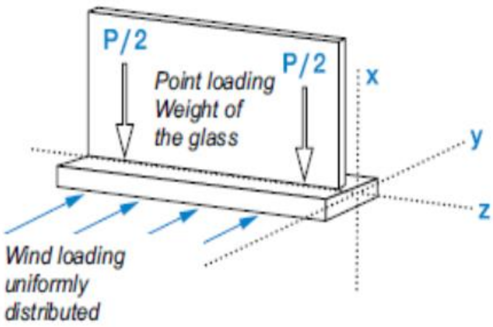


FIG .LOADS ACTING ON A TRANSOM

For the sake of simplicity in design it can be assumed (in consultation with structural engineer) that the mullions of lightweight façades alone withstand the wind loading and that the transoms alone must support the weight of the components that rest upon them.

With respect to load, the following hypotheses apply:

- **Mullions**

In the case of curtain wall façades, that is to say, where the components pass in front of the floors, the mullions must withstand a wind loading onto a rectangular surface similar to that shown in the following figure:

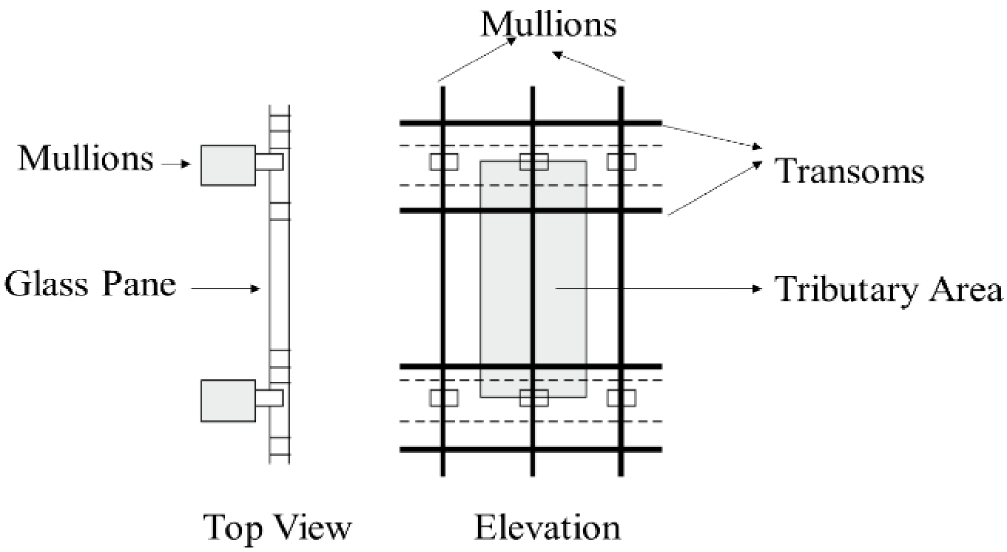


FIG CURTAIN WALL FACADE

In the case of infill grid façades, i.e. inserted between the floors, the mullions must withstand the wind loading acting on a trapezoidal surface as shown in the following figure:

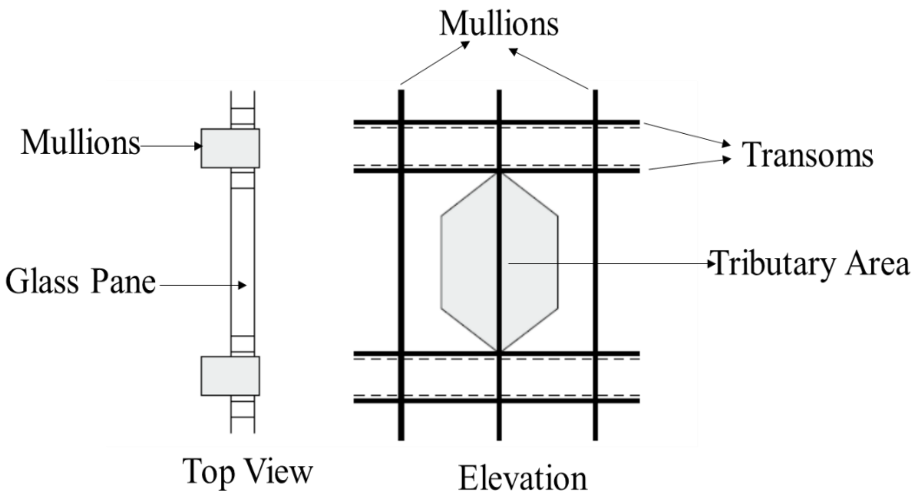


FIG PANEL FACADE

Further to transfer the load on to the primary structure, the glazing system must be supported at its extremities such that its deflection is limited and compatible with the structure of the façade, or alternatively, there must be a sufficient degree of freedom between them so that while remaining secure, the façade is not subjected to any stress arising from distortion of the primary structure. In-terms of static calculations, the mullions can be compared to a profile that has its extremities simply supported, or that has one extremity embedded and the other supported and is subjected to a distributed load. The distribution of load will be rectangular in the case of a curtain wall and trapezoidal in the case of a panel façade, as in the latter case the transoms do indeed contribute to the distribution of the load, being fixed to the floors of the building. It is always assumed that the free expansion of the mullions is permitted.

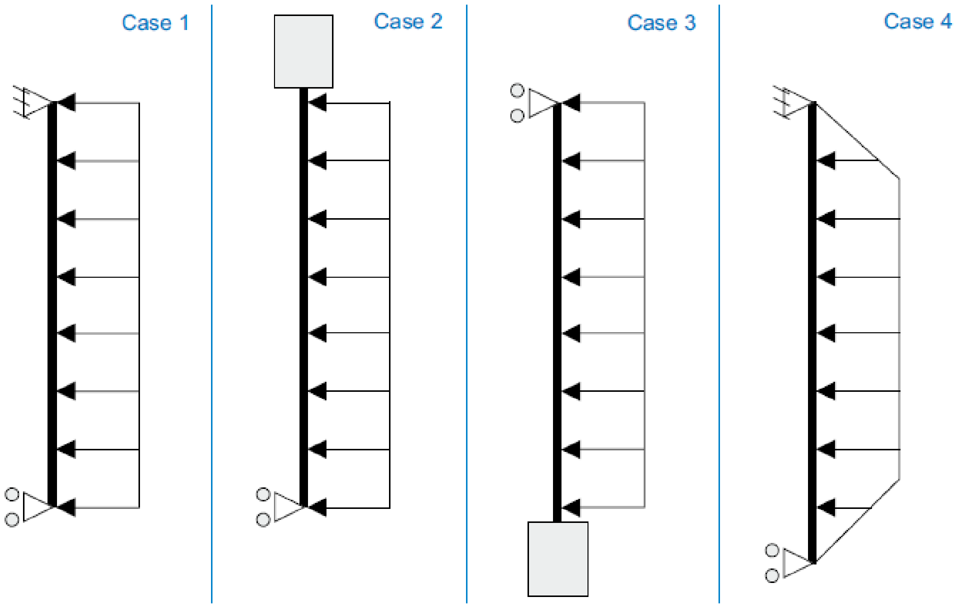


FIG LOADING CRITERIA

In view of the constructional difficulty of producing real embedding (Cases 2 and 3) that approaches the "theoretical embedding" condition (this should be verified in a test laboratory), the calculation is always carried out with the mullion assumed to be supported at both extremes (Cases 1 and 4).

Transoms

As already have been mentioned, the transoms can be assumed only to bear the vertical load of the components of the weight of the glass panel upon them. Consequently, the transom can be considered as a profile that is simply supported at its extremities. The weight of the glass panel can be considered to act as point loads as shown in the figure below. Here, a is the span of the transom, b is the distance between support and point of application of dead weight of the glass pane.

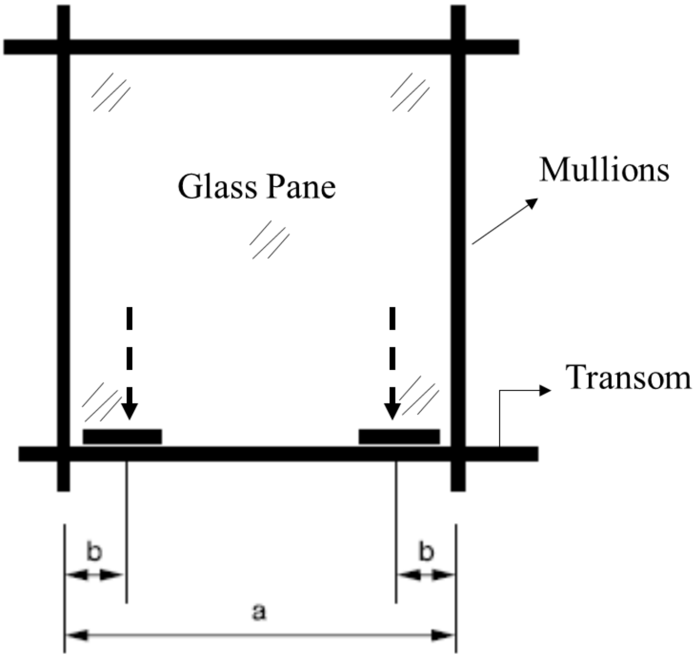


FIG SCHEMATIC DIAGRAM SHOWING LOADING ON TRANSOM

From the design perspective, mullions will be considered similar to the beam element, subjected to distributed loading (uniform/ varying). Similarly, transoms will also be designed as a beam element, subjected to two-point loads, acting in vertical plane (in the plane of glass panel) and the distributed loading due to wind, in the plane perpendicular to glass panel. In order to design both of these members, it has to be compliant

a) Strength criteria: stress induced in the member (mullion/transom) due to above discussed loading should not exceed the maximum permissible stress in the material as per IS 8147: 1976.

b) Serviceability criteria: Deflection induced due to loads should not exceed allowable deflection as specified in NBC 2016 and IS 8147: 1976.

Criteria	**Check to be Performed.**	**Reference Standard**
Compliance of strength criteria	• Check for bending stress • Check for shear stress	Clauses 7 and 8 section 3 of IS 8147:1976

	• Check for combined bending and axial tension/ • Check for combined bending and shear • Check for Bending about both the axis (Transoms Sections)	
Compliance of Serviceability Criteria	Check for maximum allowable deflection	IS 16231: Part 1

According to SP7, the maximum allowable deflection for mullions/transoms when exposed to the force of the wind

Mullions:

1. Single height glazing — Span/ 175 or 19 mm, whichever is less.
2. Double height glazing — For spans up to 4110 mm, same as single height glazing; and for spans above 4110 mm the same shall be (Span/240) + 6.35 mm.

Transoms:

The maximum frontal deflection of the transoms under wind loading, should not exceed

a) Span/ 175 or 19 mm, ***whichever is the least for wind load***

The maximum vertical deflection permitted, under its own weight load, should not exceed

b) Span/500 or 3 mm, ***whichever is the least for dead load***.

2.2 Types of Glass

Different types of glass and glazing products used in buildings shall be as per the following Indian Standards:

a) Float glass (Annealed glass) conforming to IS 14900,
b) Safety glass (Laminated and Toughened Glass) conforming to IS 2553 (Part 1),
c) Heat-strengthened glass conforming to IS 16982,
d) Insulated glazing unit (IGU) conforming to IS 17346,
e) Silvered glass mirror conforming to IS 3438.
NOTE – For guidance related to the selection of glass, refer IS 16231 (Parts 1 to 4) and IS 16978 (Parts 1 to 4).

2.3 TYPES OF FRAME MATERIALS

For the framed / semi-framed systems, materials such as aluminium, stainless steel, uPVC and Timber are commonly used.

2.3.1 ALUMINIUM ALLOY

Aluminium Extrusions and Flashing:

Extruded aluminium alloy used for structural members and additional profiles such as Interlocks, Rails, couplers etc., shall be fabricated from the most appropriate grade of alloy complying with IS 733, IS 8147 or equivalent or better (in terms of mechanical properties) and being made with complete homogenized billets to ensure uniform

property all across the profile. The chemical composition and mechanical properties of the aluminium profile used in the manufacture of the aluminium door, window and slider shall be traceable and
produced when requested. The thickness of the aluminium sections can vary but it shall meet the design, structural, performance, safety and durability requirements.
Such extrusions shall preferably be extruded aluminium grade 6063-T5, 6063-T6, 6060- T66 as per IS 8147 or equivalent. All aluminium alloys used as extruded rods/bars, tubes and profiles shall be compliant with IS 733/IS 738. Flashing, if in aluminium, around the doors and windows to be made of aluminium sheet alloy as per IS 737 or equivalent.

STAINLESS STEEL

Mullions, panels, fascia, column covers, windows, doors, trim, roofing, gutters, flashing, hardware and other items where minimum maintenance is anticipated shall be of austenitic stainless steels of type 301, 302 and 304 complying with accepted standards and employed for their mechanical properties as they are highly corrosion resistant for all normal exposures.

For interior decorative applications, where regular maintenance will be provided, type 430 may be used as it has lesser corrosion resistance properties. For external applications like in coastal regions where maximum resistance to corrosion is required, stainless steel shall be of type 316. Particular attention shall be paid to the direction of the rolling grain on self-finished stainless steel components where the finish is aesthetically important.

uPVC profiles

uPVC is a flexible material that is normally internally reinforced with steel or aluminium to give it the required strength and stiffness. It is easily formed to produce a wide variety of profiles. The inherent ability to make a variety of profiles, easier maintenance, corrosion resistance ability and heat resistance when used may be considered when choosing uPVC sections.
The uPVC profiles used for the fabrication of doors, windows and glazing system shall conform to the requirements of IS 17953.

Timber

Timber suitable for the manufacture of window and ventilator shutters shall be in accordance with IS 12896: 1990.

2.4 Types of Finish

The aluminium system may be finished by one of the following:

a) Anodizing as per IS 1868
b) Liquid organic coating
c) Powder coating as per IS 13871

Protective tape with an adhesive that does not leave stains upon removal and lasts a minimum of 3 months shall be applied. The thickness of the protective tape shall be minimum 40 microns.

a) *Steel frames* – Surface finish on stainless steel frames plays a major role in its resistance to corrosion and hence it is an important design aspect to be clearly specified. The types of surface finishes listed here shall be in accordance with applicable relevant standards:
   1) Mill,
   2) Ground,
   3) Brushed,
   4) Polished,
   5) Bead blasted,
   6) Electro polished,
   7) Coloured, and
   8) Patterned.

   Electro polishing of steel frames shall be done in accordance with available standards.

b) *Timber frames* – The function of finishes on timber is two-fold, first to improve the durability of the frame and second to add to the aesthetics. Unfinished, unprotected timber weathers as a result of gradual changes to its physio-chemical structure brought about by temperature and moisture content variations. The finishes may be of the following types:

c)
   1) *Conventional opaque systems* – Water and solvent borne,
   2) *Natural finishes* – Semi-transparent and opaque, and
   3) Water repellent preservatives, wood primers, undercoats and finishing coats (gloss, semi-gloss, flat and low sheen).

Based on the application, the appropriate type of finish shall be chosen.

2.5 Types of Anchorage

Anchorages are used primarily to join the mullions and transoms to the beam or slab through an appropriate bracket.

There are two basic types of anchors which are to be selected based on the application:

1. Stud anchors: Used where the mullions have to be fixed to the face of the beam or slab.
2. Flush anchors: Used where the mullions have their start point or termination at a slab / beam or skirting.

Factors influencing the selection of anchors and to ensure proper performance of the anchor during its service life are:

1) *Diameter* – The following parameters shall be calculated for the selection of the anchor diameter:

   i) Dead load acting on the anchor,
   ii) Live load incident to the anchor (wind load- tensile or shear), and
   iii) Weight of bracket, aluminium channels and other associated components.

2) *Length* – The length of the anchor is primarily based on the thickness of the glazing components which have to be fastened to the base material. Insufficient length shall lead to pull out failure.

3) *Material* – Stainless steel and galvanized iron are the two main types of materials used in the manufacturing of anchors.

4) *Coating* – The following type of coating shall be used based on the specific environmental condition met with:

Environmental Condition	Coating to be Used
Particular influence of moisture	Zinc plated
Occasional exposure to condensation and in coastal areas/ slightly corrosive	Hot-dip galvanized
Heavy condensation/ corrosion and in coastal areas	Stainless steel

5) *Load direction* – Based on the orientation of the anchor, they are incident to shear loading, tensile loading and combined loading of force and hence the proper diameter and depth of anchorage shall be selected.

6) *Base material* – The material characteristic of the base material also plays a major role in avoiding failure in the anchorage. The material shall be of suitable grade, have minimum thickness, shall be properly cured and have the necessary compressive stress.

7) *Embedment depth* – A critical factor in determining load capacity. Anchors installed less than minimum depth will stress the base material above its limits and may cause failure during installation or expansion of the anchor.

8) *Environmental condition* – Environmental conditions like temperature, humidity, salinity, etc, will affect the performance of the anchors and may lead to pre mature failure. Hence, careful selection of the material and coating should be done when selecting anchors which are to be installed in location subjected to adverse environmental impact such as coastal region.

2.6 Types of Substructure

2.7 Other Associated Materials

GLAZING BLOCK

Glazing blocks have the role of fixing the location of the glass unit in the frame so that load transfer occurs over the anchor points or junctions of the fixed frame or over the suspension points of an opening vent.

Glazing blocks differentiate themselves depending on their role as

- ★ Setting block
- ★ Location block

- ★ Distance piece

(A) Setting blocks:
Setting blocks are used between the bottom edge of the unit and the frame to centralize and equally support both panes of glass.

(B) Location blocks:
Location blocks are used between the edges of the glass and the frame to prevent movement of the glass within the frame by thermal expansion or when the window or door is opened or closed. They are required to prevent the weight of the glass from causing the frame to become out of square.

(C) Distance Pieces
Distance pieces are the components which are required to prevent displacement of glazing compounds or sealant by external loadings such as wind pressure.

STRUCTURAL SILICONE
Structural Silicone is a polymerized adhesive which is used to attach glass, metal or other materials to the structure of a building through which wind load and other impact loads on the façade are transferred from the glass or panel to the structure of the building. The structural silicone sealant must maintain adhesive and cohesive integrity as the façade is subjected to the various loads, thermal stresses and movements.

The following are the common types of Sealants:
Silicone Sealant

a) Acetoxy Sealant – Acetoxy silicone sealants release acetic acid (which smells a little like vinegar) as they cure, this is the most commonly used - it is more rigid and the full cure is quick. On the downside it not suitable for concrete, bricks and other porous subtracts.
b) Neutral Sealant – Neutral silicone sealants release alcohol as they cure, and has almost no smell, they have better adhesive properties for a greater number of materials including uPVC, most other plastics, glass, aluminium, lead, stone and masonry.

Acrylic Sealant

Acrylic sealant is a synthetic, water-based ingredient made from acrylic resins, used for caulking, jointing and filling cracks and gaps. Acrylic sealant are paintable.
The proper application of a sealant involves not only choosing a material with appropriate physical and chemical properties, but also having a good understanding of joint design, substrates to be sealed, performance needed, and the economic costs involved in the installation and maintenance of a joint sealant.
Typical considerations for selecting a sealant type for use in the construction industry are:
Joint Design

The specifics of a joint design must match up with a sealant's movement capabilities for the installed conditions. The practicality of installation of the sealant and other joint elements and the desired aesthetic appearance also need to be considered.

Physical and Chemical Properties.

Properties of the sealant such as, modulus of elasticity, its stress/strain recovery characteristics, tear strength, and fatigue resistance are all factors that influence sealant performance in a joint. The sealant polymeric type along with additives such as fillers and plasticizers will affect the performance of the product.

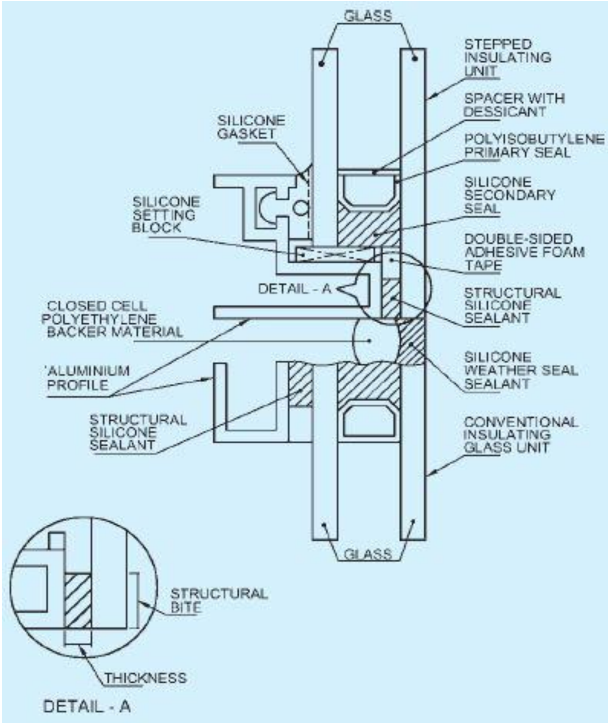
a) Durability Properties The adhesion of a sealant to a specific substrate(s) and its aging characteristics as they relate to resistance to among others ultra-violet radiation, moisture, temperature, cyclic joint movement, movement during curing, and bio-degradation can profoundly influence the service life of the installed sealant.

b) Application/Installation Properties: Important considerations include the consistency of the sealant (pourable or gunnable), pot life and tooling time, tack free time, application temperature range, and low temperature "gunnability" (i.e. ability to be dispensed easily by sealant gun). Sealants used for interior applications, even in high-rise or light commercial structures, will have properties and needs different from those used in other applications, such as structural sealant glazing or exterior building facade seals.

Determination of Structural Bite of Structural Silicone

The structural bite requirement is directly proportional to the wind load and the dimension of glass. Higher the wind load and larger the dimensions of the glass are, the greater the amount of structural bite required. The controlling variables which affect the structural bite requirement are the maximum short span dimension of glass and the design wind load that the structural glazing system should be designed to accommodate.

With a sealed IGU, there may be load sharing between the two panes of glass. If so and both panes are of the same thickness, the lateral load (P) is shared almost equally; thus, the secondary seal bite is calculated as one half that of the structural requirement. If of unequal thickness, the load shared by each pane will vary depending on the difference in thickness. Further details are to be obtained from the manufacturer.



FIG

(A) Structural bite calculation for wind load and glass dimension

$$\text{Minimum structural bite} = \frac{\text{Glass short span dimension} * \text{Wind load} * 0.5}{\text{Maximum allowable design stress}} \qquad (9)$$

NOTES:

1. Glass Short Span Dimension (SSD) is the shorter of the two dimensions (in meter) of the rectangular glass panel.
2. Wind load is the maximum wind pressure in Pascal for a return period of 10 years based on local regulations.
3. The maximum allowable design stress for the type of the structural sealant is selected.

(B) **Structural bite calculation for dead load (clause 6.3.8.1 of NBC 2016)**

$$\text{Minimum structural bite (m)} = \frac{\text{weight of glass (Kg)}}{(\text{Perimeter of the glass (m)} * \text{sealant dead load design strength } (\text{Kg/m}^2))} \qquad (10)$$

Where: P = perimeter (if the horizontal frame members will not be supporting the glass or will deflect under the dead load of the glass, consider 2 x Height only)

GASKETS

A gasket is a material which is available in various profiles, generally incorporated in the glazing systems for preventing leakage and for other important performance factors. Most gaskets form a seal as a result of compression of the bulk material, but some gaskets form a seal by deflection, either of a cantilevered arm or a hollow tube and others work by wiping contact with minimal deflection.

To seal effectively a gasket must remain in compression. However, the force exerted by a gasket in compression will gradually decrease over a period of time due to the effects of creep and stress relaxation. There will also be a reduction in recovery of compression when the load is removed.
The selection of the required type of gasket shall be based on their ability to limit air leakage and water penetration, allow relative movement between components, distribute and absorb loads and also accommodate tolerances.
Based on the method of fixing, the types of gaskets are as follows

a) Push-in gaskets are designed to be fitted into a groove in the mounting surface, prior to the formation of the joint.
b) Drive-in or wedge gaskets are designed to be forced into the gap between the mounting surface and contact surface, usually as the last stage in sealing the joint. A drive-in gasket can usually be removed by pulling it from the joint, although it may be manufactured with a rigid strip that makes this difficult.
c) Slide-in gaskets are designed to slide into a groove on the mounting surface, but must be installed from the end of the groove. A slide-in gasket can usually only be removed by sliding it out from the end of the groove.

The most commonly used gasket materials are,

a) EPDM
b) Neoprene
c) Silicone
d) Butyl
e) Thermos-plastic rubbers
f) Hypalon

PREFORMED TAPES

Preformed tapes come in rolls. The tape consists of pigments, resins, and reflective materials and comes ready to use with or without adhesives. Additional adhesive (primer) can be applied to enhance the bond. Typical requirements of preformed butyl and foam tapes can found in the below Table.

Typical Properties of Preformed Tapes

SI No	**Properties**	**Requirement**
1	Low temperature flex	No Cracks at -23°C
2	Weight Loss	2 percent, *Max*
3	Vehicle migration	1 paper stained maximum and this stain shall be no more than 3.2mm from edge of sample maximum
4	Backing removal	No transfer of tape compound to the paper
5	Yield strength	41.4 kPa, *Min*
6	Compression Recovery	Compression index, 1.22 N/mm^2 *Max*
7	Water absorption	Weight gain, Max after boiling, 40 Kg/m^3, *Max*
8	Flow test	Loss of height, 60 percent, *Max*

SECTION 4: DESIGN

4.1 GENERAL CONSIDERATIONS

Following basic considerations must be given appropriate importance at the planning stage in order to achieve apt selection and designing of glass in building facades,

a) Location
b) Climatic Zone
c) Orientation
d) Building details.
e) Natural ventilation - Window to Wall Ratio

4.1.1 *Location*

Location advantage to be leveraged by laying more emphasis on use of Passive Solar Building Design Techniques to facilitate the occupants comfort from natural sources of heat and light and less dependency on artificial lighting and HVAC consumption.

4.1.2 *Climatic Zones*

Regions having similar characteristic features of a climate are grouped under one climate zone. Predominantly, Indian subcontinent is divided into five climate zones, viz. Hot and Dry, Warm and Humid, Temperate, Composite, and Cold.

4.1.2.1 For the five-climate zone, the parameters required to be considered for planning and design of vertical fenestration are elaborated in SP7: Part 11 Approach to Sustainability.

4.1.3 *Orientation*

A good oriented building helps to save cost on the façade and takes advantage of the natural day lighting, wind movement, micro-climates, natural drainage, and topography. Ideal orientation for any building would depend on the direction in which the maximum glazing area on the elevation is facing. In ideal scenario, building oriented towards North – South increase the comfort level of occupants by allowing indirect sun light and heat exchange between exterior and interior. Accordingly, the building interiors and floor layout can be designed. Glazing is preferred very less on the eastern and western walls. However, site layout might restrict the ideal orientation and hence materials with low thermal conductivity can be considered.

4.1.4 *Building Details*

Building form plays an important role in selection of right kind of façade elements. Floor depth and corresponding glazing area surrounding the floor decides on what optical and thermal parameters of glass needs to be used. Detailed analysis is needed though to check for energy efficiency keeping in all building factors.

4.1.5 *Natural ventilation (Window to Wall Ratio)*

Natural ventilation allows more transparency and daylight through windows and other openings in the building and it is generally calculated in terms of window to wall ratio (WWR). The window-to-wall ratio is the measure of the percentage area determined by dividing the building's total glazed area by its exterior envelope wall area. Window area will have impact on the building's heating, cooling, and lighting, as well as relating it to the natural environment in terms of access to daylight, ventilation and views.

$$WWR\ (\%) = \frac{\sum Glazing\ area\ m^2}{\sum Gross\ Exterior\ wall\ area\ m^2}$$

4.1.6 *Design Reference Standards*

The following code of practices and standards shall be followed while designing the glazing system.

IS	***TITLE***
IS 16231	(Part 1) : 2018 General Methodology For Selection (*First Revision*) (Part 2) : 2018 - Energy and Light (Part 3) : 2018 Fire And Loading (*First Revision*) (Part 4) :2018 Safety Related To Human Impact (*First Revision*)
IS 800 : 2007	General Construction in Steel — Code of Practice
IS 8147 : 1976	Code of practice for use of aluminium alloys in structures
IS 465 : 1953	Withdrawn
IS 3629 : 1986	Structural Timber In Building - Specification
IS 883 : 2016	Design of Structural Timber in Buildings - Code of Practice (*Fifth Revision*)
IS 5390 : 1984	Code of practice for construction of timber ceilings
	Classification and performance requirements for doors, windows and slider – Specification (ICS 91.060.50)
SP7 : National Building Code	a)Section 8 : Glass and Glazing, Part 6: Structural Design b) Part 11 : Approach to Sustainability c) Part 4 : Fire Safety

(Note: Members to suggest more Indian codes / standards to be referred)

4.2 STRUCTURAL DESIGN CONSIDERATIONS

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

a) Overall stability and buckling resistance against the design loads
b) Strength against collapse under the design loads and the imposed deformations of supporting structures
c) Integrity and robustness against progressive collapse under the design loads
d) Serviceability under the design loads and the imposed deformations of supporting structures
e) Water and air tightness
f) Durability
g) Quality and

h) Maintainability during its design working life.

4.3 LIMIT STATE DESIGN

4.3.1 GENERAL

4.3.1.1 The limit state design considers the functional limits of strength, stability and serviceability of both structural elements and the structure as a whole. The limit state can be defined as the state beyond which the structure no longer fulfils the relevant design criteria.

4.3.1.2 The limit state design is based on the requirement that the "Resistance" of the structure should exceed the "Load Effects" for all potential modes of failure, including allowance for uncertainties in load effects and variability in resistance and material properties, i.e.,

$$Resistance \geq Load\ effects$$

4.3.1.3 The load effects shall be determined by normal structural analysis methods for axial, bending, shear or torsion in structural members and components, multiplied by a partial load factor (γ_f) to give an upper bound estimate of load effects. Resistance effects shall be determined by the normal strength of materials, geometry members and material properties. The material strength shall be divided by a partial material factor (γ_m) to give a lower bound estimate for material properties, covering the variability of material strength, member dimensions and product variability. Partial factors are specified in Clause **4.7**.

4.3.1.4 Limit states considered in the standard are either the ultimate limit state or the serviceability limit state. Glass structures or elements should be designed by considering the limit states beyond which these structures would become unfit for their intended use. Appropriate partial factors should be applied to provide adequate degrees of reliability for ultimate and serviceability limit states. Ultimate limit states concern the safety of the whole or part of the structure whereas serviceability limit states correspond to limits beyond which specified service criteria are no longer met. Apart from material factor(γ_m), the overall level of safety in any design has to take into account a partial load factor (γ_f) covering the loading and variations of expected structural behaviour. The values assigned to γ_f depend on the type of load and the load combination. The characteristic loads are multiplied by the partial load factor to check the ultimate strength and stability of a structure.

4.3.2 *ULTIMATE LIMIT STATE*

Ultimate limit state considers the strength and stability of structures and structural members against failure.

4.3.3 *Strength and Stability*

For satisfactory design of an element at the ultimate limit state, the ultimate design resistance or capacity of the glass pane must be greater than or equal to the ultimate design load effects. The ultimate design resistance of glass pane is evaluated by reducing the ultimate design strength of glass by a partial material factor. The ultimate design loads are evaluated by multiplying the characteristic loads by partial load factors as described in clause **4.7**. The layout of the structure and the interaction between the structural members should be in a manner achieving a robust and stable design.

4.3.4 *Progressive Collapse*

Glass structures should be planned and designed against disproportionate collapse such that it will not be unreasonably susceptible to situations where damage or failure of single glass element or small areas of a structure may lead to progressive collapse of a major part of the structure. For example, failure of a glass column may lead to the failure of the glass beam and glass floor. In case of a failure of one single element, the portion of the glass structure at risk of collapse should not exceed 70 m^2 (floor, frontal or total area), due to the failure of one single element. Additional measures and special consideration should be provided to enhance the structural integrity and robustness in order to minimize the risk of localized damage leading to the collapse of a major part of the structure.

4.4 SERVICEABILITY LIMIT STATE

4.4.1 *Definition*

The serviceability limit state considers service requirements for a structure or structural elements under serviceability design loads. For instance, deflection, human induced vibration and wind-induced oscillation are considered in the serviceability limit state.

For a satisfactory design of an element at serviceability limit state, the serviceability design resistance must be greater than or equal to the serviceability design load effects as described in clause **4.8**.

4.4.2 *Deflection*

Deflection or deformation of a structure or any part of it should not adversely affect its efficiency or performance. Deflection should also be compatible with the degree of movement governed by other connected elements.

4.3.3 *Vibration*

Structural analysis should be applied to determine the natural frequencies of vibration of glass structures in order to mitigate excessive oscillation due to the dynamic effects of human and other forces. For the design of glass floor or staircase, it may be necessary to consider the vibration of the members for human comfort. Reference should be made to relevant design guidelines and specialist literature.

4.4 ANALYSIS AND DESIGN OF GLASS PANE

4.4.1 *GENERAL*

The methods of analysis should be based on as accurate a representative behaviour of the structure as is reasonably practicable. The primary objective is to obtain a set of forces and moments that are in equilibrium with the design loads derived from the load combinations. In general, it is satisfactory to determine the forces and moments by linear analysis or nonlinear analysis where appropriate for ultimate limit state and serviceability limit state.

As the effect of change in the geometry under loads is significant in thin glass panes, the advanced large deflection method of analysis is more accurate and computer programs are widely used for this type of analysis. Formulae for designing standard rectangular panes in the large deflection range are provided in clauses **4.7.4** and **4.8.2**. For irregular shaped glass panes, the finite element method should be used for linear and large deflection nonlinear analysis. The boundary condition should be defined as edge-free-to-pull-in unless otherwise justified. For glass panes with small thickness, it would be subject to the nonlinear effects from the membrane stress due to out-of-plane deflections in addition to the bending stress.

In the determination of the stress and the deflection for the design purpose, the minimum glass pane thickness should be adopted as specified in IS 16231.

4.5 SPECIAL DESIGN REQUIREMENTS

4.5.1 Safety Requirement against Glass Breakage

a) Laminated glass should be used in glass elements resisting long-term load, such as roof, canopy, skylight, sloped glazing, staircase, floor, beam, column, etc., and glass balustrade.

b) Tempered glass or laminated glass should be used in the parts of building exterior façade also serving as protective barrier.

c) Where tempered glass is used in building exterior façade, the glass should be in the form of laminated glass if it meets the following conditions:

1) The size of glass pane exceeds 2.5 m^2

2) Any point of the glass pane installed is at a height 5m or more above the finished floor level of the accessible area on either side of the pane.

d) Where IGU is used in building exterior façade, the requirement in item (3) above applies to the outermost pane of the IGU only.

4.5.2 *Safety Requirement against Failure of Glass Elements*.

Glass roofs, accessible canopies and skylights, staircases, and floors subject to medium-term or long-term loads should be constructed with multi-layered glass panes and designed for ultimate design loads. These elements should also be provided with structural redundancy such that in case of failure of any single glass pane, the remaining glass pane(s) shall be able to support the unfactored characteristic loads without failure.

4.5.3 *Safety Requirement against Human Impact*.

Glass shall be designed as per IS 16231 Part 4 for safety against human impact.

4.5.4 *Strength of Glass*

The ultimate design strength (p_y) of glass under short-term load duration is given in Table 4.2.

4.5.4.1 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 4.3** Definition of load duration is given below.

4.5.5 LOAD DURATION

Load resistance of a glass structural element is determined by a given probability of breakage and load duration. Load duration is defined as follows:

a) Short-term load duration is defined as the duration of load applying not more than 3 seconds (e.g. wind load and horizontal imposed load for protective barrier).

b) Medium-term load duration is defined as the duration of load applying more than 3 seconds but not more than 1 day (e.g. maintenance load and temperature load).

c) Long-term load duration is defined as the duration of load applying more than 1 day (e.g. load types other than short-term and medium-term load durations).

Also, as the strength of glass depends on different glass surface treatment, a glass surface treatment reduction factor (γ_S) should be applied to p_y as given in Table **4.4.** Design strength of glass with surface treatment should be verified by bending test.

TABLE 4.2 ULTIMATE DESIGN STRENGTH (py) 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 4.3 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 4.4 GLASS SURFACE TREATMENT REDUCTION FACTOR (Γ) FOR DIFFERENT GLASS TYPES.

Type of glass	**Glass surface treatment reduction factor (γ_s)**
Flat clear, tinted or coated glass	1.0
Ceramic fritted or enamelled painted glass	0.625
Patterned (embossed), sand blasted or acid etched glass	0.5

4.6 ANALYSIS AND LOAD SHARING OF GLASS PANE

4.6.1 *Linear Analysis of Glass Pane*

Linear analysis is based on the original geometry prior to deformation for stress computation. It is applicable when the material stress-strain relationship is linear and when the deflection is "small". The deflection is considered "small" when it is less than 3/4 of the glass pane thickness. In the case of large deflection, the linear analysis may be too conservative as it does not take into consideration of the membrane action in addition to bending action of the glass pane.

4.6.2 *Nonlinear Analysis of Glass Pane*

When a pane is subjected to small deflection, stresses are predominantly due to bending and linear analysis is still adequate to reflect the structural behaviour. As deflection increases, stresses redistribute from bending to membrane action. At large deflection, linear analysis overestimates the stress in the pane. In such situation, a nonlinear analysis would give more accurate result.
A four-side simply supported rectangular glass pane deflects under lateral loads, e.g., wind loads, will undergo nonlinear behaviour. When the deflection is greater than its thickness, the membrane action becomes important and could be dominant over the bending action and large deflection nonlinear analysis is more accurate to reflect the actual structural behaviour. For glass panes with curved surface and under complicated boundary conditions with edges not fully restrained or for the glass panes with irregular shape, finite element method should be used. For typical four-side simply supported rectangular glass panes, the thickness of glass pane can be derived from the equations **4.9**, **4.10** and **4.11**, which are based on the nonlinear behaviour of glass panes.

4.6.3 *Analysis of Laminated Glass*

Generally, laminated glass should be analysed and designed without the composite action, and the individual glass panes is to resist load shared in accordance with the stiffness of the individual panes.

4.6.3.1 The strength and stiffness of each individual glass pane shall be checked where the proportion of the total load to be resisted by each pane is $k$pane.

4.6.2 *Nonlinear Analysis of Glass Pane*.

4.6.2.1 When a pane is subjected to small deflection, stresses are predominantly due to bending and linear analysis is still adequate to reflect the structural behaviour. As deflection increases, stresses redistribute from bending to membrane action. At large deflection, linear analysis overestimates the stress in the pane. In such situation, a nonlinear analysis would give more accurate result.

4.6.2.2 A four-side simply supported rectangular glass pane deflects under lateral loads, e.g., wind loads, will undergo nonlinear behaviour. When the deflection is greater than its thickness, the membrane action becomes important and could be dominant over the bending action and large deflection nonlinear analysis is more accurate to reflect the actual structural behaviour.

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4.6.3 *Analysis of Laminated Glass*

Generally, laminated glass should be analysed and designed without the composite action, and the individual glass panes is to resist load shared in accordance with the stiffness of the individual panes.

The strength and stiffness of each individual glass pane shall be checked where the proportion of the total load to be resisted by each pane is k_{pane}.

$$k_{pane} = \frac{{t_{pane}}^3}{\sum_i {t_i}^3} \qquad ....(4.1)$$

where,

k_{pane} = load sharing factor of glass pane being checked
t_{pane} = minimum thickness of glass pane being checked
t_i = minimum thickness of each glass pane within the assembly
i = total number of glass panes within the assembly

The load sharing equation is derived from the fact that all glass panes are deflected together and the deflection of a glass pane is reversely proportional to the cube of the thickness and is proportional to the pressure. Where composite action is justified by bending tests as outlined in Annex B1 and full considerations have been given to the long term effects on interlayer materials described in clause 4.8.5, it may be incorporated in the design provided that the degree of composite action is not greater than 70% of the stiffness of an equivalent monolithic glass pane with a total thickness equals to the sum of thickness of the individual glass panes. The bending tests should confirm that the interlayers have the capacity to adhere the two or more panes rigidly such that they form a monolithic body.

If the degree of composite action is determined by bending test, the laminated glass can be considered as a monolithic glass pane, having an equivalent thickness equal to the sum of the individual pane thickness, with its stiffness multiplied by the coefficient for degree of composite action as given in equation **4.2**. The composite action should only be utilized for resistance to short-term load. The equivalent thickness of the laminated glass should then be used for the computation of deflection and bending stress.

$$\lambda = \frac{I_{eq}}{I} = \left(\frac{t_{eq}}{\sum_i t_i}\right)^3 \qquad (4.2)$$

where,

t_{eq} = Equivalent laminated glass thickness (mm)
t_i = Minimum thickness of each pane of glass within the assembly (mm)
I_{eq}= Equivalent second moments of area (mm4), I_{eq} = $Bt_{eq}^3/12$
I = Second moment of area (mm^4), $I = B\times(\sum i\times t_i)^3/12$
B = Width of the laminated glass (mm)
λ = Degree of composite action but not more than $\lambda test$ or 0.7 whichever is the less.
λ_{test} = Degree of composite action justified by bending tests in Annex B1
i = Total number of glass panes within the assembly.

4.6.4 *Analysis of IGU*

The load sharing between the panes of an IGU can be determined by their relative stiffness. However, such assumption is not valid for glass panes separated by deep cavities. Deep cavities mean the air gap is greater than the sum of the thicknesses of the glass panes. Since the IGU is sealed, it is affected by temperature changes and atmospheric pressure changes. The loads on each glass pane of the IGU have to be increased by 25% to account for the effects due to temperature changes and atmospheric pressure changes.

4.6.4.1 The strength and stiffness of each individual glass pane shall be checked where the proportion of the total load to be resisted by each pane is $kpane$.

$$K_{pane} = \frac{1.25\times t_{pane}{}^3}{\Sigma i t_i{}^3} \qquad .....(4.3)$$

where,

K_{pane}= load sharing factor of glass pane being checked.
$t_{pane}{}^3$ = minimum thickness of glass pane being checked.
t_i = minimum, thickness of each pane of glass within the assembly

i = total number of glass panes within the assembly

4.7 ULTIMATE LIMIT STATE DESIGN

Ultimate design loads Q_{ult} are obtained by multiplying the characteristic loads Q_{char} by a partial load factor (γ_y):

$$Q_{ult} = \gamma_y \times Q_{char} \quad (4.4)$$

Design load effects S_{ult} are obtained from the ultimate design loads:

$$S_{ult} = \text{f (effects of } Q_{ult}) \quad .....(4.5)$$

Ultimate design resistance R_{ult} is a function of the characteristic or specified material strengths divided by a partial material factor (γ_m) to allow for manufacturing tolerances, variations of material strengths (p_y) and product variability from their characteristic values given in Table **4.2**; and multiplied with the strength reduction factor (γ_d) given in Table **4.3** and the glass surface treatment reduction factor (γ_s) given in Table **4.4**.

For glass :

$$R_{ult} = f\left(\frac{\gamma_a \gamma_s p_y}{\gamma_m}\right)$$

For design of a structural element at ulitimate limit states, the design resistance R

R_{ult} must be greater or equal to the design load effects S_{ult}:

$$R_{ult} > S_{ult} \quad (4.7)$$

4.7.1 *Partial Load Factors*

The partial load factor γy serves to allow for variation of loads from their characteristic values; the reduced probability that various loads acting together will reach their characteristic values at the same time; and errors in calculation and variations in structural behaviour. Partial load factors and their combinations are given in clause **4.7.2**.

4.7.2 *Load Factors and Combinations*

The following principal load combinations should be considered:

a) Load combination 1 : Dead Load, imposed load, earth, water and temperature loads
b) Load combination 2 : Dead load, wind load, earth, water and temperature loads.
c) Load combination 3 : Dead load, imposed load, wind load, earth, water and temperature loads.

The load factors and their combinations given in Table **4.6** apply to the strength and the stability for normal design conditions.

TABLE 4.6 PARTIAL LOAD FACTOR ( ) FOR LOAD COMBINATIONS UNDER NORMAL DESIGN CONDITIONS

Load combination (including wind, water and temperature pressure, where present)		Load type						
		Dead		Imposed		Earth and water pressure	Wind	Temperature
		Adverse	Beneficial	Adverse	Beneficial			
1	Dead, imposed earth, water and temperature	1.4	1.0	1.6	0	1.4	1.2	
2	Dead, wind, earth, water and temperature	1.4	1.0	–	–	1.4	1.2	
3	Dead, imposed wind, earth, water and temperature	1.2	1.0	1.2	0	1.2	1.2	

Notes:

1) Where the action of earth or water pressure is beneficial, the partial load factor γ_f should not exceed 1.0. The value of γ_f should be taken such that γ_f multiplied by the design earth or water pressure equals the actual earth or water pressure.

2) All partial load factors for adverse condition are taken as 1.0 for serviceability limit states.

4.7.2.2 *Partial material factors*

For glass, the partial material factor γ_m on properties such as material strength and modulus of elasticity is taken as 1.0.

4.7.3 The combined effect of different design resistance under different load durations against the corresponding design load effects should satisfy the equation below.

$$\left(\frac{S_{ult}}{R_{ult}}\right) \boldsymbol{s}hort\ term + \left(\frac{S_{ult}}{R_{ult}}\right) medium\ term + \left(\frac{S_{ult}}{R_{ult}}\right) long\ term \leq 1.0$$

4.7.4 *Design of Glass Pane Thickness*

For four-side simply supported glass pane with aspect ratio (b/R) less than 5, the minimum required glass thickness t should not be less than the minimum of t_1 and t_2 below.

$$t_1 = 4.87\ a^{0.965} b^{0.22} \left(\frac{R}{C}\right)^{0.545} \qquad \text{.....(4.9)}$$

$$t_2 = 2.33(ab)^{0.655}\left(\frac{R}{C}\right)^{0.87} - 1.62\left(\frac{a}{b}\right) + 1.2 \quad .....(4.10)$$

where

R = Length of shorter side of glass pane (m)
b = Length of longer side of glass pane (m)
R = Factored design pressure on individual glass pane (kPa)
= γ_f × design pressure
c = Strength coefficient (c = c_1 × γ_d × γ_s)

in which
c_1 – Glass type (Heat treatment)
= 1.0 for annealed glass
= 2.0 for heat strengthened glass
= 4.0 for tempered glass
γ_d – Load duration factor given in Table 4.3
γ_s – Glass surface treatment reduction factor given in Table 4.4.

Equations **4.9**, **4.10** and **4.11** are used to calculate the required glass thickness, taking into account different glass type, load duration and glass surface treatment. These are only applicable to four-side simply supported glass pane.

Equation **4.8** is used to check combined load duration effects by first assuming glass thickness and then calculating design load effects S_{ult} and design resistance R_{ult} under each load duration (i.e. the calculation method shall refer to recognized formulae or finite element analysis for all support configurations).

4.8 SERVICEABILITY LIMIT STATE DESIGN

4.8.1 General

The serviceability limit state considers service requirements for a structure or structural elements under applied loads.

4.8.1.1 For satisfactory design of an element at serviceability limit state, the deflection resistance must not be less than the serviceability design load effects. Partial load factor for all load types is taken as 1.0 for the serviceability design.

4.8.2 Deflection of Glass Pane

The deflections in general should not impair the structural and the serviceability performance of a structural system. Deflection of a glass pane can be computed by the finite element method allowing for large deflection effects where appropriate or by the following equations for rectangular glass panes.

Four-side simply supported:

$$\delta = t\, e^{r_0 + r_1 x + r_2 x^2}$$

where,

$$x = \ln\left[\ln \frac{p(ab)^2}{E\,t^4}\right] \qquad \text{.....(4.12)}$$

$$r_0 = 0.553 - 3.83\left(\frac{b}{a}\right) + 1.11\left(\frac{b}{a}\right)^2 - 0.0969\left(\frac{b}{a}\right)^3$$

$$r_1 = -2.29 + 5.83\left(\frac{b}{a}\right) - 2.17\left(\frac{b}{a}\right)^2\ 0.2067\left(\frac{b}{a}\right)^3$$

$$r_2 = 1.485 - 1.908\left(\frac{b}{a}\right) + 0.815\left(\frac{b}{a}\right)^2 - 0.0822\left(\frac{b}{a}\right)^3$$

Two-side simply supported:

$$\delta = \frac{5}{32}\frac{pa^4}{Et^3} \qquad \text{.....(4.13)}$$

4.8.3 *Deflection limit of glass pane* (IS 16231 to be referred)

The deflection limit ($\delta limit$) of glass pane should be taken as follows:

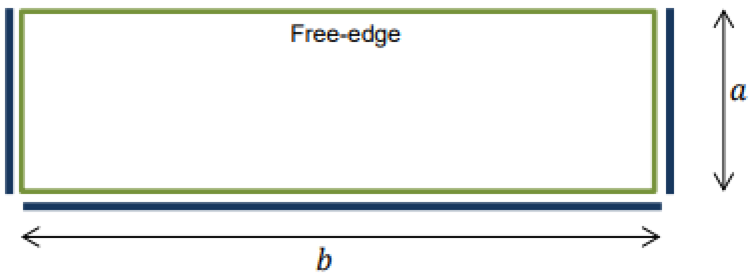
Four-side simply supported: $\delta limit$ = 1⁄60 of the short span

Three-side simply supported: $\delta limit$ = min. [⁄60 , a ⁄30] , (see Figure 5.1)

Two-side simply supported: $\delta limit$ = 1⁄60 of the Loaded span

Cantilever : $\delta limit$ = 1⁄30 of the span

Simply Supported : $\delta limit$ = 1⁄60 of the short span



FIG

4.8.4 *Deflection limit of Structural Member Supporting Glass Pane*

The deflection limit of structural member should be taken as the smaller of 1/180 of the span or 20 mm for span not greater than 7.2 m. For span greater than 7.2 m, the deflection limit of a member can be taken as 1/360 of the span.

For cantilever type member, the deflection limit should be taken as the smaller of 1 90 of the span or 20 mm.

4.8.5 *Durability*

Durability of certain components in a glass structural system need special design, quality control and testing consideration. Interlayer materials being used in laminated glass with composite action and structural sealants under long term exposure to sunlight could have their load resisting capacity reduced, which should be considered in the design life of the structure. Durability tests may be required to carry out taking local conditions into consideration. Durability tests shall be conducted as per IS 2553 : 1 (Safety Glass), IS 16982 : Heat Strengthened Glass, IS 17346 : IGU and IS 17004.

5 GLASS ELEMENT DESIGN

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.

5.1.2 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 5.4, the following simplified equations 5.1 to 5.3 can be used for checking the glass fin / glass beam.

Local buckling

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

$$\frac{Et^3}{6(1+v)} > M_w \qquad \text{..... (5.1)}$$

where

Mw = Working design moment in the glass fin (in-plane moment) with load factor γf
equal to 1.0
E = Modulus of elasticity
v = Poisson's ratio
t = Minimum thickness of glass pane being checked

5.1.2.1 *Lateral torsional buckling*

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

$$M_{cr} > 1.7M_d \qquad \text{.....(5.2)}$$

where Mcc = Critical elastic buckling moment given in Annex C
Md = Ultimate design moment in the glass fin.

5.1.2.2 *Elastic Moment Capacity*

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

$$M_e = \gamma_d \times \gamma_s \times p_{yf} \times Z > M_d \qquad (5.3)$$

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 5.1.2

Z = Elastic section modulus of glass fin

γd = Load duration factor given in Table 4.4

γs = Glass surface treatment reduction factor given in Table 4.5

5.1.2.3 *Nonlinear 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.

$$Mu > Md \qquad \textbf{(5.4)}$$

where
Mu = Ultimate moment capacity evaluated from nonlinear finite element analysis
Md = Ultimate design moment in the glass fin with appropriate load factor γf given in Table 5.2

Alternatively, in finite element analysis by shell element, the maximum principal stress (s1) of the glass pane should be smaller than the ultimate design strength of glass fin (pyf).

5.1.3 *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.

5.1.4 *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.

5.2 CURTAIN WALL, WINDOW 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 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.

5.3 TENSIONING STRUCTURAL 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.

5.3.1 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.

5.4 GLASS BALUSTRADE

Glass balustrade panes shall be classified as infill or free-standing glass panes.

5.4.1 *Glass balustrade acting as protective barrier*

When a glass balustrade also serves as a protective barrier, the glass pane or the top handrail shall be designed to resist horizontal imposed load or wind pressure. The glass pane shall be tested for its impact resistance. Handrail should either be fixed continuously to the top of the glass pane or fixed to the balustrades. Side wind effect at the corner of glass balustrade should be considered simultaneously. The balustrades at the corner should be designed to resist the induced moments and forces.

5.4.1.1 The main frame of glass balustrade (viz. handrail and balusters) is designed to withstand all loads applied to the handrail and the glass is used to form the infill panes. The glass pane should not be taken to provide any support to the main frame or handrail.

5.4.1.2 The glass pane shall be designed to withstand all the design loads. When the glass pane is subjected to a loading derived from the most unfavourable condition of wind load or horizontal imposed loads, the maximum horizontal displacement at the top rail level of the balustrade should not exceed deflection limit given in clause **4.8.3.**

In case the free-standing glass balustrade has a continuous run of 2 panels of glass or more and is designed as panic barrier in areas where people may congregate or susceptible to overcrowding, the top rail should be attached to the glass in such a manner that it would bridge over the failed glass, remain stable and is capable of resisting the working load applied across the resulting gap without causing the structural failure of the protective barrier system.

Alternatively, the top rail may be omitted if the remaining intact glass pane of laminated glass used in the balustrade is capable of resisting the working load when one layer in a laminated glass pane is broken.

Continuous bottom fixing clamps should be used for free-standing glass balustrade. Such clamps on each side of the glass panes should have a minimum width of 100 mm and be made of metal of minimum thickness of 12 mm. The clamps should be continuous for the entire length of the glass pane and have a maximum bolt spacing of 500 mm. Other clamping methods may also be used provided that such methods provide effective clamping over the length of the glass panes. Where a clamping system not relying on bolts is used, the depth over which the clamping force operates should not be less than 90 mm, unless specific tests have been carried out to prove the integrity of the structural system in resisting the design loads. Figures **6.1** and **6.2** illustrate the typical clamping detail for free-standing glass balustrade.

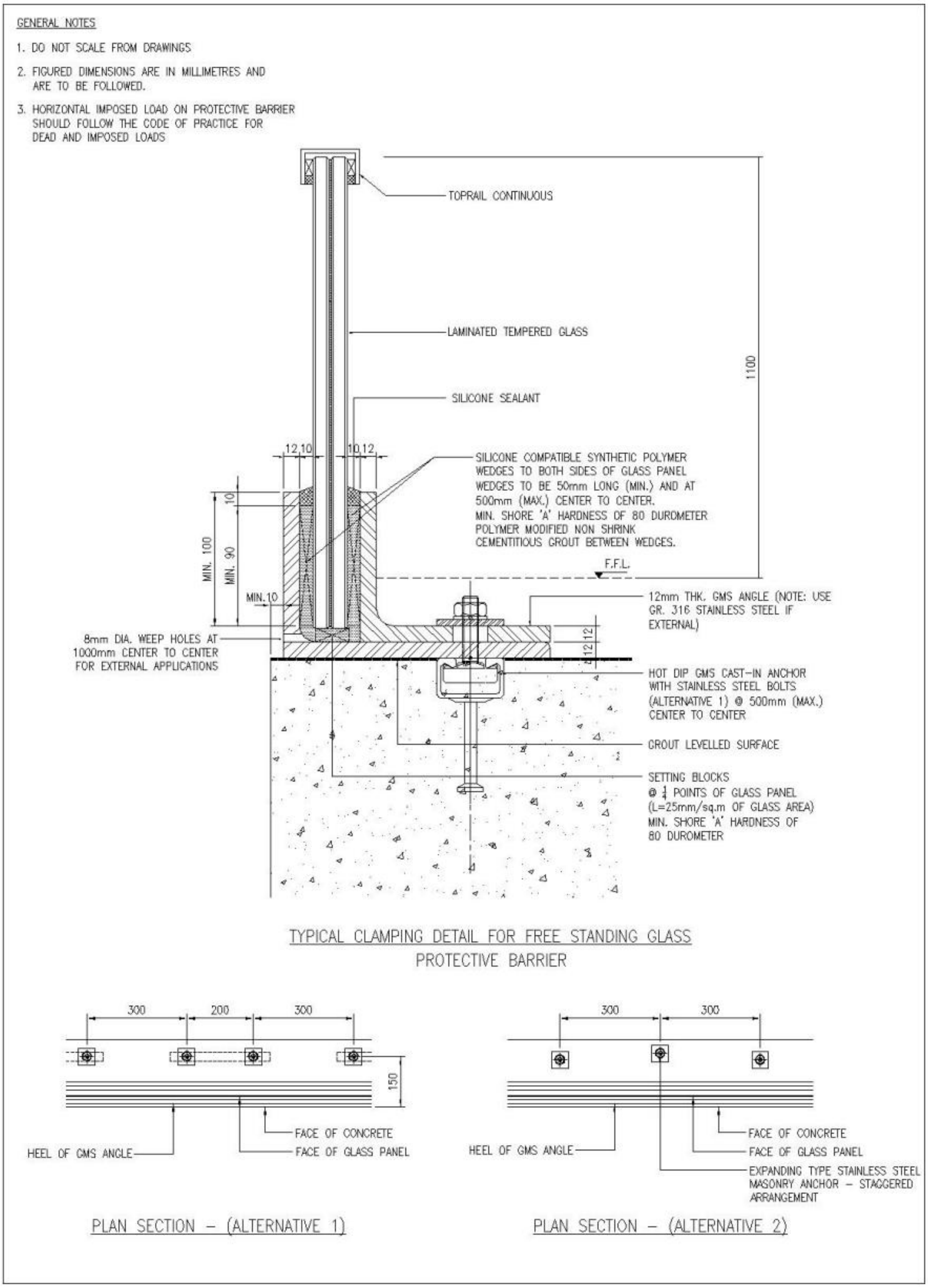


FIG. 6.1 TYPICAL GLASS BALUSTRADE DETAILS - BOLTING

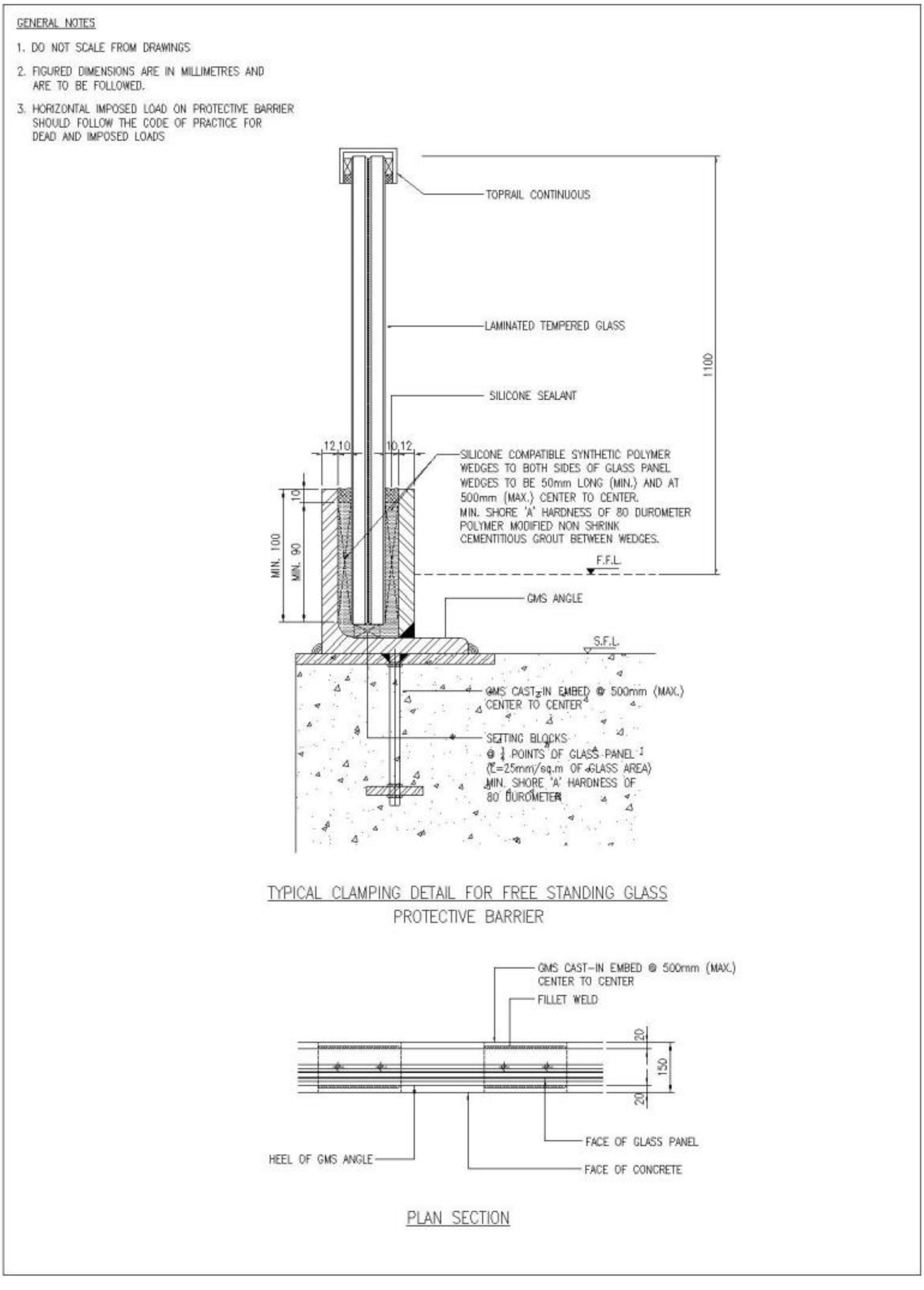


FIG. 6.2 TYPICAL GLASS BALUSTRADE DETAILS – WELDING

5.4.*2* *Impact Resistance of Glass Pane as Protective Barrier*.

Portions of glass measured up to 1100 mm from the finished floor level of the surface adjoining the barrier are defined as critical locations which are subjected to human collision and consequently likely to cause glass breakage. Glass situated at these critical locations and to be used as protective barriers should satisfy the quality and performance requirements of Safety Glass as per IS 2553 (Part1):

5.4.2.1 Glass pane for protective barriers shall be designed to resist the minimum horizontal imposed loads when separately applied or the wind load (where applicable).

ENERGY DESIGN CONSIDERATIONS

Considerations for Energy Efficiency

Glass and glazing design must take into consideration the introduction of daylighting into the interior space of the building and to manage the external and internal heat loads. External loads include solar heat gains through fenestration, heat losses across the glass surfaces and unwanted air infiltration in the building whereas internal loads include heat released by the electric lighting systems, equipment and people working in the building space.

Proper orientation of a building and due consideration to the size and placement of windows at the design stage can provide the advantage of daylighting. To maintain thermal comfort and minimize internal cooling / heating loads, the envelope needs to regulate and optimize heat transfer through roof, walls, windows, doors and other openings.

An integrated building design considers the Envelope, the Heating Ventilation and Cooling (HVAC) system and the Lighting system as a whole rather than dealing with these independently. Changing the specifications of one system can affect the performance of the other two significantly. For instance, investments in energy-efficient windows or increased envelope airtightness can result in a smaller HVAC system, thereby reducing its first cost as well as recurring energy cost. Similarly, an inefficient lighting system not only increases lighting energy consumption but could also increases the cooling load on HVAC system thereby increasing the energy consumption further.

When a building is in cooling mode, solar heat gains need to be minimized within the building space while optimizing daylight and intake of outside air. Outside air could be introduced particularly during evening/night hours when the ambient temperature drops. This strategy cools the thermal mass in the building during night hours and reduces overall cooling load during the next day. On the other hand, if the building is in a heating mode, the envelope needs to be designed with appropriate glazing selection coupled with shading strategy, to enhance solar heat gains during the daytime. Therefore, in practice, architects and building designers need to integrate and balance these varying requirement considerations while designing an energy-efficient building. Thus, the main goal of glass and glazing design should be to provide visual and thermal comfort to the occupants and thereby reduce the electricity cost for lighting and HVAC.

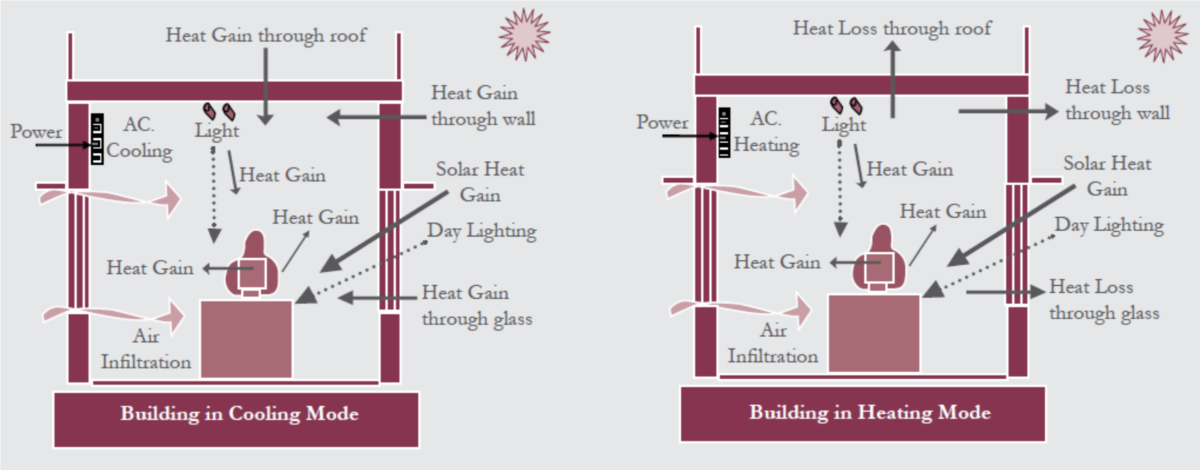


FIG.

Design Factors

The following factors / components of a glazing system shall be considered during design for achieving energy efficiency.

a)Light transmittance and glare
b)Thermal Transmittance (Solar Heat Gain co-efficient and U value)
c)Window size and placement
d) Frames
e)Shading devices
f)Air infiltration

***a)Light Transmittance and Glare*:**

Light transmission is defined as the fraction of visible light at normal incidence transmitted through the glazing. Dirt on glazing reduces the light transmission, often to an appreciable extent before becoming noticeable. To ensure daylighting levels are adequate, an allowance for the reduced light transmission should be made in daylighting calculation by introducing a ‘dirt factor’ between 0.7 and 1.0. Therefore regular cleaning of the glass becomes important.

Glare results from the excessive contrast of illumination or from an excess of illumination in the field of view. When correctly designed, natural lighting should not give a glaring problem. Even when the light transmission of the glazing is as low as 10 percent some 10,000 lux can still be experienced and glare shall almost certainly occur.

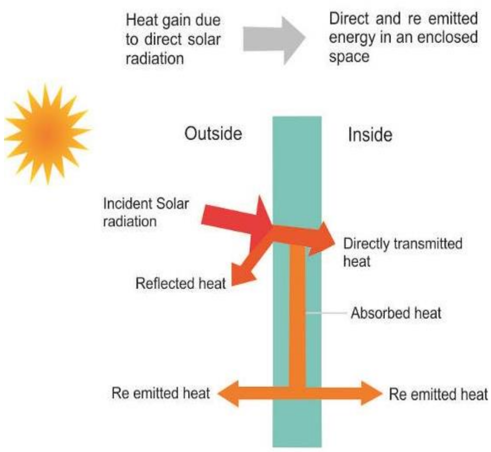
Glare can be reduced by some form of mechanical shading, for example, a canopy, an overhanging floor, a balcony or a louvre system. Alternatively, internal screening can be provided by louvres or blinds. It may also be possible to re-orientate the glazing in order to avoid entry of direct solar radiation. Alternatively, the interior layout can be suitably designed to eliminate glare. Glazing products with light transmission lower than 50 percent can reduce discomfort glare. These products decrease the sky luminance component, but permanently reducing the admission of daylight. Alternatively, shading devices, internal or external, movable or fixed, may be used. External shading devices have a great advantage as they address the solar energy transmission before entering into the building to keep the heat out. The internal shading devices will reduce glare but will not be able to prevent the solar energy from coming in the building and then this energy has to be mitigated by air-conditioning or ventilation.

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

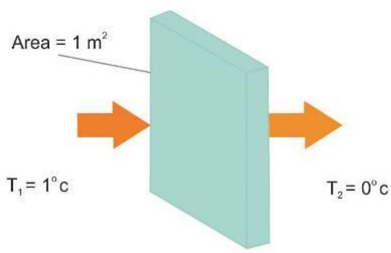
installation of windows in more than one wall to raise the general background illumination and in so doing, to reduce the contrast between a window and its surrounding surfaces use of light-colored matt finishes for the window frames and the surrounding surfaces splayed reveals, to assist in reducing the contrast between the window and its surroundings use of slender glazing bars and transoms of high reflectance and lowering window sills to allow increased illumination to enter, which increases the adaptation level and reduces the likelihood of discomfort glare

***b)Thermal Transmittance*:**

The total solar energy transmitted through the glass from the outside environment is the part of solar radiation which is transmitted directly through the glass and the part which is re-emitted from the glass after being absorbed. This heat energy which is transmitted through the glass has to be limited in-order to achieve thermal comfort for the occupants and also to reduce the energy demands of the building. This is governed by the Solar Factor or Solar Heat Gain Coefficient (SHGC) of the glass.



SHGC is the ratio of solar heat gain that passes through the fenestration to the total incident solar radiation that falls on it. SHGC is expressed as a number between 0 and 1. The lower the SHGC, the more a product is blocking solar heat gain.



The other part to be looked at is the transfer of heat from outside to inside environment through the glass, due to the temperature difference. This is known as U value which is the rate of heat flow through one square metre of glazing when there is a temperature difference of 1□C. The lower the 'U' value, the better it isCoated glasses can be used as an option for cutting down the heat transmission through the glass since they offer better thermal performance. Solar control glasses have special coatings on them which reduce the amount of solar radiation passing through the glass thereby reducing the amount of heat gain through the glass. Due to these coatings, the amount of light passing through the glass would also be reduced. Care has to be taken while selecting these glasses so that an optimum balance between the light and heat transmittance is achieved.

Low emissivity (low-E) coatings have a surface emissivity of less than 0.2. The use of such a coating on glass improves the thermal insulation. They are more efficient when used on the cavity surfaces of IGUs. Certain types of low-E glasses such as silver-based are used in double glazed units only, as the silver oxide coating will get oxidized if used in single glazed.

Insulating Glass Units (IGU) is a very effective way to reduce transfer through the glazing when used in conjunction with solar control or low-E or reflective coated glass. These units combine the performance parameters of the individual coated glasses along with the air gap inside the hermetically sealed unit to provide an overall increased reduction of heat transfer. Increasing the width of the air gap would further improve the thermal insulation of the IGUs. Use of inert gasses like argon and krypton in the air gap would also further improve the level of thermal insulation provided by the IGU.

c)Window Size and Placement:

- **Height of Window Head**

  The higher the window head, the deeper will be the penetration of daylight.
- **Sill height (height from floor to the bottom of the window)**

  The optimum sill for good illumination as well for good ventilation should be between the workspace and head level of a person. Windows close to task areas should be with an optimum visual transmission with good insulation performance as they may be source of thermal discomfort.
- **Use of separate apertures for view and daylight**

  For good lighting and glare control, the window should have clear glass with maximum daylight penetration and tinted glass below the clear glass for glare control.
- **Window Wall Ratio (WWR)**

d)Frames

For energy efficiency, some frames are designed with internal thermal breaks that reduce heat flow through the frame. These thermally broken frames can resist heat flow considerably better as compared to those without thermal breaks. The sealing between the openings and the window frames and between the opening sashes of windows and fixed portions are important areas to be addressed as major heat loss happens from this area due to poor design of sealant material. Adequate provision shall also be made to ensure that the frames are not susceptible to water ingress in case of driving rain.

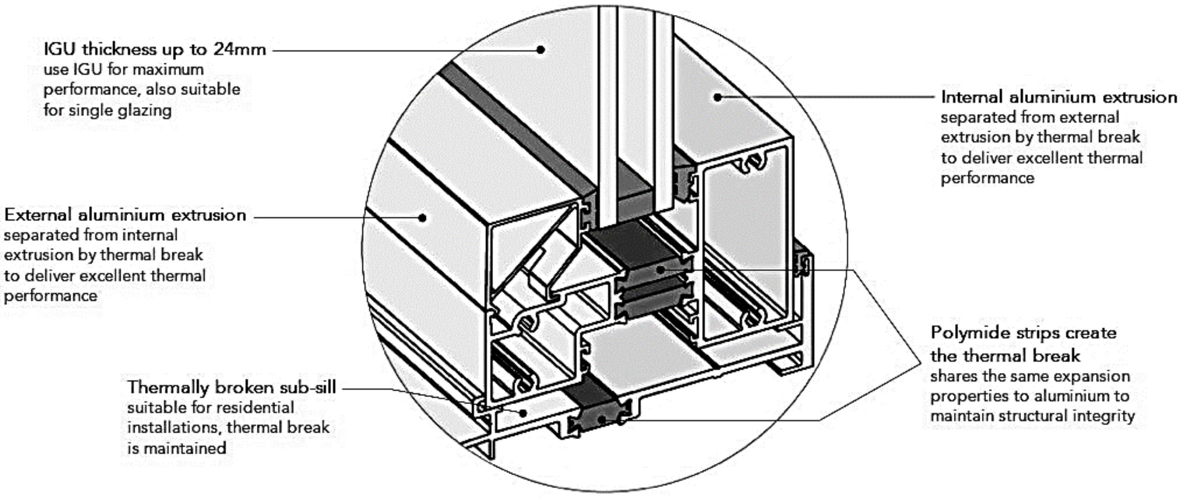
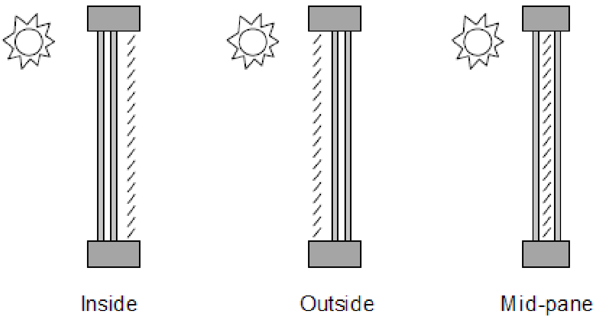


FIG FRAME

e)Shading Devices

Shading devices can be employed which help in keeping out the heat, block uncomfortable direct sun and soften harsh daylight contrasts. Shading devices are also critical for visual and thermal comfort and for minimizing mechanical cooling loads. Shading devices can be combined with the use of energy efficienct glass to further reduce the solar heat entering through the glazing system. Exterior or interior shading devices such as awnings, louvered screens, sunscreens, venetian blinds, roller shades and drapes can complement and enhance the performance of windows with low SHGC. Manual shading devices have an advantage that they can be adjusted to vary heat transmission with the time of day and season. It is desirable to break a single overhang with larger depth into multiple overhangs of smaller length. It enhances the amount of (diffused) daylight penetration in the space. Another alternative is to use screens which are effective in cutting down the heat transfer and at the same time allowing air movement.

External shading devices have a great advantage as they address the solar energy transmission before entering into the building to keep the heat out. The internal shading devices will reduce glare but will not be able to prevent the solar energy from coming in the building and then this energy has to be mitigated by air-conditioning or ventilation.

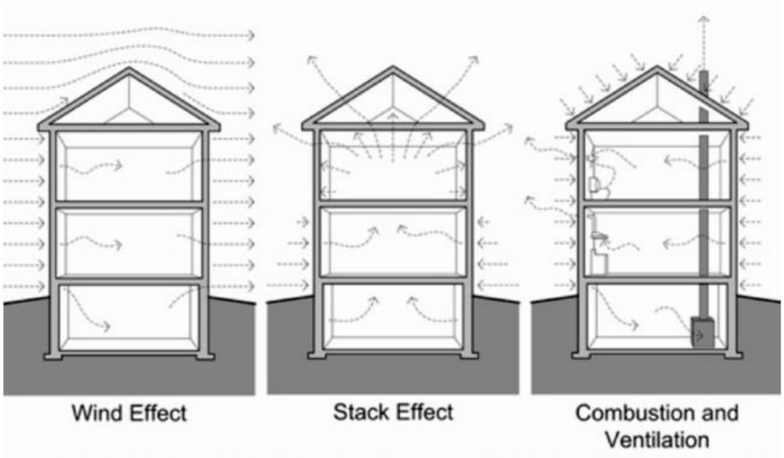


FIG

f)Air Infiltration

Inadequate control of airflow through the building envelope is often a primary factor contributing to premature building envelope failures. If moisture-laden air is permitted to travel through the building envelope, the moisture may, under certain environmental conditions condense within the walls of the structure and may even cause corrosion or rotting of the structural components and also staining of the interior and / or exterior façade. Air infiltration may be caused by wind pressure, stack pressure or fan pressure.

Wind creates a positive pressure on the windward face and negative pressure on the non-windward (leeward) facing walls, which pulls the air out of the building. Wind causes infiltration on one side of a building and exfiltration on the other. The stack effect is when warm air moves upward in a building because it's lighter than cold air and escapes out of the upper levels of the building, through penetrations and cracks in the building envelope or other openings. The rising warm air reduces the pressure in the base of the building, forcing cold air to infiltrate through open doors, windows, or other openings. The stack effect basically causes air infiltration on the lower portion of a building and exfiltration on the upper part. Mechanical equipment such as fans and blowers causes the movement of air within buildings and through enclosures, which can generate pressure differences. If more air is exhausted from a building than is supplied, a net negative pressure is generated, which can induce unwanted airflow through the building envelope.



FIG

Considerations for Controlling Air Infiltration.

a)Ensuring continuity of each component serving its role in resisting infiltration such as a window assembly or a curtain and they must be interconnected to prevent air leakage at the joints between materials, components, assemblies, and systems.

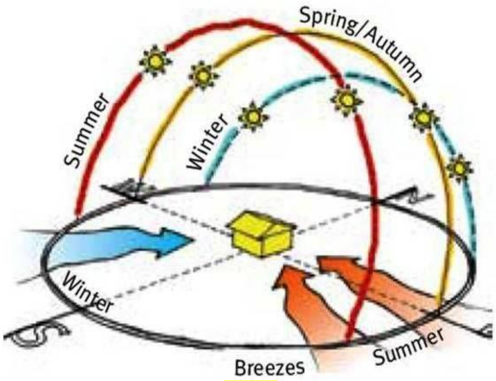
b) Effective structural support shall be ensured such that all components must resist the positive or negative structural loads that are imposed on them by wind, stack effect, and HVAC fan pressures without rupture, displacement or undue deflection and thereby resist air infiltration through them. Design considerations must be made such that this load shall be safely transferred to the structure and provision of adequate resistance to these pressures by fasteners, tapes, adhesives, etc.

ANALYSIS FOR CHOOSING THE RIGHT GLASS

Building Orientation Analysis

Design for orientation is a fundamental step to ensure that building work with the passage of the sun across the sky. Knowledge of sun paths of any site is fundamental in design building facades to let in light and passive sola gain, as well as reducing glare and overheating to the building interior. It also gives us an understanding of how the sun interacts with your building in high summer and the depth of winter.

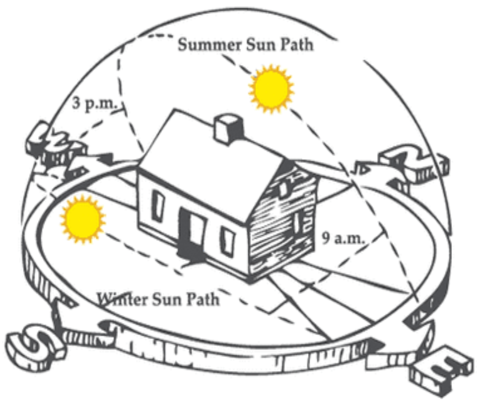
Well–oriented building maximise daylighting through building facades thereby reducing the need for artificial lighting. Zoning can be done to ensure different functional uses receive sunlight at different times of the day. The building that maximises sunlight is at deal for the incorporation of passive solar collection techniques that can reduce carbon use and enhance user comfort. Housing in temperate regions can benefit from admitting the sun into the building interior. Office buildings typically consider the reduction of excessive solar gain and glare. This is because of a greater preponderance of glazed facades and also higher internal heat gains from people, computers, etc.



FIG

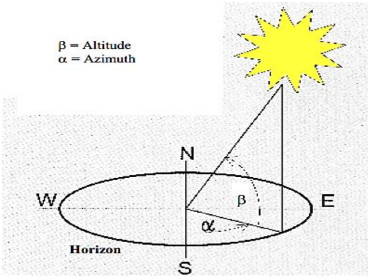
Sun Path Analysis

Sun path analysis helps us in understanding the impact of the orientation to understand the impact of seasonal changes in the building and its surroundings. It helps in designing appropriate artificial shading devices and selecting glass and other building materials for passive design strategy. The earth is made of two hemisphere. If the building (northern or southern hemisphere) the motion and position of solar incidence changes. This directly influences the inclination of solar incidence. In the southern hemisphere, the movements of the sun is from east to west through north. While in the northern hemisphere, the movements of the sun is from east to west through south.



FIG

The sun chart can be used to locate the position of the sun at any time of day, during any month, and for any location. The sun chart helps determine the impact of the sun and shading devices, i.e., shade by surrounding elements such as trees and existing buildings. The sun chart is also used to select glazing, shading and reflector design, exclusion of direct sunlight and knowing when the sun will be directly incident on your building. To visualize a sun chart, imagine looking up at the sky and seeing the sun's paths throughout the year. Using an imaginary dome over a building site, you can mark points where the sun’s rays penetrate the dome at every hour of a day.



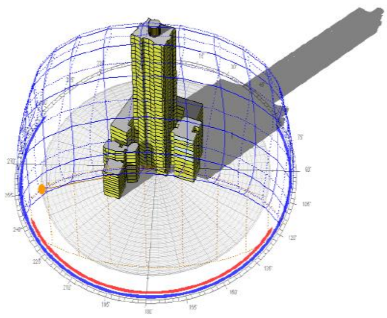
FIG

The Azimuth and Alitude can be derived for a location and time, using a sun path diagram

Solar azimuth (α) is angle along the horizon of position of the sun, measured to the east or west of true south.
Solar altitude (β) is the angle measured between the horizon & the position of the sun above the horizon. Analysis helps to understand the various positioning of the sun over the building & its impact on the building, based on this the glass can be suggested for elevation specific.

Site Shadow Analysis

Analysis helps to understand the various positioning of the sun over the building & its impact on the building, based on this the glass can be suggested for elevation specific.

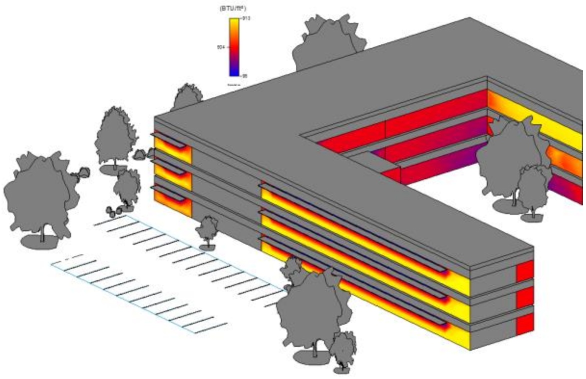


FIG

Shading also depends on climatic conditions and the nature of the building. Shading analysis takes into account different strategies. Horizontal strategies are best for the south, where the solar altitude is high whereas vertical strategies are best for east and west, where it is low. The shading on north can reduce effective daylight. The impact of the adjacent tower over the building and impact of shading devices inbuilt with the structure can be studied, which helps us to design the type, length, shape etc of the shading devices required.

Solar Exposure Analysis

To do a detailed design for glazing and facades, it is important to understand the patterns of solar radiation that affect the building. Direct solar incident radiation is the energy transmitted from the sun which lies between the wavelength range of 250 and 2500 nm. Solar radiation is typically made up of 3% ultraviolet light, 42% visible light and 55% infrared light. Infrared radiation is the major heat carrying radiation followed by the visible.

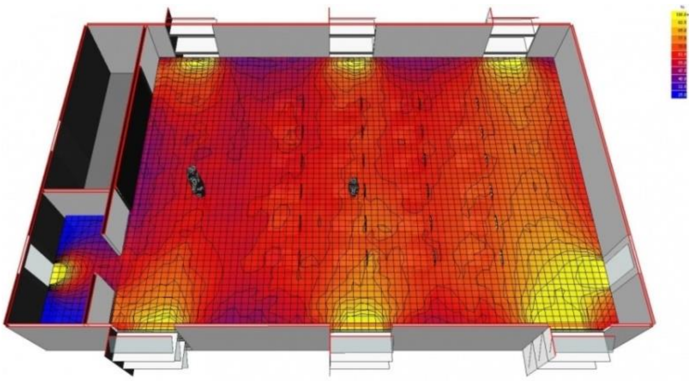


FIG

Analysis helps to understand the Sun impact over the elevation and from this the impact of the building can be understood. This helps to understand the peak load values and design can be done considering this.

Daylight Analysis

Daylights Analysis is used to find the penetration of natural light on the building floor plan or at working plane level. A good lighting strategy involves optimizing the glazed area, number of Windows and visual light transmission of glazing. This reduces the dependency on artifcal lighting strategy involves optimizing the glazed area, number of Windows, and visual light transmission of glazing. This reduces the dependency on artificial lighting. Using a glass with optimum light transmission can go a long way in curtailing the dependence on artificial lighting. The presence of natural light also rids the inmate from the claustrophobic feeling typical in many buildings with limited glazing and outdoor views. Daylighting is calculated for the overcast condition, so as to represent the worst-case condition of outdoor lux levels.



FIG

The daylighting available may be calculated in terms of ‘lux levels’ or ‘daylight factor’. Daylight factor is the percentage of outdoor lux level reaching at a particular point on the analysis plane. If the light transmission of glass is high, it may also result in ‘glare’ due to exposure to direct sun, or sun rays being reflected from highly reflective surfaces. Analysis helps to understand the ideal VLT requirement for the building. A floor plan is considered and the lux levels are calculated for the planned floor for different Visible Light Transmittance percentage of glass. The glass which allows an optimum Lux level distribution with a Visual Light transmittance is chosen.

Any glass with energy performance will sacrifice certain amount of daylight although it will be transparent for vision through it to the outside. Higher the demand for energy performance, higher will be the compromise on daylight. The selection of glass should therefore start from evaluating the daylight needs and deciding the optimum VLT. This can narrow down the options of selecting the glass which shall give the good performance for the given VLT and considering the cost and aesthetics.

Floor plate geometry plays an important role as the daylight distribution will depend on the depth of the plate from the glazed area. The farthest area from glazing will be the dimmest and the nearest area will be the brightest. Courtyard plan and atrium plan have a great advantage of harnessing maximum daylight from glazed area not subjected to direct solar radiation by using glass of higher VLT.

WINDOWS IN AIR-CONDITIONED SPACES

Windows (including both glazing and frame) affects the energy performance of a conditioned space by impacting the HVAC energy consumption and the lighting energy consumption of the building.

The types of energy flow which occur through a window impacting the HVAC energy consumption and the parameters to be considered to energy efficient windows in air-conditioned spaces can be referred from clause 8.1.3.2 of SP 7: NBC 2016.

WINDOW FOR NON-CONDITIONED / MIXED MODE BUILDINGS

The glazing system for windows in non-conditioned spaces is usually single glazed units as the windows will be opened to allow ventilation. In non-conditioned buildings, the shading device plays a crucial role in the thermal performance of a window. Windows on facades, facing different cardinal directions should be provided by the shading devices which can cut the direct incident solar radiation for the critical solar angles. The critical Horizontal Solar Angle (HSA) and the Vertical Solar Angle (VSA) for fenestrations located on the cardinal directions should be cut down by designing appropriate shading devices. The horizontal solar angle at critical hours can be cut by the vertical fins provided as an external shading device. The vertical solar angle at critical hours can be cut by the horizontal fins provided as an external shading device.

Considerations for selecting type of window and the necessary design considerations for energy efficiency and natural ventilation can be referred from clause **8.1.3.2.2 part 11** of SP 7 - NBC 2016.

DESIGN CONSIDERATIONS FOR ACOUSTIC PERFORMANCE

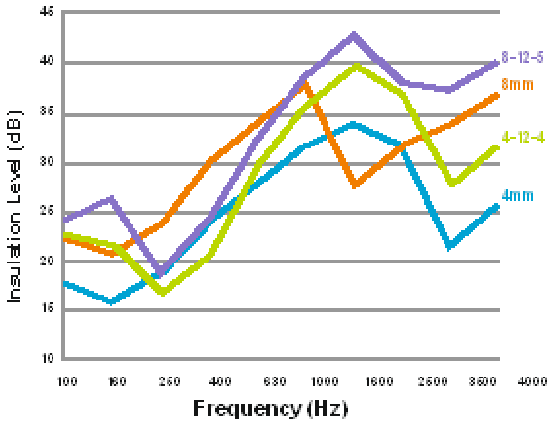
Unwanted sound is considered noise when it intrudes on our daily lives. To minimize this intrusion, all aspects of the building construction need to be evaluated. However, in this instance we will only analyze the acoustic qualities of glass. The first step in this analysis is to determine the source of the unwanted noise. This is a critical step, as the noise source can vary from low frequency traffic noise to high frequency aircraft noise. Starting from a single 6mm glass lite with an STC of 31, we can achieve STC ratings of as high as 50 with different combinations of laminated and insulated glasses. Although the increase in absolute numbers seems small, it results in a big difference in performance. An increase from 28 to 38 means 90% of the noise is reduced. A change from 28 to 43 represents a noise reduction of over 95%.

Use Glass Configurations with Different Thicknesses.

Monolithic glass has specific critical or coincident frequency at which the speed of incident sound in air matches that of bending wave of glass. At this critical frequency glass will vibrate allowing sound waves to penetrate without significant attenuation, the thickness of a single-pane glass enhances the glazing's sound insulation, for e.g., a 4mm thick glass provides an Rw of 29 dB, which can increase to 35 dB for a thickness of 12mm. However, increasing glass thickness is generally a poor choice for applications such as city structures which are primarily subjected to lower pitched sounds. This is because increasing glass thickness shifts the critical frequency trough towards lower frequencies which results in weakened protection against low pitched sound.

Use Glass Configurations with Different Thickness.

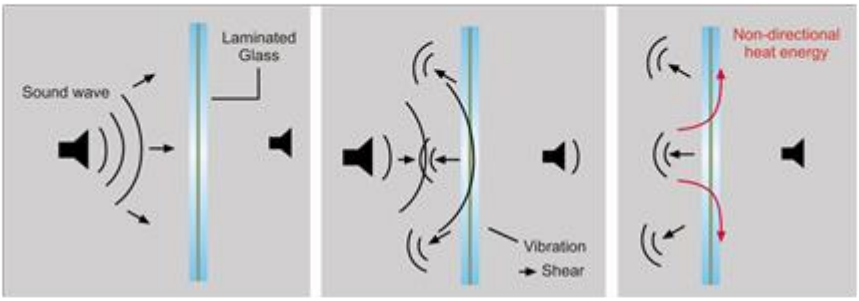
To enhance the level of sound insulation provided by double-glazing, glasses with sufficiently different thicknesses should be used so that they can hide each others' weaknesses when the overall unit reaches its critical frequency. This therefore produces a coincidence in a broader frequency zone but compared to symmetrical glazing the trough is less intense (as seen around 3,200 Hz). In this case, the increase in mass in relation to 4-12-4 glazing also helps to reduce the at low frequencies.



Use Laminated Glasses

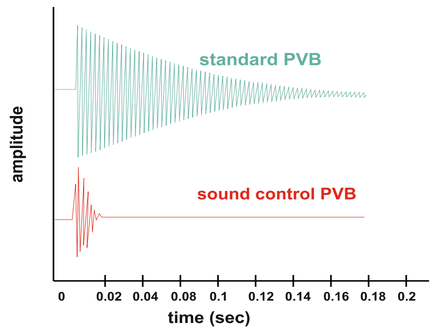
The poly vinyl butyral inter-layer (0.38m m to 1.52mm) used in laminated glass provides a dampening effect that reduces vibration by absorbing the sound waves hence reducing sound transmission. Laminated glass also has superior sound insulation qualities in the higher frequency range where the noise from sources such as aircraft is a problem.

The PVB film used in laminated glasses have a shear damping effect that has substantial sound attenuation characteristics. When the outer glass layer is exposed to bending waves, the PVB layer creates a shear strain within itself and the bending of wave energy of glass is transformed to non-directional heat energy, which is barely noticeable. During this phenomenon the sound waves are absorbed by the PVB layer and not transmitted to the second glass layer. This results in reduction of the amplitude of vibration and sound transmission as shown below.



FIG

Increasing the inter-layer thickness has marginal effect on the performance of laminated glass. Acoustically enhanced PVB's are designed to have higher damping characteristics that further reduce the amplitude of the sound waves. The graph below shows comparative decay in vibration observed in laminated glass with Standard PVB and Acoustic PVB. The sound attenuation characteristics of PVB and acoustical PVB films can be understood by the following comparative graph. Considered here is the performance of a monolithic 4mm glass with a 4.76mm (2-0.76-2) regular PVB and 4.76mm (2-0.76- 2) acoustic PVB.



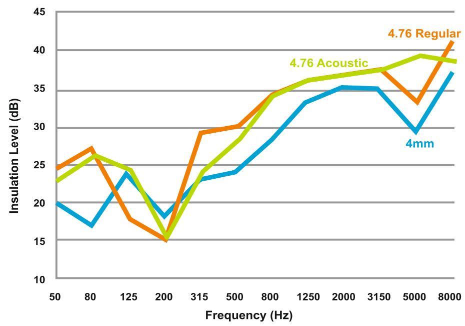
Decay of free vibration observed on laminated glass

FIG

Although the transmission curve for 4mm monolithic glass is shifted to lower values owing to its slightly smaller mass if compared to the laminated glasses, the superior performance of the PVB glass (and more so in the acoustic PVB laminate) is clearly evident in the coincidence region. The reduced plate vibrations below 800 Hz also help enhance the sound reduction properties of the laminated glass assembly.

Use Combination of Insulated and Laminated Glasses

Further increases in sound-reduction performance can be achieved by using combinations of insulated and laminated glasses. These units offer the dual benefit of greater mass and different frequency resonance of insulated glasses coupled with the damping effects of PVB laminated glasses. The following chart demonstrates the STC and Rw performance of some common glass types. Double glazed unit with certain gases also provide sound insulation characteristics.



FIG

Areas Around Windows:

It is important to note that no matter how good the noise insulation qualities of the windows are, there should be no gaps or cracks around the window frame. As long as the Rwof a window remains under 35 dB and the frame area doesn't exceed 30% of the window area, the influence of the frame on the total acoustic performance can be neglected. However as soon as Rw, lies between 35 and 40 dB, it is advised to reinforce each frame element. Windows with Rw larger than 40 dB are specific for the window concept itself which makes special advice necessary.

Acoustic Analysis

The choice of glass plays an important role in determining whether glass chosen for sound insulation purposes actually brings about noise reduction. Based on the location, type of building & noise level we need to understand and design the glass combination to suit the requirement.

National Building code of India 2016 – Part 8 – Section 4 covers the requirements and guidelines regarding planning against noise, acceptable noise levels and the requirements for sound insulation in buildings with different occupancies.

SECTION 4: FABRICATION

FABRICATION

4.1 General

The work should be fabricated in accordance with general arrangement, component and assembly drawings. These should have been commented upon by the design team where appropriate. The fabrication team should be involved in the Facade contractors' design development.

It is recommended that the fabricator should produce a quality plan in line with the principles and guidelines of Section Six of this document to demonstrate his capabilities and commitment.

a) Material used in the fabrication should be of a type to achieve the required performance and appearance. Materials should comply with the recognised national standards and match approved samples. Materials delivered should have supporting documentation verifying compliance with the project's requirements..
b) Methods used in the fabrication should be selected to achieve the specified appearance and performance. Methods used should be based upon the use of suitable equipment and experienced operatives. Method statements should contain control procedures to ensure compliance with the project requirements.
c) Control samples should be produced to adequately demonstrate the standard of workmanship and finish required. Where appropriate range samples should be established to assist in quality control procedures.

4.2 TOLERANCES

The work should be fabricated to the figured dimensions indicated within agreed permissible deviations.

Permissible deviations should be established at the design stage and be appropriate for the materials and method employed such as to achieve the project requirements for appearance and fit. These requirements are to be defined by the panel.

4.3 Components

a) All components used should comply with their respective product standards in IS and be of the appropriate grade and thickness to achieve the appearance and performance required, taking into account the methods to be employed.
b) Metals should be used in a manner to produce the greatest degree of uniformity in appearance; for example the grain direction of rolled material can affect its appearance.
c) Metals should be formed to the required shapes without flaws and defects. Profiles produced should be consistent throughout their length and within agreed tolerances.
d) Bent shapes should have straight arises and be free from grain separation, stretch marks, oil canning and other forms of distortion.
e) Extrusions should be within the tolerance limits of Indian Standard
f) Milled shapes visible in the finished work should have true surfaces and be free from tool marks, steps, indentations and unevenness.
g) Metals should be machine cut and drilled wherever possible. Cut surfaces should be true to line and level and free of burrs. Cut section which forms the contact surfaces of joints should be free of irregularities and unevenness and dressed for welding as necessary. Grinding of non-ferrous metals should be carried out using iron-free materials to avoid contamination by corrosion.
h) Metals should be welded in accordance with the relevant standards using methods to avoid distortion and discolouration of visible surfaces. Welds should be fully bonded throughout their length without holes, inclusions, cracks or porosity such that the long term performance is not compromised and the welds are strong enough for the design requirements. Welds should be ground smooth and flush with adjoining surfaces where visible or impingeing on other work. Site welding should not be carried out without prior agreement.
i) Welding procedures should comply with Indian Standard
j) Welding competence of operatives should comply with Indian Standard

k) Welding of steel using arc method should comply with Indian Standard
l) Welding of stainless steel using TIG method should comply with Indian Standard.
m) Welding of aluminium using TIG method should comply with Indian Standard or using MIG method should comply with Indian Standard
n) Glass should comply with its respective Indian Standards mentioned above of this document and be of the appropriate type and thickness to achieve the appearance and performance required. Glass should be within the established range samples and used in a manner to produce the greatest degree of uniformity in appearance.

p) Glass should be cut in accordance with the design requirements to produce 'clean-cut' edges with the required tolerances. Cutting, drilling, edge and surface treatments should be carried out before any heat treatment.
q) Sealed double glazing units should have the required glass configuration and spacer size, with all seals continuous.
r) Units which contain different glass types or surface finish should be adequately identified to ensure correct orientation. When required glass should be permanently marked to identify its type.

4.4 Assembly

a) Components should be checked for compliance with approved drawings prior to assembly in accordance with the agreed quality procedures.
    i. Final assembly should be carried out in the shop as far as possible.
    ii. Certain components should be assembled prior to the application of coatings or finishes, example- welded or curved components visible in the final works.

b) Metal to metal joints should be accurately formed without lipping and offsets in visible surfaces unless designed otherwise. Joints should be rigidly secured to prevent all but designed movement, unless shown otherwise. Where required joints should prevent leakage of air and water.

    i. Welded joints should be welded continuously along the line of contact where shown or required for proper assembly. Welds on visible surfaces should match or blend with adjoining surfaces as necessary. It should be noted that on some finishes it is not possible to avoid weld staining on visible surfaces, and where not acceptable other jointing techniques should be employed.

    ii. Mechanically fastened joints should be fixed with concealed fasteners in a manner to prevent rotation and produce 'hairline' contact lines, except as required by movement. Where necessary joints should be reinforced with cleats and sleeves for strength, alignment and sealing.

    iii. Cleats and sleeves should accurately interlock with the profile of components to be jointed and provide a surface suitable for the proper bedding of sealants.

    iv. Movement joints should be capable of accommodating all anticipated movement and operate smoothly without binding or causing noise or vibration. Movement joints should comply with the requirements of the relevant Indian Standard.

Laminating should be performed with non-water degradable adhesives in a manner to provide full contact between contact surfaces. Adhesives must be used in accordance with the manufacturer's recommendations. Visible surfaces should be free from undulations, irregularities, warping and other defects. Control samples should be agreed prior to fabrication.

4.5 Gaskets

Gaskets should comply with the relevant Indian Standard and be installed in accordance with the manufacturer's recommendations and utilising the correct tools.

4.6 Sealants

Sealants should comply with the relevant Indian Standard and be of the appropriate type to achieve the appearance and performance required. Sealants should be applied to clean surfaces, primed as necessary, in accordance with the manufacturers' recommendations and procedures agreed following adhesion and application tests. Conditions of application should be conducive to producing satisfactory results and avoid inducing undue stress in uncured material.

It is recommended that the sealant manufacturer reviews the application of his materials. Quality control adhesion tests should be carried out throughout the period of manufacture to monitor the effectiveness of the material and application techniques.

4.7 Bedding Sealants

Bedding sealants should be continuous and without voids.

4.8 Joint Sealants

Joint sealants should be continuous and without voids with the required depth-to-width ratio to accommodate expected movements. Sealants Should be applied against a backing material as necessary to control the depth and provide isolation as required. Exposed faces should be tooled to remove voids and match approved samples.

4.9 Thermal Insulation

Insulation should comply with the relevant Indian Standard and be of the appropriate type and thickness to achieve the performance requirements, taking account of any need for inherent rigidity in the material. Insulation should be extended full thickness over the entire area to be insulated and tightly fitted at terminations and penetrations to eliminate voids and cold bridges.

4.10 Vapour Control Layers

Vapour control layers should comply with with the relevant Indian Standard.

Vapour control layers should be continuous and sealed at all joints, penetrations and terminations to achieve the performance required. Vapour control layers should be securely attached to components and accommodate all expected movement of assemblies.

4.11 Finishes

All finishes should be in accordance with the with the relevant Indian Standard.

They should be applied to an agreed procedure and in accordance with any relevant standards and reviewed by the manufacturer.

All components and assemblies should be cleaned and finished in the factory prior to delivery to site. Finishes should be applied to all visible surfaces of non-ferrous metals and to all surfaces of ferrous metals, in accordance with an agreed schedule.

Coating and finishes should match agreed control samples.

4.12 Material Protection

Materials, assembled units, elements of framing and all components should be protected in such a manner that will prevent damage, distortion, uneven weathering or degradation under normal conditions of handling and storage. Particular attention should be given to the protection of edges, projecting flanges, corners and other vulnerable areas.

Where possible suitable temporary coating and coverings should be provided to protect the work until completion of the installation. Protection should avoid development of non-uniformity of appearance in finishes, and should not impart a residue which would adversely affect the adhesion of sealants, or cause other deleterious effects in the work. Protection should be capable of being temporarily removed when requested to allow inspection of finishes, and completely removed when no longer required.

SECTION 5: INSTALLATION

Glass and metal curtain walls are highly engineered, and factory built to close tolerances. Installation requires the placement of these precision-built parts on a structure built to much greater dimensional tolerances. As such, proper and timely communication between the members of the project team is an essential requirement of a successful installation.

A great many factors impact the quality of a curtain wall installation. Many of these originate in architectural design and specifications. Examples include:

a) Design wall to be installed from the floor slab and not from stages or scaffold
b) Insisting or permitting installation in inappropriate weather. Extreme cold and extreme heat are both very problematic for workers dealing with a system designed to close tolerances, when the weather has such a significant effect on both the worker and the materials being handled/assembled.
c) Recognize that curtain walls are shipped to the site by truck and must be hoisted to the work location. This imposes constraints on size but also introduces constraints with respect to loading storage in downtown locations, handling, etc.
d) The best approach is to minimize the number of trades required to complete the wall. Careful use of terminology on drawings used to describe the wall can avoid jurisdictional disputes.
e) A curtain wall is based on tremendous repetition of standardized details, with little on-site fabrication of custom components. Frequent variations in the standard detailing greatly increase the chances that custom components are required to adjust the wall. This increases the risk of poor quality construction.

5.1 Construction Scheduling:

As the project moves from design to construction scheduling becomes a significant task. Scheduling must consider:

a) Adequate time for preparation and review of shop drawings and sample.
b) Adequate time to conduct and obtain all material and system test results
c) Weather conditions expected during installation
d) Time for procurement of specialty items and their fabrication
e) Time for design, construction, and testing of mock-up if required
f) Time for design and fabrication of cast in components

g) Time for review and acceptance of special colours and finishes

Attempting to install the curtain wall before the structure is complete or not sufficiently advanced to accept it adds costs, safety concerns and a potential reduction in work quality. Scheduling must reflect the progress of associated work, such as

a) Fabrication and installation of cast in components
b) Placing of concrete for structure and slabs
c) Removal of slab shoring and form work
d) Backfilling for grade or lower level work
e) On-going associated or adjacent operations that will cause physical damage to curtain wall components (e.g. welding, laying masonry)

Like many other trades, the curtain wall contractor relies on offset lines and benchmarks set by the general contractor. Any error in the setting of these marks will impact the installation of the wall. All such marks should be set well in advance of the curtain wall installation to allow cross checking and preparation by the curtain wall contractor.

5.2 Tolerances

The greatest quality issues related to glass and metal curtain wall installation are tolerances and clearances. Failure to properly control tolerances and clearances is the reason for most curtain wall installation problems. Four different tolerances must be considered. These include building frame tolerances, installation tolerances, material tolerances and fabrication and assembly tolerances.

Building frame tolerances are most significant. It is not uncommon to find floor slabs 50 mm (2 inches) above or below a specified elevation, slab edges out of alignment by 40 mm (1 1/2 inch) or columns 25 mm (1 inch) out of plumb over a storey height. Despite these irregularities, curtain walls are to be installed plumb and at the correct elevation. It is therefore essential that specifications require the proper alignment and location of all materials related to the wall and that these requirements be enforced. Installation tolerances depend on the building tolerances. If the building frame is outside of specified tolerances, modifications to anchors can be expected.

Basic material tolerances refer to extrusion thickness, overall sizes and thickness of panels, length of extrusion. These tolerances must be recognized in joint width and location.

Fabrication and assembly tolerances are normally noticed at joints where, for example, a miter cut does not match or a butt joint is not closed.

Inadequate clearances arise most frequently due to building tolerances. Clearances are essential to allow proper working of sealant joints, to allow differential movement, to allow access for fixing and for possible size tolerance. Clearance issues are most often noted at non-typical anchors. In general, these should be at least 50 mm (2 inches) plus outward tolerance provided.

5.3 DELIVERY, HANDLING, STORAGE

Delivery of materials to the site should be made in accordance with a preagreed schedule. As delivery is almost always by truck, adequate road access and hoisting equipment should be available. Whenever possible finished material should be hoisted directly from the truck to the floor where installation is to take place. Storage on the floor slabs, while requiring coordination to avoid conflict with other trades, is ideal as it avoids multiple material moves, is generally dry and well ventilated. If the material must be stored in a marshalling area prior to lifting to specific floors the area should be:

a) Level, clear of debris and well drained
b) Graded areas should be packed to avoid settlement of crates and potential racking of frames
c) Located to allow clear future access to crates and prohibit other site traffic from close proximity to crates
d) Crates and exposed materials should be protected from mortar, lime, acids, tars and chemical splatter
e)If stored indoors where temporary heat might be used, the crates must be ventilated to avoid condensation on the aluminum

As the assemblies are moved from storage to work area handling precautions must include:

a) Material should be lifted and handled to avoid bending, twisting, racking or otherwise distorting the material
b) Special racks or dollies to store or transport materials should be used
c) Care should be taken to avoid climbing, standing or walking on materials
d) Finished aluminum parts should not be used to support scaffold, board, walkway or ladders

5.4 Construction Elevators

Exterior construction elevators are common to most multi-storey construction projects. The elevators stay in place for a significant portion of the construction schedule, often for several months after the curtain wall is installed. As such, a “unitized” bay or a hoist way opening must be left in the wall. This unitized bay is completed once the elevator is removed. The number and location of hoist ways should be identified on the project specifications.

In order to minimize the potential impact of the leave-out bay on the quality of the completed wall the following should be recognized:

a) The wall area at the leave-out bay must be specially detailed to allow installation after the rest of the wall is complete. This is especially important with unitized wall systems.
b) The wall areas adjacent to the elevators are subject to soiling and damage. Protection must be considered.
c) As the elevator leave-out bay is completed, the newly installed material may not initially match the already completed areas due to the weathering of the installed material.

5.5 ANCHORS

Field installation begins with the layout and installation of anchors. Again the quality of the anchor installation begins with the architectural design and the shop drawing development of the design. Anchor designs will vary with designer and building but several principles can be followed to enhance quality.

a) Whenever possible, the anchor should be installed on top of the slab, regardless of structure type. Anchors at the slab edges can be feasible but Canadian assembly and concrete placing practices often make this location problematic. Locating anchors on the underside of the slab should be avoided, as it is difficult overhead work requiring scaffold or ladders.
b) Regardless of the anchor detail, the anchor should be large enough to allow 3-way adjustability and rapid field connection.
c) On concrete slabs, the anchors should be set into pockets and grouted later to allow full use of floor space
d) Whenever possible, concrete embeds should be used in place of drill-in type anchors.
e) Where possible, fireproofing should follow anchor installation in steel frames.
f) Where fixing is to a steel element, welding is preferred over field drilling and bolting. Where bolting must be used, bolt holes on the steel should be predrilled.
g) Anchors should be installed by the curtain wall contractor not by the steel or miscellaneous metal contractor. Embedded parts should be fabricated by the curtain wall contractor and supplied to the general contractor for casting into the slabs. These parts must be issued early in the construction process along with shop drawings showing their position.

Despite the following of the above principles, field issues still develop where the shop drawings are not followed.

5.6 Mislocation of Slab Edge

The most common field variance is the concrete slab edge being too far in or out from theoretical position. The position of the slab edge may exceed the movement tolerances designed for the anchor. If the slab edge is too far, excessive bending forces in the cantilevering anchor and tensile forces in bolts may develop. Excessive shimming or excessively long bolts will weaken the connection. All non-typical anchors require an engineer's review and sign off.

5.7 Mislocated, Missed or Incorrect Embedments

The proper installation of embeds requires the early issue of separate shop drawings and the careful coordination of their installation. Errors will occur and special modifications again require the review of the curtain wall contractor's engineer.

Inadequate Structure at Anchor Points

Anchorage to a steel structure, provided the beam sizes conform to the structural steel drawings, are typically less of a concern than anchorage to concrete slab edges. Voids or honeycombing of concrete, particularly at groups of embedments, at slab transitions, corners and columns. Inspection of the concrete at embedments should precede anchor installation.

5.8 Excessive Shimming – Inadequate Bolt Engagement

Variances in the elevation of embedments often result in excessive shimming. Shimming almost always has a negative impact on the strength of connections. Lateral loads generate bending as well as shear loads in bolts and thread engagement is reduced. Where expansion type anchors are used, unless the length is corrected, embedment is reduced and strength is significantly reduced.

SECTION 6: TESTING

6.1 Laboratory Testing

The glazing system is subjected to various adverse environmental conditions and impacts during its service life. A properly designed and installed glazing system may be able to resist any major damage to its stability or performance under any condition within its effective life time. The glazing system and its component materials shall be tested for the required parameters and performance.

6.2 Field/On-Site Testing

Testing of the glazing system as a whole unit in site (the field) subject to loads and effects such as water infiltration, wind (air) infiltration, acoustic insulation, fire insulation, thermal performance, structural performance, etc, may be carried out for specific cases as mutually agreed to between the parties concerned, to ensure homogeneity.

The following performance tests are to be conducted on structural glazing system, if area of structural glazing exceeds 2 500 m^2 from the certified laboratories, as per the specialist literature:

Performance Laboratory Test for Air Leakage Test (–50 Pa to –300 Pa) and (+50 Pa to +300 Pa) for a range of testing limit 1 to 200 mVh.

a) Static Water Penetration Test (50 Pa to 1 500 Pa) for a range up to 2 000 ml.
b) Dynamic Water Penetration (50 Pa to 1 500 Pa) for a range up to 2 000 ml.
c) Structural Performance Deflection and deformation by static air pressure test (1.5 times design wind pressure without any failure) for a range up to 50 mm.
d) Seismic Movement Test (up to 30 mm).

6.3 Other Systems

Other types of systems or building enclosures could be used provided that the system will not fail, break or disengage from supports or supporting structures. When necessary, safety test with suitable test loads should be adopted to confirm the accuracy of structural design and analysis and their underlying assumptions.

ISO 3934:2021 - Rubber, vulcanized and thermoplastic — Preformed gaskets used in buildings — Classification, specifications and test methods.

6.4 PERFORMANCE TESTS FOR GLAZING SYSTEM

The following enlists the performance tests for glazing systems. The test specimen size and direction facing the pressurised chamber shall be mutually agreed to between the parties concerned or specifed without ambiguities in the tender documents.

6.4.1 AIR INFILTRATION/EXFILTRATION TEST

Permissible air leakages shall be 1.5 $m^3/h.m^2$ for fix area and 2 $m^3/h.m$ for crack length of operable panel. The crack length is the maximum height of the shutter per interlock or per meeting stile in a slider or per overlap joint in a double leaf door or vent, in addition to the jambs. Along the width, crack length is the maximum width of the shutter at top and bottom. All operable panels shall be opened and closed 5 times prior to commencement of test.

For facade, strip glazing, skylights and insert vents in facades, the pressure differential shall be $\pm$150 Pa for up to buildings of height 70 m and shall be $\pm$300 Pa for buildings of height beyond 70 m.

For strorefront, operable windows, sliding windows, sliding doors and doors, the pressure differential shall be +150 Pa.

> NOTE — Preload of 50 percent of design load for 10 s to be applied before commencement of the test.

6.4.2 STATIC AND DYNAMIC WATER PENETRATION TEST

If water is observed in the operable vent drainage path and the same is drained through slots after the spray is stopped it shall be considered as pass. Any water on the top surface of any exposed interior shall be considered as leakage. For sliders, only water overflowing to the interior is considered as failure. In case of leakage the remedy needs to be carried out and the retest shall be conducted. The rate of water spray shall be 3.4 litre/min.m^2 for a period of 15 min. The spray shall be located at a distance of 400 mm from the glass and 700 mm centre-to-centre horizontally and vertically. The pressure differential up to 35 m height shall be 300 Pa, beyond 35 m up to 70 m shall be 450 Pa and beyond 70 m shall be 600 Pa.

> NOTES
>
> **1** Cyclic water penetration is optional and the parameters are to be agreed mutually between the relevant stakeholders. However, cyclic water penetration is not applicable to sliding doors and windows.
>
> **2** Between each test, water should be drained and if required 450 Pa pressure applied for a period of 2 min to flush out the water from the system. There should also be a minimum of 10 min at zero pressure between tests.

6.4.3 STRUCTURAL LOAD TEST (100 PERCENT DESIGN WIND LOAD)

The deflection criteria of glass and framing members shall be as specified in **6.3.6.2**.

No damage or harmful permanent deformation of any parts except sealing materials shall be found at the maximum testing pressure. Residual displacement of structural member shall not exceed span /1 000. The slippage at supports and fixing shall not exceed 1 mm.

6.4.4 SEISMIC RACKING TEST

Criteria shall be the movement of the sub-structure in the horizontal (+/-) directions. Optional testing for vertical movements (+/-) shall be based on sub-structure movement to accommodate live load, long term creep, column shortening and thermal elongation or contraction. No glass breakage or fall out is allowed. Any damage shall be easily reparable without any part replacements required. No wall component fallout is allowed.

6.5 BUILDING MAINTENANCE UNIT (BMU) PULL OUT TEST (WHEN APPLICABLE)

A tensile load of minimum 1.5 kN shall be applied on the BMU restraint in the following directions:

a) Horizontally to the right and held for a period of 1 min,
b) Horizontally to the left and held for a period of 1 min.
c) Vertically upward and held for a period of 1 min
d) Vertically downward and held for a period of 1 min.

After each step the BMU restrain should not fail or have permanent deformation.

NOTE — If the load on the BMU restraints required by the BMU supplier is higher, the higher load shall apply.

6.6 OPERATING FORCES TEST

Maximum force required to initiate opening of a sliding door is 180 N and the maximum force to maintain the motion of a sliding door or window is 115 N. For a projected top hung or parallel open vent the maximum force to maintain motion is 135 N.

STRUCTURAL PROOF LOAD TEST (150 PERCENT DESIGN WIND LOAD AND SEISMIC FORCE, IF APPLICABLE)

Under proof load test there shall be no collapse which means any one or any combination of the following:

a) Dislodgement of any glass.
b) Dislodgement of any frame, panel or any component thereof.
c) Failure of any fixing that connect the façade to the building structure, such that the test sample is unstable.
d) Failure of any stop, locking device, fastener or support which may allow an opening light to come through.

The permanent deformation in framing members in excess of span/1 000 is not permissible and considered as failure.

NOTE – For on-site testing, the parameters shall be tested for two/third of the laboratory values.

SECTION 7: MAINTENANCE AND DURABILITY

7.1 Maintenance – Infrastructure

Regular maintenance of the building facades plays an important role in the holistic building maintenance. The access systems shall provide sufficient approach which enables all parts of the façade to be reached safely for the purpose of cleaning, inspection and maintenance and also offer high work efficiency to the maintenance workers, without also hindering the aesthetics of the building. The provisions of Part 12 'Asset and Facility Management' of SP 7 may also be referred.

The means of access and supporting infrastructure should be established at the design stage so that the loads are properly envisaged for.

Façade access requirements come in many varieties and may present challenges. Powered access cradles for facade access, cleaning of the glass directly from the ground, hoists based access and window based cleaning/access from inside the building are some of the common techniques employed. Recently, access techniques using ropes have been used for facade access and are generally considered to be safe, provided the workers have been trained and are using all the correct safety equipment and precautions.

In nearly all cases, façade access and maintenance require a worker to be exposed to working at height with its associated risks. Therefore, use of height safety equipment, anchor point attachments (like the fall restraint or fall arrest system) and those given below should be employed:

a) *Roof guardrails* – When choosing equipment for working at heights, collective protection like roof guardrails may also be considered. Roof guardrails ensure that all users are protected from falling without the need for specialised training and/or equipment. They also eliminate the need for rescue procedures to be put in place. Roof guardrails are available in fixed, free standing, straight upright, cranked upright or collapsible.

b) *Fall arrest systems and fall prevention cable systems* – Fall arrest systems allow safe access to roof areas for maintenance and inspections to be carried out by workers. Users of the fall arrest systems require wearing of full body harnesses and attachment to the cable/fall arrest system via a lanyard (rope) and shuttle device which allows them to walk the full length of the system without having to detach from the system. Fall arrest systems shall be of types horizontal, overhead, sloping and vertical lifeline type and shall comply to the relevant/available standards.

Depending on the project requirement, the maintenance infrastructure shall consist of the following systems:

1) *Roof trolley/Cradles* – Fixed or adjustable jib, telescopic jib, cradle with pantograph.

2) *Rail systems* – Hooked, anchored, turntables, rotary plates.

3) *Other systems* – Additional winches for glass replacement, parking positions/lifting platforms.

7.2 Maintenance of materials

The glazing system and the associated materials require a suitable degree of maintenance, if they are to fulfil their intended working life. Early detection of defects can mitigate expensive repairs or replacement later. The degree of inspection and maintenance required will depend on the type of glazing system and its intended design life.

7.2.1 Sealants

i) Inspection of Sealant

- The sealant shall remain intact with the substrate to which it was applied. Loss of adhesion shall not take place.
- The sealant shall not exhibit visible cracks or splitting within.
- The sealant shall not be brittle.
- It shall not exhibit blistering, chalking and discoloration.
- Chemicals and bacteria can degrade joints, or change the visual appearance of the joint, making repairs mandatory.

ii) Cleaning

- Mild soap water solutions shall be used for cleaning.
- Soft lint-free wipes shall be used for the cleaning of damaged sealant when fresh sealant is going to be applied over damaged, cured sealant. The surface shall be wiped clean until all contaminants are removed.
- The cleaning shall be started in a test patch. Care shall be taken to confirm that cleaning solutions do not mar adjacent surfaces.

iii) Repair

- A part of installed sealant may need to be repaired or replaced with new sealant of the same type if it fails in a specific area due to cohesive rupture, mechanical damage, adhesion loss, vandalism, etc.
- The specification of the new sealant shall be same as the old sealant to ensure sufficient adhesion.
- In case of a different silicone sealant is to be utilized for the repair material, then a site adhesion test shall be made to assess adhesion between the two sealants.
- The surface of the existing sealant shall be cleaned on either side of the repair area, to ensure adherence when placing new sealant onto the existing sealant.
- The newly exposed cut surfaces should be clean and prepared for the direct application of fresh sealant, if the repair is conducted immediately after the removal of the existing sealant
- Polysulfide sealant can be recognised by the specific smell of sulphur released while burning. It can be easily removed and repaired with the same material or a hybrid sealant.
- Polyurethane sealants can be recognised by the hardened skin, showing some cracks. Sealant of the same kind shall be used as plasticiser migration occurs if a different sealant is used.
- Repairs in glazing systems shall be made by cutting out the old sealant at an angle of 45 degrees, followed by applying a new sealant joint. The applied sealant shall be slightly widened, providing about 3mm of bonding surface to the glazing bead or frame.

7.2.2 Frame

i) Inspection

- Check for signs of water damage like stains, mould, or peeling paint.
- Check for weep system blockage. The blocked weep system shall be cleaned by inserting a thin wire into weep holes.

ii) Cleaning

- Caustics, corrosives, solvents or wet packing materials shall not be allowed to set on the frames as they will permanently damage the surface.
- The surfaces shall be cleaned with mild soapy water or a non-abrasive window washing solution with a soft cloth or sponge and thoroughly rinsed with clean water.
- Isopropyl alcohol diluted with water or non-abrasive cleanser such as soft scrub shall be used for removing stubborn debris.
- The cleaning shall begin in a small patch of area.
- All weep holes, roller assemblies and tracks shall be unclogged.
- Hardware components shall be lubricated using a suitable lubricant to avoid stiffness.
- Extra care shall be taken to clean and dry the unfinished exposed edges of the frame as these are susceptible to corrosion.

7.2.3 Glass

i) Inspection

- Cracks, scratches or breakage shall not be present.
- Sign of Water Ingress shall not be present.
- Condensation in between the panes shall not be present.

ii) Cleaning

- The glass shall always be protected from contaminating substances.
- The glass surfaces shall be cleaned on a regular basis. Foreign substances should not remain on surface of glass.
- The frequency of cleaning depends on the level of pollution or contaminants in the surrounding area.
- Detergents that contain either alkaline, acids or fluoride shall be avoided.
- Abrasive cleaning methods i.e. scouring pads, steel wool, and razor blades should only be used for spot cleaning, as damage to the surface may result. It is not recommended to clean the whole surface of the glass with a blade or squeegee.
- Abrasive cleaners should never be used on the coated side of the glazing.
- Thoroughly pre-rinse with warm water to loosen and wash away surface residue, grit and grime.
- Using a soft microfiber cloth or moist non-abrasive sponge, gently wash with a mild diluted soap or detergent.
- The glass shall be thoroughly rinsed with lukewarm, clean water. To prevent water spots, thoroughly dry the glazing with a dry soft cloth.
- High alkaline cleaners (high pH or ammoniated) shall be avoided.

- Cleaners shall not be allowed to sit on glazing for long periods of time and should be rinsed immediately.
- Cleaners shall not be applied under direct sunlight or at elevated temperatures.
- Dry rub or dry cleaning of glazing shall be avoided, as sand and dust particles clinging to the exterior of the glazing may scratch its surface.
- **Removing heavy oils and tars** shall be removed by thoroughly prerinsing with warm water to loosen and wash away surface residue, grit and grime and then washed with isopropyl alcohol diluted with water mixture and gently rub the area with a soft non-abrasive cloth. The surface shall then be rinsed thoroughly with lukewarm clean water. To prevent water spots the glazing shall be cleaned with a dry soft cloth.
- **Removing graffiti, paint, marker, inks and glazing compounds** – shall be removed by thoroughly prerinsing with warm water to loosen and wash away surface residue, grit and grime. Naphtha VM&P grade, Isopropyl Alcohol or Butyl glycol shall be used to gently rub the area with a soft, non-abrasive cloth. The solvent cleaners shall not be applied under direct sunlight or during high temperatures. The surface shall then be rinsed thoroughly with lukewarm clean water. To prevent water spots the glazing shall be cleaned with a dry soft cloth.
- **Removing adhesive-backed labels –** Isopropyl Alcohol, Naphtha VM&P grade or Kerosene shall be used to remove stickers and adhesives. The surface shall then be rinsed thoroughly with lukewarm clean water. To prevent water spots the glazing shall be cleaned with a dry soft cloth.

7.3 Good practices for maintenance

The common maintenance practices to be followed shall be as given below.

a) When using the cleaning equipment or carrying out maintenance on the exterior of the building, the risk to personnel and property, prior to the start of work shall be assessed at first.

b) Where applicable, qualified personnel to carry out routine or complex maintenance shall be employed.

c) Power supplies may need to be isolated prior to maintaining electrically operated equipment such as motors to opening vents, roller blinds to atrium roof and main entrance pass doors.

d) While accessing the external façade, fall arrest systems shall always be used even while working in the house cradle.

e) Manufacturer's instructions shall be followed when using cleaning fluids and shall not be mixed up with drinking water or the like. To deal with instances of contact with eyes, skin, etc, necessary eyewash arrangement and first aid equipment shall be at place.

f) Loosened fixing or bolts shall be identified, reported and attended to immediately, and shall never be tampered with.

g) Unauthorized loosening or removing of the fixings may prove dangerous and can result in structural damage and displacement of the system.

h) When lifting equipment such as hoists and sucker machines are used, it shall be ensure that they are capable of lifting the loads required. Further, the recommended safe working loads of any equipment shall never be exceeded.

j) When handling any insulation of firebreak material, ensure gloves, goggles and masks are worn as fibrous materials (if any) may cause irritation.

k) Prior to the commencement of work involving glues or sealants (particularly in confined spaces), manufacturer's advice/special instructions shall be adhered to before exposing the product to air. Such materials shall preferably be worked with, in a well-ventilated area.

m) In the case of coated glass, the following precautions shall particularly be adhered to:

   1) Any scratching will penetrate the surface of the coating and cannot be repaired.

   2) Any excessive mechanical treatment might remove the coating in localised areas.

   3) Avoid all contact with metal objects.

   4) void all chemicals that may attack the surface and damage it irreparably.

7.4 Durability and replacement

i) Sealant

- The sealant shall be replaced, when a significant portion of the sealant in a given area shows signs of failure, or when the sealant has lost its flexibility (becomes brittle).
- The sealant replacement depends on the weather the side of the building is exposed.

ii) Frame

iii) Glass

- Major cracks shall require glass replacement.
- The glass or the entire glazing system needs replacement if it shows free movement upon touch to avoid water penetration.
- Fogging or condensation in between the glasses indicates failure of the bond between the lites of glass of the insulated glass (IG) unit. Damage to these seals will require replacing the entire IG unit.

7.5 Project handover documents

7.5.1 As – built documents

- The as-built drawings shall include the latest architectural, structural, civil, mechanical, electrical, fire alarm, sprinkler, and elevator drawings referencing the as-built condition of the subject property.

7.5.2 O & M documents

- The operations and maintenance documents shall consist of manufacturer's specifications and recommendations, programming procedures and data points, narratives and other means of illustrating to the owner how the building, site and systems are intended to be maintained and operated.

- Directions to the owner or occupant on the manual cover sheet indicating that at least one copy of the materials shall be in the possession of the owner or occupant and at least on additional copy shall remain with the building.
- Operations and maintenance documents for materials, products, assemblies and systems installed under glazing systems including inspection schedule, performance criteria for replacements and repairs.
- Information and recommended schedule for required routine maintenance measures including, but not limited to, cleaning, painting and refinishing.
- Information and recommended schedule on required routine maintenance measure including, but not limited to sealants, mortar joints and screens.

7.5.3 Warranty Documents

- Warranties become effective at substantial completion.
- Warranty letters should be transmitted as a part of the closing documents.

7.6 Attic Stocks

- The construction specifications for each project include a set list and quantity of deliverable attic stock items that are expected to be delivered by the General Contractor/Subcontractors at the end of the project. These items will be stored at the building.
- Prior to the procurement and delivery of attic stock items:
  - i) Construction Manager and Property Manager decide on type and quantity of attic stock to be provided. This should be incorporated in project specifications.
  - ii) A specific storage area for the attic stock should be identified.
  - iii) If a lesser quantity, than what was originally specified is requested, then an appropriate cost deduct for these attic stock items should be obtained by the Construction Manager.
- Upon delivery of attic stock items:
  - i) The delivery of these items should be coordinated by Construction general contractor.
  - ii) A sign-off sheet that memorializes the receipt of these attic stock items, quantities and person(s) involved should be provided and included in the construction close-out file.

SECTION 8: QUALITY ASSURANCE OF FAÇADE AND FENESTRATION

8.1 Fabrication

- **Fabrication Drawings**
  - The drawings shall show all major curtain wall systems components along with detailed structural calculation for wall types.
  - The drawings shall include all tolerances.
  - Section drawings shall be provided showing all joinery, provision for vertical and horizontal expansion, glass and metal thickness and framing member profiles.

- The drawings shall provide details of drainage provision and functioning, mullion transom connection and sleeve connections.

- **Materials**
  - The manufacturer's certificate of frame material shall be checked.
  - The frame profile shall be free from die lines, pressure marks, scratches or graphite lines.
  - Anchor and reinforcing steel grade shall be as per approved standard.
  - All steel system shall be factory primed and painted.
  - The fastener types and materials shall be checked
  - The sealant type shall be verified with the manufacturer's certificate.
  - Sealant accessory compatibility shall be verified.
  - The glass types, thicknesses, dimensions and heat treatments shall be as per approved standards.
  - The glass coatings, edge sealants and edge spacer shall be as per approved standards.
  - The finish, type, colour of the materials shall be uniform.
- **Frame**
  - **Machining**
    a. All frame sections shall be fabricated in accordance with the fabrication drawing issued.
    b. Cut sections of frame shall be marked with a part code for proper identification.
    c. Frame sections shall be provided with a plastic protective tape to avoid scratches, prior to any cutting, notching and drillings,
    d. Worktables to be used shall be protected with rubber matting to avoid scratches on the frame sections.
  - **Inspection/Tolerances**
    a. The QA officer shall verify the accuracy of each tape received; against calibrated 100-cm straight edge of QA office.
    b. Tapes within 0.50 mm accuracy shall be accepted. Tapes that do not meet these criteria shall be returned to vendor for replacement.
    c. The following list of operations has been complied with the applicable tolerances, is as follows:

Operation	**Tolerance**
Saw length	+0, -0.50mm
Shear Size	+0, -0.50mm
Squareness of Sheared sheet	± 1 degree
Hole Size	+0, -0.50mm
Hole Location	+0, -0.50mm
Mill Cuts	+0, -0.50mm
Bend size	+0, -0.50mm
Angularity (Bending Sheet Metal)	± 1 degree
Radius Size	+0, -0.50mm
Welded parts location	+0, -0.50mm
Stud Weld Location	+0, -0.50mm

- **Backpans**
  - The overall fit of backpan within frame shall be checked.
  - Stiffener installation and sealing shall be verified.
  - Slope of drainage of backpans shall be checked.
  - Perimeter sealants shall be continuous.
- **Glazing**
  - The condition of glass edges and edge sealant coverage shall be checked.
  - The overall size, thickness and dimensions of the glass shall be verified.
  - Proper orientation (inside/outside) of glass shall be checked.
  - Adequate bite, edge clearance, face clearance and cap coverage shall be checked.
  - Drainage and venting provisions shall be reviewed.
  - Confirm positioning of setting blocks and locking in position
- **Structural Silicone Glazing**
  - Results of snap, butterfly and adhesion testing shall be verified and must comply with the approved standards.
  - Dust free conditions shall be ensured.
  - Proper sealant application and curing shall be checked.
- **Panel Insulation**
  - The insulation in the curtain wall panels shall be factory fitted to the panels. The mineral fiber is fully sealed within the panel behind the backing sheet installed to the spandrel area of the

- **Tagging**
  - Ensure a means of tagging defective components is in place and responsibility of correction is assigned.

8.2 Assembly

- **Loading of materials**
  - Panels shall be fabricated with steel and hardwood bases and the panels shall be stacked onto the frame with suitable spacing materials.
  - The completed pallets are then covered in shrink wrap to provide adequate protection during transport and storage of panels onsite.
  - The frames shall be braced to resist transport and lifting loads.
  - The panels shall be placed in a pre-arranged storage location over the ground girder, so as to minimize the impact on other trades working on the ground floor.
  - The storage locations shall be in an area where damage by other trades is eliminated.
  - Flashings and brackets shall be stored on floor for use on the curtain wall. These shall be delivered in boxes/pallets suitable for handling by the crane/man hoist to the floors in which it is to be installed.

- **Unpacking of panels and distribution**

- The unloading of the panels and distribution to the work area shall be done with the assistance of a suitable machinery such as gantry girder, forklift etc.
- The panels shall be positioned on steel with timber-based trolleys with wheels for easy distribution to the work area.

- **Survey Setout marks and reduced levels**
  - Check the grid line on every fourth floor. On these floors an offset line is placed across each major elevation so that position of the bracket can be accurately measured and et the edge of mullion position.
- **Setout and Positioning of steel brackets**
  - The bracket shall be positioned and a temporary restraint is installed to the bracket. The clamp shall prevent the bracket from falling from the slab edge while the bracket is packed.
  - On the intermediate floors the brackets for the corners shall be plumb in position and the intermediate brackets set with a string line and a spirit level for a plumb at the face bracket.
- **Framing**
  - The fit and fixing of framing elements shall be checked.
  - Confirm sealing of joinery including continuity across wall thicknesses
  - The fixing of anchor components, position of major load bearing holes, bolt fixing shall be checked.
- **Spandrel**
  - The venting and drainage of spandrel cavities shall be checked.
  - The condition of fabricated panels, finish, corners, flatness shall be verified.
- **Gaskets**
  - Placement, sealing and securing of all interlock and glazing gaskets shall be checked.

8.3 Installation

- **Pre-installation**

  Set up, coordinate and agree with the main contractor regarding all site logistic for item such as;
  - Material deliveries
  - Delivery schedule
  - Intermediate material storage facilities on floors (to be agreed)
  - Parking facilities on site for trailers
  - Storage area on the floors for panels & main store for loose materials/equipment.
  - Sealants/water proof membrane/EPDM glue/gasket shall be delivered in boxes either from factory or directly from the supplier. It shall be checked in accordance with the specification. It will be stored in a twenty-four-hour air condition under controlled temperature.
- **Access Equipments**
  - A life line/fixed barrier shall be installed along the perimeter of the active area, before any installation or lifting works begins. Safety belts must be attached on to this life/barrier in order to prevent any accident or unwanted fall from the building. The installation of the panels will be carried out by mobile hoist and lifting beams.

- The building will be divided into stages for installation as per program and the monorails shall be erected at site at every nth floor as agreed with site team and in according to the program to achieve access to the required floors.
- Install the monorail railing along the façade of the building having a distance of at least 600 mm from the edge of the slab for concrete wall. The railing shall be connected to a cantilever steel channel which is anchored onto the slab or reinforced concrete wall using anchor bolts.
- A lifting motor shall be attached in the process of installation. The lifting motor shall slide freely along the rail, following any sequence of installation.
- Independent Testing agency shall test the monorail in each location after erection and test certificate will be submitted to main contractor before installation starts in that area. (Before any installation or lifting works begins).
- Prior to the starter panel installation, the supervisor will inspect the installation of the brackets to ensure that they are completed i.e. lined, levelled and torque. Ensure availability and condition of hoisting outriggers, winches and lifting frames. Replace item as necessary.

- **Anchors – embeds**
  - The placement of embeds shall be verified.
  - The anchor shall be level and square to wall.
  - The offsets shall be within limits.
  - The adequacy of field welding, corrosion protection shall be verified.
  - The locking of nuts and bolts shall be checked to prevent loosening.

- **Brackets**
  - Ensure brackets are designed for specific use according to location conforming to material specifications and approval.
  - All bolts shall be tightened to the required torque using calibrated torque spanner in accordance with the installation drawings.
  - The bracket shall be mounted at the soffit (or face) of slab and at the base floor to hold the aluminum framings and steel support framings using approved fasteners, where all fixings shall have tolerances in three directions; for in & out, elevation and lateral tolerances which shall be specified.
  - Check the correct bracket type and quantity according to location
  - Provide a safety line to secure all loose equipment i.e. hand tools, etc. that will be used at the workplace.
  - Drill holes to correct diameter and depth and at correct location to avoid touching the cables of the post tension slabs. Drills become worn with use and need to be replaced at intervals.
  - Install the bracket. Prior to tightening of bolts, make sure that the bracket is in the right position. Adjust position and level according to survey markings and key brackets. Ensure the plumpness and horizontal alignment of the brackets.
  - Ensure minimum edge distance and spacing is provided. Reducing the edge distance and spacing reduces the strength of the fixing.
- **Installation of starter panel**

- The panels shall be installed with a suitable lifting device. All lifting devices shall have been submitted to the respective authority and shall be certified by an engineer.
- The weight of each panel shall have its gross weight written in the gutter head transom of the panel. This allows to check that the safe working load of the lifting equipment that is been used is not exceeded.
- The male and female mullion must engage properly and the gap based on the approved fabrication drawings must be followed.
- The installation of the panel shall commence during the commencement of elevation of project to avoid the need for a kicker frame.
- Check panel alignment after installation and correct vertical position if required.
- The installation sequence shall be zone/floor and bottom to top.

- **Framing**
  - Ensure there shall be no framing damage from shipping
  - Framing installed shall be square and plumb
  - Positive frame interlock and gasket engagement shall be verified.
  - Sealing of joinery including continuity across wall thicknesses shall be verified.
  - Proper stack joint height, verify removal of temporary shims shall be confirmed.
  - Verify splice seals in place prior to positioning subsequent frames Installation of slab edge and mullion tube firestopping and smoke seal
- **Structural Silicone Glazing**
  - Verify QC procedures in place.
  - Verify positive results of adhesion testing
  - Verify substrate cleaning and dust free conditions
  - Confirm proper sealant application and curing
  - Confirm manufacturer inspection of application

- **Smoke Flashing**
  - The smoke flashing shall be installed at the floor level. All the joints between the capping channel and any other finish material at both sill and soffit level shall be sealed with intumescent sealant.
  - The gap on the vertical surface between the face of column/wall/partition and the thickness of channel and cap shall be 2mm and to a width specified in fabrication drawing.
  - The flashing shall be provided along the entire length of the glazing system at all floor levels.

- **Sealants**
  - The position and placement of field sealants shall be checked.
  - Sealants delivered must have an expiration date of at least 4 months from their date of packing.
- **Protection**
  - Review procedures to protect installed curtain wall from damage until project complete.
  - Constantly monitor and immediately clean any concrete or tar splatter to glass.
  - Enforce procedures to protect glass from welding or metal cutting spark.