FORWARD

Glass is an integral building material for most construction projects. Virtually every building requires glass. Architects are increasingly seeking to bring natural environmental factors into the interior of buildings by maximizing natural daylight. This has been achieved through the use of larger glazed areas in facades and roofs, and through entirely glazed facades, where glass is a structural component of the building. But there are significant concerns about 'Energy' and 'Human Safety' and they need to be addressed while deciding on glass for use in building applications. There are other concerns like acoustic requirement, fire escapes etc. which have to be understood.

As buildings account for around half of all energy consumed in developed countries, they have become the prime focus of attention. Targets for reducing CO2 emissions have driven tougher legislation for energy saving glass. Building regulations in many countries now require insulating glass units (also known as double glazing) as standard, with energy efficient low emissivity (low-e) coated glass often necessary. In hot climates, there is an increasing recognition that reliance on air-conditioning can be mitigated by the use of advanced solar control glass. In India also ECBC norms are now in place that requires use of Insulating Glass in most of the buildings. Window energy labeling systems are also under development.

Normal annealed glass as sold on the shops may suffice for use in small openings in traditional windows but use of such glass in larger panes and vulnerable locations can cause grievous injuries in case of an accident. Growing awareness about human safety has driven building regulations and a code is now available as 'Use of glass in buildings- Human Safety'.

While new buildings consume most of the manufactured and processed glass, refurbishment of buildings, account for around 40 percent of glass consumption worldwide. In mature markets, windows in residential buildings are replaced every ten to fifteen years for facelift and the trend is likely to be repeated in India.

There are products available to address all the concerns. The industry dynamics are changing very fast, but the skills, awareness and knowledge among stakeholders on glass have not kept pace. This is a matter of concern as the knowledge and skills need to scale up as to shape the demands of the future habitat of emerging India.

This document from Federation of Safety Glass is aimed to impart knowledge and skills on glass as a building material and to share the latest trend that govern the structural and aesthetics possibilities of this versatile material.

We are grateful to Mr. Sharan Jit Singh, who has put in his life time of experience and knowledge in writing and compiling of this book. We are also grateful to Mr. Vivek Dubey, Ms Sheetal Khanna, Mr. Tariq kachwala, Mr. Gundeep Singh Sood, Mr. Balaji Konidala, Mr. A.R Unnikrishnan, Mr Manish Srivastava, Mr Surinder Saluja, Mr. Amit Malhotra, CCPS, Glass Academy and all the industry experts, who have helped Mr Sharan Jit Singh with their valuable inputs and guidance in bringing out this book. I am confident that this book will create the much needed awareness and knowledge about Glass.

Gurmeet S Singh
Chairman
Federation Of Safety Glass

PREFACE

For Thousands of years, glass was thought of as something to look at. It was valued in making precious objects for decorating purposes. Glass really became useful when it was thought of as something to look through. The ancient art is now a medium of architectural advertisement.

Glass is architectural. Its transparency, masking, fabrication ability, adaptability and specialization highlight its suitability for structures. To meet the specific construction needs, glass can be made transparent, translucent, opaque, diffused or stained by mechanical or chemical means. Processed and cured correctly, it is sound insulating, heat absorbent, heat reflecting, weather resistant, non-abrasive, and incombustible.

From foundations to skylights, our buildings portray our yesterday, today and tomorrow. Built on the confidence of past success, they take shape in the present, and hint at tomorrow's dream. Today can be seen in the walls of beautiful colours and reflections in glass.

ABOUT THE BOOK

This book on architectural glass aims to provide knowledge and serve as a reference guide for use of glass in buildings. It is also aimed to serve as a textbook on glass for the students of architecture and civil engineering.

It contains comprehensive information on glass and has been divided into four sections. The first two sections cover the basic information on all types of glasses and their applications with emphasis on human safety, energy and acoustics.

The third section is for further technical information on manufacturing, quality and materials connected to glass like hardware, sealants and glazing systems. The fourth section is about availability, limitations, ordering, precautions, general definitions and terminology used in glass and glazing.

For quick reference to various topics, the last pages of definitions and terminologies give an index to the topics with page numbers.

We hope that this book will meet the required objectives. We solicit the suggestions from readers and users for further additions, modifications and improvements for the second edition to make it even more comprehensive and useful.

Sharanjit Singh
Management committee member
Federation Of Safety Glass

SECTION-1, GLASS BASICS

This section describes the various types of available glasses and contains basic general information about them.
Starting with the basic float glass, it goes on to briefly describe various commonly used processed glasses giving their basic characteristics.
Further sections provide information about their practical applications and technical informations on the production technology and quality standards.

Section Contents :

HISTORY OF GLASS

Glass was used since stone age for making sharp cutting tools. It was a natural product of volcanic eruptions. The earliest known glass objects, of the mid third millennium BCE, were beads, perhaps initially created as accidental by-products of metal-working.
According to Pliny the Elder, Phoenician traders were the first to stumble upon glass manufacturing techniques at the site of the Belus River. Georgius Agricola, in De re metallica, reported a traditional serendipitous "discovery" tale of familiar type :

"The tradition is that a merchant ship laden with nitrum being moored at this place, the merchants were preparing their meal on the beach, and not having stones to prop up their pots, they used lumps of nitrum from the ship, which fused and mixed with the sands of the shore, and there flowed streams of a new translucent liquid, and thus was the origin of glass."

This account is more a reflection of Roman experience of glass production, however, as white silica sand from this area was used in the production of glass within the Roman Empire due to its high purity levels.

During the 1st century BCE glass blowing was discovered on the Syro-Judean coast, revolutionizing the industry. Glass vessels were now inexpensive compared to pottery vessels. A growth of the use of glass products occurred throughout the Roman world. Glass became the Roman plastic, and glass containers produced in Alexandria spread throughout the Roman Empire. With the discovery of clear glass (through the introduction of manganese dioxide), by glass blowers in Alexandria circa 100 CE, the Romans began to use glass for architectural purposes. Cast glass windows, albeit with poor optical qualities, began to appear in the most important buildings in Rome and the most luxurious villas of Herculaneum and Pompeli. Over the next 1,000 years glass making and working continued and spread through southern Europe and beyond.

INDIA

Indigenous development of glass technology in South Asia may have begun in 1730 BCE. Evidence of this culture includes a red-brown glass bead along with a hoard of beads dating to that period, making it the earliest attested glass from the Indus Valley locations. Glass discovered from later sites dating from 600–300 BCE displays common color.

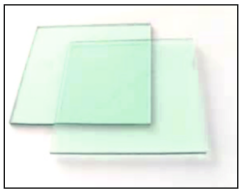
Chalcolithic evidence of glass has been found in Hastinapur, India. Some of the texts which mention glass in India are the Shatapatha Brahmana and Vinaya Pitaka. However, the first unmistakable evidence in large quantities, dating from the 3rd century BCE, has been uncovered from the archaelogical site in Takshashila, ancient India.

By the 1st century CE, glass was being used for ornaments and casing in South Asia. Contact with the Greco-Roman world added newer techniques, and Indians artisans mastered several techniques of glass molding, decorating and coloring by the succeeding centuries. The Satavahana period of India also produced short cylinders of composite glass.

VARIOUS BASIC GLASS TYPES

Float Glass :

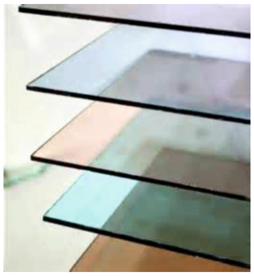
This is the most common type of glass which is generally available on glass retail shops for use in the buildings. The stock sheets of glass are cut to size generally on the glass shop itself and supplied to site for glazing in the windows or other applications.


Clear Glass

Basic float glass is manufactured by melting sand. Other ingredients such as soda ash, limestone, salt cake and broken cullet glasses are added to lower the melting temperature of silica and promote optical clarity of the finished glass product. Mixed batch of above materials is heated to a temperature of 1450 to 1650^{o} C and formed into large flat sheets by floating molten glass on molten tin, thus giving it precise flatness and transparency.

Tinted Float Glass :

It is a normal flat glass to which colour is added during manufacturing process to achieve tint and solar radiation absorption properties.

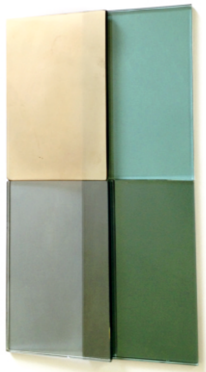

Tinted Glass

Its absorption properties help diminish energy transmissions through glass when exposed to strong sunlight. Variations in the thickness of the glass would yield different performance in terms of light and solar transmission.

Although darker shades reduce the amount of heat being transmitted to the interiors, they also reduce the amount of daylight being transmitted.

Online Coated Float Glass :

Online Coated Float Glass is also a basic clear or body tined float glass which has been coated with a thin inorganic material in the high temperature, the treatment of the surface of a moving continuous ribbon of a basic glass at a stage during its manufacture before it is cut. These are discussed in more detail under the heading "Solar Control Glasses".

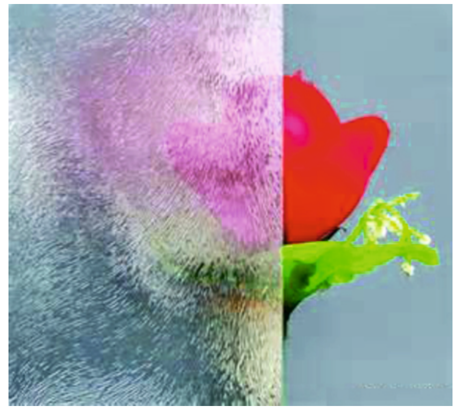

Coated Glass

Offline Coated Float Glass :

Offline Coating, a secondary process, is a metallic coating on glass by process in a vacuum atmosphere. Multiple coatings can be applied for better thermal performance in a variety of colour options. Offline Coated glasses are of two types :

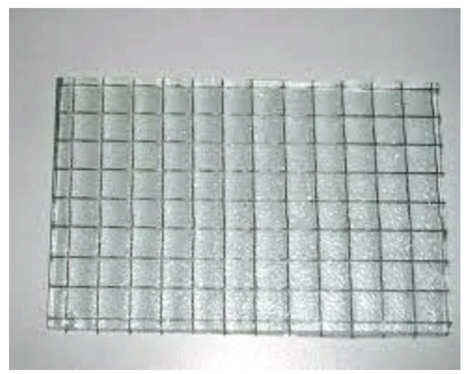
1. Offline Coated – Temperable after Coating.
2. Offline Coated – Not Temperable after Coating.

Coating surface of the offline coated glass should be positioned on interior side of the building or within the air gap of insulation glass unit (IGU). Glass with Low-e properties (silver layer as functional layer) should always be used with coating positioned within the air gap of IGU as silver coatings are efficient but prone to oxidation if kept exposed to the atmosphere



Patterned, Figured or Rolled Glass :

Patterned Glass is a decorative and translucent glass with figures or patterns on one or both surfaces of glass. In addition to diffusing light and obstructing visibility from the outside, the figures soften the interior lighting. It is manufactured by a method similar to float glass wherein the molten glass is passed through rollers instead of floating on a molten tin bath. These metallic rollers are engraved with some patterns or designs, which are cast into the formed glass and can be used in most applications for lighting but no see through. This type of glass is usually more brittle or fragile and less convenient to clean.



Wired Glass :

Wired glass is a glass in which wire mesh has been incorporated during its production. There are two kinds of wired glass:

1. Wired float glass
2. Figured wired glass .

Wired float glass will have a transparent feel allowing light as well as visibilty. Figured wired glass is much inferior, will allow light but no see through or visibilty through.

Extra Clear Glass :

Greenish appearance in clear glass is due to the presence of a small iron content in silica sand. This greenish appearance in float glass is eliminated in extra clear glass by using purer sand & further reducing the iron content in silica sand. The typical iron content for normal float clear glass is 830-850ppm, whereas the extra clear has less than 150ppm. This makes it very clear in vision with high colour rendering index.

PROCESSED GLASS TYPES

Basic glass has to be further processed to make it a more useful and high performance product to withstand high wind pressures, increase safety, solar screening, ultraviolet filtration, sound absorption, energy efficiency & fire resistance and most of all, provide pleasant interiors and impressive exteriors to perform and to look good.

Tempered Glass :

Tempered glass (also known as toughened glass) is an extremely strong glass which has been thermally heat treated to induce compressive stresses of 10,000 to 20,000 psi on the surfaces and edge compression of not less than 9700 psi.

Tempered glass is being used increasingly in architecture because of its strength and safety properties. It is usually installed in areas where safety glass is required to reduce the possibility of mechanical or thermal breakage and/ or to assure greater uniform load strength. Worldwide the use of Tempered glass or Safety glass in general has been mandated by building codes. These codes are also made for India and are in the process of being mandated.

Cut to size glass sheets are electrically heated in the furnace where it oscillates back and forth on rollers till glass reaches temperature of about 650°C. After heating, the glass is conveyed to a quenching chamber where it is cooled rapidly by a blast of air, blown through nozzles, on both sides of the glass.

Characteristics of Tempered Glass:

Strength : Toughened (or Tempered Glass) is four to five times stronger than its equivalent thickness of normal annealed float or sheet glass.

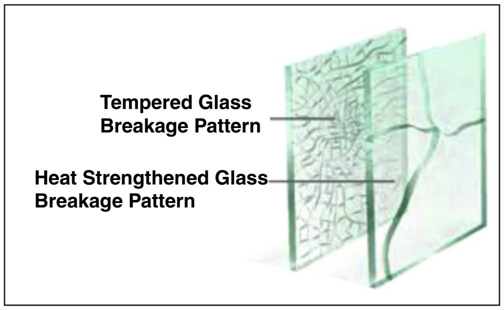
High Thermal Shock Strength : Tempered Glass provides greater thermal strength. It offers increased resistance to both sudden temperature changes and temperature differentials up to 240°C compared to normal annealed glass which can withstand temperature differentials up to 40°C only.

Safety : Tempered Glass is very difficult to break but even on breakage, it will break into small, relatively harmless fragments. This substantially reduces the likelihood of injury to people as there are no jagged edges or sharp corners which are normal in the case of breakage of annealed glass. Due to the inherent superior features of Tempered Glass, like more strength, ability to withstand sudden impacts and breaking into small pieces, it is considered as a safety glazing and so in most countries, use of Architectural Toughened Glass is mandatory for entrances in public areas or where it is to be used by general public.

Others : The Tempering process on normal glass does not alter the light transmission and solar radiant heat properties of the glass. Tempered glass cannot be further cut, ground, drilled or worked upon. Tempered Glass is prepared by completing prior to its tempering, all such works in accordance with drawings, sizes or templates.

Heat Strengthened Glass :

Heat strengthened glass is similar to tempered glass except that after heating the glass in a furnace as in the case of tempered glass, the cooling is done at a much slower pace. The heating temperature remains nearly the same for both processes. The residual stress on the edge and the glass surface differ in both cases with tempered glass having a higher level of stress.



Due to the relatively lower rate of cooling during the strengthening process, heat strengthened glass develops less stress as compared to fully tempered glass.


View in the Furnace

Characteristics of Heat Strengthened Glass:

Strength: The process increases the mechanical and thermal strength of heat strengthened glass, making it twice as tough as annealed glass but nearly half of fully tempered glass. However, its breakage characteristic is similar to annealed glass, which means that it breaks down into sharp pieces like ordinary glass even though it has been put through the heat strengthening process.

Optics: Heat strengthened glass has a comparatively flatter finish than fully tempered glass. It therefore has lesser optical distortions and so can be used in places where high optical quality is requir ed.

Safety: It can be used for general glazing where additional strength or resistance to mechanical/thermal strength is desired. The glass can also be used in high wind load areas, but cannot be used in any safety glazing applications. As Heat Strengthened glass breaks in a manner similar to that of float glass, the fragments tends to remain in the sashes, having less probability of fallout as compared to tempered glass. In comparison with tempered glass, heat strengthened glass is not easily broken spontaneously.

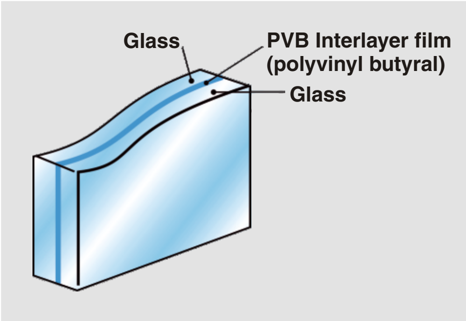
High Thermal Shock Strength : Heat Strengthened Glass will resist temperature difference of up to approximately 130°C.

Laminated Glass :

Laminated glass is two or more panes of glass with one or more layers of polyvinyl butyral (PVB) or ionomers sandwiched between them and treated. This sandwich has some unique advantages. The outer glass surfaces are hard and transparent but are strongly bonded to a transparent rubber like material on the inner surfaces of the sandwich. The glass panes can be basic float glass or tempered or heat strengthened panels. If the glass is broken, fragments remain strongly adhered to the PVB interlayer thereby nearly eliminating the risk of injury from glass and helping to resist further impact or weather damage as it does not generally fall out of the fixing.

The most common use of laminated glass is for the front windscreens of all cars. It is now finding more usage in architectural applications because of its distinct characteristics.

Characteristics of Laminated Glass :



Safety : Laminated glass doesn't shatter like ordinary glass. It absorbs impact, resists penetration, and remains intact even if broken, holding glass fragments in place and lowering the risk of injury. Global building standards increasingly specify stricter safety requirements, especially for overhead glazing where any breakage could mean a major hazard from falling glass.

Security : The rise in urban crime and terrorism also points to laminated glass as increasingly desirable as a material of construction. Laminated glass resists intrusion because the interlayer continues to safeguard the building even after the glass itself is broken. Security glass cannot be cut from only one side, so ordinary glass-cutters are useless as break-in tools. Laminated glass tends to resist impact. In multiple configurations, it can even resist bullets, heavy objects, or small explosions. In most cases, it takes many blows, all in the same spot, to penetrate the glass.

Sound Reduction : Laminated glass is an excellent barrier to noise. The sheer damping performance of the plastic interlayer makes laminated glass an effective sound control product. This makes it ideal for airports, hotels, data-processing centers, recording studios, and any building near airports, highways, or train lines.

UV Control : Ultraviolet light is the leading cause of deterioration and fading of furnishings, pictures, and fabrics. Laminated glass screens out 99% of the sun's damaging rays, protecting interior furnishing, displays or merchandise from fading effects of UV radiation.

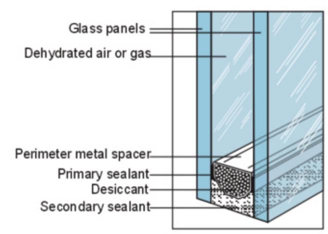
Earthquakes & Natural Disaster Protection : Earthquakes often produce a fallout of extremely dangerous shards of broken glass. But laminated glass remains in the frame, maintaining a protective envelope around the home or building to keep the weather out and deter glass shards from flying. Similarly, the heavy winds of tornados and hurricanes easily shatter conventional glass, causing injuries from flying fragments and damage to interiors exposed to the devastating weather outside.

Durability : Laminated glass retains its colour and strength for the life of the building, yet is as easily cleaned as any conventional glass.

Fire Retardacy : While standard laminated glass does not meet code requirements for fire-resistant glass, it will not disintegrate readily when exposed to heat, so it confines the fire longer, giving more time for evacuation and control of the fire. It is important though that **in case of complete glazing with laminated glass, some panels for fire escape should be glazed with tempered glass with a prominent sign 'Break in case of fire'.**

Insulated Glass :

Insulated glass is a prefabricated unit made of two or more glass panes, which have been separated by an air gap and edge-sealed together. This is also known as double glazed unit (DGU) or Insulated Glass unit (IGU). The two panes of glass are kept separated by a hollow aluminium tube spacer filled with a moisture absorbing material (desiccant) and is hermetically sealed to ensure that the air or gas in the cavity or hollow space between the two glass panes does not escape during hot climate, or outside air is not sucked in during winter or cold climate as a result of expansion & contraction of trapped dry air or gas due to change in temperature. This edge seal not only binds the individual sheets of glass together to maintain the mechanical strength of the joint but also protects the space between the glasses from outside influences. The air enclosed between the two glass panes is dried with a desiccant. Because of the low heat conductivity of the enclosed dry air between the glass panes, heat transmission through the window is drastically reduced. The sealants delay the moisture getting into the air space and the desiccant absorbs the moisture coming through the seal and during the manufacturing process. Insulated glass can also be made with three panes of glass & two air gapes. This type is known as tripple glazed units & are used only in regions having extremely cold climate.



INSULATING GLASS

Characteristics of Insulating Glass :

Insulation : Saves on heating and cooling, by reducing air to air heat transfer. The enclosed layer of air makes the insulating capability about twice that of monolithic glass. Because of this, the load on the air conditioning is greatly reduced. The use of heat absorbing or heat reflective glass will further reduce the load on the cooling system.

Prevention of Dew Condensation : With monolithic glass, the temperature difference between the outside and inside of a room will often lead to condensation. However, the insulating effect of the air layer makes it difficult for the glass to become cold enough to have condensation on its surface giving a pleasant view through in rainy or high humidity climates.

Retards Sound Transmission : Insulating glass can significantly save on exterior noise pollution. The amount of sound reduction depends on the combination of the insulating glass. Using one of the panes as laminated glass will drastically reduce sound transmission. Using dissimilar thickness of glass panes will also help combat noise.

Pleasant Room Temperature : It offers increased personal comfort and aids in energy conservation. Because of its high insulation properties, the lack of cold or warm droughts leads to a pleasant internal environment even when seated close to a glass surface.

Strength : DGU glass will marginally increase the overall strength against wind load pressure.

DECORATION ON GLASS

Glass can be decorated in a number of ways to make it a piece of art by adopting any of the processes or their combinations. The main decorating processes are Frosting, Sand Blasting, Etching, Engraving, making Textures, Grooving, Coloring, Staining, Bending, Fusion, Ceramic Printing, and Enameling.

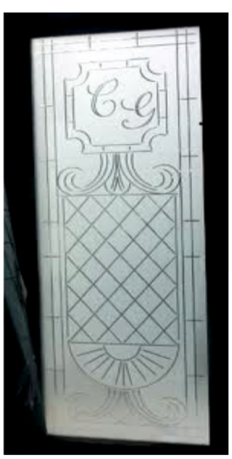
Artists can achieve almost any perceivable impression by combining one or more of these operations. Though decoration of glass is more a work of art and is mostly accomplished in glass studios, some commonly used and technically important processes are briefly described here. Most decorative glasses can be tempered, laminated or double-glazed after decoration.

Decorated glasses are extensively used for decoration in the interiors in partitions, furniture, inner doors and shower installations etc. On the exteriors, images, signage and company names or logos can be made on the entrance doors or partitioning members as well as display windows.

The best utility of decoration on glass is for 'manifestation' ***(Refer page 23 for more details)*** and for 'partial visibility or privacy.'

Frosting, Sand Blasting and Etching:

Normal glass is transparent and allows vision and light to pass through it. In certain applications it is important to allow light while eliminating or obscuring the vision as in the case of a bathroom window. Glass has very neat, clean and glossy surfaces. One of the surfaces can be frosted or obscured by blasting sand or abrasives under high pressure through a nozzle. A very thin layer of material is removed and the sand or abrasive causes a pitting on the surface obscuring its 'see through' property but not obstructing the passage of light. The final glass is known as frosted glass. Another type of frosted glass is made by acid treatment resulting in a milky smooth satin finish on glass and achieving the same objective of blocking vision but allowing light.



Frosting can also be achieved by ceramic printing or using frosted PVB film in a laminated glass. Sand blasted frosting results in a rough glass surface, which can get smudged easily with fingerprints, liquids, detergents, oils etc. It can also gain back the transparency when splashed with water. Ceramic printing or lamination option will not have this problem. It is advised not to laminate a sand blasted frosted glass as PVB will flow into the pitting and make the glass transparent again.

Normally the whole surface of glass is sandblasted

to make it frosted but sometimes this process is used to make some designs, patterns and images on the glass. This can be done by masking a part of the glass surface with a stencil mostly made by cutting the patterns or designs on a sheet or tape of vinyl and pasting on the glass surface. The area covered or masked under vinyl will not be affected by sand blasting and only uncovered area is sand blasted. Any geometric, floral, Victorian or contemporary design is possible. Such designs are known as frosted designs.

Above method removes a very thin layer of material from the glass surface but the same technique is used for deep removal of material for etching or texturing by experienced craftsmen directing the abrasive jet on the unexposed glass surface. All sand blasted surfaces will be rough but it can be smoothened out by hydrofluoric acid treatment to obtain semi glossy finishes.

Engraving and Grooving

Designs and art works can also be engraved on the glass surface using diamond tools and routers to achieve a deep cut glass effect on glass. The grooves can be made in different profiles and varying depths. They can be rough, smooth or polished or a combination of these finishes to make it a piece of art.

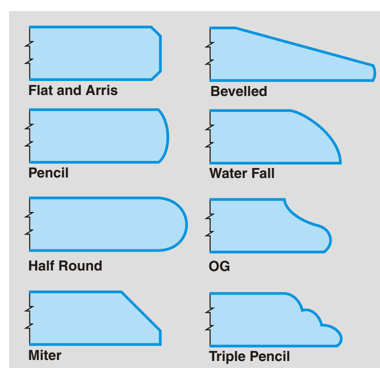
Stained Glass

Stained glass has been used since ages in churches, which was made by soldering small pieces of glass of different colors. The process being very slow and inefficient is now mostly replaced by making partitioning lines with a resin or epoxy to make it look as if small pieces of glass are joined together and then coloring different parts with different colors.

Edge Grinding & Polishing

Glass when cut to size has sharp edges and mostly flaked and uneven. A nominal grinding is necessary for tempering but there is a decorative element to the edge. Wherever the edge of the glass is visible after installation, the same has to be polished.

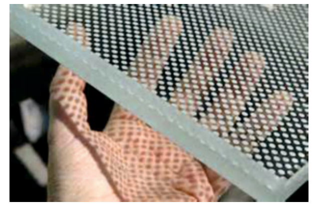
There are various profiles of the edges as are in normal mouldings. The most common edge types are listed here with a sectional drawing. The edge finish is categorized as; 'Rough Grinding', 'Neat Edge or Fine Grinding' & 'Polished or Crystal Polished Edges'.



Types of Edges

The process of grinding & polishing is similar to the one used for granite and similar stones. Excess material is removed using diamond wheels and final polishing or crystal polishing is done with Cerium Oxide. It can be done with manually operated or semi automatic or automatic line or CNC machines depending on the shapes and quantities.

Ceramic Printed Glass:



Ceramic printing on glass is done with special enamels which are applied to glass before it is tempered. During the heating process in tempering or bending, this enamel fuses into the glass and becomes a monolithic construction. It is thus, a permanent printing or coating and has all technical / mechanical characteristics of the unprinted glass. It is life long and does not deteriorate with weather, detergents, normal acids or alkalis. The enamels used are made of glass frit but the printed process is borrowed from printing on ceramics, like bathroom tiles and crockery used at home.

The common methods of applying the enamel are :

1. Roller Coating : is best for printing solid colors and for applying only one color.

2. Screen printing with ceramic frit: Is suitable for solid colors and normal patterns like dots, squares, checks or lines in single color with repetitive designs.

3. Direct on glass Ceramic Digital Printing: It is better suited when the printing design varies or changes from glass to glass and the final effect required is one large image achieved by tiling of various glasses to make one continuous image.

Certain areas of application make it important to mask a part or whole of glass for privacy or hiding the background or enhancing the look of a product or for purely aesthetical reasons. Silk screening was initially used in automobile windscreens and backlite borders to hide the silicone smudges. It was then used in domestic appliances. Lately it has been used in buildings, in curtainwalls, point fixed or bolted glazing systems, shower installations, glass doors and partitions. The size, density and colour would determine the opacity and shading, whereas the variety of dots, squares, checks and patterns will give many design combinations to achieve the desired effect. There are however limitations on color choices, designs and sizes, which may be confirmed before designing.

Ceramic printed or fritted glass is very safe and durable for architectural use for external and internal glazing but is essentially a tempered glass, which has to be ordered to specific size and shape. Since it is processed at very high temperature of about 700^{0}C, there is a limitation on colors and brightness and is not same as normal paints but is economic and technically sound option.

Enameling :

Enameled glass is a color coated glass which is made by coating an opaque layer of special paint on the surface of glass by roller coating process and then baking it to a temperature of about 300^{0} C.

The method is same as used for ceramic printing but the glass is not tempered after printing and can be cut to sizes as per needs. The colors are more vibrant and bright but are not as durable and cannot be tempered or laminated for safety and can not be used on exterior applications.

OTHER SPECIALITY GLASSES

Security Glass And Bullet Resistant :

Safety against Burglary, Theft and Vandalism : In the prevention of burglary or vandalism, one of the key factors is time. The more time it takes for the thief or vandal to overcome the obstacle, the more dissuasive and efficient it is. Basic laminated glass as a glass-PVB-glass sandwich is safe for minor intrusions but it can be further reinforced with additional layers of PVB and using multiple layered sandwich of 'GLASS + PVB + GLASS + PVB + GLASS' etc. to make for increased resistance to attack. Laminated glass offers an almost endless number of possible combinations depending on the number of glass elements and inter-layers, their thickness and their colours.

Security laminated glass against burglary is mainly used in large windows without grills and in shops for jewelry, cameras, electronic instruments etc.

Axe Test on Laminated Glass

Bullet Resistant Glass:

The increasing occurrence of armed attacks has led many companies to develop laminated glass specially formulated and tested to protect people against fire-arms. In addition to its anti-burglary function, it is designed to stop projectiles and limit or avoid splintering on the opposite side of the impact, while maintaining complete visibility and light transmission. According to the type of weapon and ammunition, and the degree of protection required, these laminated glasses vary in thickness and composition.

Thickness and Combination of the Bullet Resistant Glass will depend on factors like, resistance required against type of weapon, striking velocity, type of ammunition, mass of ammunition and range of fire etc. The different level of protection, the Bullet Resistant Glasses are manufactured for following ratings.

Rating	Ammunition	Minimum	Velocity
		Fps.	(M/S)
Level 1	9mm. Full metal copper jacket with load core	1,175	(358)
Level 2	357 Magnum Jacketed load soft point	1,250	(381)
Level 3	.44 Magnum lead semi wad cutter gas checkout	1.350	(411)
Level 4	.30 Caliber Rifle lead core soft point	2,540	(774)
Level 5	7.02mm. rifle lead core full metal jacket, military bal	2,750	(838)
Level 6	9mm. Full metal copper jacket with lead core	1,400	(427)
Level 7	5.56mm. Rifle full metal copper jacket with lead core	3,080	(939)
Level 8	7.62mm. Rifle lead core full metal copper jacket, military ball	2,750	(838)

Bullet resistant glass is generally used for cashier counter in banks, post offices, embassies, ministries, police stations, nuclear centers, military installations, high security vehicles and cash carrying vans etc.

Fire Rated Glasses :

Glass used in fire escape passages and fire doors have to fire rated. The requirement for the suitable type depends on the area of the glazing and estimated time for safe evacuation of occupants of the building in case of fire. The Fire resistance of a glass contruction element is measured against a number of criteria.

Stability & Intergrity in flames hot gases and smoke (E): The glass does not break & stays in sash for designed minimum time and prevents flames, smoke and hot gases (but not heat) from passing through. The fire remains contained.

Limiting radiation (W): The glass restricts the amount of heat passing through it to the side which is to be protected (radiation may not exceed 15kW/m^2).

Thermal insulation (I): The average temperature of the glass on the protected side remains below 140°C which eliminates the risk of self-combustion either due to radiation or convection of exposed materials and means that buildings can be evacuated safely & camly.

These are thus 3 types of fire resistants glasses namely 'E', 'EW' & 'E1' for a rating of 30, 60, 90 or 120 minutes.

Chemically Tempered Glass :

Glass can also be tempered by a chemical process but it is much more expensive and time consuming in production, as compared to the normal thermally tempered glass. It is therefore, not used in normal architectural applications.

It is generally used were thermal tempering is not possible like in thin glasses (below 3mm thickness) or for small glasses (like for watches) and certain applications were the optical quality requirements are very high.

Chemical tempering can be used on previously curved glass, and also on the glass that is less than 3 mm thick. The shape of the glass sheet will not be modified during tempering, so perfect geometry can be achieved.

Other Speciality Glasses:

There are other speciallity glasses like anti-reflective, self cleaning, photochromic, electrochromic, low refraction, low expansion glasses and many other types, which are used occasionally and rarely in achitecturial applications and are not covered in this book.

SECTION-2, APPLICATIONS

This section deals with the most important aspects of use of glass in buildings with specific emphasis and consideration for ***Human safety, Energy & Acoustics***

Section Contents :

USE OF GLASS IN BUILDINGS

Human Safety

Glass is an essential component of a building and is used as a medium to separate the exteriors and interiors of a building while allowing vision and light. It's use has been increasing in sizes, quantities and application areas due to its inherent properties and superior aesthetics.

Ordinary annealed glass is fragile and brittle and breaks into large splinters and shards with sharp edges and potential of causing grievous or even fatal injuries.

Human safety is one of the most important concerns while designing with glass. Safer and suitable glasses like tempered and laminated are now used.

General Safety Consideration :
Many human impact injuries are due to failure to take reasonable safety precautions. As stated earlier, glass may break under impact and cause injury. Most people are aware of this and treat such materials with due care. However a person's ability to perceive this potential risk and to cope with it can vary. Safety standards are therefore based on a number of factors including the assumption of a reasonable level of awareness and behaviour and also suitable product design and choice of materials.

Critical Locations
Accident statistics show that glazing in some locations in buildings is more vulnerable to human impact than in others.

These critical locations are :
(a) In-and-around doors (particularly side panels may be mistaken for doors.
(b) At low levels in walls and partitions.
(c) Overhead or sloped glazing
(d) Railings and walkways
(e)Any location with reasonable possibility of human impact

Some common cases of critical locations are illustrated as :

Case 1 : Glass used as Vertical walls sill height of more than 750mm or with Residual Protection. These locations are not likely to be subjected to human impact.
Residual protection is the safeguard provided to avoid the impact of human being to glass. It is provided on the side of glass where there are chances of Human impact. It can be achieved by providing protection in form of a sill structure or transom, chair rail or a grill inside.

Type of Glass to be used : Any glass (Safety Glass not mandatory)

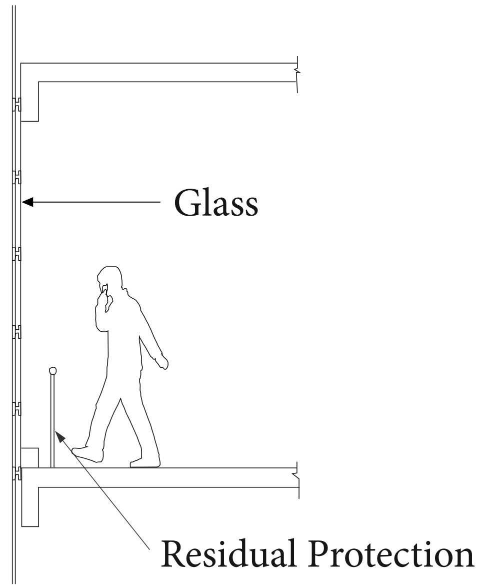


Fig. 1

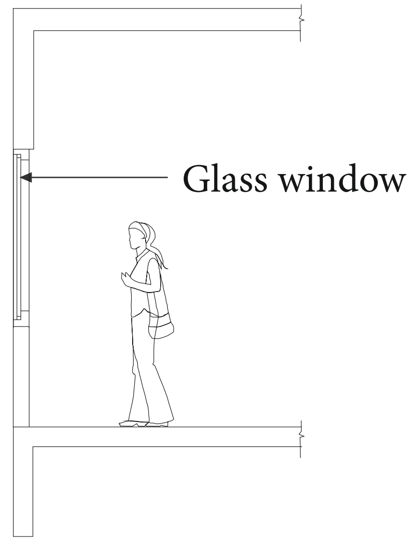


Fig. 2

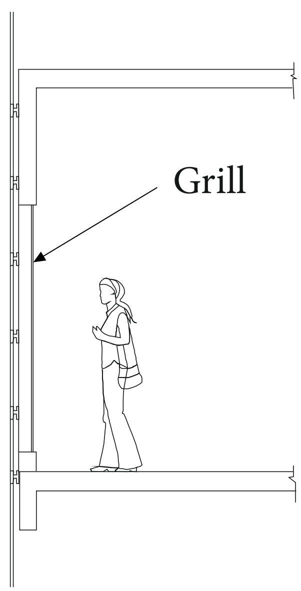


Fig. 3

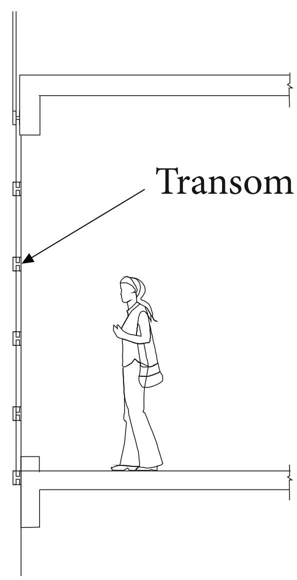


Fig. 4

Case 2 : Glass used as Vertical walls (Human Impact but no risk of fall) Hs< 0.75m & Hf ≤ 1.5m .
Type of Glass to be used : Safety glass (TF or LF)
(Hs means Sill height with reference to finished floor and Hf means height of fall of human or glass in case of change of level)

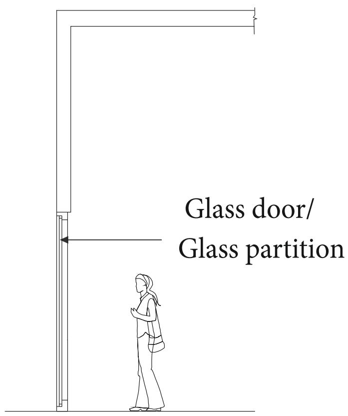


Fig. 5

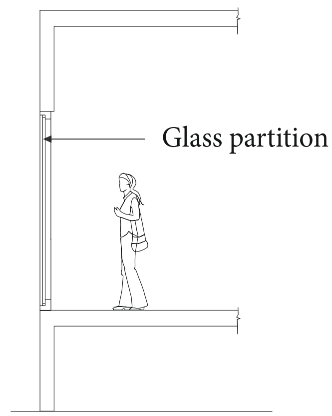


Fig. 6

Examples :

- Doors
- Side Panels
- Curtain Walls
- Glazed Area
- Doors in Bathroom,
    - a) Fully Framed
    - b) Partially Framed
    - c) Frameless
- Facade
- Windows
- Internal Partitions and Doors
- External Facade and Doors on ground floor, above floors with terraces outside.

Case 3 : Glass used as Vertical walls (human impact and risk of fall both) Hs < 0.75m & Hf $\geq$ 1.5M
Type of Glass to be used : Safety glass (LF preferred)

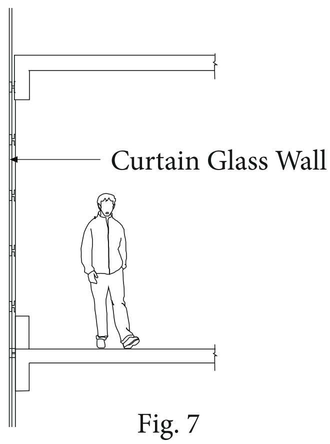


Fig. 7

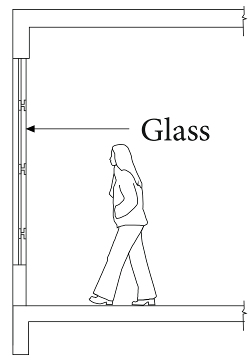


Fig. 8

Examples :

- Curtain Walls
- Facade
- Spandrels
- High Activity Area
- High Risk Area
- To avoid risk

Case 4 : Glass used in Horizontal or Sloped Glazing (risk of fall).
Type of Glass to be used : Laminated safety glass (LF)

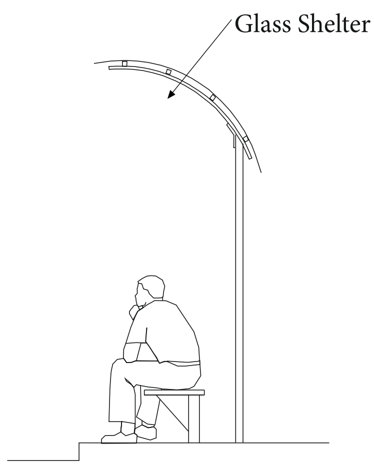


Fig. 9

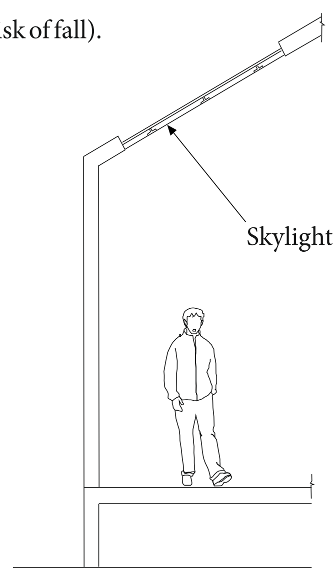


Fig. 10

Examples :

- Roof (Skylight Roof)
- Ceilings
- Bus Shelters
- Floors
- Stairs
- Sloped Facade

Case 5 : Glass acting as a balustrade, parapet or a railing (human impact and risk of fall both)
Type of Glass to be used : Laminated safety glass (LF)

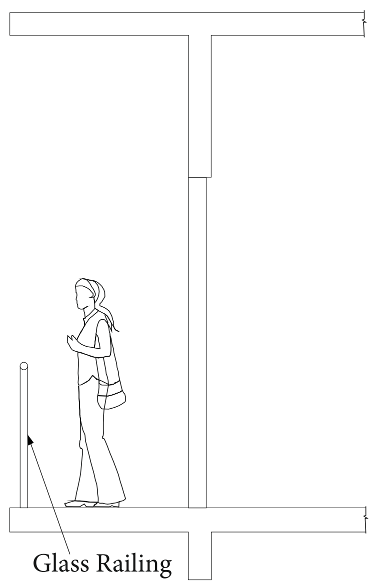


Fig. 11

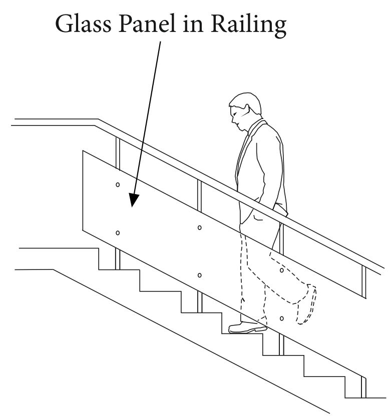


Fig. 12

Examples :

- Balustrades
- Parapet
- Railing

Precautions :

The designer, or specifier, should take precautions to reduce the risk of injuries from accidental human impact in these locations by :

(a) Selecting glass of a suitable type, thickness and size, primarily with reference to impact behavior and safety characteristics as established by testing in accordance with this guide.

(b) Providing mechanical protection to glass in critical locations, to prevent fall of glass under impact.

(c) Enhancing a person's awareness of the presence of glass by incorporating manifestation. (explained in para 'manifestation' below).

Glass in locations other than critical locations is not likely to be subject to human impact and consequently not likely to cause injury.

Design Consideration :

The principal design considerations to be taken into account by the designer, or specifier, when selecting glass should be :

(a) The properties of materials, in particular their breakage characteristics.

(b) Structural integrity of glazing systems supporting the glass.

(c) The type of the building and its use, in particular the number and likely behavior of the people expected to be in close proximity to the glass in critical locations.

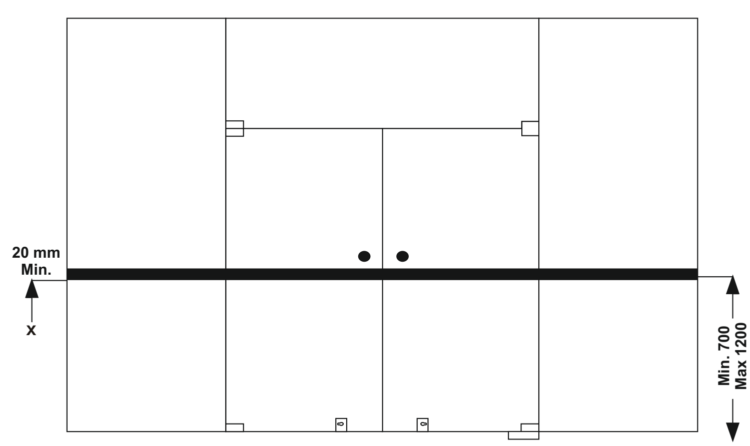
(d) Requirements for fire, security and wind loading.

(e) Thermal breakage, energy efficiency and deflection, vision, acoustics and other consideration.

(f) Impact of trolleys, carts, luggage etc. used have to be considered when required.

Manifestation :

Clear glass panels capable of being mistaken for an unimpeded path of travel should be marked to make them visible by incorporating manifestation. Manifestation employed shall be in form of opaque band of size not less than 20 mm in height and located at vertical distance from floor level to not less than 700 mm from upper edge of band and not more than 1200 mm to lower edge of the band. The manifestation shall preferably be permanent, e.g. etching of the glazing, but alternatively, if applied materials are used they shall be durable and not easily removed.



Notes :

Note 1: *The effective Toughened safety glass thickness and/or Laminated safety glass configuration shall be determined case by case with regard to :*

1. Other solicitation (wind load, snow load, dead load and human load)

2. The overall dimensions (length / width, or surface)

3. The aspect ratio of the glass length / width)

4. The glazing fixing type (framing, bolted system, structural system etc.) (AS : 1288-2006)

Note 2 : *Precautions against chances of injuries due to broken glass falling on people:*

(a) Broken annealed glass falling on people can cause grievous or even fatal injuries; hence it is recommended to use safety glass in locations other than defined in case1 where the risk of people getting hurt by falling glass is high.

(b) Toughened (tempered) glass has a safe breakage pattern, as it breaks and disintegrates into small and relatively harmless particles. However thick toughened glass particles may stay interlocked and fall as lumps of these multiple particles and can cause a minor or medium injury mainly due to the weight of the cluster.

(c) Laminated safety glass will generally not fall out of fixing. However, where laminated glass with both glasses toughened, used for horizontal or sloped glazing is used, in case of failure of both toughened glasses, it may crumple as a wet blanket and fall out of fixing. This factor needs to be considered while designing horizontal and sloped glazing.

(d) Any broken glass in any glazing should be removed immediately on breakage.

(e) Strength of the glazing system should be such that it has the ability to hold glass in place and prevent it from falling out as a whole. This is particularly important for security glasses.

Note 3 : *If Insulating Glass Unit (IGU) is used in situations mentioned in this guide then any one of the following will apply:*

(i) If IGU is installed in areas subjected to human impact on either side, then both the panes of the unit shall meet the requirements of this guide.

(ii) In situations where access is restricted to one side of the unit, then only the accessible side should meet the requirements of this guide.

Note 4 : *For inclusion of glass in furniture's the following standards the following standards may be referred :*

(a) BS 7499:1991 : Specification for inclusion of glass in the construction of furniture, other than tables or trolleys, including cabinets, shelving systems and wall hung or free standing mirrors.

(b) BS 7376:1990 : Specification for inclusion of glass in the construction of tables or trolleys.

(c) IS 7760:1985 : Specification for steel glass-front cabinet.

(d) BS EN 1727:1998 : Domestic furniture, storage furniture, safety requirements and test methods.

(e) BS EN 1153:1996 : Kitchen furniture, safety requirements and test methods for built-in and free standing kitchen cabinets and work tops.

Building design and Fire Safety :

Indian cities are changing rapidly due to the construction boom. A major part of the construction is happening in buildings where high amount of human traffic is expected to happen – like malls, commercial complexes, high rise buildings, IT parks etc. Due to the high quantum of human traffic these kinds of buildings have special needs for human safety and security. This is addressed by the utilization of modern building design methods as well as usage of new-age building materials. One of the key aspects of safety in building design that is gaining priority is protecting occupants against fire hazards.

In the event of a fire, the area engulfed by the fire is very hostile and its effects can be catastrophic to life and property. The occurrence and dispersal of fire is extremely unpredictable and uncertain. It is therefore critical that appropriate and tested products are chosen.

It is generally thought that fire safety regulations impose a uniform criterion on design. This is far from the truth. The unique qualities and performance range of modern fire rated glass systems encourages freedom and flexibility of design, while satisfying almost all necessary fire safety and protection requirements.

Passive protection Vs Active protection :

Most organizations spend huge amounts of money on active fire control systems like sprinklers, fire extinguishers, foamers etc. However statistics say that 40% of the active controls fail or are subject to a delayed start due to various reasons. It is at these times that passive fire protection systems provide for the much-required additional time for enabling quick action for saving life and property. Fire proof glass panels or complete glass screens are often required to allow vision and natural light through fire-rated internal walls and doors. Indeed, fire resistant glazing can provide an important safety benefit - other building occupants can be seen on the other side of the door, as can hazards such as smoke in the case of a fire.

The modern solutions for fire safety glass :

Internationally today, there are excellent alternatives available for clear vision safety glass. These include high performance products like transparent glasses with intumescent layers, special coatings and laminates. These products also have better performances. They have also opened up new avenues for architectural creativity, as they are transparent products, look aesthetically appealing and integrate well with the other glass products used in the interiors. These solutions are safe, impact resistant and provide clear vision fireproof glazing that has test evidences of satisfying functional and time requirements for fireproofing.

In fact today there are products that can actually substitute a brick wall in terms of fire rating property yet give transparency. While some of the fire safety glasses function as a physical barrier preventing spread of fire and smoke, certain advanced solutions can actually drastically cut off the radiant heat from a fire. Typically radiant heat from an electrical fire can reach as high as 40 KW in 30 to 60 minutes. Combustible objects like wood can auto ignite at around 10 KW of heat. 5 KW is the limit of bearable human pain. The modern fire safety glass solutions help to cut off the radiant heat apart from providing safety.

Choosing Fire resistant glazing :

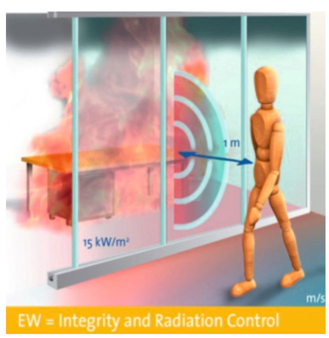
When we talk of fire, we have to factor in the radiant heat that a fire generates. Radiant heat is invisible, extremely intense electromagnetic waves that travel at the speed of light. On striking an object these waves are absorbed and their energy is converted into heat. Combustible objects like paper and wood auto ignite due to the heat when they reach their flash point.

While deciding on the ideal fire rated glazing product, it is important to decide what the design and safety needs are. We need to decide whether glazing requirement comes with only integrity or insulation or radiation control. Simultaneously we need to decide as to for what duration we need the fire resistance and whether the fire protection capability needs are from one side of the glazing (as in case of fire escape passages), or from both sides (as in case of internal partition between two sections in an office).

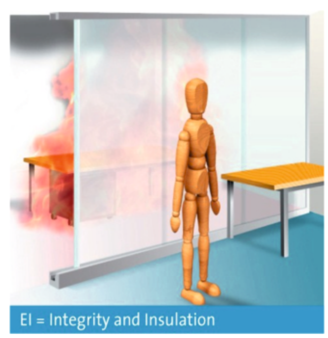
In terms of functional requirement, we have three broad ranges of international classifications each of these can be as per specific time requirements also.

E = Integrity :Glass that stops the spread of fire and smoke from the fire side to the non fire side
EW = Integrity and Radiation Control : Glass that stops the spread of fire and smoke from the fire side to the non fire side and also gives partial heat reduction – upto < 15 KW at 1 mtr distance
EI = Integrity and Insulation :Glass that stops the spread of fire and smoke from the fire side to the non fire side and also gives very high heat insulation.

Glass that stops the spread of fire and smoke from the fire side to the non fire side



Glass that stops the spread of fire and smoke from the fire side to the non fire side and also gives partial heat reduction – upto < 15 KW at 1 mtr distance



Glass that stops the spread of fire and smoke from the fire side to the non fire side and also gives very high heat insulation.

In case of external laminated glass facades, openable portions have to be left at regular distances for fire fighting and smoke exhaust.

GLASS FOR GREEN BUILDINGS AND ENERGY CONSERVATION

Buildings impact the environment in more ways than one: they deplete resources, and contribute to global warming, but they cannot be done away with since these are the places where people spend most of their time. According to experts, buildings worldwide contribute to 17% of fresh water withdrawals, 25% of wood harvest, 33% of carbon dioxide emission and 40% of material and energy use.

Green building concepts being codified by experts focus on thermal comfort at optimum energy conversation. These practices aim to bring down wastage at all levels while promoting the use of materials that do not cause harm to the surroundings. These codes lay emphasis on efficient usage of energy. This includes taking care of factors such as maximum use of day light, taking steps to bring heat gain to a minimum and incorporating the use of spectrally neutral glass materials to reduce heat gain and minimize the need for artificial lighting. A green building is similar to a conventional building in terms of external looks and functionality. However, a green building offers many tangible benefits to both the occupants and the environment, which a conventional building may not.

Some of the tangible benefits by a green building include :

1. Energy savings of 20-25%
2. Water savings of 20-40%
3. Cuts CO_2 emissions by almost 20-50%
4. Offers better thermal comfort

In additional, a green building also offers intangible benefits such as :

1. Projecting a green corporate image
2. Improving productivity level of occupants
3. Enabling optimal and minimal use of resources and non-conventional energy
4. Improving health and safety of occupants

But what exactly is a green building? A green building is the outcome of a design that focuses on increasing the efficiency of resources such as energy, water and materials.

In short, a green building can be defined as any building that is sited, designed, constructed, operated and maintained for the health and well-being of the occupants, while minimizing impact on the environment.

Why Opt for Green Buildings :

The general perception is that a green building involves higher construction costs compared to a conventional building. That said, the incremental cost of constructing a green building is recovered in 3-5 years.

People should opt for green building considering the following facts:

1. Green buildings reduce building impacts on human health and the environment during the building's lifecycle, through design, construction, operation, and maintenance.
2. Green design measure reduces operating costs, enhance building marketability, increase worker productivity and reduce potential liability resulting from indoor air quality problems.
3. Green building promotes conservation of material resources and water. Green buildings also enhance energy efficiency and promote the use of non-conventional or renewable energy like solar,wind, geothermal energy etc.

Global Rating Systems :

Globally, there exist different types of rating systems which provides a suite of set standards for the construction of green buildings. These standards, which ideally complement the geographic location of the green building, lay down the criteria for their construction, operation and maintenance.

These systems are:

1. United Kingdom – BREEAM
2. USA – LEED, Green Globes
3. Australia – Green Star
4. India – LEED India and Teri Griha
5. Canada – LEED Canada
6. Singapore – Green Marks

Green Codes in India :

The Indian Green Building Council (IGBC) coordinates the establishment and evolution of a national consensus effort to provide the industry with tools necessary to design green buildings.

Council members are working together to develop industry standards, design and construction practices and guidelines, operating practices and guidelines, policy positions and educational tools that support the adoption of sustainable design and building practices.

The introduction of LEED (Leadership in Energy and Environment Design) India and ECBC (Energy Conservation Building Code) are the two major milestones in constructing a green and energy efficient India through the building sector. Both of these systems demand upcoming building to be energy efficient. ECBC is voluntary at this stage but is likely to be made mandatory for commercial building at some time in the near future.

Development Criteria for Green Buildings :

The broad criteria for the development of energy efficient green buildings are :

1. Sustainable site operation and construction
2. Optimum and efficient water utilization
3. Energy consumption and reduction in atmosphere depletion
4. Optimum and efficient material and resource consumption
5. Indoor environmental quality

Role of Glass in Green Building :

Glass is a transparent, indispensable construction material, which plays a significant role in a achieving superior indoor environmental quality and energy efficiency. It also helps in better indoor air quality as it dose not absorbe or realease Volatile Organic Compounds (VOC). It offers several “green” benefits such as:

1. Energy efficiency
2. Thermal comfort and ventilation
3. Recyclable material
4. Day-lighting
5. Interior-exterior blending
6. Noise control

Light and Heat Management

Light without Heat :

Most modern architectural structures use glass facades. Sunlight entering a building such as office, hospital, malls, brings light as well as heat energy. Though light is beneficial and is necessary, the heat energy inside the building has to be managed especially during summer to make the working space comfortable. Hence energy efficiency of the facade or building becomes desirable.

Solar Control Glass :

Solar control glasses are meant to reduce heat from solar radiation. Due to this there is reduction of energy consumed by air conditioning. Also with improved day lighting through glass one save energy on artificial lighting. Reduction in energy saves money and also limits the carbon dioxide emissions.

Solar Spectrum :

The sun radiates solar energy by electromagnetic waves over a range of wavelengths known as the solar spectrum i.e. 290-2500 nano meters (**1 nm = 10^{-9} meters**)

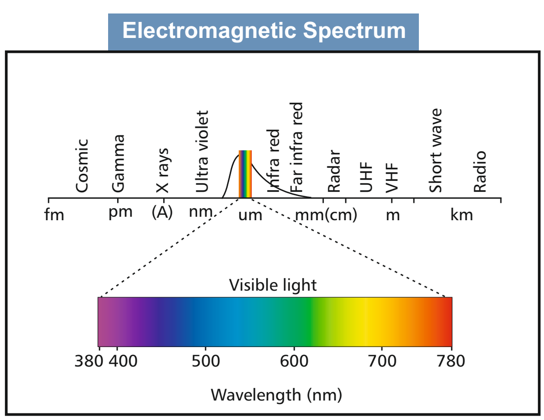
The solar spectrum is divided in to three bands i.e.

Ultra-violet (UV)	-	290 nm - 380 nm
Visible light	-	380 nm - 790 nm
Infra Red	-	790 nm - 2500 nm

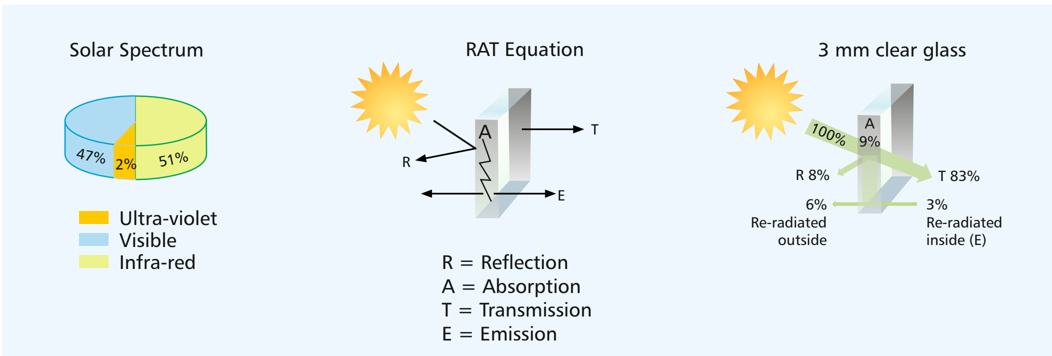
The energy distribution within the solar spectrum is

UV	=	2%
Visible Light	=	47%
Infra red	=	51%

Only visible light is seen by human eye. Shorter is the wavelength, the higher is the energy associated with the radiation. Hence high energy UV light causes sunburn, fabric to fade and plastic to deteriorate, Longer wavelengths are less damaging.

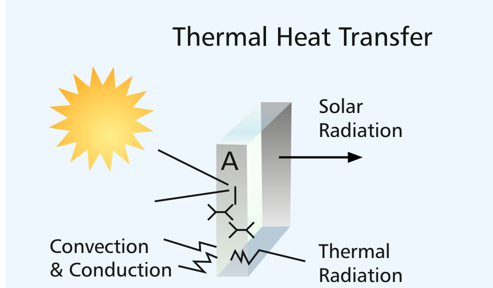


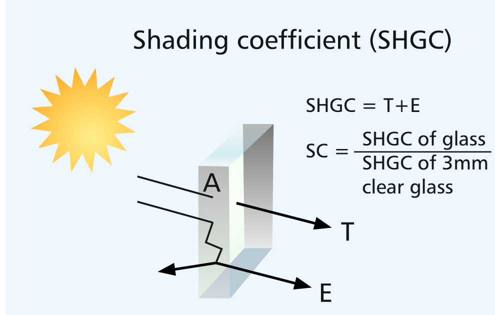
RAT Equation :
When solar energy strikes glass it is Reflected (R) Absorbed (A) and Transmitted (T) in different proportion depending on the type of glass involved. For example 3mm clear float glass reflects 8% of solar energy, absorbs 9% and transmits 83% as per following diagram:-



Thermal Heat Transfer :

Heat is transfered by:-
(i) Conduction - (heat passes through one object to another)
(ii) Convection - (heat passes by upward by warm air current)
(iii) Radiation - (heat passes through space to object)
Conduction : When there is a difference in temperature between two bodies that are in contact with each other, heat migrates from the warmer body to the cooler one. This method of heat transfer through a material is called conduction. The quality of heat which migrates over a given period of time depends on the conductivity of the body and temperature difference between the bodies. Bad conductors of heat are called insulators. Glass is a very good insulator. It has a low thermal conductivity when compared to metals like iron and aluminium.
Convection : Whenever liquids or gases are heated, they expand and circulate, and as a result heat is transferred from one place to another.





This method of heat transfer through the movement of a gas or liquid medium is called convection. Convection above a hot surface such as heated glass occurs because hot air expands, becomes less dense, and rises.

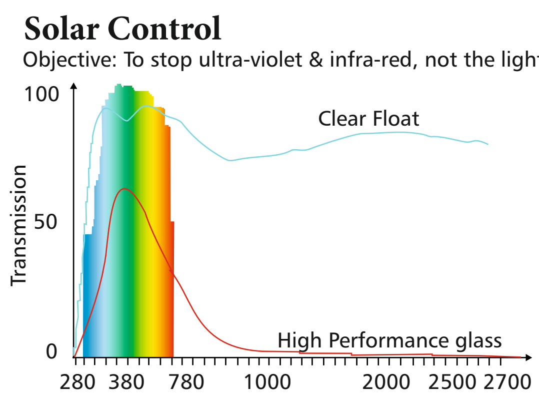
Radiation : Hot bodies emit infrared waves and electromagnetic radiation. These waves in turn warm up the objects that absorb them. This method of heat transfer is known as thermal radiation or just radiation.

Radiation is emitted by the sun in the form of short wave radiation, and by bodies heated by sun and other heating equipments, in the form of long wave radiation.

Useful Terms :

Visible Light Transmittance :
This is percentage of visible light (380-780nm's) that is transmitted through a glass.

Visible Light Reflection :
The percentage of visible light that is reflected from the glass surface.



Solar Energy Transmittance :
The percentage of solar energy that is directly transmitted through glass type.

Solar Energy Reflectance :
The percentage of solar energy that is reflected from the glass.

Relative Heat Gain :
This is commonly used by ASHRAE codes and is used for classifying window Glass. It is the total heat gain of a window relative to a window using 3mm glass.
RHG is the sum of the product of U-value and temperature difference and product of solar factor (SF) and amount of incident solar energy.

Relative Heat Gain = (U x Temperature Difference) + (SF x Amount of Incident Solar Energy)

Solar Factor or SF also known as Solar Heat Gain Co-Efficient (SHGC) :

The direct solar heat gain in a building is the sum of energy directly transmitted (i.e. short wave) and the direct solar energy aborted and re-emitted inside (i.e. long wave) by it's envelop. Solar Factor is the ratio between the total solar heat gain and incidental solar energy. The solar factor range is between 0 and 1 of the total solar heat transfer. Lower the solar factor value of a glass, the more efficient is the glazing at blocking the entry of solar energy. A solar control glass with SF of 0.4 mean that 60% of the solar radiation is blocked inside and only 40% passes inside. Similarly north facing facades non solar heat is more important. Hence orientation of building determines the glazing requirements of the building.

Shading Coefficient :

Shading Coefficient is a term generally used in Air conditioning industry.

$$\text{The shading Coefficient} = \frac{\text{Solar Factor}}{\text{Solar Factor of 3 mm glass}}$$

Solar Factor of 3 mm clear glass is 0.87

Lower the shading coefficient, lower is the amount of solar heat transmitted.

U – Value : Heat transmitted through a surface by conduction, convection and Radiation is expressed by its U – Value. U-Value is the amount of heat transferred that is lost or gained due to temperature differential of 1 degree centigrade through 1 square meter. Lower the U-Value, better is the insulation property of glass.

Factors Affecting Solar Heat Gain :

1. Orientation of the Building
2. Choice of Glass
3. Colour of Glass
4. Internal or External Glazing

Orientation of the Building :

Sun facing facades take about 80% of the total solar heat transfer. Similarly north facing facades non solar heat is more important. Hence orientation of building determines the glazing requirements of the building.

Choice of Glass :

Solar Control is the percentage of solar energy coming through a pane of glass. This can be improved by:

- Thicker Glass
- Body Tinted Glass
- Coated Glass (online or offline)
- Insulated Glass
- Combination of these Glasses

Colour of Glass :

Solar Factor of Clear Glass is 88%, whereas it is 56% in green glass. This solar factor is available from manufacture of glass as per performance chart.

Internal and External Glazing :

Using proper glazing can reduce the overall cost of energy upto around 30-35 %.

Selection Criteria :

The two main criteria for selecting solar control glasses are aesthetics and performance.

Aesthetics :

In addition to performance, glass should give a pleasing and aesthetic appeal when looking at and when looking through. Transparency, colour of the basic glass substrate, colour of the solar performance coating on glass and the light reflecting properties of the coating will combine to give an aesthetically pleasing 'look through' and 'look at'

Performance :

The glass should control the heat transmitted, control glare & heat losses.

Control of U-Value :

To achieve a lower U-Value, we have to reduce conduction, convection and IR radiation. U-value of some glasses and combinations as examples are given as under:

6mm Clear	5.7
12 mm clear	5.5
DGU 6 clear + 12 Air gap + 6 clear	2.9
DGU 6 clear + 15 Argon gas gap + 6 clear	2.7
6mm low-e	2.8
DGU 6 low-e + 15 Argon gas gap + 6 clear	1.1 to 1.4

Factor not affecting U-value :

1. Colour of the glass
2. Tempering or Lamination
3. Typical reflecting coating

Total Heat Gain (solar & Non Solar) :

1. Total heat gain depends upon solar & non-solar heat
2. Each of these depends upon many factors, for example:

(a) Geographic location, and solar intensity
(b) Orientation of façade
(c) Area of glazing
(d) Type of glass (SF & U-value)
(e) Environmental factors
(f) Temperature differences between inside and outside

3. Detailed calculations can be made assuming some generalization and some averages.

Selection of Glass :

Key parameters that describe the performance of solar control glass include

1. Visible light transmission
2. Solar factor (SF)/ Solar Heat Gain Coefficient
3. U-value i.e. W/m2k
4. Selectively:- Visible light/ total energy

TL/SF for Indian condition the ideal selectively is around.

The contribution to heat gain inside building is :

U Value X Temperature difference	8%
Solar Factor X Amount of Solar Energy incidents	92%

Additional factors to be considered are

1. There is heat being generated from inside the building too.

2. External heat is outside heat coming into building by conduction, convection & direct radiation. Internal load is all light fixtures, equipment, activities and people generating heat.

3.Glass Coatings are generally intended to reflect heat but most often, they also reflect light. The reflection of light could be Internal reflection and External relfection.

A high External reflection will cause a lot of glare and give the building a metallic look.

A high Internal reflection is not preferred in a night use building as Call Centre. Since the occupants will see their own reflected image as in the mirror, during the night use.

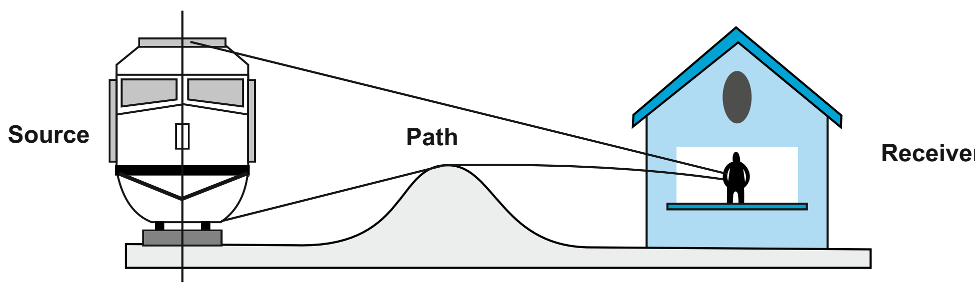
ACOUSTICS

Sound Control :

Noise or sound is an unavoidable by-product of the modern living and growing technology. Aircrafts, automobiles, trains, machines, generators, house hold appliances and even entertainment generates sound or noise that can distract attention, disturb sleep and create anxiety. It can be a hazardous to overall health and prolonged exposure to high level of sound can impair hearing permanently. While noise is unavoidable, its damaging affect can be mitigated by keeping its levels within reasonable or acceptable limits. Before trying to find solution to the problem, it is important to understand the basics of sound and how it travels.

There are 3 elements which must be present for the sound to exist

1. **Source**: When there is no source, there is obviously no sound.
2. **Receiver** : Namely the human ear. If there is no receiver, someone who hears the sound, there is sound but there is no sound problem.
3. **Path** : Through which the sound travels from the source to the Receiver. Without a path, the medium through which the sound passes to the receiver, there is no sound.

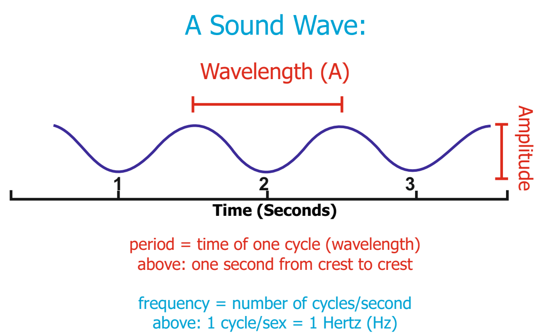


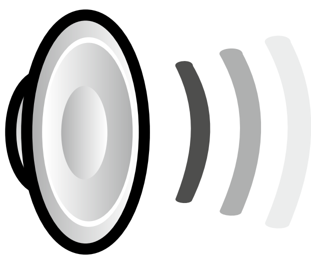
Source :

Various sources of sound, which may result into the unwanted noise, of different levels are most commonly identified in the chart given below:

SOUND	dB	LOUNDNESS
Space Shuttle	188	Dangerously loud
Jet Engine	150	Painfully loud
Low caliber Rifle	140	Painfully loud
Pneumatic drill	100	Very loud
Heavy traffic	90	Very loud
Loud Music	90	Very loud
Noisy factory/Loud street noise	90	Very loud
Vacuum Cleaner	80-90	Very loud
Average street noise/busy traffic	70	Moderate
Average TV at 1m	65	Moderate
Average office noise	60	Moderate

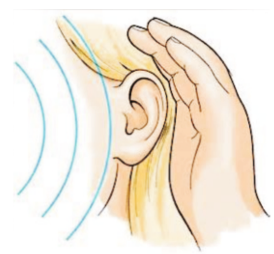
Sound is the result of rapid fluctuations of pressure, which reach a receiver. The frequency of sound is the number of times in a period of one second that the pressure changes from zero to maximum to minimum to zero, thus completing a cycle. Humans tend to be more sensitive to high and mid range frequencies such as sirens, whistles and traffic noise. Lower frequencies tend to be less irritating. These are just a few examples to give us an idea about the identity of the problem.





Amplitude

refers to the loudness of sound. The loudness of sound is often expressed in decibels (dB). Human hearing is impacted by the way it perceives sound levels. Higher and lower frequencies of the same magnitude can be perceived as less intense; therefore, to approximate the response of the human ear adjustments are made to account for human sensitivity to certain frequencies. These adjustments are identified as dBA's.

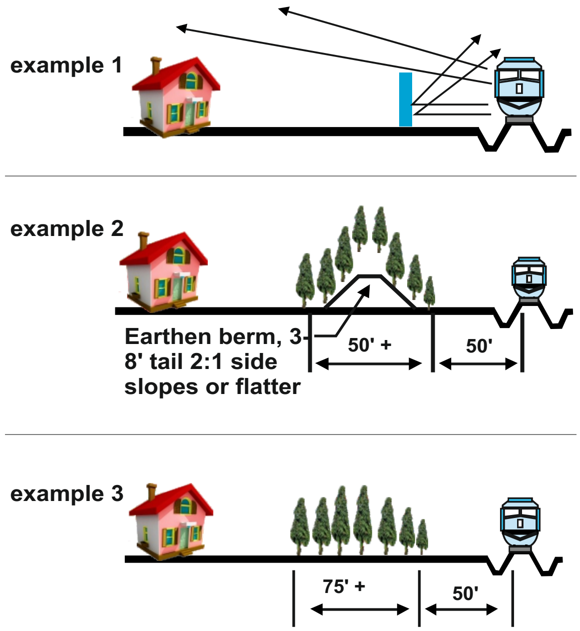


Receiver :

Human ear is the most common and important element. Different persons, communities and situation or location will have different perceptions of acceptable level of sound or noise.

It is however important to put some commonly observed acceptable values, to these levels at different locations. These are broadly identified as under :

ACTIVITY AREA	SATISFACTORY(db)	MAXIMUM (db)
Residential at night	30	40
Bedroom at night	25	30
Class room	35	45
Commercial offices	40	50
Restaurant	40	50
Theater	25	30



Path :

Sound waves can travel through solids, gases and liquid but not through vacuum. The intensity of sound is affected by the presence of materials in its path. Different materials will have different levels of resistance to the sound waves.

Although frequency and amplitude originate at the source, both are significantly altered by the physical variables in the path to the receivers. For example, walls, structures, ground absorption, atmospheric conditions such as temperature, humidity, wind and rain all contribute to changes in source noise levels before it reaches the receiver. A detailed study of the path is a critical step in understanding how to reduce noise levels at specific locations.

Noise Reduction:

It can be concluded from the previous pages that wherever the level of sound is higher than what is desirable, there is a need to reduce the effect of sound by insulation.

Sound insulation is the screening of a room against a noise source. Two types of sound insulation can be distinguished: as airborne sound insulation and impact sound insulation. Airborne sound insulation is the insulation against sound that propagates by air (e.g., insulation against traffic noise). Impact sound insulation is the insulation against sound that arises by direct contact of an object on the building element (e.g., the impact of rain on a glazing). Since facades mainly are liable to airborne sound, the discussions here will concentrate on airborne sound insulation only.

The best place to control noise is close to the source. Enclosing a noise source is an effective method and commonly used in commercial and industrial applications as a generator can be enclosed in a sound insulating chamber. But this option is impractical when addressing traffic noise issues. When the noise source has been minimized or isolated the next step is to interrupt the direct noise path by introducing a sound barrier.

The next objective is to remove reflected sound energy. The most practical method is to replace reflective surfaces with absorptive surfaces. Sound absorptive walls installed between the noise source and the receivers are effective in reducing reflective noise. The height, location and orientation of the sound will play a significant role in the wall 's effectiveness. Sound walls are most effective when built close to the source or close to the receiver. The height of the wall should interrupt line-of-sight between the source and the receiver.

If reflections can be subdued quickly, they can not develop into reverberations. Reverberations become new sources and add to the original noise source as resonance. Minimizing reflections means noise is localized to the extent whereby only direct sound, line-of sight sound will be heard.

When the direct sound diminishes in intensity as per the inverse law, the multitude of reflective sound intensities combine to produce an increase in the reflected sound levels to a point where the reflected sound can be higher than the direct sound. A typical example of this phenomenon would be a voluminous, hard surfaced gymnasium that can experience a significant build up of reflective sound intensity.

Where the direct sound and reflected sound are about equal is called the critical distance. In a typical classroom critical distance is about 12" from the source. Beyond the critical distance the sound reduction will be less than 6 dB.

Decibel Reduction :

People often ask how decibel (dB) reduction numbers relate to changes in sound levels to the human ear. Here you can listen to a recording of a skill saw at normal operating level conditions followed by six different noise level conditions, showing a 3dB, 6dB, 10dB and a 20dB noise reduction.

Reduction in Sound Levels (dB)	Change in Apparent Loudness to the Human Ear
3 dB	just barely perceptible
6 dB	clearly noticeable
10 dB	half as loud
20 dB	one fourth as loud

Decibel Addition and Subtraction :

Sound level decibels are logarithmic and so cannot be manipulated without being converted back to a linear scale. You must first antilog each number, add or subtract and then log them again in the following way:

$$L = 10 \, \text{Log}_{10} \left(\sum_{i=1}^{n} 10^{(Li / 10)} \right)$$

For example, adding three levels 94.0 + 96.0 + 98.0:

$$L = 10 \, \text{Log}_{10} \, (10^{9.4} + 10^{9.6} + 10^{9.8}) = 101.1 \text{ dB}$$

Measuring Sound Reduction :

There are several ways by which sound reduction is measured. **The Sound Transmission Class (STC)**, measured in dB, is the common measure by which acoustical performance is rated. It is the weighted average over the frequency range 100 to 5000 Hz of the **STL (Sound Transmission Loss)** and measures the decibel reduction by a partition. The higher the STC rating, the more able the material is to resist the transmission of sound. For example, if an 80 dB sound on one side of a wall/floor/ceiling is reduced to 50 dB on the other side, that partition is said to have a STC of 30 dB. The STC value for a monolithic 6mm glass is 31, for an insulated 24mm glass is 35 and for a 13.52mm laminated glass is 39.

STC ratings are used for windows doors, walls & most building materials. It is a logarithmic scale and ranges from 18 to 50 for windows. Below table list some examples of STC levels.

STC	What can be heard
25	Normal speech can be understood quite easily and distinctly through wall
30	Loud speech can be understood fairly well, normal speech heard but not
understood	
35	Loud speech audible but not intelligible
40	Onset of "privacy"
42	Loud speech audible as a murmur
45	Loud speech not audible; 90% of statistical population not annoyed
50	Very loud sounds such as musical instruments or a stereo can be faintly heard; 99% of
	population not annoyed.
60*	Superior soundproofing; most sounds inaudible

In addition to STC, another popular method of measuring sound reduction is the **weighted sound reduction index $R_{w.}$** The European Standard EN ISO 717-1 describes a method to express the airborne sound insulation by the single-number quantity. This index is a common method of rating sound insulation of buildings materials for two noise spectra's described below. It is applicable to walls, ceilings, floors, roofs, doors or windows. The index allows sound absorbent properties of materials to be calculated and is measured in a laboratory.

Optimum performance of a unit is achieved when it provides insulation at frequencies where noise is greatest. Performance of a window cannot be determined based on glass alone. Therefore, to ensure optimal acoustic insulation the correct type and composition of glazing should be selected. $R_w(C; C_{tr})$ index provides weighted correction for the human ear based on type of surrounding noise.

R_w $(C; C_{tr})$ in which,

R_w (Weighted sound reduction index in dB) is sound insulation of a building element over a range of frequencies,

C is the adaptation term when noise in question is outside background noise.

C_{tr} is the adaptation term when noise in question is road traffic (mostly low frequency noises)

According to the nature of the sound source to be insulated the right adaptation term can be chosen. Following are common examples of noise source for each type of adaptation term.

Type of Noise Source	Adaptation
Term Living activities (talking, music, radio and tv) Children playing railway traffic at medium and high speed highway road traffic > 80 km/h jet aircraft, short distance	C
factories emitting mainly medium and high frequency noise urban road traffic railway traffic at low speeds aircraft propeller driven jet aircraft, large distance disco music factories emitting mainly low and medium frequency noise.	C_{tr}

Both C and C_{tr} are generally negative and deducted from R_w to calculate noise reduction property of the material. For example, $R_w(C; C_{tr})$ = 40 (-2 ; -6) means that sound insulation for a window is 40 dB and is reduced by 6dB for traffic noise i.e. 40 - 6 = 34dB. Similarly, sound insulation against radio or TV noise is reduced by 2dB i.e. 40 - 2 = 38dB. This methodology allows designers to select optimum window specification based on the required application

Glass Performance In Acoustic Insulation :

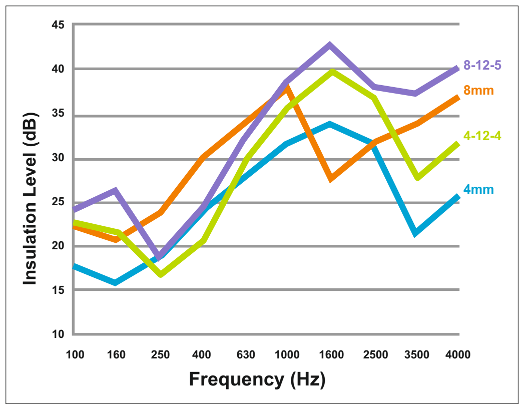
Unwanted sound is considered noise when it intrudes on our daily lives. To minimize this intrusion, all aspects of the building construction need to be evaluated. However in this instance we will only analyze the acoustic qualities of glass. The first step in this analysis is to determine the source 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 Thicker Glasses :

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 R_w 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 Thicknesses :

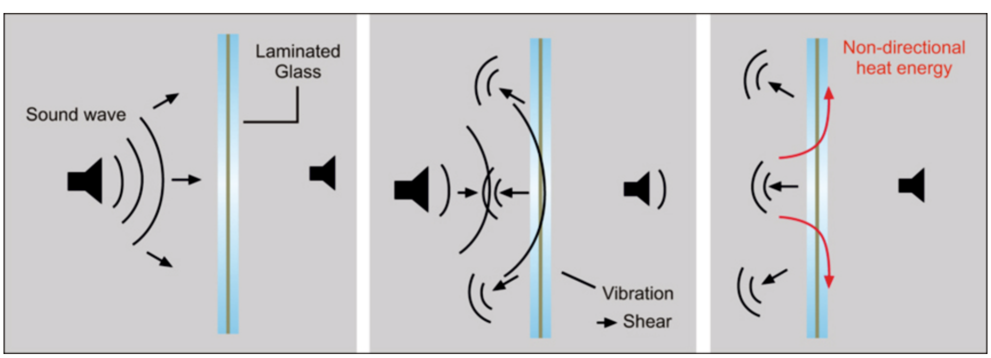
To enhance the level of sound insulation provided by double-glazing, glasses with sufficiently different thicknesses should be used so that they can hide each others' weaknesses when the overall unit reaches its critical frequency. This therefore produces a coincidence in a broader frequency zone but 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 trough at low frequencies.



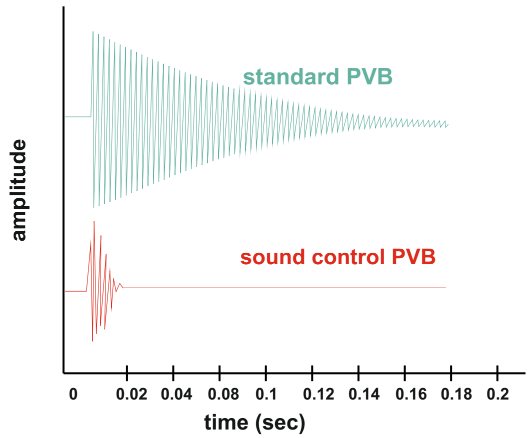
Use Laminated Glasses (preferably with Acoustic Interlayer) :

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 noticable. During this phenomena 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.



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 comparitive decay in vibration observed in laminated glass with Standard PVB and Accoustic PVB.



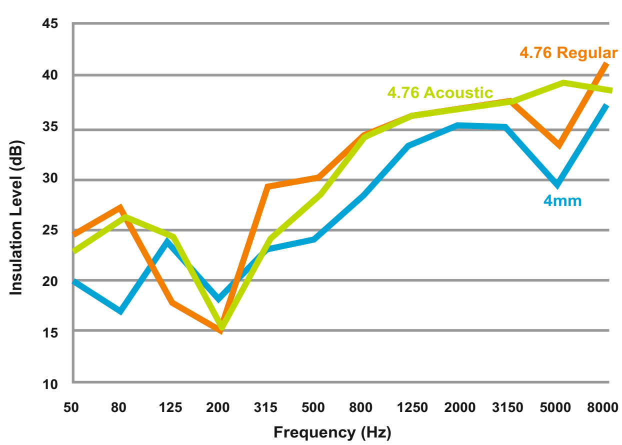
Decay of free vibration observed on laminated glass

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.

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 R_w performance of some common glass types. Double glazed unit with certain gases also provide sound insulation characteristics.



	Over all thickness	Inside	Construction Space	Outside	STC Value	R_W
Monolithic	6 mm	6 mm	—	—	31	32
Glass	12 mm	12 mm	—	—	36	37
Insulated	14 mm	3 mm	8 mm Air	3 mm	28	30
Glass	24 mm	6 mm	12 mm Air	6 mm	35	35
	35 mm	6 mm	25 mm Air	6 mm	37	37
Laminated	6.76 mm	3 mm	0.76 mm PVB	3 mm	35	35
Glass	9.76 mm	6 mm	0.76 mm PVB	3 mm	36	36
	10.52 mm	6 mm	1.52 mm PVB	3 mm	37	37
	12.76 mm	6 mm	0.76 mm PVB	6 mm	38	38
	13.52 mm	6 mm	1.52 mm PVB	6 mm	39	39
	16.76 mm	10 mm	0.76 mm PVB	6 mm	40	40
	19.52 mm	12 mm	1.52 mm PVB	6 mm	41	41
Laminated	24.76 mm	6.76 mm	12 mm Air	6 mm	39	39
Insulating	23.76 mm	6.76 mm	12 mm Air	5 mm	39	39
Glass	28.76 mm	10.76 mm	12 mm Air	6 mm	40	40
	36.76 mm	6.76 mm	25 mm Air	5 mm	42	42
	25.52 mm	6.76 mm	12 mm Air	6.76 mm	43	43

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 R_W of 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 R_W lies between 35 and 40 dB, it is advised to reinforce each frame element. Windows with R_W larger than 40 dB are specific for the window concept itself which makes special advice necessary.

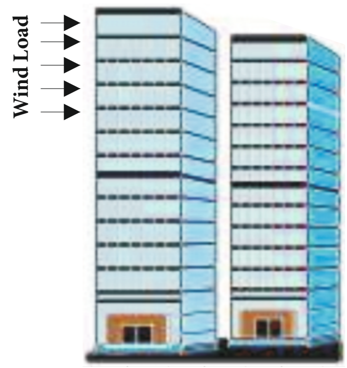
Factors not Affecting Insulation :

The following factors have no effect on the sound insulation properties of glass assemblies:

- Tint/color of glass
- Coatings (reflective/low-e) on glass
- Position of glass
- Tempering
- Annealed glass of a particular company

OTHER CONSIDERATIONS

Strength



Normally the Glass is designed or selected based on the wind loads. This is true for a normal glass in a window. In most other applications as shown in the examples of various applications in the following pages, it has to be strong enough to withstand various loads like building loads, maintenance loads, self load, loads due to building movements etc.

To understand the load behavior where glass is used as a structural member, a finite element analysis (FEA) is highly desirable. However, for common and normal applications, broad parameters have to be respected. The glazing system will indicate the loading it will induce on the glass.

Glass is weakest at the edges of the glass itself or the edges of the holes or cutouts, if any. Most glass failures will start from the edge and it is very difficult to initiate a crack from the middle of the glass. A raw cut glass will have micro fissures, which fail most easily under a nominal load. Once a crack starts from the edge, it propagates very fast and is almost impossible to stop the crack from developing through the entire surface. These fissures can be dealt with by simply grinding off the edges. A simple arising of the edge will grind off the fissures but a well-grounded smooth finish will further enhance the capability of the edge to withstand and disperse the stresses better.

Tempered glass is the strongest type of glass and in most cases; its design is limited by the allowable deflection rather than the strength. Simple load calculation for tempered glass of a particular size may be calculated as safe with a smaller thickness but it may need to use a higher thickness for need to control the deflection. (see under deflection)

Following Tables from AS: 1288-2006 will indicate a thumb rule guideline for selection of the glass thickness for particular size & application.

Maximum Permissible height & area of Annealed Glass corresponding to thickness in case of glass panes supported on all four sides

Normal Thickness (mm)	Maximum Allowable height of glass (m)	Maximum allowable glass area (sqm)
6 mm	< 1.2	0.9
8 mm	> 1.2 to < 1.6	1.8
10 mm	> 1.6 to < 2	2.7

Maximum Permissible area of Annealed Glass corresponding to thickness in case of glass panes supported on all four sides.

Type of Glass	Nominal Thickness (mm)	Maximum allowable area (sqm)
Annealed Glass	4	0.8
	5	1.2
	6	2.1
	8	3.2
	10	4.4
	12	6.3

Maximum Permissible area of Safety Glass corresponding to thickness

Type of Glass	Nominal Thickness (mm)	Maximum allowable area (sqm)
Tempered Safety Glass	4	2
	5	3
	6	4
	8	6
	10	8
	12	10
Laminated Safety Glass	6	2
	8	3
	10	5
	12	7

In case of laminated Glass the thickness of PVB is not accounted

Maximum Permissible area corresponding to thickness in case of frameless glass panel

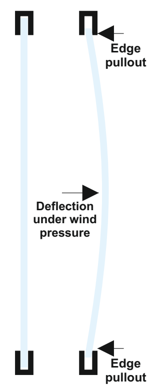
Type of Glass	Nominal Thickness (mm)	Maximum allowable area (sqm)
Safety Glass	6	3.0
	8	4.5
	10	6.0
	12	7.5

In all above cases and in cases wherein the glass area exceeds 7.5 sqm, it is recommended to check and determine thickness of the glass using finite element analysis under wind load as per IS:875 (Part 3) : 1987 (Reaffirmed 1997) for external glazing.

Point Supported Glass :

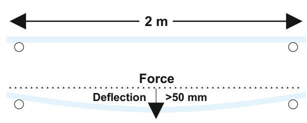
For point fixed system the glass area and glass thickness shall be determine by the specific strength analysis and type of point fixing hardware.

Deflection :



Glass is a generally perceived to be a hard, rigid brittle material which does not bend and it breaks easily while bending. While this is partially true for annealed glass, tempered glass can take a lot of bending or deflection, before it reaches the breaking point. A 6mm thick tempered glass of size 500 x 2000mm will bend more than 50mm before breakage. A 4mm fully tempered glass of same size will bend over 80mm before breaking.

This happens due to very high compression of surfaces, which make the glass very strong, and the tensile forces of bending must overcome these compressive forces. While designing with tempered glass, care must be taken to calculate the bending due to wind loads. While the glass may be safe, in extreme wind conditions, the inhabitants of the building will get scared to see a glass bending too much. The glazing system will also have a limited ability to accommodate the bend and the edge pullout has to be limited. So while a thinned glass may be safe from design point of strength, we may be required to choose a higher thickness to contain the deflection.

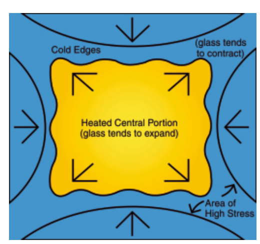


Earthquakes and Natural Disasters :

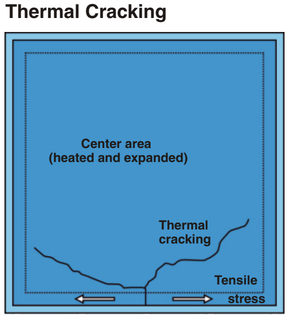
Normal annealed glass is extremely dangerous in these situations and only safety glass products (Tempered or Laminated) should be used. These products have been tested safe in automobiles against accidents. Certain buildings like hospitals, fire services, police stations etc. have much greater need to remain serviceable in such situations and should use laminated tempered glass only.

Thermal Breakage Resistance:

Thermal stress is normally generated by exposure of the central portion of glass to the heat of the sun, while the edges are in a frame and remain cooler, or when a part of glass is in shade and a part in sun. Most typically, all spandrel glasses stand potential risk to thermal breakages. Thermal breakages depend on the heat absorption properties of the glass, heat transfer properties of the cavities of insulating units, location of the building, orientation and slope, presence of blinds or heavy curtains close to glass, frame type and design etc. A thermal breakage can be easily identified as the crack will always start exactly perpendicular to the edge of the glass from the first 12 – 20 mm before propagating in random direction as shown in the diagram.



Thermal Cracking



Edges of flat glass
(cooled and bound by sash frames)

Toughened glass and heat strengthened glass eliminate all possibilities of thermal breakages, while laminated and double glazed glass without tempering or heat strengthening increase the possibility of thermal breakages.

APPLICATION EXAMPLES

Traditionally glass was used in a very small area of a building as a source of natural light, vision and some times for decorations..

Modern glass has found many new applications and the list goes on becoming longer with new ideas and innovations.

A few commonly used examples are illustrated by pictures in further pages and are broadly listed below:

- **Windows with grills**
- **Windows without security grills**
- **Aluminium curtainwalls and structural glazings**
- **Façade on bolts or spiders**
- **Doors with patch fittings, fins etc**
- **Skylights in frame**
- **Skylight with bolted systems**
- **Sloped glazings**
- **Shower installations**
- **Wall cladding**
- **Table tops and Furniture's**
- **Museums, Viewing Galleries, Display Windows**
- **Balconies with top bottom framed**
- **Balcony with glass on bolts**
- **Staircase balustrades**
- **Staircase steps**
- **Walkways**
- **Canopies**
- **Shelters**

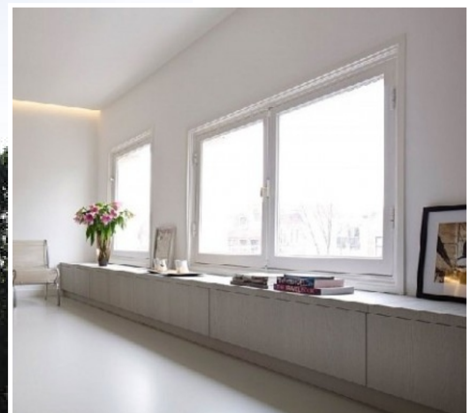
Windows with Grills

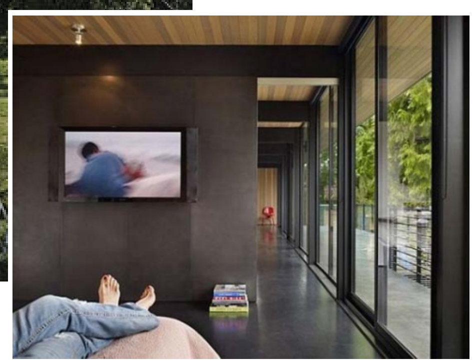
These are the most common type of traditional windows with metal grills for safety.

Any glass of suitable thickness can be used.
Recommended is tempered or laminated glass.

Windows without Security Grills

Large glasses without any grills for unobstructed and pleasant view.





Laminated glass of suitable thickness using 1.52 mm PVB.
One or both panes should be annealed or H.S; but both glasses tempered is not a good option.

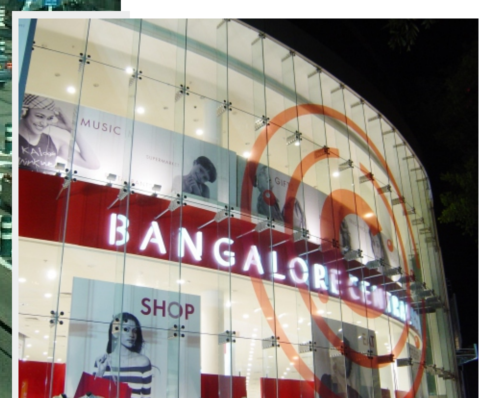
Aluminium curtainwalls and structural glazings

A neat facade of glass using aluminium frames where glass is generally glued to the aluminium section using structural silicon.

Large glass surface makes it necessary to use DGU with energy control coated glasses. One or both glasses on the DGU have to be tempered or Laminated as per the requirement of human safety norms *(see page 18)*

Facade on bolts or spiders

Complete face of clear glass connected by spiders & bolts of stainless steel. The lateral support system may be glass fins, rod rigging or wire rigging.



Mostly 12mm clear tempered glass on the face and 19mm glass for fins are used. Structural design is the key criterion for deciding on sizes and glass thicknesses. Tempered laminated 12+1.52+12 mm for face and fins is recommended.

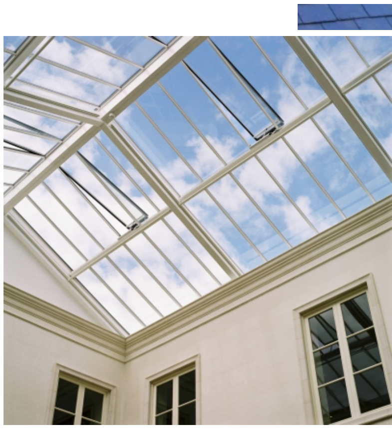
Doors with patch fittings, fins etc.

Frameless glass assemblies with patch fittings, for entrance doors, partition or enclosures.

Mostly 12mm clear tempered glass is used. For height of the opening above 3.4m lateral Support such as glass fins is needed or the thickness of glass has to increase. Thickness has to be based on the structural design and fins are required for stiffening. Seek recommendation of patch fittings supplier.

Skylights in frame

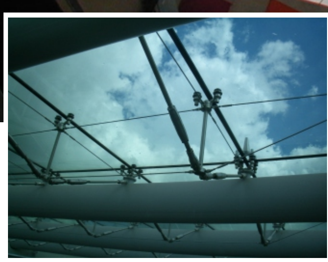
Glass is supported on frames and properly sealed from all 4 sides against water penetration.

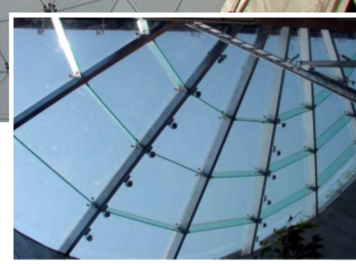


Being overhead glazing, laminated glass of appropriate thickness and minimum 0.76mm PVB to be used. Annealed glass can be used for smaller panes but heat strengthened glass for both panes is preferred.

Skylight with bolted systems

Glass is glazed with bolts supported from upper side or lower side with metal frame on cable stays or frame trusses.

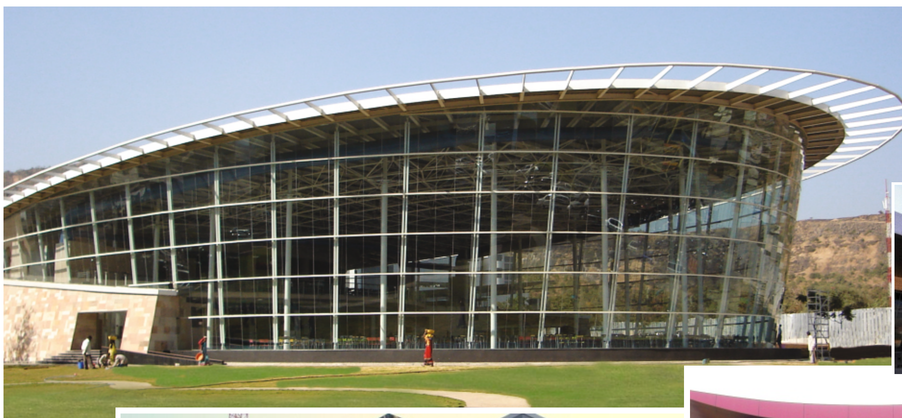




Laminated glass of suitable thickness with both glasses tempered & heat soaked are used. Mostly both glasses are 12mm or 10mm with 1.52mm PVB lamination with Ionoplast Sheets instead or PVB is preffered.

Sloped Glazings

These are aluminium or bolted façades with face slanting or sloped outward of the building at an angle of more than 15 degrees to the vertical.




Laminated glass with both panes tempered or heat strengthened should be used on the overhead or slanted out face. Exact thickness and combination will be based on design. Bolted inclined facades normally use 12+1.52+12 mm configuration. Normal aluminium structural glazing with slope normally uses '5+0.76+5mm' for panels upto 1mx2m and '6+1.14+6mm' for larger panels with both glasses as heat strengthened.

Shower Installations

Glass shower assemblies are generally used to give a larger feel and visual comfort while using the bathroom in addition to keeping non shower area clean and dry.

10mm clear tempered glass is most commonly used and 8mm tempered can be used in case of smaller panels, if they are well supported.

Wall Cladding

Glass clad wall are very neat and clean, high on aesthetics and a hygienic feel about them. Passages, lift lobbies, designer bathrooms and kitchens are the ideal places of use.

6mm ceramic printed tempered glass is most suitable. Printing can be textures or patterns or of plain flat finish. In case the designer needs very bright or lively colours, then enameled glass can be used. Enameled glass is costlier, cannot be tempered or laminated and may not be suitable on exteriors.

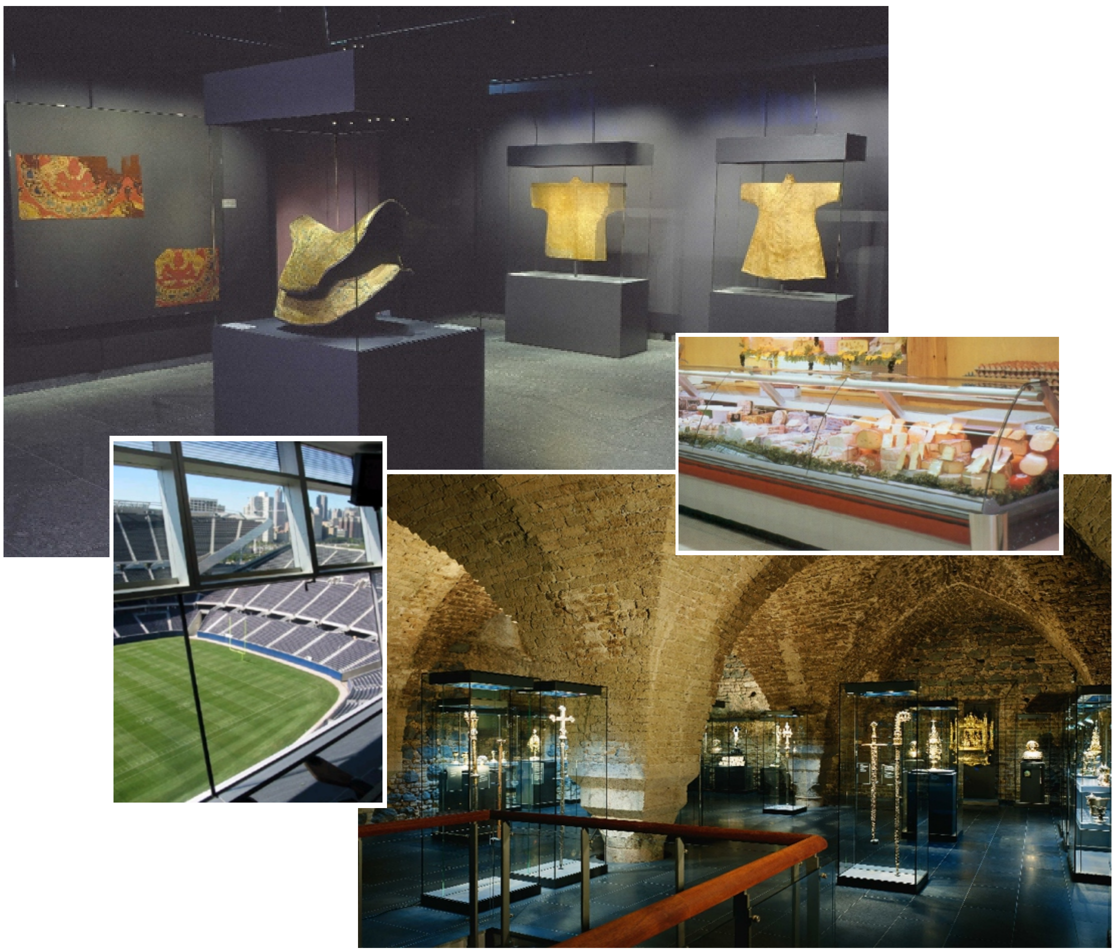
Table tops and Furnitures

Glass has become a very important element in furniture. Given below are only some examples.

Tempered glass is most commonly used. Thickness of tempered glass will depend on the size, load, supports and aesthetic appeal. Wherever edges are exposed, the edge type and finish are important. Annealed glass should not be used at all as it is very dangerous. Wherever decoration on glass is needed, it should be done before the tempering.

Museums, Viewing Galleries, Display Windows

Special glasses are needed for these applications depending on the requirements of transparency, non-glare, anti-reflection and frost freedom.



Extra clear glass is used to reduce the green tint effect of glass mostly for display windows. Anti-reflective glass is very expensive but recommended for high value displays, museums and wherever photography is needed to be done through the glass.

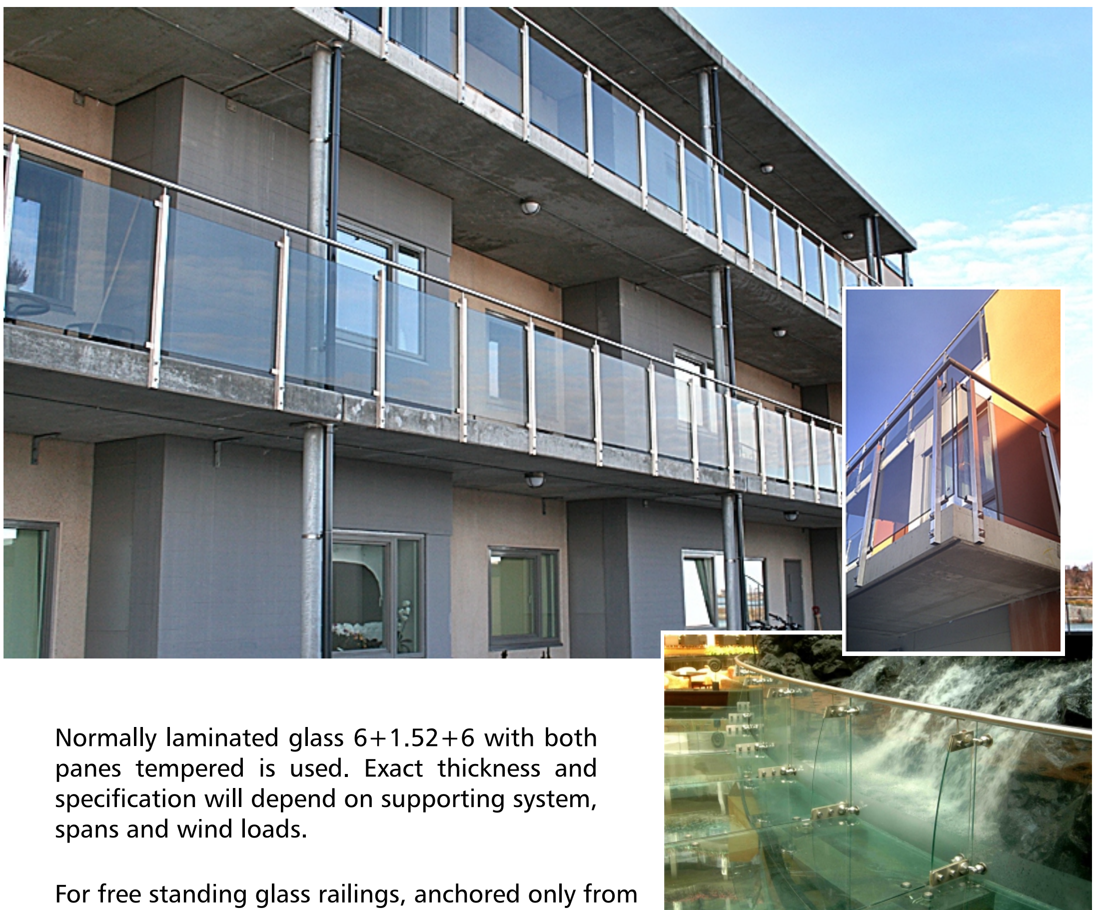
Balconies with top bottom framed

A Glass balcony brings natural light to the building and also adds to its class. The glass has to be good for strength and human safety.

Minimum specification should be laminated glass of 5+0.76+5 mm with both panes heat strengthened. Suitable specification will depend on support system, span and wind loads considered.

Balcony with glass on bolts

Glass balconies with bolted systems are less obtrusive where you see more glass and less of metal.

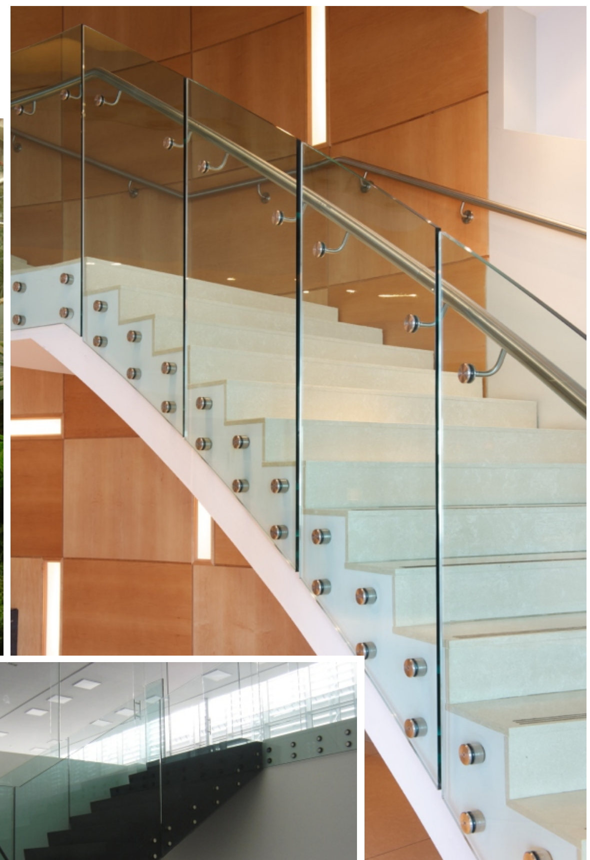


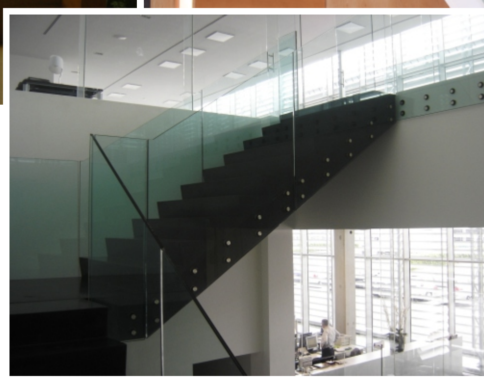
Normally laminated glass 6+1.52+6 with both panes tempered is used. Exact thickness and specification will depend on supporting system, spans and wind loads.

For free standing glass railings, anchored only from the bottom edge, Laminated glass with both glasses tempered in configuration ‘10+1.52+10mm’ or ‘12+1.52+12mm’ is used. Lamination with ionomers instead of PVB is preferred.

Staircase balustrades

These use shaped glasses, mostly trapezadal, and sometimes needing intricate and difficult cutouts. These can be flat or curved as illustrated.

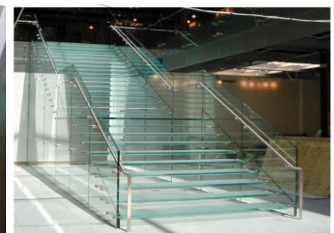


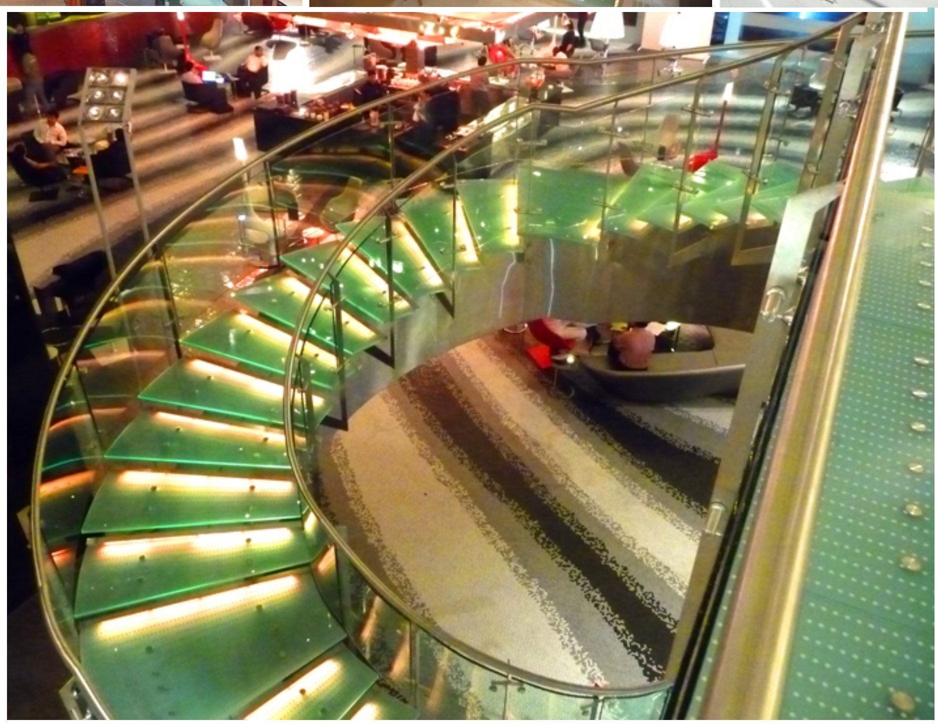


Laminated glass of suitable thickness and configuration is recommended though the most commonly used glass is tempered. In case of single tempered glass, safety film should be applied for human safety.

Staircase steps

Walkable steps of glass need a very high load bearing capability and have to be safe for humans in case of glass failure or breakage also also. There may be other considerations for see through visibility from below and anti skid treatment on glass.

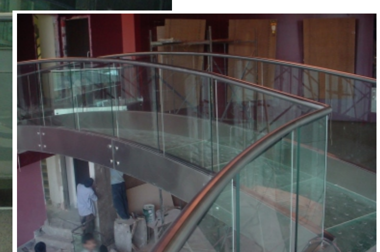




Laminated glass of 12+1.52+12 with both panes tempered and heat soaked are most commonly used and is minimum specification. This is often added with anti skid printing on top surface and one layer of translucent PVB in lamination. Actual specification will depend on design aspects based on spans, loads and support system. Though PVB can be used safely, newer lamination materials like Ionoplast Sheets with more rigidity and strength are also preferred over PVB.

Walkways

Walkways need a very high load bearing capability and have to be safe for humans in case of glass failure or breakage also. There may be other considerations for see through visibility from below and anti skid treatment on glass.



Laminated glass of 12+1.52+12 with both panes tempered and heat soaked are most commonly used and is minimum specification. This is often added with anti skid printing on top surface and one layer of translucent PVB in lamination. Actual specification will depend on design aspects based on spans, loads and support system. Though PVB can be used safely, newer lamination materials like Ionoplast Sheets with more rigidity and strength are also preferred over PVB.

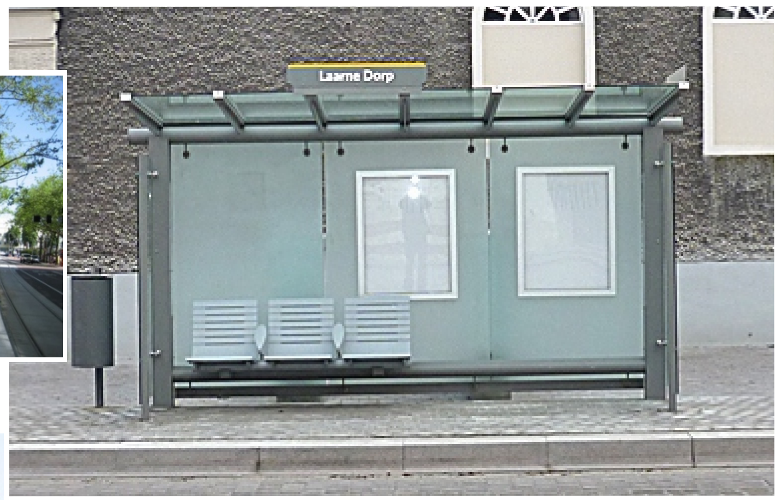
Canopies

Glass canopies are a common feature in modern building for better light and aesthetic appeal

Being overhead glazing, the glass has to be a laminated glass of suitable configuration depending on spans, support system, cleaning and maintenance loads. An FEA is recommended for canopies on bolted structural glazing.

Shelters

Glass shelters render a high feeling of safety from possible nuisance by anti social elements in such public places.



Overhead glass has to be laminated while the vertical glass panels can be tempered. Most commonly, laminated glass 6+0.76+6 mm with both panes heat strengthened is used.

SECTION-3, TECHNICAL

This section elaborates, technical details on the manufacturing of the basic glasses and for important consideration while selecting or designing the glass, giving some further important information on glazing methods, sealants and quality parameters.

Section Contents :

MANUFACTURING BASIC GLASSES

Glass as a Material:

Glass is a product of fusion of several inorganic substances. The fused mass is generally cooled to ambient temperature at a slow rate but fast enough to prevent crystallization, so that the molecules cannot arrange themselves into a crystalline pattern. This fast cooling rate used to prevent crystallization, applies only to transparent glasses. In the case of translucent and opaque glasses, the cooling rate is such that as to produce a pre determined level of crystal formation.

Glass is generally considered to be a hard transparent, brittle material with high softening point, substantially insoluble in water and organic solvents and non-inflammable in the usual sense.

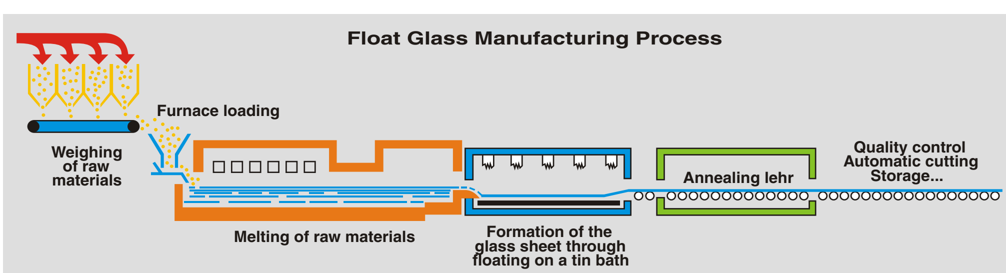
One of the most frequently quoted definitions of the term glass is that proposed in 1945 by the American Society of testing materials as "glass is an inorganic product of fusion, which has been cooled to a rigid condition without crystallization". In other words, glass can be considered as super cool ed liquid.

Types of Glass :

The primary constituent of all types of commercial glass is sand. The temperature required to fuse sand is about 1700ºC. The addition of other chemicals can dramatically reduce this temperature. Sodium carbonate, also known as soda ash and sodium oxide will reduce the fusion temperature to about 800ºC. In order to make this form of glass more suitable to use, other chemicals like calcium oxide and magnesium oxide are needed. These materials are introduced into the batch by the addition of limestone ($CaCO_3$) and dolomite ($MgCO_3$), Cullet – broken glass is also used in the batch. Generally flat glass contains a higher proportion of magnesium oxide in comparison with bottle glass.

The technology for making glass has historically evolved from

(a) Broad Glass (100-1910)
(b) Crown Glass (1696 – 1872)
(c) Cylinder method (1832 – 1930)
(d) Drawn Cylinder process (1910 – 1930)
(e) Sheet Glass
(f) Plate Glass and finally
(g) Float Glass



Float Glass :

It has been estimated that over 95% of the world's flat glass is made by the float process. This is by far the most dominant process of making flat glass and is produced in thickness is ranging from millimeters upto 25 millimeters.

The process has been dominant since 1959 when Pilkington developed the first float line. It produces glass which is reasonably flat and relatively distortion free. Manufacturing techniques ensure that uniformity of glass thickness is generally very consistent.

Float glass can also be made with various tints. The addition of tints or colour to the glass enhances its capacity to absorb solar radiation. The basic colours that float glass can be supplied in are grey, green, bronze and blue.

Materials used in Glass making
SiO_2 - Sand 70% - 74%
Na_2O - Sodium Oxide 10% - 16%
CaO - Calcium Oxide 4% - 10%
MgO - Magnesium Oxide 1% - 3%
Al_2O_3 - Aluminium Oxide 1% - 3%
Cullet - broken glass 16% - 26%

COLORANT	GLASS COLOURS
Iron	Green, brown, blue
Maganese	Purple
Chromium	Green, yellow, pink
Vanadium	Green, blue, grey
Copper	Blue, green, red
Cobalt	Blue, green, pink
Nickel	Yellow, purple
Cadmium Sulphide	Yellow
Titanium	Purple, brown
Cerium	Yellow
Carbon & Sulphur	Amber, brown
Selenium	Pink, red
Gold	Red

Glass Properties:

The average physical and mechanical properties of soda lime float glass
1. Modulus of Elasticity (E) - 10.4 x 10^{-6} psi (71.7 x 10^{-6} kPa)
2. Modulus of Rigidity (Shear) (G) – 4.3 x 10^{-6} psi (29.6 x 10^{-6} kPa)
3. Poisson's Ratio – 0.23
4. Coefficient of Thermal Expansion – 4.6 x 10^{-6} strain per °F (8.3 x 10^{-6} strain per °C)
5. Density – 156 lbs. per cubic foot (2500 kg/m3)
6. Modulus of Rupture (Flexure)[a] – 6000 lbs/sq. in (41.4 MPa):

	(Mean)	(design: 8 breaks in 1000)b
Annealed Glass --	6,000 psi (41 MPa)	2,800 psi (19 MPa)
Heat-Strengthened Glass --	12,000 psi (83 MPa)	5,600 psi (39 MPa)
Fully Tempered Glass --	24,000psi (166 Mpa)	11,200 psi (77 MPa)

Note a : These are approximate values for short load durations (under 1 minute) for undamaged glass in four-sided support.

Note b : Probability of breakage – note that these values are for the surface of the glass (not the edge) and do not take into consideration area effects.

7.Hardness (Moh's Scale) -- 5 to 6
8.Specific Heat Capacity -- 0.84-0.88 J/Kg x K)
9.Thermal Conductivity – 0.9-1.0 W/mk (.52-.57 Btu/hrftF)
10.Mean Refractive Index @ Sodium "D" Line 1.5
11.Chemical composition:

Silicon dioxide (SiO_2) 69-74%
Calcium oxide (CaO) 5-12%
Sodium oxide (Na_2O) 12-16%
Magnesium oxide (MgO) 0-6%
Aluminum oxide (Al_2O_3) 0-3 %

12. Softening Point – 715-729°C (1319-1345°F)

Annealing Point – 544 - 548°C (1011-1018°F)
Strain Point – 504-511°C (939-952°F)

13. Emissivity – 0.84
14. Reflection – 4% from each surface (for 3mm glass)
15. Visible Light Absorption – 1 to 2%
16. Far Infrared Transmission – 0
17. Chemical Resistance – Excellent
18. Electrical Resistivity - High

Specification for minimum visual light transmission of clear float glass :

Nominal Thickness (mm)	Minimum value of light transmittance (%)
2	89
3	90
4	89
5	88
6	87
8	85
10	84
12	83
15	76
19	72
25	67

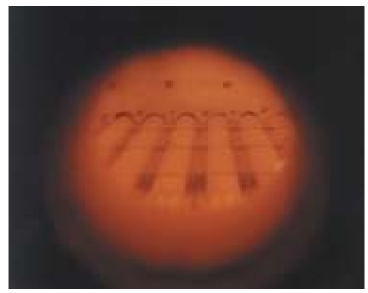
The clarity and transparence of clear float is affected by the extent of iron impurities as higher iron content results in greenish appearance. The typical iron content for good float clear glass is less than 900ppm.

PROCESSED GLASS TECHNICALS

Tempered Glass Process :

Tempered glass (also known as toughened glass) is an extremely strong glass which has been thermally heat treated to induce compressive stresses of 10,000 to 20,000 psi on the surfaces and edge compression of not less than 9,700 psi.

Tempered glass is being used increasingly in architecture because of its strength and safety properties. It is usually installed in areas where safety glass is required to reduce the possibility of mechanical or thermal breakage and/ or to assure greater uniform load strength. Worldwide, building codes in general has mandated the use of Tempered glass or Safety glass.

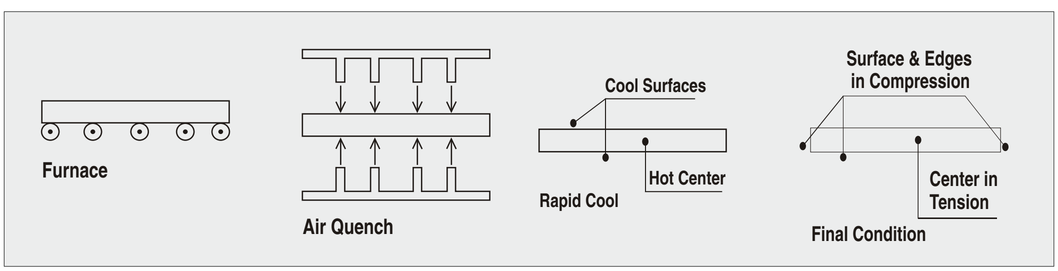


View in the Furnace

Tempering Pressure Control

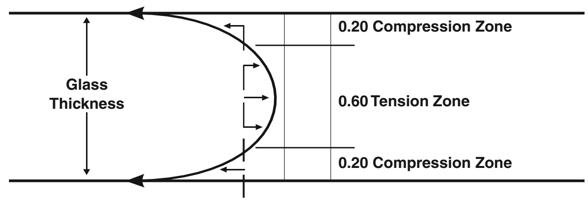
Process of Manufacture :

Cut to size glass sheets are electrically heated in the furnace where it oscillates back and forth on rollers till glass reaches temperature of about 680°C. The heating is done very evenly with highly advanced control systems and it takes 40 to 60 seconds per mm of glass thickness to achieve and stabilize at this set temperature. At this temperature it becomes very soft and flexible. From the furnace the glass is transported on roller conveyor and rapidly cooled in quench section by a blast of air on both sides of the glass.



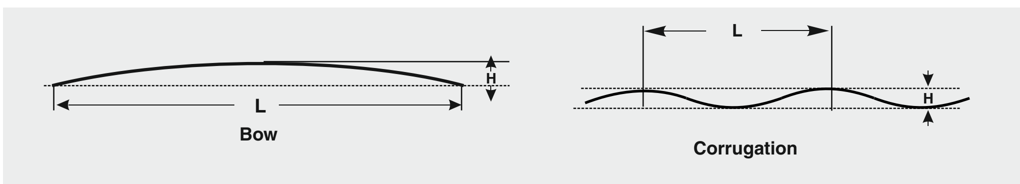
Sudden cooling or quenching after uniform heating induces compressive and tensile stresses that impart strength to the glass. Outer surface is under compressive stress while inside or core is under tensile stresses. The distribution of stress is given below:

This shows 40% of thickness of glass i.e. 20% of thickness of outer skin is under compressive zone and 60% of inner surface is under tension zone. The sum of the forces in compression is equal to the forces in tension. The toughened glass attains its strength from these forces. Any load applied on glass has to overcome the compressive stresses on the edge and surface, to cause breakage to tempered glass.



Physics of Tempered Glass :

Since glass is heated to nearly molten stage and then frozen again, the thermal treatment causes some minor physical variations. These are inherent to the process and cannot be avoided altogether but have to kept under control for a good quality tempered glass. Some of these are listed below.



Roller Marks:

White marks along the line of glass movement or small pitting caused by impregnations of dust or contamination on the rollers in the furnace, if the rollers are not clean or the glass is over heated. To Control the roller marks frequent cleaning on roller needs to be done and glass should not be heated more than necessary.. Thicker glasses (12mm and above) are more susceptible to roller marks as these are heavier glasses and the force of impregnation into the soft or molten surface is very high.

Flatness:

The physical appearance of a tempered glass is quite flat but it is not truly or perfectly flat. It has two types of bows or bends or corrugation. It has an overall bow, which is a smooth bend through the entire length of the glass, and other is waviness or corrugation, which happens due to bending in the vacant space between the oscillating rollers in the heating furnace. In Corrugation 'L' is generally 200 to 300 mm (*See image above).*

Optical Distortion:

Optical distortion is the deformation in the images when seen through or reflected on the glass. Most good quality tempered glasses will not have any noticeable optical distortion when viewing through the glass. Distortions are more prominently visible in reflected images on coated glasses and corrugation is the main cause. There can be many other reasons for distortion. If the whole glass wall is not glazed in one plane, it can also be a major cause of optical distortion in reflective or coated glass. DGU glasses will also contribute to the distortions due to climatic changes and the resultant change in air or gas pressure inside a DGU. Wind pressure on the glass also causes a temporary bend, which distorts the reflected images from glass.

Coating Burns:
Can be sometimes noticed in coated tempered glass. The coated glass before processing can have some defects and some can be caused during the processing like the coating burns.

The physics of tempered glass is such that it gives us a great value in terms of strength, safety and architectural designing, but some variations as above are inherent to the process and cannot be avoided completely. These are to be kept within the specified tolerances for achieving a good glazing as seen in most beautiful buildings. These tolerances are well defined and explained in the quality section of this guide.

Other Physical Characteristics :

Fragmentation:
Tempered glass does not break easily but when it breaks, it disintegrates into small fragments. Fragmentation is the acid test of tempering quality. Large pieces show weaker strength of glass. Uneven fragment sizes are indication of bad quality of tempering. This is a destructive test. Fragmentation of tempered glass should meet the quality standards as explained in the quality section.

Edge Strength:
Edges of all type of glasses in general including tempered glass are the weakest point. This becomes relevant if a glass has exposed edges with a possibility of impact or loading, as in the case of frameless doors. Edge strength can be improved by better grinding quality. The corner edge should also be grinded to give glass superior edge strength. During the tempering process, the edges get heated and cooled faster than the surface due to the surrounding heat resulting in higher concentration of stresses.

Anisotropy (Iridescence):
Heat-treated glass (heat-strengthened or tempered) can have an optical phenomenon that is called strain pattern or quench pattern. This phenomenon can appear as faint spots, blotches, or lines. This is the result of the air quenching (cooling) of the glass when it is heat-treated and is not to be considered a glass defect.

The heat treatment process results in a higher surface compression directly opposite the air quench, air nozzles or slots. The higher compression areas are denser and can exhibit a darker appearance under some viewing conditions especially when light is polarized, such as a skylight or other forms of reflected light. The colors of the strain pattern are sometimes referred to as iridescent, or the general condition as iridescence. The pattern that is seen under certain lighting conditions may vary from manufacturer, depending on the design of the cooling apparatus. The intensity of the quench or strain pattern is influenced by the viewing angle, lighting conditions and by the perceptiveness of the viewer. It is nearly impossible to eliminate the strain pattern or quench pattern in heat treated glass products. The presence of a strain pattern does not alter the structural integrity or safety of the glass lite.

When viewing from the interior of the building, the quench pattern may be visible from a 10° viewing angle and not apparent at a 90° viewing angle from the surface of the glass. When viewing the glass in reflectance from the exterior of the building, the quench pattern may be visible when looking at the glass surface at a 30-60° angle. Visibility of the quench pattern may be accentuated with thicker glass, tinted glass substrates, coated glass and multiple lites of heat-treated glass in laminated or insulating glass products.

Construction sites may yield viewing angles and conditions that cause the quench pattern to become visible. However, upon completion of construction; the presence of interior walls; finishes; furniture; and plants frequently results in the strain pattern being less visible or not visible at all.

The stresses introduced in the heat-treating of glass are an inherent part of the fabrication process, and while they may be affected or altered depending on the heating process, controls and/or quench design, they cannot be eliminated. Design professionals should be aware that quench patterns are not a defect in heat-treated glass and, therefore, are not a basis for product rejection.

Spontaneous Breakage due to Nickel Sulphide Inclusions :

In various situations fully tempered glass may break for no reason or provocation. Many factors might cause such spontaneous breakages, but the most common are nickel sulphide inclusions. Nickel sulphide inclusion, also known as NiS, occurs during the manufacturing process for float glass. In the glass batch, nickel-rich contaminants such as stainless steel might be present, and then combine with sulphur to form nickel sulphide inclusions. These inclusion cannot be seen or identified in the fully formed glass.

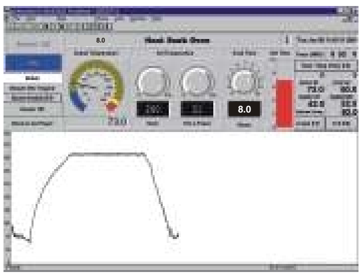
Nickel sulfide is an interesting compound that exists in different phases at different temperatures. Two specific phases of NiS exist, known as the alpha-phase and the beta-phase. At temperatures below 380°C (715 F), nickel sulfide is stable in the beta-phase. Above this temperature, it is stable in the alpha-phase. Therefore, when glass is produced in the furnace, it is overwhelmingly likely that any NiS inclusions will be in the alpha-phase. In typical annealed glass, the slow cooling process provided by the annealing lehr allows the NiS ample time to transform to its beta-phase as the glass cools. However, in the fast cooling process used in both heat-strengthened and tempered glass, there is insufficient time to complete the phase transition (which is a relatively slow process). The inclusions therefore are "trapped" in the glass in their high-temperature alpha-phase.

However, once the glass cools past the phase change temperature, the NiS inclusion seeks to re-enter its lower energy beta-phase. For "trapped" inclusions, this process takes anywhere from months to years. When NiS changes from alpha-phase to beta-phase, it increases in volume by 2 to 4%. This expansion creates localized tensile stresses that are estimated to be as much as 125,000 psi (860 MPa) at the glass-NiS Interaction surface. The magnitude of this stress drops off sharply away from the face of the inclusion, but is sufficient at the face to cause microcracking.

In the core tension zone of the glass, these microcracks are propagated by stress concentrations at the tip of the crack until the structure of the glass is undermined completely and the tempered glass undergoes its characteristic shattering, which causes the seemingly spontaneous failure. It is important to understand that since there is no data available worldwide on the amount of NiS inclusions that could occur, breakage due to NiS suicide is a property, and not a defect in tempered glasses.

Heat Soaking :

While there is no way of detecting the presence of NiS in the basic float glass before or after tempering, there is a way to reduce or nearly eliminate the on site breakages due to NiS. This is normally done for critical areas where spontaneous breakage can be a potential hazard.



Heat Soak Temperature v/s Time Graph

After tempering, the glasses are heated again to a temperature of about 290 degree C and kept at that temperature for 8 hours. This is done under a controlled process for accelerating the inversion of the nickel sulfide inclusions to their low temperature phase. In all probability, the glasses that have NiS inclusions will break during this heat soaking process. While heat-soaking does not guarantee that breakage will be completely eliminated in installed tempered glass, it reduces the chances drastically. Studies have been concluded worldwide indicating the reliability of heat soak test to as high as 98.5%.

Heat Soak Oven

Site Alterations :

Tempered glass cannot be cut or drilled after tempering. Any field alterations, including edge grinding, sand blasting or acid etching can cause premature failure. Tempered glass behaves like an inflated balloon. It can take a lot of load but if the skin is punctured, it will break or bust.

Heat Strengthened Glass :

Heat strengthened glass is a semi tempered glass which has been strengthened thermally by inducing a surface compression of 6000 to 9000 psi as compared to a range of 10,000 to 20,000 psi in case of fully tempered glass.

The heat strengthening process is same as of the traditional process of glass tempering, except that the heating temperatures are lower by 10 to 20 degrees and the cooling cycle is less rapid.

Physics of Heat strengthened glass :

Physics of Heat strengthened glass is exactly similar to the tempered glass except that the optical distortion is less due to lower bow and corrugation. The strength is half of fully tempered glass but double of the normal annealed glass. It does not break into small fragments like tempered glass and is thus not as safe. It therefore does not qualify as safety glazing material but is still used widely in structural glazing due to superior optics.

Properties Glass	Annealed Glass	Heat Strengthened Glass	Tempered
Fragmentation	Knife like pieces	Knife like pieces	Small round crystals
Thermal Stress	Up to 50° C	Up to 130° C	Up to 250° C
Strength	Not Strong	2 times of annealed	4 times of annealed
Tensile Strength	20 MPa	40 – 55 MPa	65 MPa
Bending Strength	40 N/ mm^2	60-100 N/mm^2	120 – 200 N/mm^2
Design Stress	17 MPa	27 MPa	50 MPa

Site alterations should not be attempted for the reasons as given for tempered glass

Laminated Glasses :

Laminated glass is a sandwich of two or more sheets of glass with a plastic interlayer usually polyvinyl Butyral (PVB) interlayer in between. The glass panes can be basic float glass, tempered or heat strengthened.

Lamination is a popular method used all over the world, to increase the safety and strength of glass. In addition to the basic security aspect, various other benefits like acoustic insulation, UV protection, distortions and design versatility are provided by laminated glass. These characteristics and advantages of safety glass have been explained in the earlier section of 'Glass Basics'

PVB Lamination:

PVB or Polyvinyl butyral is the most common interlayer material used in the sandwich and is standard for automobile industry. It has a very high transparency and excellent adhesion properties with glass. It is soft, has a very high stretch ability and very good tear resistance. It is available in roll sheets of various widths and are generally supplied with interleaving of polyethylene to prevent the film from sticking to itself. There are other interlayering materials described below but these have relatively poorer physical properties as compared to PVB. Some of them are explained below.

Ionoplast Sheets Lamination: Ionoplast Sheets are also being used as interlayer material for making laminated glass but these are more expensive than PVB and these are preferred for use, only where structural integrity of the interlayer is critical upon failure of both tempered glass panes of the sandwich as in case of walkways, staircase steps etc. These are also useful for some critical areas susceptible to severe hurricanes or cyclones.

Poly Urethane Lamination: PU or Poly Urethane of special grade is another good material but is more expensive and does not give any added value or advantage to PVB lamination except that it has a good adhesion to polycarbonate as well as glass and thus finds its advantage in making bullet resistant laminated glass making multiple layer sandwich of (Glass + PU + Polycarbonate + PU + Glass).

EVA Lamination: EVA or Ethyle Vinyle Acetate of special grade is also available in sheet rolls and is self adhesive to glass and can be used for lamination but only in the interiors. Its transparency is not very good and is a bit hazy. The strength is also not as good but it has the advantage that it has a good adhesion to some other materials like fabrics or tissues or other special films like LCD (Liquid crystal display). This enables to encapsulate other materials in the sandwich like (Glass + EVA +Fabric + EVA + Glass).

CIP Resin Lamination: Cast in Place or CIP resins are also used as interlayer materials and these are generally available as two part chemicals in liquid form wherein one is the main resin and other part is a hardener. These are mixed in a prescribed ratio just before pouring into a glass cavity created by a manual process. Other type is single part compounds and is cured by exposing to ultra violet or UV radiation. The base material for most resins is either polyester or acrylic and both types are not as adhesive to glass and are not as UV stable as PVB and thus tend to fade or delaminate over a period of time. The only advantage is that it does not require any significant investment in machinery for manufacture.

PVC Lamination: This is a cheap and spurious variety of lamination, where PVC is glued to the glass with some adhesives. Since there is no chemical bond between interlayer and glass, this lamination is quite unstable and is not a safety glass.

Process of manufacture: More than 95% of the laminated glass manufactured worldwide is made with PVB. The process of manufacture with PVB is elaborate and has four main steps.

Glass Preparation :

The first stage of producing laminated glass is cleaning the glass surface to ensure the highest quality of cleanliness. Glass is washed in several stages using de-mineralized water having a conductivity of 20 micro siemens . Any contamination on the glass like dust or oil or finger marks can be permanently trapped in the sandwich and it is thus necessary to have an extremely high level of cleanliness and glass after cleaning should not have any static.

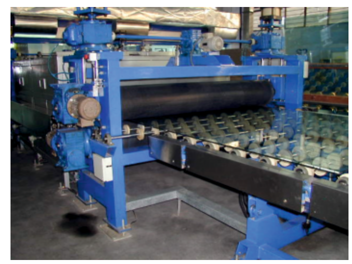
Clean glass is conveyed directly into a clean room with controlled temperature and humidity. PVB is unrolled in the clean room and interleaving polyethylene is removed. If needed it is cut to the desired sizes and stacked.

Assembly :

The sandwich of glass and PVB is made in the clean room where temperature of about (25° C) and relative humidity of about (25%) is maintained. None of the surfaces are touched by bare hands or fingers and the people working in this section have to wear gloves, masks and caps like in surgical operation rooms.

De-airing :

The glass and PVB sandwich is passed through rubber rollers under pressure to squeeze out any air pockets, trapped in the sandwich. These rollers are known as nip rolls. It is then heated to about 65°C-70°C to form an initial or partial bond between glass and PVB. It is then again passed through another set of nip rolls to squeeze out any moisture or remaining air trapped in the sandwich. This process of de-airing is also known as calendaring. De-airing can also be done by vacuum process where the edges of the sandwich are put in a vacuum ring and air is sucked out by using a vacuum pump.



Autoclaving :

These glasses after de-airing are stacked on a rack and sent to an Autoclave. The autoclave is then sealed and is heated inside to a temperature of about 135°C and pressure of about 12 Kg/cm^2 over a controlled time, temperature and pressure cycle of about 2 to 3 hours. PVB in this process becomes nearly liquid and can flow easily into any gaps or deformations of glass. After autoclaving, excess PVB flowing out of edges is clean rimmed and finished for usage.

The entire process of manufacture has to be strictly controlled to achieve proper quality as envisaged in the quality section of this guide.

Combinations and configurations:

Laminated glass can be made with any or both glass panes comprising of normal annealed glass, heat strengthened or tempered glass of virtually any thickness. It is possible to laminate multiple plies of glass and PVB as (Glass + PVB + Glass + PVB + Glass). PVB is quantified as layers of 0.38mm each and total PVB thickness is in multiples of 0.38mm. The optimum requirement of PVB thickness depends on the strength requirement and the type of glass plies being used. Normal annealed float glass can be laminated with 0.38mm thickness or 1 layer, which will have a nominal safety and the glass will stay in adhesion to the PVB and will not fall or will stay in sash upon breakage. Increasing the no. of layers will increase the capability of glass in terms of safety and resistance against forced entry. For optimum resistance against vandalism or forced entry, four layers or 1.52mm of PVB is recommended. PVB is also available in different colors, which can be transparent or translucent, and it is possible to combine the colors. Milky or frost PVB is used where light is needed but transparency is to be avoided or privacy is needed as in bathroom windows. Frost PVB can also be combined with clear or color PVB layers.

Laminating Heat-Treated glasses :
Tempered and heat strengthened glasses will have a small amount of corrugation or bow. It becomes essential to use these types in lamination where we need high mechanical strength and also the safety from fall or penetration. We have to use sufficient PVB to be able to flow into these deformations to give a single monolithic character to the glass. Minimum requirement for heat-strengthened glass is 0.76mm, though 1.14mm is preferred. For tempered glass, the minimum is 1.52mm though 1.14mm can be used for smaller panes where both glass plies are 5 or 6mm each and size of the panel is within 1000x1500mm. for higher and lower thicknesses, 1.52mm is the minimum and for larger glasses, even more PVB thickness may be needed.

Laminating other glasses :
Most kinds of decorative or patterned or coated glasses etc. can be laminated if the surface to be laminated against PVB has a flat finish. While laminating with coated glass, it must be appreciated that the adhesion is between the coating material and PVB for that surface.
Most solar and low-e coatings, which can be tempered, can also be laminated. Ceramic printed glass with full surface solid printing can be laminated but will have slightly lesser adhesion and may fail in the specified pummel test values but is safely used in most application where resistance from penetration is not a critical requirement, as in the case of wall cladding.
Printing with patterns wherein a part of the unprinted glass surface is in direct contact with PVB for adhesion is a very good option and such glasses should meet all test requirements.
Frosted or sand blasted glasses should not be laminated with PVB against the frosted or sand blasted surface of glass as PVB will flow into the pitting or micro cavities of such glass surface and the frosted glass will appear transparent again. It should be laminated against the non-frosted surface or it is advised to use frost color PVB or use frost color ceramic ink instead.
Enameled glass cannot be laminated with PVB against the enameled surface.

Defining the laminated glass construction: There are many conventions for defining the glass construction and the shortest form is used in Europe. When you say 44.2 means two glass plies of 4mm each and laminated with 2 layers or 0.76mm PVB. This is however inadequate and confusing when we want to specify two plies of 12mm tempered glass laminated with 1.52 PVB and both glasses are heat soaked. As per European method, we will write it as 1212.4 both glasses tempered float heat soaked. The most common convention in India is writing it as '12mm clear tempered float heat soaked + 1.52mm clear PVB + 12mm clear tempered float heat soaked'. This convention has a longer description but is more easily understood. If the above combination uses one layer offrosted PVB, the description will change to '12mm clear tempered float heat soaked + 0.38mm frosted PVB + 1.14mm clear PVB + 12mm clear tempered float heat soaked'.

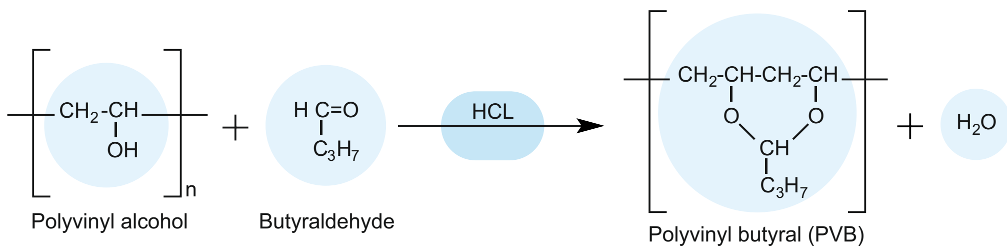
Chemistry of Laminated Glass :

To understand the chemistry of laminated glass, we need to look into the chemistry of PVB.
During lamination process chemical bonds are formed between glass and PVB inter-layers under temperature and pressure conditions. Mechanical and chemical bonds are formed between PVB and Glass. Hence it is combination of mechanical and chemical bonds that provide PVB laminated its properties.

Clean glass surface + correct moisture content of the film = good adhesion

Adhesion to glass is determined by the formation of hydrogen bonding bridge between the water compatible group of the glass surface and those of the polyvinyl.

Polyvinyl butyral is produced by acetalization of the polyvinyl alcohol with butyraldehyde in an acidic medium

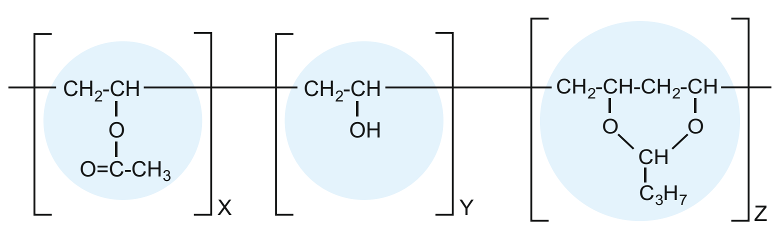


Polyvinyl Butyral Resin and Plasticizer

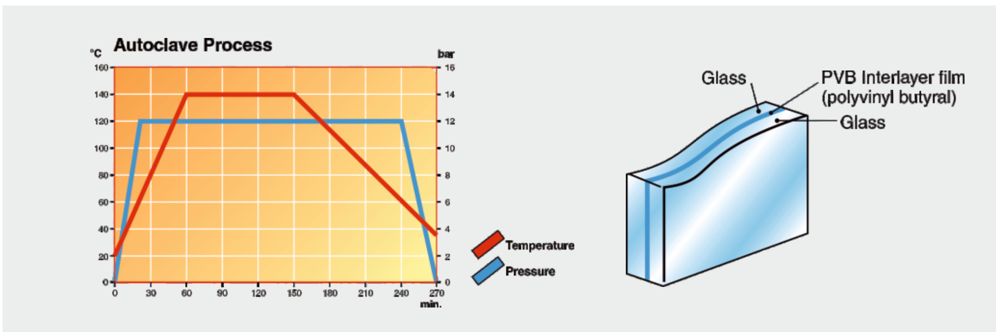
The use of PVB resin as a laminated safety glass interlayer has a lot to do with its chemical composition and particularly with the number of free hydroxyl groups in the polymer chain. The PVB resin can be varied by modifying the molecular weight of the initial polyvinyl acetate, the degree of hydrolysis into polyvinyl alcohol and the amount of butyraldehyde used for acetalization. Consequently, PVB can also be regarded as a terpolymer of vinyl acetate (x), vinyl alcohol (y) and vinyl butyral (z)

Glass Adhesion

Glass adhesion can be inhibited by water that has not been demineralized or is insufficiently purified. Mineral residues from hard water can then become concentrated on the glass surface after drying. Organic residues, such as cutting oils or greases, also greatly impact adhesion between PVB and the glass surface. Adhesion to glass depends on hydrogen bonding bridges between the water-compatible groups of the glass surface and those of the polymer.



Physics of Laminated Glass:
Physical appearance of a normal laminated glass is same as that of an ordinary float glass and is difficult to distinguish from it after glazing. It can be easily seen before glazing in the window as a clear transparent layer as shown in the figure



Strength:
Strength of laminated glass has been a subject matter of discussions, debates and research. Different design codes specify the design factor of 0.7 to 1.0 of the total thickness of the sandwich or combined thickness of 2 glass panes. For example a 5mm float + 0.76 PVB + 5mm float will have a strength equivalent to 7 to 10mm float. In actual behavior however, we need to look into the type of glazing. For a four side supported glass as glazed in a window, will behave like a monolithic glass of 10mm float. The situation will change if the load is applied on the edge of the glass or a hole. In such a case it will behave like a chain product and the strength of the sandwich will be equivalent to the strength of the specific singular glass being subjected to the load and thus equivalent to 5mm float. The strength of a chain is the strength of the weakest link in the chain. For mixed loading, we could consider a design factor of 0.7 but the decisive factor will be the glazing type and its behavior on loads upon the glass surface and edge.

Benefits of Laminated Glass :

Design Versatility and Installation Ease : Laminated glasses can be manufactured flat or curved. They can include annealed, toughened, heat-strengthened, wired, patterned, tinted or reflective glasses. Inter-layer's can be used to add colour tints and for further aesthetic and privacy needs. Laminated glass is simple to install. If the glass is not heat treated, it can be cut, drilled or notched.

Low Visual Distortion : Distortion is caused by "roller waves" in tempered and heat-strengthened glass. This can be avoided by using laminated annealed glass. Sharp reflected images are possible in curtain walls constructed with laminated annealed glass.

Applications of Laminated Glass :
Laminated glass is widely used because of its safety, security, sound reduction and solar control characteristics.

The toughness and resilience of laminated glass makes it an excellent choice for safety glazing to be used in glass skylights, sunspaces, sloped glazing installations and curtain walls.

When used in point fixed applications such as canopies or frameless facades, glazing requires special care to prevent holes from being exposed or subjected to moisture. The edge area should not be exposed especially to water. Organic solutions are not recommended as sealing material since they can cause edge de-lamination. It is better to ask the sealant supplier for compatibility to PVB.

Though annealed laminated glass can be cut at site according to design requirements, care should be taken to ensure clean cut edges.

Safety and Security : Laminated glass offers low chances of injury since the PVB inter-layers holdglass pieces even in case of breakage. It is ideal for use in skylights and balustrades since the thick plastic interlayer acts as a barrier in the event of breakage. This aspect makes it a good choice for bank teller cubicles, jewellery shops, etc and for the guards, it provides safety against forced entries.

Besides the general safety features of laminated glass, it can be strengthened further to provide protection from armed attacks involving sharp instruments and guns.

Sound Reduction : The sound damping quality of PVB layers make laminated glass an effective sound control product. The sound dampening effect provided by laminated glass is due to the visco elastic properties of the interlayer material. Noise reduction performance of IG units can be greatly improved by incorporating at least one layer of laminated glass.

Laminated glass is commonly used in airports, museums, sound studios and schools to keep away unwanted noise from airplanes, heavy machinery and traffic, to name a few.

UV Reduction : Laminated glass can block over 99% of the UV energy while allowing most of the visible light through and this can help protect valuable furnishings, displays or merchandise from the fading effects of UV radiation.

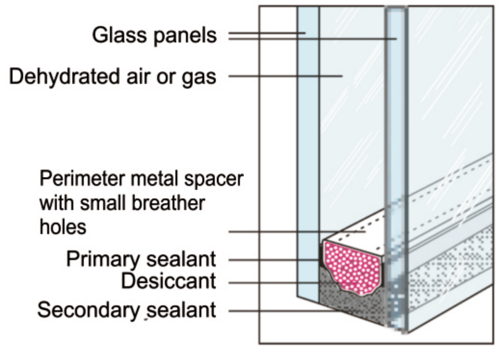
Selection Criteria :

The strength or structural performance of laminated glass is based on a number of factors like:

- Type of glass employed
- Thickness of each glass pane
- Condition of the glass surface and edge
- Unit geometry
- Nature of loading
- Unit thickness
- Total glazing area
- Aspect ratio
- Number of supporting sides
- Type of glazing systems

All these need to be taken into account when specifying laminated glass to meet a specific safety requirement

Insulated Glasses :



INSULATING GLASS

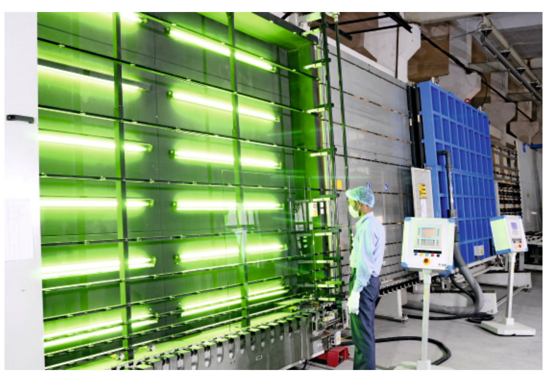
The insulated glass is a prefabricated unit made of two or more glass panes, which have been separated by an air gap and edge-sealed together. This edge seal not only binds the individual sheets of glass together to maintain the mechanical strength of the joint but also protects the space between the glass from outside influences. The air enclosed between the two glass panes is dried with a desiccant. Because of the low heat conductivity of the enclosed dry air between the glass panes, heat transmission through the window is drastically reduced. The sealants delay the moisture getting into the air space and the desiccant absorbs the moisture coming through the seal.

It is important that the edges are sealed hermetically to prevent any leakage of the dried air in the cavity into the atmosphere when the cavity air expands due to hot weather. Similarly it should prevent the atmospheric air to enter the cavity when the trapped air in the cavity shrinks due to contraction in colder weather. Any attempt to glaze two glasses separately and creating a seal on the site will fail in all probability as this will result in some leakage and result in moisture getting into the cavity and the resultant condensation will ne nearly impossible to clean.

Primarily, a spacer is used to separate the two glasses which can be of aluminium, stainless steel, plastic or soft materials but the most common is the aluminium spacer. Some thermoplastic or stainless steel spacers have better thermal performance in extreme conditions, these are not very common being more expensive and are popular only in sub zero temperature regions.

Edge sealing can be done in a single seal to address the moisture permeability and to give mechanical strength or it can be done in two stages as primary seal to prevent moisture penetration and a secondary seal to give a good mechanical strength. Most effective and most common is the dual seal with primary seal of PIB or Polyisobutalyne for preventing moisture peneteration and a secondary seal of polysulphide or structural silicon for mechanical integrity as shown in the schematic here.

Process of manufacture: Most of the insulating glass produced worldwide use aluminium spacer and dual sealing as above and is described here in various steps or stages. Insulating glass can be made using one or both panes as annealed, tempered, heat strengthened or laminated glass



Glass preparation:

The first stage of producing insulating glass is cleaning the glass surface to ensure the highest quality of cleanliness. Glass is washed in several stages using de-mineralized water. Any contamination on the glass like dust or oil or finger marks can be permanently trapped in the cavity and it is thus necessary to have an extremely high level of cleanliness This cleaning is done on line and glass after cleaning goes into assembly section.

Spacer frame preparation:

Aluminium spacer are hollow tubular profile with small breather holes on one surface are cut or bent to size and then joined at the corners with corner keys or joined at a single joint with a steel connector. Thereafter this frame is filled with a desiccant namely molecular sieves into the hollow of the tube. The primary sealant namely PIB is then applied through a hot melt extruder on the two sides of the frame making the frame ready for assembly.

Assembly:
The cleaned glasses and the frame are assembled and pressed togather to form the primary adhesion and the assembly is then transferred to the secondary sealing station.

Secondary sealing:
Is done with polysulphide or structural silicone using a two part sealant pump which sends the main compound and the hardener in a pre-defined and metered ratio in a gun to mix and apply with an application nozzle. The process can be done manually with the hand-operated gun or by using a robotic applicator. The sealant which is applied in liquid form cures to a solid rubber like material in a few hours. Thereafter the excess sealant is cleaned and the insulating glass becomes ready for supply and installation.

Benefits of Insulated Glass :

Insulation : Saves on heating and cooling by reducing air to air heat transfer. The enclosed layer of air makes the insulating capability about twice that of monolithic glass. Because of this, the load on the air conditioning is greatly reduced. The use of heat absorbing or heat reflective glass will further reduce the load on the cooling system.

Prevention of Dew Condensation : With monolithic glass, the temperature difference between the outside and inside of a room will often lead to condensation. However, the insulating effect of the air layer makes it difficult for the glass to become cold and is consequently harder for dew condensation.

Retards Sound Transmission : Insulating glass can significantly save on exterior noise pollution. The amount of sound reduction depends on the combination of the insulating glass. Using one of the panes as Laminated glass will drastically reduce sound transmission. Using dissimilar thickness of glass panes will also help combat noise. Replacing air with SF6 gas will also reduce sound transfer.

Pleasant Room Temperature : It offers increased personal comfort and aids in energy conservation. Because of its high insulation properties, the lack of cold or warm droughts leads to a pleasant internal environment. Since the inner glass is nearly at the temperature of the room, it is comfortable to be seated close to the glass surface which is not the case for non insulated glass, where sitting close to the glass can be quite uncomfortable.

Versatality:

Enables the architects to use larger glazed area for greater see through and natural light.

Impact of size of the air gap or cavity

The most common air space is 12mm and is considered optimum. A smaller cavity is generally used in case, where a window sash cannot accommodate the overall glass thickness with 12mm air gap. Care has be taken that in case of larger sizes and a smaller air cavity, there is a good possibility that the two glasses can touch each at the point of maximum deflection and rub against each other to form a chalky rubbing mark. The glasses can bend due to wind load as well as contraction of enclosed air at lower temperatures. Glasses with both dimensions (Height and Width) greater than 2m will have a higher deflection at the center and should have more than 12mm air gap.

A larger air cavity will improve the energy efficiency and sound insulation property of the glass. But in extreme climatic conditions cavities above 19mm have the possibility of convection current setting in the cavity at very hot climate conditions. The outer glass will get heated and heat up the air particles in contact with the glass by conduction. The hot air will tend to rise upwards within the cavity. Normal cavity will not allow this air to move up but a higher cavity will allow this and set up convection current, which will result in loss of insulation.

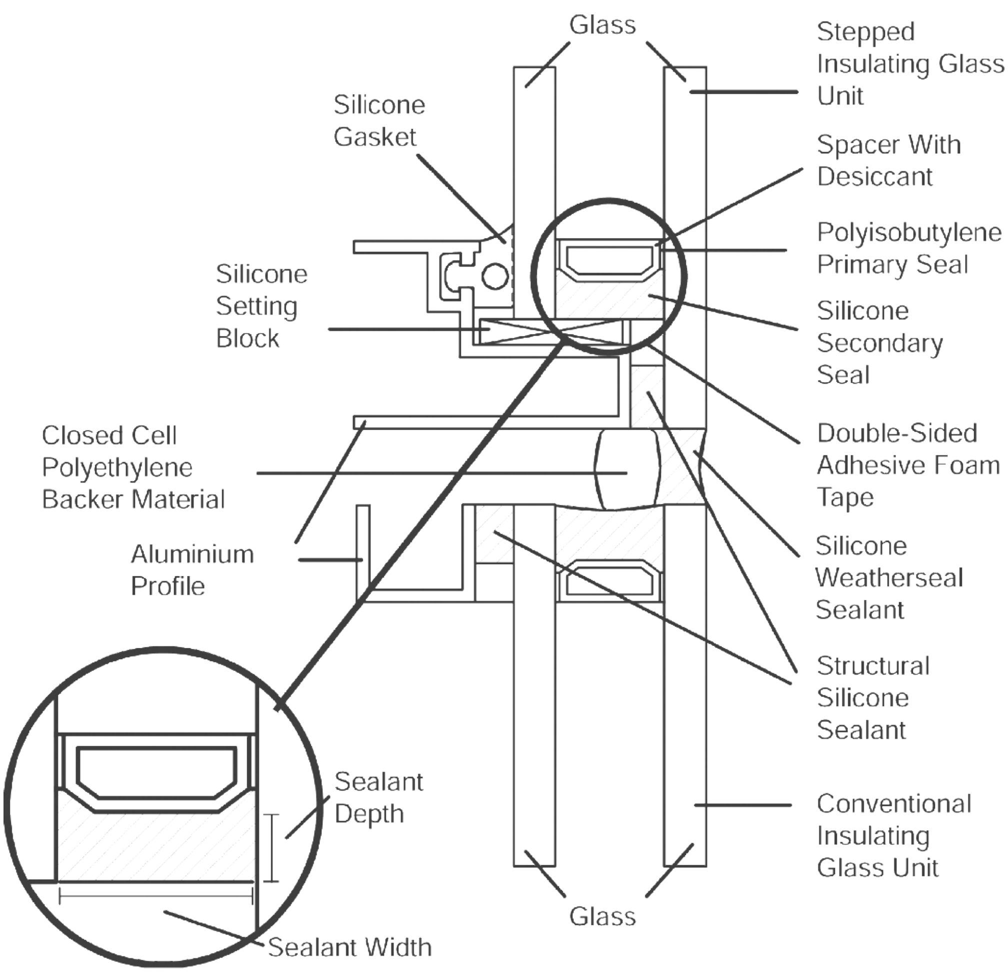
Gas filling to replace air with an inert gas

Though more than 90% of insulating glass worldwide is made with dry air gap cavity and is sufficient for normal building requirements. However, the cavity between the two glasses can be filled by some inert gases instead of air. Most commonly used gas is argon, which is heavier than air and improves the insulation property or U-Value by a small margin. Krypton and Xenon are used to improve the sound insulation property of the glass. These gases are used where the property requirements on glass are very sensitive or critical.

Designing with Insulating glass:

When used in a window sash with all four sides supported, a normal insulating glass with a nominal standard bite of 4mm is sufficient. While using it for structural glazing, the glazing method and technique comes into the fore. In such cases it is mostly the inner glass which is glued on to the main structural wall, whereas the external glass is supported by the internal glass. In such case, the integrity of the whole system has to be examined and the silicone bite may have to be increased.

The sealant depth requirement is based on the total dynamic loads applied to the IG unit. The loads may be from the wind, climate or impact. Higher wind loads and larger dimensions of the glass require greater sealant depth. Climatic loads are determined by the change in temperature and pressure on the IG unit. Climatic loads on the secondary seal are greater for smaller glass dimensions in most situations. Additional loads such as impact loads or point loads can also be considered in the determination of total dynamic load.



IG Sealant Depth Calculation for Total Dynamic Load

$$\text{Minimum Sealant Depth} = \frac{\text{Glass Short Span (mm) x Total Dynamic Load (kPa) x 0 5T}}{\text{140kPa}}$$

- Glass Short Span is the shorter of the two dimensions of the rectangular glass panel. For example, on a 1500mm by 2500mm glass panel, 1500mm is the short span.
- The maximum wind load in kPa is based on a return period of 10 years or according to local regulations. This value is provided by the design professional.
- 140 kPa (0 .14 MPa) is the Maximum Allowable Design Stress for structural silicone.
- Total Dynamic Load is the difference between the pressure in the cavity of the IG unit and the sum of wind load and atmospheric pressure. The pressure in the cavity is affected by temperature, elevation and atmospheric pressure during production of the IG unit. The stiffness of the glass panes will affect the total dynamic load.
- An insulating glass unit pressurized by wind loading deflects very similarly to the assumed trapezoidal load distribution rule. In IG units where the thickness of the inboard glass is equal to or greater than the outboard glass, the IG industry generally accepts that the insulating glass secondary seal bite carries 50 percent of the maximum windload (50/50 load-sharing principle). Thus, the secondary seal bite is calculated as one half that of the structural silicone sealant bite.
- The 50:50 load-sharing principle concludes that if the insulating glass unit is made of two symmetrical, well-sealed glass panes, where the inboard glass pane is equal to or greater than the outboard panes, then the insulating glass unit secondary sealant absorbs approximately 50 percent of the maximum windload forces placed on the unit in the field, while the silicone structural glazing sealant that attaches the insulating glass unit to the curtainwall mullion, carries 100 percent of the maximum windload. The 50:50 load-sharing principle is well documented and is generally accepted throughout insulating glass industry. Therefore, as a minimum, insulating glass units are designed with a secondary seal depth sufficient to withstand at least 50 percent of the maximum windload specifications for a specific structural silicone glazed building. In cases where the thickness of the outboard glass is greater than that of the inboard glass, the 50/50 load sharing (or 50 percent of structural bite) no longer is valid and the load-sharing must be determined.

The IG secondary seal is subject to continuous load if the outer pane of glass is not supported by horizontal framing members or setting blocks, or is being used in roof glazing or positive sloped glazing. The deadload weight of the glass must be considered in the joint dimensioning of the IG unit. Thicker glass panes will require greater sealant depth of the IG joint.

IG Sealant Depth Calculation for Continuous Load(Deadload)

$$\text{Minimum Sealant Depth (mm)} = \frac{\text{Weight of glass(kg)}}{\text{glass perimeter (m) x sealant deadload design strength } (700\text{kg/m}^2)}$$

- The glass weight is determined only for the outer pane of insulating glass unit
- The Allowable Design Stress for Continuous Load for most structural silicone is 7 kPa or $700 kg/m^2$

Precautions :

- Regardless of edge construction, the insulating edge seal cannot be exposed to moisture for prolonged time periods.
- Consideration must be given to weep holes or other alternate methods which will ensure a dry framing cavity.
- Distortion can occour in insulating glass units from changes in temperature, barometric pressure and altitude. The air between the cavity will expand and make the glass bulge or become convex whereas on drop of temperature, the air in the cavity will contract and cause the surface to become a bit concave. Such distortion is more apparent in reflective insulating glass units.
- Brewster Fringes : Brewster fringes refer to the rainbow effect occasionally seen in double glazing. This is not a deterioration or stain on the glass, but is simply caused by light refraction between four glass surfaces of similar thickness and substrate. This effect can usually be minimised by ordering the two glass panes in different thicknesses. For example, 6mm glass / 12 mm airspace / 5 mm glass.
- Handle and install insulating glass with care. Damaged edges and/or corners can result in breakage later. Insulating glass units should not be rolled on corners.
- Insulating glass units shipped to or through an area with an elevation of 1000m or more must be equipped with breather tubes or must be pressure equalized before glazing on site.

GLAZING METHODS

Any knowledge on glass is incomplete without understanding the Glazing Methods and material that are connected to the glass to make it a complete glazing. Some of the most commonly used methods are described here briefly with a view to provide basic information on the integration of various elements used in conjunction with glass.

Traditional Windows:

Windows and frames made of Wood, Aluminium, UPVC or Steel are the most common elements used traditionally for glazing with any basic glass or processed glass, based on the requirements placed upon such glazings. Large frames should ensure a deflection of less than 1/175 of its span or less than 20 mm at any point

Contrary to the common belief, the glass should not be fitted into the window sash but should be placed with clearances at both sides as well as top & bottom. The glass should always rest on the setting blocks at bottom. There should also be a clearance between the face of the glass and the rebate or beading, which can be maintained by a gasket or foam tape and subsequently sealed.

The engagement of glass into the rebate or beading, known as bite is important and will depend on the size and thickness of glass.

Rebate :

It must be dimensioned according to the glazing type, sizes and tolerances and to accommodate the glazing materials. The sill member must have adequate weep. Except open rebates, all types of rebates, channels or structural gaskets must have weep holes in order to prevent the accumulation of moisture in the rebate for prolonged periods and equalize the moisture vapour pressure between the air outside and the air inside the rebate.

There should be at least two weep holes of 6 mm dia with additional hole for every 500 mm over 1m. Oblong weep holes are preferable to circular holes.

Setting Blocks :

This method should be used to rest the glass in a frame at its correct horizontal and vertical position and preventing any glass-to-metal contact. The blocks should not be too hard or too soft. A medium hardness wood or any stable elastomeric material with a shore hardness of 75 to 90 should be good. Care should be taken that they do not cover or obstruct the weep holes.

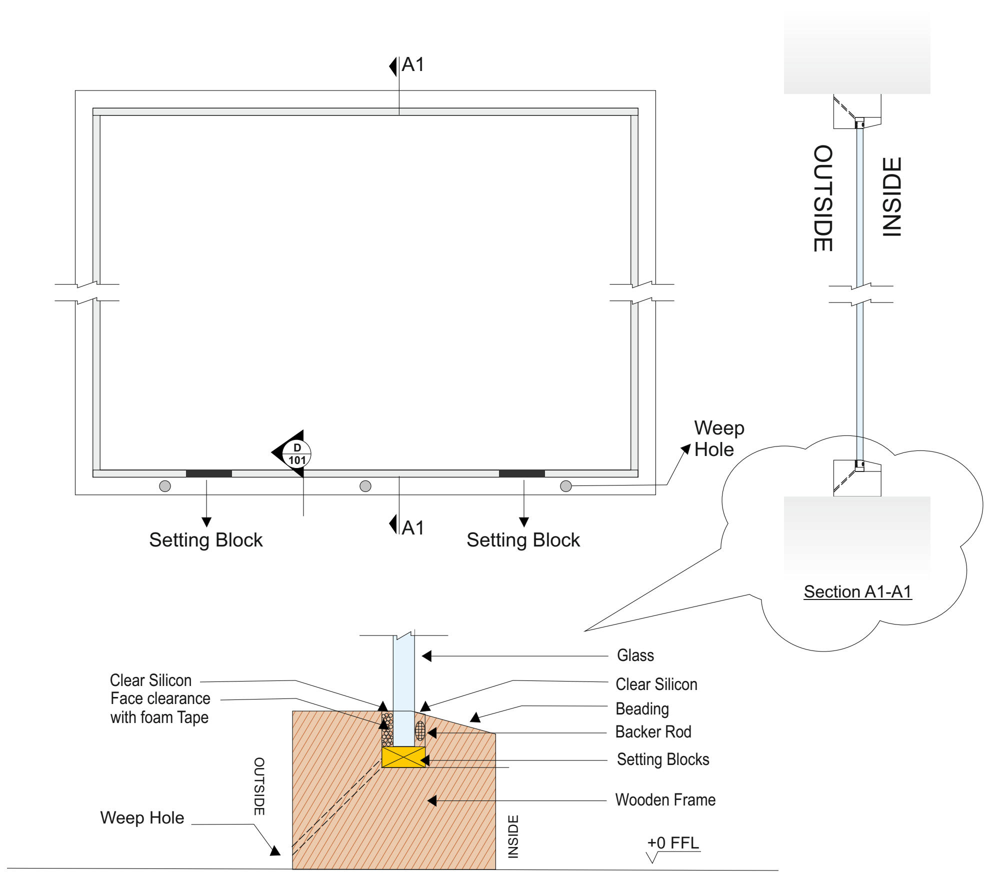
Sealing :

In case of wooden frames, foam tapes should be used for sealing, whereas in aluminium or metal frames, suitable silicones should be applied as per silicone manufacturer's instructions. Care should be taken when using laminated or double glazing for the sealant's compatibility.

Minimum Value for Clearances and Bite (mm)

Standard thickness (mm)	Windows and Curtainwall using sealing compound		
	Face clearance	Edge clearance	Bite
	a	b	c
3	3	3	6
5	4	5	8
6	4	6	8
8	5	6	8
10	5	6	10
12	5	8	12
15	5	10	15

* Bite has to Substantially higher for Security Glazing to prevent entire glass to come out of the window.



Minimum Values for Clearance and Bite (mm) Double Glazed

Insulating glass Construction (mm) Glass+Gap+Glass	Face clearance A (mm)	Bite C (mm)	Side Clearances C mm						
			Curtainwall	Fixed frame			Movable frame		
			All Side	Bottom Side	Upper Side	Vertical Side	Bottom Side	Upper Side	Vertical Side
3+AG+3	5	15	7	7	6	5	7	3	3
5+AG+5	5	15	7	7	6	5	7	3	3
6+AG+6	5	15	7	7	6	5	7	3	3
8+AG+8	7	17	8	7	6	6	7	5	4
10+AG+10	7	19	8	7	6	6	7	5	4
12+AG+12	7	21	8	7	6	6	7	5	4

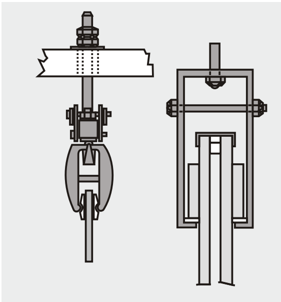
- **AG = Thickness of air or gap, gap from 8 to 25 mm**

Curtainwalling and Structural Glazing :

The traditional stick system curtainwall are a frame of aluminium with mullions and transoms quite similar to large framed glazing except that the walls form an independent envelope around the main structure and are generally not resting on the concrete structure but only connected to it. The design factors for unloading and provisions for expansions and movements of wall v/s the structure and glass v/s the aluminium are to be considered carefully. Planimetery of the whole glass wall as a single unit and special sealing elements, materials and techniques make it a highly specialized job. The glass is kept in place by placing it in the sash and fixing with a pressure plate.

Structural glazing with silicone is an even more specialized job which allows perfectly uniform large glazed surfaces, not interrupted by traditional frames or any other supporting or fitting system projecting out of the pane of the glass. Instead of being fitted in a frame, the glass is fixed to a support which in turn is attached to a structural element of the building, the tightness of the whole being obtained by a silicone seal. The glass is fixed on its support by means of a silicone seal along the edges of the internal surface. In principle, silicone is applied on all four edges but it can be limited to one, two or three edges, in which case the remaining edges are fitted into traditional frames. This technique can be used with almost any type of glass, including double glazing units.

Suspended Glazing :



This system, which is mainly used for very high glass panes, avoids flexing or buckling under self weight, which may happen if those panes would rest on their bottom edge. It also absorbs important movements of the building and it frees the lower frame from the weight of the glass. Monolithic glass panes are suspended by means of tongs which press on both sides of the glass.

Double glazed units, which cannot sustain pressure, must be suspended by means of hooks.

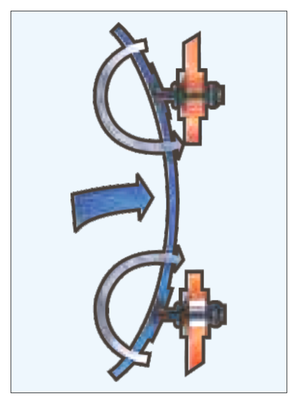
Bolted Glazing :

The bolted-on structural system is the less obtrusive alternative to glued on structural glazing.

There are several systems which hold the glass by means of visible metal parts, which only cover a small part of the glass surface. In some cases, the fixing holes can be drilled and countersunk, so that the bolts are embedded in the thickness of the glass.

For small or medium glazings not exceeding 7m in height and 50m in length, rigid bolted system or Clasped glazing can be used but with care in design and installation. This system is often used for shopfront at street level. It consists of all-glass assemblies which may include one or more single or double doors, transoms, fixed side panes, entirely made of tempered glass, assembled by various metal fittings and stiffened by mullions also made of tempered glass. This traditional system consists of attaching the glass panels and the structure with rigid bolts and steel plates. The overall sizes have to be restricted as there are no margins for building movements and earthquakes or tremors.

Bolted Systems :



Use of Knuckled bolts or articulated bolts for fixing of the glass, instead of the common fixed bolt. Knuckled bolts allow the glass, submitted to wind pressure, to be flexible and make a continuous curve instead of a double curvature. It limits sensibly the tension in the glass at suspension points.

There are three different methods to attach structural glass : first of all a steel structure can support the glass. In the second technique, vertical glass fins are used, which absorb the stress exercised on the glass using the spring plates technique. It is used chiefly for the installation of glass fins on larger surfaces. The third method is the so called rigging method, an extremely solid system, is used for roof constructions also.

Bolted glass systems are often used on main entrance elevations of big buildings, so that you can have unhindered view into the building. This technique even enables architects to make curved facades with flat panes, because the rotating bolts can be faceted up to 7 degrees. It means daring architectural constructions are possible.

Glass Doors, Shop Fronts & Partitions :

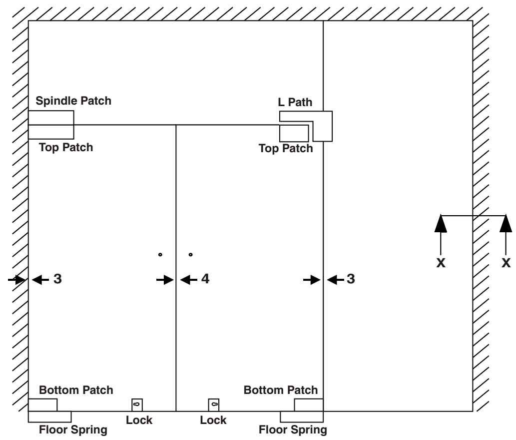
Glass doors are generally made of tempered glass, transparent or translucent, clear or tinted, with processed highly polished edges and with holes and notches factory-cut to fix the accompanying metal fittings.

There are standard door configurations (see illustrations) but any door style (swinging, sliding...) can be produced. These door systems come in a ready to assemble condition, complete with fittings, floor closers, handles, etc. and are installed in a matter of hours.

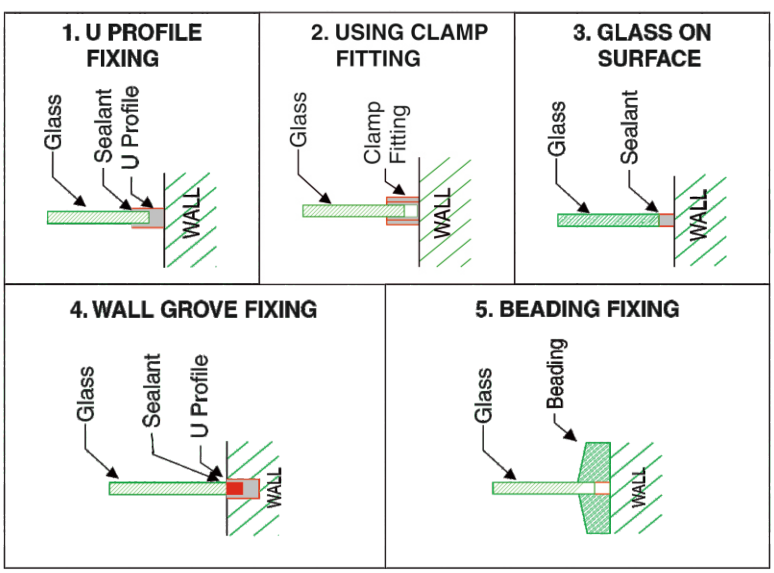
The system has tremendous advantage in terms of visual expanse, aesthetics, lighting, openness and elegance. For shops and commercial establishments they are more inviting to the customers and make a great display. For homes and offices, they provide unmatched aesthetics combined with functionality.

They are also possible with etching options as per design and artwork ranging from a simple line border to a company logo or text or any piece of artistic work or statement.

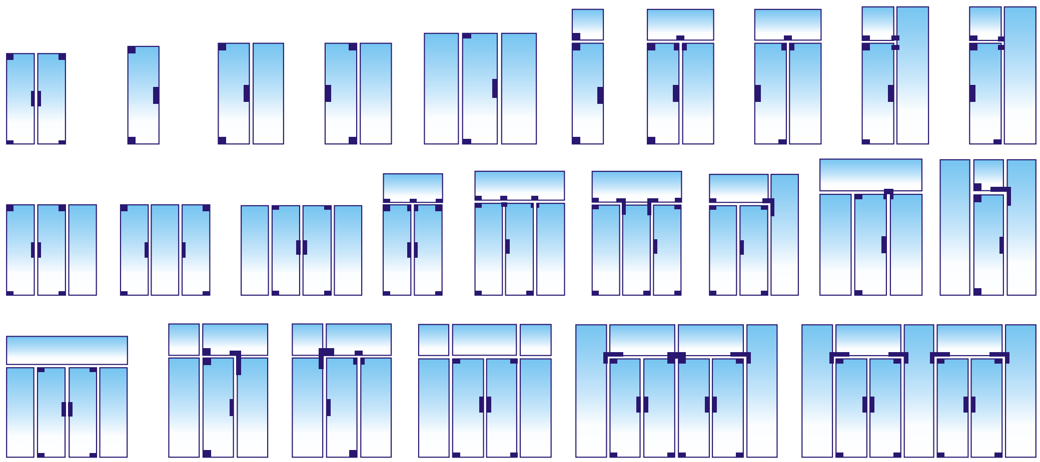
Door Fixing Method



Options for fixing to wall (Section X-X above)



Basic Configurations of Tempered Glass Door Assemblies



Shower Installations :

Most modern bathrooms use tempered glass shower doors as partition between toilet and shower. They are popular because of their neat look and space multiplier effect thereby allowing designers to plan small bathrooms which look bigger. The fixed panels and door panels can be attached to wall or glass to glass at 90°, 135° and 180°.

Electronic Glass Doors :

Another modern concept is use of microprocessor controlled sliding door panels and swing doors. Both operate on separate set of working principles but open with sensors or push buttons or touch and go. The microprocessor performs intelligent functions like differentiating between an approaching or passing person, timing speed and duration of opening etc and is programmable for day, after office and night time operations. Interface to fire alarm systems and security systems are standard features. The system operates on 24V DC current for safety and better battery in case of power failure.

Folding Glass Partitions :

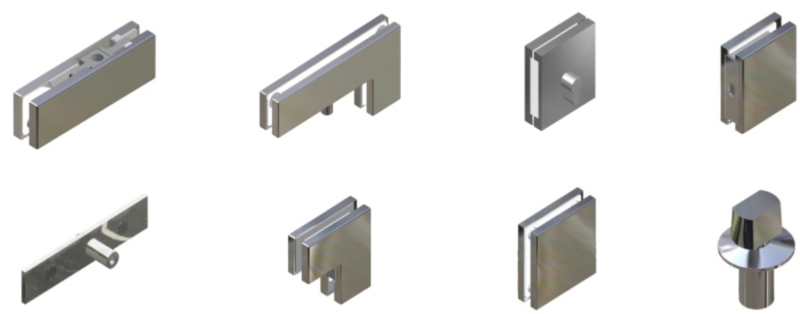
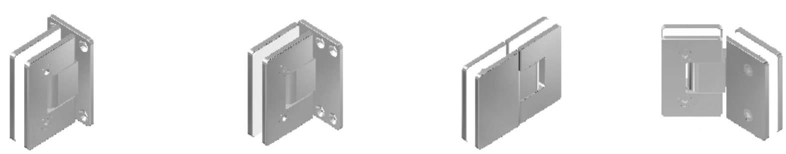
Commonly used for shopfronts in cold countries to open the entire frontage of shop during good weather and keeping the vertical panels folded and parked on a side or in remote area. In harsh weather when there is need for climate control indoors, the whole partition with one or more swing doors can be unfolded to have a fully covered glass frontage. The concept can be exploited for use as partitions of glass in hotels, farm houses, and party halls for expanding the service area to connect to open spaces such as lawns, at the time of larger gathering or parties. It can also be used in office conferencing areas. Banks can use this to partition ATM from main office.

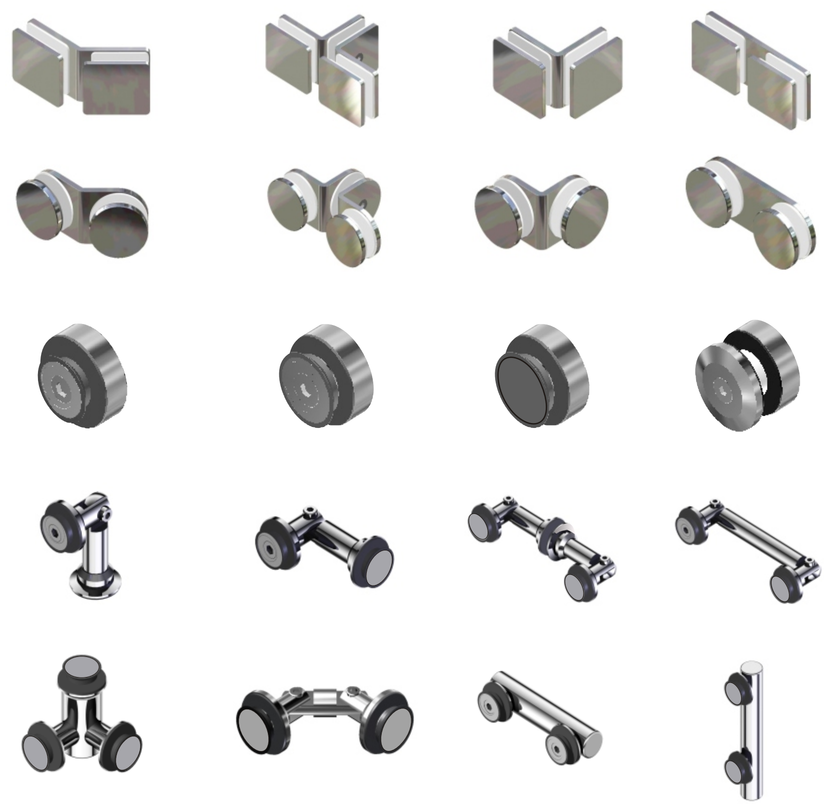
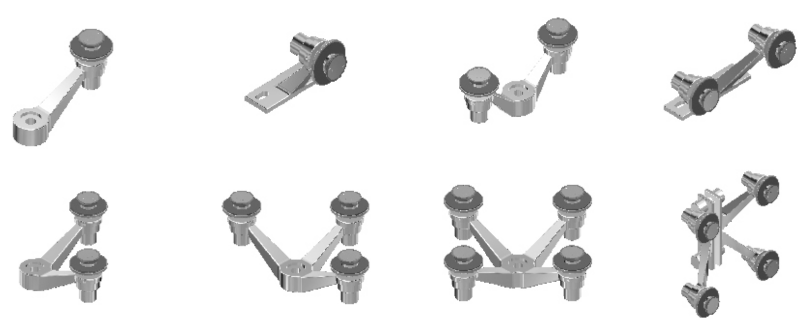
FITTINGS AND HARDWARE FOR FRAMELESS GLAZING

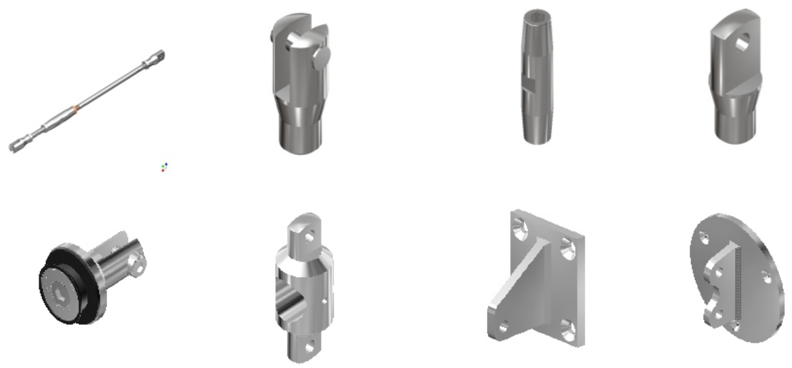
Traditionally glass was fitted into a window on opening with wood or metal all around. Now the frameless glazing, opens many new vistas by using special stainless steel connectors, fittings & bolts and make a glass assembly with these fittings.

Some of the common examples of patch fittings, connectors, spiders and fittings for bolted structural glazing are shown below:

Patch Fittings and Connectors :

Door Fittings :	
Floor Closer :	
Shower Hinge :	
Handles :	
Hand Rails :	

Connectors :	
Bolted Structural Glazing & Spiders Etc. :	
A - Spiders :	
B - Knuckled Bolts :	

Fin Plates :	
Tension Rod Systems :	

Designing with these fittings is a specialized job and advice from manufacturers should be obtained.

SEALANTS

There are many types of sealants used in sealing the glazing from water penetration or for mechanical bonding of glass with the surrounding materials.

The most commonly used modern sealant is silicone and these are available with various properties and characteristics.

Characteristics of a silicone sealant

- Best known elastic sealant
- Moisture curing
- Constant gunability over a wide temperature range
- Very good UV- and weather resistance
- Very good temperature resistance (-60° up to 280°C, depending on the grade)
- Very good resistance against ageing
- Colour stable
- Fast curing
- Very universal adhesion properties

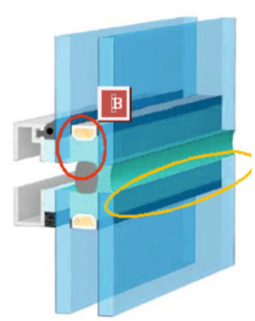
Types of Silicone Sealants

a) Acetic cure silicone sealants

- Release acetic acid during cure
- Medium to high modulus (E-mod > 0.4 N/mm²)
- Mostly used as sealant in sheet metal industry, ceramic applications, glazing applications
- Limited adhesion properties on acrylics, polyester or most other plastics as well as, galvanized steel, copper and zinc, a neutral cure silicone should be used.

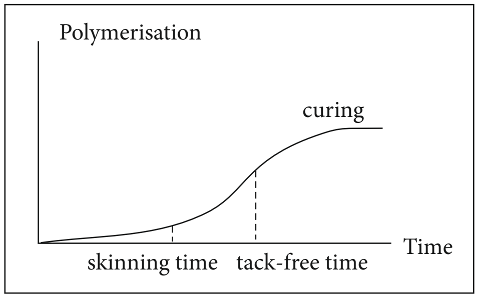
b) Neutral cure silicone sealants

- Release neutral molecules when curing: oxime (standard), alkoxy (slow cure) or benzamid (dry toolable)
- Low modulus sealants (< 0.4 N/mm²)
- General purpose sealants, window perimeter sealing, glazing applications, sanitary applications, façade applications, structural applications, …
- Good adhesion on most surfaces and also on problem surfaces such as PVC lead, zinc, uPVC, polycarbonate, concrete, plastics, copper, polyester, …
- Advantage of oxime is the good adhesion on most surfaces.
- Very elastic behaviour.
- Not every neutral silicone is compatible in contact with double glazing or with multilayer glass with films. In some cases this needs to be tested.



Curing Parameters of Silicone Sealants:

• Skin formation time: the time it takes for the silicone sealant to create a skin after the application. The skin formation is dependent on the temperature and humidity. The higher the humidity & temperature, the faster the skin formation. The skin formation on any technical data sheet is at 20°C & 50% relative humidity. You can determine the skin formation by touching the silicone. If no silicone will stay on your finger, the silicone has formed a skin. *– Skin formation can be between 1 to 30 minutes*



- Tack-Free time: means to moment the silicone sealant will not feel tacky anymore. – *Tack free time is between 5 minutes and a couple of hours later than skin formation time*
- Curing time of the sealant is dependent on a couple of parameters: thickness of the joint, humidity, temperature, surface.

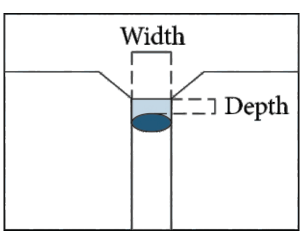
– Curing speed (20°C and 50% RH) for silicone sealants is between 1,5 – 2mm per 24 hours

Application Method Of Sealants:

- Clean the surface and make sure that it is totally free of moisture, dust and grease before applying the
- Sealants are available in ready-to-use plastic PE cartridges. Cut the nozzle at an angle of 45°, to the desired bead size (3mm for vertical joints and 4mm for corner joints). Cut the tip of the cartridge to fix the nozzle. Load the cartridge into the sealant gun sealant.
- Load the cartridge into the sealant gun sealant.
- Put masking tape on both sides of the joint leaving exact gap for filling. This will make the joint look neat, clean and uniform.
- Fill the joint with sealant. Use the right product for the right application.
- Immediately after filling the joint, the sealant should be tooled either with finger with soapy water or with a pallet knife. Tooling is essential for removing air bubbles and to fill up all the voids by the compacting action.

This results in proper adhesion and better aesthetics.

- Remove the masking tape before the sealant forms a skin.



Other Important Points:

Optimal joint dimension

Silicone sealant: depth = width/2

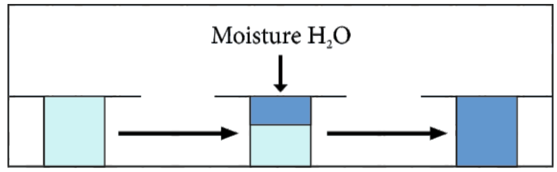
A sealant needs a minimum thickness of 5mm. For a width between 5mm and 10 mm we will have a depth of 5mm.

For larger joints we get depth = width/2.

-Joints may be maximum 30mm width.

-Only for glazing a joint of 4mm width by 6mm depth is accepted.

- Use joint backing material
- Application temperature should be between 5°C – 35°C.
- Silicone sealants are moisture curing products. A minimum of 35% relative humidity is required to get the silicone sealant cure properly



Moisture curing will be influenced by

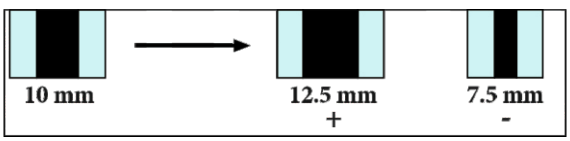
- Temperature
- Humidity
- Low humidity: < 30% relative humidity
- High humidity: > 70% relative humidity

The higher the temperature and humidity the faster the skinning and ultimate cure.

Precautions

Maximum allowed distortion:

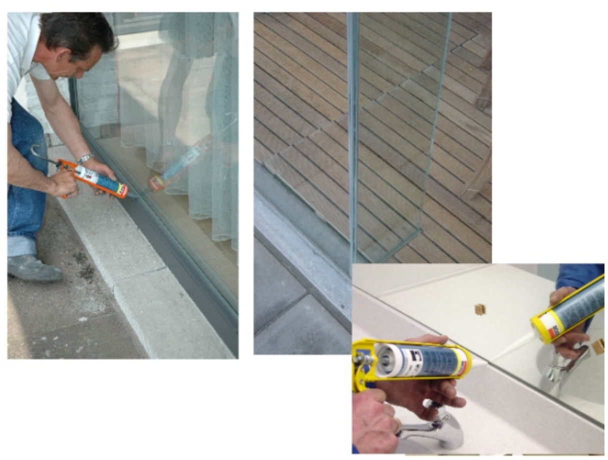
- Allowed distortion (= maximum movement a sealant can make without losing its properties like elasticity, strength, ...)



- Most silicone sealants have a maximum allowed distortion of +/- 25% movement. This means a joint of 10mm can move up to expand up to 12,5mm or contract to 7,5mm.

Guidelines for usage and applications

- Silicone between glass and window frame. You can use nearly all types of silicone as long as you have good adhesion on the frame. Important is the size of the joint.
- Silicone between glass and frame, but also in contact with the PVB film of a multilayer glass or in contact with the primary double glass sealant. Be very careful what you choose there. You can have problems if the wrong silicone is used. Glass can start to delaminate or in case of double glass, it might be possible that the butyl is attacked and releases oil. For this type of application first ask help.



QUALITY STANDARDS AND ACCEPTANCE NORMS FOR GLASS

Glass is a wonder material and is like diamond. Just as there is no diamond which is defect free, glass too have some imperfections or defects which are inherent to the process of manufacturing. It becomes important to understand these and set up some acceptance standards for various commonly used glasses for architectural use.

The Following pages are an extract from another FOSG Publication, namely "Quality Standards Manual".

2.2 Quality Parameters for float glass

2.2.1 Thickness

The thickness tolerances of float glass shall be as specified in Table 2.1

Table 2.1: Thickness and Tolerance of Float Glass

(Glass thickness shall be measured with a micrometer or caliper which is graduated to 0.01 mm or with a measuring instrument having an equivalent accuracy.)

(All dimensions are in millimeters and as per IS14900 : 2000 (Reaffirmed 2005))

Nominal Thickness	Tolerance*
3	± 0.3
3.5	± 0.3
4	± 0.3
5	± 0.3
6	± 0.3
8	± 0.6
10	± 0.6
12	± 0.8
15	± 0.8
19	± 1.2

2.2.2 Dimensions :

Tolerance on length and width of the float glass shall be in accordance with Table 2.2.

Table 2.2: Dimensional (Length or Width) Tolerance of Float Glass

(Glass dimension shall be measured with a steel scale (tape) which is graduated to 1.00 mm. The measurement shall be made on adjacent two sides.)

(All dimensions are in millimeters and as per IS14900 : 2000 (Reaffirmed 2005))

Nominal Thickness	Tolerance (Length or Width)	
	Upto and including 3 m	Above 3 m
3	+1 / -2	-
4.0	+1 / -2	-
5.0	+2 / -2	-
6.0	+2 / -2	-
8.0	+2 / -3	+3 / -4
10.0	+2 / -3	+3 / -4
12.0	+3 / -3	+4 / -4
15.0	+3 / -3	+4 / -4
19.0	+5 / -5	+6 / -6

2.2.3 Diagonals

Tolerance on diagonal of float glass shall be in accordance with Table 2.3.

Table 2.3: Diagonal Tolerance of Float Glass
(All dimensions are in millimeters and as per IS14900 : 2000 (Reaffirmed 2005))

Nominal Thickness	Tolerance (Diagonal)	
	Up to and including 3 m	Above 3 m
3	+1 / -2	-
4.0	+1 / -2	-
5.0	+2 / -2	-
6.0	+2 / -2	-
8.0	+2 / -3	+3 / -4
10.0	+2 / -3	+3 / -4
12.0	+3 / -3	+4 / -4
15.0	+3 / -3	+4 / -4
19.0	+5 / -5	+6 / -6

2.2.4 Glass Edge Finish :

Edge damage usually occurs when cutting the glass (difficulty increases with thickness) and during grinding of glass. There are no standard acceptance criteria for the edge condition of the glass. Glass with edges that are severely cut, damaged or have deep, pointed shells/vents is generally not acceptable. The glass edge finish should be in accordance with Table 2.4.

Table 2.4: Glass Edge Finish :

SNo.	Usage Typ	Finish	Allowable Defects
1	Exposed edges	Neatly polished, straight line	Small glass fragment normally conchoidal $\leq$2mm
2	Silicon or butt joint	Visible line should be straight	Small glass fragment – normally conchoidal $\leq$2mm
3	Concealed edge	Rough grinding without chips and defects	Small glass fragment – normally conchoidal $\leq$3mm

2.2.5 Warpage and Bow

The allowed warpage and bow tolerance should be in accordance with Table 2.5

Table 2.5: Warpage and Bow Tolerance Limit

Thickness	Sizes	Tolerance%	Maximum
Upto 6mm	<3 m	0.3	6 mm
Upto 6mm	>3 m	0.3	8 mm
Above 6mm	<3 m	0.3	6 mm
Above 6mm	>3 m	0.3	10 mm

Closer tolerances may be required for glasses having thickness greater than 6 mm in butt jointed applications like partitions. This should be specified by the customer in advance and agreed upon specifically between buyer and seller.

2.2.6 Surface and Body Defects

2.2.6.1 Scratches

Scratches shall be classified into the following categories: light, medium and heavy. The allowed scratches should be in accordance with Table 2.6.

Table 2.6: Visual Limits for Scratches :

S No.	Intensity and Size	Definition	Number/sqm
1	Light Scratch	Shall not be detectable beyond 50 cm	Any number
2	Medium Scratch (should not be more than 15.0 mm)	Visible up to 50 - 100cm, not visible beyond 100 cm	2
3	Heavy Scratch Max 10 mm	Visible up to 150cm, not visible beyond 150 cm	1

2.2.6.2 Bubbles / Spots / Stones

The allowed number of bubbles / spots / stones should be in accordance with Table 2.7.

Table 2.7: Bubbles / Spots / Stones Visual Limit

	Defect Size (Diameter(d))	No of Defects
All Thicknesses	d < 0.5mm	2/sqm
	0.5 < d < 1.0mm	1/sqm
	> 1.0mm	Nil
Observation distance 50 cm		

3. COATED GLASS :

3.1 Basic Definitions :

3.1.1 Coated Glass :

Glass substrate as defined in 2.1 to which a coating has been applied, as defined in 3.1.2 in order to modify one or more of its properties.

3.1.2 Coating :

One or more thin solid layers of inorganic materials applied on to the surface of a glass substrate by various methods of deposition.

3.1.3 On-Line Coating :

The treatment of the surface of a moving continuous ribbon of a basic glass, at a stage during its manufacture, before it is cut.

3.1.4 Off-line Coating :

The application of a coating to individual pieces of glass within a manufacturer's or processor's premises.

3.1.5 Additive Methods of Deposition:

Single or multilayer systems (consisting of metals, oxides, nitrides, fluorides or other compounds) added to the surface of the glass by different methods.

3.2 Definitions of Appearance Defects :

3.2.1 Uniformity Defect :

Slight visible variation in colour, either in reflection or transmission, within a coated glass pane or from pane to pane.

3.2.2 Stain :

Defect in the coating larger than punctual defect, often irregularly shaped, partially of mottled structure.

3.2.3 Punctual Defect :

Punctual disturbance of the visual transparence looking through the glass and of the visual reflectance looking at the glass. (Spots, pinholes and scratches are types of punctual defects.)

3.2.3.1 Spot :

Defect that commonly looks dark against the surrounding coating, when viewed in transmission.

3.2.3.2 Pinhole :

Punctual void in the coating with partial or total absence of coating and it normally contrasts as clear relative to the coating, when viewed in transmission.

3.2.3.3 Scratch :

Variety of linear score marks, whose visibility depends on their length, depth, width, position and arrangements.

3.2.4 Cluster:

Accumulation of very small defects giving the impression of stain.

3.3 Appearance :

3.3.1 General :

The defects affecting appearance are:

- Specific to the glass substrate (see 2.6), and
- Specific to the coating.

If a defect specific to the glass substrate is more visible because of the coating, it will be treated as a coating defect.

3.3.2 Detection of Defects :

The defects are detected visually by an observation of the coated glass in transmission and/or reflection. An artificial sky or daylight may be used, as the source of illumination. Daylight illumination is a uniform overcast sky, without direct sunlight.

3.3.3 Conditions of Examination :

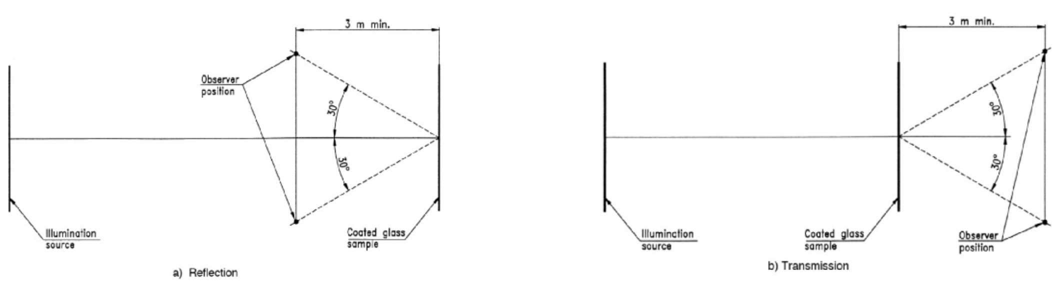
3.3.3.1 General :

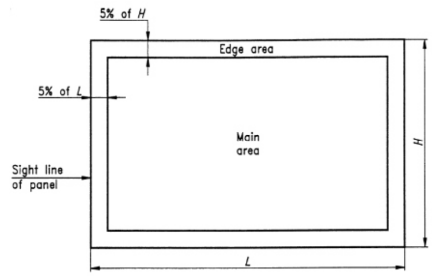
Coated glass may be examined in stock size plates or in finished sizes ready for installation. The examination may be undertaken in the factory or on site when glazed.

The pane of coated glass being examined is viewed from a minimum distance of 3 meters. The actual distance will be dependent on the defect being considered and which illumination source is being used. The examination of the coated glass in reflection is performed by the observer looking at the side which will be the outside of the glazing. The examination of the coated glass in transmission is performed by the observer looking at the side which will be the inside of the glazing.

During the examination the angle between the normal to the surface of the coated glass and the light beam proceeding to the eyes of the observer after reflection or transmission by the coated glass shall not exceed 30° (see Figure 1).

Figure 1: Schematics of Examination Procedures





For panes of coated glass in finished sizes ready to be installed both the main area and an edge area of the pane shall be examined (see Figure 2).(Each examination will take no more than 20 seconds)

Figure 2: Areas to be Examined on Finished Sizes Ready for Glazing

3.3.3.2 Uniformity Defects and Stains :

Under the conditions of examination, given in 3.3.3.1, note any coating variations either within one pane or between neighbouring panes which are visually disturbing.

3.3.3.3 Punctual Defects :

Under the conditions of examination, given in 3.3.3.1, note any spots, pinholes and/or scratches that are visually disturbing. For spots and pinholes measure the size and note the number relative to the size of the pane. If any clusters are found, their position relative to the through vision area shall be determined.

For scratches determine whether they are in the main or edge area. Measure the length of any scratches noted. For scratches greater than 75 mm long determine the distance between adjacent scratches. For scratches less than 75 mm long note any area where their density produces visual disturbance.

3.3.4 Acceptance Criteria of Coated Glass Defects :

The acceptance criteria for defects in coated glass, examined according to 3.3.3, are given in Table 3.1.

Table 3.1: Coated Glass Acceptance Criteria

Defect Types	Acceptance Criteria		
	Pane / Pane	Individual Pane	
		Main Area	Edge Area
Uniformity / Stain			
	Allowed as long as not visually disturbing	Allowed as long as not visually disturbing	
Spots / Pinholes			
> 3mm	Not Applicable	Not allowed	Not allowed
> 2mm and ≤ 3mm	Not Applicable	Allowed if not more than $1/m^2$	Allowed if not more than $1/m^2$
Clusters			
	Not Applicable	Not allowed	Allowed as long as not in area of through vision
Scratches			
> 75mm	Not Applicable	Not allowed	Allowed as long as they are separated by > 50 mm
≤ 75mm	Not Applicable	Allowed as long as local density is not visually disturbing	Allowed as long as local density is not visually disturbing

4. TOUGHENED / TEMPERED GLASS :

4.2.2 Dimensions and Squareness :

Tolerance limits for dimensions for rectangular glass panes are given in Figure 1 and tolerances on width and length should be in accordance with Table 4.1.

Figure 4.1: Tolerance Limits for Dimensions of Rectangular Panes

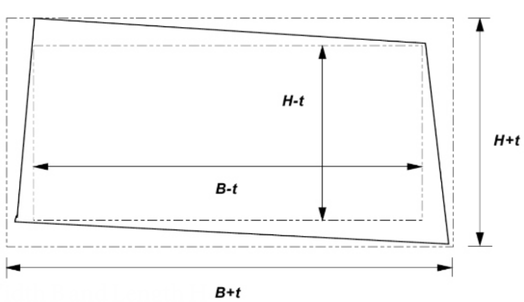


Table 4.1: Tolerances on W

(All dimensions are in millimeters and as per EN12150-1 June 2000)

Nominal Dimension of Side, B or H	Tolerance, t	
	Nominal Glass Thickness d $\leq$ 12	Nominal Glass Thickness d > 12
$\leq$ 2000	2.5	3.0
2000 < B or H $\leq$ 3000	3.0	4.0
> 3000	4.0	5.0

4.2.3 Holes and Cutouts

4.2.3.1 Hole Dimensions

The allowable hole diameter tolerance should be in accordance with Table 4.2.

Table 4.2: Tolerances on Holes :

(All dimensions are in millimeters)

	Hole Diameter Range	Dimensional Tolerance
All Thicknesses	4 to 20	± 1
	21 to 100	± 2
	Above 100	Consult the Manufacturer

4.2.3.2 Hole and Cutout Location :

The allowed hole and cutout location tolerance should be in accordance with Table 4.3.

Table 4.3: Tolerances on Hole and Cutout Location
(All dimensions are in millimeters)

All Thicknesses	For holes tolerance should be from centre of hole	± 1.5mm
	For cutouts tolerance should be from edge	± 1.5mm

4.2.4 Glass Edge Finish :

Edge damage usually occurs when cutting the glass (difficulty increases with thickness) and during grinding of glass. There are no standard acceptance criteria for the edge condition of the glass. Glass with edges that are severely cut, damaged or have deep, pointed shells/vents is generally not acceptable. The glass edge finish should be in accordance with Table 4.4.

Table 4.4: Glass Edge Finish :

S.No.	Usage Type	Finish	Allowable Defects
1	Exposed edges	Neatly polished, straight line	Small glass fragment normally conchoidal $\leq$2mm
2	Silicon or butt joint	Visible line should be straight	Small glass fragment normally conchoidal $\leq$ 2mm
3	Concealed edge	Rough grinding without chips and defects	Small glass fragment normally conchoidal $\leq$3mm

4.2.5 Flatness

4.2.5.1 General Information :

By the very nature of the toughening process, it is not possible to obtain a product as flat as annealed glass. The difference depends on the nominal thickness, the glass size dimensions and the ratio between the dimensions. Therefore a distortion known as overall bow can occur. There are two kinds of bow - (See Figure 4.3)

- Overall or general bow
- Local bow

Note 1: Overall bow can, in general, be accommodated by the framing system.

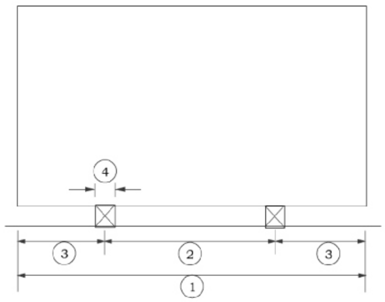
Note 2: Local bow needs to be allowed for in the glazing materials and the weather seals. For special requirements the manufacturers should be consulted.

4.2.5.2 Measurement of Overall Bow :

The pane of glass shall be placed in a vertical position and supported on its longer side by two load bearing blocks at the quarter points (see Figure 4.2). The deformation shall be measured along the edges of the glass and along the diagonals, as the maximum distance between a straight metal ruler, or a stretched wire, and the concave surface of the glass (see Figure 4.3). The measurement should be done at room temperature.

The value for the bow is then expressed as the deformation, in millimeters, divided by the measured length of the edge of the glass, or diagonal, in millimeters, as appropriate.

Figure 4.2: Support Conditions for Measurement of Overall Bow

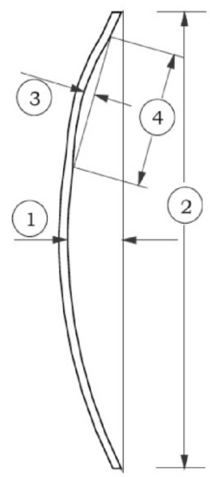


(1) B or H
(2) (B or H)/2
(3) (B or H)/4
(4) maximum 100mm

Figure 4.3: Representation of Overall and Local Bow

1. Deformation for calculating overall bow
2. B or H, or diagonal length
3. Local bow
4. 300mm length

Figure 4.3



4.2.5.3 Warpage and Bow Tolerances

4.2.5.3.1 Overall Bow Tolerances

The allowed warpage or overall bow tolerance should be in accordance with Table 4.5.

Table 4.5: Overall Bow (Bend) Tolerance Limit

Thickness	Up to 1.2 m	1.2 to 2.5 m	2.5 to 3.05 m	3.05 to 3.66 m	Above 3.66 m
4mm	4mm	4mm	6mm	NA	-
5mm	3mm	4mm	5mm	7mm	-
6mm	3mm	4mm	5mm	7mm	-
8mm	3mm	4mm	5mm	6mm	10 mm
10mm	3mm	4mm	4mm	5mm	10mm
12mm	3mm	4mm	4mm	5mm	8mm
15mm	3mm	4mm	4mm	6mm	8mm
19mm	3mm	4mm	4mm	6mm	10mm

4.2.5.3.2 Local Bow Tolerances :

Local bow can occur over relatively short distances on the edges of the glass. Local bow shall be measured over a limited length of 300mm by using a straight ruler, or a stretched wire, parallel to the edge at a distance of 25 mm from the edge of the glass (see Figure 4.3).

Local bow is expressed as millimeters / 300 mm length.(For patterned glass, local bow shall be determined by using a straight ruler resting on the high points of the pattern and measuring to a high point of the pattern.)

The maximum allowable values for the local bow, when measured according to 4.2.5.2, for glass without holes and/or notches and/or cutouts are given in Table 4.6.

Table 4.6: Maximum Values for Local Bow :

Toughening Process	Local Bowmm/300 mm
Horizontal	0.5

For horizontal tempering, 200mm from either edge parallel to the roller waves shall be excluded from measurement. This method of measurement may not be applicable for non-rectangular glasses, e.g., triangles and trapezoids.

4.2.5.4 Important Considerations for Optical Distortion:

1. Pressures, exerted around the periphery of glass by the glazing system, can also alter glass flatness thereby distorting reflected images. This is true regardless of whether or not the glass is heat treated.

2. Sealed insulating glass units also exhibit distortion regardless of glass type. Air or gas, trapped in the sealed airspace between the panes, expands or contracts with temperature and barometric changes, creating a pressure differential between the airspace and the atmosphere. The glass reacts to the pressure differential by being deflected inward or outward.

3. Regardless of glass flatness, the degree of reflected distortion perceived is primarily and largely due to the characteristics or symmetry of the object being reflected. Linear objects (such as building curtain walls and telephone poles) and moving objects (such as cars) may appear distorted. Irregular and free-form objects such as trees and clouds will appear to have little perceived distortion.

4. Specified bow and warp limits may not adequately define, or control, the distortion that may become apparent after glazing. The factors, noted above, may have a larger influence on the perceived reflected distortion than that which is caused by bow and warp from the heat-treating process. Consultation with suppliers and the viewing of full-size mockups, under typical job conditions and surroundings, is highly recommended for user or architectural evaluation of the reflective distortion.

4.2.6 Appearance :

For surface and body defects in clear or tinted toughened glasses refer to 2.2.6.

For accepted criteria of coated toughened glasses, refer to 3.3.4 and all conditions mentioned in Section 3: Coated Glass.

4.2.7 Fragmentation Test

4.2.7.1 General

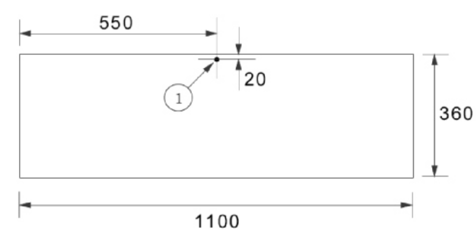
The fragmentation test determines whether the glass breaks in the manner prescribed for a thermally toughened safety float glass. Five specimens shall be tested having dimensions 360 mm x 1100 mm each, without holes, notches or cutouts.

4.2.7.2 Test Procedure :

Each test specimen shall be impacted, using a pointed steel tool, at a position 13 mm in from the longest edge of the test specimen at the mid-point of that edge, until breakage occurs (see Figure 4.4) (The fragmentation characteristics of glass are unaffected by temperatures between –50°C and +100°C) Examples of steel tools are a hammer of about 75 gm mass, a spring loaded centre punch, or other similar appliances with a hardened point. The radius of curvature of the point should be approximately 0.2 mm.

The test specimen shall be laid flat on a table without any mechanical constraint. In order to prevent scattering of the fragments, the specimen shall be simply held at the edges, e.g. by a small frame, adhesive tape etc., so that the fragments remain interlocked after breakage yet extension of the specimen is not hindered. (For thermally toughened safety glass manufactured by vertical toughening, the impact point shall not be on the tong mark edge)

Figure 4.4: Position of Impact Point :

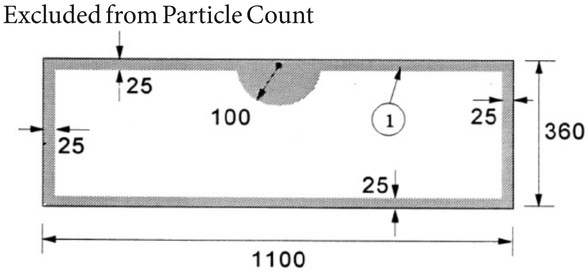


(1) Impact Point

4.2.7.3 Assessment of Fragmentation

The particle count and measuring of the dimensions of the largest particle shall be made between 4 minutes to 5 minutes after fracture. An area of radius 100 mm, centered on the impact point, and a border of 25 mm round the edge of the test specimen (see Figure 4.5), shall be excluded from the assessment.

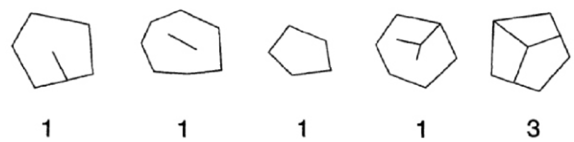
Figure 4.5: Area to be Excluded from Particle Count



(1) Excluded Area

The particle count shall be made in the region of coarsest fracture (the aim being to obtain the minimum value). The particle count shall be made by placing a mask (50 ± 1) mm x (50 ± 1) mm on the test piece. The number of crack-free particles within the mask shall be counted. A particle is 'crack-free' if it does not contain any cracks which run from one edge to another (see Figure 4.6).

Figure 4.6: Examples of Crack-Free Particles and their Number Assessment



In the particle count, all particles wholly contained within the area of the mask shall be counted as one particle each and all the particles which are partially within the mask shall be counted as half particle each (see Figure 4.7 to 4.9).

Figure 4.7: Select Area of Coarsest Fracture

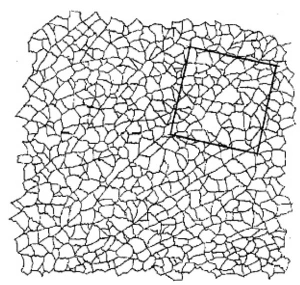
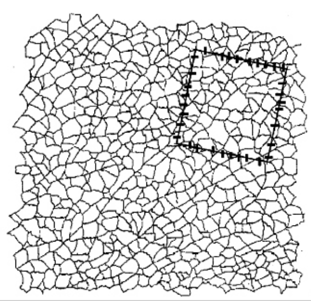
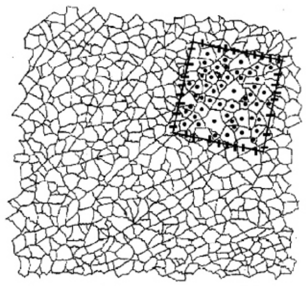


Figure 4.8: Count Perimeter Fragments as 1/2



e.g.: Number of Perimeter Particles = 32/2=16

Figure 4.9: Count Central Fragments and Add to Perimeter Count to Obtain Final Count



e.g.: Number of central fragments = 53, hence total fragments = 16 + 53 = 69

4.2.7.4 Minimum Values from the Particle Count

In order to classify a glass as a fully toughened safety float glass, the particle count of each test specimen shall not be less than the values given in Table 4.7.

Table 4.7: Minimum Particle Count :

Glass Type	Nominal Thickness (mm)	Minimum Particle Count
Float and Drawn Sheet	3	15
	4 to 12	40
	15 to 19	30
Patterned	4 to 10	30

4.2.8 Stress Measurement Test :

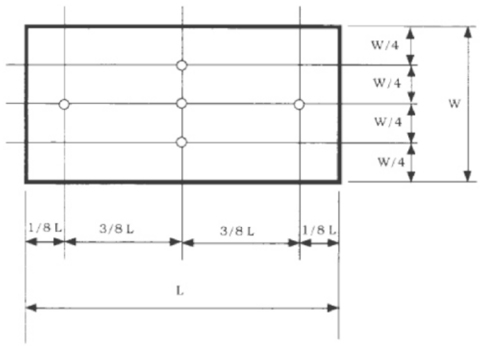
4.2.8.1 General :

Stress measurement is a non-destructive test to check the toughening properties of fully toughened safety float glass. The specimens are examined by the polariscopic or light refraction methods (The most common apparatus to conduct this test is the GASP instrument by Strainoptics Inc. Other methods like DSR may also be used) for surface or edge compression. When the range of the apparatus permits examination for edge compression only, obtain the averaged value for all midpoints of every edge.

4.2.8.2 Test Procedure :

Two surface compression measurements shall be made in each of five locations, oriented in two directions at 90° to each other, for a total of ten readings on each specimen to be tested. Average the ten readings to determine the stress level of the test sample. The five locations to be examined are shown in Fig. 4.10.

Figure 4.10: Five Points to be examined.



4.2.8.3 Assessment of Measurements :

Fully toughened glass shall have either a minimum surface compression of 69 MPa (10,000 psi) or an edge compression of not less than 67 MPa (9,700 psi).

4.2.9 Marking :

Logo position from corner edge (preferably bottom-right) should be preferably 25mm ± 5mm. All float toughened glass should have mark 'TF' along with brand name.

4.3 Other Physical Characteristics :

4.3.1 Anisotropy (Iridescence):

Heat-treated glass (heat-strengthened or tempered) can have an optical phenomenon that is called strain pattern or quench pattern. This phenomenon can appear as faint spots, blotches, or lines. This is the result of the air quenching (cooling) of the glass when it is heat-treated and should not be considered a glass defect.

The heat treatment process results in a higher surface compression directly opposite the air quench, air nozzles or slots. The higher compression areas are denser and can exhibit a darker appearance under some viewing conditions especially when light is polarized, such as a skylight or other forms of reflected light. The colors of the strain pattern are sometimes referred to as iridescent, or the general condition as iridescence. The pattern that is seen under certain lighting conditions may vary from manufacturer, depending on the design of the cooling apparatus. The intensity of the quench or strain pattern is influenced by the viewing angle, lighting conditions and by the perceptiveness of the viewer. It is nearly impossible to eliminate the strain pattern or quench pattern in heat treated glass products.

The presence of a strain pattern or the perceivable differences in the strain pattern is not a glass defect or blemish and is not cause for rejection. In addition, the presence of a strain pattern does not alter the structural integrity or safety of the glass lite.

When viewing from the interior of the building, the quench pattern may be visible from a 10° viewing angle and not apparent at a 90° viewing angle from the surface of the glass. When viewing the glass in reflectance from the exterior of the building, the quench pattern may be visible when looking at the glass surface at a 30-60° angle. Visibility of the quench pattern may be accentuated with thicker glass, tinted glass substrates, coated glass and multiple lites of heat-treated glass in laminated or insulating glass products.

Construction sites may yield viewing angles and conditions that cause the quench pattern to become visible. However, upon completion of construction; the presence of interior walls; finishes; furniture; and plants frequently results in the strain pattern being less visible or not visible at all.

The stresses introduced in the heat-treating of glass are an inherent part of the fabrication process, and while they may be affected or altered depending on the heating process, controls and/or quench design, they cannot be eliminated. Design professionals should be aware that quench patterns are not a defect in heat-treated glass and, therefore, are not a basis for product rejection.

5 HEAT-STRENGTHENED GLASS :

5.2.2 Dimensions and Squareness :

Tolerance limits for dimensions for rectangular glass panes are same as in case of tempered glass (4.2.2)

5.2.3 Holes & Cutouts

5.2.3.1 Hole Dimensions :

Same as in case of Tempered glass (4.2.3.1)

5.2.4 Glass Edge Finish :

Same as in case of Tempered Glass(4.2.4)

5.2.5 Flatness :

Same as in case of Tempered Glass(4.2.5)

5.2.5.4 Important Considerations for Optical Distortion in Heat-Strengthened Glass :

Same as in case of Tempered Glass(4.2.5.4)

5.2.6 Appearance :

For surface and body defects in clear or tinted toughened/Heat Strengthened glasses refer to 2.2.6.
For accepted criteria of coated toughened glasses, refer to 3.3.4 and all conditions mentioned in Section 3: Coated Glass.

5.2.7 Stress Measurement Test

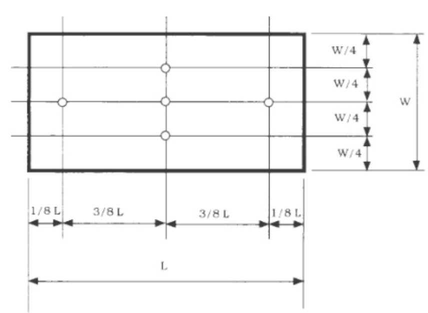
5.2.7.1 General :

Stress measurement is a non-destructive test to check the toughening properties of fully toughened safety float glass. The specimens are examined by the polariscopic or light refraction methods (The most common apparatus to conduct this test is the GASP instrument by Strainoptics Inc. Other methods like DSR may also be used) for surface or edge compression. When the range of the apparatus permits examination for edge compression only, obtain the averaged value for all midpoints of every edge.

5.2.7.2 Test Procedure :

Two surface compression measurements shall be made in each of five locations, oriented in two directions at 90° to each other, for a total of ten readings on each specimen to be tested. Average the ten readings to determine the stress level of the test sample. The five locations to be examined are shown in Fig. 4.10.

Figure 5.4: Five Points to be examined



5.2.7.3 Assessment of Measurements :

Heat-strengthened glass with thicknesses of 6 mm and less (Heat strengthening of glass thicker than 6 mm (1/4 in.) within narrow limits of surface compression is difficult. Consult manufacturer) shall have a surface compression between 24 to 52 MPa (3,500 to 7,000 psi) or an edge compression of not less than 67 MPa (9,700 psi).

5.2.8 Marking :

Logo position from a corner edge (preferably bottom right) should be preferably 25mm ± 5mm. All float heat-strengthened glass should have mark 'HS' along with brand name.

6 INSULATED GLASS :

6.2 Quality Parameters

6.2.1 Thickness

Dual-pane Insulated glass units shall conform to the nominal thickness values specified in Table 6.1.

Table 6.1: Thickness Tolerance of IGU
All dimensions in millimeters

First Pane	Second PaneI	GU Thickness Tolerance
Annealed Glass	Annealed Glass	± 1.0
Annealed Glass	Toughened or Heat-Strengthened Glass	± 1.5
Toughened or Heat-Strengthened Glass	Toughened or Heat-Strengthened Glass	± 1.5

The thickness tolerances of multi-cavity insulating glass units are obtained by using the following rules:
(a) Determine the tolerance of each composition glass/cavity/glass in accordance with Table 6.1;
(b) Calculate the squares of those values;
(c) Sum all those square values;
(d) Calculate the square root of that sum.

6.2.2 Dimensions & Squarness:

Same as in case of Tempered Glass (4.2.2)

6.2.3 Displacement / Mismatch

Displacement/mismatch tolerance between the two glass panes shall be in accordance with Table 6.3.

Table 6.3: Displacement and Mismatch Tolerance Limit

All Thickness	All Available Range of Dimensions	± 2.0

6.2.4 Glass Edge Finish :

Since most insulated glass units are used in applications where edges are either concealed or sealed with secondary sealant, it is generally not required to have glasses with polished or perfectly ground edges. In most cases arising of the edges is generally enough. However, it is recommended to have the edge finish specified as part of the quality contract with the customer.

6.2.5 Sealant Protrusion :

The allowed primary sealant protrusion should be in accordance with Table 6.4 (Although slight variations is butyl application straightness is allowed, it is absolutely critical that there are no breaks in sealant application and the line is continuous, to protect against failures of the insulated unit over its life cycle).

Table 6.4: Allowed Sealant Protrusion

All Thickness	Uniform Application of Sealant	± 2.0

6.2.6 Appearance :
For surface and body defects in insulated glass units consisting of clear or tinted glasses refer to 2.2.6.

For accepted criteria of insulated glass units consisting of coated glasses, refer to 3.3.4 and all conditions mentioned in Section 3: Coated Glass.

6.3 Quality Tests for Insulated Glass Raw Materials

6.3.1 Delta-T Test for Desiccant

This test is used to check the adsorption capacity of desiccants used in insulated glass units.
1. Take room temperature water in a beaker and measure its initial temperature (Ti) and quantity.
2.Add equal quantity of desiccant in milligrams (mg). Now the temperature of water will start rising automatically.
3. Wait till the temperature of water reaches the maximum value.
4. Measure the final temperature (Tf).
5. Calculate $\Delta T = Tf - Ti$. ΔT should be more than 32°C

6.3.2 Tests for Silicon (Two-Part)

It is very important that two part sealant be checked properly to ensure well curing. Improper mixing of silicon will result in adhesion failure and eventually lead to unit failure.

6.3.2.1 Butterfly Test:

The purpose of butterfly test is to check for an adequate mixing of the base and catalyst components. The test is performed by dispensing a bead of sealant on to a piece of white paper and folding the paper in half, smearing down the sealing bead. Then the paper is reopened and inspected visually. This should appear uniform in colour with no white streaks.

6.3.2.2 Peel Adhesion Test :

The purpose of this test is to verify adhesion of sealant to the glass substrate. An adhesive or cohesive failure of silicon with glass substrate can result due to improper curing of silicon or bad raw material quality.

1. Clean and prime the substrate.
2. Place a piece of bond breaker tape across the flat surface.
3. Apply a bead of sealant and tool it to form a strip approximately 20 cm long, 1.5 cm wide and 6 mm thick. At least 4 cm of the sealant should be applied over the bond breaker tape.
4. After sealant cure, grasp the 4 cm tab of sealant which overlays the bond breaker tape. Pull the sealant at a 180° angle. Peel back only 1 to 2 cm of sealant leaving the remainder in place for additional testing.
5.If the sealant tears within itself and remains fully bonded to the substrate, this is called "cohesive failure". 100% cohesive failure is desirable since this indicates that the strength of adhesion is greater than the strength of cohesion.

6.3.3 Butyl Quantity Test

This test is used to calculate the minimum quantity of butyl applied on a spacer. Butyl needs to be applied on spacers in a certain minimum quantity to effectively provide a primary glass to spacer seal.

1. Take a spacer system from running production and extrude butyl under standard production conditions.
2. Remove the butyl from the spacer.
3. Measure the weight of butyl.
4. Measure the length of the spacer system.
5. Calculate the ratio (length:weight) and calculate the weight of butyl per running meter.
6. The butyl quantity should be more than or equal to 2.7 grams per side per running meter.

6.3.4 Tests for Finished Insulated Glass Units

6.3.4.1 Leakage Test

The insulated glass specimen is dropped in a water tank for five minutes. There should be no bubbles appearing in the water tank and no seepage of water inside the insulated glass unit.

6.3.4.2 Dew Point Test

The dew point temperature test is used to check the humidity content in the insulated glass unit air space. A sample is cooled down until condensation (dew) forms on the interior surface. This dew point should be minimum -40°C.

6.3.4.3 Shore A Hardness Test

The insulated glass sample is cured for a total of 24 hours and a Shore A hardness meter is used to check the hardness of the cured silicon sealant. For structural silicon the Shore A hardness reading should be minimum 43.

6.4 Important Considerations for Optical Distortion in Insulated Glass

6.4.1 Interference Colouration

6.4.1.1 Brewster's Fringes

When the glass pane surfaces exhibit near perfect parallelism and the surface quality is high, the insulated glass pane shows interference coloration. These are lines varying in colour as a result of decomposition of the light spectrum. When the sun is the light source, the colours vary from red to blue. This phenomenon is not considered a defect but it is inherent to the insulated glass unit construction.

6.4.1.2 Newton Rings :

This optical effect only occurs in faulty insulated glass units and occurs when the two panes of glass are touching or nearly touching in the centre. The optical effect is a series of concentric coloured rings with the centre being in the point of contact/near contact of the two panes. The rings are roughly circular or elliptical.

6.4.2 Iridescence due to Heat-Treated Glasses :

Some processed glasses also show coloration inherent to the product, e.g. toughened glass and heat strengthened glass. Refer to sections 4.2.9.1 and 5.2.9.1 for details.

6.4.3 Glass Deflection due to Variations in Temperature and Barometric Pressure :

Temperature variations of the space filled with air and/or gas and barometric pressure variations of the atmosphere and altitude will contract or expand the air and/or gas in the cavity and consequently deflections of the glass pane will occur, resulting in distortion of reflected images. These deflections, which cannot be prevented, show variations over time. The magnitude depends partially on the stiffness and size of the glass panes, as well as on the width of the cavity. Small sizes, thick glasses, and/or small cavities reduce these deflections significantly.

6.4.4 External Condensation :

External condensation on insulated glass units may occur either inside or outside the building. When it is inside the building, it is principally due to high humidity in the room, together with a low outside temperature. Kitchens, bathrooms, and other high humidity areas are particularly susceptible. When it is outside the building, condensation is principally due to nocturnal heat loss of the outside glass surface by infrared radiation to a clear sky, together with high humidity, but no rain, in the outside atmosphere. These phenomena do not constitute failures of the insulating glass, but are due to atmospheric conditions.

7 LAMINATED GLASS :

7.2 Quality Parameters :

7.2.1 Nominal Thickness

The nominal thickness of laminated glass shall be the sum of the nominal thickness of constituent panes of glass and interlayer material.

The thickness of the pane shall be calculated as the mean of measurements taken at the centers of the four sides. The measurements shall be taken to an accuracy of 0.01mm and the mean is then rounded to the nearest 0.1mm. The individual measurements when rounded to the nearest 0.1mm shall also be within the limit deviation.

7.2.2 Dimensions :

Tolerance limits for dimensions for rectangular glass panes are given in Figure 6.1 and tolerances on width and length should be in accordance with Table 7.1.

Figure 7.1: Tolerance Limits for Dimensions of Rectangular Panes :

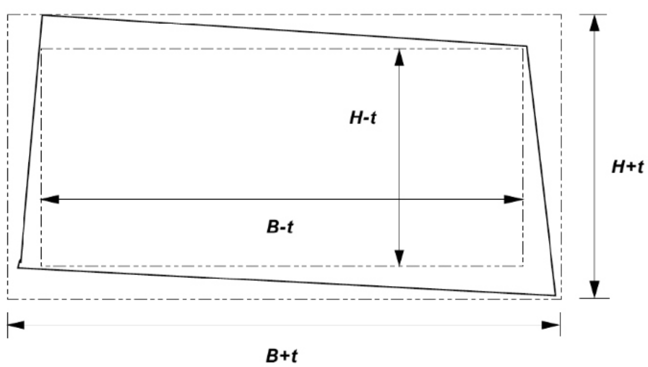


Table 7.1: Tolerances on Width B and Length H
(All dimensions are in millimeters and as per EN12543-5: 1998)

Limit Deviations t on Width B or Length H			
		Nominal Glass Thickness d > 8 mm	
Nominal Dimension of Side, B or H	Nominal Glass Thickness d ≤ 8 mm	Each Glass Pane At < 10 mm Thickness	Least One Glass Pane ≥ 10 mm Thickness
< 1100	+2 / -2	+2 / -2	+3 / -2.5
< 2440	+3 / -2	+3 / -2	+4 / -3
> 2440	+4 / -3	+4 / -3	+4.5 / -4

7.2.3 Displacement :
Displacement is the misalignment at any one edge of the constituent glass panes making up the laminated glass. The maximum allowable displacement is as given in Table 7.2.

Table 7.2: Maximum Displacement in Laminated Glass
(All dimensions are in millimeters and as per EN12543-5: 1998)

Nominal Dimension of Side, B or H	Maximum Permissible Displacement
B, H $\leq$ 1000	2.0
1000 < B, H $\leq$ 2000	3.0
2000 < B, H $\leq$ 4000	4.0
B, H > 4000	5.0

7.2.4 Glass Edge Finish:
Once the glass is toughened or heat-strengthened, it shall not be edge-worked after making into a laminate. These panels need to be individually worked upon before toughening and then assembled into a laminate.
For details of acceptable edge finishes refer to the relevant toughened and heat-strengthened standards (4.2.4 and 5.2.4 respectively).

7.2.5 Appearance
7.2.5.1 Common Definitions
7.2.5.1.1 Spot Defects

This type of defect includes opaque spots, bubbles and foreign bodies.

7.2.5.1.2 Linear Defects
This type of defect includes foreign bodies and scratches or grazes.

7.2.5.1.3 Other Defects
Glass defects such as vents and interlayer defects such as creases, shrinkage and streaks.

7.2.5.1.4 Opaque Spots
Visible defects in the laminated glass (for e.g., tin marks, inclusions in the glass or interlayer).

7.2.5.1.5 Bubbles
Usually air bubbles, these can be in the glass or in the interlayer.

7.2.5.1.6 Foreign Bodies
Any unwanted item introduced into the laminated glass during manufacture.

7.2.5.1.7 Scratches or Grazes
Linear damage to the outside surface of the laminated glass.

6.2.5.1.8 Vents
Sharp tipped fissures or cracks running into the glass from an edge.

7.2.5.1.9 Creases

Distortions introduced into the interlayer by folds visible after manufacture

7.2.5.1.10

Streaks due to Interlayer Inhomogeneity:

Optical distortions in the interlayer that are caused by manufacturing defects in the interlayer, and are visible after manufacture.

7.2.5.1.11 Edge Area

For panes sizes ≤ $5m^2$ the width of the edge area is 15 mm. The edge area width is increased to 20 mm for pane sizes > $5m^2$.

7.2.5.1.12 Vision Area

The area outside of the edge area is called as vision area.

7.2.5.2 Test Method for Inspection

The laminated glass to be observed is put in a vertical position, in front of and parallel to a matt grey screen, lit by diffused daylight or equivalent. The observer will be at a distance of 2 meters from the glass and shall observe it perpendicularly (the matt screen being on the other side of the glass). Defects that are disturbing when viewed shall be marked.

7.2.5.3 Defects in the Vision Area

7.2.5.3.1 Spot Defects in the Vision Area

When inspected according to the test method stated in 7.2.4.2, the admissibility of spot defects depends on the following:

- Size of the defect
- Frequency of the defect
- Size of the pane
- Number of panes as components of a laminated glass.

This is expressed in Table 7.3.

Table 7.3: Permissible Spot Defects in the Vision Area

Size of Defect d in mm		0.5 < d ≤ 1.0	1.0 < d ≤ 3.0			
Size of Pane A in m2		For all Sizes	A ≤ 1	1 < A ≤ 2	2 < A ≤ 8	A > 8
Number of Allowed Defects	2 Panes	No limitation, however no accumulation of defects	1	2	1 / m^2	1.2 / m^2
	3 Panes		2	3	1.5 / m^2	1.8 / m^2
	4 Panes		3	4	2 / m^2	2.4 / m^2
	≥5 Panes		4	5	2.5 / m^2	3 / m^2

Defects less than 0.5 mm are not considered and defects greater than 3 mm are not permitted (Admissibility of spot defects in laminated glass is independent of the individual glass thickness.)

An accumulation of defects occurs if four or more defects are at a distance of < 200 mm from each other. This distance is reduced to:

- 180 mm for laminated glass consisting of three panes,
- 150 mm laminated glass consisting of 4 panes, and
- 100 mm laminated glass consisting of five or more panes.

The number of permissible defects in Table 7.1 shall be increased by 1 for each individual interlayer which is thicker than 2 mm.

7.2.5.3.2 Linear Defects in the Vision Area
When inspected according to the test method given in 7.2.4.2, the linear defects are allowed as given in Table **Table 7.2:** Number of Permissible Defects in the Vision Area

Area of Pane	Number of Permissible Defects $\geq$ 30 mm in Length
$\leq 5\ m^2$	Not Allowed
5 to 8 m^2	1
$> 8\ m^2$	2

Linear defects less than 30 mm in length are allowed.

7.2.5.4 Defects in the Edge Area for Framed Glasses
When inspected according to the test method stated in 7.2.4.2, defects which do not exceed 5 mm in diameter are permitted in the edge area. If bubbles are present, the bubbled area shall not exceed 5% of the edge area.

7.2.5.5 Vents
Vents are not permitted.

7.2.5.6 Creases and Streaks
These are not allowed in the visual area.

7.2.5.7 Defects on Edge which will not be Framed
Laminated glass is usually installed in frames; when it is unframed, its edges may be
- ground edges,
- polished edges, or
- bevelled edges.

In such conditions shells, bubbles, interlayer defects and retractions are permissible if they do not become obvious when subjected to the test method in 7.2.4.2.

7.2.6 Tests for Finished Laminated Glass Units
7.2.6.1 Sampling Plan for Laminated Safety Glass
Test specimens should be representative of standard production. Test specimens should either be specially manufactured to the test size or be cut from larger panes. Test specimen with cut edges should contain at least

one edge from the original pane from which it was cut. If the final product has all its edges sealed/protected then the test specimen should also have all its edges sealed/protected.

The method of supporting the test specimen shall not cover two edges of the test specimen. If the test specimen is cut from a larger pane at least one original edge shall not be covered.

Inspect the samples prior to the test at a distance between 30 cm and 50 cm in front of a white diffuse background. Only samples free of faults (bubbles, delamination, cloudiness) shall be used for the test.

7.2.6.2 Boil Test

7.2.6.2.1 Principle

This test is used to determine whether the laminated safety glass will withstand exposure to high temperatures over an extended period of time without its properties being substantially altered.

7.2.6.2.2 Procedure

Three test specimens of size 100 X 300 mm shall be used.

Immerse all the three test specimens vertically, supported on its edge (The specimen shall be kept in the vessel of boiling water in such a way as not to touch the bottom of the testing vessel directly. A suitable arrangement may be used) first in water at 65 ± 2°C for three minutes and then immediately in boiling water for two hours.

7.2.6.2.3 Interpretation of Results

The samples are removed from the boiling water bath and inspected between 30 and 50 cm in front of a white diffuse background.

Record the number and extent of the faults occurring in the interlayer (bubbles, delamination and cloudiness, but not discolouration) for each test specimen. Disregard all faults within 15 mm from an original edge and 25 mm from a cut edge. (If wire or mesh inlays are used, individual bubbles in the immediate vicinity of inlaid wires are permissible).

Delamination taken as a criterion for evaluation after the boil test, may be described as essentially a two dimensional phenomena, in the interface between the glass and the interlayer, in which area no adhesion exists.

7.2.6.2.4 Acceptance Criteria :

No faults (bubbles, delamination, cloudiness) shall be found in the three test specimens, as per the interpretation criteria mentioned in 7.2.5.1.3. If faults are found in only one test specimen, a further test may be carried out on three new test specimens, in which case no faults shall be found in any of these test specimens.

7.2.6.3 Humidity Test

7.2.6.3.1 Principle

This test is used to determine whether the laminated safety glass will withstand exposure to atmospheric humidity over an extended period of time without its properties being substantially altered.

7.2.6.3.2 Procedure

Three test specimens of size 100 X 300 mm shall be used.
Keep all the three test specimens vertically, supported on its edge, over water in a closed container. The air temperature within the container should be maintained within the limits of 50°C.

7.2.6.3.3 Interpretation of results
The samples are removed from the boiling water bath and inspected between 30 and 50 cm in front of a white diffuse background.

Record the number and extent of the faults occurring in the interlayer (bubbles, delamination and cloudiness, but not discolouration) for each test specimen. Disregard all faults within 15 mm from an original edge, 25 mm from a cut edge or 10 mm from any crack.

Delamination taken as a criterion for evaluation after the humidity test, may be described as essentially a two dimensional phenomena, in the interface between the glass and the interlayer, in which area no adhesion exists.

7.2.6.3.4 Acceptance Criteria
No faults (bubbles, delamination, cloudiness) shall be found in the three test specimens, as per the interpretation criteria mentioned in 7.2.5.2.3. If faults are found in only one test specimen, a further test may be carried out on three new test specimens, in which case no faults shall be found in any of these test specimens.

7.2.6.4 Fracture and Adhesion Test
7.2.6.4.1 Principle :
The purpose of this test is to test the integrity of the laminated glass sample when subjected to external forced impact. The laminated safety glass is given a sudden punch and fragments from the under-surface are collected and weighed.

7.2.6.4.2 Procedure :

A hardened steel wall with a diameter of 38 mm and weighing about 225 g shall be used for the test. A square hard wood frame shall be constructed so that when the test specimen rests symmetrically on the frame, 290 X 290 mm of the specimen shall remain unsupported. The frame shall be rigidly mounted on a 12 mm steel plate and the screws or bolts used for attaching it to the steel plate shall not project below the under-surface of the plate. The complete frame shall stand upon a substantial concrete bed.
A means for dropping the ball freely from a height of 4.88 meters shall be provided such that it strikes the specimen within 25 mm from its centre. (An electro-magnet may conveniently be used for this purpose.)

Ten specimens of 300 X 300 mm shall be tested. Prior to the test each specimen shall be weighed. The specimens shall be kept at 27 ± 2°C for four hours immediately preceding the test. Each specimen in turn shall be supported on the wooden frame in such a way that the plane of the test specimen when in the frame shall be substantially horizontal. The ball shall be dropped as described above. The fragments from the under-surface of each specimen shall be separately collected and weighed.

7.2.6.4.3 Acceptance Criteria :

The test specimens shall be deemed acceptable if out of the ten specimens tested:

1. the number of specimens shown to be pierced (The specimen will be deemed to have been pierced if a split or tear exceeding 38 mm in length develops in the interlayer) in the test does not exceed four, of which not more than two are brittle, (A pierced specimen shall be deemed to be brittle if the breaks into two or more large pieces, or if the fracture is sufficient to allow the ball to pass through) and
2. if the total weight of the fragments from the underside of the unpierced specimens does not exceed 0.5 percent of the total weight of these unpierced specimens, and
3. if no unpierced specimen yields any fragment which individually weighs more than 0.5 grams.

SECTION-4, GENERAL

This section is a general reference section for understanding the general terms, phrases, definition & vocabulary used in glass and glazing.

Section Contents :

GENERAL AVAILIBILTY N LIMITATIONS

Availability of sizes:

Normal Sizes: Glass up to an area of 6 sq.m and both dimensions less than 3.66m are considered normal sizes.

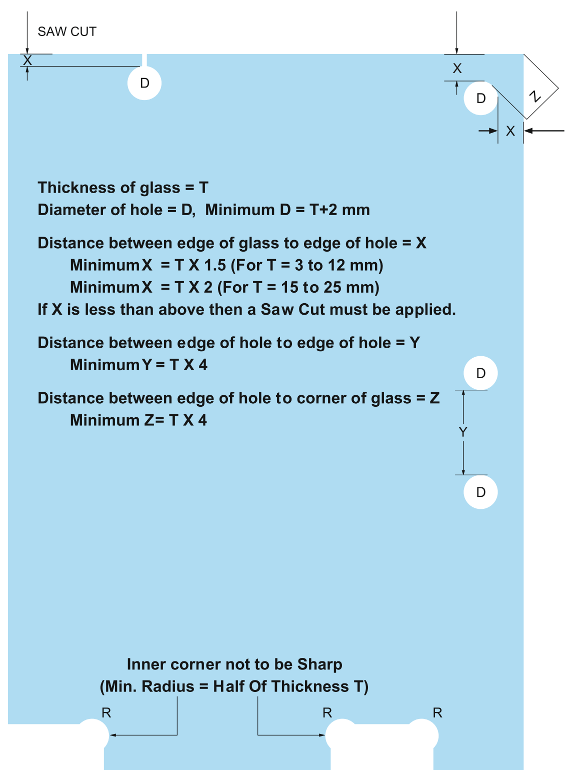
Small sizes: The smallest size of tempered glass is generally 250mm. Lamination and double glazing should be with one dimension of at least of 350mm. these are common limitations on small sizes but some processors have the capability to produce sizes smaller than these.

Large sizes: Glasses bigger than normal sizes as above and up to 2440 x 3660mm or (8x12ft) are considered large glasses. These glasses are marginally higher priced than normal sizes but are commonly available with most float manufacturers and glass processors for tempered, laminated and Double-glazed units.

Extra Large and Jumbo sizes: Glasses of size more than 2440 x 3660mm are considered Jumbo sizes and have a limited availability and very high prices. There are critical problems with transportation, loading, unloading and handling within the processing factories and at site involving huge risks and costs. It should be avoided unless the project requirement is very rigid. A few processors can make jumbo glasses with limitation on one dimension or the other. While processing of Jumbo glasses may be possible, tinted and coated float glasses are not generally not available for processing.

Special processes: Some of the processes like ceramic printing or decoration may have limitation on maximum size of process and need to be examined in advance while designing.

Holes and Cutouts: Holes and countersunk holes with diameters of up to 35 mm and cutouts for glass doors and showers are considered normal holes. Countersunk holes are generally treated at par with cutouts. Larger holes and cutouts are possible with most processors but are considered special and priced higher. There are some minimum distances between holes and the edges and these have to respected for structural stability of the glass. Please see diagram

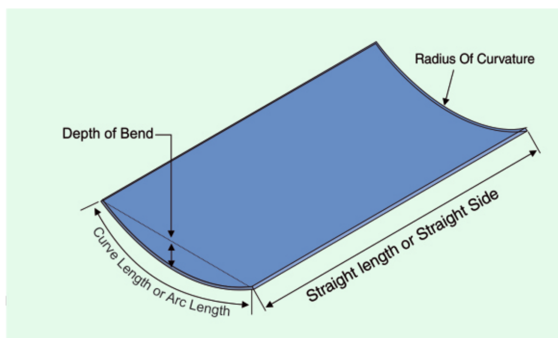


Bent glasses: Unless specified, most glasses are considered to be flat glasses. While designing with curved glasses, special attention has to be paid on what king of curve is possible and limitation on sizes and extent or depth of curvature.
Some of the curvature types are given in the diagram and are briefly described for possibilities below:

Cylindrical

Cylindrical bends and parellograms: Are one-side curvatures and generally possible with tempered, laminated as well as double glazed units. Glasses with radius of curvature less than 2000mm (2000R) are considered tight bends for tempered glass and are uncommon and difficult.
Laminated glass with both glasses tempered is manageable with thickness of both glasses as 6mm and radius of curvature more than 6000R.
Tighter bends are possible with annealed laminated glass but the total depth of bend is generally limited to less than 500mm.
Double glazed units with normal spacers are possible above 6000R. for tighter radius, special spacers and special platen press has to be used but feasible.

Parallelogram



Sketch of Bent Tempered Glass

Conical, spherical and special shapes: are possible with annealed bent glass or with annealed bent laminated glass. Special moulds have to be made for each curvature. The process is very time consuming, complicated and expensive but achievable. Depth of bends have to generally below 500mm.

Conical

Spherical

Other Special Shape

Important Considerations While Ordering Glass

Application: It is important to mention the end application of glass whether it is to be glazed in a window or frameless door or partition or curtain wall, structural glazing, a shelf, table top etc.

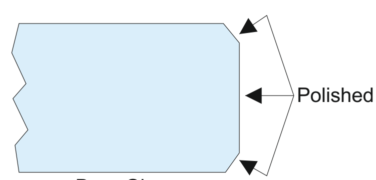
Glass construction: Has to given clearly and completely with details as explained in examples. In most cases one type of glass construction will have multiple sizes and glasses. It is advisable to give full description of glass in a header and all sizes should be given as a list and preferable in an excel sheet as most suppliers will be able to import these directly into their software for production to achieve time saving and accuracy.

Starting from outside or seeing from outside: We should always specify the glass as seen from outside and all glasses in a glass construction as proceeding from first glass outside to last glass inside while addressing all the situations and mediums coming between these glasses. *See examples*

Height and Width: Most glasses are glazed vertically in the buildings and therefore, it is important to specify height and width dimensions as 'H and W' rather than L x B. This is of particular importance for tempered glass, as it has to be uniformly tempered with roller waves horizontal to the ground. All sizes in an order should be uniformly written as 'H' for first dimension and 'W' for second dimension and then no. of glasses for this size. We should use separate cells for each of these. For horizontally glazed glasses as in shelves and tabletops, the expression 'L' and 'B' may be used.

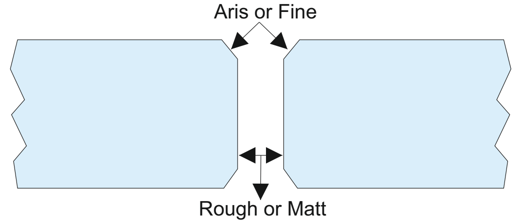
Drawings, Sketches and templates: For non-rectangular glasses, drawings, sketches or templates may be needed and it is important to mention in the order that glass is to be made as per a specified template, drawing or sketch appropriately numbered or marked. Drawings, sketches or templates are also necessary where there are holes, cutouts, printing, decoration etc. on glass. Whenever there is duplicate information e.g. there is a drawing and a template, it is important to write whether to follow the drawing or the template.

Concept drawings and proposals: Sometimes it is easier and advisable to send a concept drawing or sketch to the glass processor and ask him to propose the division between glasses and send counter proposal for an economical and functional solution.



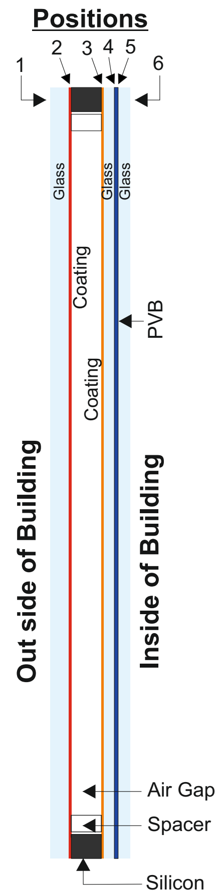
Door Glass

Edges exposed or no: Many applications will have the entire thickness of the edge exposed and such edges need to be polished and must be mentioned specifically. Wherever there is a 'glass to glass' butt joint or structural silicon glazing, what is seen or exposed, is the line of the edge and not the whole thickness of the edge. Such edges should have a neat arise and the thickness of the edge should be rough or matt finish for better adhesion to silicon.



Butt Joint

Symmetric and non symmetric: Certain glasses are symmetric where it does not matter whether these are glazed with either surface to the exterior. Typical example is a clear or tinted rectangular flat glass whether annealed, tempered, laminated or double-glazed with both glasses identical. The situation will change when one or more glasses have a coating, ceramic printing, etching, decoration etc. Also of the two glasses in a DGU are dissimilar in any manner. For such glasses, it is important to know how it is glazed. Some patterned or figured glasses will have a design, which is not rotatable, and this aspect must also be considered while ordering.



Sequencing outside to inside: While ordering for DGU or multiple glass combinations or glasses with coatings, it is important to describe the glass combination starting from outermost glass to finish at the innermost glass. For coated glasses, it is important to specify the coating position. When making elevation drawings or sketches or templates, it is important to mention “as seen from outside” on the face of the template or on the elevation. The glass in the example diagram should be written as:
8mm Green coated tempered glass (make) with coating on position # 2 + 15mm Air Gap + Laminated glass [5mm Clear Low-W coated heat strengthened glass (make) with coating on pos#3 + 1.14mm PVB + 5mm clear heat strengthened glass]
Also mention if some colored spacer or special spacer is used or silicon bite is more than 4mm standard or acoustic PVB in place of standard PVB is used.

Location of logo: Most processed glasses are marked with a non-erasable logo indicating the type of glass and processes. These markings are mandatory and also important for traceability in case of a problem or failure. The location of such marking or logo on glasses should also be prescribed or marked in the drawings.

Numbering matrix or logical referencing: While ordering the glasses, one must give a proper reference or code no. for the glasses with reference to their intended location of glazing on site. The supplier should be instructed to mark these on the glasses to enable easy sorting and fixing on site. This numbering should be logical and easily understandable by the supplier as well as people working on site. One can choose the matrix of a spreadsheet or floor #, Room # and location # assuming a clockwise or anticlockwise logic uniformly.
Many a times, there are different sizes of the same glass combination or construction in an order. In some cases the sizes are similar but vary only slightly say 3 to 6 mm. On receiving these glasses at the site, it is quite common that the glass intended for one location is fitted on another location. For example a smaller glass may be fit into a larger window but the larger glass intended for this window, will not go into the smaller window, whose glass is already fitted into larger window.

General Precautions & Maintenance

GENERAL PRECAUTIONS

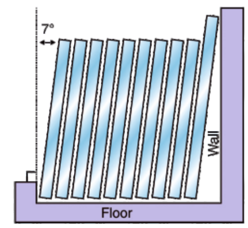
When using glass that is neither Tempered nor Heat Strengthened:

• Maintain ample space between the surface of glass, thick curtains or blinds.

• The glass surface should not be painted or coated with paper.

• Glass edges should be neatly cut or preferably grind the edges.

• Patterned or figured glass becomes dirty easily. Glaze the patterned side facing inside.



• Stacked glass should be up against a sturdy support and rest at an angle of approximately 7° from vertical.
• Protect all edges from impact and use a clean dry separating material.

With Reflective or Low-E glass:

• Cover the surface having a solar reflective or Low-E coating before painting the windows or during general construction work to prevent from mortar and other contaminants sticking to it.

With all type of glass:

• There should be no glass to metal contact.

• Glasses with holes should use nylon bushes between hole and screws or bolts.

• No site alterations should be tried with tempered or heat strengthened or IG units and their measurements, drawings or templates should be carefully planned in advance.

With Insulating glass units:

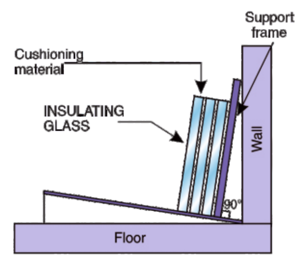
• The two panes of double glazing should be evenly supported on setting blocks inside the sash.

• For use at altitude of more than 1000m, pressure equalization is necessary before installation.

With Laminated and Insulated glass:

• Prolonged exposure to water at the edges will damage the sealants and PVB. Use proper setting blocks and adequate weep holes for draining accumulated water.

• Handle the edges carefully.



MAINTENANCE

In order to preserve its main functions, viz. transparency, performance, aesthetic aspect, all glass must be looked after carefully.

Storage, Handling & Transport: The glass must be protected against all risks of chemical or mechanical damage. Therefore, it has to be unpacked immediately upon delivery, washed and dried if humid, stored in a covered, dry and ventilated area. It has to be stored with a slope of approx. 7° from vertical, on stillages covered with soft material (felt or neoprene), in packs not exceeding 30 cm thick, the panes being separated from each other by means of interleaving material (paper, wood laths, etc.)

At the bottom, the glass panes have to be placed carefully against each other or against the interleaving material, so as to have all the same inclination. Insulating glazing units have to be stored on stillages, the base of which has to be perpendicular to the glazing. Glass must always be handled and transported vertically.

During site work: During glazing operations and until the end of the site work, the glass surface must be protected against chemical and mechanical aggression. Any pollution must be eliminated immediately.

Cleaning after end of site work:
Immediately upon end of site work, the glass must be thoroughly and carefully cleaned. This is specially important where reflective glass is concerned, which has an aesthetic function, but also specific light and energy characteristics, directly related to the cleanness of its surface. The cleaning at end of site work starts with sprinkling with clear water in order to eliminate abrasive dust from the facade. Then follows a normal cleaning.

Normal cleaning:
All glass must be periodically cleaned by means of mild cleaning products, which must be used in a solution of 5 to 8 pH. They must be free of abrasive components and fluorides. Tools may scratch the glass surface. All the glass surface must be dried immediately upon cleaning. The frequency of cleaning depends on the exterior environment, i.e. on the type and level of pollution. In normal cases, at least two cleanings a year is recommended. In all cases, compatibility of the cleaning products with the glass as well as with the other components of the facade must be ascertained. Contrary to the general belief, glass can be spoiled by static water or moisture, if allowed to stay for a long period. In such situation, sodium ions are leeched from the glass surface. Normal exposure to rain or cleaning will easily remove these ions and they do not cause any problem. However if the same water particles remain on the glass surface, they combine with sodium ions to start a chemical reaction very slowly but accelerating quite fast subsequently. The defect can be seen as white powderish patches with glass surface losing it's polish. On cleaning, the defect appears as rainbow coloured areas when seen from an acute angle in bright light. Normal care during storage or at the time of receipt of material will eliminate all possibilities of this defect.

Glass Terminology & Definitions

Annealed Glass : Another term for "ordinary" glass, most commonly used for float glass. *(page 18)*

Aspect Ratio : The ratio of a longer side of panel to its shorter side. *(page 85)*

Back Putty : The portion of the putty remaining between the glass and the depth of the rebate after the glass has been pushed into position.

Balustrade : A low wall forming a parapet to a stair, ramp, balcony, raised level, or a change in level. *(page 22, 62)*.

Beads or Glazing Beads : A strip of wood, metal or other suitable material attached to the rebate to retain the glass.

Bedding Putty : The compound placed in the rebate of the opening into which the glass is bedded.

Bent Glass : Flat glass that has been shaped while into hot cylindrical or other curved shapes. *(page 132)*

Bevelling : The process of edge finishing flat glass to a bevel angle. *(page 13)*

Bite : The width of silicone used to bond the fin or frame member to the edge of the glass panel. *(page 90, 91,92)*

Block (Setting Block) : A small piece of wood, lead 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). *(Page 90)*

***B*olted Structural Glazing (BSG)** : Assembly of glass connected with stainless steel bolts where glass is also acting as a structural member. *(Page 93)*

Brewster Fringes: A phenomenon of light sometimes observed in a DGU. *(Page 121)*

Bullet Resistant Glass : A security glass capable of resisting attack from firearms and meant to stop bullets from piercing through it. **(***Page 15)*

Ceramic Printed Glass : Also called ceramic fritted glass made by applying ceramic or glass frit before thermal tempering or bending of glass. **(***Page 14)*

Chair Rail : A fixed glazing bar, or rigid push bar, that provides protection from human impact. **(***Page 18)*

Chemically Tempered Glass : Tempered by means of chemical reaction instead of conventional method of thermal processing. **(***Page 16)*

Clear Glass : Transparent glass. **(***Page 06, 23)*

Combustible material : The material which when burnt adds heat to a fire when tested for combustibility in accordance with the IS 3808-1979: Method of Test for Combustibility of Building Materials, National Building Code of India 2005.

Corridor *:* It means a common passage or circulation space including a common hall.

Critical locations : Parts of a building most likely to be subjected to accidental human impact. **(***Page 18)*

Curtain Wall : Non load bearing structure / partition of glass attached in a frame. **(***Page 72)*

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

Door : A hinged, sliding or otherwise supported openable barrier providing entrance to and exit from a building, corridor or room. Doors may be framed or unframed. **(***Page 20, 94, 95)*

Double Glazing : Glazing that incorporates two panels, separated with an air space, for the purpose of sound insulation or thermal insulation or both. **(***Page 11, 84, 119)*

Edge Polished : Usually applied to flat glass, the edges of which have been polished after cutting. **(***Page 13)*

Edging : Grinding the edge of flat glass, to a desired shape, contour or size. (*Page 13)*

Enameling : A process of painting and baking on glass. (*Page 14)*

Exposed Edge : A glass edge that is not covered and is visible after glazing. (*Page 13)*

Extra Clear Glass : A purer form of float glass with lower iron content and improved transparency without greenish appearance of normal float glass. (*Page 07)*

Facade : Front or face of the building.

Faceted Glazing : Flat panes of glass installed vertically at an angle to each other, to form a faceted curve.

Fin : A piece of glass positioned and fastened to provide lateral support. (*Page52, 98)*

Fire resistant : It means the time during which a fire resistant material i.e. material having a certain degree of fire resistance, fulfills its function of contributing to the fire safety of a building when subjected to prescribed conditions of heat and load or restraint. The fire resistance test of structures shall be done in accordance with IS 3809-1966 Fire Resistance Test of Structure.

Fire Resistant Glass : A glass which will stay in place and prevent passage of flames, hot gases and smoke for an Integrity (E) of 30, 60, 90 or 120 minutes to facilitate safe evacuation of occupants in case of fire. It may have additional properties of Radiation Control (EW) or Insulation (EI). (*Page 16, 25)*

Flat Glass : A general term covering sheet glass, float glass and various forms of rolled and plate glass.

Float Glass : A form of flat glass produced by reheating the continuous ribbon of glass whilst it floats over a bath of molten metal. (*Page 16, 69, 102)*

Frame : A structure manufactured from timber, metal, glass or other durable material or combinations of materials such as glass fins and structural sealant, supporting the full length of a glazed panel edge.

Frameless Glazing : A glazing surface, of one or more glasses, without any visible frame and held together by patch fittings, bolts or spiders. (*Page 96)*

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

Fully Framed Glazing : Panels that have all edges framed. (*Page 45)*

Glass : An inorganic, non-metallic material produced by the complete fusion of raw materials at high temperatures, into a homogeneous liquid, which is then cooled to a rigid, condition essentially without crystallization. (*Page 02, 05, 06)*

Glazing : The securing of glass in prepared openings in windows, door panels, partitions and the like.

Green Building : A building designed for optimum energy and water usage and with concern for environment. (*Page 27)*

Grooving : A decoration process of making and polishing grooves on a glass surface. (*Page 13)*

Guarding : To prevent people from falling wherever there is a change in floor level by means of a permanent barrier.

Heat Soaking : Heat Soaking is done on toughened glass by reheating to a temperature of 290°C and keeping it at this temperature for eight hours and cooling it gradually. (*Page76)*

Heat Strengthened Glass : Glass which has been heated past its softening point and chilled rapidly to increase its strength and make it thermally safe, but which breaks like annealed glass. (*Page 09, 76, 119)*

Heat Strengthened Laminated Safety Glass : Laminated Safety Glass utilizing two or more panels of heat strengthened glass in the make up. (*Page 21)*

High Activity Area : Where multiple human activity takes place. (*Page 21)*

High Risk Area : Area prone to human injury. (*Page 21)*

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

Insulating Glass Unit (IGU) : The standard configuration for residential and commercial windows consisting of a sealed unit of two panes of glass separated by a metal spacer. (*Page 11, 84, 119)*

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. (*Page 20)*

Iridescence : A phenomenon of light where strain patterns in tempered glass become visible in polarized light. (*Page 74, 115, 121)*

Laminated Glass : A composite material consisting of two or more sheets of glass permanently bonded together by a plastic interlayer material. (*Page 10, 77, 123)*

Laminated Safety Glass : Laminated glass that satisfies the requirements for a safety glazing material according to this guide. (*Page 21)*

Manifestation : Any technique for enhancing a person's awareness of the presence of transparent glazed areas. (*Page 23)*

Maximum Thickness : The thickness of a panel of glass at the maximum thickness tolerance.

Minimum Thickness : The thickness of a panel of glass at the minimum thickness tolerance.

Mirror : A piece of glass silvered on one side, with a protective paint coating.

Monolithic Glass : A numeric designation used for reference purposes that indicates the approximate thickness of glass.

Newton Rings : Optical effect when two glass of a DGU are nearly touching at the centre. *(Page 121)*

Nominal Thickness : A numeric designation used for reference purposes that indicates the approximate thickness of glass.

Non-combustible : It means, not liable to burn to add heat to a fire when tested for combustibility in accordance with the IS:3808-1966, Method of Test for Combustibility of Building Materials.

Patch Fittings : Hardware used for frameless tempered glass door assemblies, visible only as patches. *(Page 52, 96)*

Pane : Single piece of glass cut to size for glazing.

Panel : An assembly containing one or more panes.

Parapet : It means a low wall or railing built along the edge of the roof or a floor.

Partly framed glazing : Panels that have one or more edges unframed.

Patterned Glass : Rolled glass having a distinct pattern on one or both surfaces. *(Page 07)*

Rebate : The part of a surround; the cross section of which forms an angle into which the edge of the glass is received. *(page 90)*

Reflective Coated Glass : Glass with metallic or metallic oxide coating applied onto or into the glass surface to provide reduction of solar radiant energy, conductive heat energy and visible light transmission. *(page 06, 74, 105)*

Residual protection : It is the protection provided to avoid the impact of human being to 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. (*Page 19)*

Safety organic-coated : A glazing material consisting of a piece of glass coated and permanently bonded on one or both sides with a continuous polymeric coating, sheet or film, which meets the test requirements of the safety glazing standards.

Security Glass : A laminated glass designed to resist or prevent forced entry. Generally used for large glasses in windows without safety grills. *(page 15)*

Setting Blocks : Pieces of wood, hard rubber or plastic, on which the bottom edge of glass rests in a window sash. (*Page 90)*

Shower doors, shower screens and bath enclosure : The panels, doors or windows a enclosing or partially enclosing a shower or bath. (*Page 95)*

Side Panel : A panel (openable or inopenable) located adjacent to a doorway. It may or may not be in the same plane as the doorway.

Silicon: A type of Sealant, most commonly used with glazing of glass. (*Page 99)*

Sky Light : 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 vertical fenestration. (*Page 21)*

Sloped overhead glazing : Glazing that is inclined at less than 75 degrees to the horizontal and located, wholly or partially, directly above an area that may be used by people. (*Page 21)*

Span : The dimension between supports. For panels supported on all four edges, it corresponds to the smaller of the sight size dimensions.

Spandrel : That portion of the exterior wall of a multistory commercial building that covers the area below the sill of the vision glass installation.

Spotaneous Breakage : Tempered glass breakage without any provocation or external reasons. *(page 75)*

Stained Glass : An ancient form of decorative glass made by soldering glasses of different colours into a piece of art. *(page 13*)

Tempered or Toughened : When float glass panels are heated and then cooled rapidly in a controlled Glass environment. (*Page 08, 72, 108)*

Tinted Glass : Normal float glass to which colorants are added during manufacturing process to achieve tinting and solar radiation absorption properties. (*Page 06, 69)*

Thermal Breakage : Cracking of an annealed glass due to temperature difference at the center and edges of glass. *(page 46)*

Transom : Horizontal bar of wood, aluminium or stone etc. across a window, door or partition. (*Page 19)*

Tripple Glazed Units : An insulated glass unit using three plates of glass separated by two air gaps. *(page 11)*

Toughened laminated Safety glass : Laminated safety glass utilizing two panels of toughened safety glass in the make up.

Unframed glazing : Panels without framed edges.

Wardrobe doors : Doors that provide access to built in storage areas, excluding those fitted to pieces of furniture that are not built into the building.

Weep Holes: Holes for drainage of water at the bottom of a window sash. (*Page 91)*

Wind Load : Load on glass because of the speed and direction of wind.

Window : It means an opening other than a door, to the outside of a building which provides all or part of the required natural light, ventilation.

Window Sill : Solid wall (brick or concrete wall) starting from the finished floor level to the base of first window or structural member consisting of a continuous horizontal metal/wooden forming the lowest member of a framework or supporting structure.

Wired Glass : Normal float or rolled glass with steel wire mesh embedded into it. *(page 07)*

Energy and Light Definitions:

Light Transmission (LT) : Ratio of light flux transmitted through the glass to the incident light flux expressed by the illuminant CIE D65 with spectral density between 380 and 780 nm.

Direct Energy Transmission (DET) : Percentage of solar energy flux transmitted directly through the glass with a spectral density between 300 and 2150 nm (accordingly to CIE).

Energy Reflection (ER) : Percentage of solar energy flux reflected by the glass.

Energy Absorption (EA) : Percentage of solar energy flux absorbed by the pane or panes making up the glazed wall. The absorbed energy is then reradiated to the outside or inside at different rates depending on the characteristics of the pane or panes of glass, wind speed, internal air speed, internal and external temperatures.

Solar Factor (SF) or Total Energy Transmission : A glass wall's solar factor is the ratio of the total solar energy flux entering the premises through the glass to the incident solar energy flux. The total energy is the sum of the incoming solar energy by direct transmission (DET) and the energy reradiated by the glass to the inside atmosphere after being absorbed by the glass (EA). *(Page 142)*

Solar Control Glass : A glass used for reducing the effect of heat transfer from solar radiation into the building. *(page 29, 31)*

Light Reflection (LR) : Ratio of the light flux reflected by the glass to the incident light flux expressed by the illuminant CIE D65. *(Page 31)*

Shading Coefficient (SC) : A measure of the heat gain through glass from solar radiation. Specifically the shading coefficient is the ratio between solar heat gain for a particular type of glass and that of double strength clear glass. The lower the shading coefficient, the lower the solar heat gain. *(Page 32)*

Solar Heat Gain Coefficient (SHGC) : A newly introduced term showing the amount of solar energy gained through a window. Multiplying the SHGC by 100 gives the percentage of solar energy allowed into the building. Air Mass = 1.5 *(Page 32)*

U-Value (U-Factor) : A measure of the heat gain or loss through glass due to the difference between indoor and outdoor temperatures. It is also referred to as the overall coefficient of heat transfer. The lower the U-Value, the better the insulating properties. The units are Btu/(hr)(sq.ft)(F). *(Page 10)*

K-Value : The European equivalent of the American (ASHRAE) U-Value. The units are W/sq.mt k and are based on a wind speed of 4.4 m/sec at 0°C with indoor temperature of 20°C.

Relative Heat Gain (RHG) : The total heat gain through glass for a specific set of conditions. This value considers indoor/outdoor air temperature difference and the effect of solar radiation. The units are Btu/hr/sq.ft. *(Page 31)*

American Value : 1W/sq.mt k = 0.176 Btu/sq.ft./F/h

Disclaimer:

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ABOUT FOSG

The 'Federation Of Safety Glass' is a non-profit organization formed by the safety glass manufacturers or processors. There are about 90glass-processing companies in India of which 74 are regular members of FOSG. It is managed by an elected group of 12 persons amongst the members.

FOSG is also supported by the related industry like makers of float glass, glass processing machinery, windows, aluminum fabricators, sealants, laminating materials, hardware for glass etc. It is also supported by glass media and organizers of events related to glass.

Some notable achievements are publication of quality standards, skilled manpower training manual and now this book. It has also partnered activities like setting up of quality testing lab in IIT Chennai, creation of technical course curriculum for Glass Academy, energy conservation initiatives by Glazing Society of India, Making of codes for use of glass in buildings with CCPS besides holding training and educational seminars,lectures, workshops and shows for architects, builders, actual applicators including fabricators and carpenters.

The federation is committed to raising the standards of safety glass in India and to create awareness about glass and to serve the society with buildings, designed with more safety, comfort, energy conservation and better quality of life.

FOSG

FEDERATION OF SAFETY GLASS

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