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Characteristic of Structural Glass Façade for futuristic Construction Technology

Vijay Singh Rawat, R. Divahar
School of civil engineering and architect
Adama Science and technology university, Adama, Ethiopia
Sharadchand Bhaichand Dugad
Building Construction Technology and Department
Federal TVET Institute, Addis Ababa, Ethiopia

Abstract

"Structural glass facades" and "structural glass façade technology" are terms used in this paper to describe a relatively recent class of building technology comprising a component of the building envelope. The use of façade here is synonymous with building skin. Structural glass facades integrate structure and cladding, and are used in long-span applications (spans greater than approximately 20 feet (7 meters)) where heightened transparency and a dematerialization of structure are often predominant design objectives. The structural systems are exposed, and generally refined as a consequence. The design pursuit of enhanced transparency in these façade systems has resulted in the development of increasingly refined tension-based structural systems, where bending and compression elements are minimized or eliminated altogether. In fact, it is a premise of this paper that this class of building technology can be most effectively categorized by the structural systems that have developed to support these facades.

1. Origins by culture

1.1 India (Hindu Kingdoms): Indigenous development of glass technology in South Asia may have begun in 1730 BC 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 colour. Chalcolithic evidence of glass has been found in Hastinapur, India.

1.2 Romans: Roman glass Glass objects have been recovered across the Roman Empire in domestic, industrial and funerary contexts. Glass was used primarily for the production of vessels, although mosaic tiles and window glass were also produced. Roman glass production developed from Hellenistic technical traditions, initially concentrating on the production of intensely coloured cast glass vessels. However, during the 1st century CE the industry underwent rapid technical growth that saw the introduction of glass blowing and the dominance of colour less or ‘aqua’ glasses.

1.3 Anglo-Saxon world: Anglo-Saxon glass has been found across England during archaeological excavations of both settlement and cemetery sites. Glass in the Anglo-Saxon period was used in the manufacture of a range of objects including vessels, beads, and windows and was even used in jewelry. In the 5th century CE with the Roman departure from Britain, there were also considerable changes in the usage of glass. Excavation of Romano-British sites has revealed plentiful amounts of glass but, in contrast, the amount recovered from 5th century and later Anglo-Saxon sites is minuscule.

1.4 Arab world: Arabic Linters in Khan el-Khalili, Cairo the Arab poet alBuhturi (820–897) described the clarity of such glass, "Its colour hides the glass as if it is standing in it without a container." Stained glass was also first produced by Arab architects in the Middle East using coloured glass rather than stone. In the 8th century, the Persian chemist Jabir ibnHayyan (Geber) scientifically described 46 original recipes for producing coloured glass in Kitbag al-Durraal Maknuna (The Book of the Hidden Pearl), in addition to 12 recipes inserted by al-Marrakishi in a later edition of the book. By the 11th century, clear glass mirrors were being produced in Arab Islamic Spain.

1.5 Medieval Europe: A 16th-century stained glass window Glass objects from the 7th and 8th centuries have been found on the island of Torcello near Venice. These form an important link between Roman times and the later importance of that city in the production of the material. Around 1000 CE, an important technical breakthrough was made in Northern Europe when soda glass, produced from white pebbles and burnt vegetation was replaced by glass made from a much more readily available material: potash obtained from wood ashes.

1.6 Murano glassmaking: The center for luxury Italian glassmaking from the 14th century was the island of Murano, which developed many new techniques and became the center of a lucrative export trade in dinnerware, mirrors, and other items. What made Venetian Murano glass significantly different was that the local quartz pebbles were almost pure silica, and were ground into fine clear sand that was combined with soda ash obtained from the Levant, for which the Venetians held the sole monopoly.

1.7 United States: During an excavation of the English settlement at Jamestown Island,

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Virginia, pieces of glasses were found to have been made there. A few glass window panes were also found to have been made in the Jamestown glass factory that was built in 1608.

Fig. 1.1 Glass Façade building

2. TYPE OF GLASS

- Laminated Glass
- Tempered Or Toughen Glass
- Annealed Glass
- Reflective Glass
- Insulating Glass
- Heat Strengthened Glass

2.1 LAMINATED GLASS

General: Laminated glass is type of safety glass that holds together when shattered. In event of breaking, it is held in place by an interlayer, typically of polyvinyl butyral [PVB] between two or more layers of glass. The interlayer keeps the layer of glass bonded even when broken, and its high strength prevents the glass form breaking up into large sharp pieces. This produce a characteristic "spider-web" cracking pattern when the impact is not enough to completely pierce the glass.

A typical laminated makeup would be 3 mm glass / 0.38 mm interlayer / 3 mm glass. This gives a final product that would be referred to as 6.38 laminated glasses. Multiple laminates and thicker glass increases the strength. Bulletproof glass is often made of several float glass, toughened glass and Perspex panels, and can be as thick as 100 mm.

• Top Layer : Glass
• Interlayer : Transparent thermoplastic material like TPU, PVB or EVA
• Interlayer: LED (light emitting diodes) on transparent conductive polymer
• Interlayer: Transparent thermoplastic material like TPU, PVB or EVA
• Bottom layer: Glass

Fig. 2.1.1 Cross Section of Laminated Glass

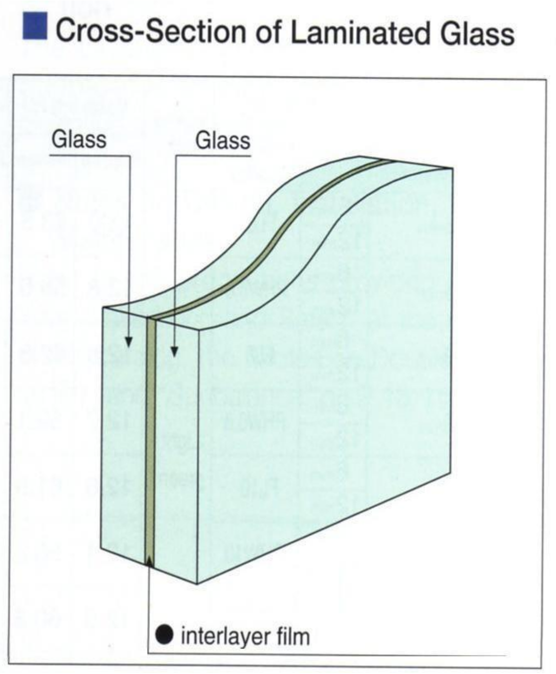

Table 2.1.1 Physical Property of Laminated Glass

Density (approximate)	2.42 – 2.52 g/cm^3
Tensile strength	32 N/m^2
Compressive strength	1000 N/mm^2
Modulus of elasticity	70 GPa
Coefficient of linear expansion	9 x 10^{-6} m/Mk
Available thickness	4.38 mm – 20.76 mm
Normally available sizes up to	2000 x 3210 mm (bigger sizes can also be made)

2.2 TEMPERED AND TOUGHENED GLASS

General: Toughened or tempered glass is glass that has been processed by controlled thermal or chemical treatments to increase its strength compared with normal glass. Tempered glass is made by processes which create balanced internal stresses which give the glass strength. It will usually shatter into small fragments instead of sharp shards when broken, making it less likely to cause severe injury and deep lacerations. Tempered glass is an extremely strong glass which is heat treated to a uniform temperature of approximately 650^{0}C and rapidly cooled to induce compressive strength of 770 kg/sq.m to 1462kg/sq.m on the surface and edge compression of the order of 680kg/sq.m. Tempered glass is not manufacture on float line. It is a separate process.

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Fig. 2.2.2 Tempered glass

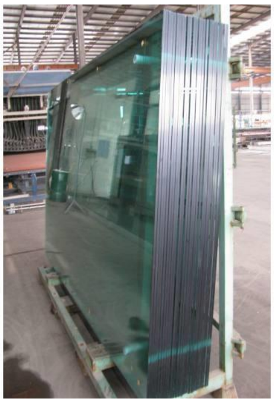


Table 2.2.2 Physical Property of Laminated Glass

Density (approximate)	2.42 – 2.52 g/cm^3
Tensile strength	120 to 200 N/sq.m
Compressive strength	1000 N/sq.m
Modulus of elasticity	70 GPa
Coefficient of linear expansion	9 x 10^{-6} m/mK
Available thickness	3 mm – 19 mm
Normally available size up to	2440 x 3660 mm

Uses- It is used in commercial applications where wind, snow or thermal loads exceed the strength capabilities of normal glass such as safety glazing for entranceway, railing, partitions or fire knock-out windows. Tempered glass can be used in balustrades, escalator side panels, handrail, shower screen, bathtub enclosures, sliding doors, squash, showcase, partitions etc.

2.3 ANNEALED GLASS

General- Normal glass is synonymous with flat glass irrespective of the process of manufacture. Float glass has a perfectly flat, brilliant surface, where as sheet glass has slight distortions. Both are referred as annealed glass and can be processed to obtain many different variety of glass for use in building. High quality, transparent glass is manufactured by floating molten glass on a tin bath at an extremely high temperature. The glass is then gently cooled to enable cutting and further processing of the glass post manufacture.

Fig. 2.3.1 Annealing Equipment

Density	2.42 – 2.52 g/cm3
Tensile strength	40 N/ sq.mm
Compressive strength	1000 N/ sq.mm
Modulus of elasticity	70 GPa
Coefficient of linear expansion	9 x 10^{-6} m/mk
Available thickness	2 – 19 mm
Normally size available up to	2440 x 3660 mm
Colour	Clear, Gray, Green

Table 2.2.2 Physical Property of Laminated Glass

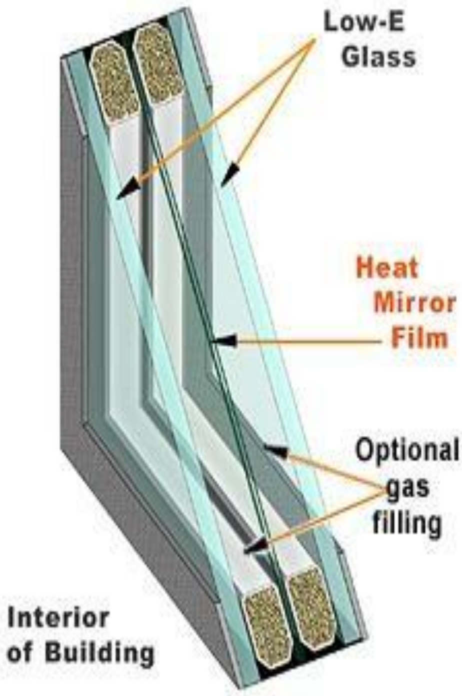
Fig. 2.3.2 Annealed Glass

Uses: Normal glass is used in residences, shopping mall, hotels, restaurants, etc. other areas where normal glass is used are:

- Windows
- Shelves
- Doors and partitions
- Solar application
- Display cases
- Shop front
- Solarium
- Greenhouse
- Railing.

2.4 Reflective Glass Reflective glass is glass which has been treated with a metallic coating which allows the glass to reflect heat. It is not reflective in the sense that it acts as a mirror although some reflective glass products do indeed have a highly reflective surface, but rather in the sense that it reflects radiation, rather than absorbing it. This type of glass use in environmentally friendly construction with the goal of reducing heat gain and loss, making structures much cheaper to heat and cool over the course of the year.

Fig. 2.4.1 Reflective Glass



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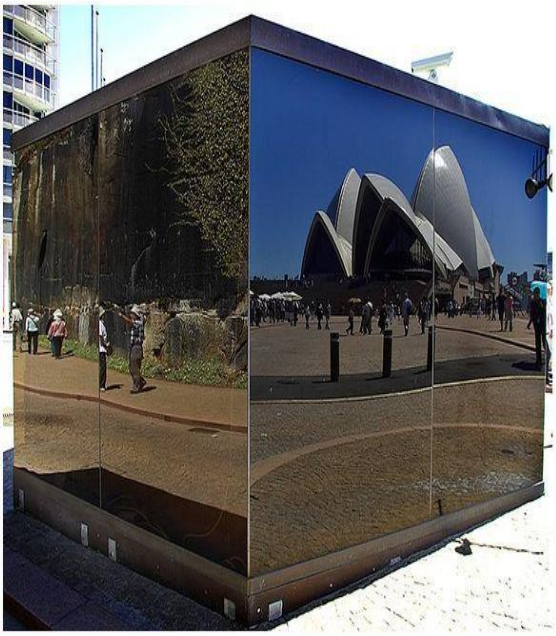

Fig. 2.5.1 Insulating Glass

Table 2.4.1 Physical Property of

Density	2.4 – 2.5 g/cm3
Available thickness	3mm – 12 mm
Normally size available up to	2250 x 3210 mm (bigger size can also made)
Density	2.4 – 2.5 g/cm3

Uses:

Reflective glass is used in office buildings, high-rise building

- Entrance.
- Privacy window.
- Decorative walls.
- Spandrel glazing.
- Vertical and sloped glazing for commercial building applications.
- Solar control applications.
- Building facades.

2.5 Insulating Glass The insulating glass is a prefabricated unit made of two or more glass panes, separated by a cavity and edges hermitically sealed together. This edge seal

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not only binds the individual's sheets of glass together. This edge seal not only binds the individual sheets of glass together to maintain the mechanical strength of the joints but also protects the cavity between the glasses from outside influences. The moisture in the cavity between the two glasses is controlled by desiccants filled in the perforated spacer. The spacer can be aluminium, composite plastics etc. the spacer insure the precise distance between the glass panes. The cavity normally filled with dry air but can be also filled with gases such as argon, krypton for better thermal performance or hydrogen Fluor oxide for better acoustic performance.

Properties:

- Heat transferred by conduction and convection due to temperature difference between the outside and inside is reduces to nearby half in the case of normal glass thus reduces the heat flow / transfer and gain loss. It is specifically very effective in winters as it saves loss of inner heat.
- They not only lower one's energy costs, but also make homes cosier by improving comfort, decreasing condensation, as well as, diminish the effects of fading. Insulated units are also highly effective in reducing unwanted sound transmission.
- In the summer, heat is transmitted through the glass and is absorbed by the walls, furniture, floors, etc. By using window and door products with a low solar heat gain coefficient, the solar radiation coming into one's home is decreased.
- This reduces the amount of heat entering the home, thereby improving one's homes' comfort level and lessening the amount of energy needed for cooling during warm weather months.
- Moreover, during the cooler seasons, insulated products create warmer interior glass surfaces, reducing frost and condensation from forming.

Use-

- Airport control towers, windows of coaches of trains, and other environments that need regulated atmosphere and prevention of condensation.
- Building that need the temperature and humidity strictly controlled such as telephone exchanges, laboratories etc.
- Office buildings, hospitals, hotels, houses and buildings with exceptionally high heating or cooling requirements.

- Building near highways, railway and airport that need sound insulation property of insulating.

3. Design Criteria

3.1 Design Consideration- This deals with the design strength of the glass and the imperial relation to evaluate the minimum thickness or the maximum allowable area of the glass panel for a particular glass type for a given set of design wind pressure, support condition and aspect ratio.

3.2 Design flexural tensile strength of glass:

The required thickness of the glass depends upon the design strength obtained after applying a factor of safety of 2.5.The minimum design strength of normal glass for thickness is 16.7N/mm and for small glasses thickness is 15.2 N/mm.

3.3 Net design wind pressure:

Net design wind pressure is an important parameter governing the thickness of glass to be used in the window panels. It depends on several factors i.e. location of building, construction patterns around buildings, topography of site, building plan and height etc.

Net design wind pressure is calculated by multiplying the net pressure coefficient and design wind pressure at certain height.

3.4 Wind zone:

India has been divide into six wind zones. Each wind zones has a specific basic wind speed. These basic wind speeds have been used to compute design wind pressures. A proper wind zone should be selected for the site of building. For ready reference, wind zones and basic wind speeds of some important cities should be referred.

Wind pressure also depends on terrain type where building is to be located. Terrain category means the characteristics of the surface irregularities of an area, which arise from natural or constructed features. Wind pressures have been computed for all the four terrain categories which are as follows:

Category 1: Exposed open terrain with few or no obstructions and in which the average height of any object surrounding the structure is less than 1.5m.

Category 2: Open terrain with well scattered obstructions having heights generally between 1.5-10m.

Category 3: Terrains with numerous closely spaced obstructions having the size of building structures up to 10m height with or without a few isolated tall structures.

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Category 4: Terrains with numerous large, high and closely spaced obstructions.

4. Design solution and discussion

Design Solutions:

- There are three basic categories of curtain walling systems: front sealed, secondary sealed and pressure equalized.
- Front sealed systems are designed to be totally impervious. They rely on exact positioning of the glazing panels and perfect mastic seals or glazing gaskets to provide a totally weather tight exterior shell.
- Front sealed systems have obvious limitations because their effectiveness is totally dependent upon the quality of the workmanship during installation and the longevity of the sealing mastics or glazing gaskets. Essentially, front sealed systems are only appropriate for use on low rise buildings in sheltered locations, where the façade is likely to be changed within 10 years.
- However, there are some proprietary systems on the market which combine continuous external gaskets with precautionary drainage, increasing the level of reassurance for specifies.
- Secondary sealed systems, as the name suggests, recognise that a 100% weather tight seal is unlikely to be achieved for the life of a façade. Thus, although designed to be weather tight, any water that does penetrate is collected and drained back to the outside through holes or slots.
- It is important that these drainage holes are large enough to overcome surface tension and winter icing. For hole drainage, minimum openings of 8mm to 10mm are recommended, while drainage slots of at least 20 by 5mm or 25 by 5mm are the recommended minimum.
- The current trend is inappropriate. Their principal benefits are speed of installation, minimal on site labour, and lower installation costs. However, these are obviated to an extent by the increased storage and shipping costs, the need for very careful site handling, and the requirement for expensive lifting equipment on site.
- Unitised systems are popular because they eliminate, or reduce, the need for on site sealing, therefore making them less reliant on the standard of site workmanship. However, for unitised systems to perform to their full potential, it is critical that the brackets to which the components are fixed are accurately installed. Unitised systems do not require decanting during refurbishment contracts.

In conclusion, unitized systems offer the benefits of factory fabrication in controlled environment, and very rapid assembly on site. However, they are generally more expensive than stick systems and require longer lead limes.

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