Glass

Introduction
Glass can be defined as an inorganic product of fusion which has cooled to a rigid condition without crystallising. It is typically hard and brittle. It may be colourless or tinted, transparent to opaque. Masses or bodies of glass may be made tinted, translucent or opaque by the presence of dissolved, amorphous or crystalline material.

Composition of glass
Glass is produced from three major ingredients:

- sand (silica)
- soda (sodium oxide)
- lime (calcium oxide)

About fifty other chemical compounds are also used in varying degrees to affect colour, viscosity or durability or to impart some other desired physical property. An average batch of glass contains about 70% silica sand, 13% lime and 12% soda with small amounts of other materials.

Properties of glass in buildings
Through the use of the latest technology glass manufacturers are constantly developing new glass products for energy management, comfort, security and ease of cleaning.

Thermal performance
Glass expands and contracts on heating and cooling and, to prevent the kind of disasters which happened on early glass curtain-walled skyscrapers, with sheets of glass falling from great heights, this should be taken into account in the design. Stresses can be set up in the glass resulting from differences in expansion rates between frames and glazing, especially where frames are metal.

Thermal insulation
Single glazing offers little thermal resistance but the effect of an air gap created by double glazing almost halves the heat loss through a single pane.
The optimum gap is about 20 mm. Heat absorbing and reflecting glasses make an effective contribution to minimising solar heat gain.

**Heat absorbing glass**
This is produced by the addition of certain minerals during melting. It significantly reduces solar heat gain and glare in a building by absorbing between 50 and 90 per cent of the infrared rays and 30 and 75 per cent of the visible light rays. As a result, this glass tends to expand and contract more than other types of glass and suitable tolerances must be left in the frame sizes. Heat absorbing glass is available in a small range of tints.

**Light and heat reflecting glass**
This is produced by coating the glass surface with metallic films. With the use of this glass, solar radiation can be reduced by up to 70 per cent. Frequently this glass forms part of a double-glazing system which protects the coated surface.

**Acoustic performance**
For any degree of sound insulation, double glazing is essential. Sound reduction values vary according to the thickness of the glass and the width of the gap.

**Fire resistance**
Although non-combustible, ordinary glass breaks and then melts in fires and double glazing offers no significant advantage over single glazing. Certain special glasses offer some degree of fire resistance.

**Glass types**

**Manufacture**
The ingredients are fed into melting tanks or furnaces and melted at about 1600°C. It flows toward the discharge or forming end where the temperature is around 1150°C.

The manufacturing process is important since there is essentially only one method - the float glass process - used for producing flat glass for architectural products today.

**Float glass**
In 1959, the Pilkington Brothers, an English company, introduced a new method for the manufacture of glass, the float glass process. In this process, the molten glass at the exit end of the furnace is poured onto a bath of liquid tin on which it floats and spreads to form a wide, flat ribbon of glass that remains untouched until it hardens.
The most striking part of this process is that, unlike the old polished plate glass manufacturing process, it produces glass having parallel surfaces, high optical quality, and fire-finished surface brilliance. It is economical in that the polished plate glass process required an investment in a huge grinding and polishing operation to obtain smooth surfaces, whereas the float process obtains these results by means of the molten tin bath.

Float glass products
Float glass manufacturing accounts for over 90% of the flat glass produced today. The products are clear, heat-absorbing, and tinted glasses.

Clear glass
Clear glass is colourless and is manufactured to meet relevant Australian standards.

Insulating (heat-absorbing) glass
Heat-absorbing glass is intended for glazing where reduction of solar heat is required. This type of glass is available in bronze, grey and blue-green colours. The colour density is related to thickness, whereas the light transmittance is reduced with an increase in thickness. Heat-absorbing glass is manufactured to comply with Australian standards.

Heat-absorbing glass is produced by adding selected metallic oxides in small amounts to the basic glass mixture. Those oxides reduce light transmission, control solar brightness and glare and absorb solar heat. As the glass becomes warm, it re-radiates this heat, with only part of the heat directed down the face of the glass. The introduction of an edge drip and a second drip as another line of defence should be considered. This is discussed further below.

Rolled glass
Rolled glass is made by pouring molten glass from a furnace and then passing it between rollers to obtain the required thickness. It then is annealed in an annealing oven and cut to required sizes. Three types of rolled glass are produced. These are:
- figured or patterned
- wire
- stained or cathedral

**Figured (patterned) glass**

Figured or patterned glass is produced by the use of rollers that have a pattern etched on either one or both of the rollers, which imparts the pattern to one or two surfaces of the glass as it passes through the rolls. A variety of patterns is available and with differing degrees of visibility through the glass (obscurity). Figured glass can be coloured, but only a limited number of colours is available.

**Wired glass**

Wired glass is produced in a manner similar to that used for figured glass, with the addition of welded wire netting or parallel wires placed in the molten glass prior to rolling. Wired glass can be obtained with a pattern (rough wire glass) or with polished faces (polished wire glass).

Wired glass is used, where permissible, in doors and windows.

**Laminated glass**

Laminated glass consists of a combination of two or more panes of glass with a layer of transparent plastic sandwiched between the panes under heat and pressure to form a single laminated unit having certain characteristics depending upon its intended use.

The plastic used is plasticised polyvinyl butyl, which may be as little as 0.381 mm thick to as much as 2.24 mm or more, as required for a specific use. The vinyl may be colourless for general use or pigmented when used for solar control.

The introduction of the plastic interlayer produces a unit that will prevent sharp fragments from shattering and flying about when it is subjected to a sharp impact and breaks since the glass adheres to the vinyl interlayer.

The glass used in the lamination may consist of clear, tinted, tempered, reflective and wire glass and the result is an adaptable, high-performance glazing material that is utilised in:

- safety glazing
- security glazing
- solar control
- sound control
**Safety glazing**

The use of laminated safety glass minimises the risk of injury from glass breakage or accidental impact. It is useful for entrance doors, sliding doors, shower enclosures, skylight and sloped glazing to name but a few applications.

Depending upon the degree of safety required, the glass components may be annealed or heat treated and the vinyl interlayer may be as little as 0.381 mm thick.

**Security glazing**

Security glazing is used, when properly designed, for three different levels of security:

- burglary resistant
- institutional security
- bullet resistant

**Solar control**

Laminated glass products utilising pigmented interlayers of polyvinyl butyl can:

- reduce solar energy transmission
- control glare and brightness
- screen out UV

Thus it provides both utilitarian and aesthetic qualities.

**Sound control**

The use of the plastic interlayer in a laminated glass unit provides a damping characteristic which enhances the acoustic performance of these units, as compared to monolithic glass and insulating glass.

Table 1 shows typical sound transmission class values (STC) for representative glass thicknesses.

<table>
<thead>
<tr>
<th>Thickness</th>
<th>STC value</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.15 mm float</td>
<td>23</td>
</tr>
<tr>
<td>6.35 mm float</td>
<td>28</td>
</tr>
<tr>
<td>12.7 mm float</td>
<td>31</td>
</tr>
<tr>
<td>25.4 mm insulating</td>
<td>32</td>
</tr>
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<td>Thickness</td>
<td>Thickness ID</td>
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<tr>
<td>--------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>6.35 mm laminated</td>
<td>34</td>
</tr>
<tr>
<td>9.50 mm laminated</td>
<td>36</td>
</tr>
<tr>
<td>12.7 mm laminated</td>
<td>37</td>
</tr>
<tr>
<td>15.9 mm laminated</td>
<td>38</td>
</tr>
</tbody>
</table>

**Reflective glass**

Reflective glasses have a transparent, thin metal or metal oxide coating deposited on one surface. These glasses owe their popularity to several factors:

- aesthetic appeal
- solar control resulting in energy savings
- occupant comfort

Since the metallic film acts as a one-way mirror, a person on the exterior has difficulty looking in during the day. However, at night with interior lights on, an occupant cannot see out but anyone on the exterior may see in. The metallic film reflects sunlight and reduces heat gain markedly.

**Low e-Glass**

Low-e is standard clear glass which has a special coating on one surface of the glass. Low-e refers to low emissivity and this describes the capacity of a surface to radiate heat. Emissivity is measured across a scale from 0 to 1 with 1 representing the highest emissivity.
The low-e coating is spectrally selective, which means it affects some wave lengths of light but not others. Long wave infrared is the heat produced by our bodies, heaters and the furnishings in a warm room. The transmission of long wave infrared is significantly reduced by the low-e coating. It reduces the amount of energy escaping through the glass keeping the room warmer and reducing the amount of heat required to be generated by the artificial heaters. The energy from the sun is called short wave infrared; a high proportion of energy from the sun will be transmitted straight through the glass.

Low-e coatings provide various performance levels and the glass can be used in a variety of ways including single glazing, laminated glass or double glazed windows.

Self-Cleaning Glass
Over the years, companies have developed completely transparent exterior coatings which are applied during manufacture to clear glass, producing a dual cleaning action. Once exposed to daylight, the coatings react with the UV rays to breakdown and disintegrate organic dirt deposits. The coatings also ensure that when water hits the glass, the hydrophilic action assists in washing dirt away without leaving spots or streaks.

Fire Resistant Glass
Ordinary annealed float glass in a heat or fire situation creates problems because it readily transmits heat and upon breaking allows the passage of flames and smoke. Provisions within the BCA and Australian standards require the use of fire resistant glazing in buildings. For bushfire prone areas, AS3959:2009 Construction of buildings in bushfire prone areas provides for either a deemed to satisfy or alternative solutions for window glazing based on a BushFire Attack Level BAL) rating.

Fire resistant glazing systems can be categorised into non-insulated and insulated units.

Non-Insulated - Wired glass is a typical non-insulating product. For clear through vision, clear polished wired is used. This product has been tested to achieve ~60/~, or only a 60 minute integrity fire resistance in a steel frame. Wired glass upon exposure breaks but the wire retains the glass fragments in place. Wired glass is not a Grade A safety glass.

Insulated - There are two types of insulating glass products:

a) The first type, glass such as Pyrobel® manufactured by Glaverbel, uses a clear intumescent interlayer in a laminated or multi-laminated glass make-up. Upon heating in excess of 120°C, the interlayer turns into a rigid and opaque fire shield. The higher the FRL requirement, the thicker the glass and the greater the number of interlayers;

b) The second type consists of a gel interlayered glass in a sealed glazing unit. The cavity is filled with a clear heat absorbing gel. Both products can provide high levels of integrity and insulation and satisfy Grade A safety glass requirements.
Glass quality standards

Flat glass
Flat glass encompasses float products (clear, heat-absorbing, and tinted) and rolled products (patterned or figured and wired). Flat glass is manufactured in accordance with AS 1288 *Glass in buildings*.

Heat-treated glass
Heat-strengthened glass and tempered glass are governed and manufactured to standards established by AS 1288 *Glass in buildings*.

Insulating glass units
The American Society of Testing and Materials (ASTM) have established standard test methods that comprise a series of tests for insulating glass units.

These standards are:

- E-774 Sealed Insulating Glass Units
- E-546 Standard Test Method for Frost Point for Sealed Insulating Glass Units
- E-576 Standard Test Method for Dew/Frost Point of Sealed Insulating Glass Units in Vertical Position
- E-774 Seal Durability of Sealed Insulating Glass Units

The equivalent Australian standards are given in AS 1288 *Glass in buildings*.

Safety glazing
Australian Standards cover such items as storm doors, sliding doors and shower doors for safety glazing for residential use, recreational buildings, schools, and public buildings.

Glazing considerations for various glass products

Insulating-glass - weep systems
The glazing system should be designed so that moisture or water does not accumulate and remain in the glazing rabbet (see figure 2), since exposure to water for prolonged periods may cause failure of the glass's organic edge seal. Figure 2 shows typical weep systems for insulating glass glazing systems exposed to humid conditions over prolonged periods of time.
Sealant compatibility
Sealants and preformed tapes used in conjunction with laminated glass should contain no solvents or oils which would react with the butyl interlayer. Generally, 100% solid system polysulphides, silicones or butyls are suitable and compatible.

Shading patterns on heat-absorbing and reflective glasses
When heat-absorbing or reflective glasses are used, it is important to avoid outdoor shading patterns that create double diagonal shading as shown in figure 3.
Heat absorbing and reflective glasses absorb more solar energy than clear glass. Because of partial shading of portions of the glazing rabbet the exposed central portion of a light becomes hotter than the shaded edges, and will expand faster than the colder shaded edges. This differential expansion results in tension stresses at or near the edges of the light.

To ensure structural reliability, the edges should be free from scratches, vents, nips, and general edge damage. The ability of heat-absorbing and reflective glass to resist solar thermal stress breakage is determined by edge strength which is a function of how the glass is cut.

Clean cut edges following the recommendations of the glass manufacturer should be used to assure structural reliability. Cuts which produce edge damage may result in thermal stress breakage.
Tension stresses in glass edges increase appreciably by partial outdoor shading. Roofs, balconies, over hangs, awnings, framing members and adjacent structures may introduce shading stress. Horizontal, vertical and diagonal shading are less severe than double diagonal shading. The most severe shading is a double diagonal shade line with a 70 degree included angle between shade lines intersecting at the middle of one edge.

Surface protection of glass from water run-off and glass damage

Glass surfaces will be affected by the run off of rain water which is absorbed into building materials. As water enters masonry and concrete, it dissolves certain alkaline materials which may be carried down over the face of the glass. In some cases these will either stain or etch the glass.

Staining (and in some cases scratching) of the glass is the result of alkalis released from concrete through water that has permeated the concrete and then leached concentrated free alkali onto the surface of the glass.

To minimise or eliminate these effects, concrete frames at window heads should be designed so that they do not splay down and back towards the glass. This particular design invites the maximum possible damage to the glass, since it creates a direct wash down the face of the glass. The introduction of an edge drip and a second drip as another line of defence should be considered.

![Diagram](image)

Figure 4: Eliminating water run down on glass
Identification of glazed openings

Glazed openings are identified during construction with markers such as tapes, colourful flags or festoons that are not in contact with the glass but held in position away from the glass and attached to the framing members. Keeping these devices away from the glass prevents them from being seen through the glass when exposed to the sun.

Do not mark or coat glass with an X, floor number, or any other symbol. Such direct marking on the glass may attack the glass, be photographed into the surface, and become incapable of being removed.

AS1288, AS2047 and AS3959

Window glass type, thickness and pane area must comply with AS 1288 Glass in buildings – Selection and installation requirements generally, and window units designed and tested in accordance with AS 2047 Windows in buildings – Selection and installation to satisfy BCA performance requirements. For this reason it is recommended that the builder provide the window manufacturer with all working drawings to ensure accuracy and correct design in relation to wind loadings, special glazing requirements in wet areas, low height applications and bushfire prone areas.

To better understand the risks associated with building in bushfire prone areas and the impacts on glazing and other construction matters you are referred to AS 3959 Construction of Buildings in Bushfire Prone Regions and the BCA Vol. 2 Part 3.7.4

In NSW BASIX regulations also include a number of certification requirements for windows. Window glazing area, type, thickness and stamping must comply with BASIX commitments.

Metal curtain walls

A curtain wall is a non-load-bearing exterior building wall that carries no superimposed vertical loads.

Metal curtain walls are exterior curtain walls that consist entirely or principally of metal or a combination of metal, glass, and other surfacing materials supported by or within a metal framework.

A window wall is a type of metal curtain wall installed between floors.

Metal curtain walls are building systems made up of numerous materials. For example:

- various metals (such as aluminium, steel, stainless steel and copper alloys)
- glass products
- insulations
- coating materials
To overcome or minimise the forces acting on the curtain wall and to provide for design considerations, it is essential the designs, details, and specifications include the following performance requirements.

**Resistance to wind loads**

Glazed curtain walls must be designed and tested to ensure structural system members are able to withstand wind loads. Consideration must be given to structural members include mullions, transoms, and meeting rails and stiles, and the perimeter frame, and, the appropriate selection of sealants and gaskets.

The structure must be designed to withstand inward and outward wind loads. Wind load design pressures will vary with geographical location, surrounding terrain, building height and building shape. At building corners and on the far side, negative (outward) pressures may exceed positive (inward) pressures. Model testing in boundary layer wind tunnels should be considered for tall buildings, buildings of unusual shape or tall buildings surrounded by other buildings.

Testing for resistance to wind loads is performed utilising ASTM E330, Structural Performance of Exterior Curtain Walls and Doors by Uniform Static Air Pressure Difference. The test should be conducted at 1.5 times the design pressure to ensure an adequate factor of safety.

**Deflections**

Deflections of framing members should not exceed 1/175 of the clear span except that when a plastered surface is involved, when the deflection should not exceed 1/360.

**Resistance to water penetration**

Water penetration is usually defined as the appearance of uncontrolled water - other than condensation - on the indoor face of the curtain wall.

Designs to control water penetration may utilise either single stage or two stage weatherproofing.
Additional research

The Australian Window Association has relevant information about

- structural and water performance of windows
- energy efficiency
- bushfire attack level
- materials
- acoustics
- verification and compliance requirements.

Go to:


Find out more about recent innovations in energy efficient glass. Go to:


http://www.efficientglazing.net/efficientglazing.aspx

http://www.efficientglazing.net/EGhome.aspx

Find out what SHGC (solar heat gain coefficient) means, and what Light-to-Solar Gain means. Go to:


The Glass and Glazing Association of Australia (AGGA) website also has articles and information on all aspects of the use of glass in construction.
