GLASS TYPES

Introduction

Glass can be used to provide a durable, transparent enclosure to a building. However, standard annealed glass can be treated in a number of ways to improve:

- **Appearance** - clear, reflective, coloured, patterned, printed;
- **Environmental properties** - heat loss, solar gain, acoustic isolation;
- **Integrity** - safety (e.g. human impact or fire resistance), security (e.g. resistance to bandits, blasts or bullets) and strength (e.g. wind or snow loads).

Glass and the Building Regulations

The use of glass types, which provide enhanced levels of environmental performance or integrity is mandatory for particular glazing situations.

**Thermal insulation**

Approved document L1 dictates insulation levels for dwellings and other buildings whose floor area exceeds 30m$^2$, and thus the maximum allowable glazed area, depending on the glass type and type of building.

**Safety (impact)**

Approved document N and BS 6262 contain guidance on glazing locations where accidental impact is likely, and selection of appropriate safety glass types. Safety glass should reduce the risk of injury, by either resisting breakage, breaking safely or breaking with no significant penetration (i.e. by containment). BS 6206 gives impact test requirements for three classes of safety glass increasing in severity from C to A.

**Safety (falling)**

Part K gives details of the requirements for protection from falling. BS 6180 gives recommendations for the design and construction of temporary and permanent barriers in and about buildings.

**Safety (fire)**

Areas next to escape routes must have a limited area of glazing or incorporate special glass types to allow the safe passage of occupants from a fire (see Approved Document B). Reaction to fire is now classified with two ratings:

1. **Integrity** - the ability of a wall or roof to retain structural strength and contain combustion products during a fire, and
2. **Insulation** - the ability of a wall or roof to resist the transfer of heat from a fire.

For all transparent glazings, sufficient infra-red radiation may be transmitted to cause ignition of materials on the other side. The exception is laminated glass with an intumescent interlayer(s), which on exposure to fire becomes opaque and limits or resists the transmission of conductive and radiative heat. The safety of overhead glazing, where falling broken or heat-softened glass may prevent safe escape of the occupants or limit safe access for firefighters, is particularly important.

**Security**

Security requirements are not covered by the Building Regulations but may be important and will vary according to the type, location and usage of the building. Security glass should reduce the risk of breakage or penetration during criminal attack in order to delay access to premises or protect personnel against attack. BS 5544 and BS 5051: Part 1 stipulate the performance requirements and test procedures for bullet- and bandit-resistant glazing respectively.
**Glass types**

**Annealed glass**

Least expensive and most readily available type of glass. The term includes float glass, sheet glass and patterned glass manufactured as follows:

1. Float glass is manufactured by pouring molten glass continuously from a furnace onto a large shallow bath of molten tin, where it floats, spreads out and forms a level surface (over ninety per cent of glass is manufactured by the float process);
2. Sheet glass is manufactured by the flat drawn process and has natural fire-finished surfaces but, because the two surfaces are never perfectly flat and parallel, there is always some distortion of vision and reflection;
3. Patterned, figured and cast glass products are manufactured by the rolling process in which semi-molten glass is squeezed between metal rollers (polished plate glass is produced by grinding, smoothing and polishing the surfaces of cast glass).

Annealed glass breaks into sharp-edged shards, although these may remain in the frame, depending on the glazing method. Annealed glass reacts to elevated temperatures by rapid expansion, which may result in failure due to excessive stresses being generated at the edges of glazing which are insulated by the frame. This phenomenon is known as thermal breakage and is discussed in greater detail in Technical Note 13 *Glass breakage*. Annealed glass is unsafe in all fire situations.

**Patterned glass**

Patterned glass transmits light with varying degrees of diffusion so that vision is not clear; usually the deeper the pattern the greater the obscuration and diffusion. Patterned glass is manufactured by the rolling process and can be toughened (depending on the pattern so the manufacturer should be consulted), laminated or made into glass units. It is available in clear and tinted forms.

Annealed glass is untreated glass manufactured from soda lime silicates, which can be cut or scratched with a wheel and snapped. It is the

**Borosilicate glass**

Borosilicate glasses, although more expensive than ordinary annealed glass, offer the advantage that they expand at one third of the rate of annealed glass and possess a higher viscosity at elevated temperatures. This means that they can withstand the high temperatures of a fire for longer periods. These glasses can now be manufactured by the float production technique as well as by drawing, and are generally supplied in a heat-strengthened or toughened state. They remain transparent during a fire situation and do not protect passers-by from the effects of heat from excessive infra-red radiation. Glass ovenware is generally made from borosilicate glass.

**Tinted and coated glass**

Glass may be produced with an inherent colour tint (of bronze, green, blue, grey, amber etc.) by adding small amounts of metal oxides to the glass composition during manufacture. The colour is achieved by absorption of some of the incident radiation increasing the temperature of the glass but reducing solar heat gain inside the building.

Alternatively, or additionally, surface coatings may be applied that modify some or all of the solar energy transmission, colour and thermal insulation properties.

Coatings may be applied to the hot glass as part of the manufacturing process or as a separate operation once the glass has been manufactured and cut. The former type may be referred to as pyroilitic coatings and have greater hardness and durability.

Most solar control and obscured glasses need to be checked for potential thermal breakage. The manufacturer can advise on the requirements for toughened or heat strengthened glass if thermal breakage is a problem.
Low-E glass

Low-E coatings reduce the emission of long-wave thermal radiation (infra-red) from the glazing and increase the reflection of this radiation. However, the coatings are transparent to short-wave solar radiation and so allow solar radiation to pass into the building. In this way beneficial winter solar radiation can be trapped within a room, and reduce the need for heating. However, summer heating can also occur and so low-E glass needs to be used in conjunction with adequate provision for ventilation. This is generally the case in domestic buildings (except conservatories with fixed glazing) but would require careful consideration for offices where limited natural ventilation could overload mechanical ventilation systems. It should be noted that low-E coatings will also reduce nighttime heat loss.

Low-E glass can be used in conjunction with solar control (i.e. tinted or reflective) glasses, but will generally result in higher glass temperatures. The need for solar control glazings should always be assessed on a project-by-project basis, possibly using energy simulation software.

Most low-E glass can be toughened and laminated. When laminated, the non-coated face has to be against the interlayer because the coating has to be on an exposed surface to resist infra-red radiation. The coating is also normally glazed towards the cavity of double glazing units to protect it from abrasion and corrosion. Pyrolitic coated glasses can be glazed with the coating on the outside of the unit, but the effectiveness of the coating is severely reduced by surface dirt or moisture.

Insulating glazing units

Insulating glazing units incorporate two or more panes separated by a spacer, which is attached and sealed by one or more perimeter seals. The gap between the panes can be filled with air, which is dried by desiccant within the spacer, or a low conductivity gas such as argon, krypton or even xenon for improved thermal insulation. Glass units should comply with the requirements of BS 5713 (e.g. for seal integrity), although a European standard prEN 1279: Part 2 is also being drafted. Technical Note 12 Specification of hermetically sealed glass units gives further information on insulating glazing units.

Wired glass

Wired glass is made by sandwiching an electrically welded steel wire mesh between two layers of molten glass in one continuous rolling process; it is supplied in rough cast (obscured) or polished (transparent) form.

Wired glass breaks into shards which are held together by the wire mesh, but sharp glass edges may be exposed, and the wire will corrode. The wire may also corrode if the edge of the glass is exposed to damp conditions, which will ultimately lead to fracture of the glass. Wired glass cannot be toughened or heat-strengthened. It is weaker than an equal thickness of annealed glass and is not a security glass.

Wired glass is designed to give limited fire resistance. The performance obtained depends upon the area of the glass, the type of framing and the glazing details. Fire-resisting wired glasses - like all fire glasses - should be specified carefully. Wired glass having a wire of diameter greater than 0.7mm is also classified as a Class ‘C’ safety glass (i.e. resists impact by containment).

Thermally toughened glass

Thermally toughened glass is formed by heating and then rapidly cooling (quenching), annealed glass. Differential cooling and hardening across the thickness of the glass generates a compressive stress in the surface layer of the glass, which is balanced by a tensile stress in the core of the pane. Depending on the skill of the operators and type of furnace, a small degree of optical distortion may occur, due to sag between the supports, during toughening.

Toughened glass is always a Class ‘A’ safety glass. Compared with annealed glass, four to five times higher loads can be applied before the compressive surface stresses are overcome (e.g. by bending of the glass under impact) and the glass fractures. This glass is also tougher.
because the flaws which are present on the surface of the glass are held in compression and prevented from developing into fractures.

Toughened glass shatters into small, relatively safe fragments. A vertical pane may remain in its frame, but sloping panes are likely to fall out when they break. The greatest risk with toughened glass is that the fragments may clump together and fall en masse.

The proposed European standard for toughened glass (prEN 12150) requires that, within 5 minutes of breakage, a 6mm thick pane of toughened float glass shall have at least 40 glass fragments in a 50mm square; this suggests a mean fragment size of 8mm. Each falling fragment therefore represents a significant projectile, and even a small clump of fragments may cause significant damage if falling from a height. For thicker panes of toughened glass the fragments will be as long as the glass is thick, and present significant projectiles when falling from a sufficient height.

The manufacturer should be consulted for details of what glass types can be toughened because not all tinted or coated glass can be toughened. Glass having a hard (pyrolytic) coating (e.g. some low-E coatings) can be toughened after coating. Some soft (sputtered) coatings can also be toughened after coating but others must be applied to the glass after the toughening process.

**Heat soaked toughened glass**

All annealed glass contains nickel sulphide impurities, in the form of small crystals. As glass is heated during the toughening process these impurities change state. The high temperature α-state of the impurities may be frozen when the glass is quenched, and recovery to the low temperature β-state may then take several years. Spontaneous breakage of the glass may follow, as the low temperature β-state of the nickel sulphide impurities occupies a slightly greater volume and generates a local stress concentration. Impurities larger than 50μm will cause failure, but only if they are in the core (tensile zone) of the glass. Nickel sulphide failures start to appear immediately after production, with a peak failure rate around four to five years after production, but may occur for 20 years.

The best protection is to obtain glass from a quality manufacturer; the next safeguard is to heat soak test. The failure of toughened glass in service can be reduced by heat soaking - the toughened glass is heated for several hours (depending on the thickness of glass and the quality of oven) to encourage reversion of the impurities to the low temperature state. Panes of glass with large impurities should shatter during this process, but this depends on the quality of the oven and procedures used for heat soaking.

One large, reputable manufacturer reckons that only one critical inclusion occurs in every 13 tonnes of glass that they produce, and that 90 per cent of the inclusions will cause premature breakage during their heat soaking process. This means that only one nickel sulphide inclusion will ‘get through’ for each 12,700m$^2$ of 4mm heat soaked toughened glass, or for each 8,500m$^2$ of 6mm heat soaked toughened glass.

Poor design (failure to check thermal safety) and careless handling (e.g. edge damage) or glazing (wrong or no setting blocks) are much more common reasons for spontaneous breakage of toughened glass than nickel sulphide inclusions. Nevertheless, heat soak testing must be specified for toughened glass in critical locations - designers are responsible for ensuring that the specification is correct.

As a minimum requirement, toughened or heat-strengthened glass located at height or overhead should be heat soaked.

**Heat-strengthened glass**

Heat-strengthened glass is formed by heating annealed glass and then cooling it under controlled conditions. Differential cooling and hardening across the thickness of the glass generates a compressive stress in the surface layer of the glass and a tensile stress in the core of the pane. Heat-strengthened glass offers
some of the strength of toughened glass (described above) but a reduced risk of failure due to nickel sulphide inclusions because of the reduced tensile stress in the glass.

Heat-strengthened glass could also be called ‘partly toughened’; by varying the strengthening process it is possible to produce glass with fracture properties anywhere between those of annealed and toughened glass.

There is no current standard which defines heat-strengthened glass. The definition of heat-strengthened glass contained within the draft European standard prEN 1863, requires heat-strengthened glass to exhibit fracture properties similar to those of annealed glass, but with a limit on the number and size of island and particle fragments. An island is a large fragment of glass, with an upper and lower limit on size and a particle is a small island.

**Laminated glass**

Laminated glass is formed by bonding together two or more panes of glass using a plastic interlayer. Any of the above forms of glass may be used, in any combination. A common interlayer material is poly-vinyl-butyral (PVB), which is used in multiples of 0.38 mm thickness. A thicker interlayer may help to reduce the risk of debris penetration on impact.

Glass is laminated for the purpose of:

- Maintaining integrity should a pane of glass break,
- Reducing the likelihood of penetration (for security or safety reasons),
- Improving acoustic properties;
- Give decorative effects.

Laminated annealed glass breaks into shards, exposing sharp edges, but these are held together by the interlayer. Different interlayer materials and thicknesses have different effects upon performance.

PVB and other interlayer materials degrade in the long-term presence of water so the edges of laminated glass should be permanently protected from immersion in liquid. Note that although laminated glass is only slightly weaker than a single pane of the same thickness it will deflect more under long-term loads, and the interlayer may soften at higher temperatures; PVB is not suitable for sustained high temperature exposure (in excess of 70°C).

Laminated glass may include one or more panes of toughened glass. If all panes are of toughened glass then the broken glazing will lose all structural integrity and may pull free from the frame, unless properly secured.

In a fire situation, glass laminated with special gels gives infra-red and insulation protection (see below), whereas PVB laminated glass may break and hang loosely from its frame. Softening of the plastic interlayer may allow such broken laminated glass to continue to fall from a slope glazing system for a significant period of time after a fire has been brought under control, and as such presents a serious hazard to fire-fighters. Proper selection of the glass can help to control this problem, for example by incorporating borosilicate glass.

PVB laminated glass is recommended for the inner pane of overhead glazing with the agreement of the local building control officer.

**Intumescent glazing**

Intumescent glazing is a special form of laminated glass in which the interlayer is a material which becomes opaque when subjected to excessive heat. This opacity may be accompanied by fracture of the glazing, but the glazing remains in place. Intumescent glazing thereby protects passers-by from the effects of intense heat.

Intumescent glass is available with several intumescent interlayers, depending upon the level of fire protection required.

**Plastics glazing materials**

A number of plastics glazing materials exist, including poly-methyl-meth-acrylate (PMMA, acrylic), poly-carbonate (PC) and ethylene-tetra-
fluoro-ethylene (ETFE). Plastic materials may be produced in multi-walled form in addition to plain sheet.

These materials are usually better at resisting impact, and when broken tend to remain in place. However, they also deflect more under load, and the designer should check that rebate depths are sufficient to ensure that the deflected glazing cannot pull free from the framing system. Note that BS 5516 bases design charts for selection of plastics glazing materials on a standard edge cover of 15mm, compared to a minimum edge cover of 7mm for glass.

Plastics glazing materials are easily scratched and discolour over time. They may be surface treated to resist the effects of ultraviolet radiation, although the treatment is often limited to one side of the sheet, meaning the materials must be installed the right way around. Many rigid plastics materials also have high rates of water vapour transmission, and cannot be used as part of a sealed multiple glazing unit. The higher coefficients of thermal expansion mean that plastics cannot be used in combination with glass.

In a fire situation some plastics may burn and release particulate contaminants or noxious gases. The use of the building may need to be considered. For example, the use of plastics glazing materials may be excluded in areas used for food or pharmaceutical preparation on the grounds of the high cost of replacing contaminated stock, should a small, localised fire occur.

Summary

There are many glass types now available. Although annealed glass forms the basis of most of these, their physical and mechanical characteristics can differ greatly. Careful design, with knowledge of manufacturer’s products and their availability, is necessary to achieve satisfactory performance.

Bibliography and References


BS 5544, 1994, Specification for anti-bandit glazing (glazing resistant to manual attack), British Standards Institution.

BS 5713, 1994, Specification for hermetically sealed flat double glazing units, British Standards Institution.


Glass types


prEN 1863 *Glass in building - Heat strengthened glass*

prEN 12150 *Glass in building - thermally toughened safety glass*