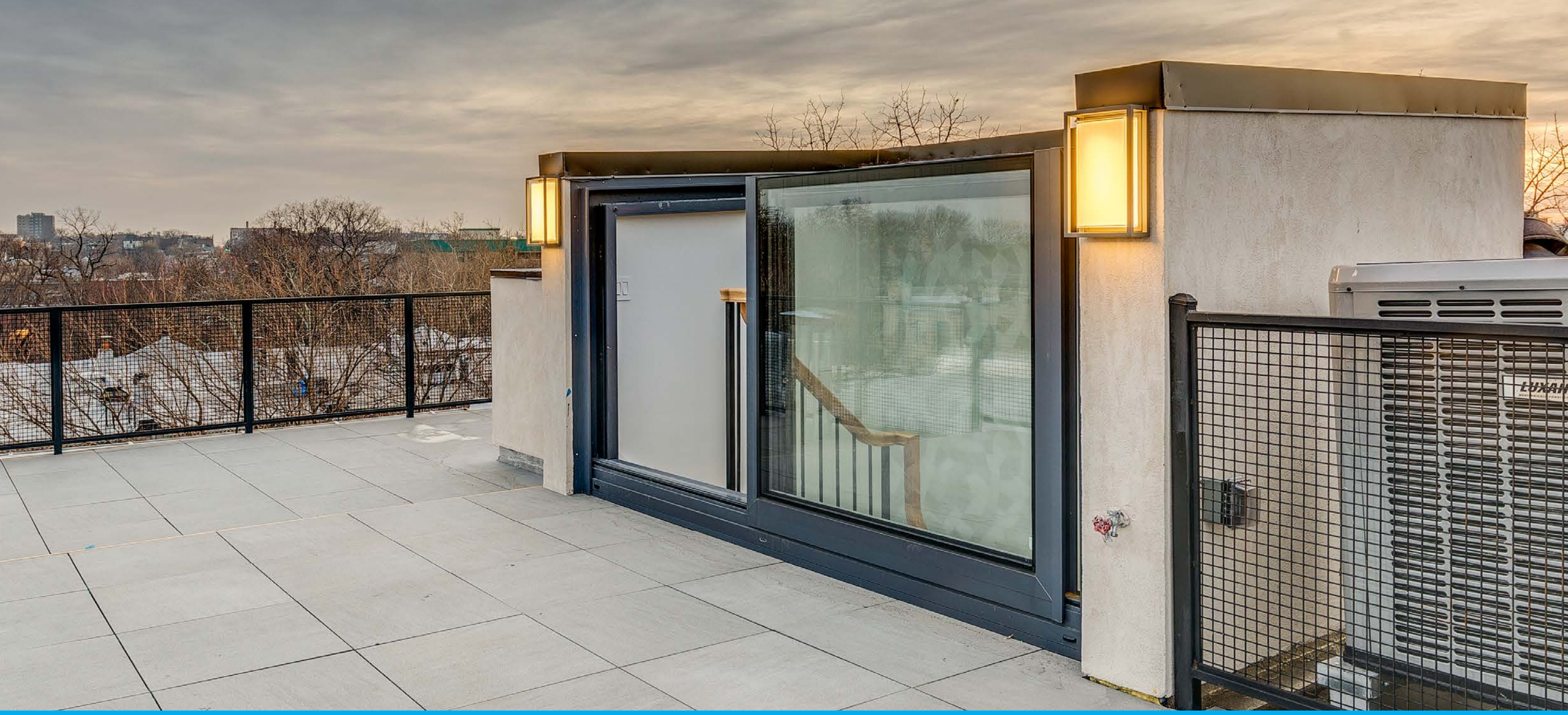

SPECIFYING GLASS IN ROOFLIGHTS

THE GLAZING VISION GUIDE

GLAZING VISION

Contents

At face value, glazed rooflights or roof windows seem fairly straightforward. They provide natural light and ventilation to a building's interior, give building occupants a view outside, and can provide a means of access or escape.

Once upon a time that simple functionality was sufficient, but the demands placed on modern building fabric require much more. Glazing units have to perform similar functions to the building elements in which they're installed - elements that are made up of many more components and materials than one or more transparent sheets in a frame.

'Transparent sheets' is a clumsy description, but materials other than glass are used in rooflight and roof window production.

Polycarbonate and glass reinforced polyester (GRP) have their applications; they are lightweight-yet-strong, cost effective, and can be shaped into domed rooflights. They are popular options for domestic conservatories and industrial or agricultural buildings.

Nevertheless, glass remains the solution of choice in the majority of applications. For it to meet all the functional requirements expected of it, however, necessitates an awful lot of options to create the right blend of characteristics for any individual project.

This guide explains those choices, guiding you through the design, specification and construction process to show how to get the best results. By the end, you'll be left in no doubt as to the inherent quality and durability of glass, and how it contributes to high performance, thermally efficient building fabric.

SECTION 1 - TYPES OF GLASS

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Glass manufacturing development

The development of glass manufacturing technology over the last 60 years has fed ambitious architectural uses of glass; in turn, the increased consumption of glass by the construction industry has fed the development of new products and glass types.

Glass for use in buildings, usually called architectural glass, requires pure materials. It cannot simply be made from recycled domestic waste glass.

Sand (silica), soda ash (sodium carbonate) and limestone (calcium carbonate) are melted together with a small amounts of salt-cake (calcium sulphate) and dolomite (magnesian limestone). Broken glass (called cullet) can be added to accelerate the melting process and recycle production waste.

Traditional production methods gave us crown glass and cylinder glass. The advent of the Fourcault process produced drawn sheet glass, problems with which were solved by the invention of plate glass. Those methods were rendered virtually obsolete in the 1950s when Sir Alastair Pilkington invented the float process and gave the world float glass.

The introduction of float glass

The overwhelming majority of glass produced for construction today is float glass; it is the 'basic' form of glass from which other options are derived. Traditional manufacturing processes are still used for conservation and heritage projects, but modern glass production has removed the distortion issues commonly associated with older glass types.

Liquid glass is floated onto a shallow bath of molten tin, at a temperature sufficient to even out surface irregularities. It is pulled from the bath, at a speed adjusted to suit the required thickness, into an annealing lehr. Here, careful temperature control allows the glass to be cooled slowly prior to cutting and final processing.

It's not uncommon for float glass to be described as annealed glass. Annealing is a process; it produces glass free of internal stresses caused by other heat treatments. However, annealed glass breaks easily into large shards. Understandably, that is considered unsafe for certain uses in buildings, and there are other ways in which float glass can be treated to improve its safety.

Example of modern glass production line.

Toughened and heat-strengthened glass

Toughened glass is designed to fragment into much smaller pieces or granules if broken, and is therefore suitable for safety applications.

Annealed glass is heated, then rapidly cooled to make the surface of the glass more resistant to tensile failure. Glass cracks due to failure at the surface. This tempering balances compression at the surface with tension in the centre of the pane, making toughened glass some four or five times stronger than annealed glass, and more resistant to blunt impact. Toughened glass cannot be cut or worked, so all processing has to be carried out prior to toughening.

Reducing the risk of spontaneous fracture

Spontaneous fracture is known to occur in toughened glass, due to the stabilising of nickel sulphide (NiS) present in the material. The risk of breakage is relatively low, but unpredictable - it could occur within weeks or years of manufacture, if at all. Heat soaking filters out about 95% of potential problem units. Toughened glass is heated to 290 deg.C and held at that temperature, accelerating the process of any nickel sulphide inclusions reverting to their ‘beta state’ and causing failure.

Inevitably, heat soaking adds cost but improves product quality and consistency, reducing the use of potentially faulty glass in the manufacture of rooflight products.

The use of heat soak testing is not regulated, but reputable manufacturers are more likely to undertake it than not - especially for large structural rooflights or in walk-on applications. Glazing Vision, for example, heat soak test all of the toughened glass they produce as standard, to make sure customers get a reliable and trustworthy solution for their project.

Heat soak testing is not a guarantee that glass will remain failure-free. The reality is that whilst a Nickel Sulphide inclusion is a possible cause, it is the most unlikely one. In particular if the glass has been heat soak tested.

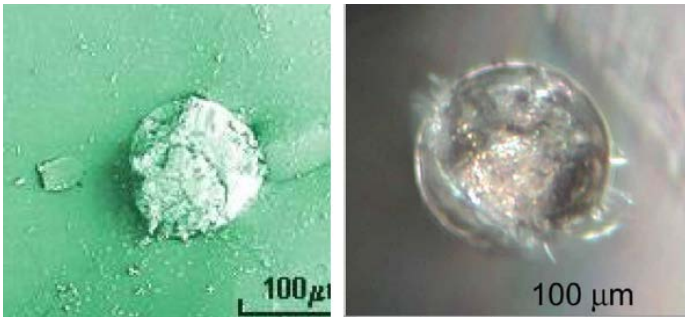
Nickel Sulphide may not be to blame

There is a problem in the industry with any unexplained glass breakage being too readily blamed on Nickel Sulphide inclusions. Nickel Sulphide has had a bad press over the years and it is very easy to blame this as the cause of an otherwise undiagnosed glass failure.

The risk of a spontaneous breakage in thermally toughened glass that has been heat soak tested in accordance with BS EN 14179-1 is 1 in 400 tonnes of glass.

Based on a typical size pane of glass in a double glazed unit this equates to a risk of 0.015% or approximately 1 in 7,000 sealed units or 1 in 14,000 panes of glass.

Other much more likely causes of glass failure are impact, other inclusions such as particles of refractory brick, undissolved silica or the chemical element silicone, surface scratches or damage from such as weld spatter or grinding dust. The surface damage can occur at any time during transport, site handling, storage or after installation.



Nickel Sulphide inclusion under extreme magnification.

There is a problem in the industry with any unexplained glass breakage being too readily blamed on Nickel Sulphide (NiS) inclusions.

Only Nickel Sulphide inclusions can cause spontaneous failure without any other influence. When the inclusion is not Nickel Sulphide or there has been surface damage to the glass, the toughened glass is weakened and therefore may fail when additional factors come into play to over stress the glass. This could be because the pane is oversize for the thickness of glass supplied or it has been overloaded by wind, snow or maintenance loads, over and above the design loads or it could be additional stress induced in the glass through having insufficient support by the framing system or structure or through poor installation or handling.

All toughened glass, when broken, will display a typical ‘butterfly’ pattern at the source of the break regardless of the cause, including impact. So looking for the butterfly pattern in the broken glass is useful to identify the location of the cause, it does not tell us the root cause. The only way to do that is to preserve the pieces of glass around this area and have them analysed under an electron microscope where surface damage or inclusions will be able to be identified.

Heat strengthened glass

Produced in a similar way to toughened glass, heat-strengthened glass is subjected to a slower rate of cooling and therefore is only around twice as strong as annealed glass (or half as strong as toughened glass). If it breaks, it exhibits similar behaviour to annealed glass. It cannot be used as safety glass on its own but, thanks to good residual strength after cracking, it does lend itself to use in a laminated pane. Heat-strengthened glass does not require heat soaking.

Both toughened glass and heat-strengthened glass are resistant to large and variable changes in temperature, suiting them to spandrel panels where there is a risk of thermal cracking. They also offer good resistance to wind pressure on tall buildings and, in particular, corners.

The heating and cooling cycle required to produce toughened or heat-strengthened glass causes optical distortion in the surface. When annealed glass is heated again, it sags slightly between the rollers carrying the glass through the furnace; the subsequent cooling results in ripples, or 'roller wave distortion'.

Roller wave mainly shows up in the reflections of the glass, and eliminating such distortion entirely is impossible. It can only be reduced, mainly by design and control of the manufacturing process and the way in which the glass is heated and cooled, and moved through that sequence. Thicker panes of glass generally remain flatter, while larger panes typically show up more distortion.

Laminated interlayers in glass

Bonding two panes of glass with an interlayer produces laminated glass, a catch-all term to cover the various combinations of glass and interlayer. Because the interlayer holds the glass even when broken, laminated glass is typically used where security is a priority, as well as in safety applications like overhead and walk-on glazing.

By far the most common interlayer is polyvinyl butyral (PVB). Ethylene-vinyl acetate (EVA) is also popular; other interlayer materials include cast-in resins, polyurethanes and ionoplast materials.

Where transparent plastic materials, like PVB and EVA, are used as the interlayer, the bond is achieved through the application of heat and pressure in a controlled environment; however, plastic interlayers make cutting difficult. Resin is a more versatile adhesive and allows for the production of curved laminates.

Demanding performance specifications are driving the development of interlayer solutions, some of which fail to offer adequate levels of adhesion.

Manufacturers of proprietary interlayers, such as ionomer-based ionoplast, claim improved performance for especially demanding applications. PVB, however, remains the popular option.

As a hygroscopic material, PVB absorbs moisture and can turn cloudy as a result. Poor storage of PVB can lead to it having an increased moisture content prior to use, while good edge sealing of the glazed unit stops moisture getting to the interlayer; either can risk delamination. Delamination may also occur if distortion in the two glass panes is poorly matched and introduces stresses in the interlayer.

Laminated glass pane with PVB interlayer.

Laminated glass is typically used where security is a priority, as well as in safety applications like overhead and walk-on glazing.

Partially shaded rooflights can be susceptible to thermal heat stress unless the correct glass specification is used.

Laminated glass performance characteristics

It is important to understand when specifying glass for use in rooflight systems, that the combination of interlayer and glass panes that make up the complete section is critical in achieving your desired performance.

Laminated glass is two or more sheets of glass bonded together with a plastic interlayer, this interlayer holds the glass together and will be retained in the frame in the instance that either or both of the glass sheets should break. It is therefore a safety glass and can be used in overhead glazing.

Annealed glass is not as strong as toughened glass and is susceptible to thermal fracture. This is caused when there is a significant temperature difference within the same piece of glass and is likely to occur where adjacent structure or trees, for instance, could cast a shadow across the glass with part of it in sunshine and part in shade. (see image above)

It can also be caused by other finishes being located close to the underside of the glass where heat coming in through the glass is reflected back to the underside. This can be caused by wide upstands or the fitting of blinds in close proximity. A rooflight with an annealed laminated inner pane would be classified as non-fragile.

Heat strenghtened laminated glass is considered the most suitable option for most general use glass rooflights.

Heat strengthened laminated glass

Heat strenghtened laminated glass is considered the most suitable option for most general use glass rooflights. It is similar to annealed laminated glass, except the sheets of glass that are laminated together have been heat strengthened. This glass is twice the strength of annealed glass and is resistant to thermal heat stress cracking and does not suffer from the very small risk of Nickel Sulphide inclusions that may affect some toughened glass.

Heat strengthened laminated glass is a more expensive option, but it offers one of the broadest specifications for overhead glazing, as it is considered a safety glass which will be retained in the frame if broken and is not susceptible to thermal heat stress cracking. A rooflight with a heat strengthened laminated inner pane would be classified as non-fragile.

Toughened and heat soak tested laminated inner pane

Toughened laminated glass is similar to annealed laminated glass except the sheets of glass that are laminated together have been toughened and heat soak tested.

This glass has all the benefits of toughened glass but without the risk of pieces of glass falling from the rooflight if the one or both of the sheets of glass in the laminate should break. It is not susceptible to thermal heat stress cracking. A rooflight with a toughened laminated inner pane would be classified as non-fragile.

SECTION 2 - GLASS PERFORMANCE

Understanding non-fragility

Glass used in rooflights that are installed on a roof that is accessible, but not designed for regular foot traffic, should be specified as 'non-fragile'.

Depending on the anticipated use of the roof, a non-fragile rooflight is designed to prevent people or objects falling through it in the event of an accident on the roof. To that end, roof access requirements should be assessed at design stage and specified carefully, helped by appropriate risk assessments.

The non-fragility of a roof glazing product is an important measure, but any such rating should not be taken to imply that the product is safe to walk on. Most rooflights are designed to be non-fragile, and to provide a level of non-fragility equivalent to the surrounding roof.

Tests for non-fragility are defined in the Advisory Committee for Roof Safety's (ACR) Red Book (ACR[M]001), which references test guidelines for glass rooflights by the Centre for Window and Cladding Technology (CWCT). Three technical notes by the CWCT carry particular weight, having been developed to establish a clear distinction between 'fragile' and 'non-fragile' glazing:

- TN66 - Safety and fragility of glazed roofing: guidance on specification.
- TN67 - Safety and fragility of glazed roofing: testing and assessment.
- TN92 - Simplified method for assessing glazing in class 2 roofs.

TN66 categorises glazed roofing using four classes:

- Class 0: roofs designed for unrestricted access by building occupants.
- Class 1: roofs walked on for occasional cleaning/ maintenance activities, which need to support the weight of people and their equipment, and which could be subject to impact from a person, and/or any object carried, falling onto its surface.
- Class 2: roofs where people are not intended to walk on the glass, but which are required to be non-fragile to protect maintenance personnel where they are:

    ◊ walking adjacent to the glass roof and could trip or fall onto its surface;
    ◊ working on the glass roof and could fall onto its surface from crawler boards or other access equipment.

- Class 3: fragile roofs.

The non-fragility of a roof glazing product is an important measure, but any such rating should not be taken to imply that the product is safe to walk on.

Domestic walk on specification glass rooflight.

Hard and soft body impact testing under TN67

TN66's classifications lead to testing under TN67, with glazing often falling into Class 2 when testing. TN67 sets out some deemed to satisfy criteria for Class 2 glass:

- The 'hard body' test is where a 100mm diameter steel ball weighing 4.11kg is dropped from a height of 1200mm.
- The 'soft body' test is where a 300mm cylindrical sand bag weighing 45kg is dropped from a height of 1200mm.
- The 'static load test' is where the glass must be broken if not already, then a static load of 180kg is placed on the test rig for 30 minutes.

The procedure is repeated on two more samples to check the consistency of results. In all cases, nothing must pass through the glass. Any fragments of glass that fall from the tested glass are measured and weighed to assess the risk to people below.

Results apply to the tested pane size, frame support system and method of glass retention in the frame; something that should be borne in mind when looking to specify a bespoke rooflight product.

Roof assembly testing under ACR[M]001

These are product tests, while ACR[M]001 details a roof assembly test, of which a rooflight can be part. Perhaps confusingly, the ACR non-fragility test defines three classes of roof assembly: A, B and C. However, since this document is about glass specifically, we are not going to dwell on these roof assembly classifications.

Only a product specifically designed to be used structurally can be taken as a walk-on rooflight, and the recommendation from the National Association of Rooflight Manufaturers (NARM) is to qualify their use with a phrase such as, "must be designed to floor loadings." Words like 'walkable' and 'mansafe' are undefined, not recognised in relation to glazing and, in some cases, are related to other proprietary roof access equipment.

Walk-on rooflights are outside the scope of TN66 and TN67, mentioned above.

180kg load used as part of soft body impact test.

Steel ball used in hard body impact test.

Specifying the correct glass for foot traffic

Glass is the only material appropriate for a rooflight product designed to take foot traffic. Glazing Vision's view is that the outer pane should be toughened, heat soak tested and laminated, usually with three glass layers - and maybe an additional sacrificial pane - for a total thickness of 25 to 49mm (or more in extreme situations).

Glazed flooring is heavier than a high-specification rooflight, and the roof structure has to be designed to take the loads imposed by products of such weight.

NARM guidance on load capacities for walk-on rooflights in different building types:

Application:	Domestic	Commercial	Heavy duty
Uniformly distributed load (UDL) (kN/m²):	up to 1.5	up to 4.0	up to 5.0
Concentrated load (kN):	up to 2.0	up to 3.6	up to 4.5

These loadings are typical examples only, specifyers should refer to BS EN 1991-1-1 and the associated National Annex when defining load capacities.

Other contributing loads to consider

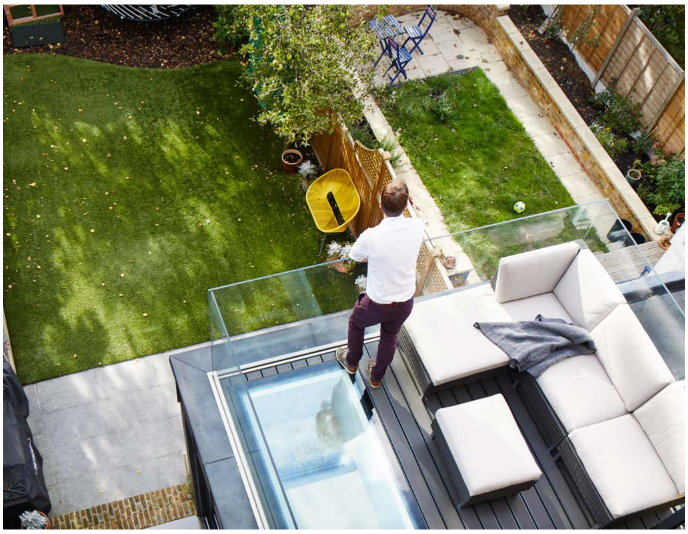
It isn't only loads imposed by people that need to be taken into account - resisting the elements is just as important. Year round, a roof is subject to wind loading and the test method in BS EN 12211 describes how to undertake and assess pressure testing, wind resistance and frame deflection.

Snow is far more seasonal but, depending on the severity of any given winter, can linger and increase over an extended period of time. The ability of roof glazing to withstand snow loading is tested in terms of long-duration loading, and any deflection in the centre of the glass measured accordingly.

Site location is a significant determining factor in the wind and snow loads to which roof glazing is exposed, and should be considered accordingly.

The performance of rooflights in the context of national building regulations - including fire safety - is the topic of a later section of this guide. For now, fire rated glass can mainly be thought about in terms of insulation (resistance to transfer of excessive heat, denoted as I) and integrity (resistance to fire penetration, denoted as E).

Other fire performance requirements imposed on roof glazing include reaction to fire and fire spread over the surface of the material. Smoke venting or smoke control may also be specified as part of a complete roof window product.



Glass 'walk on' rooflight used as part of roof terrace conversion.

Glass is the only material appropriate for a rooflight product designed to take foot traffic. Glazing Vision's view is that the outer pane should be toughened, heat soak tested and laminated.

Acoustic performance of glass

Bespoke rooflight solutions have become commonplace, especially where building owners want to make a statement or introduce a little luxury into their projects. In recent years, Glazing Vision have grown their design office in response to demand for one-off products and unique feature combinations.

The acoustic performance of rooflights is driven by whether they are double or triple glazed, the size of gap between panes, and the thickness of the panes. Glass - whether annealed, toughened or heat-strengthened - follows the mass law of sound transmission, where doubling the thickness of a pane (and therefore its weight) reduces sound transmission by 4 to 6 decibels.

Laminated glass offers a greater benefit by the use of a thicker PVB, or standard EVA, interlayer; the soft plastic material changing the composite product's response to sound transmission. Specific acoustic interlayers are available that further improve performance.

Double and triple glazed products use glass panes of different thicknesses to reduce 'sympathetic resonances' - i.e. the reduction of sound of equal frequencies. A double glazed unit might be expected to achieve a sound reduction of around 32 decibels; triple glazing may achieve a reduction of 40 decibels.

Greater benefit would only be seen with significantly increased distance between the glass panes - up to 200mm for the best, albeit impractical, effect! Scenarios in which this would be desirable lend themselves to the specification and installation of secondary glazing.

Although not directly relevant to the glass, the acoustic performance of a rooflight unit as a whole also depends on the quality of its installation and airtightness. Air leakage, and resulting sound transmission, around the whole unit can be addressed by lining the reveals with a sound absorbing material.

Reducing condensation risk using heated glass

Condensation risk has led to some people taking up the option of heated glass. Any area of glazing suffers greater heat loss compared to the building fabric around it, and therefore its surface temperature will be locally colder. When warm air containing moisture vapour comes into contact with that colder surface, the air temperature drops and excess moisture is deposited as condensation.

For rooflights that cannot achieve U-values quite low enough, and/or applications where the moisture load/humidity is particularly high (swimming pools being the obvious one), heated glass raises the surface temperature of the rooflight, reducing the potential volume of condensation occurring on it.

The best way to eliminate condensation risk is thermally efficient building fabric and controlled ventilation, rather than consuming more energy through additional heating. Changing the level of risk in one place may shift the likelihood of condensation occurring to the next-coldest surface, so heated glass should be specified with care, and for the right reasons. For example, in high humidity environments such as swimming pools.

Heated glass raises the surface temperature of the rooflight, reducing the potential volume of condensation occurring on it.

Anti slip treatments

Other applications for heated glass include evaporating rainwater or dew, and melting ice and snow. When wet, however, walk-on rooflights are slippery, and anti-slip finishes provide an antidote to the inherent risks. Homeowners might be unlikely to access their roof in adverse conditions, but on commercial and other non-domestic buildings, roof access can be required any day of the year.

Sandblasting the surface of rooflight glass is one way to increase slip resistance, while also adding obscurity and creating light diffusion. More commonly, ceramic frit is used. Evidence of fritted glass has been found from the Egyptian and Mesopotamian eras; modern techniques screen print or digital print the frit onto annealed glass before tempering it to achieve the desired performance. Fired permanently into the surface of the glass, the frit provides the slip resistance.

Textured glasses offering slip resistance are also available.

Slip resistance is measured by pendulum test values (PTV), where a higher PTV means better slip resistance. A surface with a PTV up to 24 has a high risk of slipping; 25 to 35 is a moderate risk and 36 or more is a low risk. Sandblasted glass and fritted glass generally achieve PTVs of 50 and 60 respectively, so both are considered low risk. Wet and dry tests are carried out, and lower figures are unsurprisingly achieved in wet conditions.

Ceramic frit and screen printing techniques can be used for decorative effect as well, especially in conjunction with enamelled glass. Ceramic paint is applied to the glass before toughening, and the toughening process fires the paint into the surface of the glass.

Example of typical anti slip frit pattern applied to walk on glass.

Switchable privacy glass used in Microsofts Portuguese headquarters
(credit: Smartglass International)

Glass is not always transparent

These decorative uses of glass, and other situations where clarity is particularly desirable, lend themselves to the use of low-iron glass. The silica used in the initial glass production is selected for its low iron content removing the natural green-blue colouring that occurs otherwise.

Other visual effects can be achieved using smart or switchable glass - but for entirely different reasons. Electrochromic glass features an interlayer that responds to a small electrical current passing through it, changing the glass from opaque to translucent. Switching off the electric potential makes the glass opaque again, and the level of current applied can alter the depth of colouration. This technology can be used for privacy reasons, or as a means of solar control and shading.

SECTION 3 - THERMAL EFFICIENCY, HEAT TRANSMISSION AND SOLAR GAIN

Managing light transmittance

The thermal performance of rooflight glass is just as much a part of the specification essentials described in the last section, but balancing outgoing heat loss with incoming daylight and solar energy is critical to the overall thermal efficiency of a building and the thermal comfort of its occupants. As such, it warrants a section of its own.

Designing any type of glazing into the building fabric provides natural light that is integral to the quality of the indoor environment. It creates a pleasing, stimulating and more productive environment, as well as happier people. Light transmittance is simply a measure of the amount of light allowed into a building.

A clear, double glazed rooflight could be expected to provide light transmission of up to 77%. Various coatings can be applied to glass for other performance reasons, and manufacturers have worked hard to develop treatments that still offer high levels of light transmittance. How light is then distributed in the building has a big say in how comfortable occupants feel. Diffused light is better distributed and improves the illumination of the space, compared to direct light which can cause glare.

Light transmittance is closely tied to reflectivity, where low levels of reflectivity render the glass virtually invisible. It creates a pleasing aesthetic and reduces glare for people outside the building, while providing particularly high levels of light transmittance. By contrast, high levels of reflectivity can provide a mirror finish for privacy and an increased level of solar control through a reduction in solar radiation entering the building - but likely at the expense of some light transmittance.

Understanding solar control

The measure of infrared radiation (solar heat) allowed into a building is the g-value. A g-value can be anything from 0 to 1, where 0 represents no solar heat gain and 1 is the maximum possible solar heat gain. It is calculated by dividing the total solar heat gain by the incident solar radiation (the amount of solar radiation received on the surface during a given time).

The lower the g-value, the lower the percentage of solar radiation allowed through the glass, and it can be quoted for the glass alone or for a complete glazed unit. Better, lower g-values also result in lower light transmission.

g-values are typically used in Europe; the equivalent in North America is solar heat gain coefficients (SHGC). The difference between the two is how air mass is treated, so while they are similar they should not be compared directly. Both represent a move away from shading coefficients, which measure the solar heat gain through the material relative to a standardised sheet of clear float glass.

Large areas of glazing, as well as placing greater demands on the manufacturer in terms of production and supply, are more likely to require solar control in an effort to control the effect on internal temperatures. A large expanse of glazing is architecturally impressive, but smaller, well-placed areas of glazing can provide good levels of illumination and aid temperature control inside the building, throughout the day.

It isn't just the effect of allowing solar heat to pass through glass that needs to be thought about. The effect of solar absorption needs to be kept in mind, since the thermal stress of one part of the glass getting hotter than another can cause cracking to occur.

Solar control glass naturally gets hotter than other types of glass; the lower sun of spring and autumn concentrates more solar energy on glass panes, but the edges tend to cool more quickly because of the greater disparity between daytime and night-time temperatures, setting up temperature differentials across the pane. This only applies to using annealed glass; using toughened or heat-strengthened glass avoids the issue.

Most glass manufacturers offer a thermal stress analysis form, which can be filled in to help with assessing the risk.

Diffused light used to good effect in university lecture hall.

Diffused light is better distributed and improves the illumination of the space, compared to direct light which can cause glare.

Confusion about U-values

Utilising the potential of various coatings and glass types has other benefits. Compared to the total surface area of the building fabric, the heat loss through relatively small areas of roof glazing is more than offset by the contribution of solar gains and the reduced use of artificial lighting. Anybody involved with building design and specification should be aware of U-values as a measure of thermal transmittance (the movement of heat energy) through building fabric from warm to cold.

There is the potential for confusion around U-values for rooflights since, like g-values, it is common to see both whole-unit and centre pane values used.

Approved Document L, Conservation of Fuel and Power, states that U-values should be assessed using the methods and conventions set out in the Building Research Establishment's BR 443, as with dwellings.

U-values should be assessed for the whole thermal element, which in the case of a rooflight or roof window would be the combined performance of the glazing and the frame. You can find more information on U-values in Glazing Vision's Approved Document L and Rooflights whitepaper.

Beware of centre pane U-values

Centre pane U-values address the thermal performance of the glass only. They appear lower than whole-unit values because the cold bridging effect of the spacer and edge seal are not accounted for. Unfortunately, this means some manufacturers rely on quoting centre pane U-values when they should offer whole-unit U-values.

Specifiers can find themselves misled if a centre pane value is made to appear as though it is a better performing product - a tactic which is not in compliance with building regulations. However, centre pane values are useful for comparing one glass against another when being used in the same frame, as well as in conservation projects where traditional frame designs offer no meaningful thermal performance.

In addition to treatments for solar control and reflectivity, there are also low emissivity (low-e) coatings that impact on the loss of heat from inside the building by reflecting long wave radiation back in.

A material's emissivity determines the amount of thermal radiation emitted from its surface. Low-e surfaces emit less thermal radiation, and glazing units benefit from this through the application of a microscopic coating of tin, silver or zinc to certain faces of the glass panes in the unit.

In contrast to the short wave radiation from the sun that heats the building interior, the heat energy transferring back through the building fabric, from warm inside to cold outside, is long wave radiation. Glass with the low-e coating reflects long wave radiation, effectively keeping more heat energy in the building.

There are two types of coating: hard and soft. Hard coat is applied while the glass is still molten, whereas soft coat is applied later in the process. Hard coat is more durable, as its name suggests. Soft coat remains delicate, is only applied to the sides of panes facing into a sealed airspace, and has a lower emissivity than hard coat.

The difference in emissivity between the two means argon-filled glazing with a hard coat treatment will typically offer a centre pane U-value of 1.4 W/m^2K, while a soft coat treatment will see that improved to 1.1 W/m^2K. It's a meaningful distinction, yet some manufacturers will simply claim their glazing to be "low-e". Making a hard coat treatment sound like a similar benefit to soft coat is another reason for specifiers to be clear about the features of the products they're selecting.

Selecting glass that provides high light transmittance, effective solar control and excellent thermal performance is the holy grail. The term selectivity is used to describe this balanced combination of performance characteristics, where a higher selectivity is seen as the optimum combination.

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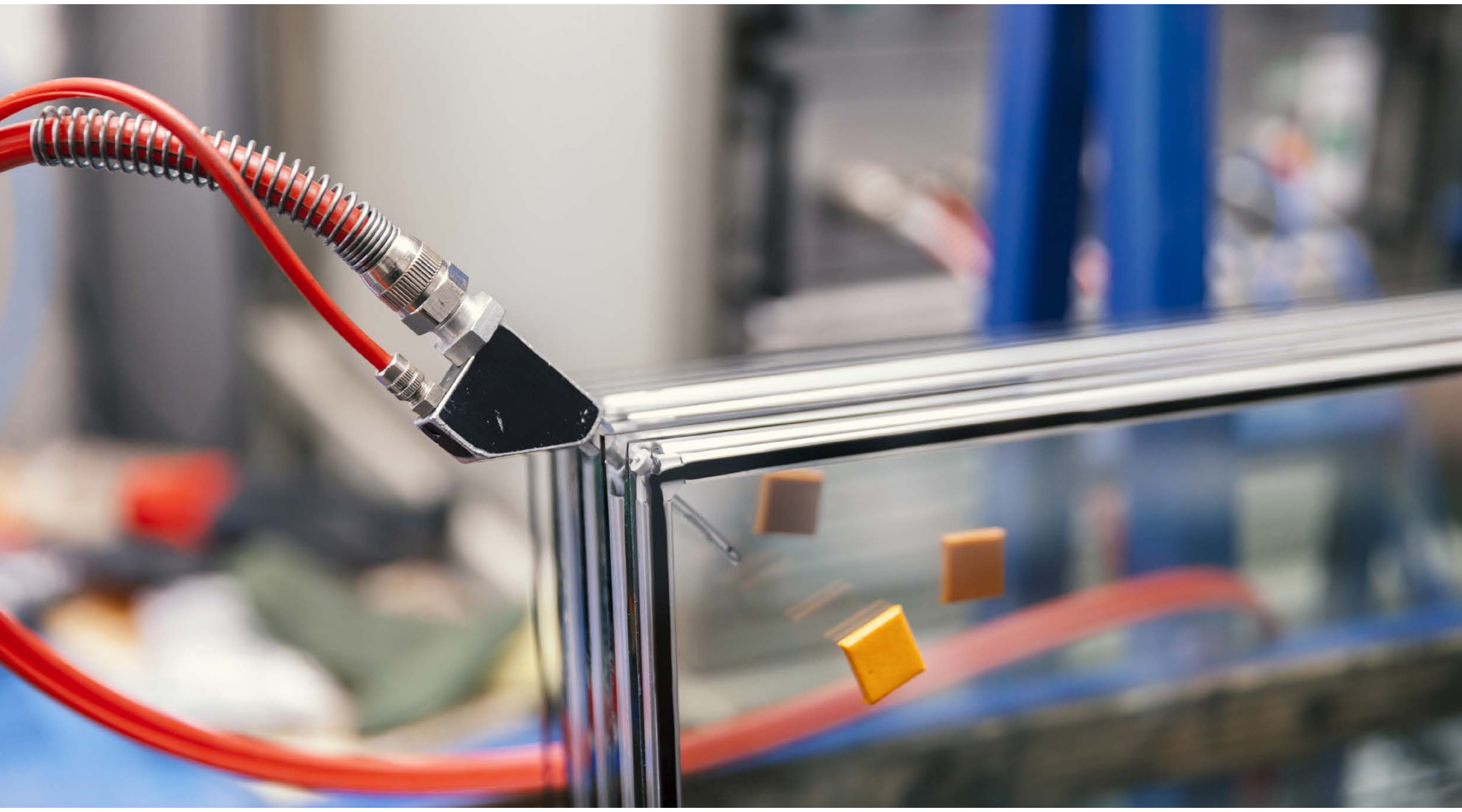


Filling glazed unit cavity with inert gas.

Gas filled cavities

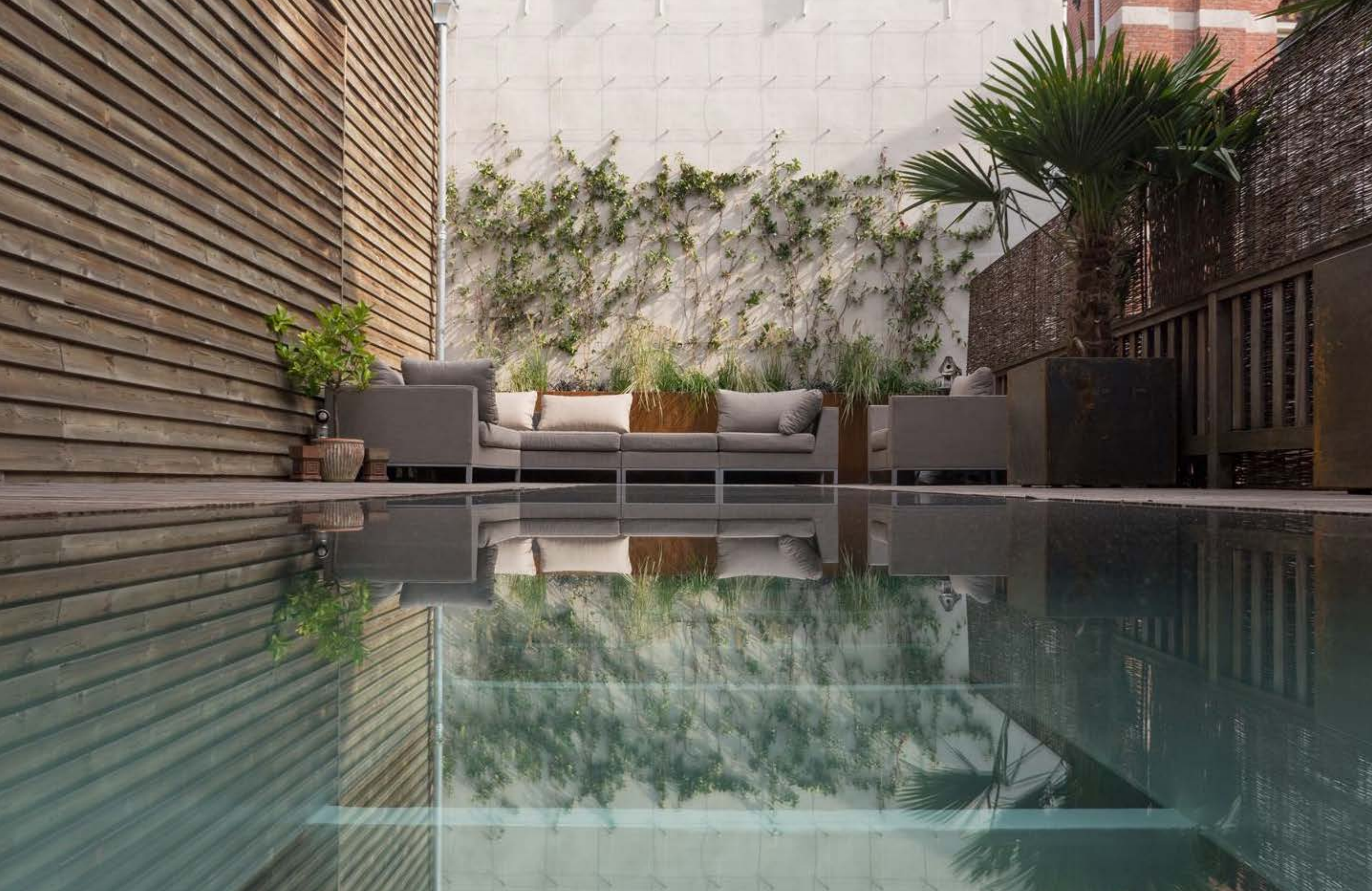
These days, most people understand the benefits of having a glazing unit that is more than just single glazed. Double glazing, triple glazing and even quadruple glazing improve the thermal - and acoustic - performance by introducing sealed layers of gas between the panes.

A well-known feature of products is to fill the sealed space between panes with an inert gas like argon, whose thermal conductivity is some 34% lower than still air. Some manufacturers use krypton and xenon, both of which offer further improvements in thermal efficiency, but which are more expensive.

Warm edge spacer bars

Separating panes of glass in a glazed unit requires a spacer bar around the edge. Traditionally, spacer bars are aluminium but, like any metal, aluminium has a high thermal conductivity. It acts as a thermal bridge (or cold bridge), conducting heat from inside the building at the edge of the glass and bypassing features otherwise designed to improve the efficiency of the glazing. ‘Warm edge’ spacer bars are becoming more common, using materials with a lower thermal conductivity to slow the rate of heat loss and create a more even surface temperature across the whole glass pane.

Used effectively and in combination, the thermal efficiency features described in this section can result in condensation occurring on the outside face of a glazed unit. The glass does such a good job of retaining heat inside the building that its external surface temperature is particularly cold. When the air comes into contact with it, the temperature of the air drops to the extent that it cannot retain the same quantity of moisture vapour and the excess is deposited as condensation.



SECTION 4 - BUILDING REGULATIONS AND STANDARDS

Security and external safety

In some detail, section 2 covers fragility testing and 'walk on' rooflights, describing the standards of performance that glass should achieve. That was centred on preventing anybody from accidentally falling through a rooflight, but what about if someone sets about deliberately trying to gain entry to a building through one?

Following the 2015 introduction of Part Q, with its single requirement to Schedule 1 of the Building Regulations in England, security and the vulnerability of glass have become buzzwords. The Welsh government consulted on the inclusion of requirement Q1 in their own building regulations which came into effect in November of 2018. Section 4 of the Scottish technical handbooks includes '4.13 Security'. The requirements in all three countries relate only to dwellings.

Making easily accessible glass secure

For now we'll focus on Part Q in England and Wales which requires an easily accessible window to be robust and fitted with appropriate hardware to resist physical attack. 'Easily accessible' is defined as being within 2m vertically of an accessible level surface (such as the ground or a balcony), or within 2m vertically of a flat or sloping roof no more than 3.5m above ground level. A secure window meets the requirements of one of the following standards:

- PAS 24:2012
- STS 204 Issue 3:2012
- LPS 1175 Issue 7:2010, security rating 1
- LPS 2081 Issue 1:2014, security rating A

Glazing Vision offer products tested to LPS 2081: the Secure and the Secure+. LPS 2081 tests replicate physical attack and assess the complete unit of glass, frame and hardware. Of course, this guide specifically concerns glass and, in the test, rooflight glass is allowed to break but should remain sufficiently intact to prevent an intruder gaining entry into the building.

The use of a laminated interlayer in the glass maintains the integrity of the unit long enough for the rooflight to withstand an attack for the required period of time. Although the toughened outer pane may break relatively quickly when using the right tools and applying some knowledge of how best to attack the glass, the interlayer is much more difficult to penetrate.

It is the complete unit that is tested, so use of laminated glass alone does not guarantee a particular rating. You can find out more on Approved Document Q in Glazing Vision's Approved Document Q whitepaper. Design guidance specific to other building types sets out security expectations for non-domestic applications.

Tool set used in LPS2081.

LPS 2081 tests replicate physical attack and assess the complete unit of glass, frame and hardware.

Internal safety

Keeping people from entering a building through a rooflight - whether deliberately or accidentally - is one thing, but there is also a need to protect the people already in there. Where building users are concerned, the aim is to prevent falling debris from causing injury.

Just as a laminated inner pane should provide the last line of defence to anyone coming through the glass, it is also the ideal choice for minimising the risk of glass falling into the space below if the pane is broken.

The National Association of Rooflight Manufacturers (NARM) recommends that inner panes always be laminated. Subject to them not affecting the non-fragility classification, toughened or heat strengthened laminates should be considered over annealed laminates, which are prone to thermal stress failure.

Example where toughened outer pane has shattered under attack, but laminated inner remains intact (note frame damage where hand tools have been levered).

Guidance for glazing at height

Rooflights with a pane size greater than 5m requires a laminated inner pane as referenced in BS 5516-2:2018. Where it is no more than 5m above floor level, and in limited other circumstances, toughened glass may be used as long as it is heat soak tested.

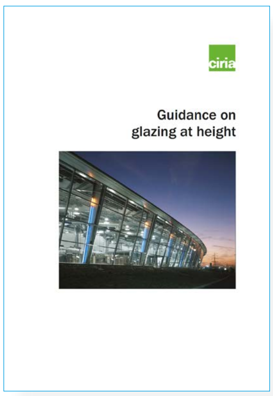
Generally, the acceptability of toughened glass should always be determined by a risk assessment, and that assessment should be carried out in accordance with document C632 ‘Guidance on Glazing at Height’, published by the Construction Industry and Research Information Association (CIRIA).

National building regulations include provisions for avoiding collision with areas of glazing in high risk areas (‘critical locations’), although these are typically vertical panes in doors, side panels or at low level, and therefore not relevant to rooflight glass. EN 12600 is the standard used to define impact safety across Europe.

The safe cleaning of translucent elements in a roof is also addressed, which is more to do with the siting of roof windows and rooflights than performance characteristics of the glass.

In England, glazing safety is covered by Part K of the building regulations, which incorporated Part N in 2013. The building regulations in Wales continue to maintain a separate Part K and Part N. Section 4 of the Scottish technical handbooks, and technical booklets H and V in Northern Ireland, have similar intent in those countries.

Document C632F ‘Guidance on Glazing at Height’, published by the Construction Industry and Research Information Association (CIRIA).



Fire performance

Fire safety: Approved Document B addresses fire spread across both internal and external surfaces.

The performance of external roof coverings dictates how close those coverings may be used to boundaries and other buildings. A covering rated as B_{ROOF}(t4) can generally be used without restriction; in Scotland, this is also called a covering of 'low vulnerability', a category which includes glass at least 4mm thick.

The definition of an internal ceiling lining includes glass, but typically doesn't include the frame into which the glass is fitted. The performance required depends on the location of the glazing and the building type, but a rating of class D-s3,d2, C-s3,d2 or B-s3,d2 could be expected. Class B-s3,d2 is the most onerous, and glass is capable of achieving it.

European ratings and classifications should be the norm, but it's not uncommon to still see national classifications referred to. Regulations give guidance on how national and European classifications relate, but it is important to bear in mind that the two are not equivalent.

Regulatory requirements for means of escape are generally unlikely to encompass roof glass, with one notable exception. Where an escape route is provided over a flat roof, the roof should have a fire resistance according to the use of the building (as given in the guidance to the regulations). Should a walk-on rooflight form part of the escape route, then it would have to meet the same requirement.

Ensure you stay up to date with the latest Approved Document B changes via the government website as this is regularly being updated due to the ongoing Grenfell Tower Inquiry.

Visual quality

The development of low-iron glass described in section 2 of this guide is a good example of the kind of demands that have come to be placed on glass manufacturers, thanks to the increased expectations of architects, specifiers and clients.

It's not uncommon for complaints to be raised about 'defects' in glass when, in fact, the product meets all the necessary standards; the issue arises because flawless, perfectly clear glass was anticipated.

The act of tempering annealed glass to produce either toughened or heat-strengthened glass changes its physical characteristics (from an isotropic material, where physical properties are uniform in all directions, to anisotropic, where they depend on the direction of measurement). The visual appearance of the glass alters as a result, with patterns of colour variation becoming visible.

The glass manufacturing industry generally does not consider it a defect but, often through limited understanding, some customers do. Ironically, the move towards clearer (low-iron) glass can actually exacerbate this patterning. Confusingly, that has led some manufacturers to offer products which they claim are free from anisotropy, even though the phenomenon is essentially unavoidable; it has also led to increased specification of 'basic' annealed glass, where possible.

Guidelines for the visual inspection and assessment of glass are given in a variety of British/European standards (depending on the type of glass), as well as produced by bodies such as the CWCT (see Technical Note TN35), the Glass and Glazing Federation (GGF), and Hadamar in Germany. Angles and distances from which glass should be viewed may vary, but the method of inspection and definition of a defect is consistent.

Visual inspection is generally carried out at the point of manufacture, where it can be done under controlled conditions that may not be possible on site. Of course, mishandling of a product during transportation, on site or during installation may cause scratches or blemishes that can only be inspected under site conditions. Inspection should be through the glass, not of the glass itself.

Typical defects include distortion (related to the degree of flatness achieved), small deposits embedded in the glass, bubbles and fine scratches.

Glass manufacturers' production processes are optimised to meet at least the product quality governed by British/European standards, and their own internal quality standards. Glazing Vision's internal quality standard works to achieve the Haddamar standard.

Choosing to impose a higher standard can extend lead times if product is found to fall short, but it leads to greater customer satisfaction and less disruption to projects on site. It provides reassurance to customers, and eliminates the temptation for specifiers to request a higher standard - which they may not fully understand, and would impose a far higher cost and extended lead time.

On the edge

The term 'shelled glass' refers to glass damaged by impact; most often on the edges. During manufacture, any edge damage is ground out (prior to tempering, in the case of toughened or heat-strengthened products); corners may be 'dubbed' to take out some of the sharpness. It's an important aspect of quality, particularly as edge treatments can be so distinctive. There is more about glass edges in the next section.

SECTION 5 - DESIGN AND DELIVERY

35 staff sitting upon 18m wide glass unit (credit: Henze-Glas)

We talked at length in section 3 about sizing glazing appropriately as part of the building fabric, taking into account orientation and shading, and how that impacts daylighting and the balance of heat loss against solar gains.

While balance is the best approach to optimising comfort and energy efficiency, there will always be projects where glass is used simply to make a statement. For some designers, the only limit on glazing will be the extent of their imagination! For the rest of us, certain practicalities need to be kept in mind.

Logistical challenges

Glass is durable and stable; a quality product with good aesthetics that is UV and weather resistant. But it's heavy! Weight is arguably the most significant constraint on its use, affecting its ability to be moved from the production line, loaded, transported, unloaded, and then moved into position to be fixed - all without damage or breakage.

It's not hard to picture a situation occurring where a site is small enough or awkward enough to make moving unwieldy glazed units extremely difficult, after a smooth kerbside delivery. Being aware of those potential issues highlights the value of clear communication between client, designer, contractor and manufacturer, to prevent unforeseen hitches.

All of that assumes, of course, that the glass can be manufactured in the first place! The size of both the supplier's and the fabricator's production lines will define the maximum size that can be produced before the matter of whether it can be lifted is considered.

Glass manufacturers also impose minimum sizes - for cost, practicality and quality reasons, although producing smaller pieces may be done offline by cutting large sheets - and a maximum aspect ratio. The length of the long side compared to the short side, anything from around 10:1 to 12:1 is typically quoted in order to avoid distorting the glass - particularly toughened glass.

Be aware of manufacturing limitations

When talking about glass, we are mainly talking about flat sheets (or at least, flatness within specified tolerances, depending on the type of glass). Manufacturing glass with some curvature is possible, but it is expensive; more defined shapes, such as domed rooflights, are better suited to polycarbonate. However, glass is ideal for features like box rooflights and, in conjunction with a manufacturer's design team, can be used to create elaborate designs such as pyramids.

In reality, most projects are unlikely to trouble the limits of production in terms of sheer size (although some do!). The performance requirements of the glazed unit itself - what's expected of it in day-to-day use - define what is possible.

Hardware has its own limits; hinges, for example, are designed for a maximum load. Manufacturing something bigger or heavier might be well within the fabricator's capabilities, but the mechanism has to be capable of bearing the weight. Specifying bespoke hardware in conjunction with the rooflight manufacturer might be an option, but with the knock-on effects to cost and lead times.

The type and thickness of glass imposes limitations, emphasising the importance of being aware of the treatment required for a given application. Thin annealed glass has a smaller maximum size than toughened glass of the same thickness, which in turn has a smaller maximum size than thicker toughened glass.

Glass rooflight with supporting aluminium back to back angle.

Taking the weight

Designing for greater structural loads - whether that be dynamic wind loads or pedestrian traffic, or imposed loads such as snow - affects glass thickness and pane size. The amount of deflection caused by loads must be within the acceptable limits of the pane thickness and dimensions, and manufacturers can advise on this using specialist software and knowledge of their products.

Roof glazing forms part of the building fabric and structure so, as well as bearing the loads imposed on it, must also be capable of being supported by surrounding building elements.

A common solution, especially for 'off the shelf' items of known weights, is to double-up roof joists or rafters, provide trimmers or noggins at the top and bottom of the opening, and fix the glazed unit in accordance with the manufacturer's instructions. The timbers take the weight of the unit and distribute it to the rest of the roof.

Standard 600mm or 1200mm wide rooflights are designed to fit conveniently between rafters spaced at 600mm centres; obviously this includes the frame. Consulting with a structural engineer is always advised, particularly as supporting calculations may be required for the purposes of obtaining building regulation approval, but is likely to be essential in the case of bespoke items with large spans imposing significant load on the roof.

It isn't just a case of glass supporting loads imposed on it, or a building supporting the weight of glass; glass can be used as a structural support material itself. Glass fins - or columns, or mullions, depending what you are reading - are a support system for engineered glass facades, usually acting as an entrance or atrium feature on large commercial buildings.

The fins restrain the facade against wind deflection and other lateral loads without breaking the sight lines between inside and outside like steel columns would. Laminated or toughened glass is used, often wider than is strictly necessary because of the aspect ratio limitations. Glass fins can also be used to support modular sections of glass in rooflights, as an alternative to using additional framing elements, such as the aluminium back to back angles featured above.

Design on the edge

Keeping to the theme of a seamless transition between inside and out, frameless glass achieves a minimalist look by hiding the glass supports and fixings within the building fabric. Since the glass doesn't have to be installed within a frame, there is greater flexibility in glass options - but the detailing is specific to each individual project.

Whether multiple panes are installed in a frame to form a glazed unit, or supported in a frameless design for cutting edge architectural impact, the treatment of the glass edge matters.

We've already talked about handling and transportation in this section, and it is the edges - particularly of toughened glass - that are most at risk from a lack of care. Damage to the edge can lead to breakages. As mentioned in section 4, any shelling should have been ground out during manufacture.

The way glass is subsequently glazed must protect the edge, cushioning it if necessary. Contact between the edge and a hard surface should be avoided, either by leaving a clearance or cushioning it by use of a gasket or neoprene lining.

Glass cannot be supplied with a clean cut edge because, simply, it is sharp and a risk to health and safety. To take out that sharpness, most glass is supplied with an arrised edge - not a perfect finish, but enough to make handling easier. A ground edge provides a smoother finish, with a polished edge being the next stage on from that for applications where the aesthetic of the edge finish is important. Polished edges provide glass with a greater tolerance to thermal stress, while damaged edges make it more susceptible.

Single-pitch, multi-part glazing units featuring several panes in a single frame rely on butt joints between the panes. For eaves or ridge roof glazing, where multiple glass panes in the same frame meet at an angle, a stepped joint detail provides the necessary seal. For both butt and stepped joints, ground edges or polished edges should be the minimum finish of the pane edges.

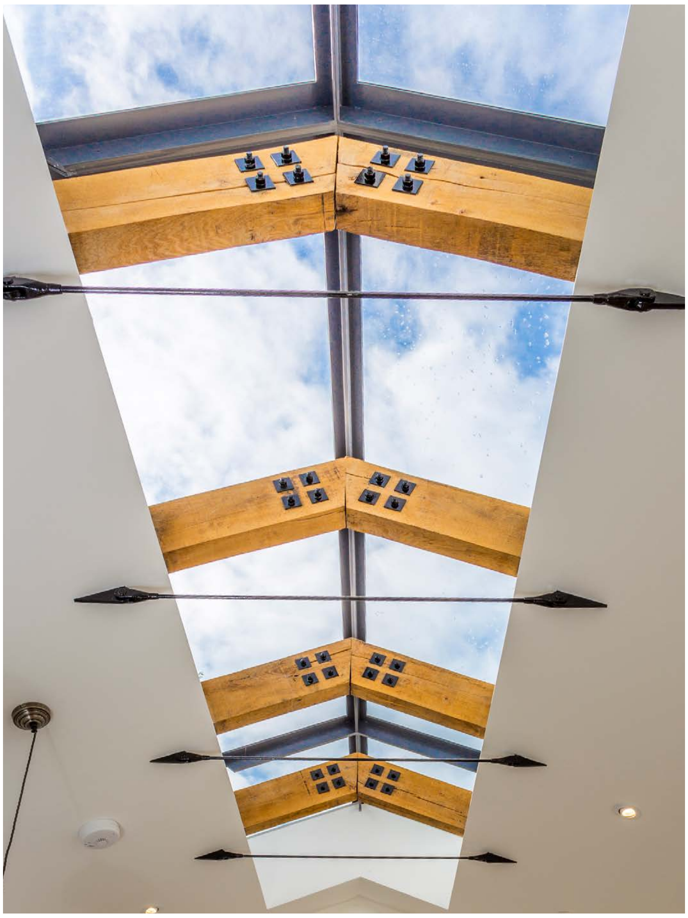
The connection between panes is subject to temperature, moisture, UV and mechanical stresses. For a sealant to provide a suitable connection, it must be stable, compatible and UV resistant. The joint must be assessed for its ability to withstand loads imposed on the glazing and have sufficient 'bite'.

A note on cost

It's a rare building project where cost doesn't enter the equation at some point. Whether it's avoiding going over-budget or eking out a few pounds of profit somewhere, the price of materials and services is bound to come up at some point. In an ideal world, everything would be lifecycle costed to establish the best long-term value for money, but the price at time of purchase is usually king.

As with most products and materials, quality comes at something of a premium - especially when moving away from a standard range of products.

Requesting a bespoke product that needs testing to prove it meets certain performance criteria incurs costs that may not be immediately obvious. Multiple examples have to undergo testing to corroborate the results observed. In some cases, such as testing to CWCT standards, at least three versions of the product need to be produced. Then there are the service-related costs, including longer lead times, transport and handling, and storage if the new product cannot be stored on site, or the site is not ready to receive it.



Modular Ridgeglaze rooflight.

Single-pitch, multipart glazing units featuring several panes in a single frame rely on butt joints between the panes. For eaves or ridge roof glazing, where multiple glass panes in the same frame meet at an angle, a stepped joint detail provides the necessary seal.

SECTION 6 - OPERATION AND USEFUL LIFE

Don't forget about the maintenance

As with most things, keeping rooflight glass in good working order will extend its useful life. That means regular maintenance and cleaning - rarely the easiest of tasks when it comes to buildings, and a potential source of unwanted extra expense. Roof access is risky even with the proper equipment, so it's difficult to blame people if they put off an otherwise routine task until another day.

Assessing the life expectancy of roof glazing is an imprecise science. Laboratory testing and certification procedures can estimate a minimum lifespan, but the actual useful life of a product will depend on the combination of features specified, the quality of installation, environmental factors and the use and treatment to which the product is subject once the building is occupied.

Building location also plays a part. Sheltered, low-rise applications are typically friendlier to a product than an exposed or high-rise building. Air quality, cleanliness and pollution levels have a significant impact, so units used in urban or industrial environments may suffer more than those in rural locations.

Expected lifespans

Some buildings are designed with a specific lifespan in mind, and should be designed and specified accordingly to ensure components can be reused. Generic figures from 60 to 100 years might be quoted as a 'typical' building lifespan; most will likely end up being used for longer than that, while some may fail prematurely.

Where a product is granted a certificate by a third-party testing body like the British Board of Agrément, a statement on durability is based on the assumptions such as:

- Installation is in accordance with other parts of the certificate.
- The product is not used in a corrosive environment.
- The product is subject to "suitable maintenance".

Defining "suitable maintenance" is never easy, but can be taken to include cleaning and generally following the manufacturer's instructions on how best to care for the product. With that in mind, a minimum useful life of 20 to 30 years is well within the capabilities of rooflights from established manufacturers, produced in accordance with industry standards.

A cleaning regime should include both the internal and external surfaces of the glass. Regular cleaning also allows regular inspections, so it should be possible to keep an eye out for defects in order to address them sooner rather than later.

Defects arising from installation may not become apparent for several years. Maybe it takes a once-in-fifty-year storm to highlight a leak, or a particularly cold winter to show up a source of condensation risk. Either way, proper detailing of the rooflight as part of the roof structure, and making sure the rooflight is an effective part of a continuous thermal envelope, can be achieved through clearly communicated project briefs, correct specification and consultation with the rooflight manufacturer.

As part of the specification process, operational treatments can be requested that reduce the maintenance burden for building occupants.

EnduroShield manufacture a proprietary glass treatment, which acts like a 'non-stick' frying pan coating. It resists tree sap, bird droppings and atmospheric pollution, reducing instances of staining or discolouration and making cleaning easier. Any Glazing Vision product can be supplied with a factory-applied EnduroShield coating.

SECTION 7 - GLOSSARY OF TERMS

Acoustic performance of glass
Glass follows the mass law of sound transmission, where doubling the thickness of a pane (and therefore its weight) reduces sound transmission by 4 to 6 decibels. Laminated glass offers a greater acoustic benefit, especially if using a specific acoustic interlayer. Double and triple glazing uses panes of different thicknesses to reduce 'sympathetic resonances'; triple glazing performs better.

Annealing
The process of heating glass and cooling it slowly to remove internal stresses. Annealed glass breaks easily into large shards.

Anti-slip finish
Treatment such as sandblasting, ceramic frit or textured glass to provide slip resistance.

Architectural glass
The name given to glass used in buildings. Requires pure materials and cannot be made from recycled domestic waste glass.

Aspect ratio
The length of the long side of a glass pane compared to the short side. Usually ranges from 10:1 to 12:1 to avoid distorting the glass, particularly toughened glass.

Ceramic frit
Material screen printed and fired into the surface of glass, used as an anti-slip finish or for decorative effect in enamelled glass.

Enamelled glass
Glass that has had ceramic paint applied before toughening.

EnduroShield
A proprietary glass treatment manufactured by EnduroShield. Acts like a 'non-stick' frying pan coating, resisting tree sap, bird droppings and atmospheric pollution, reducing instances of staining or discolouration and making cleaning easier.

Fins
Also called columns or mullions. A support system for engineered glass facades that restrain the facade against wind deflection and other lateral loads without breaking the sight lines between inside and outside like steel columns would.

Fire rated glass
Performance is mainly considered in terms of insulation (resistance to transfer of excessive heat, denoted as I) and integrity (resistance to fire penetration, denoted as E). Other performance requirements include reaction to fire and fire spread over the surface of the material. Smoke venting or smoke control may be specified as part of a complete roof window product.

Float glass
The 'basic' form of glass from which all other options are derived. Manufactured using a technique developed by Sir Alastair Pilkington in the 1950s, rendering the likes of crown glass, cylinder glass and plate glass obsolete. May be described as annealed glass; annealing is a process.

Fragility / fragile glazing
See 'Non-fragility / non-fragile glazing'.

g-value
The measure of infrared radiation (solar heat) allowed into a building. Can be anything from 0 to 1, where 0 represents no solar heat gain and 1 is the maximum possible solar heat gain. Better, lower g-values also result in lower light transmission. Can be whole-unit or centre pane.

Heat-strengthened glass
Produced in a similar way to toughened glass but subjected to a slower rate of cooling. Not considered a safety glass unless laminated.

Heat soaking / heat soak testing
Toughened glass is subject to unpredictable spontaneous fracture, due to nickel sulphide (NiS) in the material. The risk of breakage is relatively low, but heat soaking filters out about 95% of potential problem units.

Heated glass
An option developed in response to condensation risk and should be specified with care. Other applications for heated glass include evaporating rainwater or dew, and melting ice and snow.

Inert gas
Fills the sealed space between panes of double- and triple-glazed units. Argon has a thermal conductivity some 34% lower than still air. Krypton and xenon offer further improvements in thermal efficiency, but are more expensive.

Interlayer
The bonding layer between two panes in laminated glass. The most common interlayer is polyvinyl butyral (PVB). Ethylene-vinyl acetate (EVA) is also popular; other interlayer materials include cast-in resins, polyurethanes and ionoplast materials.

Laminated glass
A catch-all term to cover the various combinations that can be created when bonding two panes of glass with an interlayer. Typically used where security is a priority, and in safety applications like overhead and walk-on glazing.

Light transmittance
A measure of the amount of light allowed into a building. See also: 'Reflectivity'.

Low-emissivity (low-e) coating
A treatment, which can be used in addition to solar control and reflectivity, to alter the loss of heat back out of the building.

Low-iron glass
For situations where clarity is particularly desirable, the silica used in the initial glass production is selected for its low iron content, removing the natural green-blue colouring that occurs otherwise.

Non-fragility / non-fragile glazing
Most rooflights are designed to be non-fragile, and to provide a level of non-fragility equivalent to the surrounding roof, but should not be taken as being safe to walk on. Typically designed to prevent people or objects falling through in the event of an accident on the roof. Tests for non-fragility are defined in the Advisory Committee for Roof Safety's (ACR) Red Book (ACR[M]001).

Reflectivity
Closely tied to light transmittance. Low levels of reflectivity render the glass virtually invisible, creating a pleasing aesthetic, reducing glare for people outside the building, and providing high levels of light transmittance. High levels of reflectivity can provide a mirror finish for privacy and increase solar control - but likely at the expense of some light transmittance.

Roller wave distortion
When annealed glass is heated for treatment, it sags slightly between the rollers of the conveyor, causing a distortion that shows up in the reflections of the glass.

Selectivity
The balance of light transmittance, solar control and thermal performance characteristics. A higher selectivity is seen as the optimum combination.

Shading coefficient
Largely replaced by g-values (Europe) and solar heat gain coefficients (North America). Measure of the solar heat gain relative to a standardised sheet of clear float glass.

Shelled glass
Glass damaged by impact, most often on the edges.

Snow loading
A seasonal loading that, depending on the severity of any given winter, can linger and increase over an extended period of time. Testing is in terms of long-duration loading, and any deflection in the centre of the glass measured accordingly. Site location should be taken into consideration when assessing snow loading.

Solar control
Techniques to impact on the amount of solar radiation entering a building.

Solar heat gain coefficient (SHGC)
North American equivalent to the g-values used in Europe. Should not be compared directly.

Spacer bar
Separates panes of glass in a glazed unit. Traditionally aluminium, which causes a thermal bridge. 'Warm edge' spacer bars use materials with a lower thermal conductivity to slow the rate of heat loss and create a more even surface temperature across the whole glass pane.

Switchable glass
An interlayer responds to a small electrical current passing through it, changing the glass from translucent to opaque. The level of current applied alters the depth of colouration. Used for privacy reasons, or as a means of solar control and shading.

Tempering
The act of heat treating glass to create either toughened or heat-strengthened glass.

Thermal stress
The effect of one part of the glass getting hotter than another and causing cracking.

Toughened glass
Annealed glass that has been heated and rapidly cooled to make the surface of the glass more resistant to tensile failure. Breaks into smaller pieces or granules. Toughened glass cannot be cut or worked, so all processing has to be carried out prior to toughening.

U-value
The measure of thermal transmittance (the movement of heat energy) from warm to cold. Whole-unit U-values include the glass and frame.Centre pane U-values are for the glass only; they appear lower because the cold bridging effect of the spacer and edge seal are not accounted for. Some manufacturers rely on quoting centre pane U-values when they should offer whole-unit U-values.

Visual quality
It's not uncommon for complaints to be raised about 'defects' in glass when, in fact, the product meets all the necessary standards; the issue arises because flawless, perfectly clear glass was anticipated. For example, tempering annealed glass changes its physical characteristics and the visual appearance of the glass alters as a result. The phenomenon is essentially unavoidable, and patterns of colour variation do become visible.

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Walk-on rooflight

A product designed to be used structurally, the use of which is often qualified with a phrase such as, “must be designed to floor loadings.” Words like ‘walkable’ and ‘mansafe’ are undefined, not recognised in relation to glazing and, in some cases, related to other proprietary roof access equipment. Glass is the only material appropriate for a product designed to take foot traffic.

Wind loading

A type of loading imposed on roofs and roof glazing all year round. The test method in BS EN 12211 describes how to undertake and assess pressure testing, wind resistance and frame deflection. Site location should be taken into consideration when assessing wind loading.

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