



During the design of full height glazing, balustrade infill panels, free-standing glass barriers or other glazing that people may be exposed to either intentionally or accidentally, an assessment of any additional risks associated with the design is recommended.

Whilst Building Regulations, British and International Standards and Codes of Practice aim to provide guidance on the suitable specification of glazing, there are some elements that may not be considered to be suitably covered. For example, for full height glazing and containment, regulations are limited in that they don't provide guidance for residual containment in the event of glass failure.

Risk assessments may cover financial risks, such as cost of replacement glazing, and performance risks, such as aesthetics and acoustic performance, as well as safety. This document is not intended to act as comprehensive guidance on risk assessments for glazing, or other construction works.

## RESPONSIBLE PERSONS

It is generally considered the responsibility of the building architect or designer to ensure that potential risks associated with the end use of the building are adequately managed. A competent person, or group of competent persons, would be expected to carry out a full risk assessment for all elements of design, with consideration of potential hazards arising from use of the building, or areas around the building.

## GLASS & GLAZING SAFETY RISKS

There are several considerations for glass and glazing risks, typically categorised into glass breakage, containment, falling glass and mode of breakage.

### GLASS BREAKAGE

The risk of glass breaking will depend on the forces to which it is exposed. Static personnel, climatic and maintenance loads can all be considered in designed for strength, however, consideration of higher energy impact forces should also be considered for accidental design scenarios.

Fracture due to thermal stress should be considered for annealed glass types, and interlayer temperature stability for laminated glasses. Calculations can typically be carried out to determine the expected risk, based on installation conditions, and quality of edgework.

Nickel sulphide (NiS) is another risk, associated with thermally toughened and heat strengthened glass types. This risk can be reduced through the application of heat soak testing in accordance with EN 14179 [1, 2].

### CONTAINMENT

Laminated glass is the only glass type that will likely offer some level of residual containment in the event of glass breakage. Although compositions comprising two toughened panes are commonly applied to full height glazing, for example, some consideration would

be expected to be given to the potential for the glass to be broken, the subsequent risk associated and whether this risk needs to be managed.

## FALLING GLASS

Overhead sloping glazing and external glazing at height both have the potential to fall in the event of glass failure. Consideration should be given to the requirements of Building Regulations and associated standards, as well as to the behaviour of glass types in the event of failure.

## MODE OF BREAKAGE

Glass will typically break in one of 3 ways, with the mode of breakage defined by EN 12600:2002 [3] in 3 categories;

### (MODE A) FRACTURE INTO LARGE SHARDS

This mode of breakage is typical of annealed or heat strengthened glass, and results in sharp, often large, shards of glass. These shards have the potential to cause piercing and cutting injuries.

### (MODE B) FRACTURE WITH NO SEPARATION OF SHARDS, FRAGMENTS OR ANY SIGNIFICANT OPENINGS

This mode of breakage is typical of laminated glass. The interlayer prevents large sections of glass separation from the pane, and so limits the potential for cutting/piercing injuries. With a sufficiently thick interlayer, the laminated pane will also retain some residual strength after failure.

### (MODE C) FRAGMENTATION

Fragmentation is typical of thermally toughened glass and results in small relatively blunt fragments, which have a low likelihood of causing any significant cutting or piercing injury. Toughened glass has no residual strength upon failure, and, depending on the cause of breakage and subsequent forces, will often fall from the frame on failure.



Figure 1 - Illustration of glass modes of breakage

## FUNDAMENTALS OF RISK ASSESSMENTS

When carrying out a risk assessment, hazard and risk are the key considerations, as defined by the HSE;

- A **hazard** is anything that may cause harm
- **Risk** is the chance, high or low, that somebody could be harmed by these and other hazards, together with an indication of how serious the harm could be.

Consideration should be given to likelihood of occurrence, likelihood of harm and consequence (severity of injury). In general, risks should be reduced to a level that is as low as reasonably practical (ALARP).

A common format for illustrative purposes of a risk matrix follows. Matrices are a relatively simplistic approach to classifying risk, and would be expected to be used conservatively when assessing likelihood and severity.

LIKELIHOOD OF INJURY	Extremely High Almost Certain	Yellow	Red	Red	Red	Red
	High Very Probable	Yellow	Yellow	Red	Red	Red
	Moderate Very Possible	Green	Yellow	Yellow	Red	Red
	Low Possible	Green	Green	Yellow	Yellow	Red
	Insignificant Unlikely	Green	Green	Green	Yellow	Yellow
RISK MATRIX	Insignificant No Medical Attention Required	Low First Aid Treatment	Moderate Injury Requiring Rest & Recovery	High Injury or Injuries Requiring Hospitalisation	Extremely High Disability or Death	
	SEVERITY OF INJURY					
		TOLERABLE	UNDESIRABLE	INTOLERABLE		

Figure 2 - Example of risk matrix

Human factors need to be understood by the designer/architect in order to appropriately determine the level of risk. For example, the expected footfall beneath overhead glazing within a shopping centre would influence the potential for injury occurring due to an increased population exposed to a potential hazard. This would need to be considered alongside the risk that the glazing could fall.

## CONSIDERATIONS FOR GLASS & GLAZING

The following section is not exhaustive, but is intended to provide some guidance on specific risks and hazards associated with glazing in different installations, as well as potential solutions.

### FULL HEIGHT GLAZING ACTING AS GUARDING

Full height glazing is typically designed with consideration to the requirements of building regulations [4, 5, 6, 7, 8], BS 6180:2011 [9] and BS 6262-4:2005 [10]. More commonly, design now also considered the requirements of Eurocodes [11, 12], with EN 1991-1-1 [13, 14, 15] and PD 6688-1-1 [16] being used for provision of load requirements.

Toughened glass is commonly accepted as glazing in critical locations due to its safe breakage characteristics, which meet the requirements for containment as per BS 6180 and BS 6262-4. However, as the breakage of toughened will result in fragmentation, there is no residual strength to resist subsequent impacts or loadings. As such there is also limited integrity to hold the glass in place, resulting in a potential for it to fall from the frame or supports into which it is mounted.

When assessing risk, consideration can be given to the use of an annealed laminated pane within the glazing construction. Whilst this glass type is generally considered weaker mechanically, and so cannot withstand the same levels of static loading, with a sufficient EN 12600 classification, the glass would be expected to provide containment even when fractured.

As below, the laminated pane used externally, under normal conditions, won't be exposed to the internally applied loadings, but will provide containment in the event of accidental fracture of the internal pane.

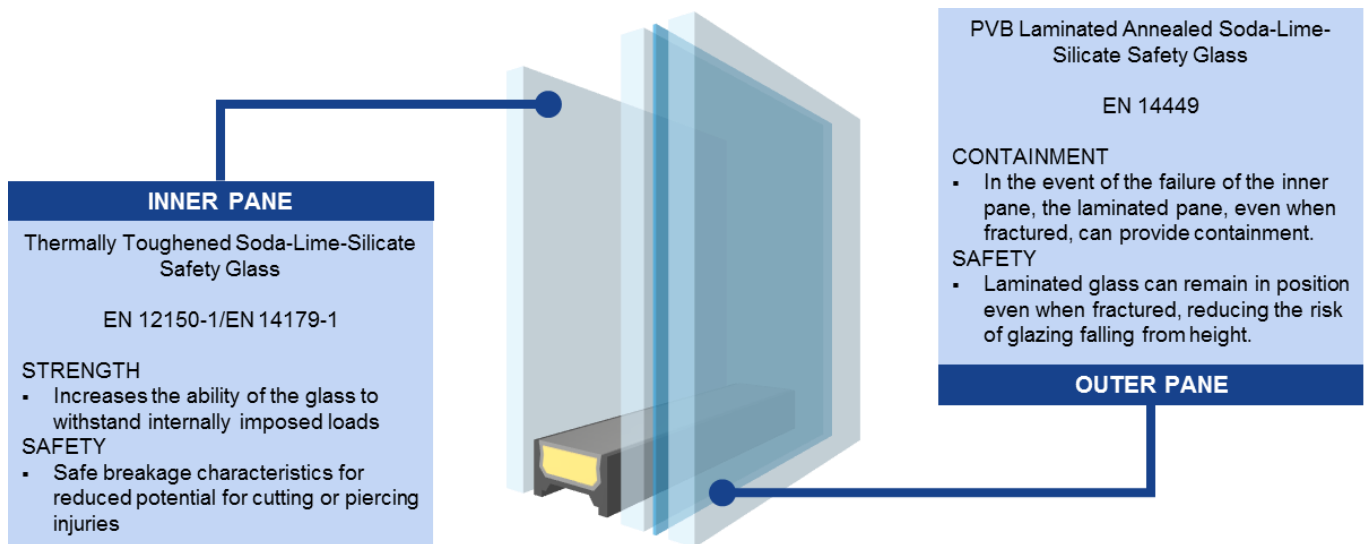


Figure 3 - Example specification for low risk design

## JULIETTE BALCONIES

It is becoming more common to see Juliette balconies, where a pane of glass is used externally to provide guarding. Often these panes are being secured by a partial frame or bolt fixed, without an independently secured handrail. BS 6180 provides little guidance on this sort of design, with bolt fixed and partially framed infill panels considered to have independent handrails.

Ordinarily, this glass would be expected to provide guarding and containment, as the balcony doors will likely open to an extent to allow access to the outside. In the event of glass failure, a monolithic toughened pane would be expected to fall from any fixings or partial framing, leaving an unguarded area. In order to give this risk more consideration, the requirements for free-standing barriers can be adopted, for which those without an independently secured handrail, a toughened laminated glass is used.

The hazard and risk associated with the use of monolithic toughened glass may be deemed acceptable if the building occupants are familiar with the environment, i.e. a single family dwelling, and the balcony doors are considered to act as residual containment. This would need to be considered by the architect/designer responsible.

However, to reduce risk, either the installation of an independent handrail system, and/or the use of toughened laminated glass can be considered.

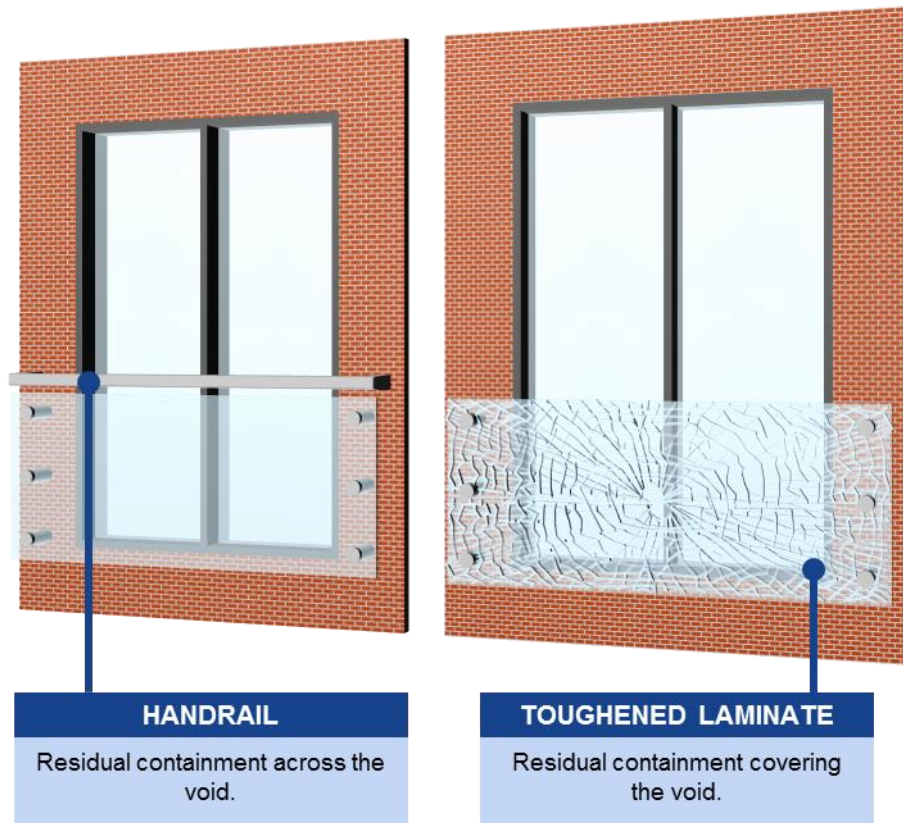


Figure 4 - Juliette balcony example glass types

## VERTICAL GLAZING AT HEIGHT

When considering suitable specifications for vertical glazing at height, typically windows or facades panels, consideration should be given to those internal and external to the building.

In the event of failure of the outer pane, there is a potential hazard in that glass can potentially fall from height onto those below. The level of this risk of injury occurring will be dependent on glass type, installation conditions, and levels of foot traffic below. The potential for injury will be dependent on the height the glazing would fall, the type of glass and thickness of glass.

Although thermally toughened glass is less likely to break due to accidental impact, resulting from bird strike or window cleaning apparatus for example, if broken, the likelihood of glass falling would typically be greater than annealed or laminated glass. With consideration to the impact energy of falling clumps of toughened glass, where energy would be proportional to height, the severity of any injury due to impact from falling glass would also be expected to increase as height increases.

In order to mitigate this risk, a suitable laminated glass construction, either annealed or heat strengthened glass, may provide enough residual strength to prevent the glass falling from the supporting elements. An annealed laminate would also carry additional benefits, as indicated below. Applicability would be dependant on stability with regards thermally induced stresses.

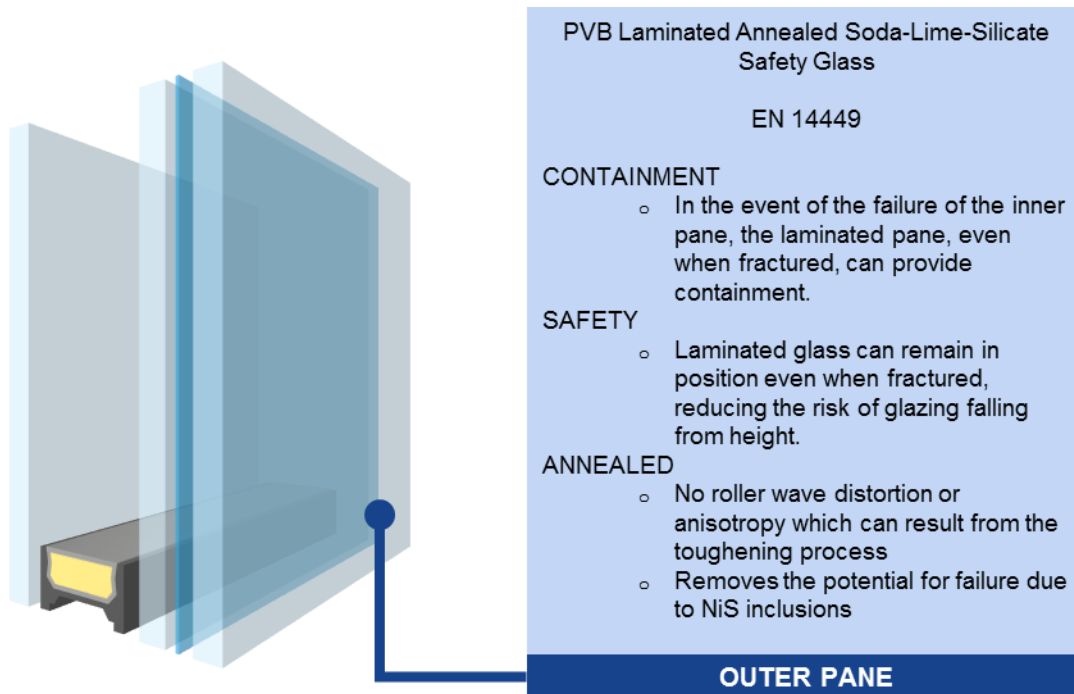


Figure 5 - Glazing at height example specification

## POST APPLICATION OF FILM

The application of films to glazing, either for decorative purposes, security performance or additional solar control should be carefully considered.

Applied to annealed monolithic or laminated constructions, films may increase the risk of thermally induced stresses leading to failure of the glass. Thermal safety checks can be carried out; however, this would typically be expected to be the responsibility of the film supplier or manufacturer.

When applied to monolithic toughened glass, the film may affect the safe breakage characteristics, and would invalidate the EN 12600 classification, requiring testing with the film applied. With regards safe breakage, if the film is sufficiently robust to hold glass fragments together, but isn't secured suitably within the frame, if a toughened pane failed, it may fall as a single mass. For example, if a 1.5 m x 2.0 m size pane of 8 mm toughened glass were to fall 50 m, as a whole mass of 60 kg, the potential energy released on impact would be approximately 29 kJ. This would equate approximately to the energy of impact with a typical 5 door car travelling at 15 mph.

## OVERHEAD SLOPED GLAZING

Overhead sloped glazing has additional safety requirements, as per BS 5516-2:2004 [17], which limits the glass types permissible based on height above finished floor level.

**Table 1 - Overhead glazing types (BS 5516-2)**

Height, H, Above Floor Level	Single Glazing or Lowest Pane of an IGU
$H \leq 5 \text{ m}$	Laminated
	Wired
	Thermally Toughened <sup>1,2</sup>
	Heat Soak Thermally Toughened <sup>1,2</sup>
$5 \text{ m} < H \leq 13 \text{ m}$	Laminated
	Wired
	Thermally Toughened <sup>1,2</sup>
	Heat Soaked Thermally Toughened <sup>1,2</sup>
$H > 13 \text{ m}$	Laminated
	Wired

1. Restrictions Apply:  $\leq 6 \text{ mm}$  Nominal Thickness,  $\leq 3 \text{ m}^2$  Area

2. If the lower pane is thermally toughened, then the upper panes must also be a type from within the table.

The use of toughened laminated glass in overhead applications should be considered carefully, as with both panes broken, toughened laminates under gravity can sag, and have the potentiality to fall, as a single mass, from height.

## REFERENCES

- [1] European Committee for Standardization, EN 14179-1:2005 - Glass in building. Heat-soaked thermally-toughened soda lime silicate safety glass. Definition and description, CEN, 2005.
- [2] European Committee for Standardization, EN 14179-2:2005 - Glass in building. Heat-soaked thermally-toughened soda lime silicate safety glass. Evaluation of conformity/product standard, CEN, 2005.
- [3] European Committee for Standardization, EN 12600:2002 - Glass in building - Pendulum test - Impact test method and classification for flat glass, CEN, 2002.
- [4] HM Government, The Building Regulations 2010 - Approved Document K - Protection from falling, collision and impact, 2013.
- [5] Riaghaltas na h-Alba, *Technical Handbook 2015 - Domestic*, Riaghaltas na h-Alba, 2015.
- [6] Riaghaltas na h-Alba, *Technical Handbook 2015 - Non-Domestic*, Riaghaltas na h-Alba, 2015.
- [7] Department of Finance and Personnel, Building Regulations (Northern Ireland) 2012 Guidance - Technical Booklet H - Stairs, ramps, guarding and protection from impact, DFPNI, 2012.
- [8] Environment, Community and Local Government (Éire), Building Regulations 2014 - Technical Guidance Document K - Stairways, Ladders, Ramps and Guards, Government Publications (Éire), 2014.
- [9] British Standards Institute, BS 6180:2011 - Barriers in and about buildings. Code of practice, BSI, 2011.
- [10] British Standards Institute, BS 6262-4:2005 - Glazing for buildings - Code of practice for safety related to human impact, BSI, 2005.
- [11] European Committee for Standardization, EN 1990:2002 - Basis of structural design, CEN, 2002.
- [12] European Committee for Standardization, NA to BS EN 1990:2002+A1:2005 - UK National Annex for Eurocode - Basis of structural design, BSI, 2002.
- [13] European Committee for Standardization, NA to BS EN 1991-1-1:2002 - UK National Annex to Eurocode 1. Actions on structures. General actions. Densities, self-weight, imposed loads for buildings, CEN, 2002.
- [14] European Committee for Standardization, NA to IS EN 1991-1-1:2002 - Irish Annex to Eurocode 1 - Actions on structures - Part 1-1: General actions - Densities, self-weight, imposed loads for buildings, CEN, 2002.
- [15] European Committee for Standardization, EN 1991-1-1:2002 - Eurocode 1. Actions on structures. General actions. Densities, self-weight, imposed loads for buildings, CEN, 2002.
- [16] British Standards Institute, PD 6688-1-1:2011 - Recommendations for the design of structures to BS EN 1991-1-1, 2011: BSI.
- [17] British Standards Institute, BS 5516-2:2004 - Patent glazing and sloping glazing for buildings. Code of practice for sloping glazing, BSI, 2004.