Balustrade infill panels are designed to be retained within a structure with a handrail and balusters that are designed to withstand the applied line loads. The glass infill panel does not provide any structural support to the balustrade and should be designed to withstand the infill uniformly distributed (UDL) and concentrated point loads only.

Numerous infill designs are possible, and BS 6180:2011 [1] provides guidance on; fully framed, two-edge framed, clipped and bolt fixed, each with different design requirements.

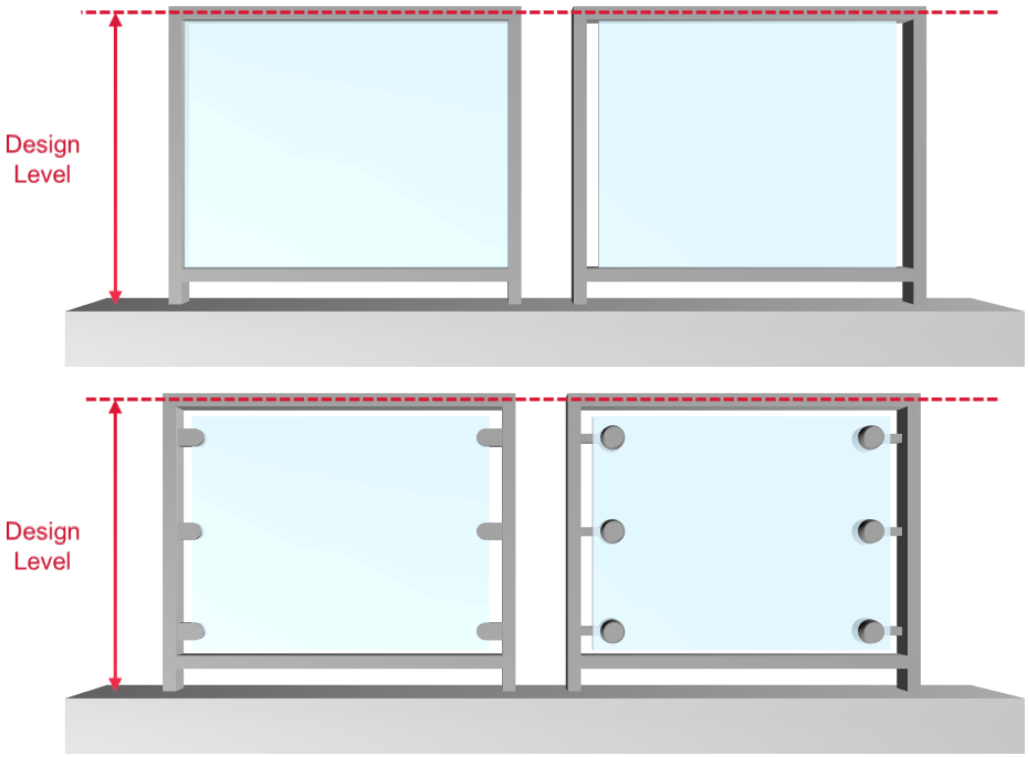

Figure 1 – Infill support types, clockwise from top left; fully-framed, top/bottom edge supported, disk fixed and edge clamped

The minimum barrier height is determined by the building occupancy, and the area of the building, as discussed in **Guards & Barriers Documents 1A and 1B**. 1100 mm is typically considered the minimum barrier height when balustrades with glass infill panels are under consideration.

HANDRAILS

For balustrades with glass infill panels, BS 6180:2011 requires that a top rail/handrail be used, however, it is becoming more common for balustrades to be designed without handrails, and have the glass performing this function.

With no handrail present, the glass would be expected to withstand the line load, as well as the UDL and concentrated point load. There would also need to be consideration to the behaviour of the glass upon failure, and a balustrade consisting of only balusters and the infill panel may be considered more akin to a free standing barrier where handrails are concerned. As such, toughened laminated glass would provide greater safety.

AREAS SUBJECTED TO LOADING

In the case of glass infill panels, the entire infill panel will be expected to withstand the applied UDL and concentrated point load. The below illustrates the location of each load. The UDL is indicated by the shaded red region, the concentrated load by the red dot. The concentrated load will always be applied at the worst location, which will, under most conditions, be at the centre of the infill panel or directly between point supports.

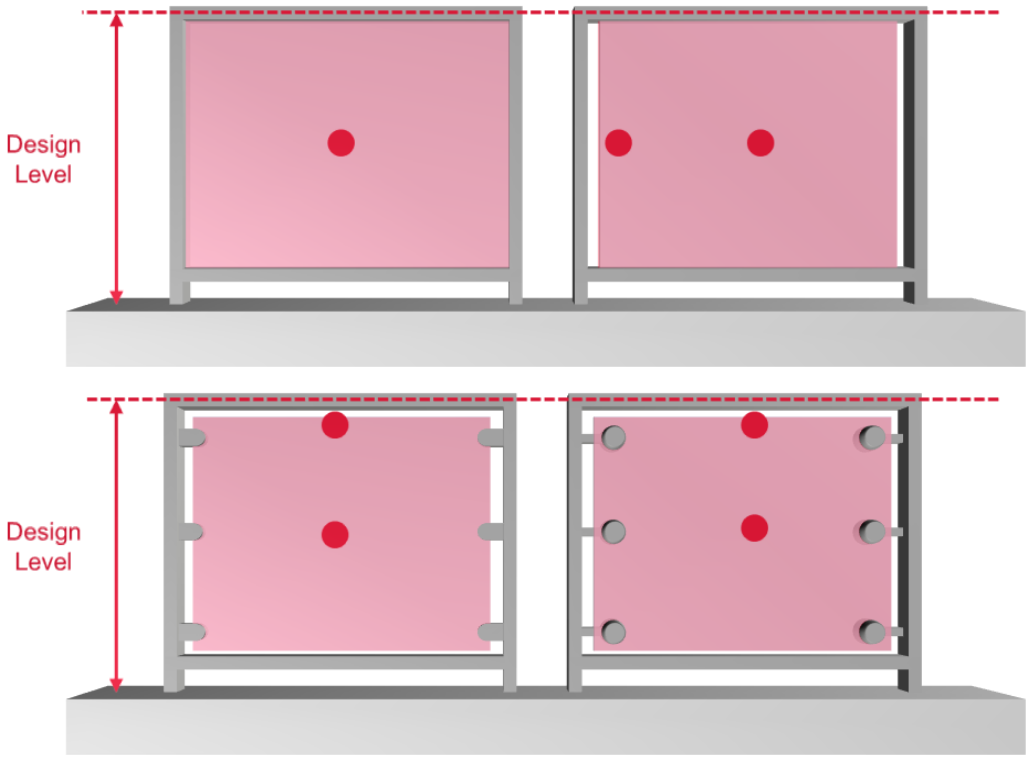

Figure 2 – Load location areas for balustrade infill panels

ALLOWABLE STRESS

Allowable stress is based on partial or global safety factors, and is discussed in **Guards & Barriers Document 4A**.

It should be noted that when designing glass infill panels that are clamped or bolted, the additional stress generated around the point fixings region will usually exceed the allowable stress of annealed glass. As such, fully toughened monolithic or laminated glass is typically specified for this application.

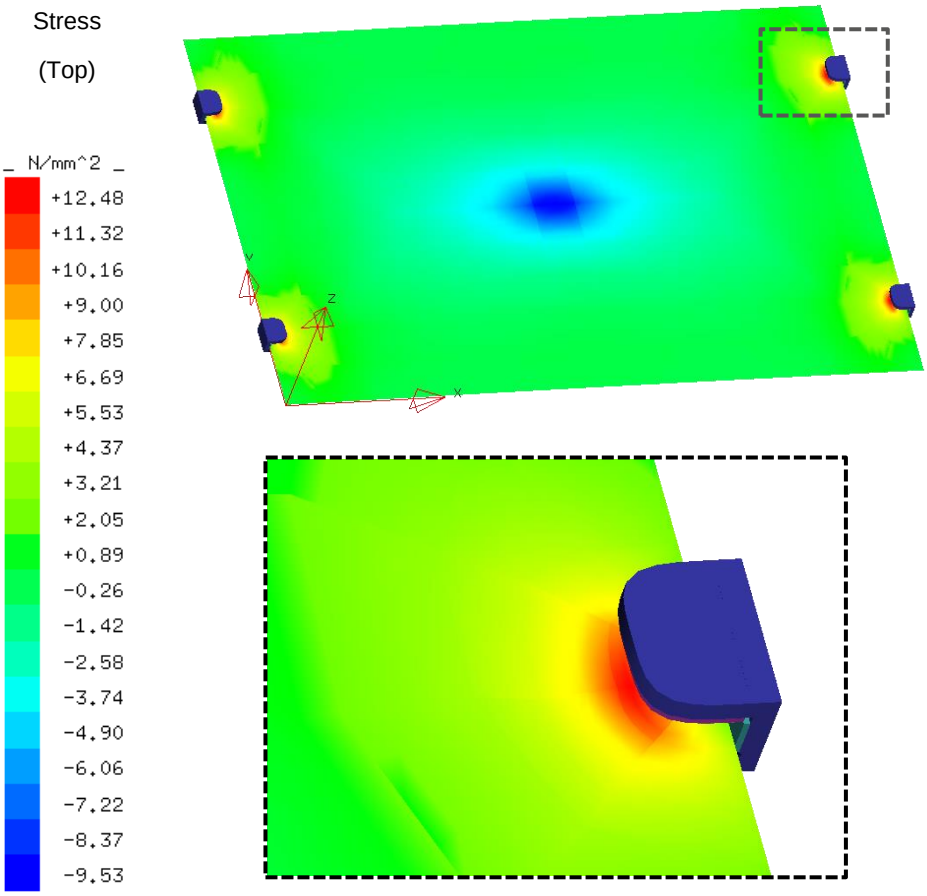

Figure 3 – Stress concentration around balustrade infill clamp fixing

ALLOWABLE DEFLECTION

The allowable deflection of glazing under loading is restricted based on occupant comfort, based on BS 6180:2011, "*…a barrier that is structurally safe should not possess sufficient flexibility to alarm building users when subject to normal service conditions.*" In the case of glass infill panels, the allowable deflection is as follows.

Table 1 - Allowable deflection for balustrade infill panels

Glass Support	Allowable Deflection (mm)	Definition of *L*
Fully Framed **Two-Edge Framed** **Clipped** **Bolt Fixings**	Minimum of L/65 or 25	Longest Dimension Span Between Supports

CONTAINMENT

BS 6180:2011 requires that glass infill panels not only withstand the applied loadings with regards to stress and deflection, but also provide containment. The requirements are defined, in the form of EN 12600:2002 [2] classifications, and are dependent upon the free line distance from a permanent structure to the barrier, as below;

Table 2 - Glass types for containment for balustrade infill panels

Free Line (mm)	EN 12600 Class	Glass Type	Thickness
≤1500	3	Toughened	6
		Toughened Laminated	---
		Laminate	---
>1500	1	Toughened	10
		Toughened Laminated	---
		Laminate	---

When considering the breakage of toughened glass, the glass must not break to provide containment, as such, the 3rd of the 3 values should be considered. For laminated glass, the CE marking declared performance characteristics must be considered.

BS 6180:2011 provides guidance for toughened, as above, whilst evidence of the performance of a toughened laminate must be provided by the manufacturer of the pane. The following glass types are typically considered suitable, depending upon design, for barrier infill panels.

Table 3 - Glass types for balustrade infill panels

Glass Type	Standard
Thermally Toughened Soda Lime Silicate Glass	EN 12150-2 [3]
Heat Soaked Thermally Toughened Soda Lime Silicate Glass	EN 14179-2 [4]
Laminated Safety Glass	EN 14449 [5]
Laminated Thermally Toughened Soda Lime Silicate Glass	
Laminated Heat Strengthened Soda Lime Silicate Glass	

WIND LOADING

Under normal circumstances, external glazing will also be subjected to wind loading. These loadings are typically considered separately from barrier loadings as per BS 6180:2011; "*Barriers should be designed to resist the most unfavourable likely imposed loads and wind loads separately*".

However, consideration should be given to worst case scenarios where wind loads act unfavourably in concert with barrier loads. The requirements of EN 1990 [6] and EN 1991-1-4 [7, 8] should also be taken into account where applicable.

REFERENCES

[1] British Standards Institute, *BS 6180:2011 - Barriers in and about buildings. Code of practice,* BSI, 2011.

[2] European Committee for Standardization, *EN 12600:2002 - Glass in building - Pendulum test - Impact test method and classification for flat glass,* CEN, 2002.

[3] European Committee for Standardization, *EN 12150-2:2004 - Glass in building. Thermally toughened soda lime silicate safety glass. Evaluation of conformity/Product standard,* CEN, 2004.

[4] 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.

[5] European Committee for Standardization, *EN 14449:2005 - Glass in building. Laminated glass and laminated safety glass. Evaluation of conformity/product standard,* CEN, 2005.

[6] European Committee for Standardization, *EN 1990:2002 - Basis of structural design,* CEN, 2002.

[7] European Committee for Standardization, *EN 1991-1-4:2005+A1:2010 - Eurocode 1. Actions on structures. General actions. Wind actions,* CEN, 2005/2010.

[8] European Committee for Standardization, *NA to BS EN 1991-1-4:2005+A1:2010 - UK National Annex to Eurocode 1. Actions on structures. General actions. Wind actions,* CEN, 2005/2010.

[9] British Standards Institute, *BS 6262-4:2005 - Glazing for buildings - Code of practice for safety related to human impact,* BSI, 2005.

[10] HM Government, *The Building Regulations 2010 - Approved Document K - Protection from falling, collision and impact,* 2013.

[11] European Committee for Standardization, *EN 572-9:2004 - Glass in building. Basic soda lime silicate glass products. Evaluation of conformity/Product standard,* CEN, 2004.