Structural-Safety
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The Institution of Structural Engineers | ice Institution of Civil Engineers | HSE

SCOSS
Standing Committee on Structural Safety

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STRUCTURAL SAFETY OF GLASS IN BALUSTRADES

Barriers in buildings may include balustrading, internal partitions and the external façade. Glass is commonly used as an infill or even as a structural component in all of these applications.

Balustrades are more likely to be designed and installed on an ad hoc basis, with minimal compliance to basic standards and regulations, and as such, less thought may be given to the wider safety critical issues.

Balustrades and other barriers not designed and built to an appropriate standard may pose a serious risk to safety and this alert has been prepared to raise awareness of the issue.

1. Introduction

In addition to complying with the appropriate building regulations, the design of barriers in Great Britain is covered by BS 6180:2011 which describes a barrier as an *'element of building or structure, permanent or temporary, intended to prevent persons from falling and to retain, stop or guide persons or vehicles'*.

Barriers in buildings may include balustrading, internal partitions and the external façade. Glass is commonly used as an infill or even as a structural component in all of these applications.

Barriers in the form of internal partitions and the external façade tend to be manufactured as complete systems, and the designers of such systems are much more aware of safety issues, following guidance published by bodies such as the Institution of Structural Engineers (see **Structural use of glass in buildings, second edition**) and the **Centre for Window and Cladding Technology**.

Balustrades are more likely to be designed and installed on an ad hoc basis, with minimal compliance to basic standards and regulations, and as such, less thought may be given to the wider safety critical issues.

Annex B of **BS 6180** identifies a range of suitable glass fixing methods, including both bolted fixings and clamped fixings. The increased use of glass in balustrades has led to the development and use of proprietary fixing systems which differ from those methods detailed in BS 6180. While BS 6180 allows alternate fixings to be used, they must be justified by testing or calculation.

In recent years, there have been serious issues with balustrades not working in a safe manner. The education sector alone has reported failures in schools where there has been a lack of good practice in terms of design, installation and maintenance. For example, in March 2019, **a glass panel in a balustrade at a school in Manchester failed**, allowing a pupil to fall from height through the exposed hole, on to a concrete surface below, sustaining minor injuries.

Balustrades and other barriers not designed and built to an appropriate standard pose a serious risk to safety.

2. Who should read this alert?

This alert is aimed at property owners with existing barrier systems or who are intending to install new barrier systems. However, it should also be read by contractors, architects, structural engineers, building surveyors, facilities managers, maintenance organisations and anyone specifying, procuring or maintaining barriers for use in and around buildings. Those involved in Building Control, Central Government and Local Authorities who participate in construction frameworks might also be interested.

Although the guidance is aimed principally at the use of glass in balustrades, much of it is applicable to glass in barriers generally.

3. Background

Balustrades can be procured from a manufacturer as a proprietary system, from component suppliers as a kit of parts, or from a traditional fabricator as a bespoke design. Each approach may apply a variety of methods for system creation and installation, which has led to numerous instances of non-compliance with BS 6180 and the building regulations.

Several cases have revealed inappropriate methods of fixing glass infill panels, which has resulted in glass panels slipping out of a balustrade system under gravity loads. Glass slippage in this manner has led to glass-to-metal or glass-to-concrete contact, which has caused the glass infill to break, and could potentially lead to an intact pane of glass falling from height.

Clause 8.4.4 of BS 6180 refers to *'Clipped infill panels'* and states that *'the clips should be positioned around the periphery of the infill panel, at a maximum spacing of 600mm'*, which implies that clips are required on all edges of the glass. If this requirement were followed, then the glass could not slide out.

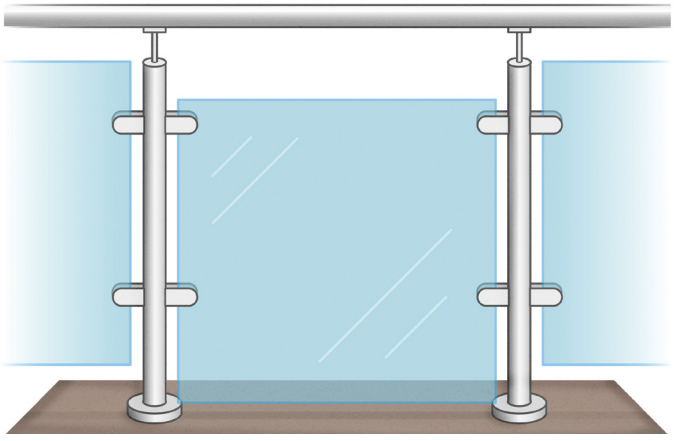

Figure 1
Sketch of glass slippage on central panel where clamp fixings are provided in the vertical faces only

Another issue was reported in **CROSS report 741 Dangerous glass infill panels on balustrade**, published in January 2019, which described a number of problems relating to free-standing glass balustrade systems, some of which incorporate monolithic toughened glass. Free-standing balustrades present particular risks if the glass loses any significant degree of structural integrity upon failure; monolithic toughened glass will collapse upon failure, as will some forms of laminated glass if not held upright by an additional form of structural support such as a continuous handrail system.

Clause 5.1 of BS 6180:2011 states that *'in the assessment of the need for a barrier and the type of barrier to be provided, the designer should give consideration to the likely hazards, the building use and the risks to building users.'* The intention is that the designer should carry out a risk assessment and act accordingly to ensure adequate safety, in addition to meeting the minimum performance requirements set out in the standard.

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Clause 5.3 of the same standard then states *'the barrier adopted should be designed so as to minimize the risk of persons falling, rolling, sliding or slipping through gaps in the barrier.'* It could be argued that this should still apply if a glass infill panel were to fracture in-service. The designer of glass for use in barriers should consider what will happen if the glass were to fail (crack or shatter) in-service. BS 6180 defines a requirement for 'containment' in regard to accidental human impact (soft body impact), but 'containment' has a very restricted definition as applied in the standard.

The requirement in BS 6180 is that when subject to accidental human impact (two different levels of impact are allowed for) the glass either should not break, or if it does break it should not allow penetration by the impactor. Importantly, the standard identifies that the 'should not break' requirement can be satisfied by the use of monolithic toughened glass of 6mm or 10mm thickness (depending upon the assumed level of impact).

Whilst monolithic toughened glass is classed as a 'safety glass', this definition relates to safety from injury caused by the process of the glass breaking and not any secondary consequences, such as falling from height caused by the absence of effective guarding once the glass has broken.

Although monolithic toughened glass can achieve the containment requirement of BS 6180, it will not retain any structural integrity should it fail in-service for any other reason. For example, monolithic toughened glass would not protect a person who is leaning on the glass when it breaks. Likewise, monolithic toughened glass could fall out of the barrier if it were to fail spontaneously, leaving a significant opening through which a person could fall. Such accidents could be avoided by the use of a suitably designed and fixed laminated glass panel.

The performance of a barrier system also depends upon the behaviour of the supporting structure to which the system is to be fixed. Deformation of the supporting structure under loads applied to the barrier may lead to additional stresses being imposed on barriers and any glass contained within. Likewise, if the supporting structure is sufficiently flexible that it moves under direct loading, it may impart some induced movement to the barrier, which could generate stresses within the barrier system, for which it may not have been designed.

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4. Regulations and standards

In England and Wales, reference should be made to the Building Regulation 2010 requirement K2 (both countries) and requirements K4 (England) / N1 (Wales), including Regulation 7 for materials and workmanship.

In Scotland, the building standards technical handbooks (**domestic**› and **non-domestic**›) provide guidance on achieving the standards set in the Building (Scotland) Regulations 2004, including Regulation 8 for fitness and durability of materials and workmanship.

The specification of monolithic toughened glass with clamp-fixings could result in panes of glass slipping vertically within their clamp-fixings, which may be viewed as a breach of the above building regulations. The combination of an appropriate form of laminated glass with a suitable fixing system can provide sufficient integrity to remain in place and act as a barrier even after the glass has fractured.

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Barriers include a variety of materials and fixings, and there are many design risks that can compromise the integrity, compliance and safety of a system. Regulations and standards can be followed to manage these risks, but often only identify a minimum standard of performance, and require the specifier and designer to understand the particular requirements of a given application in order to ensure that the barrier is fit for purpose. A competent designer will be aware of the regulations and standards applicable to a particular application, as well as relevant guidance which should be followed.

See Annex A for further details on the regulations and guidance.

5. Barrier certification

CE-marked or Kitemarked products demonstrate that a product has been tested to certain standards, and that a declared level of performance is available. However, it does not mean that the system will be suitable for the intended use. The designer must still ensure that a suitable risk assessment is carried out to demonstrate that the system as designed, assuming that it is properly installed, is fit for purpose. It is then necessary for others to ensure that the system is properly installed, inspected and maintained.

Care must be taken that product documentation is accurate and relevant. Further details can be found in the 2014 SCOSS Alert on **Anomalous documentation for proprietary products**›.

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6. Risk assessment

The greatest risk comes from systems that have been selected on the basis of lowest cost, without a proper risk assessment having taken place, which is contrary to the recommendation of BS 6180. Failure to properly assess risk can lead to a significant threat of life-changing injury, or even a fatality.

The risk assessment is a safety critical part of the specification and design process. It must be carried out by someone who is competent to undertake such assessments. The risk assessment should be carried out as early as possible in the process and should not be passed down the supply chain to component/system suppliers or the installer.

The following is recommended in relation to risk assessments:

- If any design changes are made to the barrier or its supporting structure after a design risk assessment is carried out, the designer must be informed;
- If it is intended to change the designer, manufacturer or installer of the barrier after the risk assessment has been carried out, then the risk assessment must be communicated in full to the new party by the appropriate dutyholder;
- Fixings which rely solely on clamping action (friction) to resist in-plane forces, where there is a risk that the glass could slide in any direction (including upwards and sideways), should only be used if they are justified by testing or calculations. Such fixings may be supplemented by other mechanisms such as through-fixing or support ledges to provide reliable resistance to in-plane forces. Whatever fixing method is used, evidence should be available to demonstrate that the fixings will retain the glass, under all loads that can reasonably be foreseen, for the design life of the installation;
- Where possible, laminated glass should be regarded as the preferred option, and the glass should be selected and fixed so that it will remain in place, and still act as a barrier to falling, in the event of glass failure. The primary exception to this would be when a barrier does not protect people from a significant fall, such as barriers whose purpose is to act as a partition between spaces or to guide people around a space, in which case the use of monolithic toughened glass might be considered sufficient.

As stated previously, BS 6180 requires that a risk assessment be undertaken, and recommendations on glass selection for the purpose of containment are limited to the issue of accidental human impact and do not necessarily satisfy other performance requirements.

Fixings which rely solely on clamping action (friction) to resist in-plane forces, where there is a risk that the glass could slide in any direction (including upwards and sideways), should only be used if they are justified by testing or calculations

7. Fire safety

There may be other performance requirements, such as fire safety, which prohibit the use of certain types of glass or glass generally in some forms of barrier. The designer should consider all regulations and standards which apply to the safe design and use of barriers in and about buildings, and ensure that a fully compliant design is provided.

With regard to fire, **MHCLG Circular 02/2018** of 29 November 2018, applicable to England, and subsequent guidance, has identified that 'specified attachments' to the building envelope including balconies may only be constructed from (non-combustible) materials that achieve European Class A1 or Class A2-s1,d0.

The forms of laminated glass that are in common use at present do not meet either of these fire performance classifications under testing due to the presence of a combustible polymer interlayer(s) between two or more panes of glass. However, as identified above, the use of monolithic toughened glass may present a significant risk to life safety if it were to fail in-service and as such may not comply with the relevant building regulations.

It is therefore recommended that the use of glass in balustrades is discussed with the relevant building control authority, from the perspective of life safety.

8. Installation of barriers

Even if barriers have been properly designed, they may not perform as expected unless properly installed, inspected and maintained. SCOSS are aware of a number of issues during the installation of barriers with glass, including:

- Reliance on clamping of glass, with no through fixings to provide positive retention. Such systems often include resilient pads of rubber/plastic between the glass and the fixing. Failure to properly tighten the clamp fixings, or loosening of fixings by vibration, or post-installation relaxation of the rubber/plastic pads, can lead to relaxing of the grip on the glass and subsequent slippage under gravity or vertically applied loads.
- Misalignment of fixings may generate bending stresses in the glass, leading to a reduction in load capacity and a higher risk of breakage under load.
- Omission or under-tightening of fixings will increase loads on other fixings, again leading to a reduction in load capacity and a higher risk of breakage under load.

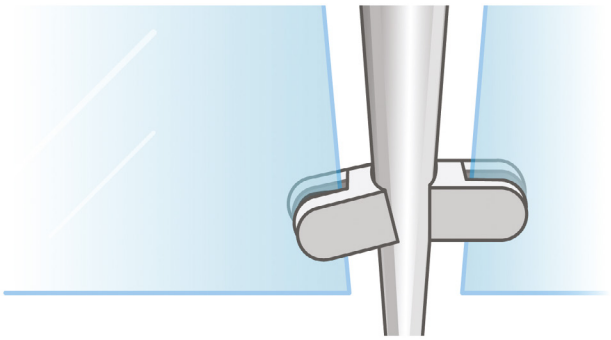

Figure 2
Glass under stress due to misaligned clamp fixing

With regard to installation, the principal contractor and the installer should ensure that:

- The supporting structure has been checked prior to installation and is in suitable condition to accept any fixings/anchors required as part of the installation;
- The installer is familiar with the correct installation procedures as stated on the construction drawings;
- The installer is using the correct tools, and working in compliance with the manufacturer's installation instructions;
- Installers know what to do in the event that they are not able to install as per the design drawings, particularly if there are any issues with fixings and anchors;
- Fixings and anchors are properly installed, aligned and tightened, so as not to stress any glazed element during installation, and are inspected and signed off before the barrier is put into service.

The **Construction Fixings Association website** is a useful source of information.

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9. Principal contractors

During construction, the principal contractor should:

- Ensure that the designer of any barrier has, as a minimum, complied with the requirements of the building regulations Part K (England, Wales), Part N (Wales) and Mandatory Standards 4.4 and 4.8 (Scotland), taking note of the guidance in Approved document K (England, Wales), Approved Document N (Wales), the Technical Handbooks (Scotland), BS 6180 and the relevant Eurocodes (and their National Annexes) for structural design;
- Ensure that the loading requirements for the barrier system are in line with those recommended in BS 6180 and relevant Eurocodes, including National Annexes;
- Ensure that a suitable supporting structure has been designed for fixing of the barrier, and that an appropriate form of anchor is identified and specified;
- Ensure that a proper risk assessment has been carried out and documented, in line with the recommendation of BS 6180, and with particular regard to any glazed element of the barrier;
- Ensure that adequate factors of safety have been specified for any safety critical elements;
- Ensure that fixing systems are designed to allow for sufficient adjustment on site to accommodate misalignment between elements without stressing components including glass.

10. Department for Education guidance

In May 2019, the Department for Education revised their **Output Specification: generic design brief and technical annexes** to ensure the safe procurement of barriers for schools.

Technical Annexes B and D have been updated to include the following key points:

- The design and the materials (including any glass) used for all balustrades and guarding shall be as defined in BS 6180:2011 and Approved Document K;
- Designs shall be certified by Chartered Structural Engineers or a BSI Kitemark registered manufacturer;
- Balustrade and barrier systems shall be installed by qualified, accredited and certified installers.

11. Managing barrier risks in-service

To identify risks while the barrier is in-service, it is suggested that the building owner or facilities maintenance manager conducts regular visual inspections of the entire barrier system. It is recommended that building managers, caretakers and security guards are briefed to look out for signs of distress such as chipped glass or loose handrails.

Issues to look out for during regular surveys include:

- Evidence of glass-to-metal contact;
- Evidence of glass slippage, movement or distortion;
- Chips or other damage to any glass component that could lead to spontaneous breakage or reduction of load capacity;
- Corrosion of metal components or flaking of coatings which indicates that the system has not been subjected to regular inspection and maintenance;
- Missing or loose fixings;
- General movement or looseness of components.

If it is suspected that a barrier system has not been properly installed, or that an element has become loose or damaged, then immediate action should be taken to protect the area in question and carry out suitable repairs or other maintenance.

It should always be remembered that barrier systems which are intended to prevent falls from height could lead to life-changing injuries or loss of life if safety critical elements of the system should fail in-service.

To identify risks while the barrier is in-service, it is suggested that the building owner or facilities maintenance manager conducts regular visual inspections of the entire barrier system

FEEDBACK
If you have any comments or questions regarding this SCOSS Alert, please **Submit Feedback**.

PRESENTATIONS
Structural-Safety are giving lunchtime presentations to organisations who are interested in learning more about the work that Structural-Safety (SCOSS and CROSS) do, including sharing examples of safety issues to learn from.

For more information contact **events@structural-safety.org**.

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Annex A - Regulations and standards

In England and Wales, reference should be made to the Building Regulation 2010 requirement K2 (both countries) and requirements K4 (England) / N1 (Wales), which require:

Protection from falling

K2. (a) Any stairs, ramps, floors and balconies and any roof to which people have access, and
(b) any light well, basement area or similar sunken area connected to a building, shall be provided with barriers where it is necessary to protect people in or about the building from falling.

Protection against impact

K4/N1. Glazing, with which people are likely to come into contact whilst moving in or about the building, shall –
(a) if broken on impact, break in a way which is unlikely to cause injury; or
(b) resist impact without breaking; or
(c) be shielded or protected from impact.

In both countries, Regulation 7 requires that:

Regulation 7 Materials and workmanship

7. (1) Building work shall be carried out –
(a) with adequate and proper materials which –
(i) are appropriate for the circumstances in which they are used,
(ii) are adequately mixed or prepared, and
(iii) are applied, used or fixed so as adequately to perform the functions for which they are designed; and
(b) in a workmanlike manner.

In Scotland, the building standards technical handbooks (**domestic**› and **non-domestic**›) provide guidance on achieving the standards set in the Building (Scotland) Regulations 2004. Reference should be made to Mandatory Standards 4.4 and 4.8 from the technical handbooks, which require:

Standard 4.4 Pedestrian protective barriers

Every building must be designed and constructed in such a way that every sudden change of level that is accessible in, or around, the building is guarded by the provision of pedestrian protective barriers.

Standard 4.8 Danger from accidents

Every building must be designed and constructed in such a way that:
(a) people in and around the building are protected from injury that could result from fixed glazing, projections or moving elements on the building
(b) fixed glazing in the building is not vulnerable to breakage where there is the possibility of impact by people in and around the building [...]

In Scotland, Regulation 8 requires that:

Regulation 8 Fitness and durability of materials and workmanship

1. Work to every building designed, constructed and provided with services, fittings and equipment to meet a requirement of regulation 9 to 12 must be carried out in a technically proper and workmanlike manner, and the materials used must be durable, and fit for their intended purpose [...]

The specification of monolithic toughened glass with clamp-fixings could result in panes of glass slipping vertically within their clamp-fixings, which may be viewed as a breach of the building regulations, Regulation 7 (England and Wales) or Regulation 8 (Scotland). The combination of an appropriate form of laminated glass with a suitable fixing system can provide sufficient integrity to remain in place and act as a barrier even after the glass has fractured.

Designers of barriers containing glass should be aware of the following regulations and standards:

- Building regulations and associated Approved Documents or Technical Standards, particularly:
    - o Part A Structure, and Approved Document A (England);
    - o Part A Structural safety, and Approved Document A (Wales);
    - o Part B Fire safety, and Approved Document B (England and Wales);
    - o Part K Protection from falling, collision and impact, and Approved Document K (England and Wales);
    - o Part M Access to and use of buildings, and Approved Document M (England and Wales);
    - o Part N Glazing - safety in relation to impact, opening and cleaning, and Approved Document N (Wales);
    - o Regulation 7 Material and workmanship, and Approved Document 7 (England and Wales);
    - o Building Standards technical handbooks, **domestic** and **non-domestic** (Scotland), including Mandatory Standards 4.4 Pedestrian protective barriers and 4.8 Danger from accidents;
    - o Regulation 8 Fitness and durability of materials and workmanship (Scotland);
- **BS 6180:2011 Barriers in and about buildings. Code of practice**
- **BS 5395-1:2010 Stairs. Code of practice for the design of stairs with straight flights and winders**
- **BS EN 1991-1-1:2002 Eurocode 1. Actions on structures. General actions. Densities, self-weight, imposed loads for buildings**
- **BS 8300:2009+A1:2010 Design of buildings and their approaches to meet the needs of disabled people. Code of practice**
- **BS EN ISO 14122-3:2016 Safety of machinery. Permanent means of access to machinery. Stairs, stepladders and guard-rails**
- **BS 6262-4:2018 Glazing for buildings. Code of practice for safety related to human impact**
- **BS EN 12600:2002 Glass in building. Pendulum test. Impact test method and classification for flat glass**
- **BS 8539:2012 Code of practice for the selection and installation of post-installed anchors in concrete and masonry**
- **BS EN 16612:2019 Glass in building. Determination of the lateral load resistance of glass panes by calculation**