Technical Update 4

Use of glass overhead

The CWCT 'Standard for slope glazing systems' published in January 1999 covers all aspects of overhead sloping glazing systems. The purpose of this update is two fold:

- To give further guidance on the safe use of glass in overhead slope glazing systems
- To extend the scope of the CWCT Standard to include the performance of glass in slope glazing systems that are between vertical and 15° of vertical.

Slope glazing is defined as glazing that makes an angle of 15° or more with the vertical. This definition has been used for a long time and relates to the loading experienced by the glass, notably snow loading. Glass that is vertical may stay in place after failure provided that:

- The failure is due to thermal stress, or an edge defect, or is induced internally by a nickel sulfide inclusion.
- There is no impact or significant lateral loading (e.g. from wind) to dislodge the glass fragments
- The glass is retained in a four-sided rebate. (Glass held by bolted fixings is likely to fall upon breakage. Glass unsupported on one edge is likely to incur more localised falling of fragments.)

Note that although glass that is sloping with an angle of between 0° and 15° from the vertical is not termed slope glazing, toughened glass used in this situation is likely to fall on fracture due to the action of its own weight even if there is no impact. Where there is a risk of overhead glazing failing and falling onto occupied areas, a risk assessment should be carried out.

Clause 2.4 of the CWCT Standard for slope glazing systems covers glazing selection. The first paragraph of this clause states, 'The selection of glazing systems shall be based on a sensible assessment of the consequences of glazing failure, coupled with an assessment of the risk of glazing failure'. The selection of materials permitted by the remainder of the clause will be subject to this risk assessment which may preclude the use of some options or require the adoption of additional safety measures. The risk assessment should be undertaken in collaboration with the building owner to help ensure that the owner's requirements and concerns are duly identified and addressed. When selecting glass many factors may have to be considered including solar gain, thermal fracture, acoustics, bomb blast and so on.

Clause 1.5.5.4 states that toughened glass shatters into small, relatively harmless, fragments. A vertical pane may remain in its frame but sloping panes are more likely to fall out when they break. The greatest risk with toughened glass is that the fragments may clump together and fall *en masse*.

Glass fragments have been seen to remain together in clumps up to 250 mm diameter. These have a natural tendency to fall edgeways and only break up on impact with a sufficiently hard surface. Such clumps may weigh up to two kilograms each and when falling from heights above five metres can have considerable energy. Toughened glass fragments are less harmful than large shards of glass but still have sharp edges.

For thicker glasses the individual fragments will include fragments with length equal to the glass thickness, although numerous smaller fragments and splinters will also occur. The thicker glasses with the larger fragments are more likely to fall as clumps. Even if full separation occurs the fragments will be larger and a greater mass of fragments will fall.

Single glazing

Clause 2.4.2 allows the use of heat soaked toughened glass for glazing up to five metres above the lowest floor level. Heat soaking toughened glass greatly reduces, but does not eliminate, the risk of failure by the presence of a critical nickel sulfide inclusion. The distinction between glass used below five metres and that used above five metres is to do with the kinetic energy of the falling glass and because low level glazing is frequently associated with smaller thinner panes of glass (conservatories and walkways). Where thicker or larger panes are used serious consideration should be given to the use of alternative glasses, such as laminated glass, or provision of a wire mesh under the toughened glass, see below.

For glass used between five and thirteen metres above lowest floor level, Clause 2.4.2 allows heat-soaked toughened glass to be used in thicknesses up to 6 mm and pane sizes up to $3m^2$. This requirement limits the total mass of glass that can fall to 45 kilograms. However, it should be noted that the glass might fall as clumps of unseparated fragments weighing up to 2 kilograms. The right hand column of Clause 2.4.2 states that ‘consideration should be given to positioning a wire mesh below the glazing, such that falling clumps of broken glass are broken into clusters no larger than 25 mm square’. A wire mesh should be provided unless the risk assessment shows that it is not necessary.

Meshes may be provided in the form of screens, sunshading and so on and may not detract from the appearance of the glazing. When used at height, a wire mesh may not be readily apparent to the casual viewer.

A mesh will catch or fragment the glass in case of failure. However, toughened glass should be heat soaked to reduce the risk of failure due to the presence of critical nickel sulfide inclusions. This reduces the risk of fragments falling, albeit through the mesh. A reduced risk of failure also reduces the need for repair, which frequently entails working at height.

Clause 2.4.2 allows the use of laminated glass in all situations. The strength in use and post-failure behaviour of laminated glass both depend on the glasses used to form the laminate and the type of interlayer. Post-failure behaviour is mainly determined by the types of glass used to form the laminate. Clause 1.5.5.5 describes laminated glass. If a piece of laminated glass is made only from sheets of toughened glass then once both sheets have failed the laminate has little integrity and ability to carry load, even its own weight. Post-failure, a laminate of two layers of toughened glass fragments attached to either side of a resin or plastic interlayer is flexible and will sag under its own weight. It will only remain in its frame provided it is retained by clamping or adhesives along the supported edges. Membrane action can then occur with the interlayer in tension.

In the light of recent concerns on the use of toughened glass in overhead situations, it would now appear prudent for any one proposing to use laminated toughened glass in a sloping situations to investigate post-failure behaviour before allowing this combination of glass and laminate to be used. With point connected glass the glass should not tear away from the connections after fracture. Again the specifier will require appropriate tests. Once laminated glass falls from its frame or fixings it falls as a single piece and presents a greater threat than falling toughened glass.

Laminated glass containing at least one sheet of glass which is not toughened will retain greater integral stiffness after failure of the glass sheets. It will therefore still be able to resist some load and is less likely to fall from the frame. The non-toughened sheet may be annealed or heat strengthened. Heat strengthened glass is used to reduce the risk of thermal fracture occurring. It is prudent to investigate the post-failure behaviour and consider whether a wire mesh or bars are required to catch the glass. Because laminated glass falls as a single blanket it may be retained by a limited number of bars rather than a complete wire mesh.

Multiple glazings

The above considerations that apply to single glazing also apply to the lower pane of multiple glazing units. This is the principle of Clause 2.4.3 of the CWCT Standard for slope glazing systems. Where the lower pane of a multiple glazing unit may fall on fracture the post failure behaviour of the next lowest layer must also be considered. Every project should be considered on its own merit and specific requirements. Decisions on the selection of glass should be based on a full risk assessment.

If safety is the primary concern, the CWCT's advice is to use a laminated glass as the lowest glazing layer. This should comprise at least one sheet of non-toughened glass. This should remain in place and retain any fragments of glass in the event of the upper layer failing. As a further precaution, following risk analysis, bars may be fixed to retain the laminated glass if it falls from its fixings as a result of, say, severe impact. In cases where it is not possible to use laminated glass the advice given above should be considered and an appropriate viable glass selected on the basis of minimising risk to occupants. The upper layer may be annealed, heat strengthened or toughened glass. The latter will provide greatest resistance to impact and thermal fracture and heat strengthened glass provides greater resistance than annealed glass.

With existing overhead glass installations, the question of whether or not a mesh or other measures should now be introduced may arise. The answer depends upon the conclusions of an appropriate risk assessment. If the building's usage or performance to date does not give any reasonable cause for concern, then no action may be required.