Technical Note No 67 supersedes TN 42

SAFETY AND FRAGILITY OF GLAZED ROOFING: testing and assessment

Technical Note 66 describes a system for the classification of fragility of glass roofs. This Technical Note describes the testing and assessment of glass roofs to establish compliance with this classification system.

This Technical Note is one of eight describing the performance of glass. They are:

TN61 Glass types
TN62 Specification of insulating glass units
TN63 Glass breakage
TN65 Thermal fracture of glass
TN66 Safety and fragility of glazed roofing: guidance on specification
TN67 Safety and fragility of glazed roofing: testing and assessment
TN68 Overhead glazing
TN69 Selection of glass to prevent falls from height

Introduction

Technical Note 66 describes a system for the classification of fragility of glass roofs. The classification requires the glass roof to be tested to demonstrate acceptable performance. This Technical Note describes how these tests should be carried out.

This test sequence has been developed by the CWCT in collaboration with roof glazing designers, contractors and test houses, in response to concerns that existing standard tests for the fragility of roofing (e.g. ACR [M]001 Test for non-fragility of profiled sheeted roofing assemblies) were not readily applicable to glazed roofing.

It is intended that the CWCT test sequence will be adopted as a standard method of test for the fragility testing of glazed roofs. The test sequence is applied to the whole assembly, consisting of the glass, supporting structure, manner of fixing, glazing materials, and all other components rather than any single component.

The test sequence uses a combination of hard and soft body impacts and a static load test on the glazing system after fracture of the glass. The soft body impact tests are based on the ACR fragility test and the hard body impacts are based on BS EN 356.

A competent person should review the test procedures to ensure that the test sequence is applicable to the proposed building. This will include establishing test details, such as temperatures and any modifications to accommodate particular requirements of the building.

Competent person

A competent person is someone who can demonstrate that they have sufficient professional or technical training, knowledge, actual experience and authority to enable them to:

a) Carry out their assigned duties at the level of responsibility allocated to them
b) Understand any potential hazards related to the work (or equipment) under consideration
c) Detect any technical defects or omissions in that work (or equipment)
d) Recognise any implications for health and safety caused by those defects or omissions
e) Be able to specify a remedial action to mitigate those implications.

In this context, a competent person is someone who can demonstrate a:

a) Thorough knowledge of glazed roofing and of the mechanical and physical properties and behaviour of the glazed assemblies when subjected to this test; and
b) Extensive knowledge and experience of installation of glass, its usage limitations, behaviour and mode of failure in service.

For these tests, the responsibilities of the competent person include ensuring that the worst-case scenario has been covered when:

a) Defining the roof assembly to be tested
b) Defining the impact position(s)
c) Determining any conditioning of the samples and test temperatures
d) Determining how glass is to be broken
Safety and fragility of glazed roofing

Sample preparation

The roof assembly to be tested should be constructed using the design and materials that represent, as far as possible, the intended use. Any structure used to support the roof assembly should be at least as stiff as the proposed structure to which it will be fixed.

The effect of temperature on fragility should be considered as some laminated glass interlayer materials become stiffer at low temperatures and softer at high temperatures. This may necessitate testing both at ambient temperature (20±5°C) and at the maximum temperature the glass is likely to reach in use, however where it can be established prior to testing which temperature is more critical, testing can be limited to the critical temperature. The maximum temperature will often be around 40°C but may be significantly higher in some circumstances. The appropriate temperatures for the test should always be determined by the competent person and should be based on a realistic assessment of the maximum temperature the glass is likely to reach during maintenance work.

Consideration should also be given to testing at sub-zero temperatures to establish the effect on the materials constituting the glazed roof should the building be expected to encounter prolonged periods of cold. Routine maintenance is unlikely to be carried out in freezing conditions but access to roof mounted plant may be necessary.

A minimum of three test panes or units, which are representative of those to be used in the glazed roof, should be tested within the roof assembly. The framing system used to support the glass may be used for more than one test provided that there is no visible evidence of damage due to previous tests.

Testing should be carried out on a glazing system that is at a pitch equivalent to or less than that to be used on the building. Since glazing which is angled is more likely to deflect an impact without breaking than glazing which is horizontal.

Testing procedure

Assessment of fragility requires a sequence of tests. The tests making up the sequence are described in this section and the tests making up the sequence for different classes of roof are given in Table 1.

Impact tests may be carried out as serviceability tests or safety tests. The same test procedures and impact energy are appropriate for both types of test but the assessment criteria will differ. For a serviceability test there should be no damage to the glazing system that would affect its future service in the building. In a safety test the requirement will normally be that the glass remains in place and the impactor is prevented from passing through the glass. Any glass fragments falling from the assembly during the test should be limited to a maximum dimension of 50mm and a maximum combined mass of 50g.

It is recommended that tests on the upper pane of a class 1 roof be treated as serviceability tests. Other tests may be treated as safety tests unless specified otherwise.

Soft body impact test

The soft body impact test is carried out using a 300mm diameter cylindrical bag filled with sand and with a mass of 45kg. The impactor is dropped from a minimum height of 1200mm which gives an impact energy of at least 530J. The procedure is described in ACR(M)001.

The test was developed to simulate the effect of a person falling on a roof surface from a standing position. Where a person could fall onto the roof from a greater height, this test may not be appropriate.

Hard body impact test

The hard body impact test is carried out using a 100mm diameter steel ball with a mass of 4.11kg dropped through a height of 1200mm to give an impact energy of 48J.

This test is intended to simulate the effect of impacts that might arise from tools and equipment being dropped onto the roof. The impactor was chosen as it is a standard impactor used in other tests on glass.

Static load test

The static load test is carried out after the impact testing has been completed. If the glass has not
been broken during the course of the impact testing all glass plies should be broken prior to the static load test.

The static load test is carried out by applying a static load of up to 180kg. The test load should be determined using the guidance given below and agreed by the competent person. The load is kept in place for 30 minutes. No penetration of the assembly by the static load should occur and the glass panes should not pull out or fall free from the assembly during the allotted time.

The static load is intended to represent the weight of a person (90kg) who may fall onto the glass and become injured and, where appropriate, a second person giving assistance (180 kg total load). Where the glass panes are sufficiently small to allow assistance to be given from an adjacent pane or other place of safety, the load representing the second person is not required. For small panes the weight of the injured person may be distributed over more than one pane and the test load may be less than 90kg.

The load should be distributed over an appropriate area. A suggested arrangement of the load for a pane supported on all four edges is shown in Figure 1. Where the loaded area is not within the area of the pane under test the magnitude of the load may be reduced accordingly.

The 30 minute period is considered to be the time the glass should maintain load bearing capacity in order to allow assistance to arrive and the rescue of the injured person.

Where glass panes are to be broken this can be achieved using a pointed tool as described in BS EN 12150. For toughened glass the object is to create the normal fragmentation pattern and this can be achieved by the use of the tool half way along the long edge about 13mm in from the edge. For annealed and heat strengthened glass with continuous support along all four edges the object is to form at least three cracks radiating in distinctly different directions from the centre of the pane. The cracks should extend for a distance of at least 150mm. Where the glass is supported at discrete points, the competent person shall determine whether this fracture pattern is appropriate or whether an alternative pattern is more appropriate, for example with cracks radiating from the support points. For laminated glass both outer plies of glass should be broken.

**Selection of test locations**

The locations for impact and application of static load should generally be selected to give the worst case situation however in some cases this may be considered unduly conservative. For example if the risk is from a person falling on the glass from an adjacent solid area of roof, it may be reasonable to carry out tests towards the edge of the pane rather than in the centre.

Impacts near the centre of a pane of glass are likely to cause much of the impact energy to be absorbed by elastic deformation of the glass, whereas impacts near the corners of the glass will transmit more energy into the framing system. Impacts near points of attachment may generate higher stresses in the glass. Impacts near the centre of a pane may however generate high stresses in the underside of the lower pane, and cause the lowermost layer of glass to break even if the uppermost layer does not.

For glazing systems with no external framing elements (eg with silicone weatherseals between adjacent panes), impacts on the edges or corners of the glass may be much more likely to cause the upper pane to break, but may have little effect on the lower pane.

Impact locations should include the following:

- Centre of pane
- Midspan of any unsupported edge, 150mm from the edge
- Within 300mm and not more than 150mm from a support
- Any other location specified by the competent person.
Where visual inspection indicates that the glass is undamaged by an impact, it may be subject to further impacts in different locations.

**Other considerations**

The test does not answer all possible considerations for the fragility of glazed roofs. It is therefore the responsibility of the competent person to decide if any additional tests are appropriate.

The following points are known to be left unanswered and should be considered prior to testing:

- There is no provision or agreed test procedure for establishing the effects of time, temperature and weather on the fragility of the glazed roof assembly. Consequently, degradation of the materials and components making-up the assembly will occur which, along with poor maintenance of the glazing system (e.g. worn glazing materials not being replaced) may cause a deterioration in performance over time.

- Glass breakage from more severe causes of impact, such as the impact of loose tiles and other roofing components during a storm, are not considered.

- The assessment is specific to the assembly with the materials and dimensions tested. There is no procedure given for extending the fragility test to similar glazed roofing assemblies. Consequently, any changes to the design of the assembly or to the glass specified (e.g. change in glass thickness/glass, reduction in pane size, etc.) may require a new test to be carried out subject to the judgement of a competent person.

**Use of previous results**

Testing for fragility is expensive and roof designers may wish to base the assessment of a proposed roof on the results of previous tests. Manufacturers of roofing systems may wish to test their systems.

The use of previous results is only acceptable where it can be shown that the previous test was at least as onerous as required for the proposed roof. Seemingly minor changes in the roofing assembly may have a significant effect on the results.

In many cases the static load test at elevated temperature will be the critical part of the test sequence. Previous tests may be considered sufficient where:

- The framing system tested is the same as that for the proposed roof in all respects including method of retaining the glass, type and thickness of retaining gaskets, spacing of fixings for pressure plates, and
- The glazing tested is the same as that for the proposed roof including glass type and thickness, type thickness and grade of interlayer in laminated glass, type and width of glazing unit edge spacer and edge sealant, and
- The upper test temperature is greater than or equal to that required for the proposed roof, and
- The pane size tested is greater than or equal to that for the proposed roof.
Table 1: Test sequence for glazed roofs

<table>
<thead>
<tr>
<th>Test</th>
<th>Description of test</th>
<th>Roof class and glazing type to which test applicable</th>
<th>Roof class 1</th>
<th>Roof class 2</th>
<th>Roof class 3</th>
<th>Assessment criteria</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>single igu</td>
<td>single igu</td>
<td>single igu</td>
<td></td>
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</tr>
<tr>
<td>1</td>
<td>Prepare test sample at specified conditions – this requires storage at the specified</td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
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<tr>
<td></td>
<td>temperature +/-5°C for 12 hours</td>
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<td></td>
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<tr>
<td>2</td>
<td>Conduct soft body test to outermost pane</td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>N/A N/A Class 1 roof: the glass should not break. Class 2 roof: the glass may break</td>
<td>Required to simulate person falling on glass. Serviceability requirement for Class 1 roof. Safety requirement for Class 2 roof</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>but the impactor should be retained and the size of falling fragments be limited.</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Conduct hard body test to outermost pane</td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>Class 1 roof: the glass should not break. Class 2&amp;3 roof: the glass may</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>break but the impactor should be retained and the size of falling fragments be limited.</td>
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</tr>
<tr>
<td>4</td>
<td>If the test does not break the upper glass pane, then it should be broken prior to</td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>N/A N/A Although glass may not be broken in the test it is possible that breakage can</td>
<td>Although glass may not be broken in the test it is possible that breakage could occur in a real situation</td>
</tr>
<tr>
<td></td>
<td>the next test.</td>
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<td></td>
<td></td>
<td></td>
<td>occur in a real situation</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Conduct a soft body impact test as in stage 2 on lower pane of glazing unit</td>
<td></td>
<td>N/A</td>
<td>✔</td>
<td>✔</td>
<td>N/A N/A The glass may break but the impactor should be retained and the size of falling fragments be limited.</td>
<td>Required for class 1 and 2 roofs in case upper pane is broken by another cause. Safety requirement in all cases.</td>
</tr>
<tr>
<td>6</td>
<td>Conduct a hard body impact test as in stage 3 on lower pane of glazing unit</td>
<td></td>
<td>N/A</td>
<td>✔</td>
<td>✔</td>
<td>N/A N/A The glass may break but the impactor should be retained and the size of falling fragments be limited.</td>
<td>Required for class 1 and 2 roofs in case upper pane is broken by another cause. Safety requirement in all cases.</td>
</tr>
<tr>
<td>7</td>
<td>Conduct a repeat soft body impact as in stage 2</td>
<td></td>
<td>✔</td>
<td>N/A</td>
<td>✔</td>
<td>N/A N/A The glass may break but the impactor should be retained and the size of falling fragments limited.</td>
<td>Required for class 1 and 2 roofs in case upper pane is broken by another cause. Safety requirement in all cases.</td>
</tr>
<tr>
<td>8</td>
<td>Break any unbroken glass plies. Gradually apply static load comprising a weight of</td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>N/A N/A Load to be retained for duration of test and the size of falling fragments be limited.</td>
<td>Magnitude and distribution of load to be agreed by competent person.</td>
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<td>up to 180kg, as determined by the competent person and leave for a minimum of 30</td>
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<td>minutes.</td>
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<tr>
<td>9</td>
<td>Assess the size of any glass fragments that have fallen from the glazing assembly</td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>Maximum dimension of any fragment 50mm Mass of all fragments limited to 50g.</td>
</tr>
<tr>
<td></td>
<td>during testing.</td>
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<tr>
<td>10</td>
<td>Repeat the test sequence on any panes or units still to be tested.</td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Where required repeat the test sequence at other specified temperatures.</td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
</tr>
</tbody>
</table>

Key: igu – insulating glazing unit, ✔ test applicable, N/A test not applicable