SAFETY AND FRAGILITY OF GLAZED ROOFING
- guidance on specification and testing

This Technical Note provides guidance on some of the safety issues, which need to be taken into account in the design of glazed roofing and in the completion of risk assessments involving glazed roofing. A test for assessing the fragility of glazed roofing is also included and the test method justified. This method ensures that the whole assembly, consisting of the glass, supporting structure, manner of fixing, glazing materials and all other components is tested rather than just the glass component.

Introduction

A designer must consider many issues when specifying glass for use in glazed roofs. These issues may increase design complexity and costs considerably. Such issues may require:

- Sufficient strength to support all anticipated loads.
- Safe post-failure behaviour in the event of breakage both for people on and beneath the roof.
- Sufficient rigidity to prevent deformation under load, which may cause concern to those either on or within sight of the glass.
- Sufficient slip resistance to prevent people slipping and injuring themselves when walking on glass.

Glazed roofs can always be designed to withstand any specified loading or impact, typically by using glass which has higher strength, and by designing the frame and supports to carry the load. There may however, be considerable cost implications and constraints. These include limitations from the manufacturing and fabrication processes and the ease with which heavy glass panes can be safely handled during transportation and construction.

This Technical Note is aimed specifically at glazed roofs not accessible by the public but where it is possible for persons working on or in the immediate vicinity to fall and/or drop objects onto the glazed roof during cleaning/maintenance activities. In these circumstances there may be several potential hazards such as contact with broken glass, the person falling through the roof and objects including broken glass falling onto people below.

In this Technical Note the term 'glazed roof' will refer to both fully glazed roofs and to glazed parts of roofs, ie rooflights. It is intended to cover a significant number of the safety concerns with glazed roofs. It does not endeavour to cover all possible concerns due to the complexity of the issues involved.

This Technical Note is not applicable to roofs that are accessible by the public which should be designed in a similar manner to glass floors and other walk-on glass surfaces, including withstanding the appropriate design loads from BS 6399-1. Many of the issues discussed will however be relevant.

Roof types

In this Technical Note glazed roofs are classified into three types. These are:

Type 1
Roofs which may be walked on for occasional cleaning/maintenance activities and which will therefore need to support both the weight of people on the glass and their equipment. Such roofs could be subject to impact from a person, and/or any object carried, falling onto its surface.

Type 2
Roofs where people are restricted from walking on the glass, but may walk adjacent to the glazing. Such roofs could be subject to impact from people tripping and falling onto its surface. Objects being carried may also fall onto its surface.

Type 3
Roofs where people are restricted from walking on or falling on to the glass, by a feature such as a barrier. Impact from a person should not be possible, but objects may still be accidentally dropped onto its surface.
Preferred approaches

It should always be remembered that the alternative approach to designing glass for impact and other loads is to exclude persons and objects from the glass.

The CDM Regulations require the designer to consider the implications of the design for future cleaning, maintenance and repair. If the design is such that the only means for cleaning or glass replacement is for a person to walk on the glass then the designer has a duty to ensure that cleaning and replacement can be undertaken in a safe manner. Designing for the consequences of an accident is legally no substitute for designing to avoid the accident in the first place.

Techniques that can be used for reducing the risk of impact include:

- Providing a permanent gantry to permit safe access to the glazing. This reduces the potential for the roof to be impacted although objects may still be dropped on the glass. It may be that this gantry should be designed to accommodate the weight of a replacement pane of glass over and above the weight of the maintenance team.
- Putting a barrier around the glass to exclude persons from the risk area. This may include the use of a mesh or screen above the glass to prevent objects from landing on the glass surface. Such screens may also provide an element of shading.
- Putting in place and enforcing method statements and risk assessments for the cleaning and maintenance operations.
- Providing suitable spreader boards and safety harness/fall arrest attachment systems as part of the glazing contract (i.e. not expecting the local window cleaner/glazier to carry these items as standard) and storing them near where they are required to be used. These items will not be used if they are locked in a cupboard in the basement.
- Reducing the potential for people to fall on to the glazed roof as a result of slips and/or trips. This should include both glazed roofing surfaces and any adjoining walkway surfaces from which people may fall onto the glazed roof.

Reducing slippages

Surfaces should have sufficiently high coefficients of friction that they do not pose a significant hazard of causing slips (and/or trips) in both dry and wet conditions. Glazed roofs will also need to be designed to remove surface water thereby reducing the potential for water to cause slipping. This may be achieved by inclining the roof at a shallow angle that is sufficient to allow water to run off, but is not at too high an angle that it increases the potential for slipping.

The slip resistance of glass surfaces can be increased by fritting and other processes such as sandblasting or etching. All of these processes may help to trap dirt and increase the difficulty of cleaning the glass which may make their use impractical.

Footwear should also provide adequate grip in both dry and wet conditions.

Signage

Where a glazed roof is designed to be walked on it must be clearly labelled as such, as it may otherwise give the impression to onlookers that it is safe to walk on all other glazed roofs. Signage should also indicate limitations to the permitted access and may take the form of ‘Access permitted in accordance with maintenance manual only’. Equally, glazed roofs which are NOT safe to walk on must be clearly labelled. It is not normally considered good practice to mix walk-on and non-walk on glass in a glazed roof. In the event that a glazed roof is not labelled it should be assumed that it is not safe to walk on.

Design issues

The design and selection of glass for glazed roofs should involve the preparation of a risk assessment, to consider safety issues arising at all stages of design, construction, building operation and maintenance of the completed building. As part of this risk assessment the designer should consider the possibility of a person or object falling onto the roof surface.

These issues typically include:

- Is there access to the glazed part of the roof, or to an adjacent non-glazed part of the roof (e.g. core roof)?
- Is access required to the glazed part of the roof, for any reason, including maintenance, cleaning or glass replacement?
- Is it unavoidable that persons have to walk
on the glazed part of the roof?
- Is placement of maintenance and/or cleaning loads onto or across the glazed part of the roof unavoidable?
- Is there any part of the building, or an adjacent building, which overlooks the glazed roof, from which objects may fall, be dislodged or be thrown by vandals on to the glazed roof?
- Is there a risk that objects may be thrown onto the glazed roof from below?
- Is there a risk of objects such as stones being dropped by birds such as seagulls?
- Is there potential for unauthorised use of the glazed roof as a working platform?

In each of these situations there is a potential for persons or objects to fall onto the glazed roof surface. Depending upon the particular risk it is possible to assess the likely impacts that may occur, and to specify glass appropriately.

In the event of an accident occurring there should be a procedure for recovering an injured person which must be incorporated into the cleaning/maintenance strategy of the building. This should not impose greater loads or impacts on the glass than allowed for in the design.

**Glass safety**

There are several safety issues that the designer will need to consider.

These include:
- Will the person and/or object that falls onto the glazing fall through or rebound? For a given glass type and configuration there will always be some size of object that will go through, if it falls from a sufficient height.
- Should the glass remain intact, or is it permitted to crack/shatter?
- Will the glass fall out or remain in place if it cracks (or if the frame deforms)?
- Will fragments of the glass or its framing system be dislodged or protrude from either the upper or lower surface of the glazing? Fragments dislodged from the upper surface may slide from the roof, fragments with exposed edges may cause injury to the person who falls onto the glass, fragments dislodged from the lower surface may fall onto people below.
- Will the glass be required to retain a specified level of strength and/or security, stay in place for a specified length of time prior to removal, withstand a specified temperature, remain weathertight, or maintain some other aspect of performance, after it has initially broken?
- Could the glass have broken or been damaged due to some other minor incident before the worst-case event occurs? For example, could the glass surface have been scratched deeply by grit embedded in the soles of someone’s shoes or from contact with maintenance equipment? Will the glass be weakened sufficiently that it breaks when people are on the glass with the consequent risk of fatalities or injuries?

**Designing to resist impact**

Impact is usually classified in terms of whether the impacting object is a hard body or a soft body, and the maximum energy that could be given up by the impacting object. Hard bodies tend to be smaller (e.g. tools and stones) and impart less energy during impact, but this impact is localised over a very small area, and is more likely to cause localised crushing of a glass surface. Soft bodies are frequently much larger and heavier (e.g. a person) but the impact is distributed over a wider area and is partially absorbed by the soft body itself.

The reaction of a pane of glass to an impact depends upon its stiffness, the location of the impact and whether the impact is perpendicular or a glancing blow. The form and stiffness of the support system is also significant, as is the glass type and the presence of an air gap (multiple glazing) or interlayer (laminated glass). All these will help to absorb some of the impact energy.

Whilst a large thin pane of glass might be considered to be relatively weak, it is also very flexible, and a perpendicular impact near the centre might only cause a substantial oscillation to occur. Conversely, a smaller thicker pane of glass will not deflect and will experience larger forces.

A greater risk of breakage may also exist if the glass is struck a glancing blow, or if the glass is struck near an edge or corner, where the glass is less able to deflect.

This latter phenomenon is used to important effect in railway carriage windows, which are usually double-glazed. The safety instructions require a passenger attempting to break the glass in an emergency to strike the glass near the corner. If the glass is struck near the centre of the pane then even the special metal-pointed hammer that is provided may require an extremely severe blow before the glass will break.
The form and stiffness of the framing system will also affect the resistance to impact. If the framing system uniformly supports the edge of the glass and is reasonably flexible then the impact energy may be partly absorbed by the frame. Similarly, if there are thick soft gaskets between the glass and the frame then this may help to absorb some of the energy.

Conversely if the glass is rigidly fixed, for example using bolted or clamp fixings with relatively thin hard gaskets then there will be less absorption of energy at the fixings, and the glass might be more likely to break.

The edge profile of the glass pane may also have an effect on pane strength. This is because the pane edges contain small flaws from handling and other damage that may concentrate any impact stresses. These flaws can potentially weaken the edge sufficiently that it may break from the edge when stressed. Edge working the cut edges, typically by arrissing, will generally reduce the size of these flaws, reduce the stress concentration and reduce the incidence of low impact strength, due to edge damage.

Finally, if the pane sustains damage, such as significant scratches, chips, etc. during handling, installation or use, larger stress concentrations which weaken the glass will be produced under a given load. In the case of toughened glass, surface damage will also reduce the depth of the compressive surface stress which helps to give the glass its strength. As a result any glass that is damaged will break at a lower impact energy than glass that is in a pristine or undamaged state.

**What form of glass?**

A key decision to be made when designing for impact is whether to use monolithic or laminated glass.

**Monolithic glass** is a single pane of glass with the same properties throughout. It may be stronger than laminated glass, thickness for thickness, although it will lose some or all of its strength when it cracks. On glazed roofs, if a sloping monolithic pane of glass breaks, glass fragments are likely to fall immediately. In addition, a person or object which falls onto monolithic glass and breaks it will almost certainly fall through.

**Laminated glass** on the other hand will retain more strength and stability on breakage. If a laminated pane breaks the glass is likely to remain in place if:

- the loads applied are not too high;
- the laminated glass’s interlayer is sufficiently strong;
- the interlayer is not heated sufficiently to cause it to soften and relax; and
- the glass does not pull away sufficiently from its means of support.

Consideration must also be given to the choice of interlayer thickness and interlayer material as these may both affect the strength, stability and ability to retain fragments on glass breakage. The edge of laminated glass may also be subject to delamination if exposed to the weather or moisture.

For type 1 glass roofs which are designed to be walked on the use of a sacrificial glass pane as the outermost surface should be considered in order to prevent damage to the load-bearing glass panes beneath. This sacrificial layer will be damaged by chips, scratches, etc., but its breakage should not affect strength and safety.

**What type of glass?**

The next decision for the designer is which glass type to use; annealed, heat strengthened, toughened or wired glass.

In general, the use of single monolithic annealed or heat strengthened glass is not considered appropriate for glazed roofing, except possibly for very low risk buildings such as greenhouses, because of concerns over safety. **Toughened glass** is stronger, and has the highest resistance to impact. However, it can still be broken, losing a significant proportion of its structural integrity and should not be relied upon. Toughened glass may also break for other reasons and will need to be heat soaked if risks of spontaneous breakage due to nickel sulfide inclusions are to be reduced (CWCT, 2002).

A pane of laminated glass which comprises only toughened glass layers becomes a flexible sheet of fragments if all of the layers of glass are broken. Various methods can be used to prevent the broken laminate from falling including use of a ply of annealed or heat strengthened glass, bonding the glass to the fixings and the use of structural interlayers.
Thermal stress breakage may occur with laminated glass containing annealed glass plies. Laminates containing only heat strengthened or toughened glass plies should not be susceptible to thermal stress breakage but will be more expensive and may not have the same optical quality.

Wired glass if used will tend to hold broken glass in place on breakage. However, the glass has a relatively low strength, is susceptible to thermal stress breakage and if penetrated by a person may lead to injury due to the presence of sharp glass edges and metal wires. A safety wired glass with a thicker gauge than standard is available.

Safety glass, as defined in Building Regulations Approved Document N and BS 6262-4 should be considered for the outermost pane of roof glazing, particularly for type 1 and 2 roofs. This will reduce the risk of cutting injuries to people falling on the glass.

What type of glazing?

Glass may be used in single glazing or insulating glass units.

For single glazing overhead, the preferred option is to use laminated glass containing at least one ply of non-toughened glass.

For insulating glass units overhead, the preferred option is to use a monolithic toughened outer pane (for strength, impact resistance and thermal safety) and a laminated inner pane containing at least one ply of non-toughened glass (to reduce the risks of objects, including the toughened outer pane, from falling through the unit in the event of an impact).

These glass configurations may be inappropriate in some cases, as in the event of a fire, the fire brigade may need to break the glazing for smoke venting purposes. In this case a single pane of toughened glass or an inner and outer pane of toughened glass may be more appropriate, but this has the drawback that it may not prevent people and objects from falling through on impact. A safer alternative could be to design the glazing to resist impact as described above and have the glazing automatically opened by the fire detection system in the event of a fire.

Legislation and statutory requirements

Areas of completed roofs which incorporate glazing are workplaces if they are accessible to maintenance and cleaning operatives.

This will extend to persons working on equipment located on the roof, which may include items as diverse as building services plant, telecommunications equipment and weather monitoring stations. As such the Workplace (Health, Safety and Welfare) Regulations 1992 applies to the roof. The impending Work at Height Regulations will also apply once they are published. The Workplace regulations are discussed in the Health and Safety Commission Approved Code of Practice and Guidance L24.

Workplace (Health, Safety and Welfare) Regulations - Regulation 13 specifically relates to falls or falling objects and will be revoked when the Work at Height Regulations come into force. The guidance notes for this regulation identify the risk of falls through fragile materials when working on roofs. A fragile surface in this case a roof is defined as:

‘A surface or assembly which would be liable to fail if any reasonably foreseeable loading were applied to it.’ For the purpose of this guidance, the surface referred to in the Regulation is the roof.’

For more detailed advice reference can be made to the HSE publication Safety in roofwork HSG33. This publication is one of a series that provides health and safety guidance for construction. It is noted that nearly one in five construction-related deaths occurs as a result of falls from or through roofs, and falls through fragile materials is the most common cause of death in this category (and indeed the biggest single cause of fatal accidents in the construction industry).

The terms ‘fragility’ and ‘fragile material’ are used in HSG33 to describe ‘a material or assembly which will not safely support the weight of a person and any materials they may foreseeably be carrying’. Importantly HSG33 also indicates that the assessment of fragility must take account of real life conditions - e.g. consider if the component or assembly is at the limit of its manufacturing or positional tolerance. In the case of glass structural design it is customary to assume that the thickness of each layer of glass is at the lower limit of its normal manufacturing tolerance, as defined in standards such as BS EN 572-2.
Testing for fragility

Fragile materials and surfaces include a wide range of possible roofing materials and surfaces. HSG33 makes the statement that: ‘If a person fell through an element it would clearly have failed and so be considered fragile. It would also fail if it temporarily supported the person after the initial impact only to collapse a short time afterwards so that the person fell. For this reason elements should have a suitable reserve of strength after initial impact.’

A glass roof can be considered to be a fragile surface in that it can be relatively easy to break by a hard body impact from a pointed object. It can however be very strong and can withstand significant loads without breaking when used as a glass floor or in structural glazing, when it is designed appropriately and glass is correctly selected and installed.

At the present time there are no British or European standards for assessing the impact resistance of glazed roofing systems.

The Advisory Committee for Roofwork (ACR) has published ACR(M)001 ‘fragility test for testing roofing systems’. This has been developed to represent the impact of a person accidentally falling onto a roof surface. The test has not been specifically developed with glazing in mind and requires a glazing expert to assess its applicability to glazed roofs. It does however test the assembly including the support system as well as the strength of the glass unlike several alternative impact tests.

Test methods that have been commonly used for impact testing using soft body tests are summarised in Appendix 1, while test methods for hard body tests are summarised in Appendix 2. These tests are highlighted for background information and comments on their relevance to glazed roofs are given.

All these tests have their drawbacks and to overcome these a fragility test sequence for glazed roof assemblies has been developed by the CWCT Standards Group in collaboration with the HSE. The CWCT Test sequence is described in Appendix 3.

Changes to a glazing system may sometimes have a counter-intuitive effect on performance. For example, some glazing configurations can give lower strength if the thickness of some of the glass layers is increased. Changes to a previously tested glazed roof assembly should be assessed and may require further testing.

Guidance on glass configuration

A glass specifier may find the following guidance useful when deciding on a glass configuration. The information should not be used in lieu of undertaking a test.

It is anticipated that glazed roofs incorporating insulating glass units which pass the CWCT fragility test will have an upper pane of monolithic toughened safety glass or laminated safety glass in order to minimise the potential for injury should breakage occur on human impact. A lower pane will be a suitably robust laminated glass to reduce the risks of people and/or objects including the glass fragments from the outer pane falling through the roof in the event of impact.

It is anticipated that glazed roofs which pass the CWCT fragility test and use single glazing will comprise a suitably robust laminated safety glass in order to reduce the risks of people and/or objects falling through the roof in the event of impact.

A suitably robust laminated safety glass is likely to have a minimum interlayer thickness of 0.76 mm pvb or around 1.5 mm cast-in-place resin.

In addition all toughened glass should be heat soaked to a recognised standard, using appropriately calibrated equipment to ensure that the heat soak regime maintains the glass within the required temperature range. This is to reduce the likelihood of NIS induced spontaneous breakage.

Summary

A glazed roof should be tested for fragility if a person may fall on to it while walking either on the glass or in close proximity to it. It is always possible for glazed roofing to be designed to resist such impacts.

Various tests can be carried out to assess the fragility of a glazed roof, but each has its drawbacks. A CWCT fragility test sequence has been devised to overcome many of these drawbacks and to provide a standard industry approach to the testing of glazed roofs. The test may need further modification if it does not reflect the circumstances in which the glazed roof is to be used.
References

CWCT, Technical update 10 – Use of glass overhead.


The Workplace (Health, Safety and Welfare) Regulations HMSO 1992

The Work at Height Regulations (In preparation)


Health and safety in roof work. HSG 33, HSE 1998 ISBN 0717614255


BS 8200:1985 Code of practice for design of non-loadbearing external vertical enclosures of buildings


Note:

This guidance may not cover all aspects of the safety of glazed roofing due to differences in building design and use, and to changes in good practice, which may develop over time in light of new product developments, methods, ideas, etc.

It is emphasized that it is the duty of all employers and of people who have control over workplaces to reduce building risks 'so far as is reasonably practicable' under the Health and Safety at Work 1974 and 'where necessary for reasons of health or safety' under the Workplace (Health, Safety and Welfare) Regulations 1992.
### Appendix 1: Commonly used soft body impact tests

<table>
<thead>
<tr>
<th>Test</th>
<th>Details</th>
<th>Impactor(s)</th>
<th>Impact energy</th>
<th>Comments</th>
</tr>
</thead>
</table>
| ACR[M]001:2000  | The test is designed to represent the effect and impact energy of a person accidentally slipping/tripping and falling onto a roof surface. The person being in a standing position on the roof surface before impact. The impactor is dropped from a single height of 1200 mm. Roofing assemblies are classified as:  
  - **Fragile** where the impactor passes through the assembly on the first drop.  
  - **Class C** non-fragile where the impactor is retained on the assembly after one test.  
  - **Class B** non-fragile where the impactor is retained on the assembly after two drops.  
  - **Class A** non-fragile where the impactor is retained on the assembly after two drops and there is no significant damage to the assembly that would affect long-term strength and weather performance. | 300 mm cylindrical bag filled with sand of mass 45 kg. | 530 J         | This test method requires a glazing expert to assess its applicability to glazed roofs. The test does however simulate the force that a 90kg person would apply if he/she fell onto the roof from a standing position with a factor of safety of 1.15.  
  Test samples are required to be 'conditioned to ensure that they are tested in a condition which could reasonably exist in service and which would be the worst case for impact strength'. These conditions, such as elevated or low temperatures which may affect the performance of laminated glass, are not defined and are left to the judgement of the competent person.  
  The impactor is left in its fallen position for a period of five minutes but this may be too short to simulate the time a person may lie on broken glazing before being rescued.  
  The mass of the impactor is 45 kg, which is less than the normal allowance for a workman and will affect the validity of the assessment of load bearing capacity after impact.  
  The test does not simulate the potential hard body impact that may occur as a result of a workman's tools for example hitting the glass and causing breakage before the person impacts the glass.                                           |
| BS 8200:1985    | This is a standard test for ensuring the safety of people who may accidentally impact wall cladding. In the test an impactor is allowed to swing against the cladding surface from different heights and locations. To pass the test the structural safety of the building should not be affected by damage, cladding should not have the potential to fall or to cause serious injury to people inside or outside the building and the impactor should not pass through the cladding.  
  Note that there is also a serviceability test which has an impact energy of 120J. | 400 mm spherocional bag filled with glass spheres of mass 50 kg. | 350 or 500 J  | This test method is not specifically designed for glazing and may therefore require a glazing expert to assess its applicability to glazed roofs.  
  The test does not have a provision for assessing the load bearing capacity of the assembly after impact/breakage.  
  The test does not simulate the potential hard body impact that may occur as a result of a workman's tools for example hitting the glass and causing breakage before the person impacts the glass.                                           |

*cont’d*
## Appendix 1: Commonly used soft body impact tests (cont’d)

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>BS 6206:1981</td>
<td>The purpose of the test is to categorise safety glasses for situations where glass may be subjected to human impact. In the test an impactor is allowed to swing against the glass from three different heights (305, 457 and 1219 mm). The test is intended to represent the impact energies of a running child. The glass must break safely or not break at all if it is to pass the test at each drop height.</td>
<td>300mm leather bag filled with lead of mass 45 kg.</td>
<td>135, 202 or 538 J</td>
<td>This test assesses the soft body impact strength of the pane of glass and not the roofing assembly. The test does not simulate the potential hard body impact that may occur as a result of a workman’s tools for example hitting the glass and causing breakage before the person impacts the glass. Glass which breaks safely and therefore passes the test (e.g. monolithic toughened glass) can have little or no residual strength. This may allow a person to fall through on impact if the glass breaks. Glass which resists breakage and therefore passes the test (e.g. thick monolithic annealed and heat strengthened glass) can have little residual strength if broken such as by a hard body impact. This may allow a person to fall through on impact if the glass breaks. The test does not have a provision for assessing the load bearing capacity of the assembly after impact/breakage.</td>
</tr>
<tr>
<td>BS EN 12600:2002</td>
<td>The test has been developed to serve the same purpose as BS 6206. The test will supersede BS 6206 as a common European standard for testing the impact safety of glasses. The impactor is allowed to swing from three different heights (190, 450 and 1200 mm). The glass is classified into both impact classes and breakage classes.</td>
<td>Double tyre with added steel weights of mass 50 kg.</td>
<td>93, 221 or 588 J</td>
<td>This test assesses the soft body impact resistance of a glass pane and not the roofing assembly. The test does not simulate the potential hard body impact that may occur as a result of a workman’s tools for example hitting the glass and causing breakage before the person impacts the glass. The test does not have a provision for assessing the load bearing capacity of the assembly after impact/breakage.</td>
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This test will be superseded by BS EN 12600, but plastics sheet glazing materials will still be tested in accordance with BS 6206.
### Appendix 2: Commonly used hard body impact tests

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>BS 8200:1985</td>
<td>This is a standard test for assessing the impact resistance of wall cladding. The impactors are used by dropping them onto a horizontal test specimen - in each case the impact energy is a function of the height through which the impactor travels before it strikes the specimen. The test requires that the cladding should not sustain damage which is not easily repairable and which does not cause deterioration of performance. There should also be no indentation marks that are visually unacceptable from the impacts.</td>
<td>50 mm steel ball of mass 0.5 kg or 62.5 mm steel ball of mass 1.0 kg.</td>
<td>3, 6 or 10 J</td>
<td>This test method is not specifically designed for glazing and may therefore require a glazing expert to assess its applicability to glazed roofs. The test does not simulate the potential soft body impact from a person impacting the glass. The test does not have a provision for assessing the load bearing capacity of the assembly after impact/breakage.</td>
</tr>
<tr>
<td>BS EN 356:2000</td>
<td>Test is used to categorise the resistance to manual attack of glazing. The impactor is dropped from several heights, between 1500 mm and 9000 mm depending upon level of performance being tested. To pass the test the glass must resist penetration of the impactor.</td>
<td>100 mm steel ball of mass 4.11 kg.</td>
<td>60 to 363 J</td>
<td>This test does not simulate the potential soft body impact from a person impacting the glass. The test does not have a provision for assessing the load bearing capacity of the assembly after impact/breakage.</td>
</tr>
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</table>
Appendix 3: CWCT fragility test for glazed roofs

Introduction

This test has been developed by the CWCT Standards Group in collaboration with the HSE, roof glazing designers, contractors and test houses, in response to concerns that existing standard tests for the fragility of roofing (e.g. ACR[M]001:2000) were not readily applicable to glazed roofing.

It is intended that the CWCT test will be adopted as a standard method of test for the fragility testing of glazed roofs. The test 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 uses a combination of soft body impacts based on the ACR fragility test and hard body impacts based on BS EN 356.

A competent person should 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.

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.

Those type 1 and 2 glazed roofing assemblies which are composed of insulating glass units are tested using stages 1, 2, 3, 4, 5, 7, 8, 9 and 10 in Table A3-1.

Type 1 and 2 glazed roofing assemblies composed of single glazing are tested using stages 1, 2, 3, 6, 7, 8, 9 and 10 in Table A3-1. The tests will assess fragility and establish how the assembly performs under both soft and hard body impact.

Type 3 glazed roofing assemblies whether they comprise single glazing or insulating glass units are tested using stages 1, 3, 7, 8, 9 and 10 in Table A3-1 to assess fragility and establish how the assembly performs under hard body impact.

Testing procedure

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.

Testing should be carried out on glass 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 flat.

Effect of temperature on testing

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 will normally necessitate testing both at ambient temperature (20±5°C) and at the maximum temperature the glass is likely to reach in use. The maximum temperature will normally be around 40°C as this represents the temperature that glass in an atrium or other glazed roof structure may reach within the UK, but may be higher in some circumstances. 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.
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
d) Deciding the number of tests necessary to ensure results are statistically significant
e) Determining the number of panes or units to be tested
f) Evaluating the degree of damage to the assembly
g) Approving of the test report.

Note that the competent person can in theory be any one involved in the whole building life cycle including the glazing system manufacturer.

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.

- There is no procedure for how glass panes are to be broken where they have remained intact after testing at stage 3 and need to be broken to allow for further testing at stages 4 to 7.

- The nature/form of the static load used in stage 7 is not clearly defined. This may have the potential to lead to differences in test behaviour if different forms of static load are used.

- There is no scope given to 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 type, reduction in pane size, etc.) may require a new test to be carried out subject to the judgement of a competent person.
### Table A3-1: Test sequence for glazed roofs

<table>
<thead>
<tr>
<th>Stages of test sequence</th>
<th>Pass criteria</th>
<th>Purpose</th>
<th>Impactor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Prepare test assembly at specified conditions. This requires storage at 20±5°C for 12 hours if an assembly is to be tested at ambient conditions.</td>
<td>None.</td>
<td>To ensure all components of the assembly are in the same condition prior to testing. This in turn means that each component will perform in a manner that is typical of its behaviour at the specified conditions.</td>
<td>None.</td>
</tr>
<tr>
<td>2. Carry out soft body impact test to outermost pane in accordance with ACR[M]001:2000.</td>
<td>Glass should not break or be displaced from the assembly.</td>
<td>The ACR[M]001:2000 test method was designed to represent the effect and impact energy of a person accidentally slipping and/or tripping and falling onto a fragile roof surface. The glass is required not to break or be displaced to limit the potential for human injury and for penetration on impact.</td>
<td>300 mm cylindrical bag filled with sand of mass 45 kg and impact energy 530 J.</td>
</tr>
<tr>
<td>3. Carry out hard body impact test to outermost pane as defined in BS EN 356:2000, but with the impactor dropped from a single height of 1200 mm. Note if the outer pane has remained intact it should be broken to enable further testing to be undertaken.</td>
<td>Glass may break, but penetration of the assembly by the impactor and displacement of glass panes from the assembly is not allowed.</td>
<td>This hard body impact test is to simulate glass breakage that might occur as a result of a workman's tools for example hitting the glass before the person impacts the test assembly. Impactor was chosen to be representative of a heavy hard body object that in most cases will cause glass breakage when dropped.</td>
<td>100 mm steel ball of mass 4.11 kg and impact energy 48 J.</td>
</tr>
<tr>
<td>4. Where an inner pane is present, such as in insulating glass units, carry out soft body impact test on inner pane as in stage 2.</td>
<td>Glass may break, but penetration of the assembly by the impactor and displacement of glass panes from the assembly is not allowed.</td>
<td>This soft body test on the inner pane is required to represent the effect and impact energy of a person accidentally falling, breaking and penetrating the outermost pane and falling onto the innermost pane. The glass should not allow penetration or be displaced in order to prevent the person from falling through.</td>
<td>300 mm cylindrical bag filled with sand of mass 45 kg and impact energy 530 J.</td>
</tr>
<tr>
<td>5. Where an inner pane is present, such as in insulating glass units, carry out hard body impact test on inner pane as in stage 3.</td>
<td>Glass may break, but penetration of the assembly by the impactor and displacement of glass panes from the assembly is not allowed.</td>
<td>This hard body impact test to inner pane to simulate glass breakage that might occur in a worst-case scenario.</td>
<td>100 mm steel ball of mass 4.11 kg and impact energy 48 J.</td>
</tr>
<tr>
<td>6. Where single glazing is present, carry out soft body impact test as in stage 2.</td>
<td>No penetration of the assembly by the impactor, or displacement of glass panes from the assembly.</td>
<td>This soft body test is to simulate the potential impact of a person hitting the glazing after a hard body impact, such as a dropped tool, has caused glass breakage. The glass should not allow penetration or be displaced in order to prevent the person from falling through.</td>
<td>300 mm cylindrical bag filled with sand of mass 45 kg and impact energy 530 J.</td>
</tr>
<tr>
<td>Stages of test sequence</td>
<td>Pass criteria</td>
<td>Purpose</td>
<td>Impactor</td>
</tr>
<tr>
<td>-------------------------</td>
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</tr>
<tr>
<td>7 Gradually apply static load comprising a weight of 180 kg (e.g. 4 x 45 kg soft body impactors) to the broken glazing and leave for a minimum of 30 minutes.</td>
<td>No penetration of the assembly by the static load, nor displacement of glass panes from the assembly during the allotted time.</td>
<td>This static load is considered representative of the weight of a person (90 kg) who may fall onto the glass and become injured requiring a second person to come and give assistance (180 kg total load). 30 minutes 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. All glass panes need to be broken in order to simulate the worst-case scenario of a single person carrying hard objects who impacts a glazed roof.</td>
<td>None.</td>
</tr>
<tr>
<td>8 Assess the size of any glass fragments that have fallen from the assembly during testing.</td>
<td>Glass fragments (or clumps of fragments) should not exceed 50 grammes in weight and should pass through 25 mm square mesh.</td>
<td>Glass fragments should be as small as possible in order to reduce the potential for injury should the glazing be impacted fall from height. Alternatively, a mesh or similar feature below the roofing assembly could be used to catch and/or break-up any glass which falls.</td>
<td>None.</td>
</tr>
<tr>
<td>9 Repeat test sequence on any panes or units still to be tested.</td>
<td>See stages 1 to 8 above.</td>
<td>This ensures a sufficient number of tests are carried out to show that the test results are representative of the roofing assembly being tested.</td>
<td>See stages 2 to 5 above.</td>
</tr>
<tr>
<td>10 Where required repeat the test sequence at other specified temperatures.</td>
<td>See stages 1 to 9 above.</td>
<td>This assesses if the safety of the roofing assembly will be affected by extremes in temperature.</td>
<td>See stages 2 to 5 above.</td>
</tr>
</tbody>
</table>