Introduction

Facades may be subject to impact during normal use. They must be able to resist such impacts without causing safety hazards. Damage affecting serviceability should also be minimized but may be accepted where components are readily replaceable.

Materials such as masonry and concrete are robust and can generally be expected to resist normal impacts however many materials used in modern facades are more susceptible to damage and require testing to assess their performance.

This Technical Note reviews the need for impact testing of walls under typical UK conditions. The impacts considered are generally horizontal and the guidance is considered applicable to surfaces within 15º of vertical. At greater slopes performance requirements may be modified based on the perceived risk of impact. Additional considerations may apply in particular locations. Examples include resistance to wind blown debris in areas affected by hurricanes, resistance to sustained attack and vehicle impacts.

Technical Note 42 gives guidance on impact requirements for glass roofs resulting from maintenance activities at roof level but more severe impacts from objects dropped from greater heights are not included. Impacts considered in Technical Note 42 are vertical arising from falling people and objects.

A summary of recommendations and test methods for impact resistance of building components is given in Appendix A.

Types of impact

Hard and soft body impacts
The building envelope may be subject to impact from a variety of causes. Walls are required to be resistant to impact from soft bodies, principally people, which deform on impact to distribute the load, and from more rigid objects referred to as hard bodies. Hard body impacts are generally considered to have lower impact energy than soft body impacts but hard body impacts from access equipment, skateboards etc could be at higher levels of impact energy. Hard body impacts tend to cause failure by localised punching whereas soft body impacts tend to cause failure by generalised bending. For this reason hard impacts can be damaging even at low impact energy.

Serviceability impact
It has been UK practice to require serviceability under impact. Following a serviceability impact test there should be no loss of performance. Damage of an aesthetic nature such as indentations on metal panels may be acceptable depending on the severity of the damage, the nature of the material and location of use.

In some cases it may be impractical to achieve this level of performance with the chosen construction but the loss of performance can be reduced. An example is the use of glass facades where it is difficult to prevent glass breakage but it is possible to use a glass which remains secure and weathertight.

Safety impact
The building envelope may be subject to more severe accidental impacts which it is unreasonable to resist without damage but where the consequences for the safety of those in and around the building must be considered. Safety considerations include:
- Falling materials dislodged by the impact
- Inability to provide containment during or following impact
- Injury from human contact with the surface during or following impact.

Impacts in normal building use

Human impact
Soft body impacts may arise from falls, trips or people being pushed against the façade. Impacts are generally limited to areas within approximately 1.5m of the adjacent ground or floor.

Objects
Shopping trolleys and other moving manually operated hard objects can cause large localised impact loads. Where there is a risk of such moving objects being able to impact the envelope and cause significant damage a barrier may be used to prevent impact.

Impacts are limited to areas within approximately 1.5m of the adjacent ground or floor. Smaller impacts from thrown objects will occur at higher levels.

Furniture
Furniture may be pushed against the inner face of the building envelope. The impact energy is limited by the ability of an individual to impart energy to the relatively heavy furniture. It is normally assumed that meeting the requirements of a soft impact safety test will give adequate robustness. BS 5234-2 gives guidance on impact requirements for internal partitions.

Malicious behaviour
A degree of abuse must be expected however where there is a high risk of vandalism, impact resistance has to be considered on a project-by-project basis. An alternative approach to increasing resistance against impact loads is to provide additional security. Availability of materials that can be used to cause damage, such as loose stones, can also be controlled. If increased resistance to impact is required it may be advantageous to use a different wall construction at ground floor level and other affected areas. For example a brick or block wall at ground level with rainscreen panels above.

Several organisations including the Home Office, local crime prevention office, the 'secured by design' website and specialist consultants can also provide guidance.

Appendix 6 of CIRIA ‘Guidance for glazing at height’ gives information on the resistance of glass to deliberate impact.

Roofs
Roofs are vulnerable to impacts from dropped and falling objects. These can range from stones dropped by birds to falling masonry and large objects dropped by vandals. Specific guidance is outside the scope of this Technical Note. TN42 gives guidance on fragility of rooflights and contains a suitable test regime.

Maintenance
Walls have to sustain loads imparted to them during maintenance and repair operations. For vertical surfaces impacts may occur due to ladders being placed against the wall, handling of scaffold poles, use of mobile elevating work platforms, cradles and rope access.

Impacts from permanent cradles will normally be reduced by use of suitable buffers or, less commonly, guide rails. Specifiers can require that cradles are designed to limit the severity of potential impacts to the values given in Appendix B.

Impacts from other forms of access equipment are more dependent on the care taken by the operators and no specific guidance on impact loads to be expected is available.

Exposure categories
Table 1 gives six exposure categories for impact based on recommendations in BS8200. Risk of impact can be reduced by provision of security, design of site layout to
keep people away from the building surfaces and avoiding the use of materials that could be used as missiles.

### Impact tests

Assessment of impact performance requires the use of tests to simulate the types of impact the wall may be subjected to in service.

All impact tests comprise an impactor and a method by which it is swung, dropped or fired at the component under test. Full definition of a test includes the following:

- Details of test specimen,
- Type of impactor,
- Impact energy,
- Location of test on sample,
- Number of impacts,
- Assessment criteria.

#### Test specimen

The performance of a surface in an impact test will depend on how it is supported. If the specimen can deflect or move during the test, some of the impact energy will be absorbed in this movement. Impact tests on building envelope samples may be carried out on full-scale samples erected for weathertightness testing. The behaviour of these samples should closely represent the behaviour in service. If tests are carried out on separate samples, the support should be at least as rigid as that likely to occur in service as more rigid support conditions absorb less energy and therefore increase the severity of the test.

#### Types of impactor

Hard body tests are commonly carried out with a steel ball of 0.5 or 1kg that is dropped onto a horizontal specimen supported off the floor. A test procedure is given in BS 8200 and BS EN 950 uses a similar test for doors. Tests can also be carried out by swinging the ball against a vertical specimen.

Soft body tests have traditionally been carried out using a bag filled with sand or glass spheres that is allowed to swing against a vertical specimen. BS 8200 uses a sphericonical canvas bag filled with glass spheres. More recently the double tyre pendulum impact test has been developed.

### Table 1 Exposure zones

<table>
<thead>
<tr>
<th>Areas within 1.5m of ground</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Readily accessible to the public and others with little incentive to exercise care. Prone to vandalism and abnormally rough use.</td>
<td>External walls in vandal prone areas.</td>
</tr>
<tr>
<td>B</td>
<td>Readily accessible to the public and others with little incentive to exercise care. Chances of accident occurring and of misuse.</td>
<td>Walls adjacent to pedestrian thoroughfares when not in category A.</td>
</tr>
<tr>
<td>C</td>
<td>Accessible primarily to those with some incentive to exercise care. Some chance of accident occurring or of misuse.</td>
<td>Walls adjacent to private open gardens. Back walls of balconies.</td>
</tr>
<tr>
<td>D</td>
<td>Only accessible, but not near a common route, to those with a high incentive to exercise care. Small chance of accident occurring or of misuse.</td>
<td>Walls adjacent to small fenced decorative garden with no through paths.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Areas more than 1.5m above ground</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>Above zone of normal impacts from people but liable to impacts from thrown or kicked objects. May also be subject to impact during maintenance.</td>
<td>1.5 to 6m above pedestrian level in location categories A and B.</td>
</tr>
<tr>
<td>F</td>
<td>Above zone of normal impacts from people and not liable to impacts from thrown or kicked objects. May also be subject to impact during maintenance.</td>
<td>Wall surfaces at higher positions than those defined in E above.</td>
</tr>
</tbody>
</table>

Table 1 Exposure zones

*From BS8200 – Code of practice for design of non-loadbearing external vertical enclosures of buildings.*
Impact performance of cladding

and this is now used for glass (BS EN 12600), windows (BS EN 13049) and curtain walling (BS EN 14019). The total mass of the impactor is 50kg and the tyres are inflated to a pressure of 3.5bar.

Test impact energy
The severity of the impact test is defined by the drop height or impact energy of the impactor. These are related by the formula:

$$E = mgh$$

Where:

- $E$ is the impact energy (J)
- $m$ is the mass of the impactor (kg)
- $g$ is the acceleration due to gravity ($m/s^2$)
- $h$ is the vertical distance through which the impactor falls before hitting the surface (m).

In BS 8200 hard body tests, the impact energy is in the range 3 to 10J. For soft body tests it ranges from 120 to 500J. BS EN 13049 and BS EN 14019 use a series of impact classes as shown in Table 2.

<table>
<thead>
<tr>
<th>Class</th>
<th>Drop height (mm)</th>
<th>Impact energy (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>1</td>
<td>200</td>
<td>98</td>
</tr>
<tr>
<td>2</td>
<td>300</td>
<td>147</td>
</tr>
<tr>
<td>3</td>
<td>450</td>
<td>221</td>
</tr>
<tr>
<td>4</td>
<td>700</td>
<td>343</td>
</tr>
<tr>
<td>5</td>
<td>950</td>
<td>466</td>
</tr>
</tbody>
</table>

Table 2 BS EN 14019 impact classes

For comparison the drop heights in BS EN 12600 for safety glass are given in Table 3.

<table>
<thead>
<tr>
<th>Class</th>
<th>Drop height (mm)</th>
<th>Impact energy (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1200</td>
<td>588</td>
</tr>
<tr>
<td>2</td>
<td>450</td>
<td>221</td>
</tr>
<tr>
<td>3</td>
<td>190</td>
<td>93</td>
</tr>
</tbody>
</table>

Table 3 BS EN 12600 impact classes

In BS EN 14019 the full designation of the impact class includes an I or E to denote that the impact was carried out on the internal or external surface respectively.

These figures relate to the kinetic energy of the impactor at the moment of impact. During the impact some of this energy is absorbed by the impactor and some is transferred to the impacted surface either in the form of elastic deflection or permanent damage.

Tests by Newman (2004) have shown that the double tyre pendulum impactor transfers more energy to the test sample than the bag filled with glass spheres and thus for the same impact energy is a more severe test. It has been concluded that the 343J impact with the pendulum impactor is at least as severe as the 500J impact with a canvas bag filled with glass spheres described in BS 8200.

Test location
The most critical location will depend on the type of test and type of construction. For example the critical location for a soft body test would be in the centre of a panel if the failure mode is by bending of the panel but may be adjacent to a fixing where the failure mode is localised around the fixing point.

BS EN 14019 sets out impact locations on curtain walls. These are mid height of a vertical framing member, midspan between Mullions at cill height (on transom or infill as appropriate), crossing of mullion and transom and mid point of a spandrel panel.

For the internal classification, the impact at mid height of the Mullion is not required. It would be more appropriate to test a transom close to its junction with the Mullion, as this would put the maximum load on the joint, rather than allowing the impact to occur on the Mullion/transom intersection.

Only one impact is permitted at any location but there is no guidance on repeat tests (if any) required to assess performance.

BS 8200 does not give guidance on test locations.

BS EN 13049 states that the impact may be at:
Impact performance of cladding

- The centre of the infill,
- A corner of the infill,
- The centre of the longest edge of the largest area of infill,

whichever is most critical.

BS EN 12600 has a specified size of glazing which is tested at the centre.

Assessment criteria
Assessment criteria for impact tests depend on the purpose of the test (safety or serviceability) as well as the test specification. Failure criteria are described in the CWCT Standard test methods for building envelopes as follows.

For a safety test:
- Fracture of components,
- Punching failure,
- Dislodgement of components.

These test criteria appear simple but some commonly used materials such as terracotta tiles have low resistance to hard body impact and are unlikely to satisfy them. Fracture of components may be considered acceptable if they remain in place.

For a serviceability test:
- Fracture of components,
- Punching failure,
- Indentation of any component surfaces,
- Displacement panels or components such as gaskets,
- Subsequent failure of an air permeability or water penetration test.

Some judgement is required in interpreting these requirements as metal panels may suffer minor dents which are acceptable and fracture of components such as terracotta tiles may be acceptable if they are readily replaceable.

The test on windows is concerned with the interaction of the components and the main requirement is to prevent the formation of an opening through which an ellipsoid 400 mm x 300 mm can pass. The opening could be formed by failure of hardware allowing the window to open, glazing being dislodged due to failure of the retention mechanism or distortion of the frame. Failure of the glazing material is excluded.

Specification

CWCT Standard test methods for building envelopes includes hard and soft body impact tests that can be used to assess both safety and serviceability. For soft body tests the double type impactor or a spherical/conical bag can be used. For hard body tests steel balls of 50 and 63 mm diameter are used. The test methods require the following information to be supplied.

- Components or assemblies to be tested,
- Location, sequence and number of impacts to be applied,
- Type of impactor to be used,
- Whether test is to assess serviceability or safety.

Appendix B gives suggested impact test classes for both hard and soft body tests in relation to the location of the wall and the risk of impact. However the specifier needs to consider how these requirements are to be applied.

Materials/components to be included

The values given in appendix B are applicable to curtain walls and rainscreen walls however the specifier needs to consider whether they should be applied to glazing.

Areas of glazing are generally excluded from impact tests on walls. However where walls contain significant areas of glass it is reasonable to expect the glass to be subject to the same level of impact. There are safety requirements for glass in the Building Regulations relating to impact from people however there are no impact requirements requiring serviceability after impact and no requirements for hard body impacts. Tests may be carried out on areas of glazing to check that the glazing is not dislodged from
the frame rather than to assess the impact resistance of the glazing.

**Impact test locations**
Appropriate test locations on the components should be identified based on the type of construction and possible failure modes as discussed above.

For curtain walling the locations in BS EN 14019 may be appropriate.

For panels, test locations will generally include the centre of the panel, corner and centre of longest side. Where tests are carried out near a panel edge, care should be taken to ensure that the impact is applied to a single panel so that the impact energy is not shared with other panels.

**Number of tests**
There is little established guidance on the number of tests required. A single test is inadequate but if a fresh area has to be used for each test the number of tests must be limited for economic reasons. A minimum of three tests should be carried out. Where the failure mode is by fracture it is desirable to test sufficient samples to give a probability of failure.

**Exceptional actions**
This Technical Note considers normal impacts which a façade may be expected to withstand. Some facades will be exposed to higher levels of impact described below.

**Vehicular collisions**
An envelope should not be expected to withstand the full force of a vehicular impact which is moving at speed without incurring damage or without penetration. This could result in safety risks to people inside the building and to the need for the building envelope to be rebuilt at great cost. Where these eventualities are undesirable a barrier should be placed in front of the envelope.

Guidance on protecting the envelope from impact and on the loads that such barriers should resist is given in Building Regulations Approved Document K and BS 6399-1.

**Intrusion**
Components of the building envelope can be broken by impact in order to gain access or entry to the inside of the building.

The most vulnerable areas are glazing, and opening lights. Detailed guidance is outside the scope of this Technical Note. Further guidance is given in the following Standards:

- BS 8220-2
- LPS 1175
- BS 7950
- BS EN 356
- BS 5544.
- DD ENV 1627

**Hail resistance**
This is not normally specified separately in the UK but is considered to be covered by the overall robustness requirements. It is a problem associated with particular regions of the world and micro-climates such as those in the Alps.

BS EN 13583:2001 gives a method of test for determining the hail resistance of some roofing materials. Existing UK practice is to have a general requirement for hard body impact (BS 8200) on the outer surface of all building envelopes. Where there is concern about hail conditions components can be tested according to the method in BS EN 13583:2001 but note that impact will depend on orientation of the component and the micro-climate that it is to be used in. Alternatively a hard body impact test can be specified with an appropriate impact energy.

**Wind blown debris**
This impact load is not normally specified in the UK; it is associated with geographical locations affected by hurricanes and typhoons, such as Florida.

In areas prone to hurricanes and typhoons buildings may be damaged by wind blown debris. ASTM E1886 describes a test for
impact using a 4.5 m length of 100 mm x 200 mm timber.

References


ASTM E1886-05 Standard Test Method for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials


BS 5544: Specification for anti-bandit glazing (glazing resistant to manual attack)


BS 7950: Specification for enhanced security performance of windows for domestic applications

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


BS EN 950: Door leaves - Determination of the resistance to hard body impact.


BS EN 12600: Glass in building - Pendulum test - Impact test method and classification for flat glass.

BS EN 13830: Curtain walling - Product standard.

BS EN 13049, Windows – Soft and heavy body impact – Test method, safety requirements and classification.

BS EN 13583: Flexible sheets for waterproofing - Bitumen, plastic and rubber sheets for roof waterproofing - Determination of hail resistance

BS EN 14019: Curtain walling - Impact resistance - Performance requirements.


## Appendix A  Recommendations for impact on building components

<table>
<thead>
<tr>
<th>Construction type</th>
<th>Guidance on performance requirements</th>
<th>Type of impact</th>
<th>Performance classification</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Roofs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glass</td>
<td>CWCT TN42</td>
<td>Hard</td>
<td>CWCT TN42</td>
<td>BS EN 356</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Soft</td>
<td>ACR(M)001:2005</td>
</tr>
<tr>
<td>Potentially fragile materials</td>
<td>ACR(M)001:2005</td>
<td>Hard</td>
<td>ACR(M)001:2005</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Soft</td>
<td>ACR(M)001:2005</td>
</tr>
<tr>
<td>Flexible roof sheeting</td>
<td></td>
<td>Hail</td>
<td>BS EN 13583</td>
<td>BS EN 13583</td>
</tr>
<tr>
<td>Plastic rooflights</td>
<td>Hard</td>
<td>BS EN 1873</td>
<td>BS EN 1873</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Soft</td>
<td>BS EN 1873</td>
</tr>
<tr>
<td><strong>Walls</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Curtain walling</td>
<td>CWCT TN52</td>
<td>Hard</td>
<td>CWCT TN52</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Soft</td>
<td>BS EN 14019 (safety)</td>
</tr>
<tr>
<td>Other walls (Rainscreen, render, etc)</td>
<td>CWCT TN52</td>
<td>Hard</td>
<td>CWCT TN52</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Soft</td>
<td>CWCT TN52</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CWCT Standard test methods for building envelopes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>BS EN 13049</td>
</tr>
<tr>
<td><strong>Windows</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hard</td>
<td>BS EN 13049 (safety)</td>
<td>BS EN 13049</td>
</tr>
<tr>
<td><strong>Doors</strong></td>
<td></td>
<td>Hard</td>
<td>BS EN 950</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Soft</td>
<td>BS EN 949</td>
</tr>
<tr>
<td><strong>Glass</strong></td>
<td>Building Regs N1 BS 6262-4</td>
<td>Hard</td>
<td>BS 6262-4</td>
<td>BS EN 12600</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Soft</td>
<td>BS 6206</td>
</tr>
<tr>
<td><strong>Plastic glazing</strong></td>
<td>Building Regs N1 BS 6262-4</td>
<td>Hard</td>
<td>BS 6234-2</td>
<td>BS 5234-2</td>
</tr>
<tr>
<td><strong>Internal partitions</strong></td>
<td>BS 5234-2</td>
<td>Hard</td>
<td>BS 5234-2</td>
<td>BS 5234-2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Soft</td>
<td>BS 5234-2</td>
</tr>
</tbody>
</table>
Appendix B  Recommended impact classes

Experience has shown that the impact requirements in BS 8200 have proved satisfactory. The values given below are therefore based on these recommendations but for soft body tests have been expressed in terms of the equivalent BS EN 14019 impact classes to maintain consistency with European practice.

Soft body tests

<table>
<thead>
<tr>
<th>Exposure category*</th>
<th>Safety</th>
<th>Serviceability</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>No values are given as severity of potential vandalism needs to be assessed</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>BS EN14019 Class 4</td>
<td>BS EN14019 Class 1 or 2</td>
</tr>
<tr>
<td>C</td>
<td>BS EN14019 Class 4</td>
<td>BS EN14019 Class 1 or 2</td>
</tr>
<tr>
<td>D</td>
<td>No values given as risk of impact is minimal</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>BS EN14019 Class 3</td>
<td>BS EN14019 Class 1 or 2</td>
</tr>
<tr>
<td>F</td>
<td>BS EN14019 Class 3</td>
<td>BS EN14019 Class 1 or 2</td>
</tr>
</tbody>
</table>

* As defined in Table 1

Tests carried out by BRE indicate that currently available stick curtain wall systems can achieve this level of performance. Glazing can also be designed to satisfy these criteria in cases where glazing is present at the specified impact points.

Hard body tests

<table>
<thead>
<tr>
<th>Exposure category*</th>
<th>Safety</th>
<th>Serviceability</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>No values are given as severity of potential vandalism needs to be assessed</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>10J</td>
<td>10J</td>
</tr>
<tr>
<td>C</td>
<td>10J</td>
<td>6J</td>
</tr>
<tr>
<td>D</td>
<td>No values given as risk of impact is minimal</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>10J</td>
<td>6J</td>
</tr>
<tr>
<td>F</td>
<td>3J</td>
<td></td>
</tr>
</tbody>
</table>

*As defined in Table 1

The levels of serviceability performance do not guarantee an absence of damage requiring maintenance. Specifiers may wish to set higher or lower standards based on assessment of initial costs and maintenance costs.