

BRE Test Report

Impact resistance tests on Lapitec stone panel wall system

Prepared for: Stephen Pike
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BRE
Watford, Herts
WD25 9XX

Customer Services 0333 321 8811

From outside the UK:
T + 44 (0) 1923 664000
F + 44 (0) 1923 664010
E enquiries@bre.co.uk
www.bre.co.uk

Prepared for:
Stephen Pike,

The Marble & Granite Centre Ltd , Troy Wharf,
Old Uxbridge Road, West Hyde,
Rickmansworth, Herts, WD3 9YB



Prepared by

Name Malcolm Pound

Position Senior Consultant and Laboratory Manager

Date 03 November 2014

Signature

A handwritten signature in black ink, appearing to read 'M. C. Pound', is written over a light blue horizontal line.

Authorised by

Name Dr. Tim Yates

Position Technical Director

Date 5th November 2014

Signature

A handwritten signature in black ink, appearing to read 'Tim Yates', is written over a light blue horizontal line.

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1 Introduction

At the request of Stephen Pike, The Marble & Granite Centre Ltd , Troy Wharf, Old Uxbridge Road, West Hyde, Rickmansworth, Herts, WD3 9YB, BRE issued proposal number 134627 on 27 February 2014 for the test work and assessment of a Lapitec stone panel wall system. The proposal was accepted by The Granite and Marble Centre on 09 April 2014.

The tests measure the resistance to impacts from soft and hard objects. Evaluation of the results is based on criteria in BS EN 12600¹ and BS 8200².

This report details the results of soft and hard body impact tests performed on Lapitec stone panels to methods based on those in BS EN 12600 and BS 8200 respectively.

Testing at BRE was conducted by Malcolm Pound on 15 and 16 October 2014 against job number 295071 under the BRE Terms and Conditions for Testing.

Tests were witnessed by:

- 1) Mr C Kelsey The Marble & Granite Centre Ltd
- 2) Mr J Holmes Fischer Fixings
- 3) Mr R England London Stoneworks (installer)
- 4) Mr S Lyons London Stoneworks (installer)
- 5) Mr J England London Stoneworks (installer)

In addition, pull-out tests were undertaken on anchorage fixings in 12 specimens.



2 Test programme

Soft body impact testing

BS EN 12600 Glass in building – Pendulum test – Impact test method and classification for flat glass was specified as the Lapitec stone panels have some properties similar to glass.

Soft body impacts simulate accidental or deliberate impacts by humans.

The tests use an impactor (as specified in BS EN 12600) with two pneumatic tyres fitted to wheel rims that carry two steel weights of equal mass. The total mass of the impactor is 50 ± 0.1 kg. The pneumatic tyres were inflated to 0.35 ± 0.02 MPa (50.76 psi or 3.5 bar). The impactor is suspended on a steel cable so that at rest it is within 5 mm to 15 mm of the surface of the test specimen.

The impactor is first raised to the lowest drop height (190 mm) from rest and released to swing and strike the centre of one panel of the specimen. After the initial impact the impactor is restrained, preventing further impacts.

After each impact the specimen is closely examined for any signs of damage. If unbroken the test is repeated on the same test specimen at the next higher drop height (450 mm and then 1200 mm).

When using this impactor drops heights of 190 mm, 450 mm and 1200 mm produce impact energies of 93 Nm, 220.7 Nm and 588.6 Nm respectively. A Newton metre (Nm) is equivalent to a Joule (J)

Hard body impact testing

The test from BS 8200 is designed to simulate impacts that can occur when tools or other hard objects hit the surface of a wall. It provides information about the degree of resistance to such impacts and classifies the product tested accordingly.

The tests use a 50 mm diameter, 0.50 kg steel ball impactor. The impactor was suspended from a light cord so that at rest it was within 5 mm of the surface of the test specimen.

The impactor is first raised to a drop height that gives impact energies of 3 Nm and released to swing and strike the specimen. After the initial impact the impactor is restrained, preventing further impacts.

Tests were carried out at the centre of panels, at a joint to adjacent panel and at 150 mm away from a corner.

After each impact the specimen is closely examined for any signs of damage. Tests were repeated on the same test specimen (at the discretion of the client) at other positions. If unbroken after 3 Nm impacts then impacts were carried out at 6 Nm impact energy.

When using this steel ball impactor drop heights of 612 mm and 1220 mm give impact energies of 3 Nm and 6 Nm.



Determination of strength around the Fischer FZP K fixings

The Anchorage test was adapted from BSEN 13364 2002: Determination of breaking load at dowel hole. The test method has been modified to allow for the testing of undercut anchors in the rear face of the test specimen.

10 number tests were carried out on 300 x 300 x 20 mm panels. Each panel had one Fischer fixing (FZPII 11 x 12/18 A4) fixed into the rear centre of the panel to a depth of approximately 12 mm.

2 number tests were carried out on 300 x 300 x 12 mm panels. Each panel had one Fischer fixing (FZPII 11 x 7 M6/T/9 AL) fixed into the rear centre of the panel to a depth of approximately 5 mm.

All fixings were installed by the client.

Two reaction rings (Figures 15 and 16 show the test set ups) were used during the testing:

The first ring had an internal diameter of 110 mm (however this was found to be adding restraint to the anchor point, see Figure 17) and was replaced with a larger ring of 270 mm internal diameter.

Figures 18 and 19 show the typical failures.

The load was applied at a rate of 1.5 mm/minute



3 Assessment criteria

Soft body impact

According to BS EN 12600, with respect to glass, inspect the test specimen after each impact and note whether:

- It remains unbroken
- It broke in accordance with either the requirements A or B, Clause 4, BS EN 12600
- It broke and failed to conform to the requirements of Clause 4 (as below).

BS EN 12600 Clause 4:

- a) Numerous cracks appear, but no shear or opening is allowed within the test piece through which a 76 mm diameter sphere can pass when a maximum force of 25 N is applied. Additionally, if particles are detached from the test piece up to 3 minutes after impact, they shall, in total weigh no more than a mass equivalent to 10,000 mm² (0.01 m²) of the original test piece. The largest single particle shall weigh less than the mass equivalent to 4,400 mm² (0.0044 m²)
- b) Disintegration occurs and the 10 largest crack free particles collected within 3 minutes after impact and weighed, all together, within 5 minutes of impact shall weigh no more than the mass equivalent to 6,500 mm² (0.0065 m²) of the original test piece. The particles shall be selected only from the portion of the original test piece exposed in the test frame. Only the exposed area of any particle retained in the test frame shall be taken into account in determining the mass equivalent.

According to BS 8200 (with respect to non-load bearing external walls) when considering test impacts for retention of performance of opaque exterior wall surfaces:

- The wall, when subjected to impacts should not have a reduced performance.
- The results of tests on brittle materials will be either failure or no damage

Hard body impact

According to BS 8200 when considering test impacts for retention of performance of opaque exterior wall surfaces:

- The wall, when subjected to impacts should not have a reduced performance.
- The results of tests on brittle materials will be either failure or no damage.



4 Test specimen

The Granite and Marble Centre supplied new components and constructed test specimens onto BRE's test rig. Figures and drawings in the Annex to this report show the general test set up of the test specimen mounted on BRE's test rig.

Details of the test specimen are below:

- Type:** Lapitec stone panel wall system comprising an aluminium support frame mounted on a timber backing frame fixed to BRE's test rig.
- BRE test rig:** The BRE test rig comprises an adjustable steel frame with adjustable steel columns fixed to the laboratory's concrete floor.
- Backing frame:** Three horizontal timbers, each 175 mm x 70 mm, fixed to three steel uprights with bolts and wood screws.
- Support frame:** Aluminium brackets fixed to the timber backing frame (as above) with 5 mm diameter x 50 mm long woodscrews. The top most brackets are 175 mm long and fixed to the timbers with six screws each; those on the bottom two timbers are shorter and fixed to timbers with four screws each.
Four aluminium, 80 mm x 50 mm box section vertical rails with 2.5 mm thick walls, are fixed to the aluminium brackets. Each vertical rail is attached to three brackets (i.e. one bracket per horizontal timber in the backing frame) with 4.8 mm diameter x 16 mm self-drilling/tapping screws.
Four horizontal rails are fixed to outer face of the vertical rails using flat brackets (by Fischer fixings) above and below fixed with two 4.8 mm diameter x 16 mm self-drilling/tapping screws each.
- Stone panels:** Two thicknesses of the Lapitec stone panel wall system were tested; 12 mm thick panels and 20 mm thick stone panels.
- Fixings:** 12 mm thick panels are fixed with Fischer fixings FZPII 11 x 7 M6/T/9 AL with 7 mm engagement into four holes on the back of each panel.
20 mm thick panels are fixed with Fischer fixings FZPII 11 x 12/18 A4 into four holes on the back of each panel.
- Dimensions:** Overall size of a four panel array was 3010.1 mm wide x 3010.1 mm high.
Overall size of a two panel array was 3010.1 mm wide x 1500 mm high
Each panel was 1500 mm x 1500 mm with a 6 mm gap between panels



5 Results

5.1 Impact Tests

The weight and air pressure of the pneumatic tyres of the soft body impactor were checked prior to the day's testing and confirmed to be 50.0 kg and 0.35 ± 0.02 MPa (50.76 psi or 3.5 bar) respectively.

The weight of the hard body impactor was checked at found to be 0.5 kg. Laboratory conditions were 993 mb, 60.3% RH at 20°C on the test date.

The test results are in Tables 1 and 2 in the order in which they were carried out and in photographs in the Annex to this report.

12 mm thick panels

Test	Results
Soft body impacts: At the centre of a panel 190 mm drop height, 93.1 Nm 450 mm drop height, 220.5 Nm Soft body impact: At the centre of an adjacent panel 190 mm drop height, 93.1 Nm	No apparent damage Panel broke into large fragments that fell from the test rig Panel broke into large fragments that fell from the test rig
Actions after the soft body impacts; The top panels, in an array of four, were moved down to the lower positions and hard body impacts carried out.	
Hard body impacts: At the centre of a panel 3 Nm 6 Nm At a vertical joint between adjacent panels 3 Nm 6 Nm Near a corner of a panel 3 Nm	Small scuff mark on panel surface – no other apparent damage Punched a hole through the panel and parts broke away from the back face Chipping and shelling at impact point Cracked right across one panel – adjacent panel had chipping and shelling at impact point Corner of panel broke off

Table 1. 12 mm thick Lapitec stone panel wall system – soft and hard body impacts



20 mm thick panels

Test	Results
Soft body impacts: At the centre of a panel 190 mm drop height, 93.1 Nm 450 mm drop height, 220.5 Nm 1200 mm drop height, 588.0 Nm	No apparent damage No apparent damage Panel broke into large fragments that fell from the test rig
Actions after the soft body impacts; Two new panels were installed and hard body impacts carried out.	
Hard body impacts: At the centre of a panel 3 Nm 6 Nm At centre of adjacent panel 6 Nm At a vertical joint between adjacent panels 3 Nm and 6 Nm Near a corner of a panel 6 Nm 6 Nm (repeat) 3 Nm	Small scuff mark on panel surface – no other apparent damage Punched a hole through the panel and parts broke away from the back face Punched a hole through the panel and parts broke away from the back face Chipping and shelling at impact point Corner broke off Corner broke off Corner broke off

Table 2. 20 mm thick Lapitec stone panel wall system – soft and hard body impacts



5.2 Anchorage Tests

Given below in Table 3 are the results of the pull anchorage tests

Specimen	Reaction ring diameter	Thickness	Embedment Depth	Breaking load	Comments
	(mm)	(mm)	(mm)	(N)	
SR M1 (white)	110	19.89	11.8	6692	Broke into 3 pieces
SR M2 (white)	110	19.84	12.22	5698	Cone failure
SR M3 (white)	110	19.95	12.37	5954	Cone failure
SR DG 1 (dark grey)	110	20.17	12.32	6197	Cone Failure
SR DG 2 (dark grey)	110	20.27	12.14	6216	Cone Failure
LR DG 3 (dark grey)	270	20.27	11.87	3212	Broke into 3 pieces
LR DG 4 (dark grey)	270	20.26	12.22	3106	Broke into 3 pieces
LR LG 1 (light grey)	270	19.93	11.98	5329	Broke into 3 pieces
LR LG 2 (light grey)	270	19.85	12.07	3969	Broke into 3 pieces
LR LG 3 (light grey)	270	20.00	11.90	4644	Broke into 4 pieces
SR R1 (red)	110	12.59	4.62	2044	Cone failure
SR R2 (red)	110	12.75	4.90	1375	Cone failure

Table 3. Results of the anchorage tests



6 Conclusions and assessment

6.1 Impact tests

Soft body and hard body impact tests to BS EN 12600 and BS 8200 respectively, were conducted on 1500 mm x 1500 mm panels of 12 mm thick and 20 mm thick Lapitec stone panel wall system as described herein. Other than the fixings and test panels no components were changed on the backing or support frames during the course of the impact testing. Findings were as follows:

6.1.1 Soft body impacts

12 mm thick panels: When subjected to 93.1 Nm impact (190 mm drop height) at the centre of a panel, disintegration of the panel occurred on impact. When measured the largest crack free fragments do not conform to the test requirements of Clause 4a or b in BS EN 12600 (see Section 3 of this report, Assessment criteria).

The 12 mm thick Lapitec stone panel wall system does not achieve Class 3 of BS EN 12600. (Class 3 is the lowest drop height and impact energy class in that standard).

20 mm thick panels: When subjected to 588 Nm impact (1200 mm drop height) at the centre of a panel, disintegration of the panel occurred on impact. When measured the largest crack free fragments do not conform to the test requirements of Clause 4a or b in BS EN 12600 (see Section 3 of this report, Assessment criteria).

The 20 mm thick Lapitec stone panel wall system achieved Classes 2 and 3 of BS EN 12600 but failed at Class 1. (Class 1 is the highest drop height and impact energy class in that standard).

6.1.2 Hard body impacts

12 mm thick panels: When subjected to 3.0 Nm impact near a corner of a panel a large section broke away on impact. In BS 8200, for brittle materials, the results of the impact tests are defined as either failure or no damage. (see Section 3 of this report, Assessment criteria).

The 12 mm thick Lapitec stone panel wall system failed when subjected to hard body impacts at the lowest impact energy (3 Nm) given in BS 8200 for retention of performance of exterior wall surfaces.

20 mm thick panels: When subjected to 3.0 Nm impact near a corner of a panel a large section broke away on impact. In BS 8200, for brittle materials, the results of the impact tests are defined as either failure or no damage. (see Section 3 of this report, Assessment criteria).

The 20 mm thick Lapitec stone panel wall system fails when subjected to hard body impacts at the lowest impact energy (3 Nm) given in BS 8200 for retention of performance of exterior wall surfaces.



6.1.3 Fixings, brackets and framework

Throughout the test impacts the fixings, brackets and framework stayed intact and apparently undamaged. Fixings only came adrift when the fracture pattern across a panel passed through fixing holes in the rear of the panels.

6.1.4 General comments on impact resistance

There is no British or European Standard specifically for this type of product and so reference is made to standards for natural stone products and external envelopes.

(a) The 12mm thick panels have limited resistant to hard and soft body impacts at the dimensions used. They may be more suited for use at smaller plan dimensions and/or in locations where there is little risk of impact damage.

(b) The 20mm thick panels meet Categories E and F in Table 11 BS8298:2010 Part 1 where Categories E and F are described in Table 10 (BS8298:2010 Part1)

E	Parts of the wall more than 1.5 m but only up to 6 m above floor level, typically out of reach of direct human impact but within range of thrown objects or in a zone where a ladder or other access equipment might be used.
F	Parts of the wall more than 6 m above floor level, where access equipment might be used.

There is no requirement in BS8298:2010 for high body impacts but reference to the now withdrawn BS8200:1985 shows that the performance of the 20mm panels is acceptable for ensuring the safety of persons but not for retention of performance. The panels are particularly vulnerable at the corners.

BS8298:2010 Part 1 includes some guidance on improving the impact resistance of stone panels and this is included in Annex 2.

6.2 Anchorage tests

The results from the anchorage tests showed that the method of securing the test specimens had a significant effect on the results. Use of a smaller retention ring (110mm) resulted in a 'cone' failure and higher results than the larger ring (270mm) where failure was due to cracking of the specimen.

The mean failure load using the larger ring was 4052N which indicates that under a typical urban wind environment panels up to around 1.3m² would meet the typical required factor of safety (8). It is possible to use a lower factor of safety if the co-efficient of variation in the test results is lower (<10%) but the test results showed a surprisingly high co-efficient of variation but one that was consistent with the results of testing in Italy in 2011 by Fischer.



7 References

1. BS EN12600:2002 Glass in building – Pendulum test – Impact test method and classification for flat glass. British Standards Institution, London.
2. BS 8200:1985 Design of non-load bearing external vertical enclosures of buildings. British Standards Institution, London.
3. BS 8298: 2010 Code of practice for the design and installation of natural stone cladding and lining. Part 1: General.

Annex 1 – Images

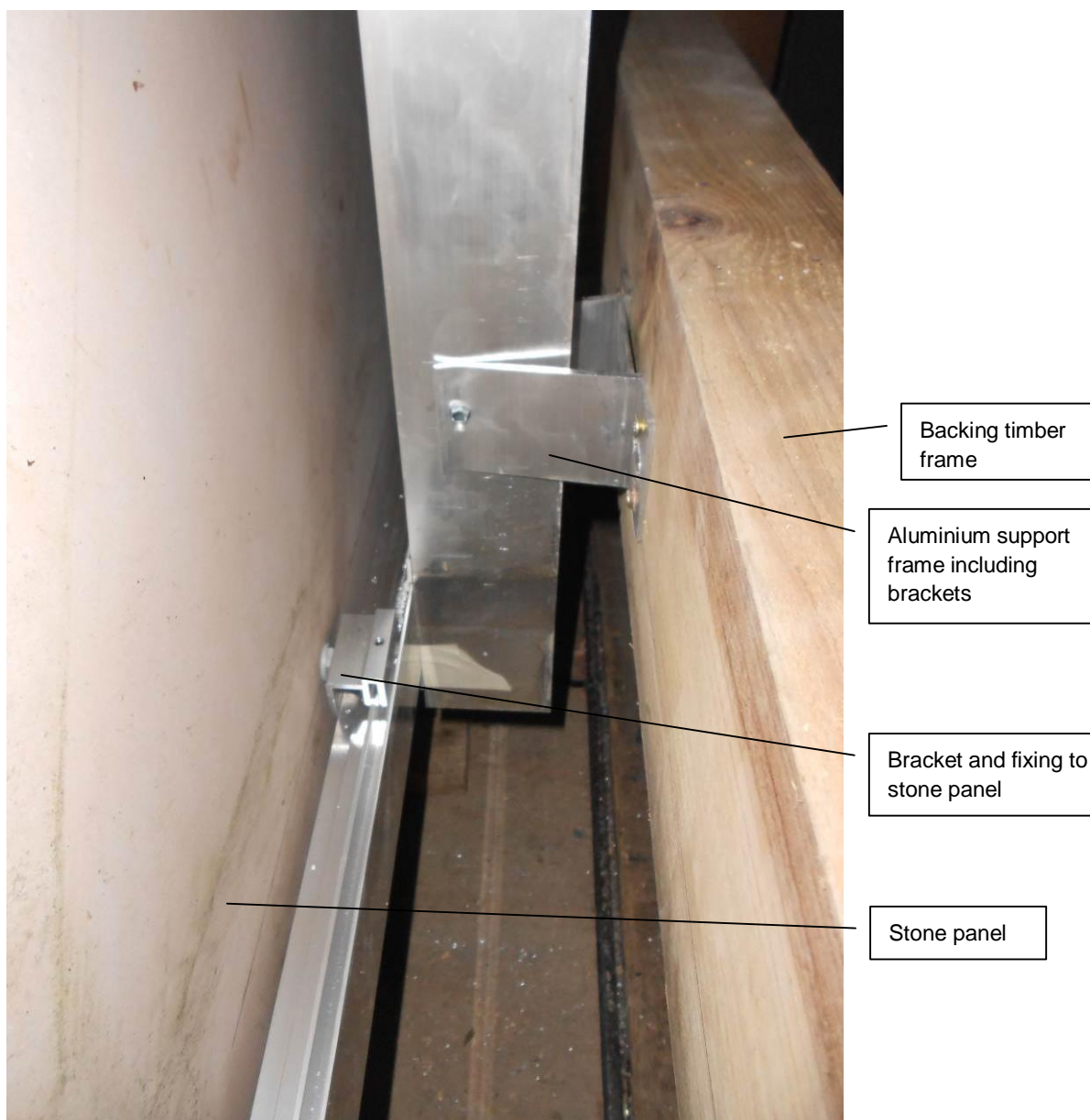


Figure 1. Lapitec stone panel wall system

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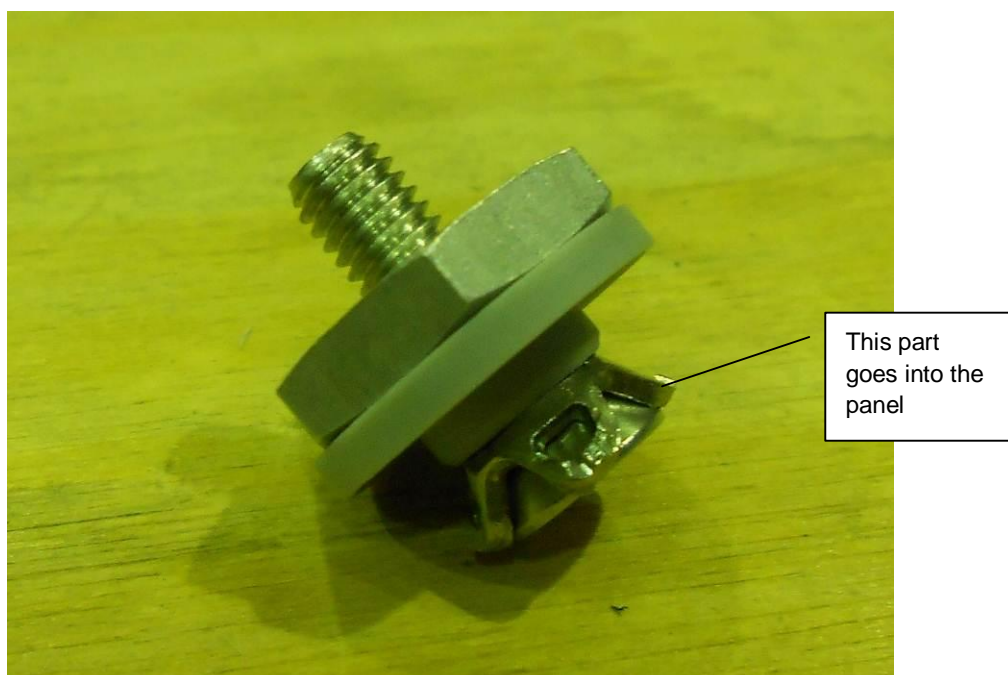


Figure 2. 12 mm thick panels are fixed with Fischer fixings FZPII 11 x 7 M6/T/9 AL with 7 mm engagement into four holes on the back of each panel.



Figure 3. 20 mm thick panels are fixed with Fischer fixings FZPII 11 x 12/18 A4 into four holes on the back of each panel.

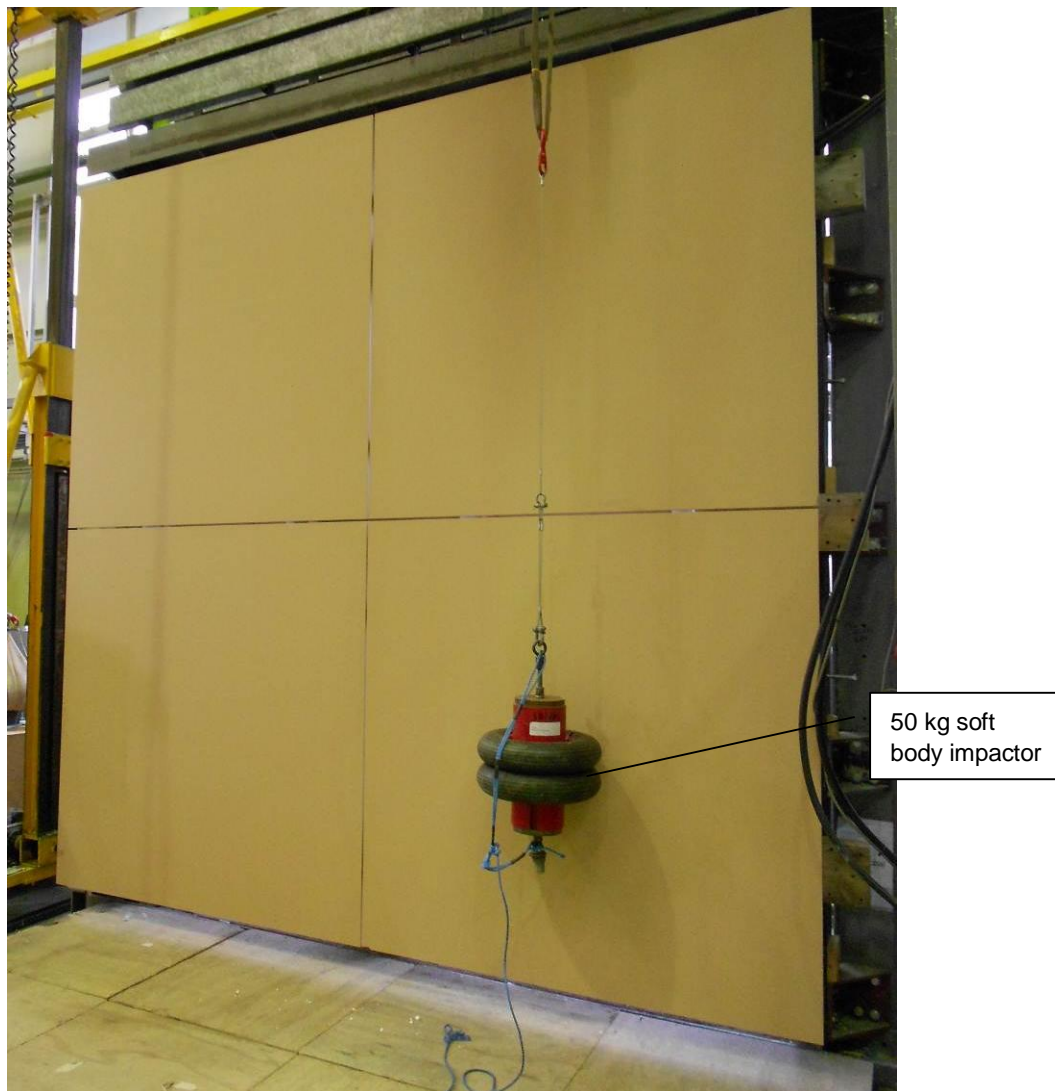


Figure 4. 12mm thick Lapitec stone panel wall system prior to first soft body impact test

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Figure 5. After a soft body impact on 12 mm thick panels – at 93.1 Nm



Figure 6. 12mm thick Lapitec stone panel wall system prior to first hard body impact test

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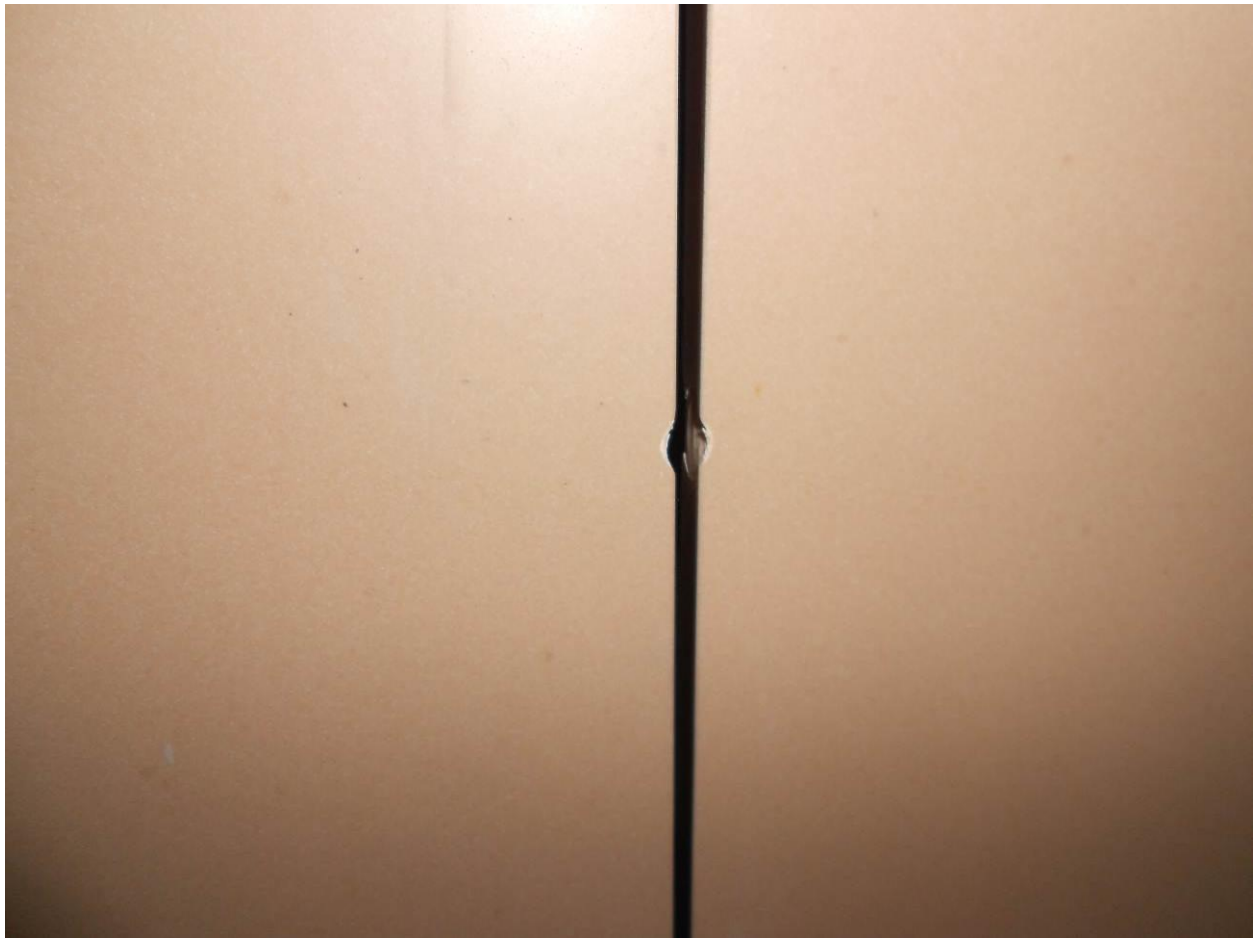


Figure 7. Typical damage after hard body impact on 12 mm thick panels – at joint with adjacent panel



Figure 8. Typical damage after hard body impact on 12 mm thick panels – on the reverse side of the panel

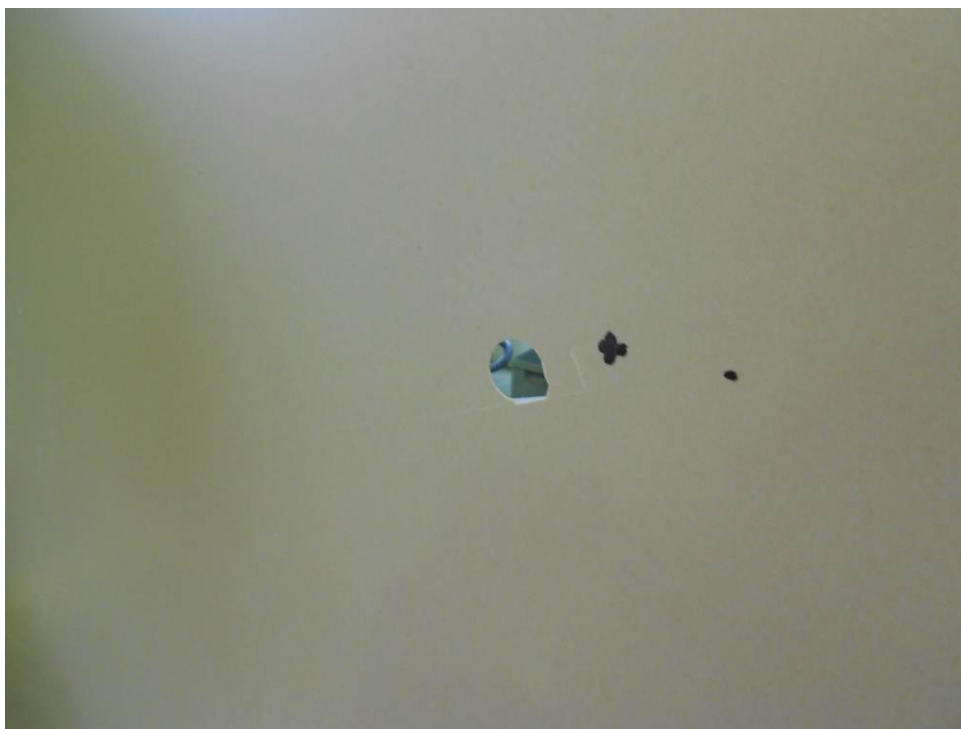


Figure 9. Typical damage after hard body impact on 12 mm thick panels – damage on the front face corresponding to Figure 8 above.

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Figure 10. After a soft body impact on 20 mm thick panels – at 588 Nm

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Figure 11. Typical damage after hard body impact on 20 mm thick panels – damage on the front face corresponding to Figure 12 below.



Figure 12. Typical damage after hard body impact on 20 mm thick panels – on the reverse side of the panel.

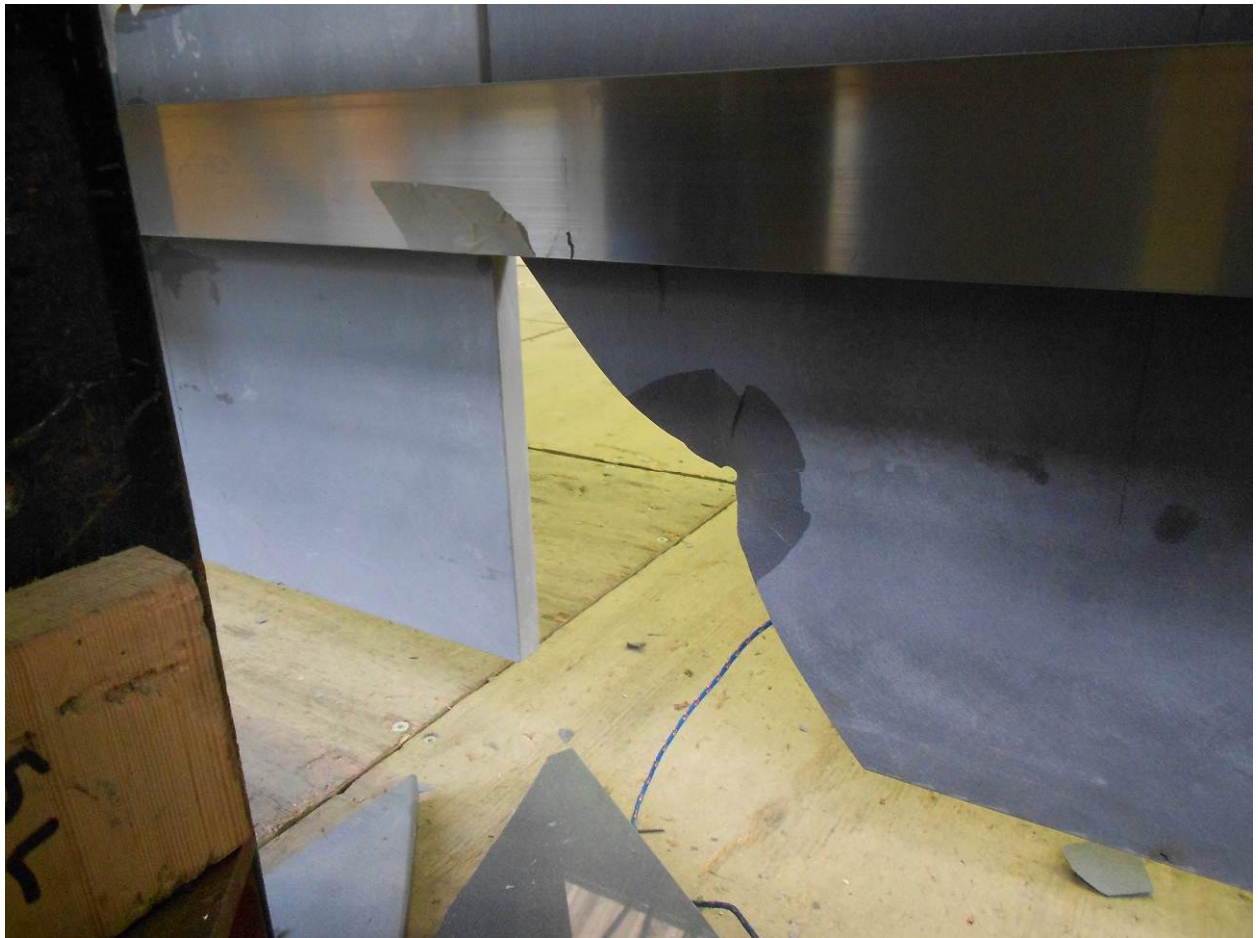


Figure 13. Typical damage after hard body impact on 20 mm thick panels – near a corner of the panel.



Figure 14. Typical damage after hard body impact on 20 mm thick panels – near to corners of the panels.

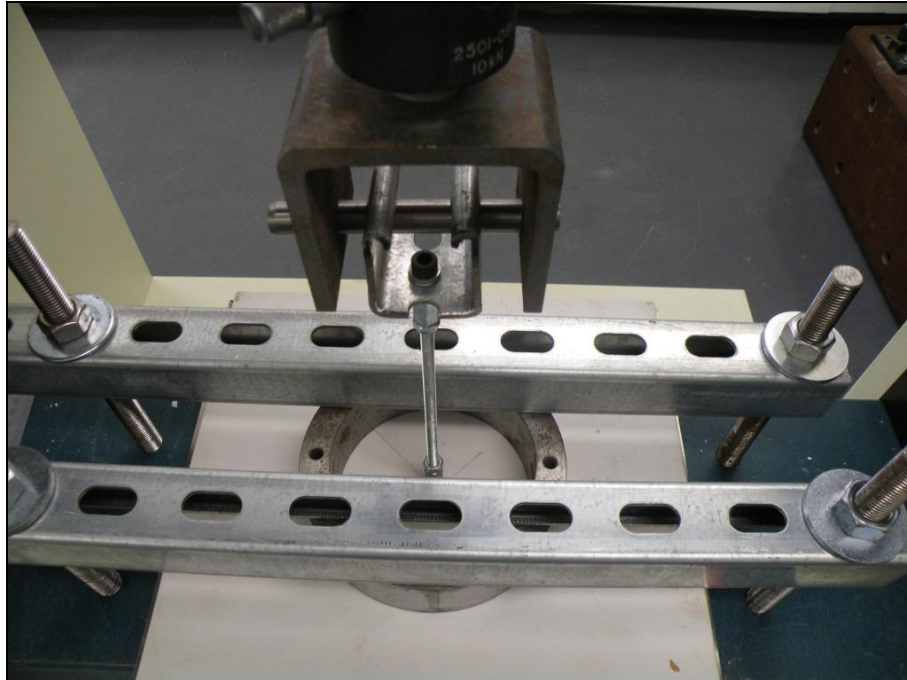


Figure 15: Showing test set up with 110 mm diameter ring



Figure 16: Showing test set up with 270 mm diameter ring

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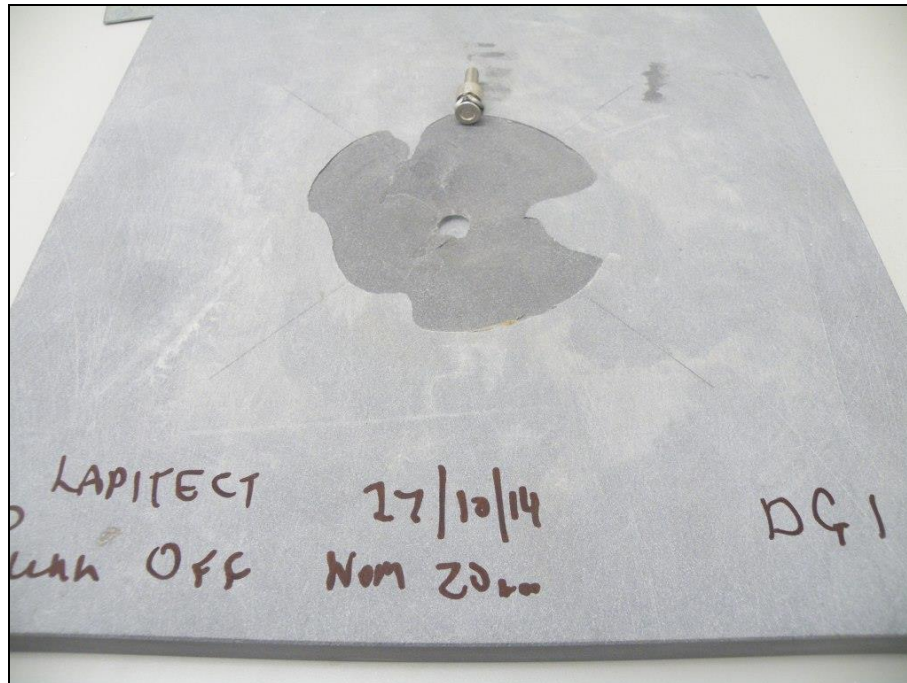


Figure 17: Showing failure on 20 mm thick panel (DG1) with 110 mm ring note the curved shape of the break were the ring was adding additional restraint.

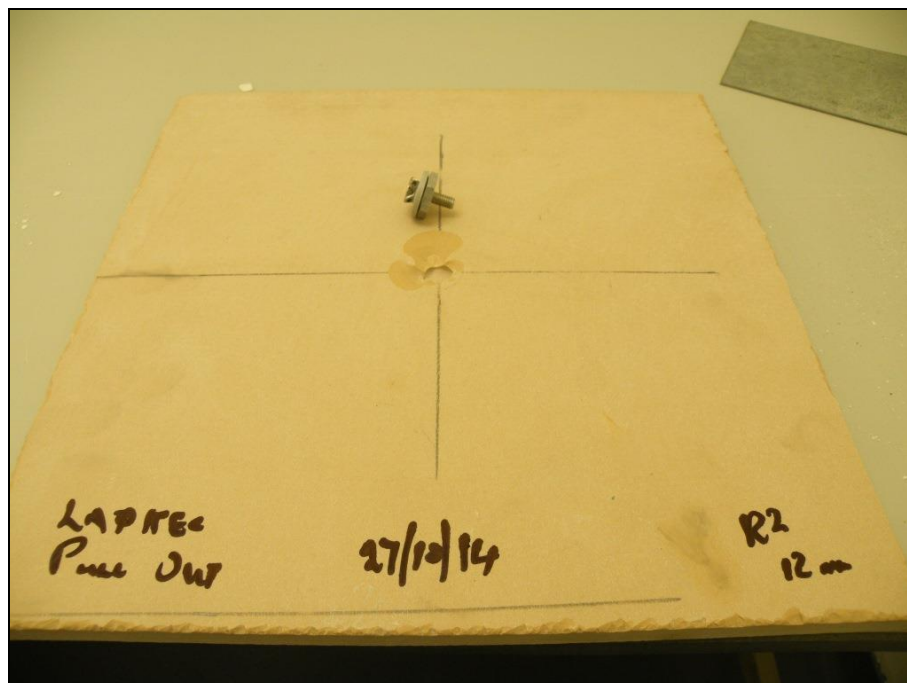


Figure 18: Showing failure on 12 mm thick panel (R2) with 110 mm ring note the no additional restraint was provided by the restraint ring.

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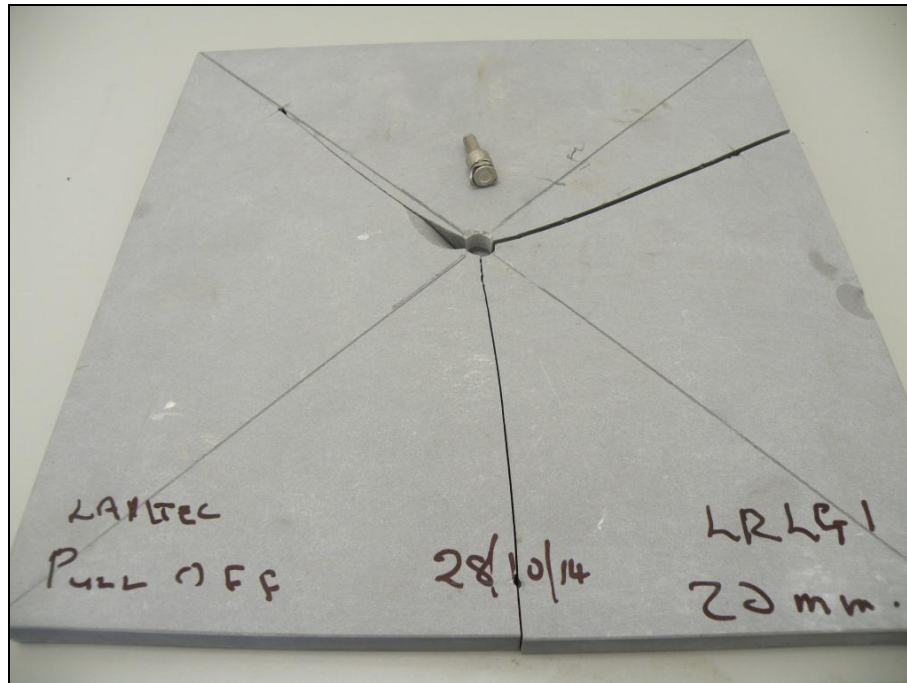


Figure 19: Showing failure on 20 mm thick panel (LRLG1) with 270 mm diameter ring specimen broke into 3 pieces.

Annex 2 – extract from BS8298:2010 Part 1

6.14.2 Improving soft body impact resistance

Generally, the best impact resistance is achieved by using a thicker panel (lower bending stresses, greater thickness of stone over fixings), with shorter spans (lower bending stresses); more flexible fixings (energy absorbed by deformation of fixing or material around fixing); or a more flexible support frame or backing wall (energy absorbed by deformation of supporting structure).

The following factors should be taken into account as they influence the impact resistance of a stone panel for a given thickness and type of stone:

- a) the span of the panel between fixing points;

NOTE 1 A larger span means that the stone is more flexible and bends more, transmitting less force to the fixing points. This is more likely to lead to a type A failure.

- b) the distance from the corner of the panel to the fixing point;

NOTE 2 If the fixing is further from the corner, an impact near the corner is more likely to cause a type B failure, due to high bending stresses in the stone at the point of fixing. These bending stresses are magnified by the machining or drilling of the stone to accommodate the fixing.

- c) the thickness of stone between the fixing and the front face of the stone;

NOTE 3 Forces which are transmitted to the fixings are primarily resisted by the thin layer of stone between the face of the stone and the fixing. A fixing which is nearer to the face of the stone is weaker.

- d) the degree of cutting to accommodate the fixing;

NOTE 4 Cutting, drilling or machining of the stone in order to accommodate the material both reduces the thickness of material that absorbs loads and generates stress concentrations. As the degree of cutting or machining increases, the risk of a type C failure or a type B failure initiating at a fixing point increases.

- e) the presence of resilient material between the fixing and the stone;

NOTE 5 If the fixing is isolated from the stone by a material that is able to absorb some energy through compression, such as a rubber or sealant material, this reduces the localized stresses in the stone at the point of fixing, and reduce the likelihood of a type B or type C failure.

- f) stiffness of the support brackets;

NOTE 6 If the support brackets are overdesigned, they are less able to deflect under an applied load, and this increases the proportion of the energy which can be absorbed by the stone itself.

- g) stiffness of the backing wall or support framework;

NOTE 7 If the backing wall or support framework is able to deflect, it absorbs some of the impact energy and reduces the probability of the stone breaking. If the backing wall or support framework is too flexible, it can cause the stone panels to break as the framework rebounds from the impact.

- h) edge working.

NOTE 8 Working of the edge of the panel, e.g. with a rebated edge or a continuous kerf to accommodate fixing, reduces the strength of the edge of the panel, thereby increasing the probability of breakage due to excessive bending stresses.

If greater spans are necessary, it is possible to place pads or a stiffening structure behind the panel. If pads are used behind the stone panel, these should have a layer of resilient material between the pad and the stone to prevent hard contact of stone against metal.

The worst locations for accidental impact are within 1.5 m of the floor so thicker stone or a different type of cladding should be considered for these locations if impact resistance is a particular concern.