THE RED BOOK

Materials
Standard

ACR[M]001:2019

Test For Non-Fragility of Large Element Roofing Assemblies

[Sixth edition - Amended May 2020]

BCSA	NARM
BSIF	NFRC
EPF	RTA
EPIC	RIDBA
FASET	SPRA
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Advisory Committee for **Roofsafety**

www.the-acr.org

The Advisory Committee for Roofsafety (ACR) is a body dedicated to making working on roofs safer. Founded in 1998 by HSE, ACR comprises representatives of major roofworking federations and associations and HSE. ACR has published a range of guides covering the design, specification and safe working on roofs. ACR acknowledges HSE's continuing support for this work and looks forward to making a solid commitment to Helping Great Britain Work Well. Further information can be found on the ACR web site at www.the-acr.org.

PREFACE

The original standard, which this revised standard replaces, arose out of concerns expressed by the HSE and the roofing industry about the lack of guidance on what constitutes a fragile roof assembly. Its basis is a series of tests, carried out by the HSE, which quantified human impact loads on surfaces. The report of these tests has been included in this document. Most roofing Trade Associations sent delegates to the working group, which formalised this standard.

The standard has been regularly revised: the last revision (5th edition) incorporated amendments recognising the unique safety issues associated with glass as a rooflight material. It was produced in conjunction with the Centre for Window and Cladding Technology (CWCT) who had already devised specific non-fragility tests for large area glazing based on the ACR soft body impact test, and with the National Association of Rooflight Manufacturers (NARM). It can be used in conjunction with CWCT publications and resolved confusion within the roofing industry by both designers and users as to which "standard" they should be working to, to provide a non-fragile glass rooflight and provided clear guidance on non-fragile roof glazing applications to the benefit of manufacturers, designers, contractors and building users.

This 6th edition of the Standard includes further revisions to provide clarification on use of the Class A classification, detailing the types of roof that Class A is, and is not, relevant to, and how most roofs should be designated and treated. This edition also incorporates revisions produced in association the Metal Gutter Manufacturers Association (MGMA) and Metal Cladding and Roofing Manufacturers Association (MCRMA) to clarify that this standard is applicable to all accessories within and adjacent to large element roofs and eliminate any possible misinterpretation that it is not applicable to certain products.

This 6th edition of the Non-Fragility Standard has been revised under my tenure as Chairman. The previous 5th edition included glass as a non-fragile roofing product. This 6th edition considers the issues of large element accessories, including smoke vents and gutters with particular reference to Boundary Wall and Valley Gutters which are commonly used by roofers as a right of passage over the roofs.

This edition also looks at the use of Class A Non-fragile products - sometimes referred to as "walk on" roofing. Whereas the use of stronger materials to be fitted to roofs is to be encouraged and will save lives, the assumption that the roof is safe to walk on regardless of condition or age of the roofing material, could lead to complacency and ultimate failure.

Graham Willmott (Chairman 2019)

CONTENTS

FOREWORD

In an effort to reduce the numbers of people falling through roofs, there is an increasing demand for roofing products to be non-fragile. Unfortunately, a clear accurate standard means by which manufacturers could show that they are meeting this requirement had not existed until the publication of the 1st edition of this document in 2000. Specialist Inspectors Report [SIR] No 30, published by the HSE (now withdrawn), offered some advice and this document builds upon this advice, to remove any ambiguities and define a method for testing for non-fragility, which gives consistent results when repeated or reproduced by different assessors.

Roofing products in use are subjected to a wide variety of conditions, e.g. weather, internal atmospheres, varying degrees of structural loads, misuse etc, possibly for 50 years or more. Therefore, this document can only be considered as giving information on a product's performance under test at the time of the test. It should be borne in mind that a product's properties may change during its service life. The test is not suitable for testing old sheets on a test rig or in situ on an existing structure to determine if an existing roof is fragile. It must be recognised that the non- fragility test is testing not only the sheet/product but the structure that supports it plus the washers, fixings, sealants, and the state of the supporting structure.

Guidance on longer-term non-fragility for roofing assemblies should be obtained from recognised Trade Association publications and industry standards. For example, guidance on achieving up to twenty-five years non-fragility for GRP in-plane rooflights is contained in NARM Technical Document NTD03, from the National Association of Rooflight Manufacturers.

While this document provides a method specifically for testing profiled sheeted roof assemblies, the basic method of applying the instantaneous load is applicable to any surface upon which infrequent passage by persons is likely.

The testing of Glass Roofs and Glass Rooflights is now fully explained in Section 3 Classification of Roof Construction Para 3.5

Important revisions to the sixth edition

The sixth edition of the document contains the following technical changes:

SECTION	REVISION
Endorsement	Statement prepared in conjunction with the Health & Safety Executive (HSE)
Preface	Reference to a fuller understanding of the use of products with a Class A rating. The testing of large element accessories including smoke vents and gutters.
Scope	Lists out the typical large element items that need to be tested for non-fragility including retrofit accessories.
Testing to determine Non-Fragility	Considers the roof elements that cannot be tested on the test rig without making changes to the rig.
3.5	A new section to provide further clarification on the testing of glass.
6. Roof Design Requirements	Explanation on the application of Class A Product.
REVISIONS IN MAY 2020 AMENDMENT TO 6th EDITION	
3.5	Additional paragraph to provide further clarity on classifications for glass

INTRODUCTION

The performance of a product is defined as its behaviour related to foreseeable use. For roofs, this means protecting the inside of a building from the weather. Therefore, they do not have to provide the same level of performance that is required for floors. But, for the purpose of designing the structure, which supports them, roofs are assigned loads to be supported depending on whether access onto them is or is not required. These loads are static loads.

However, these static loads do not account for the fact that people who walk across roofs may stumble and fall onto them, applying an instantaneous load which may be much greater than the static loads prescribed for the roofs. Under these types of impact, roofs have failed, allowing the person to fall through and suffer serious injury or death. The situation became intolerable and a solution had to be found.

To provide this solution, the Health and Safety Executive undertook research, which allowed the magnitude and distribution of the instantaneous force to be quantified. This data lead to the development of a test which represented a human impact incident on a surface reasonably accurately.

The test, which is specified in this document, checks whether a surface can support, without catastrophic failure, the loads that will be applied by a person falling onto it and is applicable to any surface, wherever it is. It does not specify any other requirements, allowing a manufacturer maximum freedom on choice of materials. In addition, the method of classification will allow specifiers to select roofing products on the basis of their particular needs.

SCOPE

The tests described in this document are applicable to any large element roof assembly and any accessories, which may be fitted on it, and are intended to provide information about whether the particular element can support the instantaneous loads imposed by a person stumbling or falling onto it

The tests are applicable to:

- large element roof assemblies
- any details of the roof assembly itself as well as the plane areas (for example hips and curved crowns)
- any accessories which may form part of that roof (for example in-plane rooflights)
- any accessories which are mounted directly on to the roof assembly (for example out of plane rooflights and suntubes, louvre smoke vents, access hatches)
- any adjacent or peripheral details which anyone on the roof may access (for example northlights, valley gutters, boundary wall gutters)

The scope includes any accessories which are retrofitted on to a roof. It is also applicable to assessing non fragility of a roof after any retrofitting work (for example if a hole is cut into an existing roof, to ensure that has not rendered the roof fragile).

Additional guidance on testing for non-fragility of roof glazing is included.

PRINCIPALS BEHIND THE TEST

Human impact loads can occur anywhere on a roof. Therefore, any test, which purports to check fragility of a roof, should check its resistance to impact everywhere, by a suitable means. This test satisfies this requirement by checking a roofing product’s ability to first arrest and then retain a load falling through gravity and impacting at locations, which, in the opinion of people with many years experience in the roofing industry, are most susceptible to fracture under impact loads. The test rig is relatively rigid, designed to simulate the most rigid localised areas of a roof. The rigidity of the test rig should never be reduced (for example by using more flexible purlins or omitting stiffening struts), even where an actual roof may be more flexible in certain areas. Where an actual roof may be more rigid (for example if concrete purlins are being used) then the rigidity of the test rig should be increased accordingly.

0. DEFINITIONS

For the purposes of this document, the following definitions apply:

0.1 Competent Person

0.1.1 Person(s) 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), recognise any implications for health and safety caused by those defects or omissions; and

d) Be able to specify a remedial action to mitigate those implications.

In this context, for assessing non-fragility, a competent person is one who can demonstrate that they have:

e) Thorough knowledge of roofing and of the mechanical and physical properties and behaviour of the particular product and assembly when subjected to this test.

f) An understanding of the effects on the product under test when purlin centres are increased and decreased and the nature of failure when the resulting structure becomes more or less rigid.

0.2 Inspection

Visual exercise, which is not carried out at close quarters.

0.3 Examination

Thorough inspection carried out at close quarters, which may, at the discretion of a competent person, be more than just visual.

1. QUALITY CONTROL TESTS

1.1 Applicability of test

1.1.1 The quality control tests are non-destructive tests used to confirm the consistency of the materials used in roofing products, by testing samples from production batches. Consistency of production shall be demonstrated by consistency of weight and of cross-sectional properties.

1.1.2 These tests are not necessary when it can be shown that the materials forming the roof structure comply with the requirements of a relevant current European, British or ISO standard.

1.2 Selecting the samples

Five test samples should be taken at random from a production batch without being specially prepared.

1.3 Consistency test procedures

The consistency test shall test the consistency of the weight of a number of material samples and their cross-sectional properties.

1.3.1 *Weight of samples*

The test samples shall be weighed, and consistency of weight shall be taken as an indicator of consistency of production.

1.3.1.1 Each of the five test samples shall be weighed and the weight recorded. The average, W_{av}, of the weight of the five samples shall be calculated and recorded. To satisfy the requirements of this standard the weight of each sample shall be within 10% of the average

1.3.2 *Cross-sectional properties*

For each sample deflections under load shall be measured. Consistency of deflection shall be taken to demonstrate cross-sectional consistency.

Each of the samples shall be subjected to a test, as detailed below:

1.3.2.1 The test sample shall be simply supported 150mm from its ends on a rigid support and shall be level to within ± 1°. The test load shall be applied over an area 250mm x 250mm.

1.3.2.2 A pre-load of 20 kg shall be applied at the centre of the test sample and held there for two minutes. The load shall be removed and the sample in this state shall be the datum for all subsequent measurements of deflection.

1.3.2.3 A test load of 100kg shall be applied, in 10kg increments. At each incremental load point the deflection under load shall be measured and recorded. The load shall be removed and on completion of this operation, the deflection of the sample shall be re-measured.
1.3.2.4 On completion of testing the following average values from Five tests shall be calculated:

a) The deflection under maximum load;
b) The residual deflection after removal of the load;
c) The deflection modulus, E, defined as follows (see Figure A2/1, in Annex 2):
i) For non-linear load deflection behaviour: the gradient of the straight line connecting the origin of the load deflection curve to the 20kg point;
ii) For the linear load deflection behaviour: the gradient of the line.

1.3.2.5 For a material to satisfy the requirements for cross-sectional consistently of this standard, no individual test deflection modulus shall be more than 10% different from the average values calculated in (a), (b) and (c) above.
1.3.3 Only samples which satisfy the requirements of 1.1.2 or both the requirements for consistency, described in and 1.3.1 and 1.3.2, shall qualify for a non-fragile classification under this standard.

2. TESTING TO DETERMINE NON-FRAGILITY

2.1 Principle of the Test

A specified weight shall be released in a controlled fall under gravity towards the test sample at critical points, to check if the test sample has an adequate resistance to withstand the impact from the weight.

Note 1: A competent person [see 0.1] must supervise the entire test.

The competent person's responsibilities include ensuring that the worst-case scenario has been covered when:

a) Defining roof assembly to be tested (2.3.1)
b) Defining test position(s) (2.3.5)
c) Determining any conditioning of the samples (2.3.2)
d) Deciding the number of tests necessary to ensure results are statistically significant (2.3.6 and 2.3.7)
e) Determining the number of profiles to be tested (2.3.8)
f) Ensure a risk assessment for the test work itself has been carried out prior to commencement and the appropriate measures are taken
g) Evaluating the damage to the assembly taking into account that an assembly's failure in service could cause serious injury or death to a person (3)
h) Together with signing off the test report (4.1(f))

2.2 The Test Rig

The test rig, which is to be used for "flat" large element roof assemblies (such as profiled metal sheets and in-plane rooflights) shall be as shown in Annex 4.

When testing particular aspects of a roof assembly, where the rig is not appropriate, such as for hip arrangements, or for purlin centres that vary from the norm for that product including closer purlin centres, or for curved roofs, or for ancillaries such as out-of-plane rooflights, or adjacent products such as valley gutters, the rig must be adapted so that it realistically simulates the particular construction to be tested, to the satisfaction of the competent person.

If the rig has to be adapted, it is the responsibility of the competent person to ensure that (i) the rig has been adapted so that the assemblies tested can be installed in accordance with manufacturer's installation instructions (ii) the principles detailed in the section "Principles behind the Test" have been followed (in particular that the rig should be relatively rigid, even where an actual roof may be more flexible in certain areas, to ensure the worst case has been tested). Where appropriate the advice and guidance of a structural engineer should be obtained.

It should be noted that any accessories built into the roof should satisfy the ACR test for non-fragility but this does not replace the requirements of the product standards for that specific product. For example gutters should be designed or tested to BS 9101 and in addition meet the requirements of the ACR(M)001.

2.3 The Test

2.3.1 The roof assembly to be tested shall be the worst case as prescribed by the relevant industry guidance or competent person [see 0.1] and shall be fixed onto the test rig prescribed in 2.2. Note that if the structure to be tested is deemed to be less onerous than the test rig described in the Test, the test rig should not be adjusted to match the less onerous design.

2.3.2 The samples shall 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 – see Note 2. The competent person shall prescribe the conditioning

> **Note 2:** Conditioning may require the samples to be soaked in water to achieve saturation, or testing at elevated or low temperatures, as prescribed by the competent person.

2.3.3 The impact is obtained by the vertical fall under gravity of a cylindrical sandbag. A typical test apparatus is shown in Annex 2, Figure A2/2. The sandbag is suspended by a quick release mechanism to the point C1, which ensures that the underside of the sandbag is a minimum of 1200 mm above the highest surface of the test sample

2.3.4 The sandbag shall comprise a cylindrical canvas bag of diameter 300 mm – see Note 3. The sand shall be dry, have an apparent density of approximately 1500 kg/m^3 and shall pass through a sieve of aperture size 2 mm. Just before carrying out the test, the sandbag shall be weighed, and it shall weigh at least 45 kg.

> **Note 3:** The sandbag is shown in Figure A1/1 in Annex 1.

2.3.5 From its initial position, a minimum of 1200mm above the highest surface of the sample under test, the sandbag shall be allowed to fall freely under gravity on to the surface of the test sample. It shall impact the test sample at the position determined as the worst case by the competent person (see 0.1). The competent person shall use existing data (typically industry guidance) to establish which test position(s) is the worst case, or in the absence of such data shall carry out a sufficiently rigorous test programme to establish this position(s). As a minimum, the test sample shall be impacted at [see also figure A2/3 in Annex 2]:

> **i)** Within 150mm of the centre of the test sample;
> **ii)** Within 300mm of the support point, at least 150mm away from the support; and
> **iii)** Within 150mm of the edge of the sheet, adjacent to the underlap with the other sheet.

When testing profiled sheet, impacts shall be carried out on both trough and crown of the profile, unless the competent person has determined which of these is the worst case, in which case that shall be used.

> **2.3.5.1** Sheets shall be tested in the same span configuration as they are to be used: single, double and triple span arrangements will require testing separately. Tests on triple span sheets can be assumed to be representative of sheets spanning more than 3 purlin spaces. Every location in every span of double and triple span sheets must be tested.

2.3.6 The test described above shall be carried out on at least three samples. The result declared shall be the lowest classification of any individual sample. Where the test result is borderline, or there is significant variation between test results of individual samples, the competent person (see 0.1) shall ensure sufficient further tests are carried out to ensure the test results are statistically significant, and the declared result will be consistently achieved.

2.3.7 It is not a requirement to test each sample in each of the three positions specified. The number of positions, which must be tested, may be reduced. However, such rationalisation of testing shall be supported by evidence, supplied by the competent person (see 0.1), that the test positions used include the worst case.

2.3.8 Where a manufacturer or supplier provides the same product in a number of profiles, the number of profiles to be tested shall depend on the instruction of the competent person (see 0.1). Different profiles should normally be tested independently; results from one cannot usually be assumed to apply to another. Where sufficient data is available to demonstrate that variation between profiles will not affect results (typically in the form of industry guidance) then the competent person may be able to use such data to avoid the need to test all profiles.

> **Note 4:** Specific guidance on the application of this test to GRP profiled rooflight sheeting is given in NARM Technical Document NTD03, which can be obtained from NARM.

2.3.9 Where different manufacturers make the same profile to the same nominal specification but with possible variations in process, raw materials, etc (e.g. profiles from different rooflight manufacturers), then results from one cannot be assumed to apply to another, and performance of each product must be demonstrated individually.

2.3.10 The manufacturer(s) of any components used in the assembly shall ensure that the samples tested are representative of all production. If any alterations are made to product design or manufacturing method which may affect the test results, any existing classification should be disregarded, and the test should be repeated.

3. CLASSIFICATION OF ROOF CONSTRUCTION

3.1 Fragile Classification

Carry out the drop-test described in 2.3. If the impactor passes through the test assembly and hits the ground, the test assembly shall be classified as **fragile.**

3.2 Non-Fragile Classifications

To be classified as non-fragile, under the test described in 2.3, the sheet/product under test within the assembly shall arrest the fall of the impactor and retain it on the sheet/product under test for a period of at least 5 minutes. The requirement to retain the impactor for 5 minutes may be reduced on the instruction of the competent person – see Note 5. During this 5-minute waiting period, it is essential that the Competent Person satisfies themselves that the drop bag is being wholly retained by the sheet under test and not supported by any of the surrounding sheets or any substructure. If necessary, the bag should be moved to accommodate this or the test repeated.

Note 5: If in the opinion of the competent person there is no likelihood of the test impactor causing further elongation or tearing that would allow it to pass through the test sample, the test may be terminated.

3.2.1 Section 3 describes the criteria for the classification of a roofing assembly. The intention of the drop test is that it should be carried out for the worst case of impact on a sheet/product within an assembly, and that the full weight of the sandbag should be retained by the sheet/product at the point of impact. The purpose of this is to see if factors such as further elongation or tearing occur which could lead to failure of the sheet/product. In the 3rd edition, paragraph 3.2 referred to the *assembly under test*, and the need for the *assembly* to retain the sandbag impactor for at least 5 minutes after impact.

3.2.2 There was concern that the reference to *"the assembly to retain the sand bag"* could be interpreted as being acceptable for some of the weight of the sand bag to be supported by other elements of the assembly such as an adjacent purlin or sheet, as well as the sheet under test. For this reason, the wording of paragraph 3.2 was altered in the 4th edition to emphasise that the full weight of the sand bag should be retained on the sheet under test.

3.2.3 Manufacturers test results may be unclear whether or not the full weight of the sandbag was applied to the sheet under test for at least 5 minutes after impact. To comply with the amended requirement, manufacturers may consider that they need to repeat a substantial number of tests. The ACR have considered this and have taken the view that products complying with the 3rd edition do not need to be re-tested. The reason behind this is that the ACR are unaware of products tested to earlier editions failing in service after impact. New products and assemblies, or amendments to previously tested assemblies should be tested to the latest edition.

3.3 Assemblies subjected to a single drop test

If after the first impact the impactor is retained on the test sheet, satisfying conditions set out in 3.2, and no other drop tests are carried out on the assembly, the assembly shall be classified as a **Class C non-fragile assembly.**

3.4 Assemblies subjected to multiple drop-tests

3.4.1 The impactor may be removed, and the test sheet may be subjected to a second drop test at the same locations as the first drop from 1200mm measured from height at which the impactor is retained on the test sample after the first drop.

3.4.2 If the impactor passes through the test sheet and hits the ground, the assembly shall be classified as a **Class C non-fragile assembly**.

3.4.3 If the impactor is retained on the test sheet, satisfying the conditions set out in 3.2, the assembly shall be classified as a **Class B non-fragile assembly.**

3.4.4 On conclusion of the second drop test, the load shall be removed and the assembly examined by the competent person and if, in his opinion, the roof sheet and the assembly shows no signs of significant damage that will affect the long term strength and weatherability of the assembly – see Note 6, the assembly may be classified as a **Class A non-fragile assembly**.

The competent person should also refer carefully to Section 6 of this document before awarding a Class A rating

Note 6: Any tearing at the fixings, fractures in the sheet or the assembly support structure, delamination of the sheet or damage to the surface protection which could accelerate the degradation process should be seen as sufficient to withhold a Class A rating. See also paragraph 6.1.

3.4.5 A flowchart for the tests is given in Annex 3.

3.5 Testing of Glass Roofs and Glass Rooflights

There are unique safety issues associated with glass. Glass may pass the ACR soft body impact test set out in this document, but it is particularly susceptible to hard body impacts that do not form part of the ACR test, which may cause it to shatter, and may allow shards of glass to fall on to people below. This has been recognised by the glass industry for some time and as a result the Centre for Window and Cladding Technology (CWCT) devised specific non-fragility tests for large area glazing. These were based on the ACR soft body impact tests, together with additional hard body impact and residual load tests, and limits to the size of shards of glass falling from broken panes, to minimise risk to any personnel beneath. Reference to these tests was included within the 5th edition of ACR[M]001.

The soft body test sequence and classification system described in ACR[M]001 is not, on it's own, appropriate for glass roofs, or glass rooflights. Glass roofs and glass rooflights should therefore **only** be classified non-fragile to ACR[M]001 if they **also** achieve non-fragility to the appropriate CWCT standard.

The CWCT tests for larger areas of glazing are described in CWCT Technical Note No. 66 "Safety and Fragility of Glazed Roofing: guidance on specification" and Technical Note No. 67 "Safety and Fragility of Glazed Roofing: testing and assessment"

For projects where Class 2 roofs are specified, CWCT Technical Note No. 92 "Simplified Method for Assessing Glazing in Class 2 roofs" (developed in conjunction with ACR) provides a simplified test method, and also a "deemed to satisfy" solution, thus avoiding expensive testing on projects where there may only be small areas of glazing. Tests for Class 2 roofs only take into account the performance of the inner pane.

CWCT defines roofs incorporating glazing depending on access (see CWCT TN 66):

a) Class 0 glazed roofs (and walk-on glass rooflights) are designed for unrestricted access and should be designed to floor loadings (as prescribed in BS EN 1991-1-1 including the National Annex). They should be designed with the outermost glass leaf sacrificial, so that the full design load will be supported even if the outer leaf has been accidentally broken. These roofs/rooflights would achieve Class A to ACR[M]001 but are specialist constructions outside the normal scope of CWCT or ACR recommendations.

b) Class 1 glazed roofs are designed for occasional foot traffic for maintenance only. These roofs need to support both the weight of people on the glass and their equipment and resist impacts from falling people or any object/equipment being carried without damage. As a minimum they should be classified non-fragile for Class 1 roofs in accordance with CWCT TN 67 and achieve Class A to ACR[M]001.

c) Class 2 glazed roofs (including most glass rooflight applications) are where people are never intended to walk on the glass but may walk adjacent to it. The glazing should be non-fragile for Class 2 roofs to CWCT TN 67 or TN 92 and would achieve Class B non-fragile to ACR[M]001.

d) Class 3 glazed roofs should be considered as fragile roofs.

In order to be classified **Class B** or **Class C** non-fragile to ACR[M]001, a glass roof or glass rooflight should also, as a minimum, be classified by CWCT as non-fragile for a **Class 2** roof.

In order to be classified **Class A** non-fragile to ACR[M]001, a glass roof or glass rooflight should also, as a minimum, be classified by CWCT as non-fragile for a **Class 1** roof.

Glass roofs or glass rooflights which have not been classified non-fragile to CWCT standards should be regarded as **fragile** to ACR[M]001.

It should be noted that the testing defined in CWCT Technical Notes 92 and 67 apply specifically to glass and are not appropriate for other glazing materials (such as polycarbonate or GRP) for which the ACR drop test as described in this document applies.

4. TEST REPORTS

4.1 Test Report Contents

The test report shall contain the following information:
a) A detailed description of the assembly tested
b) A detailed description of the observations from the close examinations required in 3.4.4 and 3.5
c) The results of the consistency tests if carried out;
d) Confirmation that the test for fragility was carried out in accordance with this test method, and date of the test
e) The classification which the material satisfies;
f) The name, address and dated signature of the competent person(s), including a statement confirming evidence of compliance with the requirements of **0.1**.

4.2 Test Report Supporting Evidence

Photographs and videos may be supplied as evidence to support (a), (b) and (c).

4.3 Test Report Availability

This test report shall be made available to any person who asks for confirmation that the claim for ACR classification of the assembly is correct.

5. MARKING AND LABELLING

5.1 Product Labelling

Each sheet or component shall be marked clearly and visibly using a durable method which does not affect the long-term performance of the material. The labelling shall contain the following:
a) Name of the manufacturer;
b) Product reference or specification.

6. ROOF DESIGN REQUIREMENTS

6.1 Typical Roof Non-Fragility Classifications

A non- fragility rating of Class B or Class C is perfectly acceptable for most typical roofing applications. Class A ratings will not be achieved by many roofs and is solely intended for roofs that are designed for frequent foot traffic and have therefore been designed to floor loadings. Designers should not specify Class A for typical roof assemblies, unless they have been designed to floor loadings.

The non-fragility classification of a complete roof assembly is governed by the lowest performing element of the assembly. Where possible, non-fragility classification of an accessory mounted in a roof should be at least as good as the classification of the roof (without accessories). If the non-fragility classification of an accessory (for example a rooflight or louvre smoke vent assembled into the roof) is lower than the classification of the roof without accessories, then the non-fragility classification of the whole roof is reduced when the accessory is incorporated into the roof.

Similarly, if an accessory has a higher rating than the roof it is proposed to fix it to is installed, then the non-fragility classification of the accessory when assembled into that application is limited to that of the surrounding roof.

For clarity the competent person should ensure that this is taken into account when awarding a non-fragility classification, for example, a Class A rating cannot be awarded to an accessory (such as a valley gutter or a walk on rooflight) unless that accessory is being fitted into a roof which also achieves Class A.

Designers should also consider expected life of the roof and its longer-term maintenance requirements. Most roofing materials, washers and fixings will diminish in strength with time and will eventually become a **'Fragile'** element. Manufacturers should be contacted for their advice on long term non fragility and then design their roof to match their durability requirements.

7. COMPLAINTS PROCEDURE - A CODE OF PRACTICE

Where it is suspected that a manufacturer or supplier is using an ACR[M]001 classification incorrectly, this should be reported to the relevant Trade Association.

In the first place, the Trade Association receiving such a report should investigate this claim. If it is found that the classification is being used incorrectly, the member should be instructed to withdraw it. In addition, the manufacturer should inform any person who has bought the product of the change in classification.

Where there is a dispute about the correctness of a classification, the Trade Association should refer the matter to the Advisory Committee for Roofsafety [ACR], through their delegate on the Committee.

Upon receipt of a referral, The ACR shall follow the procedure set out in Annex 5.

The Non-Fragility Test described in this document is the intellectual property of the Advisory Committee for Roofsafety (ACR) and has the full approval and support of the Health & Safety Executive. The ACR allows all organisations that test their products under this test procedure, to use the ACR Classifications to describe their products as appropriate. However, in the event of any dispute, the ACR reserve the right to withdraw the right to an organisation to classify its products using the ACR Classifications.

8. ACCEPTABLE USE OF THE RED BOOK BY MANUFACTURERS AND SUPPLIERS

The ACR Red Book (ACR[M]001) is drafted, owned, maintained and published by the ACR. The ACR hereby freely grants permission to anyone, on successful and correct application of the Red Book Test and procedures, to market/advertise their products by using or claiming compliance or equivalence with an appropriate Red Book designated classification or by reference to the ACR or its publication. However, in doing so the ACR retains the right to withdraw its permission for such use from anyone it considers is:

a) Applying a Red Book classification incorrectly or;
b) Using Red Book procedures incorrectly or;
c) Claiming equivalence incorrectly.

The ACR decision in all matters relating to the correct interpretation/application of the Red Book is final and any use of the Red Book to test/advertise products indicates acceptance of these restrictions.

When a new version of the Red Book is published, it supersedes all previous versions of the publication which automatically become withdrawn and should be considered obsolete. Reference to the page footer will take the reader to the ACR website for details of the latest version.

ANNEX 1

A1.1
The sandbag for use in the drop test for fragility - see 2.3.4 - shall be as in Figure A1/1.

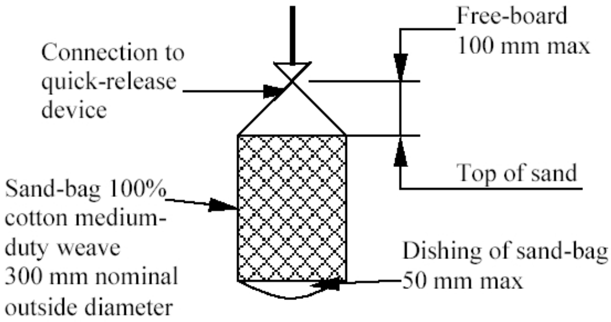


Figure A1/1 - Sandbag for drop test

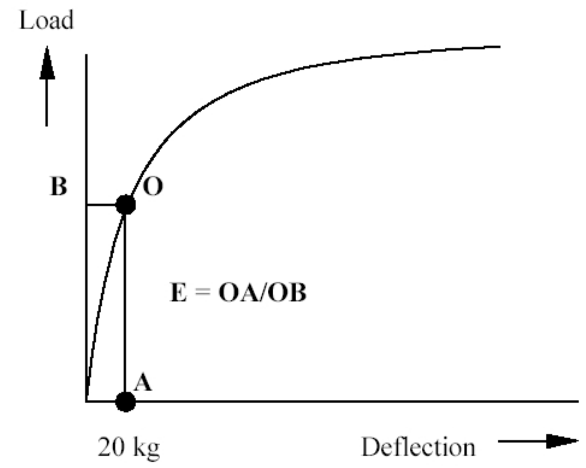
A1.2
The bag shall be filled with the dry sand, in layers not exceeding 150 mm deep. Each layer shall be compacted by ramming with a 32 mm diameter x 1.0m long reinforcing bar. The ramming action shall be achieved by raising the reinforcing bar to a height of at least 50 mm above the sand and letting it fall through gravity at least ten times. The compacting action shall be spread over as much of the surface of the sand as possible.

A1.3
On completion of the compaction of the sand, the bag shall be drawn tight as close as possible to the top surface of the sand. The free space above the sand shall not exceed 100 mm. The bag shall be tied to ensure that sand cannot escape.

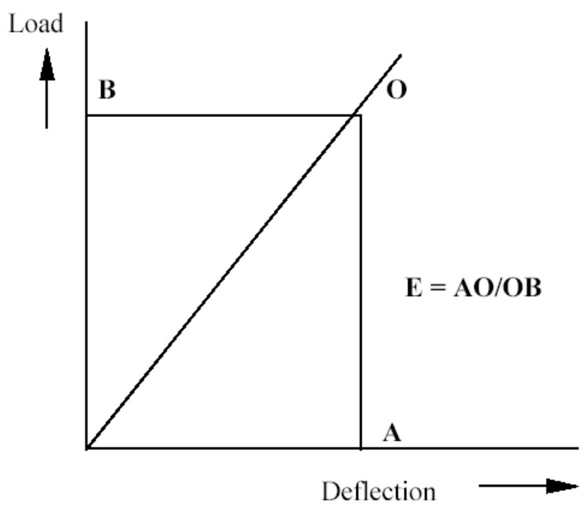
A1.4
The connection to the quick release device shall be arranged to ensure that the bag hangs within 1.5° of the vertical.

ANNEX 2

A2.1
The figures referred to in the text at 1.3.2.4, 2.3.3 and 2.3.5 are shown in Figure A2/1, A2/2 and A2/3 respectively.



E for non-linear load-deflection behaviour



E for linear load-deflection behaviour

Figure A2/1 - Methods of calculating E from load deflection curves [1.3.2.4]

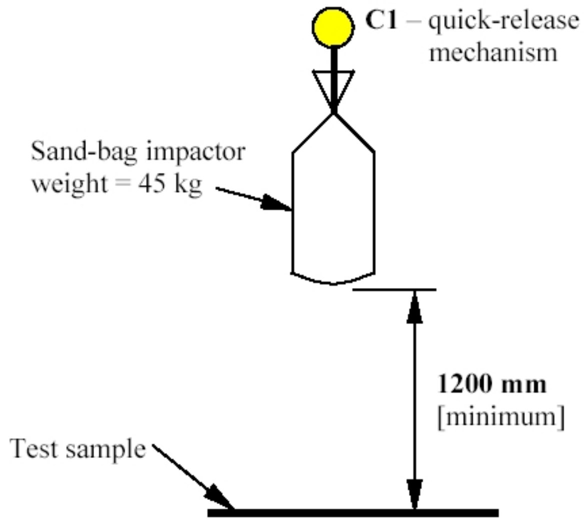
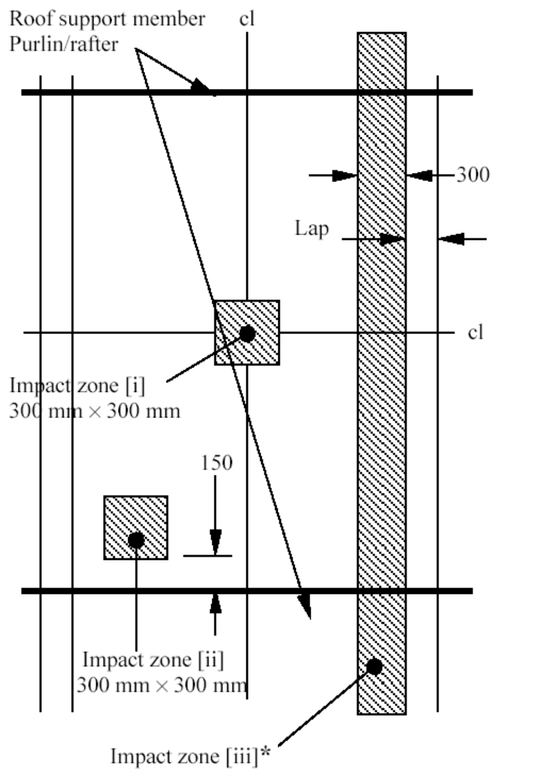


Figure A2/2 - Arrangement for drop test [2.3.3]



Note 1: * exact position in zone [iii] to be specified by the competent person.
Note 2: All dimensions are in millimetres.

Figure A2/3 - Impact zones for drop test in accordance with 2.3.5

ANNEX 3

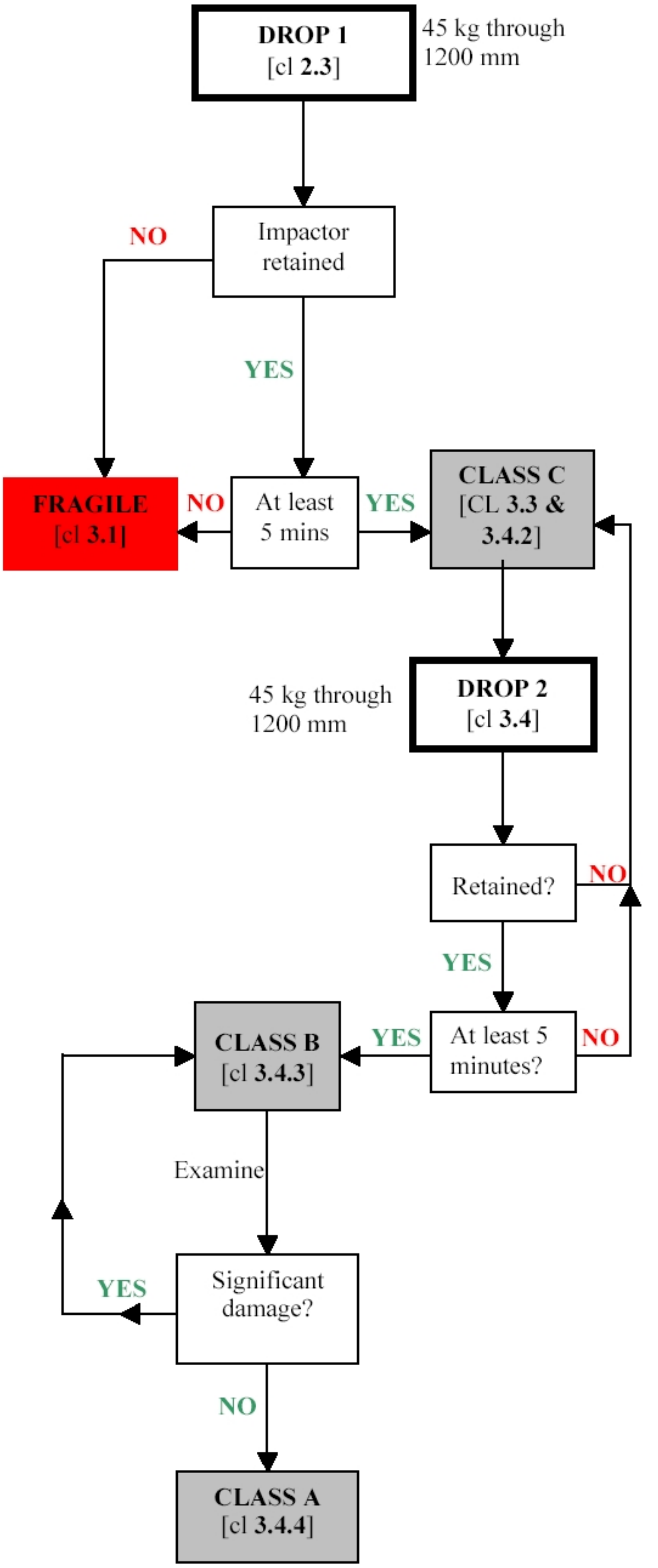
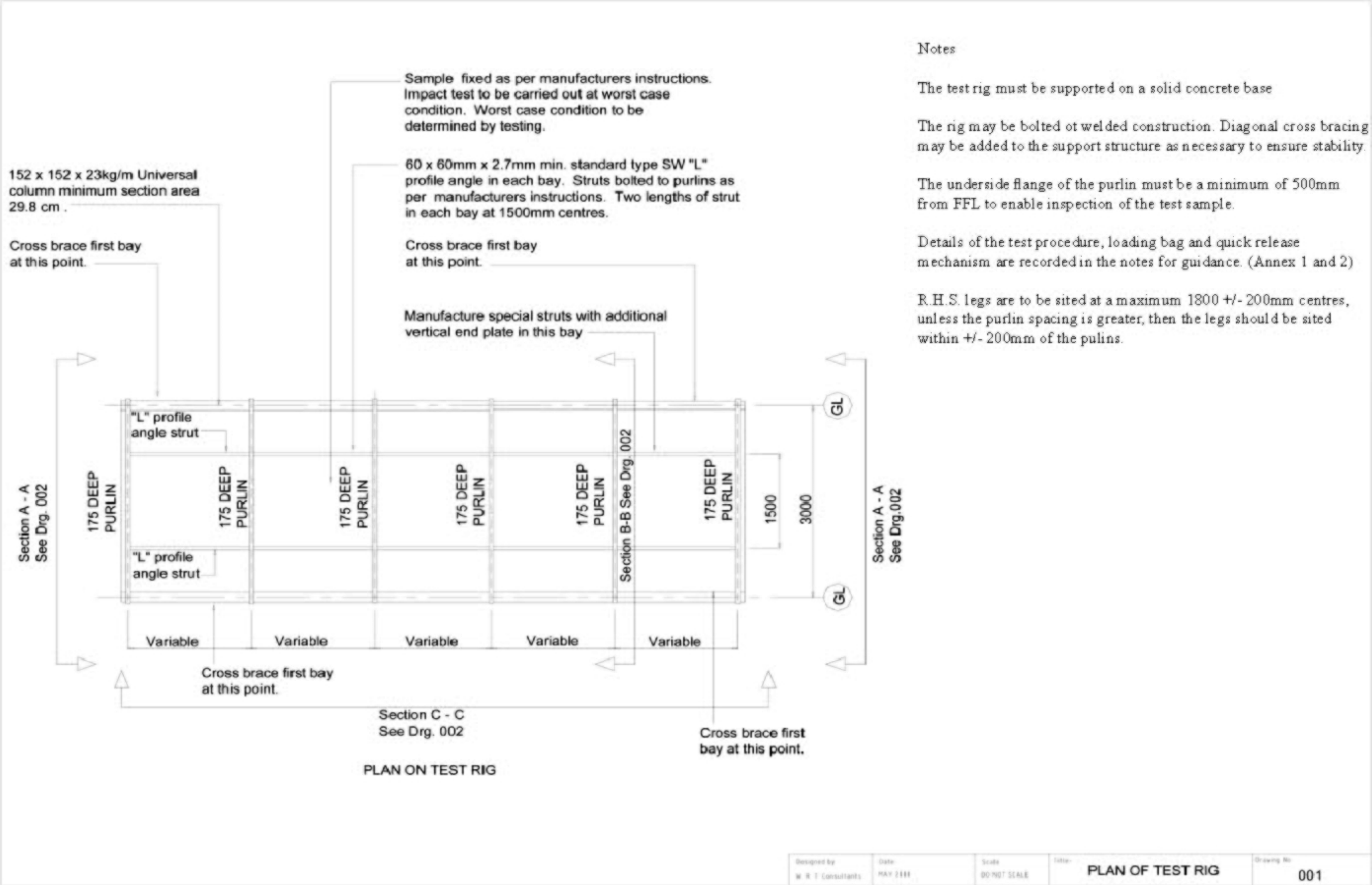
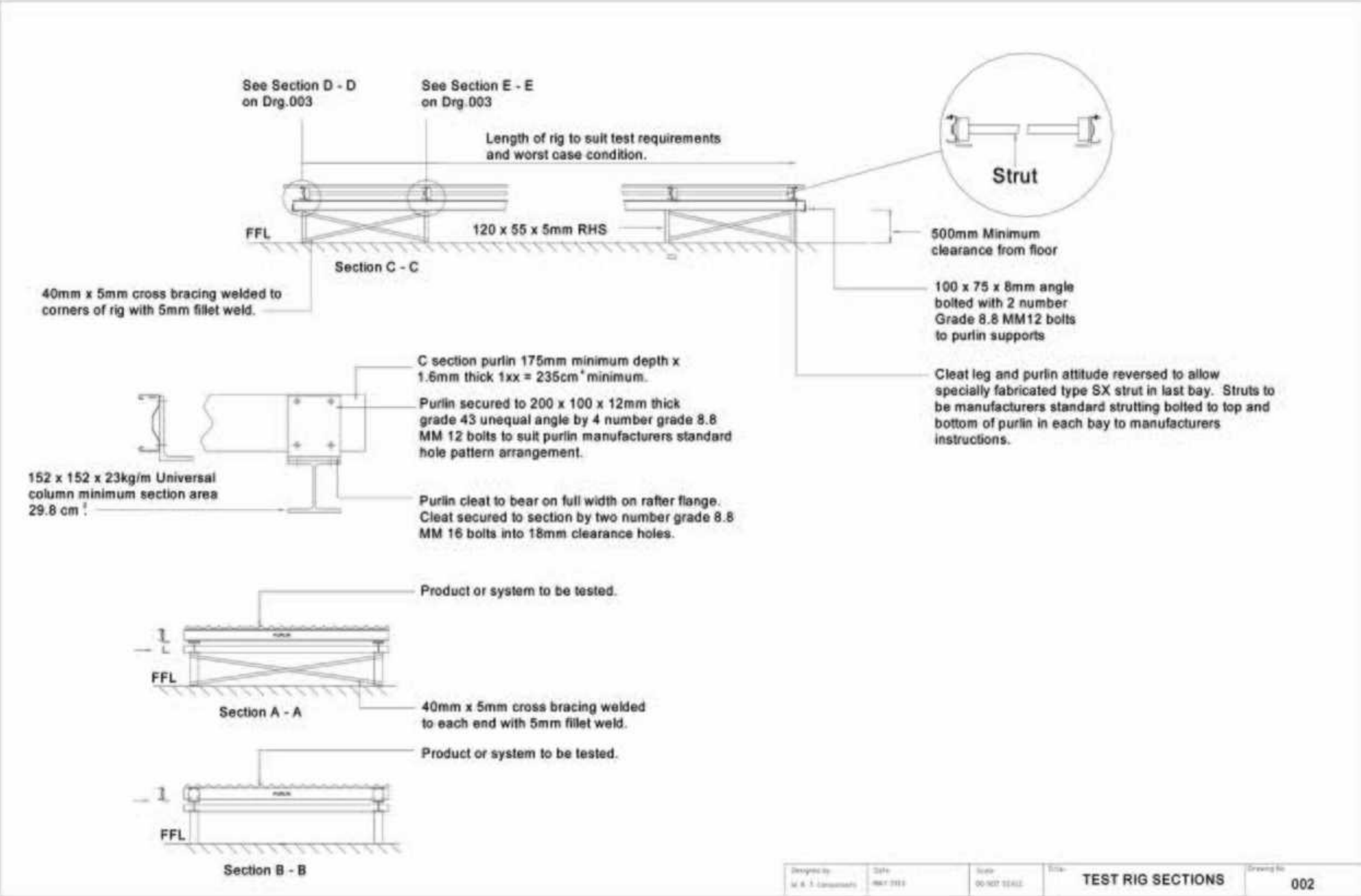


Figure A3/1 - Flow-chart for classification

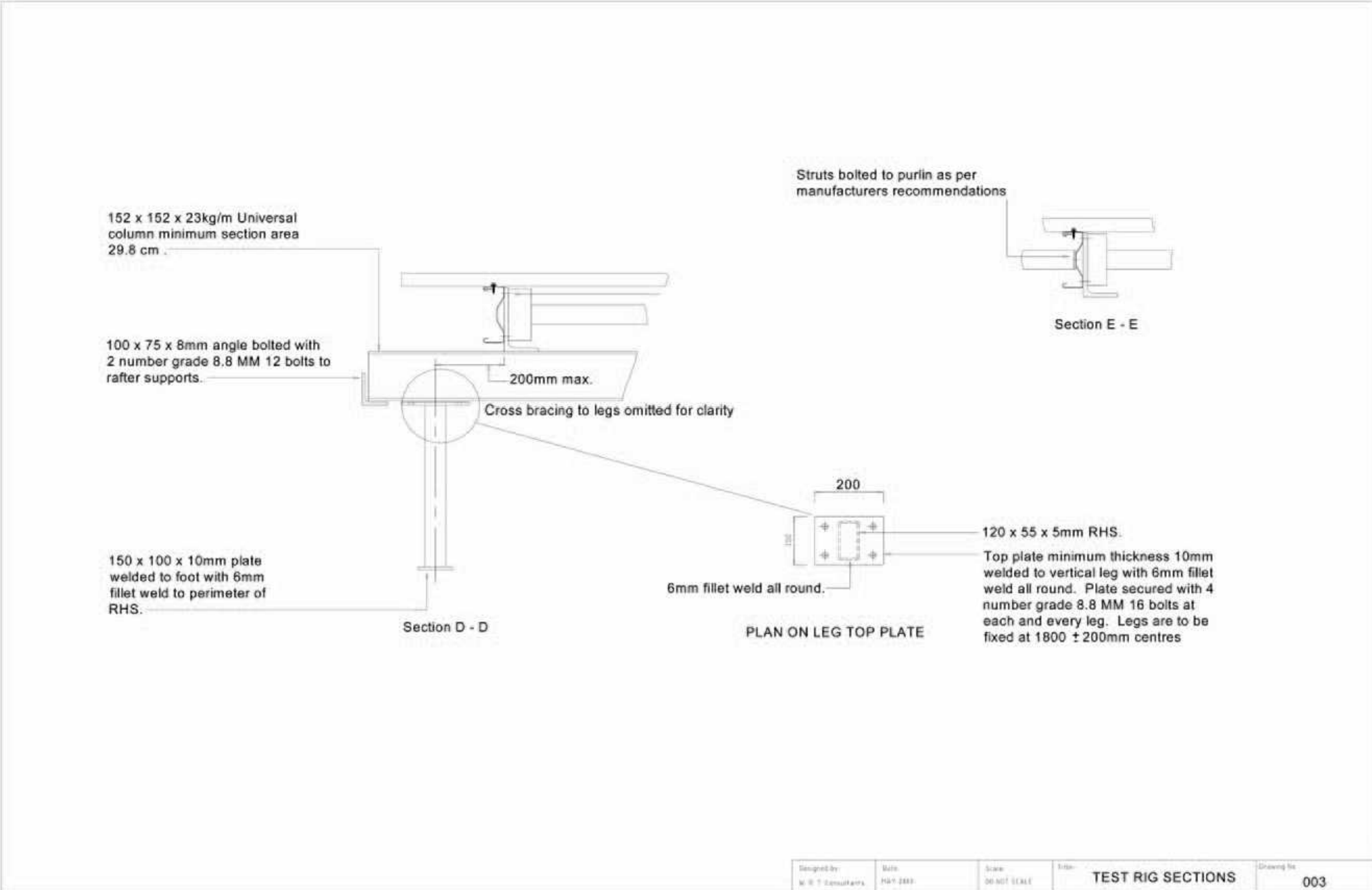
ANNEX 4



Annex 4/1 Drawing 001 - Plan of Test Rig

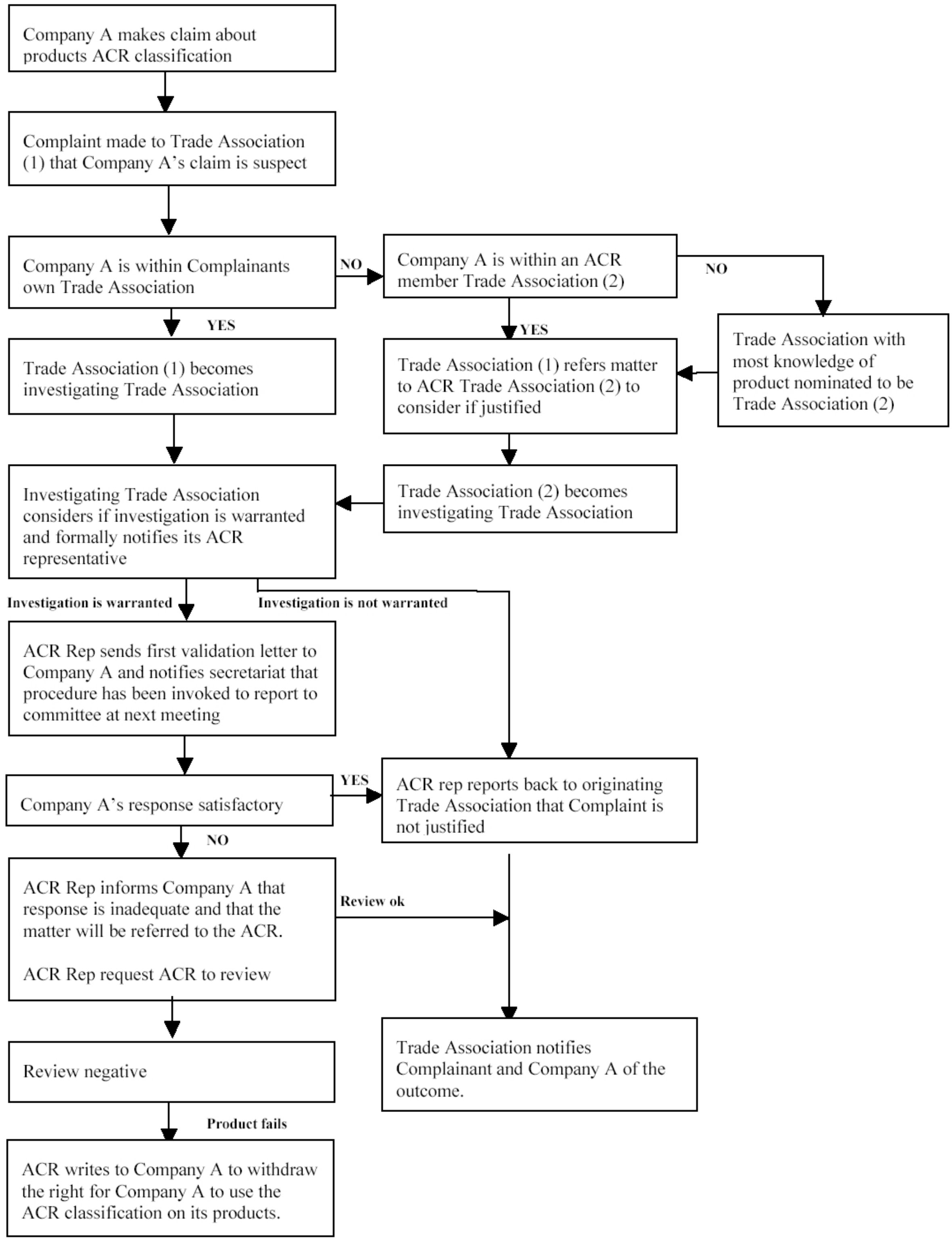


Annex 4/2 Drawing 002 - Sections and Details



Annex 4/3 Drawing 003 - Test Rig Sections and Details

ANNEX 5


Company A makes claim about products ACR classification
Complaint made to Trade Association (1) that Company A's claim is suspect
Company A is within Complainants own Trade Association
NO
Company A is within an ACR member Trade Association (2)
NO
YES
YES
Trade Association with most knowledge of product nominated to be Trade Association (2)
Trade Association (1) becomes investigating Trade Association
Trade Association (1) refers matter to ACR Trade Association (2) to consider if justified
Trade Association (2) becomes investigating Trade Association
Investigating Trade Association considers if investigation is warranted and formally notifies its ACR representative
Investigation is warranted
Investigation is not warranted
ACR Rep sends first validation letter to Company A and notifies secretariat that procedure has been invoked to report to committee at next meeting
Company A's response satisfactory
YES
ACR rep reports back to originating Trade Association that Complaint is not justified
NO
ACR Rep informs Company A that response is inadequate and that the matter will be referred to the ACR.
ACR Rep request ACR to review
Review ok
Review negative
Trade Association notifies Complainant and Company A of the outcome.
Product fails
ACR writes to Company A to withdraw the right for Company A to use the ACR classification on its products.

ANNEX 6

REPORT ON TESTS CARRIED OUT TO DETERMINE HUMAN IMPACT LOADS ON ROOFS

THE PROBLEM

1. At the time of developing the test set out in the 1st Edition of ACR[M]001, BS 6399 - part 3[i] prescribed live loads for roofs, which they recommend should be used for their design. These were static loads and it was presumed that their use provided a reliable structure.

2. For most structural components, the combination of recommended live loads with component self-weights ensures that the resulting design loads are high enough to make loads from human impact events, e.g., stumbles and falls, insignificant. With roofs, this is not the case. Consequently, many people working on roofs have fallen through them, often to their deaths. This should not be acceptable to civil and structural engineers; workers on roofs deserve the same level of protection as other workers.

3. The problem is exacerbated when engineers (and architects) design building components to penetrate the roof, e.g., vents, chimneys etc, which usually require maintenance and regular access across the roof.

4. Construction health and safety law had recognised this problem many years ago and made it illegal for persons to work on or near fragile materials. Unfortunately, the engineering professions did not and have not risen to the challenge; they continue to specify fragile roofs.

5. This led to the Health and Safety Executive [HSE] publishing the Specialist Inspector Report (SIR) 30[ii], with the intention of encouraging the development of a definitive test for non-fragility, which would ensure that a roof assembly would not fail under the load of a person. Because these hopes were not realised, the HSE acted to provide a means of assuring non-fragility.

DEVELOPING THE TEST

Governing Principles
6. In keeping with the principles of UK health and safety law, the Test would have to be reasonably practicable; that is, it would have to satisfy two requirements, it should:
a) Provide a safe margin against failure under human impacts; and
b) Not be so onerous as to reclassify materials known to be non-fragile

Existing Information
7. An examination of existing information indicated that there were ready-made solutions available. A test based on the theoretical consideration of energy (see note 1), as used in some parts of Europe, could have provided a solution. However, it would have penalised the roofing industry, because it would have required the production of heavier-duty roof sheets, requiring heavier structures to support them. Consequently, this approach was abandoned. However, to ignore the theoretical approach and base the test on an empirical approach would require the acquisition of data.

> **Note 1:** A 100kg man with his centre-of-gravity acting at 1.0m above the surface falls onto the surface with an energy of 1000 J at impact. By applying a factor of safety of 2.5, you arrive at design impact energy of 2500 J, which defines the test: a 100 kg sandbag allowed to fall through 2.5m.

Acquiring the necessary data
8. This was a major problem. In order to provide a safe margin against failure, it would be necessary, initially, to obtain an accurate assessment of the forces. Three options were available. We could:
a) Base the test on theoretical considerations of energy;
b) Use already published data, which used anthropomorphic dummies; or
c) Develop our own data

9. There was some doubt about using the approach advocated in 9 (a), because it was almost impossible to calculate how much energy the human body could absorb. Using published forces, based on the use of anthropomorphic dummies [9 b)] were also considered but discarded, because dummies do not model a body's unique capability to absorb energy accurately. Consequently, both methods could give an overestimate of the forces and their use would probably have violated governing principle 6 b).

10. Therefore, it was agreed that the only way to quantify human impact forces accurately, to allow the provision of a credible safe margin [governing principle 6 a)], was to use people to generate the forces.

Test should represent the actual event
11. Another problem was replicating an impact event in a test. For any test method to be representative of the human impact event, it would have to satisfy three conditions:
a) It would have to apply the same total force to the surface; with
b) The same time-history, at least for the first impact; and if possible
c) Generate the same local effects

12. Therefore, the impact surface would have to measure the total load as well as the instantaneous load over the period of the impact. A special impact table would have to be constructed.

The Impact Table
13. A point for consideration was the stiffness of the impact table, because its flexibility would, in accordance with impact theory, modulate the forces being measured. After due consideration, it was agreed that the best course of action would be to use a stiff impact table, as this would give the highest forces and a better indication of forces at stiff points, e.g., impact close to a rafter.

14. Consequently, the impact table comprised a stiff steel platform covered with approximately 1000 load cells, supported at each corner on a load cell. The surface load cells would record the local load at 50 Hz, while the load-cells under the corners would record the total impact force over the same time; allowing the requirements of 11 a) and 11 b) to be met and the comparison required by 11 c).

THE TESTS
15. Volunteers fell on to the impact table in various ways: stumbling while walking across it, falling from standing to sitting, etc. The forces applied to the table for each event were recorded: providing the forces applied by humans when they fall on to a surface, as well as a time-history of the event. The data was provided in two ways: a time-history plot and a pressure visualisation, which showed the build-up of pressure over the whole impact event. Outputs from typical impact events are shown in Figures 1and 2, at the end of this report.

ASSIGNING FACTORS OF SAFETY
16. Having acquired the necessary data, the next significant point was the assignation of a factor of safety (FoS) to the impact force. Any FoS would have to provide an adequate margin against failure in the extreme case and, by default, a larger margin against failure for the non-extreme cases. For the purpose of this exercise, the FoS was arrived at simply, by applying multipliers for perceived sources of error in the test method, which were:
a) The 85 kg weight of the test specimen was less than the 95th percentile man, who weighs 94 kg. Assuming a linear relationship between weight and impact force, this required an adjustment factor for weight, k_W, of 1.1.
b) Errors in measuring the load, which, due to the careful calibration of the equipment, was considered to be very low. Nevertheless, an adjustment factor for measuring error, k_E, of 1.1 was applied.
c) Fabrication tolerances in the material to be tested, which was taken as being covered by assuming that the material was 10% less thick than it should be. On the assumption that one failure mode would be due to bending, the ultimate bending strength of the thinner material would be $1.0^2 / 0.9^2$ less than a specimen fabricated to the correct thickness. This indicated the application of a factor for fabrication tolerance, k_F, of 1.25.
d) Differences in impact velocity, due to different heights of fall – people vary in height. This was accounted for by assuming that the impact velocities varied by the ratio k_V, where:

$$k_V = [2gh_1]^{1/2} / [2gh_2]^{½}$$ and using

h_1 = 1.0m the height to the posterior of the volunteer; and
h_2 = 1.15m, the height to the posterior of a taller man.
Indicating an impact velocity correction factor, k_V, of 1.1.
e) Finally, there had to be a minimum margin against failure. This was the most difficult part of the exercise, as this minimum margin had to be applied to the extreme case. For the answer, HSE accident statistics were examined and these showed that the majority of people [approximately 85%] who fell through roofs had, reportedly, stumbled on the roof. The other 10-15% had fallen, either forwards or backwards. And, as the

tests had shown that the maximum force occurred when a person falls from standing to sitting, this was chosen as the extreme event to attract the minimum FoS. In line with some existing standards, a factor of safety, k_s, of 1.15 was assigned to this force.

17. This gave the overall minimum factor to be applied to the measured "extreme" force, which was 1.9, being the product of the factors (see note 2), k_w….k_s, listed above in 16 a) to 16 e). This was rationalised to 2.0, and eventually defined the test for assuring non-fragility as: the dropping, under gravity, of a bag of diameter 300 mm containing 45 kg of dry sand through 1.2 m onto the surface, determined by trial-and-error.

Note 2: By the method of SRSS the minimum factor becomes 2.7

18. This test has been adopted by the Advisory Committee for Roofsafety and has been published as ACR [M] 001: 2000 – Test For Fragility of Roofing Assemblies[iii].

REFERENCES

[i] **British Standards Institution.** BS 6399-3 - Code of practice for imposed roof loads (Withdrawn March 2010);
[ii] **Health and Safety Executive.** Specialist Inspector Report No 30 – Test for fragility; (Now withdrawn)
[iii] **Advisory Committee for Roofsafety.** Materials Standard ACR[M]001:2000 – Test for Fragility of Roofing Assemblies.

FIGURES REFERRED TO IN THE TEXT

The figures included below are referred to in the text at paragraph 15.

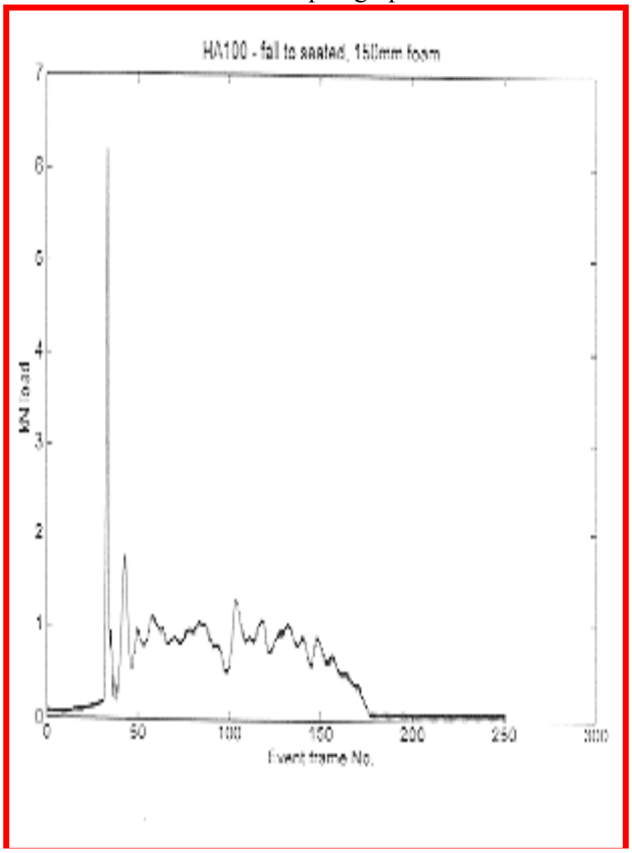


Figure 1 - Impact Time-history: standing to seated

DRAFT OF 12 February 2001

Figure 7: Video frame and pressure image of stumble event

Figure 8: Video frame and pressure image of fall to seated event

Figure 9: Video frame and pressure image of bagdrop

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15

Figure 2 - Instantaneous pressure readings for first impact [at peak load]. These pictures are built up every 1/50th of a second from the first impact In the figures, the colours indicate intensity of pressure: red is the highest intensity and blue is zero [Image abstracted from the contract research report]

Acknowledgements
The Author is grateful for the work of the Health and Safety Laboratory, Sheffield. They developed the loading table and the complicated electronics, which recorded the necessary data. Without their contribution, this work could not have taken place.

This document can be downloaded free of charge from the ACR website at www.the-acr.org where the up to date list of members can also be found.

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Edge Protection Federation [EPF] www.epf-uk.org	**Roof Tile Association [RTA]** www.rooftileassociation.co.uk
Engineered Panels in Construction [EPIC] www.epic.uk.com	**Rural Industrial Design and Building Association [RIDBA]** www.ridba.org.uk
Fall Arrest Safety Equipment Training [FASET] www.faset.org.uk	**Single Ply Roofing Association [SPRA]** www.spra.co.uk
Health and Safety Executive [HSE] www.hse.gov.uk	**The Institute of Roofing [IoR]** www.instituteofroofing.org
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