Grenfell Tower – fire safety investigation:
The fire protection measures in place on the night of the fire, and conclusions as to:

the extent to which they failed to control the spread of fire and smoke;
the extent to which they contributed to the speed at which the fire spread.

Phase 1 Report – Appendix F

Reaction to fire tests and classifications

REPORT OF

Dr Barbara Lane FREng CEng

Fire Safety Engineering

24th October 2018

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On behalf of	:	Grenfell Tower Inquiry
On instructions of	:	Cathy Kennedy, Solicitor, Grenfell Tower Inquiry
Subject Matter		To examine the circumstances surrounding the fire at Grenfell Tower on 14th June 2017
Inspection Date(s)	:	6th October, 1st November, 7-9th November 2017

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Appendix F– Reaction to fire tests and classifications

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F1 Introduction

F1.1 Relevant test evidence

F1.1.1 I have carried out an analysis of the suite of fire tests supporting the provisions made in the statutory guidance document Approved Document B 2013 (ADB 2013), for the *Construction of External Walls* as Section 12.

F1.1.2 I have been assisted in what has been a complex study and presented here in this Appendix, by my colleague Mr Tom Parker.

F1.1.3 The suite of fire tests supporting the statutory guidance for Section 12 *Construction of External Walls* is itself complex. It includes National Class fire tests and European Class fire tests. The National and European fire tests do not, in general, test materials the same way. The results of the tests are classified differently also. I explain all of this in detail in this Appendix.

F1.1.4 Both frameworks – National and European – are referred to in parallel throughout Section 12 of ADB. As I explain in this Appendix, no guidance is provided on which regime takes precedence when differing performances are allowed by means of the provisions in ADB 2013, for the same material or product. The existence of differing performances in the statutory guidance is a critical problem. In my opinion, this requires urgent review and change.

F1.1.5 Much of the guidance provided in Section 12 of ADB 2013 is, as it states in Appendix A of ADB 2013:

"*given in terms of performance in relation to British or European Standards for products or methods of test or design or in terms of European Technical Approvals. In such cases the material, product or structure should:*

***a**. be in accordance with a specification or design which has been shown by test to be capable of meeting that performance; or **b**. have been assessed from test evidence against appropriate standards, or by using relevant design guides, as meeting that performance; or **c.** where tables of notional performance are included in this document, conform with an appropriate specification given in these tables*"

F1.1.6 So, the statutory guidance is clear that fire performance is to be shown by tests, or assessed from test evidence for compliance with that guidance.

F1.1.7 Where that clarity gets lost is the interpretation of fire tests and the interpretation of fire test assessments, and how they relate to the actual building condition.

F1.1.8 As stated in BS 476 – Part 10: 2009 "*Within the field of reaction to fire, direct field of application is the application of the test results for a material or product in accordance with the details of how they were tested. Specifically,*

this means that when compared with the field of application, the mounting and fixing arrangement used in the test method is applied directly to the use of the material or product in real end use conditions."

F1.1.9 This has become an area of confusion, disagreement, and loose interpretation of what is perceived to be a grey area. I am not alone in having this opinion but I am equally clear there is an opposing body of opinion who consider the current state of affairs to be acceptable. I do not.

F1.1.10 I acknowledge I have now analysed the relevant fire tests in the last few months, at a level of detail I had not done before the Grenfell fire.

F1.1.11 However, I have had to rely on the provisions made in the ADB 2013 in my own work, and in reviewing others work, over the many years I have been a fire engineer.

F1.1.12 I am therefore familiar with the conflicting opinion in the industry from long before the Grenfell fire, regarding the application of relevant test evidence for materials forming building envelopes, and indeed other fire safety systems.

F1.1.13 It is also my experience over many years that fire test results have been applied to end use conditions, that are substantially different.

F1.1.14 I have myself raised concerns with various product manufacturers and the DCLG regarding interpretations of relevant test evidence and assessments over the years.

F1.1.15 I have also provided expert opinion in multiple remedial works disputes, since 2011, where I have required the fire safety construction to have been fire tested, or when assessed to be assessed against relevant fire tests. Again, I acknowledge my position has been strongly opposed in those disputes.

F1.1.16 The difference in opinion in industry has only deepened since the Grenfell fire. There has been much argument, very well publicised, regarding what the required performance of materials and products forming an external wall should be.

F1.1.17 The DCLG's decision to classify the core of an ACP panel as *Filler material*, and by means of this word categorise the core as an Insulating material/product, immediately after the Grenfell fire, has served to deepen this conflict.

F1.1.18 I do not agree with their interpretation and I have provided my analysis that has allowed me to draw this conclusion in this Appendix F.

F1.1.19 I have researched extensively on definitions for construction forms including rain screen cladding systems and how the word filler is applied.

F1.1.20 I present these definitions, as I have found them, in Section F6.4. I note no such definition has been provided, in the post-Grenfell clarification made by the DCLG on this subject.

F1.1.21 On reflection however, this difference, serves as a useful indicator of the current lack of clarity regarding the content of Section 12 of the ADB 2013, and particularly as it applies to an ACP rainscreen cladding panel. These panels are composite in nature; created in many forms with combustible polymeric material. It is substantially different from the classic brick/block cavity wall.

F1.1.22 Insulating core panels were provided with a specific clarification in ADB 2013, and this too is needed for ACP panel systems when used in a rainscreen cladding system. I note that insulating core panels were also installed throughout the external wall in the 2012-2016 refurbishment.

F1.1.23 Therefore, what is important now, is to remove any means for loose interpretation of fire safety requirements regarding external wall construction. This Appendix F has been written as a means of creating a detailed understanding of the requirement at the time of the Grenfell Tower Fire, and also to provide a basis for formulating future changes.

F1.2 Summary of Appendix F conclusions

F1.2.1 There is no definition of external surface, or filler in ADB 2013.

F1.2.2 There is no guidance on which standard takes precedence when differences in fire performance result between National Class and European Class, in meeting the provisions in ADB 2013.

F1.2.3 In terms of the performance of External Surfaces used above 18m. a material or the surface of a composite product can be either of:

a) Class 0: when composed throughout of materials of limited combustibility defined by testing to British Standards (by reference to Table A7 any test as per the National Class); or

b) Class 0: A Class 1 material which has a fire propagation index (I) of not more than 12 and sub-index (i1) less than 6, defined by testing to British Standards (by reference to Section 13b of Appendix B of ADB 2013); or

c) Class 0: composed throughout of materials of limited combustibility (A2) defined by testing to European Standards (by reference to Table A7 European classes); or

d) Class B: defined by testing using European Standards (by reference to Diagram 40 ADB 2013).

F1.2.4 Class B is not a material of limited combustibility (as defined in Table A7 of ADB 2013). However, it is currently an acceptable performance for an External Surface.

F1.2.5 Not all Class 1 materials with index (I) not more than 12 and sub-index (i1) less than 6 are materials of limited combustibility (refer to Section 13 of Appendix A of ADB 2013). However, it is currently an acceptable performance for an external surface.

F1.2.6 A Class B material can by its very definition never be a Class A2 (the limited combustibility Class stated in Table A7 of ADB 2013) material, yet it is currently an acceptable standard.

F1.2.7 Class 1 with index (I) less than12 and sub index (i1) less than 6 and Class B are of fundamentally different performance to either a National Class material of limited combustibility or a European Class material of limited combustibility.

F1.2.8 Using the National Class test methods as an example, and with reference to the explanations provided in BS 476 Part 10:2009, as follows:

a) A Class 1 material is classified using BS 476-7. This standard specifies a test method for determining the lateral spread of flame over the surface of an essentially flat material, composite or assembly.

b) A National Class material of limited combustibility is classified using: BS 476-4- this standard specifies a test method for determining whether building materials are non-combustible by measuring the temperature rise caused by heating of a specimen in a tubular furnace or observing the duration of any specimen flaming. And also using:

c) BS 476-11 - this standard specifies a method of test for assessing the heat emission from building materials in a furnace at a temperature of 750 ºC. The method is intended to be used for reasonably homogeneous materials. It may be used for non-homogeneous materials if it is possible to obtain a test specimen representative of the material as a whole.

F1.2.9 Additionally, materials which could achieve a Class 1 and I< 12 i1<6 ranking may not also achieve Class B or better when tested under the European Class framework. I provide an example of this when reviewing the thermal insulation installed in Grenfell Tower in Section 11 of my main report.

F1.2.10 The two classifications are not comparable because the testing for a Class B material is more onerous, than the testing for Class 1 when an Index (I) is less than 12 and Sub index (i1) less than 6, for an ACP panel. This because both the edges and surface of the material are exposed to direct heat in the European testing processes. I discuss this further in Section F6.6.

F1.2.11 The European test framework does not allow the surface only to be exposed to direct heat. The full composite product is exposed to direct heating instead

of just the outer layer. (Note in BS EN 13823 the burner is offset from the sample but the standard required that joints are included in the specimen which would therefore expose the edge of an ACM panel to heat).

F1.2.12 This is a fundamental difference in assessment, and this is particularly relevant to a composite product like ACP when it has a combustible core, and subject to the provisions of Diagram 40 of the ADB 2013.

F1.2.13 Regarding insulation materials and products. I have concluded these can be:

a) A material of limited combustibility defined by testing methods to National Class; or

b) A material of limited combustibility defined by testing methods to European Class.

F1.2.14 In general, a limited combustibility material tested to British Standards would also achieve limited combustibility to European Standards as the tests are very similar as discussed in Section F8.

F1.2.15 Insulation is not typically a composite product; except when part of an insulating core panel. These panels are the subject of specific guidance in ADB 2013 Appendix F. And I discuss this further in Section 11 of the main report. I think a distinction for composite external surfaces should also be made in the statutory guidance.

F1.2.16 I have concluded that *Filler* has a formal definition within the construction industry, and the composites industry. I have not been able to attribute the definitions I have found to the core material of an ACP panel.

F1.2.17 I carried out my assessment herein, as until the DCLG post- Grenfell Fire clarification, I had no prior professional experience of the core of an ACP system, being termed *Filler material* within the category of Insulation Product/Material in ADB 2013.

F1.2.18 The external surface, the insulation and the cavity barriers, are addressed in turn in Section 12 of the ADB 2013 (12.6, 12.7, and 12.8), and together form the External Wall construction. That has been my professional experience also.

F1.2.19 However, there is a more fundamental issue here regarding the fire performance of the core in a composite external surfaces, such as those found in rainscreen cladding systems formed with ACP.

F1.2.20 I have concluded in Appendix D that the that the legal requirement is to demonstrate compliance with the functional requirement of the Building Regulations 2010.

F1.2.21 It is my opinion having carried out this detailed review of the suite of test standards in Section F8, that in order to comply with the Building Regulations, I must consider the whole of the product which forms the external surface of the rain screen cladding panel system – and so the two layers of aluminium and the core (typically approx. 4mm thick in total). Otherwise the performance of the core is entirely omitted when considering the construction of the external walls.

F1.2.22 For the avoidance of doubt, I do not consider it possible to comply with the functional requirements of the Building Regulations B4 (1) if the relevant test evidence omits the core in an ACP rain screen cladding system, or the relevant test evidence is based on a test that does not expose the edges of the ACP to direct heat.

F1.2.23 I consider that an urgent change to Section 12 of ADB 2013 is needed, which I explain in Section 2 of my Expert Report.

F2 Structure of this Appendix

F2.1.1 In this Appendix, I set out the methods of testing materials to both European and National Class. As stated in BS 476:10: 2009 "*These tend to be the test methods that are used to demonstrate conformity to the requirements of regulations, e.g. the building regulations in the UK*".

F2.1.2 The provisions made in Section 12 of the ADB 2013 places restrictions on the reaction to fire of material in certain instances.

F2.1.3 This Appendix considers the provisions as relate to external fire spread, and therefore the material classification of interest relates to insulation and the external surface material in buildings greater than 18m.

F2.1.4 However, ADB 2013 does use the same classification processes, for other regulations such as B2 internal linings.

F2.1.5 I will first describe the relevant fire tests used to classify materials for use in the external wall construction of buildings.

F2.1.6 I will explain the provisions made for external wall surfaces and for insulation in ADB 2013.

F2.1.7 I will explain the sample sizes and sample types the relevant reaction to fire tests require; and in what are two distinct performance standards:

a) materials of limited combustibility (relevant to Section 12.7 of ADB 2013)

b) external wall surface provisions (relevant to Section 12.6 of ADB 2013)

F2.1.8 I will explain the National and European performance types and tests for those performance types.

F2.1.9 Finally, I will explain the overlap of testing requirements for these two distinct performance standards.

F2.1.10 The issue of the definition of an external wall surface as it relates to Filler is explored in Section F6.4.

F2.1.11 As a result, I have carried out an investigation of the materials that formed the building envelope at Grenfell Tower. The results of my investigation can be found in Section 8 of my main report. In Section 11 of my report, I have assessed those materials, using the evidence available to me regarding their compliance with the Building Regulations. I give my opinion on whether and how they comply with the Building Regulations.

F2.1.12 A crucial component in formulating that opinion is determining:

a) which materials are required to be of limited combustibility;

b) what an external surface is, and so which materials are required to comply with Diagram 40 of the Approved Document B.

F2.1.13 I have relied on the facts and opinions I express in this Appendix F, in carrying out my analysis of the materials forming the building envelop at Grenfell Tower.

F3 List of defined terms

F3.1.1 These following definitions are provided to assist in the reading of this Appendix only:

F3.1.2 **Non-combustible-** The highest level of reaction to fire performance. The relevant test criteria are set out in Appendix A paragraph 8 (ADB 2013 Appendix E).

F3.1.3 **Material of limited combustibility**- A material performance specification that includes non-combustible materials and for which the relevant criteria are set out in Appendix A, paragraph 9. (ADB 2013 Appendix E).

F3.1.4 **Composite**- A combination of materials which are generally recognised in building construction as discrete entities e.g. coated or laminated materials (BS 476-7:1997 Section 3.14).

F3.1.5 **Exposed surface(s)**- Surface(s) of the product subjected to the heating conditions of the test (BS 476-7:1997 Clause 3.1).

F3.1.6 **Surface -** The outside part or uppermost layer of something (Oxford English Dictionary).

F3.1.7 **Spread of flame**- Propagation of the flame front over the surface of the product under the influence of imposed irradiance (BS 476-7:1997 Clause 3.2).

F3.1.8 **Flame front**- Furthest extent of travel of a coherent flame along the reference line marked on the test specimen (BS 476-7:1997 Clause 3.3).

F3.1.9 **Irradiance (at a point on a surface)**- Total thermal radiant flux incident on an infinitesimal element of the surface containing the point, divided by the area of that element (BS 476-7:1997 Clause 3.4).

F3.1.10 **Sustained flaming**- Existence of flame on or over the surface of the specimen for periods of over 3s (BS 476-7:1997 Clause 3.8) or persistence of flame on or over a surface for a minimum period of time (BS EN 13823: 2010 Section 3.10) or persistence of flame for a period greater than 3s (BS EN ISO 11925-2:2010).

F3.1.11 **Material**- Single substance or uniformly dispersed mixture, e.g. metal, stone, timber, concrete, mineral fibre, polymers (BS 476-7:1997 Clause 3.10).

F3.1.12 **Product**- Material, composite or assembly about which information is required (BS 476-7:1997 Clause 3.11) (BS EN ISO 11925-2:2010).

F3.1.13 **PCS (Pouvoir Calorifique Supérieur)**- The gross heat of combustion which is the heat of combustion of a substance when the combustion is complete and any produced water is entirely condensed under specified conditions. (BS EN 13501-1 Clause 3.1.21).

F3.1.14 **Substrate**- Material used, or representative of that used immediately beneath a surface in end use; e.g. fibre cement board beneath a floor covering (BS 476-7:1997 Clause 3.12); or product which is used immediately beneath the product about which information is required (BS EN 13823: 2010 Clause 3.3).

F3.1.15 **Specimen**- Piece of product, which is to be tested. Note: This can include the mounting technique used in its end use application. This can also include an air gap and/ or a substrate where appropriate (BS EN 13823: 2010 Clause 3.2).

F3.1.16 **Lateral flame spread (LFS)**- Lateral flame spread on the long specimen wing (BS EN 13823: 2010 Clause 3.5).

F3.1.17 **Filler**- Coating material with a high proportion of extender intended primarily to even out irregularities in substrates to be painted and to improve surfaces (BS EN ISO 6707-1).

F3.1.18 **Filler, surface**- Composition for filling voids and undulations in a substrate to produce a smooth, even surface (BS 6100-6 Section 06 83015).

F3.1.19 **Filler, joint**- Jointing material or jointing section to fill to partly fill a joint gap (BS 6100-6 Section 06 73003).

F3.1.20 **Jointing product**- Product used to connect the components of a joint (BS EN ISO 6707-1 Clause 3.3.5.97).

F3.1.21 **Gasket, Cladding**- Flexible, preformed extrusion or moulded section that provides a seal between part of a structure and cladding or between adjacent cladding units (BS 6100-6 Section 06 22001).

F3.1.22 **Sealant**- Material applied in an unformed state which, once cured or dried, has the adhesive and cohesive properties to seal a joint (BS EN ISO 6707-1 Clause (3.4.4.35).

F3.1.23 **Seal**- Component fitted into a joint to prevent the passage of dust, moisture, and gases (BS EN ISO 6707-1 Clause 3.3.5.57).

F3.1.24 **Seal** (verb)- Action placing the appropriate products in the joint in order to prevent the penetration of water, moisture and or air between. elements, components and assembles made of the same or dissimilar materials (BS EN ISO 6707-1 Clause 3.5.1.19).

F3.1.25 **Cavity wall insulation material** thermal insulation material positioned in a cavity (BS 6100-6: 2008 clause 06 23030)

F3.1.26 **Full fill insulation** thermal insulation material that completely occupies the space between the leaves of a cavity wall (BS 6100-6: 2008 clause 06 23032)

F3.1.27 **Retrofit insulation** full fill insulation introduced after the construction of a wall (BS 6100-6: 2008 clause 06 06 23033)

F3.1.28 **Injected insulation** retrofit insulation in a foam state under pressure (BS 6100-6: 2008 clause 06 23034)

F3.1.29 **Blown insulation loose**-fill insulation that is applied or installed by means of compressed air (BS 6100-6: 2008 clause 06 23035)

F3.1.30 **Partial fill insulation material** preformed thermal insulation material fixed to one leaf of a cavity wall, retaining an air space (BS 6100-6: 2008 clause 06 23036)

F3.1.31 **Insulation blow hole-** hole in the leaf of a cavity wall for introducing blown insulation (BS 6100-6: 2008 clause 06 28006)

F3.1.32 **Insulation sight hole-** hole in the leaf of a cavity wall for checking that thermal insulation material has filled the cavity to that point (BS 6100-6: 2008 clause 06 28007)

F3.1.33 **Ventilated rainscreen**-System of cladding in which panels of sheet material are used to shield the majority of a wall from direct rainfall, combined with an air gap (cavity) and drainage system behind the panels. NOTE 1 The drainage

system is used to intercept and remove any water which penetrates the rain screen. Some or all of the joints between the panels are deliberately left open in order to ventilate the cavity. NOTE 2 The cavity can also incorporate an element of insulation, a vapour control layer and/or a breather layer (BS 8298-1 Clause 3.37).

F3.1.34 **Pressure-equalized rainscreen-**[1]- whereby open joints between the panels are combined with compartmentation of the cavity behind the panels to generate pressure in the cavity. This reduces the pressure difference across the joints and reduces both the amount of water ingress through those joints and the wind load on the cladding panels. The initial flow of air through the joints during the pressure equalization process can carry some fine water droplets through the joints, so drainage is needed. (BS 8298-1 Clause 3.27). Additionally, the BBA certificate 08/4510 states:

F3.1.35 Reynobond Architecture Wall Cladding Panels are flat aluminium composite panels comprising two 0.5 mm thick aluminium alloy sheets (EN AW-3005, H46 to BS EN 573-3: 2013) bonded to either side of a low-density polyethylene (LDPE) core.

F3.1.36 All three parts of the panel together form one composite rainscreen panel product. Where composite construction is defined as *"a form of construction made up of different materials that act monolithically, one of which is usually preformed"* (BS ISO 6707-1 Clause 3.3.5.7).

F3.1.37 The combined purpose of the three layers together is to act together as one product to shield the majority of a wall from direct rainfall as is the defined purpose of ventilated rainscreen panels in BS 8298-1 Clause 3.37.

F3.1.38 In addition to this the panel as a whole has to resist wind load in a ventilated rainscreen cladding system. This is stated in CWCT Technical note 77 Assessment and Certification of Rainscreen Systems as:

When a rainscreen wall is subject to wind load, the wind load may act on the rainscreen panels or the backing wall. Wind load acting on the rainscreen is often transferred to the structure through the backing wall but can be applied directly to the structural frame if the cladding rails are sufficiently robust to span between floors.

F3.1.39 When a wind load is applied, the whole panel will bend either toward the building or away from the building.

F3.1.40 This will result in one of the aluminium sheets being loaded in compression and the other side in tension. The PE core in the centre is required to transfer the shear force between the two sheets of aluminium i.e. integral to the structural performance of the panel.

[1] Note: A ventilated rainscreen was installed at Grenfell Tower as referenced in the NBS specification HAR00000872 item No. 120, not a pressure equalised rainscreen)

F4 Performance requirements and relevant test standards

F4.1 Building Regulations 2010 requirements

F4.1.1 Regulation 4 of the Building Regulations 2010 states:

"4. — (1) Subject to paragraph (2) building work shall be carried out so that—

(a) it complies with the applicable requirements contained in ***Schedule 1****; and*

(b) in complying with any such requirement there is no failure to comply with any other such requirement.

(2) Where—

(a) building work is of a kind described in regulation 3(1)(g), (h) or (i); and

(b) the carrying out of that work does not constitute a material alteration, that work need only comply with the applicable requirements of Part L of Schedule 1."

F4.1.2 Schedule 1, referenced in Building Regulation 4(1)(a), contains 16 *Parts* listed Part A to Part P. Part B is titled *Fire Safety*. Part B is subdivided into five *Requirements*. These are:

a) Means of Warning and Escape B1.

b) Internal fire spread (Linings) B2.

c) Internal fire spread (Structure) B3.

d) External fire spread (Structure) B4.

e) Access and facilities for the fire and rescue services B5

F4.1.3 *Requirement* B4 relates to external fire spread:

External fire spread

"B4(1) The external walls of the building shall adequately resist the spread of fire over the walls and from one building to another, having regard to height, use and position of the building

(2) The roof of the building shall adequately resist the spread of fire over the roof and from one building to another, having regard to the use and position of the building."

F4.2 Approved Document B 2013- General provisions

F4.2.1 ADB 2013 is an approved document that is issued by the Secretary of State to provide practical guidance on meeting the requirements of Building Regulations relevant to fire safety.

F4.2.2 ADB 2013 references and uses National BS 476 classifications and European Class to specify the minimum level of fire performance of elements of construction, within its recommendations.

F4.2.3 Page 92 of ADB 2013 states:

"In the secretary of state's view, the requirements of B4 will be met:

a) If the external walls are constructed so that the risk of ignition from an external source and the spread of fire over their surfaces, is restricted, by making provision for them to have low rates of heat release"

F4.2.4 Section B4. ii of ADB 2013 states:

"Provisions are made in Section 12 for the fire resistance of external walls and to limit the susceptibility of the external surface of walls to ignition and to fire spread"

F4.2.5 Section 12.2 of ADB 2013 states:

"Provisions are also made to restrict the combustibility of external walls of building that are less than 1000mm from the relevant boundary and, irrespective of boundary distance, the external walls of high rise buildings and those of the Assembly and Recreation purpose groups. This is in order to reduce the surface's susceptibility to ignition from an external source and to reduce the danger from fire spread up the external face of the building"

F4.2.6 Section 12.5 of ADB 2013 states:

"The external wall of a building should not provide a medium for fire spread if it is likely to be a risk to health or safety. The use of combustible materials in the cladding system and extensive cavities may present such a risk in tall buildings.

External walls should either meet the guidance given in paragraphs 12.6 to 12.9 or meet the performance criteria given the BRE Report Fire performance of external thermal insulation for walls of multi-storey buildings (BR 135) for cladding systems using full scale data from BS 8414-1:2002 or BS 8414-2:2005.

The total amount of combustible material may also be limited in practice by the provisions for space separation in Section 13 (see paragraph 13.7 onwards)."

F4.2.7 The provisions made for the performance of the external was as specified in Section 12.6-12.9 of ADB 2013 are reviewed below.

F4.3 ADB 2013 Section 12.6 - External wall surface classifications

F4.3.1 Section 12.6 of ADB 2013 2013 states:

"The external surfaces of walls should meet the provisions of Diagram 40."

F4.3.2 Diagram 40 of ADB 2013 2013 is shown below in Figure F.1.

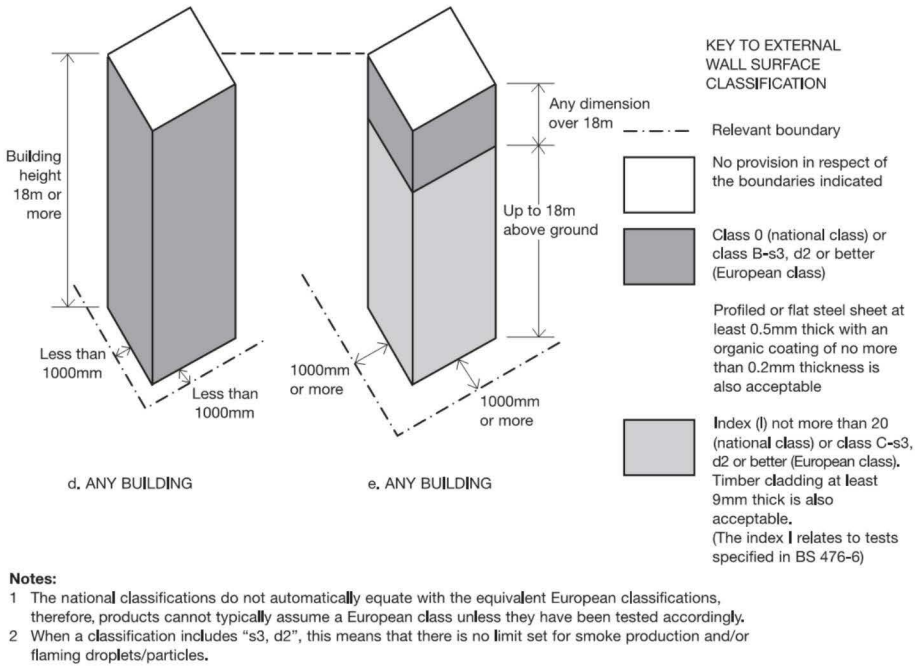

Figure F.1: Diagram 40 of ADB 2013

F4.3.3 Note 1 of ADB 2013 Diagram 40 states:

"The National Class do not automatically equate with the equivalent European Class, therefore, products cannot typically assume a European class unless they have been tested accordingly"

F4.3.4 European Class can equate to National Class (namely Non-combustible in Table A6 of ADB 2013 2013 and limited combustibility in Table A7 of ADB 2013 2013). However as per Note 1 National Class cannot be used to demonstrate a European Class.

F4.3.5 Table F-1 below summarises the provisions made through Diagram 40 of ADB 2013 2013. I explain the various classifications for Class 0 in Section F5, as there is more than one in ADB 2013.

Table F-1: Provisions for external Walls and Surfaces Diagram 40 of ADB 2013

Height of cladding above ground level	National material classification	European material classification
Any dimension over 18m	Class 0 (limited combustibility to BS 476-4 or BS 476-11 or BS 476-6 and BS 476-7 together)	Class B-s3, d2 or better (tested to one or more of BS EN ISO 1182, BS EN ISO 1716; BS EN 13823; BS EN ISO 11925-2 as required by BS EN 13501-1)
Up to 18m above ground level	Index (I) not more than 20 (to BS 476-6 only)	Class C-s3, d2 or better (tested to one or more of BS EN ISO 1182, BS EN ISO 1716; BS EN 13823; BS EN ISO 11925-2 as required by BS EN 13501-1)

F4.4 Section 12.7 of ADB 2013- Insulation materials/products – provisions for limited combustibility

F4.4.1 The provisions made for Insulation Materials/Products is stated in Section 12.7 of ADB 2013 as:

"12.7 In a building with a storey 18m or more above ground level any insulation product, filler material (not including gaskets, sealants and similar) etc. used in the external wall construction should be of ***limited combustibility*** *(see Appendix A). This restriction does not apply to masonry cavity wall construction which complies with Diagram 34 in Section 9."*

F4.4.2 *"Materials of limited combustibility"* is defined in Appendix A in ADB 2013. Limited combustibility is obtained based on the results of one or more tests to either British or European Standards as specified by Table A7 of ADB 2013. It should be noted that Table A7 also lists *"Non-combustible"* materials (as defined in Table A6 of ADB 2013) as *"materials of limited combustibility"*.

F4.5 Section 12.8 and 12.9 of ADB 2013 - Cavity Barriers

F4.5.1 Concealed spaces or cavities in the construction of a building provide a ready route for smoke and flame spread. BR135 advises *"If fire enters a void in the system, whether that void is created by a fire or is part of the design, and the insulation is exposed to the fire source, any combustible material present may become involved, and there is potential for the fire to propagate throughout the system if adequate fire barriers are not installed."*

F4.5.2 Section 12.8 of ADB 2013 states:

"Cavity barriers should be provided in accordance with Section 9"

F4.5.3 Section 9.2 of ADB 2013 states:

F4.5.4 *Provisions for cavity barriers are given below for specified locations. The provisions necessary to restrict the spread of smoke and flames through cavities are broadly for the purpose of sub-dividing:*

F4.5.5 *a. cavities, which could otherwise form a pathway around a fire-separating element and closing the edges of cavities; therefore, reducing the potential for unseen fire spread; and*

F4.5.6 *Note: These should not be confused with fire-stopping details, see Section 10 and Diagram 33 (see also paragraphs 9.3 to 9.7).*

F4.5.7 *b. extensive cavities (see paragraphs 9.8 to 9.12).*

F4.5.8 *Consideration should also be given to the construction and fixing of cavity barriers provided for these purposes and the extent to which openings in them should be protected. For guidance on these issues, see paragraphs 9.13 to 9.16 respectively.*

F4.5.9 **Pathways around fire separating elements and closing edges of cavities**

F4.5.10 Diagram 33 of ADB 2013 shows where cavity barriers are required to prevent fire and smoke spread around fire separating elements. I have shown this in Figure F.2

F4.5.11 Cavity barriers are therefore required to close the top of the cavity; close around openings in the external wall; and at the junction of fire resisting elements and the external wall.

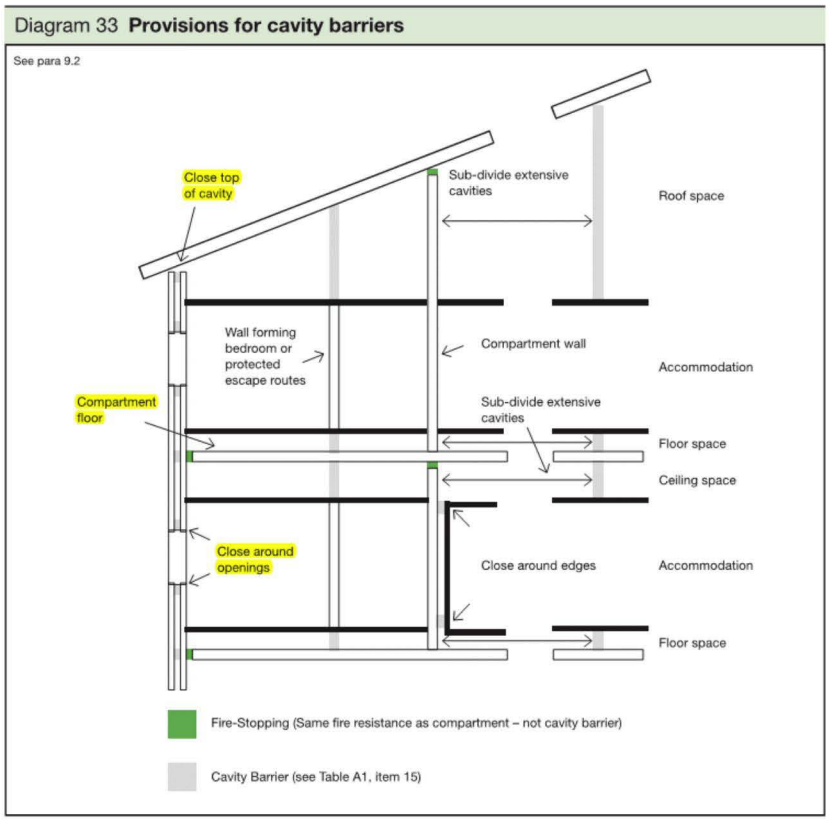

Figure F.2 Diagram 33 from ADB 2013

F4.5.12 The top of the external wall cavity for Grenfell Tower is highlighted with a dashed red line in Figure F.3

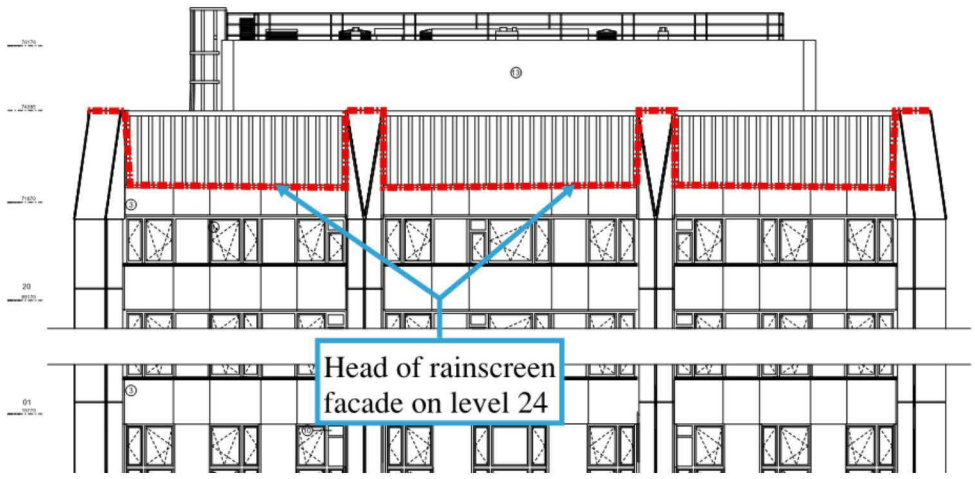

Figure F.3 Elevation of Grenfell tower- Top of external wall cavity indicated with red dashed line

F4.5.13 It should be noted that the recommendation of the statutory guidance to provide these cavity barriers is not affected by the reaction to fire properties of materials in the cavity unlike the cavity barriers required to subdivide cavities discussed in F4.5.14.

F4.5.14 **Subdivision of extensive cavities**

F4.5.15 Section 9.8 of ADB 2013 states:

F4.5.16 *"Cavity barriers should be used to subdivide any cavity, including any roof space so that the distance between cavity barriers does not exceed the dimensions given in Table 13."*

F4.5.17 The dimension in Table 13 are either 10 m or 20m dependant on the reaction to fire properties of materials exposed in the cavity.

F4.5.18 It should be noted that Table 13 states that it only applies to Purpose Groups 2-7. This does not include flats which are Purpose Group 1a in accordance with Appendix D of ADB 2013. The residential parts of the building from level 03-23 therefore would not have had to meet the cavity barrier spacing in Table 13 but would have had to comply with Diagram 33 for the provision of cavity barriers to prevent pathways around fire separating elements and closing edges of cavities.

F4.5.19 Levels ground to level 2, contain the boxing club, nursery and two community rooms which are assembly and recreation which is purpose group 5.

F4.5.20 Table 13 of ADB 2013 therefore applies only to Ground, level 1, and level 2. The provisions of Table 13 do not therefore apply from level 3 to level 24.

F4.5.21 **Construction of cavity barriers**

F4.5.22 Section 9.13 to 19.6 of ADB 2013 provides performance standards for the Construction and fitting of cavity barriers.

F4.5.23 Section 9.13 of ADB 2013 states:

F4.5.24 *"Every cavity barrier should be constructed to provide at least 30 minutes' fire resistance. It may be formed by any construction provided for another purpose is it meets the provision of cavity barriers (See Appendix A, Table A1, item 15)"*

F4.5.25 Appendix A, Table A1, item 15 of ADB 2013 states cavity barriers should achieve 30 minutes integrity and 15 minutes insulation to either the relevant part of BS 476 or the relevant European standard. This performance is required from each side separately.

F4.5.26 Integrity and insulation are defined in BS476-20 as follows:

F4.5.27 **Integrity**-*the ability of a specimen of a separating element to contain a fire to specified criteria for collapse, freedom from holes, cracks and fissures and sustained flaming on the unexposed face* (BS 476-20:1987 clause 2.9).

F4.5.28 **Insulation**-*the ability of a specimen of a separating element to restrict the temperature rise of the unexposed face to below specified levels* (BS 476-20:1987 clause 2.8).

F4.6 ADB 2013 Section 12.5- Alternative means of compliance using BR 135

F4.6.1 The provisions made in Section 12.5 in ADB 2013, when using BR135, is addressed in Appendix E and I will not therefore reproduce it here.

F4.7 Tests referenced by ADB 2013 to determine the reaction to fire of materials

F4.7.1 The classifications referenced in Sections 12.6 to 12.9 of ADB 2013 are obtained based on the results of one or more tests.

F4.7.2 The relevant standard tests applicable in the UK for testing combustibility and surface spread of flame of materials that have been reviewed within this Appendix are as follows:

a) British Standards

i. BS 476-4:1970-*Fire tests on building materials and structures. Non-combustibility test for materials*

ii. BS 476-6:1989-*Fire tests on building materials and structures. Method of test for fire propagation for products*

iii. BS 476-7:1997 *Fire tests on building materials and structures. Method of test to determine the classification of the surface spread of flame of products*

iv. BS 476-11:1982 *Fire tests on building materials and structures. Method for assessing the heat emission from building materials*

b) European Standards

i. BS EN ISO 1182:2002 Reaction to fire tests for building products. Non-combustibility test

ii. BS EN ISO 1716:2002 Reaction to fire tests for building products. Determination of the heat of combustion

iii. BS EN 13823: 2010 Reaction to fire tests for building products - Building products excluding floorings exposed to the thermal attack by a single burning item (+A1:2014)

iv. BS EN ISO 11925-2:2010 *Reaction to fire tests - ignitability of products subjected to direct impingement of flame. Single-flame source test*

F4.7.3 Appendix A of ADB 2013 provides guidance on the performance of materials, products and structures and the tests required to demonstrate such performance.

F4.7.4 Section 8 of Appendix A of ADB 2013 states:

"Non-combustible materials are defined in Table A6 either as listed products, or in terms of performance:

*a. (National classes) when tested to **BS 476-4:1970** Non-combustibility test for materials or **BS 476-11:1982** Method for assessing the heat emission from building products; or*

*b. (European classes) when classified as class A1 in accordance with **BS EN 13501-1:2007**, Fire classification of construction products and building elements, Part 1-Classification using data from reaction to fire tests when tested to **BS EN ISO 1182:2002**, Reaction to fire tests for building products – Non-combustibility test and **BS EN ISO 1716:2002** Reaction to fire tests for building products – Determination of the gross calorific value.*

Table A6 identifies non-combustible products and materials and lists circumstances where their use is necessary."

F4.7.5 Section 9 of Appendix A of ADB 2013 states

"Materials of limited combustibility are defined in Table A7:

a. *(National classes) by reference to the method specified in **BS 476: Part 11:1982**; or*

b. *(European classes) in terms of performance when classified as class **A2-s3, d2** in accordance with **BS EN 13501-1:2007**, Fire classification of construction products and building elements, Part 1 – Classification using data from reaction to fire tests when tested to **BS EN ISO 1182:2002**, Reaction to fire tests for building products – Non-combustibility test or **BS EN ISO 1716:2002** Reaction to fire tests for building products – Determination of the gross calorific value and **BS EN 13823:2002**, Reaction to fire tests for building products – Building products excluding floorings exposed to the thermal attack by a single burning item.*

Table A7 also includes composite products (such as plasterboard) which are considered acceptable and where these are exposed as linings they should also meet any appropriate fame spread rating."

F4.7.6 Section 10 of Appendix A of ADB 2013 states:

"Flame spread over wall or ceiling surfaces is controlled by providing for the lining materials or products to meet given performance levels in tests appropriate to the materials or products involved."

F4.7.7 Section 11 of Appendix A of ADB 2013 states:

"Under the National Class, lining systems which can be effectively tested for 'surface spread of flame' are rated for performance by reference to the

method specified in BS 476-7:1971 Surface spread of flame tests for materials or 1987 method of classification of the surface spread of flame of products, or 1997 method of test to determine the classification of the surface spread of flame of products under which materials or products are classified 1, 2, 3 or 4 with class 1 being the highest

Under the European Class lining systems are classified in accordance with BS EN 13501-1:2007, Fire classification of construction products and building elements, Part 1- classification using data from reaction to fire tests. Materials or products are classified as A1, A2, B, C, D, E, or F, with A1 being the highest. When a classification includes "s3, d2", it means that there is no limit set for smoke production and/or flaming droplets/ particles."

F4.7.8 Section 12 of Appendix A of ADB 2013 states:

"To restrict the use if materials which ignite easily, which have a high rate of heat release rate and/ or which reduce the time to flashover, maximum acceptable 'fire propagation' indexes are specified where the national tests methods are being followed. These are determined by reference to the method specified in BS 476-6:1981 or 1989 Method of test for fire propagation of products. Index of performance (I) relates to the overall test performance, whereas sub-index (i1) us derived from the first three minutes of test."

F4.7.9 The reaction to fire tests referenced by Appendix a Section 11 for determining a European Class are described in Appendix A Section 7 Reaction to fire of ADB 2013:

"All products, excluding floorings, are classified as A1, A2, B, C, D, E or F (with class A1 being the highest performance and F being the lowest) in accordance with Appendix A.4.2 of BS EN 13501-1:2007

The relevant European test methods are specified as follows

> *BS EN ISO 1182:2002, Reaction to fire tests for building products – Non-combustibility test.*
>
> *BS EN ISO 1716:2002, Reaction to fire tests for building products – Determination of the gross calorific value.*
>
> *BS EN 13823:2002, Reaction to fire tests for building products – Building products excluding floorings exposed to the thermal attack by a single burning item.*
>
> *BS EN ISO 11925-2:2002, Reaction to fire tests for building Products, Part 2 – Ignitability when subjected to direct impingement of a fame.*
>
> *BS EN 13238:2001, Reaction to fire tests for building products – conditioning procedures and general rules for selection of substrates."*

F4.7.10 The test results to establish the European Class (to the tests referenced in F3.2.21 of this Appendix) are stated in Table 1 of BS EN 13501-1, shown below in Figure F.4.

Table 1 — Classes of reaction to fire performance for construction products excluding floorings and linear pipe thermal insulation products

Class	Test method(s)	Classification criteria	Additional classification
A1	EN ISO 1182 [a] and	$\Delta T \leq 30$ °C; and $\Delta m \leq 50$ %; and $t_f = 0$ (i.e. no sustained flaming)	-
	EN ISO 1716	$PCS \leq 2{,}0$ MJ/kg [a] and $PCS \leq 2{,}0$ MJ/kg [b c] and $PCS \leq 1{,}4$ MJ/m^2 [d] and $PCS \leq 2{,}0$ MJ/kg [e]	-
A2	EN ISO 1182 [a] or	$\Delta T \leq 50$ °C; and $\Delta m \leq 50$ %; and $t_f \leq 20$ s	-
	EN ISO 1716 and	$PCS \leq 3{,}0$ MJ/kg [a] and $PCS \leq 4{,}0$ MJ/m^2 [b] and $PCS \leq 4{,}0$ MJ/m^2 [d] and $PCS \leq 3{,}0$ MJ/kg [e]	-
	EN 13823	$FIGRA \leq 120$ W/s and $LFS <$ edge of specimen and $THR_{600s} \leq 7{,}5$ MJ	Smoke production [f] and Flaming droplets/particles [g]
B	EN 13823 and	$FIGRA \leq 120$ W/s and $LFS <$ edge of specimen and $THR_{600s} \leq 7{,}5$ MJ	Smoke production [f] and Flaming droplets/particles [g]
	EN ISO 11925-2 [f]: Exposure = 30 s	$F_s \leq 150$ mm within 60 s	
C	EN 13823 and	$FIGRA \leq 250$ W/s and $LFS <$ edge of specimen and $THR_{600s} \leq 15$ MJ	Smoke production [f] and Flaming droplets/particles [g]
	EN ISO 11925-2 [f]: Exposure = 30 s	$F_s \leq 150$mm within 60 s	
D	EN 13823 and	$FIGRA \leq 750$ W/s	Smoke production [f] and Flaming droplets/particles [g]
	EN ISO 11925-2 [f]: Exposure = 30 s	$F_s \leq 150$ mm within 60 s	
E	EN ISO 11925-2 [f]: Exposure = 15 s	$F_s \leq 150$ mm within 20 s	Flaming droplets/particles [h]
F	No performance determined		

[a] For homogeneous products and substantial components of non-homogeneous products.
[b] For any external non-substantial component of non-homogeneous products.
[c] Alternatively, any external non-substantial component having a $PCS \leq 2{,}0$ MJ/m^2, provided that the product satisfies the following criteria of EN 13823: $FIGRA \leq 20$ W/s, and $LFS <$ edge of specimen, and $THR_{600s} \leq 4{,}0$ MJ, and s1, and d0.
[d] For any internal non-substantial component of non-homogeneous products.
[e] For the product as a whole.
[f] In the last phase of the development of the test procedure, modifications of the smoke measurement system have been introduced, the effect of which needs further investigation. This may result in a modification of the limit values and/or parameters for the evaluation of the smoke production.
s1 = $SMOGRA \leq 30$m^2/s^2 and $TSP_{600s} \leq 50$m^2 ; **s2** = $SMOGRA \leq 180$m^2/s^2 and $TSP_{600s} \leq 200$m^2; **s3** = not s1 or s2
[g] **d0** = No flaming droplets/ particles in EN 13823 within 600 s;
d1 = no flaming droplets/ particles persisting longer than 10 s in EN 13823 within 600 s;
d2 = not d0 or d1.
Ignition of the paper in EN ISO 11925-2 results in a d2 classification.
[h] Pass = no ignition of the paper (no classification);
Fail = ignition of the paper (**d2** classification).
[i] Under conditions of surface flame attack and, if appropriate to the end–use application of the product, edge flame attack.

Figure F.4 Test results requirements to classify a material to BS EN 13501-1

F4.7.11 Descriptions of the tests referenced in Figure F.4 are provided in Section F7 of this Appendix.

F4.7.12 The British Standard "*Guide to the principles, selection, role and application of fire testing and their outputs*" BS 476-10:2009; also provides useful definitions and explanations, upon which I have relied, in writing my Appendix F.

F4.8 Definition of Non-combustible materials

F4.8.1 Section 8 of Appendix A of ADB 2013 states:

"Non-combustible materials are defined in Table A6 either as listed products, or in terms of performance:

*a. (National classes) when tested to **BS 476-4:1970** Non-combustibility test for materials or **BS 476-11:1982** Method for assessing the heat emission from building products; or*

*b. (European classes) when classified as class A1 in accordance with **BS EN 13501-1:2007**, Fire classification of construction products and building elements, Part 1-Classification using data from reaction to fire tests when tested to **BS EN ISO 1182:2002**, Reaction to fire tests for building products – Non-combustibility test and **BS EN ISO 1716:2002** Reaction to fire tests for building products – Determination of the gross calorific value.*

Table A6 identifies non-combustible products and materials and lists circumstances where their use is necessary."

F4.8.2 Table A6 of ADB 2013 is provided in Figure F.5.

Table A6 **Use and definitions of non-combustible materials**

References in AD B guidance to situations where such materials should be used	Definitions of non-combustible materials	
	National class	European class
1. refuse chutes meeting the provisions in the guidance to B3, paragraph 8.34c. 2. suspended ceilings and their supports where there is provision in the guidance to B3, paragraph 9.12, for them to be constructed of non-combustible materials. 3. pipes meeting the provisions in the guidance to B3, Table 14. 4. flue walls meeting the provisions in the guidance to B3, Diagram 39. 5. construction forming car parks referred to in the guidance to B3, paragraph 11.3.	a. Any material which when tested to BS 476-11:1982 does not flame nor cause any rise in temperature on either the centre (specimen) or furnace thermocouples b. Totally inorganic materials such as concrete, fired clay, ceramics, metals, plaster and masonry containing not more than 1% by weight or volume of organic material. (Use in buildings of combustible metals such as magnesium/aluminium alloys should be assessed in each individual case). c. Concrete bricks or blocks meeting BS EN 771-3:2003 d. Products classified as non-combustible under BS 476-4:1970	a. Any material classified as class A1 in accordance with BS EN 13501-1:2007 *Fire classification of construction products and building elements*, Part 1 – *Classification using data from reaction to fire tests*. b. Products made from one or more of the materials considered as Class A1 without the need for testing as defined in Commission Decision 2003/424/EC of 6th June 2003 amending Decision 96/603/EC establishing the list of products belonging to Classes A1 "No contribution to fire" provided for in the Decision 94/611/EC implementing Article 20 of the Council Directive 89/106/EEC on construction products. None of the materials shall contain more than 1% by weight or volume (whichever is the more onerous) of homogeneously distributed organic material.

Note:
The National classifications do not automatically equate with the equivalent classifications in the European column, therefore products cannot typically assume a European class unless they have been tested accordingly.

Figure F.5:Table A6 of ADB 2013

F4.8.3 There are therefore four methods of demonstrating non-combustible (a, b, c and d in Table A6) to National Class and two methods of demonstrating non-combustible to European Class ('a' and 'b') in Table A6 of ADB 2013.

F4.8.4 Descriptions of the Test Standard BS 476-4 and BS 476-11 referenced in Table A6 are provided in Sections F7.2.1 and F7.2.11 of this Appendix respectively.

F4.8.5 It should be noted that the current version of BS 476-11 states that the standard has been superseded by BS EN ISO 1182.

F4.8.6 Decision 96/603/EC lists 28 types of materials which can be considered Class A1 without the need for testing (under certain limitations).

F4.9 Definition of limited combustibility

F4.9.1 Limited combustibility is the National Class performance for insulation in buildings with a storey at greater than 18m in accordance with ADB 2013 Section 12.7.

F4.9.2 Section 9 of Appendix A of ADB 2013 states

"Materials of limited combustibility are defined in Table A7:

*c. (National classes) by reference to the method specified in **BS 476: Part 11:1982**; or*

*d. (European classes) in terms of performance when classified as class **A2-s3, d2** in accordance with **BS EN 13501-1:2007**, Fire classification of construction products and building elements, Part 1 – Classification using data from reaction to fire tests when tested to **BS EN ISO 1182:2002**, Reaction to fire tests for building products – Non-combustibility test or **BS EN ISO 1716:2002** Reaction to fire tests for building products – Determination of the gross calorific value and **BS EN 13823:2002**, Reaction to fire tests for building products – Building products excluding floorings exposed to the thermal attack by a single burning item.*

Table A7 also includes composite products (such as plasterboard) which are considered acceptable and where these are exposed as linings they should also meet any appropriate fame spread rating."

F4.9.3 Table A7 is provided below in Figure F.6 for reference:

Table A7 **Use and definitions of materials of limited combustibility**

References in AD B guidance to situations where such materials should be used	Definitions of materials of limited combustibility	
	National class	European class
1. stairs where there is provision in the guidance to B1 for them to be constructed of materials of limited combustibility (see 5.19).	a. Any non-combustible material listed in Table A6.	a. Any material listed in Table A6. b. Any material/product classified as Class A2-s3, d2 or better in accordance with BS EN 13501-1:2007 *Fire classification of construction products and building elements*, Part 1 – *Classification using data from reaction to fire tests*.
2. materials above a suspended ceiling meeting the provisions in the guidance to B3, paragraph 9.12.	b. Any material of density 300/kg/m' or more, which when tested to BS 476-11:1982, does not flame and the rise in temperature on the furnace thermocouple is not more than 20°C.	
3. reinforcement/support for fire-stopping referred to in the guidance to B3, see 10.18.	c. Any material with a non-combustible core at least 8mm thick having combustible facings (on one or both sides) not more than 0.5mm thick. (Where a flame spread rating is specified, these materials must also meet the appropriate test requirements).	
4. roof coverings meeting provisions: a. in the guidance to B3, paragraph 8.29; or b. in the guidance to B4, Table 16 or c. in the guidance to B4, Diagram 47. 5. roof deck meeting the provisions of the guidance to B3, Diagram 30a. 6. class 0 materials meeting the provisions in Appendix A, paragraph 13(a). 7. ceiling tiles or panels of any fire protecting suspended ceiling (Type Z) in Table A3.		
8. insulation material in external wall construction referred to in paragraph 12.7. 9. insulation above any fire-protecting suspended ceiling (Type Z) in Table A3.	Any of the materials (a), (b) or (c) above, or: d. Any material of density less than 300kg/m³, which when tested to BS 476-11:1982, does not flame for more than 10 seconds and the rise in temperature on the centre (specimen) thermocouple is not more than 35°C and on the furnace thermocouple is not more than 25°C.	Any of the materials/products (a) or (b) above.

Note:

1. The National classifications do not automatically equate with the equivalent classifications in the European column; therefore, products cannot typically assume a European class unless they have been tested accordingly.
2. When a classification includes "s3, d2", this means that there is no limit set for smoke production and/or flaming droplets/particles.

Figure F.6: ADB 2013 Table A7

F4.9.4 There are therefore four methods of demonstrating limited combustibility to National Class (a, b, c, and d noting that method d. is only applicable to insulation) and two methods of demonstrating limited combustibility to European class ('a' and 'b') in Table A7 of ADB 2013

F4.9.5 Option 'b' of the European column lists class A2 to BS EN 13501-1 as a means of demonstrating limited combustibility. It should be noted that BS EN 13501-1 lists two methods of demonstrating class A2. This is either by using the results from BS EN ISO 1182; or the combined results from BS EN 1716 and BS EN 13823.

F4.9.6 Option 'a' of Table A7 for both National Class and European Class both reference any material listed in Table A6.

F4.9.7 When all of the methods of demonstrating non-combustible classification (i.e. Table A7 option 'a' are included with the two methods of demonstrating Class A2 there are therefore seven methods of demonstrating limited combustibility to National Class and four methods of demonstrating limited combustibility to European class.

F4.10 Definition of *Class 0*

F4.10.1 Section 13 of Appendix A of ADB 2013 states:

"The highest national product performance classification for lining materials is Class 0. This is achieved if a material ***or the surface of a composite product*** *is either:*

a. Composed ***throughout*** *of materials of limited combustibility*

b. A Class 1 material which has a fire propagation index of not more than 12 and a sub-index (i1) of not more than 6"

F4.10.2 As I have explained in F4.9.7 there are seven methods of demonstrating *limited combustibility* to National Class and four methods of demonstrating limited combustibility to European Class. However, it should be noted that National Class option 'd' in Table A7 states that it is only relevant to insulation material in the external cavity wall referred to in Section 12.7 of ADB 2013 (see item '8' in Table A7). This method of demonstrating limited combustibility is therefore not relevant to the external surface performance standards of Section 12.6 or Diagram 40 of ADB 2013.

F4.10.3 There are therefore ten methods (6 national and 4 European methods) of demonstrating Class 0 either to National Class or European Class under Appendix A - Section 13a of ADB 2013, with one additional method given under Appendix A Section 13b (using BS 476-6 and BS 476-7).

F4.10.4 I have therefore identified 11 methods of demonstrating Class 0 in accordance with ADB 2013 which are relevant to Section 12.6 of ADB 2013.

F4.10.5 I note here that ADB 2013 does not provide a definition as to what constitutes a surface. This is discussed further in Section F6.4.

F4.10.6 Appendix A Section 9 of ADB 2013, states "*Composite products defined as materials of limited combustibility should in addition comply with the test requirement appropriate to any surface rating specified in the guidance on requirements B2, B3 and B4*." I have incorporated this in my review of the insulating core panels installed at Grenfell Tower.

F4.11 Definition of Index I not more than 20

F4.11.1 'Index I not more than 20' is the National Class performance for external surfaces with a dimension up to 18m where the height of the building is greater than 18m in accordance with Diagram 40.

F4.11.2 'Index I not more than 20' is a specific result obtained by testing a material to BS 476-6.

F4.11.3 There is no other method to demonstrate that a material's I index value is less than 20. ADB 2013 does not state a list of materials deemed to achieve I<20. Even if a material was classified as non-combustible it could not be stated as

achieving I<20 without the material having been specifically tested to BS 476-6.

F4.11.4 It should be noted however that one of the three ways of demonstrating Class 0 is testing a material to BS 476-7 and BS 476-6.

F4.11.5 Demonstrating Class 0 using BS 476-6 requires is I is less than 12 and i_1 is less than 6. This is different.

F4.11.6 However, a Class 0 material tested using this methodology would also be compliant for use as the external surface material up to 18m, as it is a higher performance than Index I not more than 20.

F4.11.7 There are therefore two means of demonstrating Index I not more than 20 to National Class as Class 0 when tested to BS 476-6 and BS 467-7, as per Section 13b of Appendix A of ADB 2013 also achieves this.

F4.12 Definition of Class B-s3, d2 or better

F4.12.1 Class B-s3, d2 or better is the European class performance for the external surface material of any dimension of a building greater than 18m above ground level in accordance with Diagram 40 of ADB 2013.

F4.12.2 Note 2 of ADB 2013 Diagram 40 states *"When a classification includes "s3, d2", this means that there is no limit set for smoke production and/or flaming droplets/ particles."*

F4.12.3 As per Table 1 of BS EN 13501-1, Class B-s3, d2 or better is: Class A1, Class A2, or Class B.

F4.12.4 There is one method of demonstrating Class A1; two methods of demonstrating Class A2; and one method of demonstrating Class B in accordance with BS EN 13501-1 Table 1.

F4.12.5 Additionally, a material can be deemed to be a nominal Class A1 without testing pursuant to Commission decision 96/603/EC, as amended, as referenced in the introduction section of BS EN 13501-1.

F4.12.6 There are therefore five ways to demonstrate Class B in accordance with ADB 2013.

F4.13 Definition of Class C-s3, d2 or better

F4.13.1 Class C-s3, d2 or better is the European Class performance for the external surface material of any dimension of a building less than 18m above ground level in accordance with Diagram 40 of ADB 2013.

F4.13.2 In addition to the methods of demonstrating Class A1, A2 and B (see above), there is one method of demonstrating Class C in accordance with BS EN 13501-1 Table 1.

F4.13.3 There are therefore six ways to demonstrate Class C or better in accordance with ADB 2013.

F4.14 Equivalence of National and European classes: External Surfaces

F4.14.1 Note 1 to Diagram 40 in ADB 2013 states:

"National Class do not automatically equate with the equivalent classifications in the European column; therefore, products cannot typically assume a European class unless they have been tested accordingly."

F4.14.2 This is repeated in Note 1 to Table A6 and Table A7 in ADB 2013.

F4.14.3 European Class can however be used to demonstrate certain the National classes, as I explain below.

F4.14.4 Combustible and Limited Combustibility are both National Class defined in Table A6 and Table A7 of ADB 2013 respectively.

F4.14.5 Both Table A6 and Table A7 of ADB 2013 also provide European Class methods to demonstrate either Non-combustible or Limited Combustibility, as shown in Figure F.7 and Figure F.8.

PERFORMANCE OF MATERIALS, PRODUCTS AND STRUCTURES **B**

Table A6 **Use and definitions of non-combustible materials**

References in AD B guidance to situations where such materials should be used	Definitions of non-combustible materials	
	National class	European class
1. refuse chutes meeting the provisions in the guidance to B3, paragraph 8.34c. 2. suspended ceilings and their supports where there is provision in the guidance to B3, paragraph 9.12, for them to be constructed of non-combustible materials. 3. pipes meeting the provisions in the guidance to B3, Table 14. 4. flue walls meeting the provisions in the guidance to B3, Diagram 39. 5. construction forming car parks referred to in the guidance to B3, paragraph 11.3.	a. Any material which when tested to BS 476-11:1982 does not flame nor cause any rise in temperature on either the centre (specimen) or furnace thermocouples b. Totally inorganic materials such as concrete, fired clay, ceramics, metals, plaster and masonry containing not more than 1% by weight or volume of organic material. (Use in buildings of combustible metals such as magnesium/aluminium alloys should be assessed in each individual case). c. Concrete bricks or blocks meeting BS EN 771-3:2003 d. Products classified as non-combustible under BS 476-4:1970	a. Any material classified as class A1 in accordance with BS EN 13501-1:2007 *Fire classification of construction products and building elements*, Part 1 – *Classification using data from reaction to fire tests*. b. Products made from one or more of the materials considered as Class A1 without the need for testing as defined in Commission Decision 2003/424/EC of 6th June 2003 amending Decision 96/603/EC establishing the list of products belonging to Classes A1 "No contribution to fire" provided for in the Decision 94/611/EC implementing Article 20 of the Council Directive 89/106/EEC on construction products. None of the materials shall contain more than 1% by weight or volume (whichever is the more onerous) of homogeneously distributed organic material.

Note:

The National classifications do not automatically equate with the equivalent classifications in the European column, therefore products cannot typically assume a European class unless they have been tested accordingly.

Figure F.7: Table A6 of ADB 2013 (European Class methods indicated with the orange box)

Table A7 Use and definitions of materials of limited combustibility

References in AD B guidance to situations where such materials should be used	Definitions of materials of limited combustibility	
	National class	European class
1. stairs where there is provision in the guidance to B1 for them to be constructed of materials of limited combustibility (see 5.19).	a. Any non-combustible material listed in Table A6.	a. Any material listed in Table A6. b. Any material/product classified as Class A2-s3, d2 or better in accordance with BS EN 13501-1:2007 *Fire classification of construction products and building elements*, Part 1 – *Classification using data from reaction to fire tests.*
2. materials above a suspended ceiling meeting the provisions in the guidance to B3, paragraph 9.12.	b. Any material of density 300/kg/m' or more, which when tested to BS 476-11:1982, does not flame and the rise in temperature on the furnace thermocouple is not more than 20°C.	
3. reinforcement/support for fire-stopping referred to in the guidance to B3, see 10.18.	c. Any material with a non-combustible core at least 8mm thick having combustible facings (on one or both sides) not more than 0.5mm thick. (Where a flame spread rating is specified, these materials must also meet the appropriate test requirements).	
4. roof coverings meeting provisions: a. in the guidance to B3, paragraph 8.29; or b. in the guidance to B4, Table 16 or c. in the guidance to B4, Diagram 47.		
5. roof deck meeting the provisions of the guidance to B3, Diagram 30a.		
6. class 0 materials meeting the provisions in Appendix A, paragraph 13(a).		
7. ceiling tiles or panels of any fire protecting suspended ceiling (Type Z) in Table A3.		
8. insulation material in external wall construction referred to in paragraph 12.7. 9. insulation above any fire-protecting suspended ceiling (Type Z) in Table A3.	Any of the materials (a), (b) or (c) above, or: d. Any material of density less than 300kg/m^3, which when tested to BS 476-11:1982, does not flame for more than 10 seconds and the rise in temperature on the centre (specimen) thermocouple is not more than 35°C and on the furnace thermocouple is not more than 25°C.	Any of the materials/products (a) or (b) above.

Note:

1. The National classifications do not automatically equate with the equivalent classifications in the European column; therefore, products cannot typically assume a European class unless they have been tested accordingly.
2. When a classification includes "s3, d2", this means that there is no limit set for smoke production and/or flaming droplets/particles.

Figure F.8: Table A7 of ADB 2013 (European Class methods indicated with the orange box)

F4.14.6 Section 13a of Appendix A of ADB 2013 states that one method of demonstrating Class 0 is: "*if a material or the surface of a composite product is composed throughout of materials of limited combustibility*."

F4.14.7 The National Class of Class 0 can therefore be demonstrated by achieving class A2 or better (i.e. limited combustibility) as shown in Figure F.7 for a material or for the surface of a composite product to the European Class methodology.

F4.14.8 However, there are **also** British Standards to demonstrate Limited Combustibility.

F4.14.9 In general terms, a surface of a composite product should achieve either the relevant British or European Class.

F4.14.10 However, a problem arises because of the two other allowable categories in ADB 2013 Diagram 40.

F4.14.11 The first difficulty arises with the second definition of Class 0 in Appendix A section 13b:" a *Class 1 material which has a fire propagation index (I) of not more than 12 and sub-index (i1) of not more than 6."*

F4.14.12 A significant number of materials could pass the criteria set by Appendix A 13b of ADB 2013 by means of Class 1, but not pass a European standard test for limited combustibility to an A2 standard, and hence not be classified as Class 0 by means of ADB 2013 Appendix A Section 13a.

F4.14.13 The second difficulty arises with the Class B category: Class B is not a European material of limited combustibility, which must be the higher category of Class A2.

F4.14.14 Class B is also unlikely to be a British material of limited combustibility. The European test for Class A2 which is limited combustibility to Table A7 of ADB 2013 (BS EN ISO 1182) is very similar to the national Standard for limited combustibility (BS 476-11) to the point that the current edition of BS 476-11 states that it has been superseded by the current BS EN ISO 1182. I explain this further in SectionF8.

F4.14.15 If a material can only achieve Class B and not Class A2 it is unlikely that it would achieve limited combustibility to the British standards also.

F4.14.16 I explain the test set up for each of the tests referred to herein, in Section F6. I rely on the differences in how the materials are tested in giving my opinion about the likelihood of pass/fail referred to above, and my knowledge of the test evidence submitted to the Public Inquiry.

F4.15 Equivalence of National and European classes: Insulation material/products

F4.15.1 ADB 2013 Section 12.7 requires insulation material in buildings greater than 18m to be Limited Combustibility.

F4.15.2 As I have explained above, limited combustibility is defined as Class A2 or better in Table A7 of ADB 2013.

F4.15.3 One method of attaining this classification is using the test standard BS EN ISO 1182.

F4.15.4 The national standard test specific to Limited Combustibility only (i.e. not non-combustible and hence limited combustibility) is BS 476-11:1982.

F4.15.5 As I have explained above, part of the European test for Class A2 (BS EN ISO 1182) is very similar to the national Standard for limited combustibility (BS 476-11) such that the current version of BS 476-11 states that it has been superseded by BS EN ISO 1182 (see Section F4.8.5).

F4.15.6 I therefore conclude that there is no significant difference between materials tested to and achieving Limited Combustibility to European and National tests.

F4.15.7 An insulation material/product facing into a cavity, in non-residential building, must comply with Section 12.8 and Section 12.7. For Section 12.8 this means its surface performance as well as its insulation performance must be classified.

F4.15.8 Therefore, where an insulation has a Class 0 classification: if the insulation material has been tested to BS 476-4, BS 476-11 or BS EN ISO 1182, as required for material of limited combustibility and it was classified as class 0 via section 13a of Appendix A of ADB 2013, it can indeed be both.

F4.15.9 If the insulation has been subjected to the surface tests only (BS 476-6 and BS 476-7), and has not been tested to BS 476-4, BS 476-11 or BS EN IO 1182, it cannot be both.

F5 Summary of methods of classification of materials to ADB 2013

F5.1 Overview

F5.1.1 In summary, in Section F4 I explained that there are multiple methods in the National framework and again in the European framework for classifying materials as either Class A1, A2, Class B, Class C, Class 0, Index I is less than 20, or better. All of these are relevant to the provisions made in Section 12.6 and 12.7 of the ADB 2013.

F5.1.2 I note that certain methods can be used to demonstrate more than one type of performance classification. For example, all Non-Combustible materials can also be categorised as Materials of Limited Combustibility and as Class 0, by means of the definitions provided in Table A6, Table A7, and Appendix A 13a of the ADB 2013.

F5.1.3 All Limited Combustibility products tested to British Standards, or Limited Combustibility products tested to European standards, can be classified as Class 0, by means of the definitions provided in Appendix A 13a / Table A7 of ADB 2013.

F5.1.4 All A1 materials can be classified as Non-Combustible, Limited Combustibility and Class 0, by means of the definitions provided in Table A6/ Table A7/Section 13a of Appendix A of ADB 2013.

F5.1.5 All A2 materials can be classified as Limited Combustibility and Class 0, by means of the definitions provided in Table A6/ Table A7/Section13a of Appendix A of ADB 2013.

F5.1.6 A Class B material cannot be a Non-Combustible material, of Limited Combustibility or a Class 0 material, as it does not meet the definitions in Table A6/ Table A7/Section 13a of Appendix A of ADB 2013.

F5.1.7 However, a Class B material is permitted to be used as an external surface under Diagram 40 in ADB 2013.

F5.1.8 In my opinion, bearing in mind the performance stated in a. on Page 92 of ADB 2013 is "*external walls are constructed so that the risk of ignition from an external source and the spread of fire over their surfaces, is restricted, by making provision for them to have low rates of heat release*", Diagram 40 provides contradictory advice on the fire performance of external surfaces.

F5.1.9 This is because a material can be tested using either the National or European framework. It is possible that a material could achieve the required fire performance of Diagram 40 to the National Class but not achieve the stated European Class.

F5.2 Summary Table of test requirements

F5.2.1 The following Section in my report, lists out all the test requirements, as I have found through my review of ADB 2013, which are relied upon to demonstrate the performance of materials, or products used in external walls.

F5.2.2 I have separated my findings into National Class (Table F-2) and European Class (Table F-3).

F5.2.3 A reference has been provided demonstrating where each of the methods has been obtained from in brackets under the description of the method.

F5.2.4 The numbering of the National and European Class has been created for this Appendix only - to allow each of the methods of compliance of ADB 2013 to be referenced separately throughout this Appendix F.

F5.2.5 Column 1 lists all of the nine methods in the National framework and lists the six methods in the European framework, for classifying materials as either Class 0, Index I is less than 20; Class C or better or Class B or better; all of which are directly relevant to achieving compliance with Section 12.6 and 12.7 of the ADB 2013 in my opinion.

F5.2.6 Columns 2, 3, 4, 5, 6, and 7 state whether a given method could achieve a given classification. For example, if a material was tested using National Class Method 8 and achieved the required performance criteria, the material could be classified as Class 0 or Index I is less than 20 therefore could be used as cladding above and below 18m. The material would however not be classified as Non-combustible or Limited Combustibility therefore the product could not be used as insulation in buildings above 18m unless further testing was carried out.

F5.2.7 Columns 8- 17 list all of the National Standard tests referenced by ADB 2013.

F5.2.8 The required test result to demonstrate that a material achieves a given classification is highlighted in blue in Columns 8- 17 of for National Class. Where a cell is not highlighted no result is required for that test.

F5.2.9 For, example National Class Method 1 can be used to demonstrate the material is Non-combustible, of Limited Combustibility and Class 0 by testing the material to BS 476-11: 1992 only and achieving Flame duration (s) of 0s; a rise in furnace thermocouple temperature of 0°C; and a rise in specimen thermocouple temperature of 0°C.

F5.2.10 The National Classification 1 can be used to demonstrate the material is Non-combustible, of Limited Combustibility and Class 0; whereas National Classification 5 can only be used to demonstrate Limited Combustibility and Class 0.

F5.2.11 National Class Method 5 uses the same test standard as National Classification Method 1(BS 476-11) but sets a lower standard of a rise in specimen thermocouple temperature of 20°C and no limit is set on the rise of the furnace thermocouple.

F5.2.12 It should be noted that while Limited Combustibility, Class 0, Class B or better or Class C or better can be demonstrated using multiple methods, Index I is a specific result to BS 476-6. BS 476-6 is the only way that Index I and sub index i1 can be measured.

F5.2.13 I have applied the same methodology to derive all the European Class results also.

F5.2.14 My only intention here is show the complexity of the reaction to fire testing system.

Table F-2: Test result requirements for British Classification methods (Blue cells indicate a required result from a given test)

							Material combustibility tests									Surface spread of flame test	
		Insulation performance provisions of ADB 2013	External surface performance provisions of ADB 2013				BS 476-11:1982			BS 476-4:1970		BS 476-6:1970			BS 476-7:1997	
Classification Method	Method can be used to demonstrate Noncombustible (as defined in Table A6 of ADB 2013)	Method can be used to demonstrate Limited combustibility (ADB 2013 Clause 12.7 National Class requirement for insulation products in buildings with the height to any storey greater than 18m)	Method can be used to demonstrate Class 0 (ADB 2013 Diagram 40 National Class requirement for external surface materials at any dimension of a building greater than 18m where the building height is greater than 18m)	Method can be used to demonstrate Index (I) not more than 20 (ADB 2013 Diagram 40 National Class requirement for external surface materials at any dimension of a building less than 18m where the building height is greater than 18m) (note can only be demonstrated by testing to BS 476-6)	Method can be used to demonstrate Class B-S3, d2 or better (ADB 2013 Diagram 40 European Class requirement for external surface materials at any dimension of a building greater than 18m where the building height is greater than 18m)	Method can be used to demonstrate Class C-S3, d2 or better (ADB 2013 Diagram 40 European Class requirement for external surface materials at any dimension of a building less than 18m where the building height is greater than 18m)	Flame duration (s)	Rise in furnace thermocouple temperature (°C)	Rise in specimen thermocouple temperature (°C)	Temperature rise (°C)	Flame duration (s)	Fire Propagation index (I)	Sub index (i1)	Minimum Density (kg/m^3)	Spread of flame at 1.5-minute limit (mm)	Final spread of flame limit (mm)
National Classification Method 1 Any material which when tested to BS 476-11:1982 does not flame nor cause any rise in temperature on either the centre (specimen) or furnace thermocouples (Table A6 ADB 2013)	Yes	Yes	Yes (Clause 13a)	No	No	No	0	0	0							
National Classification Method 2 Totally inorganic materials such as concrete, fired clay, ceramics, metals, plaster and masonry containing not more than 1% by weight or volume of organic material. (Use in buildings of combustible metals such as magnesium/aluminium alloys should be assessed in each individual case). (Table A6 ADB 2013)	Yes	Yes	Yes (Clause 13a)	No	No	No										

							Material combustibility tests								Surface spread of flame test	
		Insulation performance provisions of ADB 2013	External surface performance provisions of ADB 2013				BS 476-11:1982			BS 476-4:1970		BS 476-6:1970			BS 476-7:1997	
Classification Method	Method can be used to demonstrate Noncombustible (as defined in Table A6 of ADB 2013)	Method can be used to demonstrate Limited combustibility (ADB 2013 Clause 12.7 National Class requirement for insulation products in buildings with the height to any storey greater than 18m)	Method can be used to demonstrate Class 0 (ADB 2013 Diagram 40 National Class requirement for external surface materials at any dimension of a building greater than 18m where the building height is greater than 18m)	Method can be used to demonstrate Index (I) not more than 20 (ADB 2013 Diagram 40 National Class requirement for external surface materials at any dimension of a building less than 18m where the building height is greater than 18m) (note can only be demonstrated by testing to BS 476-6)	Method can be used to demonstrate Class B-S3, d2 or better (ADB 2013 Diagram 40 European Class requirement for external surface materials at any dimension of a building greater than 18m where the building height is greater than 18m)	Method can be used to demonstrate Class C-S3, d2 or better (ADB 2013 Diagram 40 European Class requirement for external surface materials at any dimension of a building less than 18m where the building height is greater than 18m)	Flame duration (s)	Rise in furnace thermocouple temperature (°C)	Rise in specimen thermocouple temperature (°C)	Temperature rise (°C)	Flame duration (s)	Fire Propagation index (I)	Sub index (i1)	Minimum Density (kg/m^3)	Spread of flame at 1.5-minute limit (mm)	Final spread of flame limit (mm)
National Classification Method 3 Concrete bricks or blocks meeting BS EN 771-3:2003 (Table A6 ADB 2013)	Yes	Yes	Yes (Clause 13a)	No	No	No										
National Classification Method 4 Products classified as non-combustible under BS 476-4:1970 (Table A6 ADB 2013)	Yes	Yes	Yes (Clause 13a)	No	No	No				50	10					
National Classification Method 5 Any material of density 300/kg/m' or more, which when tested to BS 476-11:1982, does not flame and the rise in temperature on the furnace thermocouple is not more than 20ºC (Table A7 ADB 2013)	No	Yes	Yes (Clause 13a)	No	No	No	0		20					>300		

							Material combustibility tests								Surface spread of flame test	
		Insulation performance provisions of ADB 2013	External surface performance provisions of ADB 2013				BS 476-11:1982			BS 476-4:1970		BS 476-6:1970			BS 476-7:1997	
Classification Method	Method can be used to demonstrate Noncombustible (as defined in Table A6 of ADB 2013)	Method can be used to demonstrate Limited combustibility (ADB 2013 Clause 12.7 National Class requirement for insulation products in buildings with the height to any storey greater than 18m)	Method can be used to demonstrate Class 0 (ADB 2013 Diagram 40 National Class requirement for external surface materials at any dimension of a building greater than 18m where the building height is greater than 18m)	Method can be used to demonstrate Index (I) not more than 20 (ADB 2013 Diagram 40 National Class requirement for external surface materials at any dimension of a building less than 18m where the building height is greater than 18m) (note can only be demonstrated by testing to BS 476-6)	Method can be used to demonstrate Class B-S3, d2 or better (ADB 2013 Diagram 40 European Class requirement for external surface materials at any dimension of a building greater than 18m where the building height is greater than 18m)	Method can be used to demonstrate Class C-S3, d2 or better (ADB 2013 Diagram 40 European Class requirement for external surface materials at any dimension of a building less than 18m where the building height is greater than 18m)	Flame duration (s)	Rise in furnace thermocouple temperature (°C)	Rise in specimen thermocouple temperature (°C)	Temperature rise (°C)	Flame duration (s)	Fire Propagation index (I)	Sub index (i1)	Minimum Density (kg/m^3)	Spread of flame at 1.5-minute limit (mm)	Final spread of flame limit (mm)
National Classification Method 6 Any material with a non-combustible core at least 8mm thick having combustible facings (on one or both sides) not more than 0.5mm thick. (Where a flame spread rating is specified, these materials must also meet the appropriate test requirements) (Table A7 ADB 2013)	No	Yes	Yes (Clause 13a)	No	No	No										
National Classification Method 7 Any material of density less than 300kg/m3, which when tested to BS 476-11:1982, does not flame for more than 10 seconds and the rise in temperature on the centre (specimen) thermocouple is not more than 35°C and on the furnace thermocouple is not more than 25ºC. **(Insulation only as per table A6)** (Table A7 ADB 2013)	No	Yes	No (although this is a method of demonstrating limited combustibility it explicitly states this method only applies to clause 12.7)	No	No	No	10	25	35					<300		

							Material combustibility tests								Surface spread of flame test	
		Insulation performance provisions of ADB 2013	External surface performance provisions of ADB 2013				BS 476-11:1982			BS 476-4:1970		BS 476-6:1970			BS 476-7:1997	
Classification Method	Method can be used to demonstrate Noncombustible (as defined in Table A6 of ADB 2013)	Method can be used to demonstrate Limited combustibility (ADB 2013 Clause 12.7 National Class requirement for insulation products in buildings with the height to any storey greater than 18m)	Method can be used to demonstrate Class 0 (ADB 2013 Diagram 40 National Class requirement for external surface materials at any dimension of a building greater than 18m where the building height is greater than 18m)	Method can be used to demonstrate Index (I) not more than 20 (ADB 2013 Diagram 40 National Class requirement for external surface materials at any dimension of a building less than 18m where the building height is greater than 18m) (note can only be demonstrated by testing to BS 476-6)	Method can be used to demonstrate Class B-S3, d2 or better (ADB 2013 Diagram 40 European Class requirement for external surface materials at any dimension of a building greater than 18m where the building height is greater than 18m)	Method can be used to demonstrate Class C-S3, d2 or better (ADB 2013 Diagram 40 European Class requirement for external surface materials at any dimension of a building less than 18m where the building height is greater than 18m)	Flame duration (s)	Rise in furnace thermocouple temperature (°C)	Rise in specimen thermocouple temperature (°C)	Temperature rise (°C)	Flame duration (s)	Fire Propagation index (I)	Sub index (i1)	Minimum Density (kg/m^3)	Spread of flame at 1.5-minute limit (mm)	Final spread of flame limit (mm)
National Classification Method 8 A Class 1 material which has a fire propagation index (I) of not more than 12 and sub-index (i1) of not more than 6. (Clause 13b of Appendix A of ADB 2013)	No	No	Yes (Clause 13b)	Yes	No	No						12	6		165	165
National Classification Method 9 Index (I) not more than 20 (Diagram 40 of ADB 2013/ Clause 12 of Appendix A of ADB 2013)	No	No	No	Yes	No	No						20				
National Classification Method 10 Class 1 material (note if a class 1product achieves I<12 and i1 <6 to BS 476-6 then can be classified as class 1) (Clause 11 of Appendix A of ADB 2013)	No	No	No	No	No	No									165	165

							Material combustibility tests								Surface spread of flame test	
		Insulation performance provisions of ADB 2013	External surface performance provisions of ADB 2013				BS 476-11:1982			BS 476-4:1970		BS 476-6:1970			BS 476-7:1997	
Classification Method	Method can be used to demonstrate Noncombustible (as defined in Table A6 of ADB 2013)	Method can be used to demonstrate Limited combustibility (ADB 2013 Clause 12.7 National Class requirement for insulation products in buildings with the height to any storey greater than 18m)	Method can be used to demonstrate Class 0 (ADB 2013 Diagram 40 National Class requirement for external surface materials at any dimension of a building greater than 18m where the building height is greater than 18m)	Method can be used to demonstrate Index (I) not more than 20 (ADB 2013 Diagram 40 National Class requirement for external surface materials at any dimension of a building less than 18m where the building height is greater than 18m) (note can only be demonstrated by testing to BS 476-6)	Method can be used to demonstrate Class B-S3, d2 or better (ADB 2013 Diagram 40 European Class requirement for external surface materials at any dimension of a building greater than 18m where the building height is greater than 18m)	Method can be used to demonstrate Class C-S3, d2 or better (ADB 2013 Diagram 40 European Class requirement for external surface materials at any dimension of a building less than 18m where the building height is greater than 18m)	Flame duration (s)	Rise in furnace thermocouple temperature (°C)	Rise in specimen thermocouple temperature (°C)	Temperature rise (°C)	Flame duration (s)	Fire Propagation index (I)	Sub index (i1)	Minimum Density (kg/m^3)	Spread of flame at 1.5-minute limit (mm)	Final spread of flame limit (mm)
National Classification Method 11 Class 2 material (Clause 11 of Appendix A of ADB 2013)	No	No	No	No	No	No									215	455
National Classification Method 12 Class 3 material (Clause 11 of Appendix A of ADB 2013)	No	No	No	No	No	No									265	710
National Classification Method 13 Class 4 material (Clause 11 of Appendix A of ADB 2013)	No	No	No	No	No	No	No performance determined	No performance determined	No performance determined	No performance determined	No performance determined	No performance determined	No performance determined	No performance determined	No performance determined	No performance determined

Table F-3: European Class methods- required test results (Blue cells indicate a required result from a given test)

							Material combustibility tests				Hybrid test			Surface spread of flame test	
		Insulation performance provisions of ADB 2013	External surface performance provisions of ADB 2013				EN ISO 1182			EN ISO 1716	BS EN 13823			EN ISO 11925-2 (30s exposure)	EN ISO 11925-2 (15s exposure)
Classification Method	Method can be used to demonstrate Noncombustible (as defined in Table A6 of ADB 2013)	Method can be used to demonstrate Limited combustibility (ADB 2013 Clause 12.7 National Class requirement for insulation products in buildings with the height to any storey greater than 18m)	Method can be used to demonstrate Class 0 (ADB 2013 Diagram 40 National Class requirement for external surface materials at any dimension of a building greater than 18m where the building height is greater than 18m)	Method can be used to demonstrate Index (I) not more than 20 (ADB 2013 Diagram 40 National Class requirement for external surface materials at any dimension of a building less than 18m where the building height is greater than 18m) (note can only be demonstrated by testing to BS 476-6)	Method can be used to demonstrate Class B-S3, d2 or better (ADB 2013 Diagram 40 European Class requirement for external surface materials at any dimension of a building greater than 18m where the building height is greater than 18m)	Method can be used to demonstrate Class C-S3, d2 or better (ADB 2013 Diagram 40 European Class requirement for external surface materials at any dimension of a building less than 18m where the building height is greater than 18m)	Rise is temperature (ΔT)(°C)	Change in mass(ΔM) (%)	Duration of sustained flaming (Tf) (s)	Pouvoir Calorifique Supérieur (Gross heat of combustion) (PCS) (MJ/kg)	Average growth rate of the heat release rate of the material after the fire source is switched from the auxiliary burner to the primary burner measured twice after the total heat release rate exceeds 0.2MJ and 0.4MJ respectively) (FIGRA) (W/s)	Lateral flame spread (LFS)	Total heat release from the specimen in the first 600s of exposure to the main (primary) burner flame (i.e. 300s<t<900s) (THR 600s) (MJ)	Flame Spread (Fs) (within 60s) (mm)	Flame Spread (Fs) (within 20s) (mm)
European Classification Method 1 Class A1 to BS EN 13501-1 using evidence from BS EN ISO 1182 &BS EN ISO 1716 (Table A6 ADB 2013 and Table 1 of BS EN 13501-1)	Yes	Yes	Yes (Clause 13a)	No	Yes	Yes	30	50	0	2					
European Classification Method 2 Products made from one or more of the materials considered as Class A1 without the need for testing as defined in Commission Decision 2003/424/EC of 6th June 2003 (Table A6 ADB 2013)	Yes	Yes	Yes (Clause 13a)	No	Yes	Yes									

							Material combustibility tests				Hybrid test			Surface spread of flame test	
		Insulation performance provisions of ADB 2013	External surface performance provisions of ADB 2013				EN ISO 1182			EN ISO 1716	BS EN 13823			EN ISO 11925-2 (30s exposure)	EN ISO 11925-2 (15s exposure)
Classification Method	Method can be used to demonstrate Noncombustible (as defined in Table A6 of ADB 2013)	Method can be used to demonstrate Limited combustibility (ADB 2013 Clause 12.7 National Class requirement for insulation products in buildings with the height to any storey greater than 18m)	Method can be used to demonstrate Class 0 (ADB 2013 Diagram 40 National Class requirement for external surface materials at any dimension of a building greater than 18m where the building height is greater than 18m)	Method can be used to demonstrate Index (I) not more than 20 (ADB 2013 Diagram 40 National Class requirement for external surface materials at any dimension of a building less than 18m where the building height is greater than 18m) (note can only be demonstrated by testing to BS 476-6)	Method can be used to demonstrate Class B-S3, d2 or better (ADB 2013 Diagram 40 European Class requirement for external surface materials at any dimension of a building greater than 18m where the building height is greater than 18m)	Method can be used to demonstrate Class C-S3, d2 or better (ADB 2013 Diagram 40 European Class requirement for external surface materials at any dimension of a building less than 18m where the building height is greater than 18m)	Rise is temperature (D T)(°C)	Change in mass(D M) (%)	Duration of sustained flaming (Tf) (s)	Pouvoir Calorifique Supérieur (Gross heat of combustion) (PCS) (MJ/kg)	Average growth rate of the heat release rate of the material after the fire source is switched from the auxiliary burner to the primary burner measured twice after the total heat release rate exceeds 0.2MJ and 0.4MJ respectively) (FIGRA) (W/s)	Lateral flame spread (LFS)	Total heat release from the specimen in the first 600s of exposure to the main (primary) burner flame (i.e. 300s<t<900s) (THR 600s) (MJ)	Flame Spread (Fs) (within 60s) (mm)	Flame Spread (Fs) (within 20s) (mm)
European Classification Method 3 Class A2 to BS EN 13501-1 using evidence from BS EN ISO 1182 (Table A7 of ADB 2013/Clause 7 of Appendix A of ADB 2013/ Table 1 of BS EN 13501-1)	No	Yes	Yes (Clause 13a)	No	Yes	Yes	50	50	20						
European Classification Method 4 Class A2 to BS EN 13501-1 using evidence from BS EN ISO 1716 and BS EN 13823 (Table A7 of ADB 2013/Clause 7 of Appendix A of ADB 2013 / Table 1 of BS EN 13501-1)	No	Yes	Yes (Clause 13a)	No	Yes	Yes				3	120	< Edge of specimen	7.5		
European Classification Method 5 Class B to BS EN 13501-1 using BS EN 13823 and BS EN ISO 11925-2 (Clause 7 of Appendix A of ADB 2013/ Table 1 of BS EN 13501-1)	No	No	No	No	Yes	Yes					120	< Edge of specimen	7.5	150	

							Material combustibility tests				Hybrid test			Surface spread of flame test	
		Insulation performance provisions of ADB 2013	External surface performance provisions of ADB 2013				EN ISO 1182			EN ISO 1716	BS EN 13823			EN ISO 11925-2 (30s exposure)	EN ISO 11925-2 (15s exposure)
Classification Method	Method can be used to demonstrate Noncombustible (as defined in Table A6 of ADB 2013)	Method can be used to demonstrate Limited combustibility (ADB 2013 Clause 12.7 National Class requirement for insulation products in buildings with the height to any storey greater than 18m)	Method can be used to demonstrate Class 0 (ADB 2013 Diagram 40 National Class requirement for external surface materials at any dimension of a building greater than 18m where the building height is greater than 18m)	Method can be used to demonstrate Index (I) not more than 20 (ADB 2013 Diagram 40 National Class requirement for external surface materials at any dimension of a building less than 18m where the building height is greater than 18m) (note can only be demonstrated by testing to BS 476-6)	Method can be used to demonstrate Class B-S3, d2 or better (ADB 2013 Diagram 40 European Class requirement for external surface materials at any dimension of a building greater than 18m where the building height is greater than 18m)	Method can be used to demonstrate Class C-S3, d2 or better (ADB 2013 Diagram 40 European Class requirement for external surface materials at any dimension of a building less than 18m where the building height is greater than 18m)	Rise is temperature (ΔT)(°C)	Change in mass(ΔM) (%)	Duration of sustained flaming (Tf) (s)	Pouvoir Calorifique Supérieur (Gross heat of combustion) (PCS) (MJ/kg)	Average growth rate of the heat release rate of the material after the fire source is switched from the auxiliary burner to the primary burner measured twice after the total heat release rate exceeds 0.2MJ and 0.4MJ respectively) (FIGRA) (W/s)	Lateral flame spread (LFS)	Total heat release from the specimen in the first 600s of exposure to the main (primary) burner flame (i.e. 300s<t<900s) (THR 600s) (MJ)	Flame Spread (Fs) (within 60s) (mm)	Flame Spread (Fs) (within 20s) (mm)
European Classification Method 6 Class C to BS EN 13501-1 using BS EN 13823 and BS EN ISO 11925-2 (Clause 7 of Appendix A of ADB 2013)	No	No	No	No	No	Yes					250	< Edge of specimen	15	150	
European Classification Method 7 Class D to BS EN 13501-1 using BS EN 13823 and BS EN ISO 11925-2 (Clause 7 of Appendix A of ADB 2013 / Table 1 of BS EN 13501-1)	No	No	No	No	No	No					750			150	
European Classification Method 8 Class E to BS EN 13501-1 using BS EN 13823 and BS EN ISO 11925-2 (Clause 7 of Appendix A of ADB 2013/ Table 1 of BS EN 13501-1)	No	No	No	No	No	No									150

							Material combustibility tests				Hybrid test			Surface spread of flame test	
		Insulation performance provisions of ADB 2013	External surface performance provisions of ADB 2013				EN ISO 1182			EN ISO 1716	BS EN 13823			EN ISO 11925-2 (30s exposure)	EN ISO 11925-2 (15s exposure)
Classification Method	Method can be used to demonstrate Noncombustible (as defined in Table A6 of ADB 2013)	Method can be used to demonstrate Limited combustibility (ADB 2013 Clause 12.7 National Class requirement for insulation products in buildings with the height to any storey greater than 18m)	Method can be used to demonstrate Class 0 (ADB 2013 Diagram 40 National Class requirement for external surface materials at any dimension of a building greater than 18m where the building height is greater than 18m)	Method can be used to demonstrate Index (I) not more than 20 (ADB 2013 Diagram 40 National Class requirement for external surface materials at any dimension of a building less than 18m where the building height is greater than 18m) (note can only be demonstrated by testing to BS 476-6)	Method can be used to demonstrate Class B-S3, d2 or better (ADB 2013 Diagram 40 European Class requirement for external surface materials at any dimension of a building greater than 18m where the building height is greater than 18m)	Method can be used to demonstrate Class C-S3, d2 or better (ADB 2013 Diagram 40 European Class requirement for external surface materials at any dimension of a building less than 18m where the building height is greater than 18m)	Rise is temperature (D T)(°C)	Change in mass(D M) (%)	Duration of sustained flaming (Tf) (s)	Pouvoir Calorifique Supérieur (Gross heat of combustion) (PCS) (MJ/kg)	Average growth rate of the heat release rate of the material after the fire source is switched from the auxiliary burner to the primary burner measured twice after the total heat release rate exceeds 0.2MJ and 0.4MJ respectively) (FIGRA) (W/s)	Lateral flame spread (LFS)	Total heat release from the specimen in the first 600s of exposure to the main (primary) burner flame (i.e. 300s<t<900s) (THR 600s) (MJ)	Flame Spread (Fs) (within 60s) (mm)	Flame Spread (Fs) (within 20s) (mm)
European Classification Method 9 Class F to BS EN 13501-1- no declared performance (Clause 7 of Appendix A of ADB 2013/ Table 1 of BS EN 13501-1)	No	No	No	No	No	No	No performance determined	No performance determined	No performance determined	No performance determined	No performance determined	No performance determined	No performance determined	No performance determined	No performance determined

F5.2.15 The methods I have identified and presented in Table and have been summarised in Table F-4, Table F-5 and Table F-6.

F5.2.16 Therefore, it is important to note the level of complexity involved when considering the compliance methods for external surfaces and for insulation products/materials.

F5.2.17 I provide further supporting information in Section F6.

Table F-4: Summary of methods of compliance specific to insulation in the external wall construction of building greater than 18m

		Applicable methods of demonstrating compliance with clause 12.7 of ADB 2013		
Relevant to	**ADB 2013 clause 12.7 material performance provision**	**National Classification methods which can be used to demonstrate compliance with clause 12.7 of ADB 2013**	**European Classification methods which can be used to demonstrate compliance with clause 12.7 of ADB 2013**	**Total numbers of ADB 2013 compliant methods**
Compliance of insulation in buildings with a story greater than 18m with ADB 2013 Section 12.7	**Limited Combustibility**	National Class Method 1 National Class Method 2 National Class Method 3 National Class Method 4 National Class Method 5 National Class Method 6 National Class Method 7	European Class Method 1 European Class Method 2 European Class Method 3 European Class Method 4	11

Table F-5 Summary of methods of compliance specific to the cladding of the external wall construction of building greater than 18m forany dimension above 18m

		Applicable methods of demonstrating compliance with clause 12.6/ Diagram 40 of ADB 2013 of ADB 2013 of external surface materials at any dimension of a building greater than 18m (where the building height is greater than 18m)		
Relevant to	**ADB 2013 section 12.6/ diagram 40 material performance provision of external surface materials at any dimension of a building greater than 18m (where the building height is greater than 18m)**	**National Classification methods which can be used to demonstrate compliance with section 12.6/Diagram 40 of ADB 2013 of external surface materials at any dimension of a building greater than 18m (where the building height is greater than 18m)**	**European Classification methods which can be used to demonstrate compliance with section 12.6/Diagram 40 of ADB 2013 of external surface materials at any dimension of a building greater than 18m (where the building height is greater than 18m)**	**Total numbers of ADB 2013 compliant methods**
Compliance of external surface materials at any dimension of a building greater than 18m (where the building height is greater than 18m) with ADB 2013 Clause 12.6 **[National Class]**	**Class 0** (ADB 2013 Diagram 40 National Class performance standard for external surface materials at any dimension of a building greater than 18m where the building height is greater than 18m)	National Class Method 1 National Class Method 2 National Class Method 3 National Class Method 4 National Class Method 5 National Class Method 6 National Class Method 8	European Class Method 1 European Class Method 2 European Class Method 3 European Class Method 4	11 (Note although National Classification method 7 is a method of demonstrating limited combustibility it cannot be used to demonstrate class 0 for external surfaces as the method is only relevant to insulation).
Compliance of external surface materials at any dimension of a building greater than 18m (where the building height is greater than 18m) with ADB 2013 Clause 12.6 **[European Class]**	**Class B-S3, d2 or better** (ADB 2013 Diagram 40 European Class performance standard for external surface materials at any dimension of a building greater than 18m where the building height is greater than 18m)		European Class Method 1 European Class Method 2 European Class Method 3 European Class Method 4 European Class Method 5[2]	5

[2] Note that European Classification 5 is both compliant and noncompliant with ADB 2013 Diagram 40 as described in F6.3

Table F-6 Summary of methods of compliance specific to the external wall construction of building greater than 18m for any dimension below 18m

		Applicable methods of demonstrating compliance with clause 12.6/ Diagram 40 of ADB 2013 of ADB 2013 of external surface materials at any dimension of a building less than 18m (where the building height is greater than 18m)		
Relevant to	**ADB 2013 section 12.6/ diagram 40 material performance provision of external surface materials at any dimension of a building less than 18m (where the building height is greater than 18m)**	**National Classification methods which can be used to demonstrate compliance with section 12.6/Diagram 40 of ADB 2013 of external surface materials at any dimension of a building less than 18m (where the building height is greater than 18m)**	**European Classification methods which can be used to demonstrate compliance with section 12.6/Diagram 40 of ADB 2013 of external surface materials at any dimension of a building less than 18m (where the building height is greater than 18m)**	**Total numbers of ADB 2013 compliant methods**
Compliance of external surface materials at any dimension of a building less than 18m (where the building height is greater than 18m) with ADB 2013 Clause 12.6 **[National Class]**	**Index (I) not more than 20** (ADB 2013 Diagram 40 National Class performance standard for external surface materials at any dimension of a building less than 18m where the building height is greater than 18m)	National Class Method 8 National Class Method 9		2 (Note Index I is a specific test result that Index I is a specific result to BS 476-6. BS 476-6 is the only way that Index I and sub index i1 can be measured. hence only National class method 8 and 9 are relevant)
Compliance of external surface materials at any dimension of a building less than 18m (where the building height is greater than 18m) with ADB 2013 Clause 12.6 **[European Class]**	**Class C-S3, d2 or better** (ADB 2013 Diagram 40 European Class performance standard for external surface materials at any dimension of a building less than 18m where the building height is greater than 18m)		European Class Method 1 European Class Method 2 European Class Method 3 European Class Method 4 European Class Method 5 European Class Method 6	6

F6 Review of issues in the methods of demonstrating compliance of material performance

F6.1 Consistency of fire safety standards of insulation and external wall materials

F6.1.1 As I have explained above, the overall performance for insulation and for the external wall surface of buildings are different.

F6.1.2 However, two of the four acceptable External Surface standards for a building height more than 18m - for any dimension above 18m, also apply to insulation materials used in buildings with a storey 18m or more above ground level.

F6.1.3 These are two different measurements of height. In a building with a storey more than 18m above ground level, the Insulation performance is relevant to any dimension whereas the external surface is for any dimension above 18m only.

F6.1.4 If a designer chooses to demonstrate Class 0 by relying on Section 13a of Appendix A of ADB 2013 i.e. "*the surface of the composite material is composed throughout of material of limited combustibility*", that standard of fire performance for an external surface at a dimension above 18m is then the same as that required for insulation in a building with a storey more than 18m above ground level.

F6.1.5 However, as I have explained in Section F4.3 of this Appendix, there are two other acceptable performances for external surfaces above 18m. These do not rely on methods to determine materials of limited combustibility (a Class 1 material where I <12 and i1 <6; or a Class B material).

F6.1.6 Although Diagram 40 states one performance criterion for National Class and one performance criterion for European Class above 18m, there are in fact multiple ways that each of those criteria can be demonstrated.

F6.1.7 One consequence of the multiplicity of performance criteria is that there are two performances for external surfaces at a dimension above 18m which are less onerous than that for insulation used in buildings with a storey above 18m. Materials which could not achieve *limited combustibility* to comply with the insulation performance standard could potentially be used at a dimension above 18m for an external surface should they pass one of the other criteria set for Class 0 (using BS 476-6 and BS 476-7 testing or a Class B European material).

F6.1.8 The compliance methods for limited combustibility are less complex, and apply to insulation products/materials only.

F6.2 Heat exposure methods for the test specimens

F6.2.1 It is possible using British Standard tests to demonstrate an external surface material is Class 0 by only exposing the external surface to direct heat during the test, with no direct exposure to the substrate (BS 476-6 and BS 476-7).

F6.2.2 I have arrived at this conclusion by reviewing the testing methodology (presented in my Section F7) of all of the relevant National and European Test Standards to referenced in ADB 2013 to demonstrate Class 0: BS 476-4, BS 476-6; BS 476-7; BS 476-11; BS EN ISO 1182; BS EN ISO 1716.

F6.2.3 It should be noted that BS EN 13823 only exposes the external surface and not the core to heat, however it has to be used in conjunction with BS EN ISO 1716 or BS EN ISO 11925-2 to demonstrate class A2 or class B, and hence suitability for use as the external surface above 18m.

F6.2.4 Both BS EN ISO 1716 and BS EN ISO 11925-2 expose the combustible core directly to heat. In BS EN ISO 1716 the core material is ground to a powder and ignited. In BS EN ISO 11925-2 a gas flame in impinged directly on the edge of the material if the edges are exposed in the end use. This is discussed further in F7.

F6.2.5 I have provided an indicative diagram in Figure F.9 which shows the heat exposure of an example composite material with a combustible core.

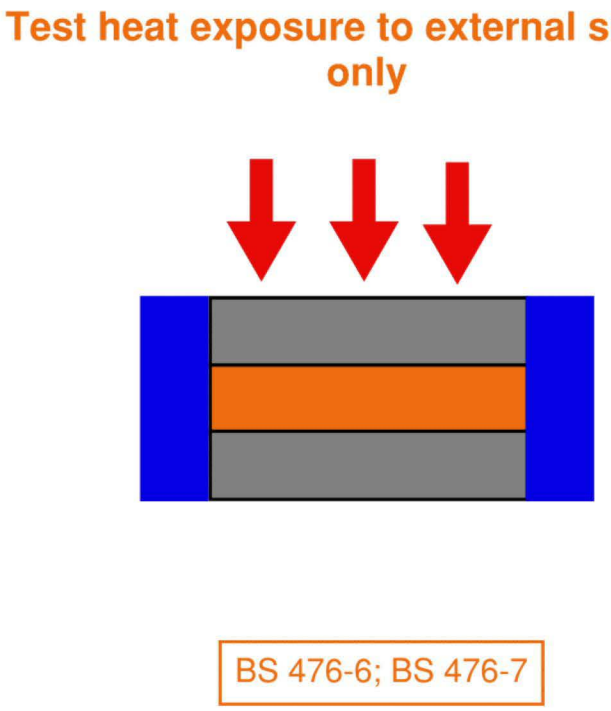

Figure F.9: Method of heat exposure to BS 476-6 and BS 476-7 (National Class method 8) (Orange- combustible core; Blue- sample holder; Grey- Non-combustible outer layer)

F6.2.6 All other National and European test methods to demonstrate Class 0 require direct heat exposure to the substrate as shown in Figure F.10 as I have determined in Section F7 by review of the testing methodologies set out in all of the relevant standards.

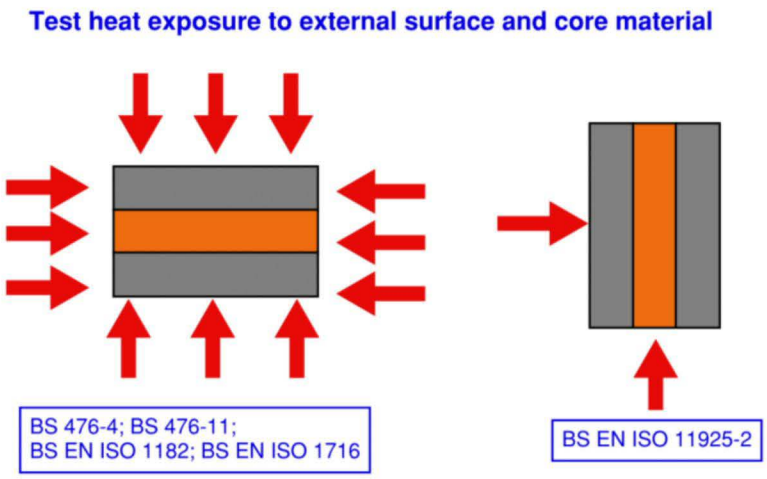

Figure F.10: Standard test where the external surface and the core are exposed to direct heating (Orange- combustible core; Grey- Non-combustible outer layer)

F6.3 Order of precedence of test results

F6.3.1 A material that is classified as Class 0 (i.e. compliant with the provisions made in Section 12.6 of ADB 2013) to the National Class system could achieve a European Class which would be noncompliant with the provisions made in Section 12.6 of ADB 2013.

F6.3.2 The reason for this is that it is possible to demonstrate Class 0, using National Class Method 8, without directly exposing the combustible core to heat.

F6.3.3 The equivalent European class would require the combustible substrate to be directly exposed to heat along with the external surface.

F6.3.4 By exposing the combustible core to direct heating, it is less likely to achieve the required performance standard as the material will heat faster and therefore be more likely to undergo combustion.

F6.3.5 ADB 2013 provides no guidance on whether the more onerous classification takes precedence or whether, in case of conflict, the National or European Class takes precedence.

F6.4 My review of Government guidance of the definitions of filler/ insulation/ external surface

F6.4.1 Note 4 in Annex B of *Government building safety programme – explanatory note* issued after the Grenfell Tower fire states:

*"For the avoidance of doubt; the core (filler) within an Aluminium **Composite Material** (ACM) is an "insulation **material/product**", "insulation **product**", and/or "filler material" as referred to in Paragraph 12.7 ("Insulation Materials/Products") in Section 12 "Construction of external walls" of Approved Document B (Fire safety) Volume 2 Buildings other than dwelling houses. (The important point to note is that Paragraph 12.7 does not just apply to thermal insulation within the wall construction, but applies to any element of the cladding system, including, therefore, the core of the ACM)."*

F6.4.2 ADB 2013 Section 12.7 is directly under the title Insulation Materials/Products. I have therefore no understanding why it applies to anything else.

F6.4.3 I note that BR 135 makes no reference to Filler, and insulating core panels which form their own Appendix F in ADB 2013, use the term core and not filler.

F6.4.4 I have carried out a detailed literature review of definitions for rain screen cladding, filler materials, and I present these here. So I cannot agree with this statement.

F6.4.5 However, for the avoidance of any doubt, I do not consider it acceptable to ignore the core in an ACP rain screen cladding system.

F6.4.6 I explain my opinion in F6.5.

F6.5 My definition of external surface, insulation, and filler

F6.5.1 Section 12.6 of ADB 2013 states: "*The **external surfaces** of walls should meet the provisions in Diagram 40."*

F6.5.2 Section 12.6 of ADB 2013 states:

*"In a building with a storey 18m or more above ground level any **insulation product**, **filler material** (not including gaskets, sealants and similar) etc. used in the external wall construction should be of limited combustibility."*

F6.5.3 External surface, insulation, and filler material are not defined terms in ADB 2013. I am aware there is a range of opinion on what the definitions should be, and particular relating to the word Filler.

F6.5.4 External surface, insulation, and filler material are also not defined terms in any of the following test standards referenced by ADB 2013:

a) British Standards

i. BS 476-4:1970-*Fire tests on building materials and structures. Non-combustibility test for materials*

ii. BS 476-6:1989-*Fire tests on building materials and structures. Method of test for fire propagation for products*

iii. BS 476-7:1997 *Fire tests on building materials and structures. Method of test to determine the classification of the surface spread of flame of products*

iv. BS 476-11: 1982 *Fire tests on building materials and structures. Method for assessing the heat emission from building materials*

b) European Standards

i. BS EN ISO 1182:2002 *Reaction to fire tests for building products. Non-combustibility test BS EN ISO 1716:2002*

ii. BS EN ISO 1716:2002 *Reaction to fire tests for building products. Determination of the heat of combustion*

iii. BS EN 13823: 2010 *Reaction to fire tests for building products - Building products excluding floorings exposed to the thermal attack by a single burning item (+A1:2014)*

iv. BS EN ISO 11925-2:2010 *Reaction to fire tests - ignitability of products subjected to direct impingement of flame. Single-flame source test*

F6.5.5 **Definition of insulating material and how this relates to external ACP rain screen cladding**

F6.5.6 I have carried out a literature review using the Construction Information Service. I found the following definitions of insulation material.

F6.5.7 BS ISO 6707-1: 2017 *Buildings and civil engineering works — Vocabulary* Part 1 'General Terms' defines "*insulating material"* as:

"Material for preventing or reducing the passage of heat, cold, sound, or electricity."

F6.5.8 BS ISO 6707-*1Buildings and civil engineering works — Vocabulary* Part 1 'General Terms' defines "*thermal insulating material"* as:

"Material that is intended to reduce heat transfer and that derives its insulating properties from its chemical nature and/ or its physical structure."

F6.5.9 The insulation used in the external wall construction of Grenfell tower was provided "*to reduce heat transfer"* and therefore can be defined as insulation.

The performance for any insulation, and as relates to Grenfell the Celotex and Kingspan insulation, is therefore *limited combustibility* to comply with ADB 2013 Section 12.7.

F6.5.10 Using the Construction Information Service, I can confirm there is no specific British Standard relating to ACP type rain screen cladding.

F6.5.11 However, there is British Standard *Code of practice for stone based rain screen cladding* (BS 8298-4). This provides a useful reference regarding the rainscreen layer and thermal performance, as follows:

"6.3 Thermal performance

For a ventilated rain screen system, the air gap should be assumed to be a well-ventilated airspace and the rain screen layer should be disregarded when calculating the overall heat loss through the wall in accordance with BS EN ISO 6946".

F6.5.12 The British Standard *Code of practice for stone based rain screen cladding* (BS 8298-4) also explains:

"A ventilated rain screen should have the following key elements:

a) An outer layer (the rain screen), intended to shelter the building from the majority of direct rainfall. Some joints between panels or at the edges of the rain screen should be left open.

b) A cavity, which can include insulation, intended to collect any water which passes through the joints in the rain screen layer, and to permit such water to flow down to a point where it is collected and drained from the cavity. The insulation layer should not completely fill the cavity.

c) A backing wall, intended to provide a barrier to air infiltration and water ingress into the building

NOTE 4 A ventilated rain screen cladding system is either pressure-equalized or drained-and-ventilated."

F6.5.13 Therefore, in my opinion, an ACP rain screen cladding layer is not an insulation material or product, and it functions as an external surface with the purpose of sheltering the building from the majority of rainfall. The entire product is the external surface: both aluminium layers and the core.

F6.5.14 In addition to this performance, the panel as a whole has to resist wind load in a ventilated rainscreen cladding system. This is stated in CWCT Technical note 77 Assessment and Certification of Rainscreen Systems as:

When a rainscreen wall is subject to wind load, the wind load may act on the rainscreen panels or the backing wall. Wind load acting on the rainscreen is often transferred to the structure through the backing wall but can be applied directly to the structural frame if the cladding rails are sufficiently robust to span between floors.

F6.5.15 When a wind load is applied, the whole panel will bend either toward the building or away from the building.

F6.5.16 This will result in one of the aluminium sheets being loaded in compression and the other side in tension. The PE core in the centre is required to transfer the shear force between the two sheets of aluminium i.e. integral to the structural performance of the panel.

F6.5.17 **Definition of filler material**

F6.5.18 ADB 2013 Insulation Material/Products Section 12.7 states

"In a building with a storey 18m or more above ground level any insulation product, filler material (not including gaskets, sealants and similar) etc. used in the external wall construction should be of limited combustibility (see Appendix A). This restriction does not apply to masonry cavity wall construction which complies with Diagram 34 in Section 9."

F6.5.19 ADB 2013 therefore places restrictions on the material properties of insulation products, and filler materials in building above 18m; however, it excludes specific types of filler material which are *gaskets, sealants and similar*.

F6.5.20 ADB 2013 provides no definition of what filler, gaskets or sealants are.

F6.5.21 I have therefore made reference to the British Standard series BS 6100 *Building and civil engineering -Vocabulary* and the ISO standard BS ISO 6707:2017 *Buildings and civil engineering works — Vocabulary* for the relevant definitions.

F6.5.22 The British Standard BS 6100-6 *Building and civil engineering – Vocabulary* –Part 6: Construction Parts makes reference two types of filler relevant to cladding as defined below:

F6.5.23 **Filler, surface-** "*Composition for filling voids and undulations in a substrate to produce a smooth, even surface"* (BS 6100-6 Section 06 83015)

F6.5.24 **Filler, joint**- "*jointing material or jointing section to fill to partly fill a joint gap"* (BS 6100-6 Section 06 73003)

F6.5.25 The two exemptions explicitly stated by ADB 2013 are gaskets and sealants. These are defined as follows:

F6.5.26 **Gasket, Cladding**- "*Flexible, preformed extrusion or moulded section that provides a seal between part of a structure and cladding or between adjacent cladding units"* (BS 6100-6 Section 06 22001)

F6.5.27 **Sealant**- "*material applied in an unformed state which, once cured or dried, has the adhesive and cohesive properties to seal a joint"* (BS EN ISO 6707-1 Clause 3.4.4.35)

F6.5.28 Both the definitions of gaskets and sealants refer to their purpose as providing a seal.

F6.5.29 A seal is also defined in BS EN ISO 6707-1 Clause 3.5.1.19 as follows:

F6.5.30 **Seal** (verb)- "*action placing the appropriate products in the joint in order to prevent the penetration of water, moisture and or air between elements, components and assembles made of the same or dissimilar materials*."

F6.5.31 The purpose of gaskets and sealants is therefore to seal (as defined above). Gaskets and sealants are therefore joint fillers as defined in BS 6100-6. And they are not surface fillers.

F6.5.32 My interpretation of ADB 2013 is therefore that ADB 2013 requires Joint and Surface fillers to have the same performance as insulation, but expressly excludes gaskets and sealants only.

F6.5.33 I have tried to find samples of Surface Filler. I have found in Trade literature "*Fine surface filler - an easy to use ready mixed filler for filling small holes and surface imperfections in most porous surfaces such as plaster and wood. Dries to a very smooth finish that can be painted or papered*."

F6.5.34 This is further confirmed by the definition of Filler provided in the BS ISO 6707-1:2017; Section **3.4.4.42:**

Filler: *Coating material with a high proportion of extender intended primarily to even out irregularities in substrates to be painted and to improve surfaces"*.

F6.5.35 Alternatively, I also found that cavity walls are subject to specific types of insulation, as defined in BS 6100-6: 2008;

F6.5.36 **Cavity wall insulation material**: thermal insulation material positioned in a cavity. (BS 6100-6: 2008 clause 06 23030)

F6.5.37 **Full fill insulation**: thermal insulation material that completely occupies the space between the leaves of a cavity wall; (BS 6100-6: 2008 clause 06 23032) or

F6.5.38 **Partial fill insulation material**: preformed thermal insulation material fixed to one leaf of a cavity wall. (BS 6100-6: 2008 clause 06 23033)

F6.5.39 A rainscreen by its nature requires partial fill (the cavity is then left between the insulation attached to the backing wall and the rainscreen panel). Other forms of external wall don't require partial fill. I note for example that Section 12.7 excludes masonry cavity walls entirely.

F6.5.40 I have also found a body of expertise and literature relating to composite materials. This is entirely outside my area of expertise. But I have read that in that area the word *Filler* is also used. For example, Micro or Nano fillers can be introduced to polymers to alter the overall constitution of a foam. I

have found a whole range of filler powders and additives can be added, so that when formed the fillers reduce shrinkage, add weight and add fire retardancy, to cast polymer products.

F6.5.41 A filler in that context appears to me to be something added to change the properties of a polymeric type material.

F6.5.42 I am aware that insulating core panels and ACP come with a range of core material, all with different compositions.

F6.5.43 Arconic (who supplied the Reynobond 55 PE panels for Grenfell Tower) also sell for example an FR [3]panel (PE with fire retardant mineral core).

F6.5.44 However, I cannot conclude in the context of *filler material (not including gaskets, sealants and similar) etc*. as written in Insulation Materials/Products Section 12.7, the intention was for designers to consider micro or nano fillers, filler powder or additives, when introduced to polymeric material.

F6.5.45 I consider the evidence tends more towards the definition of filler material as relates to Buildings, where filler is clearly defined as a joint or a surface filler (BS EN ISO 6707-).

F6.5.46 I note the use of the word core throughout BR 135, which does not mention the words *Filler material* anywhere. And I note that throughout Appendix F in Approved Document B 2013, as relates to another form of composite panel, it too uses the word core, and not *Filler material*.

F6.5.47 I have therefore concluded the following as a result.

F6.5.48 The core of an ACP system is bonded to the outer aluminium layers forming one composite product. All three layers together act as one monolithic construction to *shield the majority of a wall from direct rainfall* and also to transfer wind load. (Refer to BS 8298-1 2010 clause 3.37).

F6.5.49 The purpose of the core is not to fill or partly fill a joint gap.

F6.5.50 The purpose the core is not to fill voids or undulations in a substrate.

F6.5.51 The purpose of the core is not to even out irregularities in substrates to be painted and to improve surfaces.

F6.5.52 I acknowledge the manufacturer of the "plastic" core may very well incorporate fillers, for cost or performance reasons. I note in the fire test reports disclosed to me no information on any filler provided to a core has been provided.

F6.5.53 Therefore, I cannot agree with the clarification provided after the Grenfell Fire, that the *Filler material* referred to in Section 12.7 of the ADB 2013, was

[3] https://www.arconic.com/aap/north_america/en/product.asp?prod_id=1534 [accessed 11/04/2018]

intended to incorporate the external surface (dealt with by means of Diagram 40) when it is formed of an aluminium composite panel.

F6.5.54 I am aware that there is a range of opinion on this issue and others consider that the core in an ACP is now *filler* and therefore is dealt with by the provisions made for insulation under Section 12.7 of the ADB 2013.

F6.5.55 For the reasons I have set out above, I disagree with this view.

F6.5.56 **Definition of external surface and how it relates to ACP rain screen cladding systems**

F6.5.57 ADB 2013 Section 12.6 and Diagram 40 makes reference to a material performance required for the *external surfaces of walls*.

F6.5.58 For any dimension above 18m, ADB 2013 specifies that the external surface should achieve Class 0 or Class B or better to European Class.

F6.5.59 Section 13 of Appendix A of ADB 2013 states:

"The highest national product performance classification for lining materials is Class 0. This is achieved if a material ***or the surface of a composite product*** *is either:*

a. Composed ***throughout*** *of materials of limited combustibility*

b. a Class 1 material which has a fire propagation index (I) of not more than 12 and sub-index (i1) of not more than 6."

F6.5.60 I have therefore asked myself what would constitute an external surface of a building when composite materials are used and hence what the material performance they are required to achieve.

F6.5.61 **Composite** is defined as a "*combination of materials which are generally recognised in building construction as discrete entities e.g. coated or laminate materials"* (BS 476-7:1997 Clause 3.14)

F6.5.62 **Material** is defined as "*a single substance or uniformly dispersed mixture, e.g. metal, stone, timber, concrete, mineral fibre, polymers"* (BS 476-7:1997 Clause 3.10)

F6.5.63 **Product** is defined as "*a material, composite or assembly about which information is required"* (BS 476-7:1997 Clause 3.11) (BS EN ISO 11925-2:2010)

F6.5.64 **Surface** is defined in the Oxford English Dictionary as "*The outside part or uppermost layer of something"*.

F6.5.65 In my opinion there are three potential ways an external surface of a building could be considered. I have provided these in Table F-7 below – I have carried out this exercise for completeness only. All must be considered with regard to the functional requirements also.

Table F-7: Options for the potential assessment methods as relate to composite external surfaces

Option for the definition of an external surface in a rain screen cladding system	**Definition**	**Resultant ADB 2013 guidance for ACP rain screen panels**
Option 1	All rain screen cladding surfaces in a single plane: with the outermost edge of the outermost layer of the outermost building component of the rain screen considered as an external surface only.	The aluminum facing would be considered the external surface therefore required to be Class 0 (either of the 3 types) or Class B -s3 d2 or better to comply with ADB 2013 Section 12.6 above 18m. The PE core in of itself would not be subject to any performance criteria in ADB 2013 apart from being included as the substrate to the aluminum outer surface in the relevant fire testing (note I discuss issues around this in F6.2) Note however that the PE core would be included as the substrate as part of the testing to demonstrate Class B which inherently results in the core being exposed to heat (unlike the equivalent national testing) which could result in a failure to achieve the required classification.
Option 2	All surfaces of the external rain screen cladding material that do not directly face into the cavity are considered as the external surfaces.	The aluminum facing and the PE core would both therefore be considered as the external surface and therefore require to be Class 0 or Class B-S3, d2 or better to comply with ADB 2013 Section 12.6 above 18m The Aluminum facing would achieve Class A1 therefore would be compliant. However, the PE core would likely fail to achieve Class B-S3, d2 or any of the tests provided for in Class 0. Therefore, the use of the panel would be noncompliant with ADB 2013 Section 12.6.

Option for the definition of an external surface in a rain screen cladding system	Definition	Resultant ADB 2013 guidance for ACP rain screen panels
Option 3	The entire external rain screen cladding product is considered to be a composite material.	The aluminum facings and the PE core would all be considered as a composite material and so the external surface and all layers therefore required to be Class 0 or Class B or better; The Aluminum facing could achieve Class A1 by European Decision 96/203 however the PE core would fail to achieve Class B-S3, d2 or any test relevant to Class 0. Therefore, the use of the composite material would be noncompliant with ADB 2013 Section 12.6.

F6.5.66 I have indicatively marked my definitions in Figure F.11.

F6.5.67 The functional requirements for the external wall construction are clear in my opinion.

F6.5.68 B4. (1) *The external walls of the building shall adequately resist the spread of fire over the walls … having regard to the height, use and position of the building.* And:

F6.5.69 *In the Secretary of State's view, the Requirements of B4 will be met: a. if the external walls are constructed so that the risk of ignition from an external source and the spread of fire over their surfaces, is restricted, by making provision for them to have low rates of heat release;*

F6.5.70 In Option 1 it is possible to avoid exposing the material at most risk of ignition to direct heat by testing to BS 476-6 and BS 476-7.

F6.5.71 In my opinion just as the ACP panel acts as one surface with respect to withstanding rainfall and wind, it also acts as one system during a fire. The Grenfell Fire, and all the DCLG BS 8414 tests published since the Grenfell Fire clearly demonstrated this too.

F6.5.72 Therefore, it is my opinion, having carried out the detailed review of the suite of test standards (now following in section F7), that in order to comply with the Building Regulations, I must consider the entire rain screen cladding panel i.e. the two layers of aluminium and the core (typically 0.5mm Aluminium with a 3mm polyethylene core) as the external surface.

F6.5.73 Otherwise the performance of the core is entirely omitted when considering the construction of the external walls, if one relies on BS 476-6 and BS 476-7 testing to demonstrate Class 0.

F6.5.74 All other methods of assessing the reaction to fire of an external surface (as I have reviewed in Section F6.2 would require heat exposure to the core and hence addresses the hazard of the combustible core.

F6.5.75 This interpretation is also consistent with the functional requirement of Building Regulation B4 (1).

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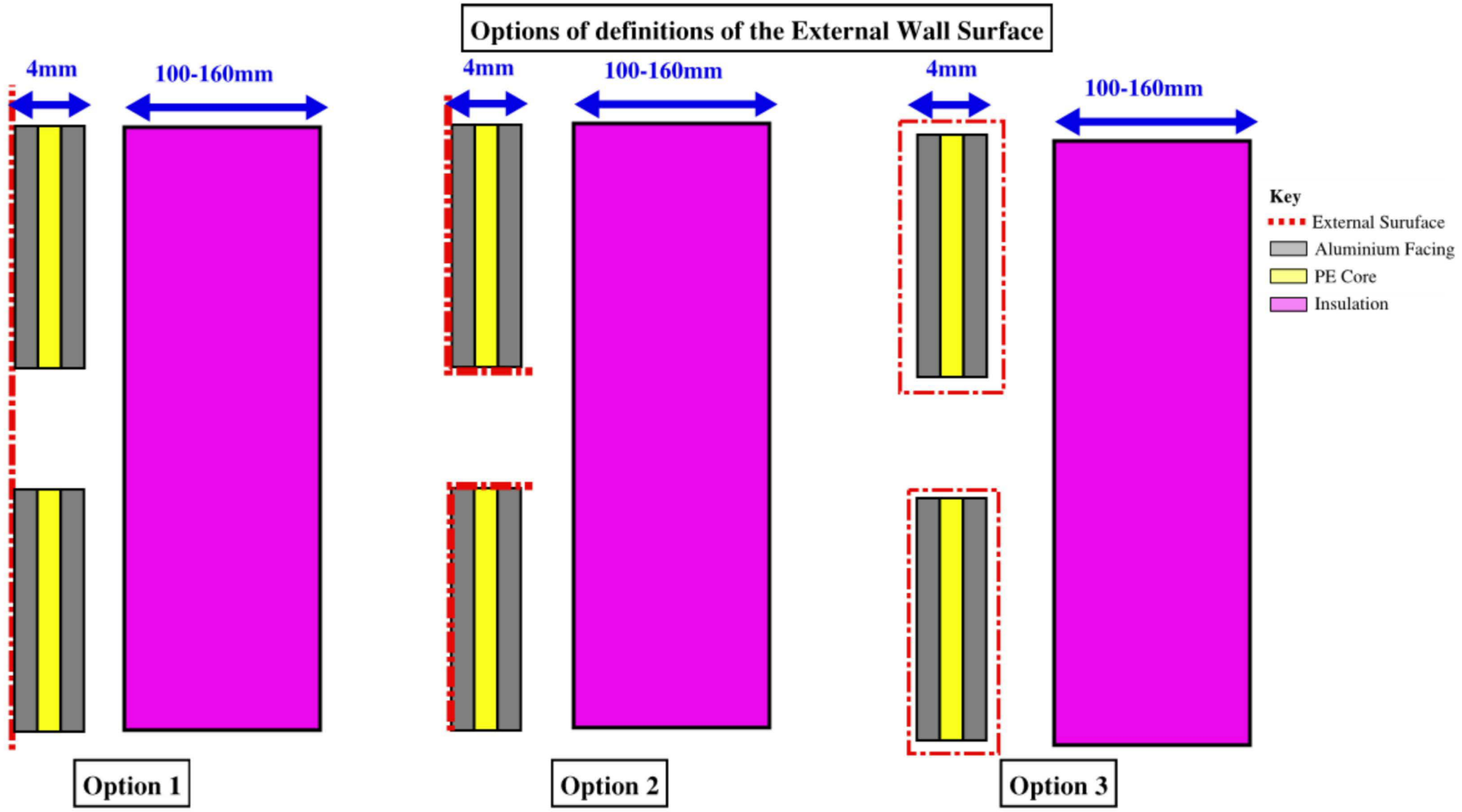


Figure F.11: My defined options for defining external surface

F6.6 Summary of issues in the methods of demonstrating compliance of material performance

F6.6.1 Figure F.12 and Figure F.13 below summarises the main issues in demonstrating material performance that I have concluded.

F6.6.2 This diagram shows the two methods of complying with Diagram 40 (Class 1 material where I<12 and i1<6 and Class B) which are an inherently lower standard of reaction fire than that required of insulation materials.

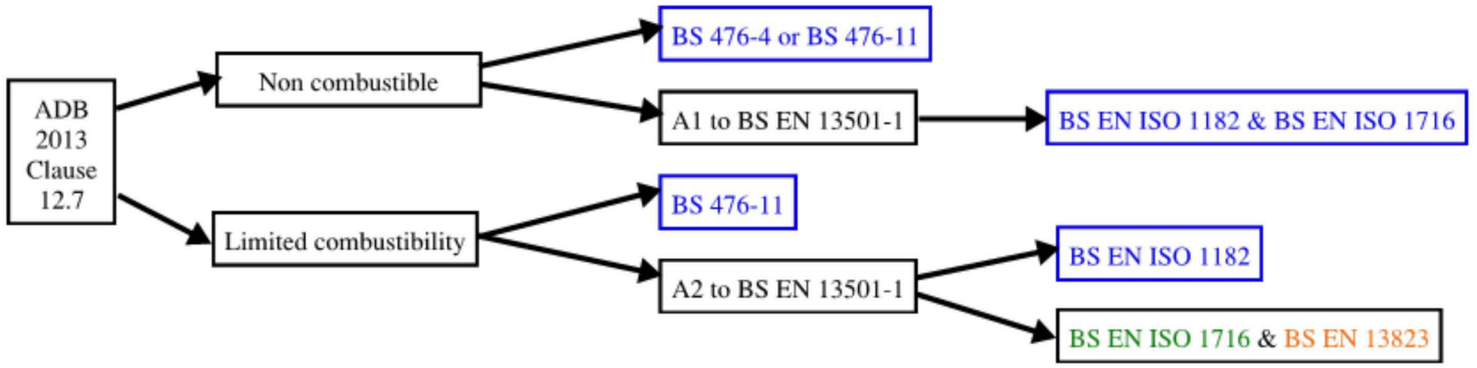
F6.6.3 It also shows the disparity between achieving Class 0 by European tests (As class A2 or better) while allowing Class B materials.

F6.6.4 It also shows how not all Class 0 materials are of equivalent fire performance and there is a method of demonstrating Class 0 without directly exposing the core of ACP panels to heat using BS 476-6 and BS 476-7. This is because the core of an ACP panel is only heated by conduction through the outer aluminium facing. The heat exposures shown in the tests relevant to demonstrating Class 0 are shown indicatively in Figure F.14, Figure F.15 and Figure F.16.

ADB 2013 Section 12.7 routes for compliance

ADB Performance requirements for compliance

Clause 12.7 insulation classification- Limited combustibility



Key

BS xx-xx	Test heat exposure to external surface and core material
BS xx-xx	Test heat exposure to external surface and core material
BS xx-xx	Test heat exposure to external surface and core material

Figure F.12: Routes for compliance with Section 12.7 of ADB 2013

Comparison of ADB 2013 12.6/ Diagram 40 routes for compliance and clause 12.7

ADB Performance requirements for compliance

Clause 12.7 insulation classification- Limited combustibility
Clause 12.6/ Diagram 40 External wall surface classification - Class 0 (national class) or class B-s3, d2 or better (European Class)

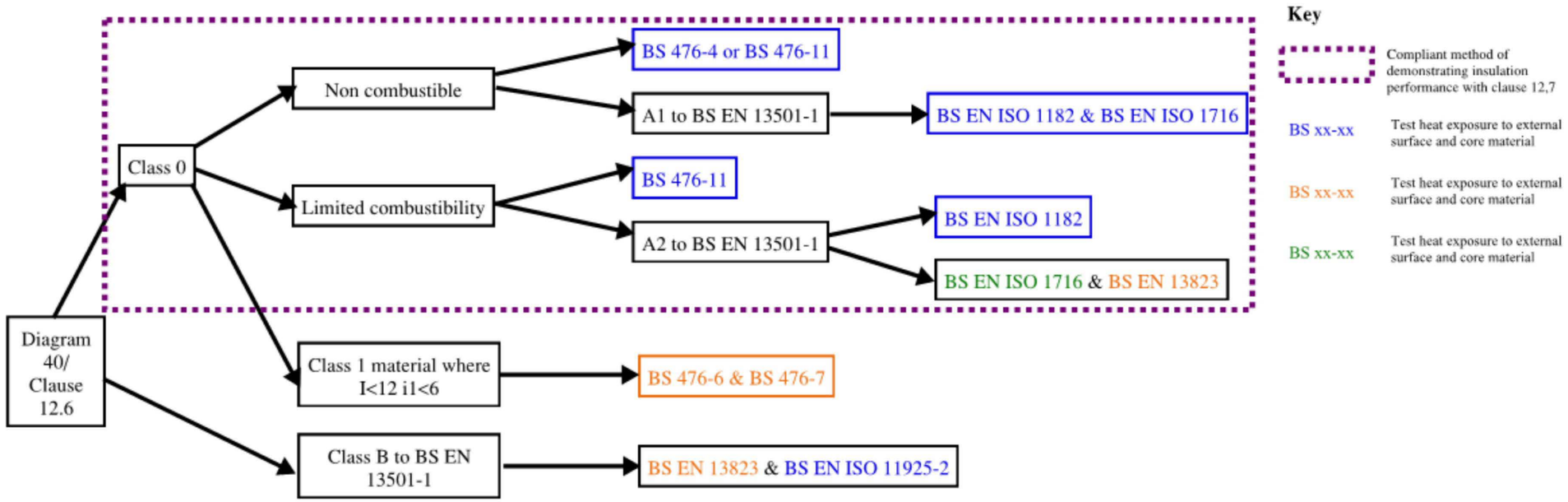


Figure F.13 Routes for compliance with Section 12.7 of ADB 2013 for a building with a storey above 18m (Note two additional methods introduced for external surfaces which are not included as methods of demonstrating compliance of insulation material with a storey at greater than 18m)

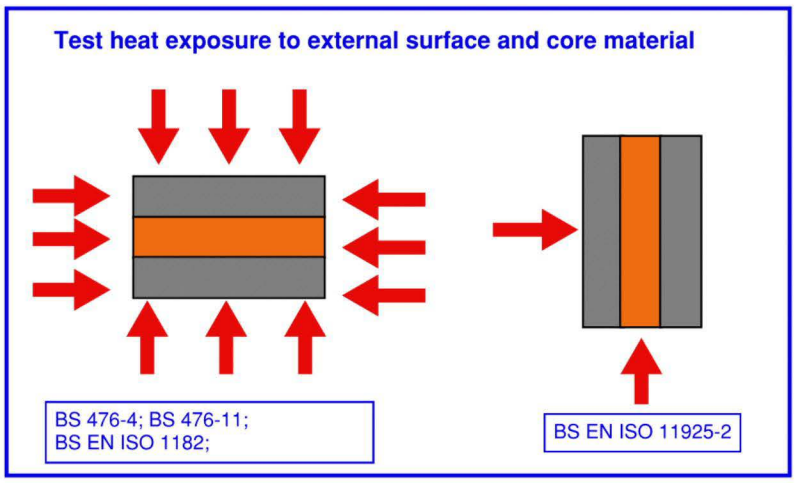


Figure F.14: Test Standards where the surface and core of ACP panels is exposed directly to heat (derived from my review of test standards F7) (Red arrow denotes direction of heat exposure; Grey- non-combustible outer layers; Orange- combustible core)

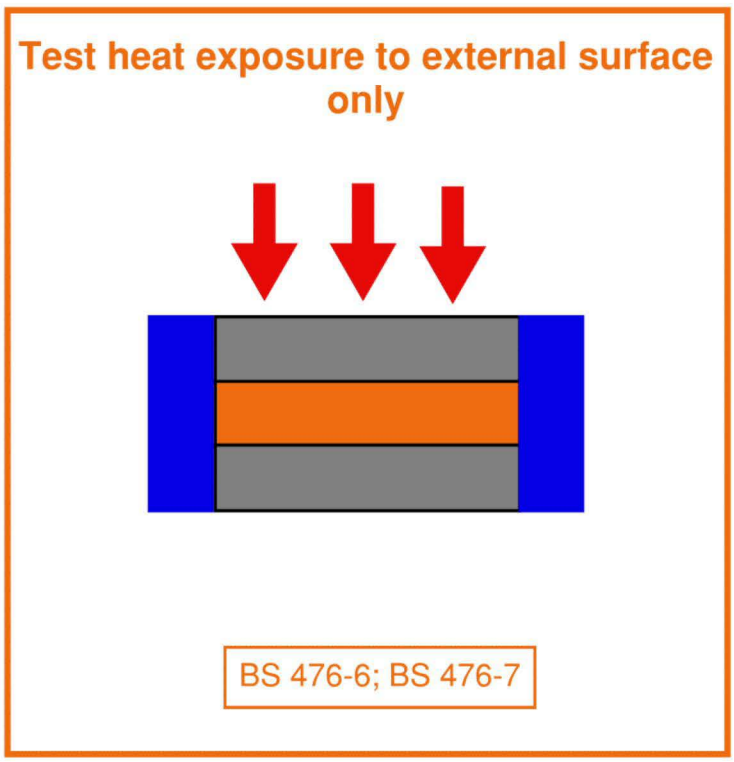


Figure F.15: Test Standards where only the surface of ACP panels is exposed directly to heat (derived from my review of test standards F7) (Red arrow denotes direction of heat exposure; Grey- non-combustible outer layers; Orange- combustible core; Blue- sample holder)

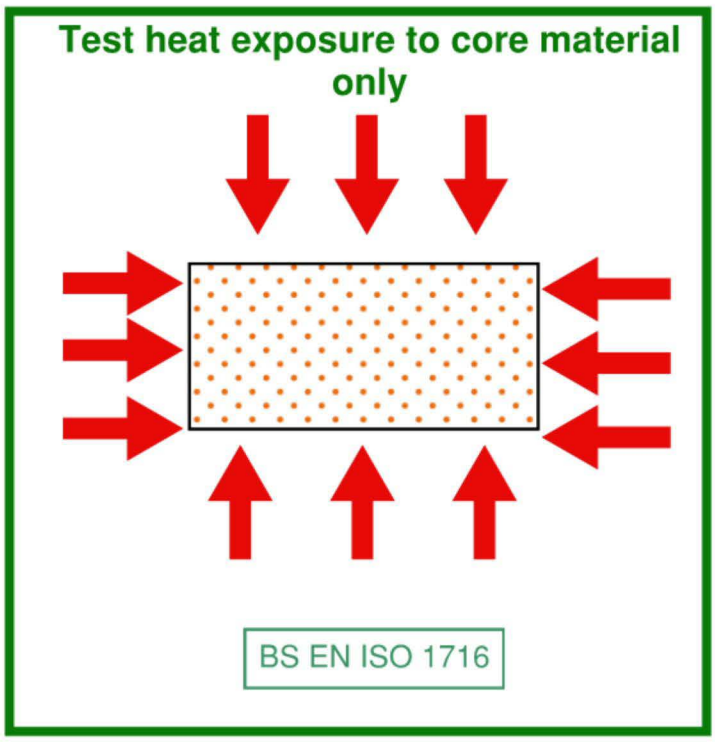


Figure F.16: Test Standards where only the core of ACP panels is exposed directly to heat (derived from my review of test standards F7) (Red arrow denotes direction of heat exposure)

F7 Material performance test descriptions

F7.1.1 In this section I review the relevant British standards in Section F7.2 and European standards in Section F7.3 for materials testing.

F7.1.2 I specifically also review how slim components such as ACP panels are tested in Section F7.4.

F7.2 British Standard tests

F7.2.1 **BS 476-4:1970-Fire tests on building materials and structures. Non-combustibility test for materials**

F7.2.2 This test standard is used to demonstrate non-combustible material performance.

F7.2.3 I explained in Section F4.9 and F4.10 that all non-combustible materials are also limited combustibility and therefore achieve the performance for the external wall surface provided for in ADB 2013 Section 12.6 and for insulation as provided for in Section 12.7 for buildings above 18m.

F7.2.4 Section 1 *Scope* of the test standard states:

"This British Standard specifies a method of test for determining whether building materials are non-combustible within the meaning of the definition."

F7.2.5 In this test, a 40mm by 40mm by 50mm high section of the material to be tested is placed in an electric furnace set at 750°C for 20 minutes.

F7.2.6 If a composite material is less than 50mm thick, the sample size is either increased to the 50mm height using multiple layers; or the individual layer thicknesses are proportionally increased to meet the size required; or each layer is tested separately to the full 50mm thickness. Examples of this are shown in Figure F.17.

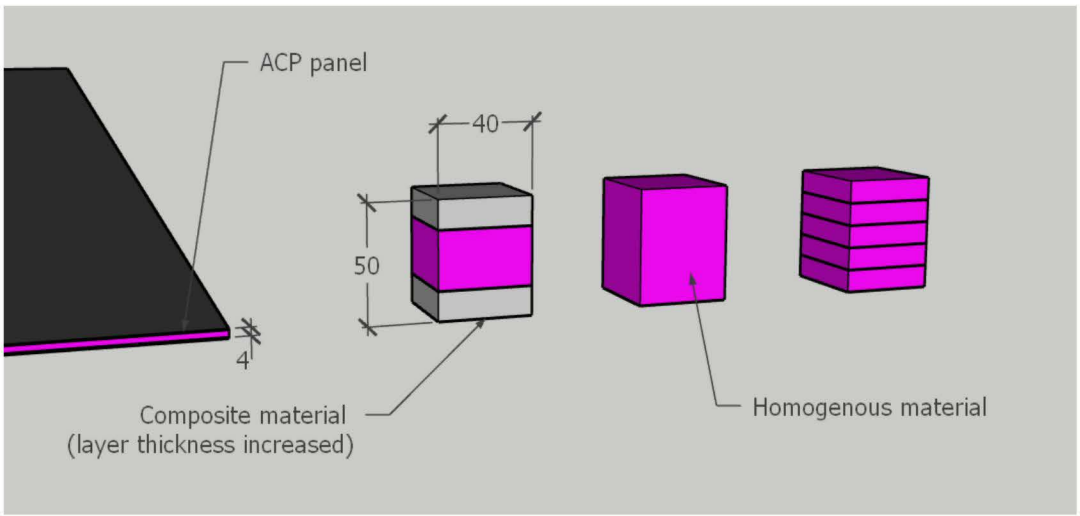


Figure F.17: Samples sizes of BS 476-4 test compared with a typical ACP panel thickness

F7.2.7 One temperature measurement is taken inside the sample and one temperature measurement is taken inside the furnace. The temperature rise in both of these thermocouples is recorded for the full 20-minute duration of the test.

F7.2.8 The test is repeated on two further samples i.e. three samples tested in total.

F7.2.9 Section 8 of the test standard states:

"The material shall be deemed non-combustible if, during the test, none of the three specimens either

1) causes the temperature reading from either of the two thermocouples to rise by 50 °C or more above the initial furnace temperature, or

2)is observed to flame continuously for 10 s or more inside the furnace.

Otherwise, the material shall be deemed combustible."

F7.2.10 It is noted in the March 2014 amended versions of BS 476-4 that the standard has been superseded by BS EN ISO 1182:2010.

F7.2.11 **BS 476-11: 1982 Fire tests on building materials and structures. Method for assessing the heat emission from building materials**

F7.2.12 This test standard is used to demonstrate non-combustibility and limited combustibility material performance as stated in Table A6 and Table A7 of ADB 2013. A material of limited combustibility meets the external wall surface provisions in ADB 2013 Section 12.6 and the provisions for insulation performance in Section 12.7 (when buildings have a storey more than 18m above ground level).

F7.2.13 Section 1 *Scope* of the test standard states:

"This Part of this British Standard describes a method for assessing the heat emission from building materials when inserted into a furnace at a temperature of 750°C."

F7.2.14 A 40mm diameter 50mm high cylinder of the sample material is placed in an electric furnace set at 750°C until temperature equilibrium is reached in the sample (i.e. the sample or furnace temperature stops increasing or returns back to the start temperature) or 120 mins has elapsed.

F7.2.15 If the thickness of the material is less than 48mm (i.e. 50mm subtract a 2mm allowable tolerance in the Standard) then the test material is made by using a sufficient number of layers of the material and/or by adjustment of the material thickness. This is shown in Figure F.18.

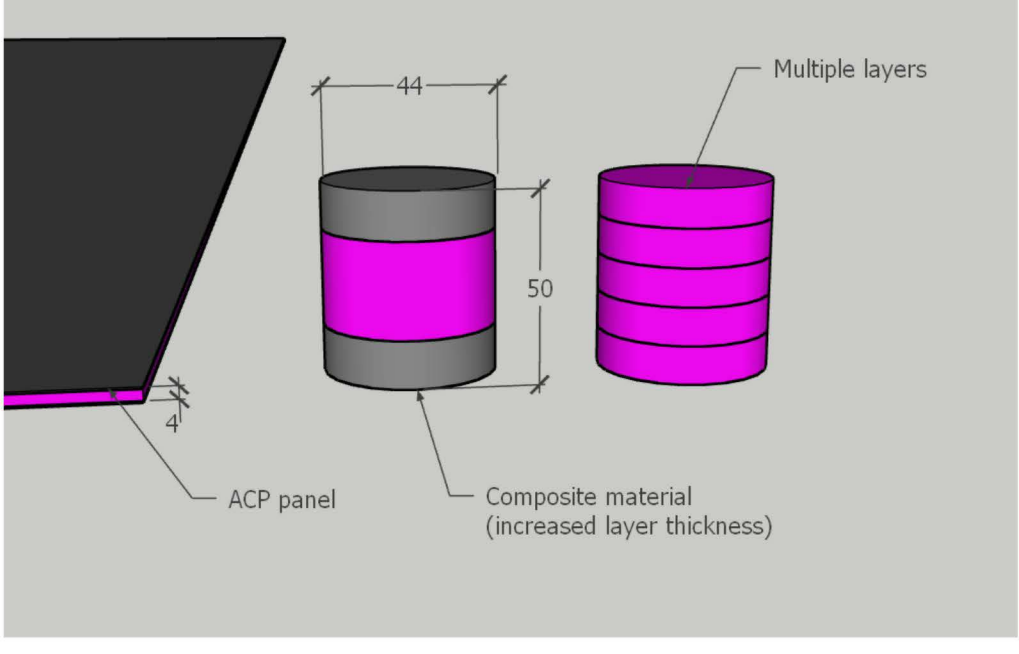


Figure F.18: Sample sizes of BS 476-11 test vs ACP panel thickness

F7.2.16 One temperature measurement is taken inside the sample and one temperature measurement is taken inside the furnace. The temperature rise in both of these thermocouples is recorded for the full duration of the test.

F7.2.17 The test is repeated on four further samples i.e. five samples tested in total.

F7.2.18 No pass/fail criteria are set out in the standard. The test results can be used to classify the material as per the criteria stated in Table A6 and Table A7 of ADB 2013 where non-combustible is defined as where "*the material does not flame nor cause any rise in temperature of either the centre (Specimen) or furnace thermocouple"* and limited combustibility is defined as *"does not flame and the rise in temperature of the furnace thermocouple is not more than 20°C"* with no requirement on the sample thermocouple.

F7.2.19 It is noted in the March 2014 amended versions of BS 476-4 that the standard has been superseded by BS EN ISO 1182:2010.

F7.2.20 **BS 476-6:1989-Fire tests on building materials and structures. Method of test for fire propagation for products**

F7.2.21 This test standard is used to demonstrate one part of one method (Section 13b of Appendix A of ADB 2013) of the Class 0 requirement ($I < 12$ $i1<6$); and for a building with a dimensions less than 18m - I is less than 20 in accordance with Diagram 40 of ADB 2013.

F7.2.22 This test is therefore relevant to the external wall surface provisions of ADB 2013 Section 12.6 only and has no bearing on the provisions for insulation as per Section 12.7, which is for limited combustibility only.

F7.2.23 BS 476-6 and BS 476-7 cannot be used to demonstrate a material is of limited combustibility.

F7.2.24 The scope of the test standard states:

"This part of BS 476 specifies a method of test, the result being expressed as a fire propagation index that provides a comparative measure of contribution to the growth of fire made by an essentially flat material, composite or assembly. It is primarily intended for the assessment of the performance of internal wall and ceiling linings."

The test apparatus consists of a "combustion chamber" containing a horizontal gas burner and two electric heating elements rated for 1000W. This is shown in Figure F.19.

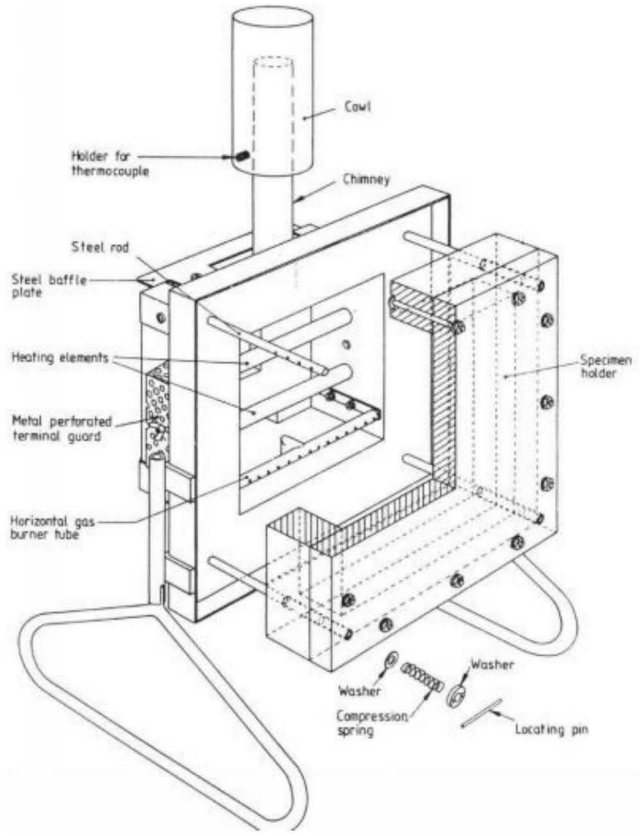


Figure F.19: Test apparatus for BS 476-6 test

F7.2.25 The combustion chamber is initially calibrated using a calcium silicate board. The gas burner is adjusted to output 527.7 W at the start of the test.

F7.2.26 After 2 minutes 45s from the test start the electrical heaters are turned on to output 1800W. This is then reduced to 1500W after 5 minutes.

F7.2.27 The temperature in the chimney is measured using two thermocouples and the temperature increase above ambient is recorded. A graph of the calibration curve is shown below in Figure F.20.

F7.2.28 It should be noted that the sample is only exposed to heat on the external surface. No heat is directly applied to any of the substrate layers. This is entirely different to the equivalent European tests which would be used to demonstrate class B or better (and therefore compliant for use as the external surface of a building above 18m).

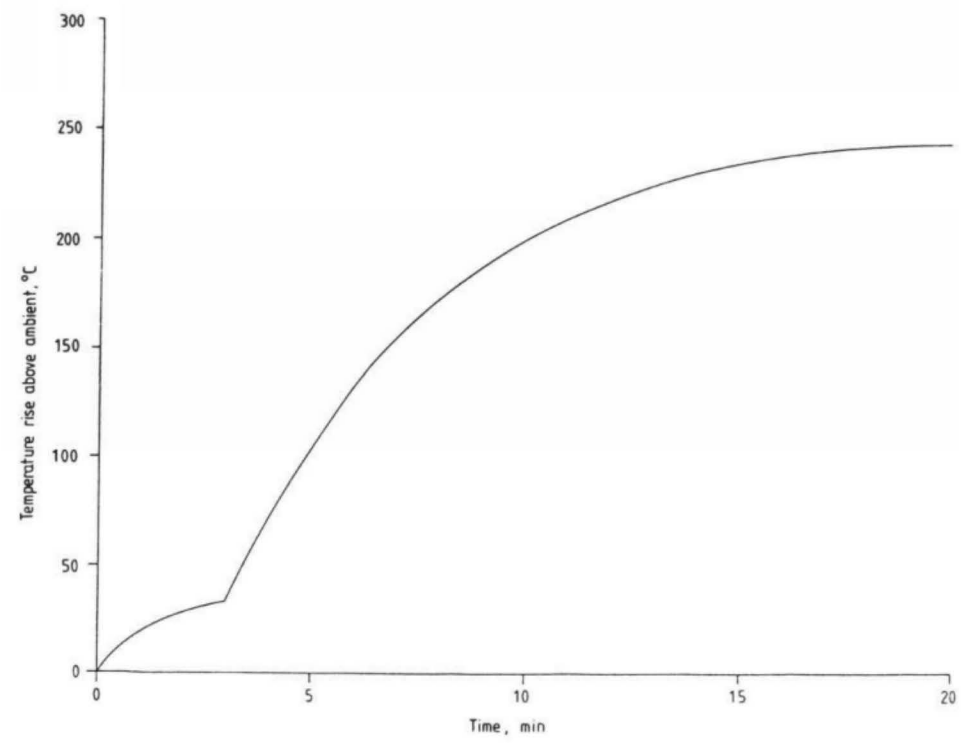


Figure F.20: BS 476-6 calibration curve

F7.2.29 The test procedure is then repeated but with the actual material to be tested instead of the calibration board. The test sample is 225mm by 225mm. If the material or composite material is less than 50mm, the full thickness of the material is tested. The temperature rise in the flue gases of the chimney is again recorded.

F7.2.30 Averages of the rate of rise of temperature of the flue gases of the tested sample above that of the calibration board are taken in time steps specified in Clause 8.3.7 of the standard.

F7.2.31 The remaining samples (a minimum of three and maximum of five) are then also tested and averages of their rate of rise of temperature are also taken.

F7.2.32 The average rates of rise of temperature are then combined using the equations stated in Clause 10.3 of the standard to obtain the fire propagation index (I) and sub-indices (i1, i2, and i3).

F7.2.33 The fire propagation index I and sub index (i_1) can then be used to classify the material as I explained in section F5 of this Appendix.

F7.2.34 BS 476-7:1997 Fire tests on building materials and structures. Method of test to determine the classification of the surface spread of flame of products

F7.2.35 This test standard one method of achieving Class 0 when used in conjunction with the test standard BS 476-6. This method is referenced in Section 13b of ADB 2013.

F7.2.36 This test is therefore relevant to the external wall surface provisions of ADB 2013 Section 12.6 only and has no bearing on the provisions made for insulation as per Section 12.7 which is for limited combustibility only.

F7.2.37 This test is the British Standard test for surface spread of flame to determine the National Classes: Class 1, Class 2, Class 3, and Class 4.

F7.2.38 Only Class 1 is relevant to Section 12.7 of ADB 2013. All other classifications would be noncompliant for use as an external surface above 18m.

F7.2.39 The sample is set up as shown below in Figure F.21.

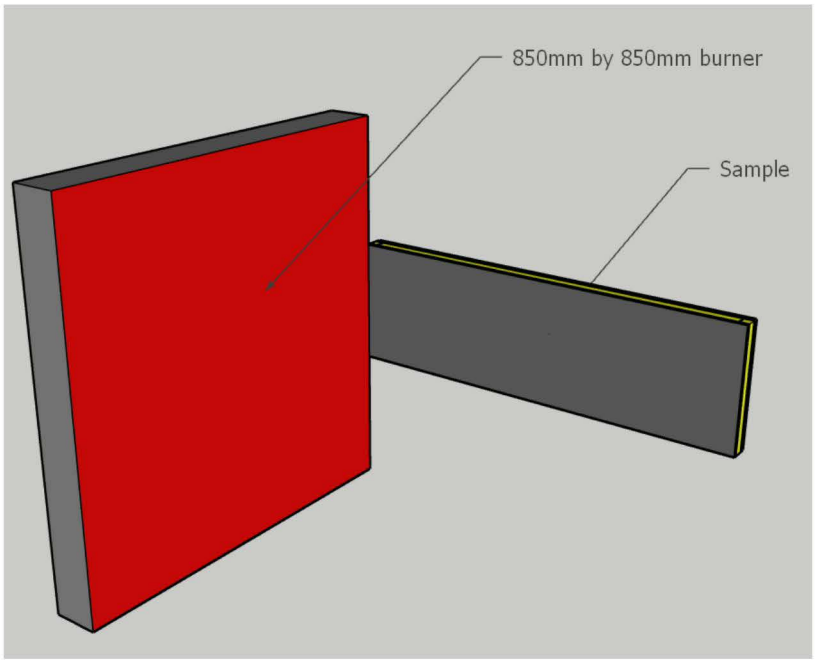


Figure F.21: BS 476-7 test set up

F7.2.40 The sample size for the BS 476-7 test is 885mm by 270mm.

F7.2.41 A radiation panel is used to heat the external surface of the product with a pilot gas burner providing direct flame impingement to surface of the panel at the bottom left hand side for 1 minute at the start of the test to ignite the sample. No heat is directly applied to any of the substrate layers of composite materials.

F7.2.42 The horizontal flame spread across the sample is measured.

F7.2.43 The flame spread across the sample is measured during two time steps: 0-1.5 minutes; and 1.5 minutes to 10 minutes.

F7.2.44 The National Classes Class 1, Class 2, Class 3, and Class 4 are determined based on how far the flame front has spread (over the two time steps defined in F7.2.43)

F7.2.45 Only Class 1 is relevant to Section 12.6 of ADB 2013 as Diagram 40 requires Class 0 which is defined as a Class 1 material to BS 476-7 with I<12 and i1 is <6 to BS 476-7.

F7.2.46 Diagram 40 makes no other reference to any BS 476-7 test classification.

F7.2.47 The results of a BS 476-7 test have no bearing on compliance with Clause 12.7 of ADB 2013 therefore Classes 2, 3, and 4 are not discussed further.

F7.3 European Standard tests

F7.3.1 **BS EN ISO 1182:2002 Reaction to fire tests for building products. Non-combustibility test**

F7.3.2 This test standard is used to demonstrate Class A1 and hence non-combustible material performance.

F7.3.3 BS EN ISO 1182 is the European equivalent of BS 476-11 and is almost identical in set up and testing procedure. This is discussed further in Section F7.4.

F7.3.4 **BS EN ISO 1716:2002 Reaction to fire tests for building products. Determination of the heat of combustion**

F7.3.5 This test standard is used to demonstrate Class A1, A2 only, and hence non-combustible and limited combustibility material performance.

F7.3.6 Class A1 and A2 are better than Class B or class C. A1 being the highest and F the lowest classification.

F7.3.7 A material classed as either A1, or A2 to this test would therefore be compliant for use as the external surface above and below 18m in accordance with Diagram 40 of ADB 2013; and compliant with ADB 2013 Section 12.7 for use as insulation material in a building greater than 18m.

F7.3.8 Section 1 of the standard states:

"This International Standard specifies a method for the determination of the gross heat of combustion (QPCS) of products at constant volume in a bomb calorimeter."

F7.3.9 Section 4 of the standard states:

"In this test, a test specimen of specified mass is burned under standardized conditions, at constant volume, in an atmosphere of oxygen, in a bomb calorimeter calibrated by combustion of certified benzoic acid. The heat of combustion determined under these conditions is calculated on the basis of the observed temperature rise, taking account of heat loss and the latent heat of vaporization of water. This is a test method for determining an absolute value of the heat of combustion for a product and it does not take into account any inherent variability of the product."

F7.3.10 Section 7.1 of the standard states:

"In order to assess a product, each of its components shall be evaluated, taking into account the rules for non-substantial components. If a non-homogeneous product cannot be delaminated, its components shall be provided separately. A product can be delaminated when it is possible to separate one component from another without any part of the other component adhering to the component to be evaluated"

F7.3.11 A 50g sample from 5 locations across the material or every layer of a composite material is taken and ground into a fine powder. This powder is then placed into the bomb calorimeter and ignited. The temperature increase of the water in the bomb calorimeter is measured. The amount of heat energy given off by the sample is then back calculated from the increase in temperature of the water.

F7.3.12 It should be noted that Section 7.1 of BS EN ISO 1716 states:

"WARNING — Any aluminium or other metallic component of a product shall not be tested in the bomb calorimeter, with the risk of serious injury to the operator due to overheating and/or overpressure causing the bomb calorimeter to explode."

F7.3.13 **BS EN 13823: 2010 Reaction to fire tests for building products - Building products excluding floorings exposed to the thermal attack by a single burning item (+A1:2014)**

F7.3.14 BS EN 13823 is used for determining Class A2, B, C and D to the European Class BS EN 13501-1 with different pass criteria for each of the classifications as shown in Table F-3 in Section F5 of this report. This is relevant to materials of limited combustibility (A2 or better in accordance with table A7 of ADB 2013) and external wall surfaces (Class B for any dimension above 18m and Class C for any dimension below 18m in accordance with ADB 2013 diagram 40).

F7.3.15 Class A2 **also** requires the material to have been tested to BS EN ISO 1716. This is relevant to materials of limited combustibility only and hence compliance with Section 12.7 of ADB 2013.

F7.3.16 Classes B, C and D would **also** require the material to be tested to BS EN ISO 11925-2 for vertical fire spread. This is relevant then to external wall surfaces which can be Class B or better above 18m.

F7.3.17 This test is described in Section 1 of the test standard as:

"Test for determining the reaction to fire performance of construction products excluding floorings, and excluding products which are indicated in Table 1 of EC Decision 2000/147/EC, when exposed to thermal attack by a single burning item (SBI)."

F7.3.18 An L shaped sample is constructed with a *short wing* 525mm wide by 1500mm high and a *long wing* 1000mm wide by 1500mm high. This is the largest of the small-scale tests undertaken on materials however is still smaller than a full-size ACP panel as discussed in F7.4.

F7.3.19 Clause 5.1.1 of BS EN 13823 states:

F7.3.20 *5.1.1 The corner specimen consists of two wings, designated the short and long wings. The maximum thickness of a specimen is 200 mm.*

F7.3.21 Clause 5.1.1 of BS EN 13823 states:

F7.3.22 *5.1.2 Specimens with a thickness of more than 200 mm shall be reduced to a thickness of 200mm by cutting away the unexposed surface, unless otherwise specified in the product specification.*

F7.3.23 *5.2.2 Standard mounting*

*When **products** are tested using a standard mounting, the test results are valid for that end use application and can be valid for a wider range of end use applications. The standard mounting used and its range of validity shall be in accordance with the relevant product specifications, and the following:*

c)Boards that in their end use application are fixed mechanically to a substrate with a cavity behind it shall be tested with a cavity between substrate and backing board. The distance between the substrate and the backing board shall be at least 40 mm.

F7.3.24 Product is defined as a material, **composite** or assembly about which information is required (BS 476-7:1997 Clause 3.11) (BS EN ISO 11925-2:2010).

F7.3.25 My understanding of this is therefore that any product <200mm is tested using the full depth of the product. For an ACP panel this would therefore include both aluminium outer faces and the PE core.

F7.3.26 A propane gas burner is placed in the corner junction between the two wings, which directly impinges flames onto the external surface of the sample.

F7.3.27 The test set up is shown below in Figure F.22.

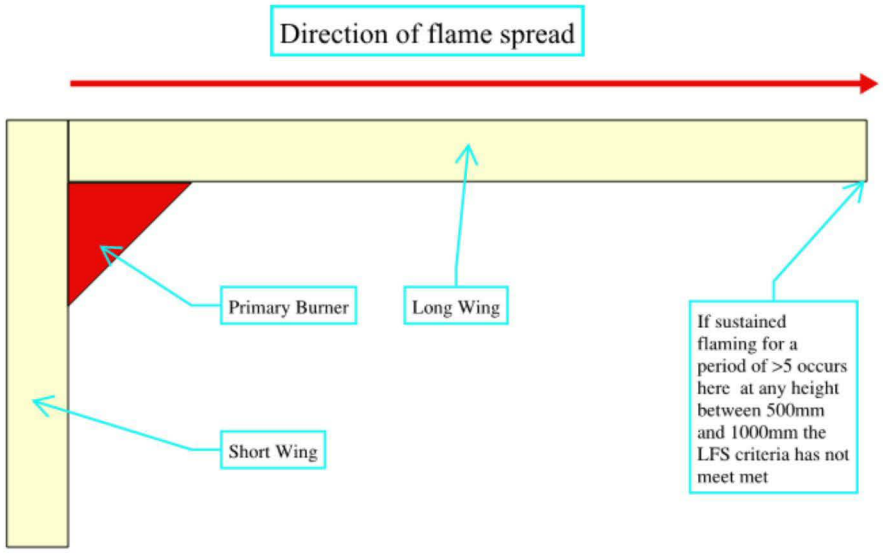


Figure F.22: BS EN 13823 test set up (plan view from above) (note there is also a secondary calibration burner not shown in this diagram)

F7.3.28 The test is allowed to calibrate for 300s then the burner is turned on which directly impinges flames onto the outside surface of the material for 1260s (21 minutes)

F7.3.29 Three properties are measured

- FIGRA- maximum of the quotient of heat release rate from the specimen and the time of its occurrence using a THR-threshold of 0,2 MJ
- THR 600s- total heat release from the specimen in the first 600 s of exposure to the main (primary) burner flames
- LFS-Lateral flame spread along the 1000mm *long wing*

F7.3.30 FIGRA and THR_{600s} are measurements of the combustibility of the material

F7.3.31 **BS EN ISO 11925-2:2010 Reaction to fire tests - ignitability of products subjected to direct impingement of flame. Single-flame source test**

F7.3.32 BS EN ISO 11925-2 is one of the tests used to determine the European Class B, C, D and E. For Classes B, C, and D the material would have to also be tested to BS EN 13823 and meet criteria set out in Table F-3 of this Appendix.

F7.3.33 This test is therefore relevant to demonstrating the performance of external surfaces (Class B or better above 18m in accordance with Diagram 40): However, it is not relevant to the compliance of insulation materials, as Class B

is a lower classification than the A2 or better class which is defined in table A7 of ADB 2013 as limited combustibility.

F7.3.34 Section 1 of BS EN ISO 11925-2 states the purpose of the test is:

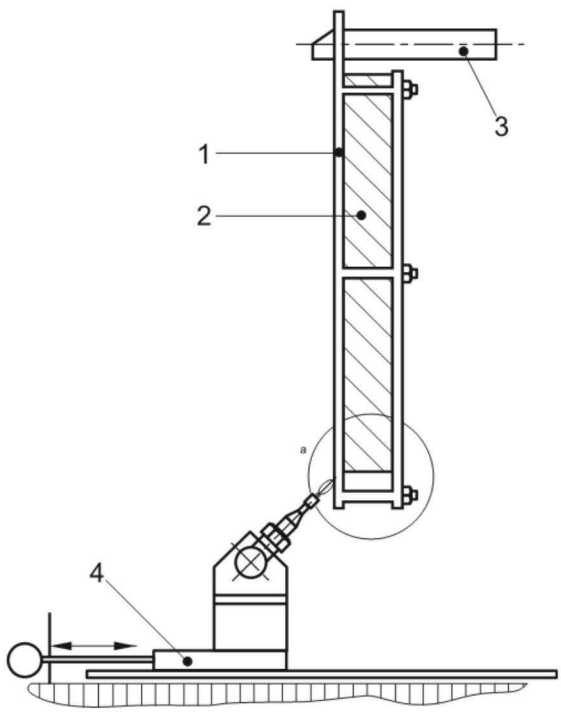
"for determining the ignitability of products by direct small flame impingement under zero impressed irradiance using vertically oriented test specimens".

F7.3.35 A 90mm wide by 250mm high specimen is exposed to direct flame impingement of a propane gas burner as shown below in Figure F.23.

F7.3.36 Section 5.2 of the test standard states:

"Specimens normally having a thickness of 60 mm or less shall be tested using their full thickness."

F7.3.37 The full depth of an ACP panel could therefore be tested.



Key
1 specimen holder
2 specimen
3 support
4 burner base

Figure F.23: BS EN ISO 11925-2 test apparatus

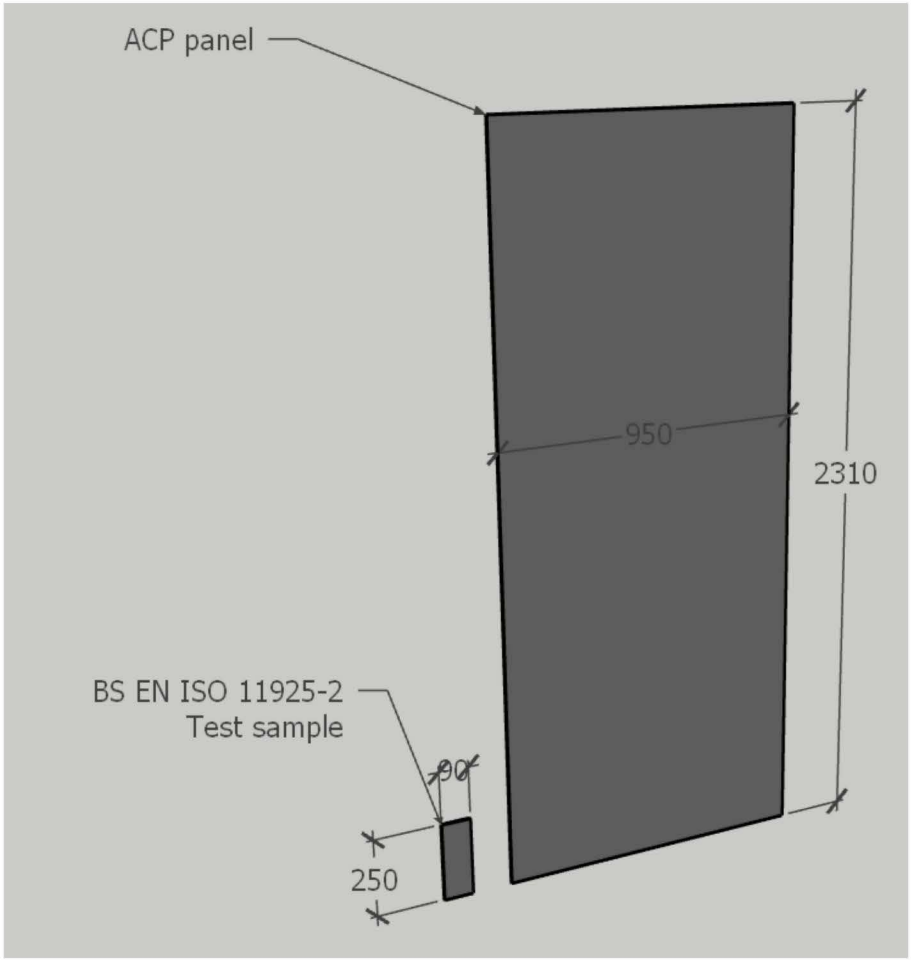


Figure F.24: Relative size of BS EN ISO 11925-2 sample and an ACP panel

F7.3.38 The gas burner is either directed onto the external surface of the material or where the material is a composite of multiple layers, the flame is also impinged on the bottom edge of the sample. The exposure is shown in Figure F.23.

F7.3.39 For tests to determine Classes B, C, D the flame is impinged for 30s and the vertical flame spread measured after 60s from the start of the test (i.e. flame spread after 30s of exposure to the gas burner followed by 30s of no exposure)

F7.3.40 For tests to determine Class E, the flame is impinged for 15s and the vertical flame spread measured after 20s from the start of the test (i.e. flame spread after 15s of exposure to the gas burner followed by 5s of no exposure)

F7.3.41 Therefore, it is very important to note that if the end use of the material will have no edge coverings, the samples are tested with no covering over the edges.

F7.4 Testing of slender samples (such as ACM panels)

F7.4.1 Typically, ACM panels are ~4mm thick.

F7.4.2 The relevant test standards make specific reference to how thin products should be tested as I have presented in Table F-8.

Table F-8 Thin specimen preparation to relevant test standards

Testing framework	Test Standard	Relevant clause of Standard for slim samples	Relevance to ACP panel testing
National Tests	BS 476-4	Section 4 of standard states: *If the thickness of the material is less than the height as specified in Clause 3, each specimen shall be made of a sufficient number of layers to achieve this thickness. These layers shall occupy a horizontal position in the specimen holder and shall be held together firmly, without compression, by means of fine steel wires to prevent air gaps between layers. The density of the specimen shall be representative of the density of the material.* *For composite materials of a thickness such that an Integral number of layers cannot be put together to give a specimen of the specified size (see Clause 3), the specimen shall be prepared to the required thickness by adjusting the thicknesses of the different components so that their proportions in the specimen shall be the same as those in the material. If it is not possible to follow either procedure in the preparation of the specimens, tests shall be performed on the individual component layers of the material and reported accordingly.*	All three layer of the ACP panel (aluminium and PE core) must be included in the test specimen and made up to the required specimen size either by layering the composite or expanding the individual layers of the composite panel to the correct depth or testing the aluminium and PE core as separate elements.
	BS 476-6	Clause 4.2.2 of the Standard states *Products of normal thickness 50mm or less shall be used to full thickness*	All three layer of the ACP panel (aluminium and PE core) must be included in the test specimen
	BS 476-7	Clause 5.3.3 of the standard states: *All specimens shall be tested at full thickness providing they fit into the specimen holder. If the product is of such a thickness that it will not fit into the specimen holder, its thickness shall be reduced by cutting away the unexposed face of the product to reduce the thickness to a minimum of 50 mm.*	All three layer of the ACP panel (aluminium and PE core) must be included in the test specimen
	BS 476-11	*2.2.1 If the thickness of the material to be assessed (see 2.1 and A.1) is not50 ± 2mm, the specimen shall be prepared as follows:* *a) for a material with a thickness greater than52mm, it shall be reduced to give a specimen of height specified in 2.1*	All three layer of the ACP panel (aluminium and PE core) must be included in the test specimen either by layering the composite or expanding the individual layers of the composite panel to the correct depth

Testing framework	Test Standard	Relevant clause of Standard for slim samples	Relevance to ACP panel testing
		; b) if the thickness of the material is less Than 48mm, specimens of the height specified in 2.1 shall be made by using a sufficient number of layers of the material and/or by adjustment of the material thickness; the layers shall occupy a horizontal position in the specimen holder and shall be held together firmly, without significant compression, by means of two fine steel wires of nominal diameter 0.5mm (see A.1).	
European tests	BS EN ISO 1182	Clause 5.2.1 of the standard states: *If the thickness of the material is different from (50 ± 3) mm, Specimens of the height 50 ± 3mm shall be made using a sufficient number of layers of the material or by adjustment of the material thickness.*	All three layer of the ACP panel (aluminium and PE core) must be included in the test specimen and made up to the required specimen size by layering the material.
	BS EN ISO 1716	Section 7.1 of the standard states: *"In order to assess a product, each of its components shall be evaluated, taking into account the rules for non-substantial components. If a non-homogeneous product cannot be delaminated, its components shall be provided separately. A product can be delaminated when it is possible to separate one component from another without any part of the other component adhering to the component to be evaluated."*	The PE core must be tested however it should be noted that Section 7.1 of BS EN ISO 1716 states: "*WARNING — Any aluminium or other metallic component of a product shall not be tested in the bomb calorimeter, with the risk of serious injury to the operator due to overheating and/or overpressure causing the bomb calorimeter to explode."*

Testing framework	Test Standard	Relevant clause of Standard for slim samples	Relevance to ACP panel testing
	BS EN 13823	5.1.2 *Specimens with a thickness of more than 200 mm shall be reduced to a thickness of 200mm by cutting away the unexposed surface, unless otherwise specified in the product specification.* 5.2.2 *Standard mounting* *When products are tested using a standard mounting, the test results are valid for that end use application and can be valid for a wider range of end use applications. The standard mounting used and its range of validity shall be in accordance with the relevant product specifications, and the following:* *c)Boards that in their end use application are fixed mechanically to a substrate with a cavity behind it shall be tested with a cavity between substrate and backing board. The distance between the substrate and the backing board shall be at least 40 mm.* Note Product is defined as a material, composite or assembly about which information is required (BS 476-7:1997 Clause 3.11) (BS EN ISO 11925-2:2010).	Any product <200mm is tested using the full depth of the product. For an ACP panel this would therefore include both aluminium outer faces and the PE core.
	BS EN ISO 11925-2	Section 5.2 of the test standard states: *"Specimens normally having a thickness of 60 mm or less shall be tested using their full thickness."*	

F7.5 Relative sizes of test samples

F7.5.1 The sizes of all of the small-scale test requirements for sample sizes to determine material performance is shown in Figure F.25 to scale.

F7.5.2 It can be seen in Figure F.25 that none of the test samples in any of the materials tests are of equivalent dimensions to the full ACP panel.

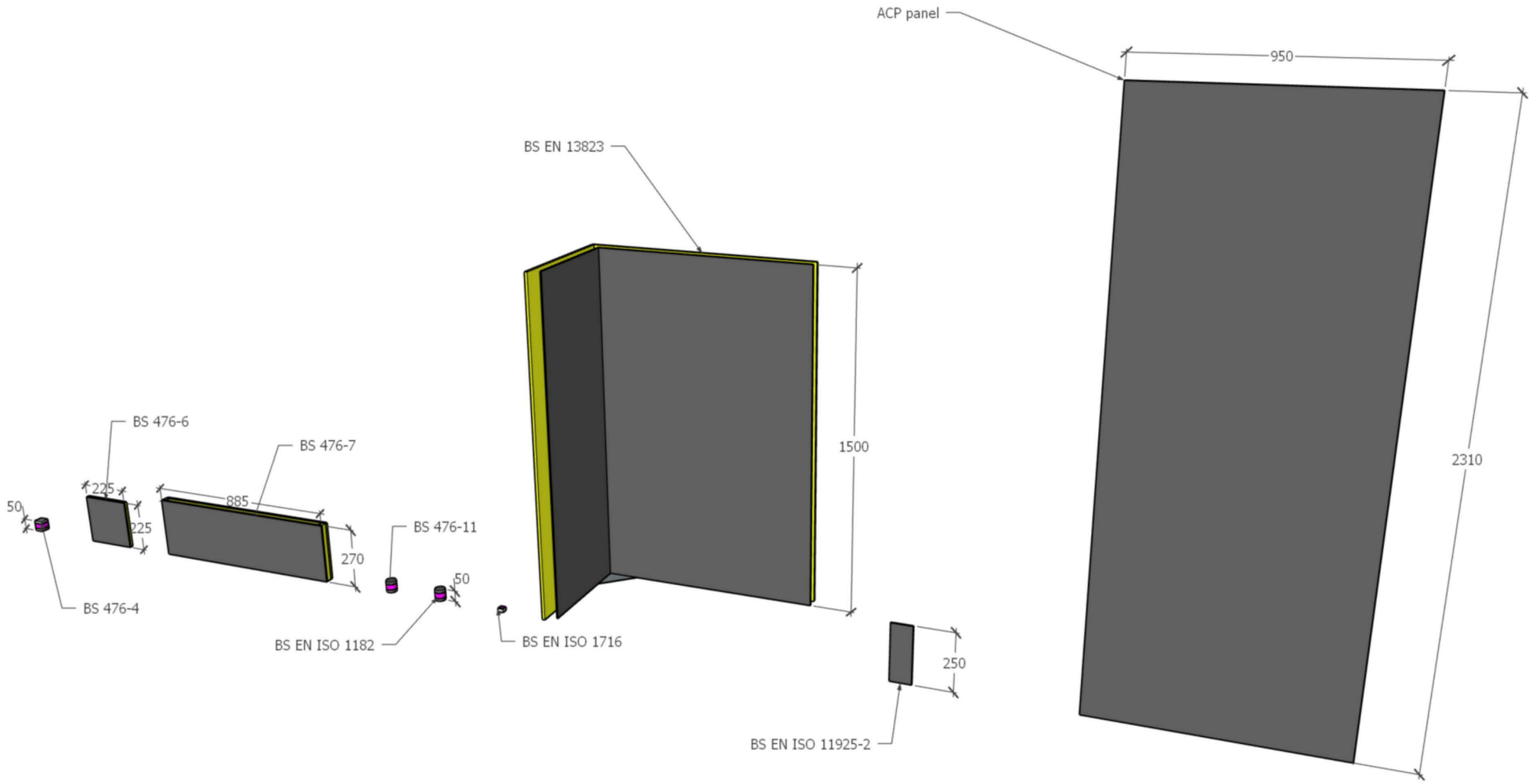


Figure F.25: Relative sizes of all small-scale test samples against the size of a full size ACP panel

F7.6 Summary of the test standard requirements

F7.6.1 I have reviewed the eight test standards (both National and European) referenced in ADB 2013 to provide materials classifications.

F7.6.2 The eight test standards can be used individually or in combination to demonstrate one or more material of limited combustibility classifications; multiple methods of classifying a material as Class 0; multiple methods of demonstrating a material is classified as Class B or better; or classified as Class C or better.

F7.6.3 In reviewing the methodologies of the different test standards, I have made the following observations:

F7.6.4 The test standards BS 467-6 and BS 476-7 would not expose the core of composite materials directly to heat. Its exposure is indirect by heat transfer through the outer aluminium layer.

F7.6.5 The national Test Standards BS 476 – 4 and BS 476 – 11 both expose the core of composite material directly to heat as the full depth of the composite material is placed inside a furnace and heated from all sides.

F7.6.6 The European test standards BS EN ISO 1182, BS EN 1716, and BS EN ISO 11925-2 all expose the core directly to heat. In BS EN ISO 1182 the full depth of the composite material is placed inside a furnace and heated from all sides. In BS EN 1716 the core is ground to a powder then ignited. In BS EN ISO 11925-2 a gas flame id impinged directly onto the exposed edge of the sample if the edge is exposed in end use (as occurs in ACM panels)

F7.6.7 The European test standard BS EN 13823 does not directly expose the core of ACP panels to heat. However, it cannot be used in isolation to demonstrate Class A2, B or C and must always be used in conjunction with a European test that exposes the core directly.

F7.6.8 This difference is critical in products where the combustible core of the product is exposed in practice, and also by very means of its thickness within a composite. Particularly in ACM material used in panel forms, which are approximately 3-4mm in thickness. It is very difficult to demonstrate the core in such a slender composite would not be exposed to heat in practice – either via an exposed edge or via conduction through the aluminium sheet.

F7.6.9 I have also noted that none of the sample sizes in these test standards are representative of the size of an actual ACP panel. The typical dimensions of an ACP panel are 2.3m high by 0.9m whereas the largest test standard specimen is that from the BS EN 13823 test which is only 1.5m high.

F8 Test set up and procedures: a comparison of British and European Standards

F8.1 Introduction

F8.1.1 From the review in Section F7, the test standards can be broadly categorised as either a test that measures the amount of energy a specimen realises when it undergoes combustion (either directly or indirectly through temperature rise); or tests on how far a flame spreads across a surface.

F8.1.2 The aim of this section is to explain what the similarities and differences between the test standards are and so form an opinion on if and how the current tests are comparable.

F8.2 Measurement of heat energy released by material during combustion

F8.2.1 The Table F-9 below compares the test setup and procedures along with the pass criteria for tests where the heat energy released during combustion is measured.

Table F-9: Comparison of tests to British and European Standards where the heat energy released during combustion is measured

Parameter	BS 476-4 (1970)	BS 476-11 (1982)	BS EN ISO 1182:2010	BS EN ISO 1716:2010
Formal name of test	Fire tests on building materials and structures – Part 4. Non-Combustibility test for materials	Fire tests on building materials and structures – Part 11: Method for assessing the heat emission from building materials	Reaction to fire tests for products – Non-combustibility test	Reaction to fire tests for products – Determination of the gross heat of combustion (calorific value)
Purpose of test	To determine whether building materials are non-combustible within the meaning of the definition. Materials used in the construction and finishing of buildings or structures are classified 'non-combustible' or 'combustible' according to their behaviour in the 'non-combustibility' test.	A method for assessing the heat emission from building materials when inserted into a furnace at a temperature of 750°C.	A method for determining the non-combustibility performance, under specified conditions, of homogenous products and substantial components of non-homogenous products. For the selection of construction products which, whilst not completely inert, produce only a very limited amount of heat and flame when exposed to temperatures of approximately 750°C.	A method for the determination of the gross heat of combustion of products at constant volume in a bomb calorimeter. It is a test method for determining an absolute value of the heat of combustion for a product and it does not take into account any inherent variability of the product.
Date test came in	Part 4 first published in 1970 – (This standard has been superseded by the current BS EN ISO 1182, but it has been retained based on legitimate need for the standard within non-EU markets).	1982 – (This standard has been superseded by the current BS EN ISO 1182, but it has been retained based on legitimate need for the standard within non-EU markets).	February 2002 (this has been withdrawn and replaced by June 2010 version).	February 2002 (this has been withdrawn and replaced by August 2010 version).
Specimens				
Number of specimens	3	5		3 specimens (two additional if required) composed from at least five randomly selected parts taken from across the thickness
Height of specimen	50 ± 3mm	50 ± 2mm	50 ± 3mm	Specimen is fine powder obtained by grinding.
Diameter of specimen	Width and breadth: 40 + 0, -2mm	Cylindrical: 45 + 0, -2mm		
Thickness of material	Less than the height	Within 50 ± 2mm	Within 50 ± 3mm	
If thickness of material does not follow above criteria (note this is relevant to ACM panels where the panel thickness is typically only 4mm)	Each specimen made of a number of layers to achieve this thickness	-Material with thickness greater than 52mm should be reduced to specified height. -Material with thickness less than 48mm made of a number of layers to achieve the thickness.	-Specimens of the height 50 ± 3mm shall be made using a sufficient number of layers of the material or by adjustment of the material thickness.	Prepared using the crucible method: -Insert the previously weighed mixture of specimen and benzoic acid into the crucible. -Connect the previously weighed firing wire to the two electrodes. -Loop down the firing wire to touch the powder in the crucible. If a fine powder cannot be obtained and/or a complete combustion cannot be obtained, then the test shall be conducted using the "Cigarette" method: -Place a previously weighed firing wire down the centre of the mandrel. - Wrap the previously weighed cigarette-making paper around the mandrel and glue the two overlapping edges together. -Leave sufficient paper to twist around the firing wire at the lower end of the mandrel and insert the whole assembly into the mould. (Firing wire shall project through the bottom). -Remove mandrel -Insert previously weighed mixture of specimen and benzoic acid in the cigarette-making paper.
Layers used to increase thickness	Horizontal position, held together firmly, without significant compression, by the means of two fine steel wires to prevent air gaps between layers.			

Parameter	BS 476-4 (1970)	BS 476-11 (1982)	BS EN ISO 1182:2010	BS EN ISO 1716:2010
				-Remove the filled "cigarette" from the mould and twist together ends of the paper to seal. -Weigh (Total mass shouldn't vary from the masses of the constituents by more than 10mg) -Put into crucible -Connect firing wire to the two electrodes.
Conditioning of specimen	Before test specimens shall be: -Dried in a ventilated oven at 60 ± 5°C for 24 hours -Then cooled to ambient temp in a desiccator containing anhydrous calcium chloride	Before test specimens shall be: -Conditioned to constant mass at a temperature of 23 ± 2°C and a relative humidity of 50 ± 10%. (For 24h) -Retained in this condition until immediately prior to testing.	Conditioned as specified in EN 13238. Then: -Dried in a ventilated oven maintained at 60 ± 5°C for between 20 hours and 24 hours. -Then cooled to ambient temperature in a desiccator prior to testing. -Mass of each specimen determined to an accuracy of 0.01g prior to test.	Powdered specimen, the benzoic acid and the cigarette-making paper shall be conditioned in accordance with EN 13238 or ISO 554.
Apparatus				
Furnace	Tubular electric furnace comprising a tube of refractory material of: -a density between 1500 and 3200 kg/m^3, -Internal diameter of 75mm, -Height of 150mm, -Overall wall thickness between 10 and 13mm.	Comprising a refractory tube surrounded by a heating coil and enclosed in an insulating surround. Furnace tube shall be made of an alumina refractory material of: -density 2800 ± 300kg/m^3, - Internal diameter of 75 ± 1mm, -Wall thickness of 10 ± 1mm, -Overall wall thickness (including cement applied to retain the electrical winding) shall not exceed 15mm.	A furnace comprising of a refractory tube surrounded by a heating coil and enclosed in an insulated surround. Made of alumina refractory material of: - density 2800 ± 300kg/m^3, - Internal diameter of 75 ± 1mm, -Height of 150 ± 1mm, -Wall thickness of 10 ± 1mm. Furnace tube fitted in the centre of a surround made of insulating material 150mm in height and 10mm wall thickness. This will be mounted on a stand and shall be equipped with a specimen holder and a device for inserting the specimen holder into the tube.	Calorimetric Bomb: -Volume (300 ± 50) ml; -Mass not greater than 3.25kg; -Casing thickness at least 1/10 of the inner diameter of the body (The lid is intended to receive the crucible and the electric firing device. The lid, including and seals, shall be capable of withstanding an internal pressure of 21MPa.) Calorimeter: -Jacket: double-walled container which is thermally insulated together with an insulated lid. Filled with water. Calorimetric Vessel: Polished metal container to accommodate the bomb which should be immersed in water. Stirrer: Driven by a constant-speed motor. To prevent the transfer of heat to and from the calorimeter. Temperature measuring device: Capable of giving a resolution of 0.005K. Crucible: Made of metal, with a flat base, 25mm in diameter and 14mm to 19mm high. Timing Device: Capable of recording the time elapsed to the nearest second and accurate to within 1s in 1h. Electric power source: With voltage to the firing circuit not exceeding 20V for the firing. Pressure gauge and needle-valve: Attached to the oxygen supply circuit to show the pressure in the bomb while it is being filled. Two balances: -One analytical balance with an accuracy of 0.1mg;
Underside of furnace	-There shall be a cone-shaped air-flow stabilizer, 500mm long and reducing from 75mm internal diameter at the top and 9mm internal diameter at the lower end. -Made of steel sheet (approx. 1mm thick) and finished smooth on inside, particular attention being given to the joint with the furnace, which should be a close, airtight fit and finished smooth internally.	-Open-ended cone-shaped airflow stabilizer 500mm long and reducing uniformly from an internal diameter of 75 ± 1mm at the top to an internal diameter of 10 ± 0.5mm at the bottom. -Made of steel sheet (approx. 1mm thick) and smooth on the inside. -Joint between the stabilizer and the furnace tube shall be an airtight fit and shall be finished smooth on the inside. - Upper half of the stabilizer shall be insulated externally with a 25mm thick layer of mineral fibre insulating material with thermal conductivity 0.04 ±0.01 W/ (m K) at a mean temp of 20°C.		
Top of furnace	Draught shield: -Made of steel sheet (same as the stabilizer cone) -Internal diameter of 75mm -Height of 50mm	Draught shield: -Made of steel sheet (same material as the stabilizer cone) -Internal diameter of 75 ± 1mm -Height of 50mm -Exterior shall be insulated with a 25mm thick layer of mineral fibre insulation with thermal conductivity 0.04 ± 0.01 W/ (m K) at a mean temp of 20°C.		
Winding	Electric winding of the furnace shall be so arranged that a vertical zone of at least 60mm length in the central part of the empty furnace maintains the operating temperature, uniform to within ± 10°C as measured by the thermocouple located 10mm from the wall. This can be achieved by having closer windings at the two ends of the furnace tube or by means of separate windings at the two ends regulated independently of the central section. To	Furnace tube shall be provided with a single winding of 80/20 nickel/chromium resistance tape that is 3mm thick. The ends of the tape shall be terminated in a junction box		

Parameter	BS 476-4 (1970)	BS 476-11 (1982)	BS EN ISO 1182:2010	BS EN ISO 1716:2010
	minimise temperature fluctuations in the furnace it is necessary to use a voltage stabilizer in the circuit able to maintain voltage within ±0.5% of the nominal value.			-The other is a balance with an accuracy of 0.1g.
Stand	Furnace mounted to a stand with lower end of air flow stabilizer near floor level. To prevent draughts shields can be placed consisting of boards 4-5mm thick, fixed around the stand to a height of approximately 550mm from the floor.	Firm and horizontal, on which the furnace, stabilizer cone and draught shield are mounted. A base a draught screen attached to reduce draughts around the bottom of stabilizer cone. Draught screen shall be 550mm high and bottom shall be 250mm above the base plate.		
Holder	Specimen should be placed in a holder of nichrome of heat resisting steel wire of 1- 1.5 mm diameter with a fine metal gauze tray of heat resisting steel being placed in the bottom. -Weight shall not exceed 20g -Holder shall be suspended from lower end of an adjustable tube of heat resisting steel with outside diameter of approximately 6mm and internal diameter of 2mm.	-Specimen holder and its gauze base shall be made of nickel/chromium or a heat-resisting steel wire. -Gauze base placed in the bottom of the holder. -Total mass of the specimen holder shall be 15 ± 2g		N/A
Insertion device	-Metallic rod moving freely in a vertical tube fitted to the side of the furnace -The heat resisting steel tube with the specimen holder being fixed by means of a space bar to the sliding rod -Specimen should enter the furnace quickly and without any mechanical shock. -Specimen holder should occupy a predetermined position in the furnace, in the middle of the constant temperature zone and equidistant from the walls.	-A device provided to lower the specimen holder precisely down the axis of the furnace tube -Provided so that the geometric centre of the specimen is located rigidly at the geometric centre of the furnace during the test -Shall consist of a metal sliding rod moving freely within a vertical guide fitted to the side of the furnace.		
Specimen holder for loose fill materials	N/A		Cylindrical and of the same outer dimensions as the specimen, made of a fine metal wire gauze of heat-resisting steel similar to the wire gauze used at the bottom of the normal holder. Specimen holder shall have an open end at the top and the mass of the holder shall not exceed 30g.	N/A
Thermocouples				
Size and description	-Mineral-insulated stainless-steel-sheathed thermocouples used to measure temperature - External diameter of 1.5mm, -nickel/chromium v. nickel/aluminium thermocouple elements of 0.3mm nominal diameter, -Hot junction of the insulated type.			N/A
Location	-Attached to the top and bottom edges of the draught shield	-Furnace thermocouple: Located 10 ± 0.5mm from the furnace tube wall and at a height corresponding to the mid-point of the furnace tube -Specimen thermocouple: Positioned so that its hot junction is located at the geometric centre of the specimen. This shall be achieved by means of the 2mm diameter hole in the top of the specimen.		

Parameter	BS 476-4 (1970)	BS 476-11 (1982)	BS EN ISO 1182:2010	BS EN ISO 1716:2010
		-Contact thermocouple: Shall have its end bent to allow a horizontal contact with the interior of the furnace wall.		
Temperature observation	-2.5mm diameter holes -Desirable to use a temperature recorder, say of 1000°C range, which will give a continuous measurement during the test. -Equipment shall have an accuracy of at least 0.5%.	-A zero current device capable of continuously measuring the output from the thermocouples to the nearest 1°C. -Capable of assimilating the incoming data and producing a permanent record of this at intervals of not greater than 0.5s. -Operating range of 10mV full scale deflection with a "zero" of approximately 700°C.	- The furnace thermocouple shall be initially calibrated at 750°C and shall be replaced after 200 test runs. - The additional two thermocouples for specimen centre and surface temperature should be controlled at 100°C. (Use of these two thermocouples is optional).	
Test procedure				
Setup	-Apparatus sited so that it is not exposed to draughts, sunlight or to intense artificial illumination when in use. -Measure furnace temperature using the thermocouple. This should be positioned so that the hot junction is 10mm from the wall of the furnace and at mid-height of the specimen. -Second thermocouple should be placed in centre of specimen inserted from the top through a 2mm diameter hole drilled (where necessary for this purpose) and shall maintain contact with the material at the bottom. -Furnace heated and its temperature stabilized at 750 ± 10°C for a minimum period of 10 min.	-Apparatus sited so that it is not exposed to draughts, sunlight or to intense artificial illumination when in use. -Remove specimen holder from the furnace, position furnace thermocouple and connect it to the temperature indicator. -Adjust power input to furnace so that the temperature is stabilized for at least 10 min at 750 ± 5°C, taking a continuous record of this temperature.		-Conducted in a room where the temperature remains at room temperature and is stable, within ±2 K. -Switch on the apparatus at least 1h before testing. -Place specimen in the crucible. -Place the crucible in the holder. -Attach the firing wire and loop it to touch the specimen. -Check that a good electrical contact is ensured between the two electrodes and the firing wire. - Place the holder in the body of the calorimetric bomb. -Adjust the lid and tighten onto the body of the bomb. Connect bomb to body of oxygen and fill until a pressure of 3.0MPa to 3.5MPa is achieved. -Place the bomb in the calorimeter vessel. -Cover the upper surface of the bomb cap with distilled or demineralized water and weigh. -Check the bomb does not leak (no continuous stream of bubbles). -Place calorimeter vessel in the water jacket.
Process	-Specimen inserted in furnace performed in not more than 5s. -Record made for a further 20 min of the temperature of the two thermocouples by a means of continuous recorder. -Note occurrence and duration of any flaming in the furnace. -Stabilized heating current shall be maintained unchanged for the period of the test.	-After stabilizing furnace, record the mean temperature as the initial furnace temperature $T_{f,initial}$(in °C). -Weigh Specimen and record mass and actual dimensions. -Insert into specimen holder and insert the specimen thermocouple into the specimen. -Place specimen into furnace not taking more than 5s and start timing device immediately. -Record temperatures from specimen and furnace thermocouples throughout test. -Continue test until a final temperature equilibrium is established. (When the temperature gradients are negative and less than 5°C over a period of 10 min or a test time of 120 min has been completed). -Record max temperatures and the temperatures at the end of the test for the furnace and the specimen. -Weigh specimen and record mass.	-Room temperature shall not change by more than 5°C during a test. -Insert one specimen prepared and conditioned into the specimen holder suspended on its support. -Place the specimen holder in the furnace not taking more than 5s for this operation. -Start the timing device immediately following the insertion of the specimen. -Record throughout the test temperature measured by the furnace thermocouple. -If required measure throughout the temperature measured by the surface thermocouple and centre thermocouple. -Carry out test for a period of 30 min. -If final temperature equilibrium has been reached in this time the test is stopped. -If not then continue test at 5 min interval checking each time if the final temperature equilibrium has been reached.	Proceed as follows: -Set temperature measuring device and start the stirrer and the timing device. -Bring water in the calorimeter vessel to a temperature that is approximately equal to that of the jacket. -Close the electric circuit to cause combustion. -Remove bomb from the calorimeter, leave to stand for 10 min, and then slowly reduce the pressure. -Open the bomb. -Verify that complete combustion has taken place (neither a sooty deposit inside the bomb nor traces of residual carbon on the sides of the crucible) -Rinse and dry the bomb. -If complete combustion has not occurred, try a different method of test specimen preparation.

Parameter	BS 476-4 (1970)	BS 476-11 (1982)	BS EN ISO 1182:2010	BS EN ISO 1716:2010
		-If first and second specimens both have a test time of 120 min then no other specimens are required to be tested.	-Stop test once it has been reached or after 60 min and note duration of test. -Remove specimen from furnace. -After cooling, weigh the specimen.	
Notes	N/A	Record the number of specimens tested and for each specimen calculate: -Furnace and specimen temperature rise (max-final) -Calculate and record arithmetic mean of the temperature rises. -Note the sum of the recorded durations of sustained flaming and the mean. -Record the density from actual dimensions and mass and then the mean. -Record the mass loss as a percentage and then calculate the mean.	-Record the mass, in grams before and after the test for each specimen. -Note the occurrence of any sustained flaming and record the duration of such flaming in seconds. -Record initial temperature (average temperature over the final 10 min of the stabilization period). -Record the maximum temperature over test period. -Record the final temperature (average temperature over the final 1 min of the test period). -Note the occurrence of any steady blue-coloured luminous gas zones -Note the occurrence of any sustained flaming and record the duration of such flaming in seconds.	-Make corrections for manual apparatus. -Make corrections for isothermal calorimeter. -Calculate gross heat of combustion of the specimen. -Calculate the gross heat of combustion of the product.
Test Appendix				
Information included	-Name or identification mark of material. -Brief description of material. -Density of material. -Date of receipt of material. -Date/Dates of test. -Test results. -Designation of material as combustible or non-combustible according to test criteria.	-Quote individual results. -Observations made during test and comments on difficulties. -Name and address of testing laboratory. -Name and address of sponsor. -Name and address of manufacturer/supplier. -Date of test. -General description of material tested. -Number of specimens tested. -Relationship of combination materials that may have been used. - The following statement: “The results relate only to the behaviour of the specimens of the material under the particular conditions of the test. The results obtained on an individual material used in a combination should not be construed as reflecting the performance of the material combination as a whole, which may be influenced by the mechanism of combining the individual materials together, such as with adhesives. The results are not intended to be the sole criterion for assessing the potential fire hazard of the material in use.”	-Reference to the BS EN ISO 1182 standard -Any deviation from the test method; -Name and address of the testing laboratory; -Date and identification number of the report; -Name and address of the sponsor; -Name and address of the manufacturer/supplier (if known); -Date of sample arrival; -Identification of the product; -Description of the sampling procedure (where relevant); -General description of the product tested; -Details of conditioning; -Date of test; -Calibration results; -Test results; -Observations made during the test; -The statement: “The test results relate to the behaviour of the test specimens of a product under the particular conditions of the test; they are not intended to be the sole criteria for assessing the potential fire hazard of the product in use.”	Reference to the BS EN ISO 1182 standard -Any deviation from the test method; -Name and address of the testing laboratory; -Date and identification number of the report; -Name and address of the sponsor; -Name and address of the manufacturer/supplier (if known); -Date of sample arrival; -Identification of the product; -Description of the sampling procedure (where relevant); -General description of the product tested; -Details of conditioning; -Date of test; -description of method to cure material, where relevant; -Water equivalent; -Test results; -Observations made during the test; -The statement: “The test results relate to the behaviour of the test specimens of a product under the particular conditions of the test; they are not intended to be the sole criteria for assessing the potential fire hazard of the product in use.”

F8.2.2 It can be seen from the Table F-9 above that BS 476-11 and BS EN ISO 1182:2010 are essentially the same test. The main difference is that the test duration of BS 476-11 is 120 minutes whereas the test duration of BS EN ISO 1182:2010 is limited to 60 minutes.

F8.2.3 It should be noted that the current edition of BS 476-11 states that it has been superseded by the current BS EN ISO 1182. In effect, the European standard BS EN ISO 1182 is just an updated version of the British Standard BS 476-11.

F8.2.4 It can also be seen through my analysis in Table F-9 above that the only material difference between BS 476-4 and BS 476-11/ BS EN ISO 1182:2010 is the sample size/shape (50mm ×40mm cuboid compared to a 50mm high cylinder with a 45mm diameter in BS EN ISO 1182:2010) and the duration of exposure (20 minutes compared to 120 minutes in BS 476-11 and 60 mins in BS EN ISO 1182:2010).

F8.2.5 It can also be seen in Table F-9 above that BS EN ISO 1716:2010 is dissimilar to the other three tests in the following key ways: the material tested in the BS EN 1716 test is not solid but instead is ground into a fine powder; combustion is initiated using an external ignition source in the BS EN 1716 test whereas there is no ignition source in the other tests; and the energy release by the material is measured in watts not in temperature rise of either the specimen or the furnace.

F8.3 Review of differences between tests that measure spread of flame across a surface

F8.3.1 In Table F-10 below I provide my comparison of the British Standard/ European Standards described in Section F7 which measure the spread of flame across the surface of a material (either horizontally or vertically)

Table F-10 Comparison of Surface spread of flame tests to British and European Standards

	Test Standards	Specimen dimensions			Total test duration	Heat Exposure			Measurements of flame spread taken		Flame spread Pass criteria	
		Height (mm)	Width (mm)	Depth (mm)		Type	Duration	Exposure location	Horizontal	Vertical	Cladding below 18m	Cladding above 18m
National Standard [Test used as one method of demonstrating Class 0]	BS 476-7	270	885	Full product thickness (Clause 5.3.3)	600s	850mm×850mm radiant panel calibrated to 32.5 kW/m^2 at 75mm from edge of specimen	600s	Radiation heat exposure to external surface of material + 1-minute exposure to pilot flame where the centre of the orifice of the burner is positioned: a) (28 ± 2) mm in front of the surface of the specimen; b) (6 ± 2) mm above its exposed lower edge; c) (15 ± 5) mm from the inside vertical edge of the specimen holder at the corner closest to the radiation panel	Yes	No	No requirement	Spread of flame <165mm after 1.5 minutes & Spread of flame<165mm after 600s
European standard [Tests used to demonstrate Class B and C to BS EN 13501-1)	BS EN 13823	1500	1000		1560s	30.7 kW propane burner (triangular burner side length 250×250mm)	1260s	Direct flame impingement on external surface of specimen	Yes	No	Flame spread <1000mm horizontally after 1560s	Flame spread <1000mm horizontally after 1560s
	BS EN ISO 11925-2	250	90	Full product thickness (Clause 5.2)	60s	Single point source, propane burner 20mm flame length	30s	Direct flame impingement on external surface of specimen and direct flame impingement on the exposed edge of the specimen	No	Yes	Vertical flame spread <150mm after 60s (30s exposure +30s of no exposure)	Vertical flame spread <150mm vertically after 60s (30s exposure +30s of no exposure)

F8.3.2 As I have described none of the tests referenced in ADB 2013 that measure the spread of flame across a surface are comparable. The main differences are that the specimens are all different sizes; the heat exposure types and durations are different in all three tests and the measurements of the flame spread distances are all different.

F8.3.3 It should also be noted that of the three tests only BS EN ISO 11925-2 measures the vertical spread of flame.

F9 Application to Grenfell Tower

F9.1.1 My analysis is presented in Section 11 of my main report.