Final Report For Sector Group C – Sandwich Panels

Report on experimental programme and recommendations

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Prepared for :

Sector Group C of the Partners In Innovation Project - Addressing the implications of European harmonisation and so-called ‘exotic products’

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Executive Summary

This programme of work forms part of a Partners in Innovation project to consider the issues surrounding the ‘difficult to test’ or so called ‘exotic products’. The testing of sandwich panel systems within the European system of fire testing and classification have been considered difficult to test because:

- of the problems relating to the production representative intermediate scale specimens,
- their often potentially complex fire behaviour and
- the standard reference scenario, the room corner test, does not properly represent the products in their normal ‘end use’ application, which is typically as free-standing or frame mounted units.

Four systems were tested using the ISO/FDIS 13784-1 test procedure. The systems were supplied and installed by individual members of the PII group in the knowledge that the standard states that the connections between the panels, and between the walls and the ceiling, should be representative of those in end-use application. To the best of our knowledge, this guidance was followed by the partners. The partners were invited to consider testing panels which would be representative of the new proposed Approved Document Part L requirements. The ultimate choice of product for test was the responsibility of the individual partners.

The systems are referred to by the composition of the panel core material and mounting details as follows:

- Modified phenolic foam core, steel-faced sandwich panel system - System 1 (free standing around support frame)
- Rigid Polyisocyanurate (PIR) foam core, steel-faced sandwich panel system – System 2 (frame mounted)
- Rigid Polyurethane (PUR) foam core, steel-faced sandwich panel system – System 3 (frame mounted)
- Rock fibre core, steel-faced sandwich panel system – System 4 (frame mounted)

The ISO/FDIS 13784-1 test standard provides a method for assessing the fire performance of free-standing and frame mounted specimens with the same fire source and profile as that used for the ISO 9705 test.

The reaction to fire performance of these systems were also determined in accordance with the draft product standard for sandwich panels. The results obtained from the SBI

tests were compared with the data from the ISO/FDIS tests and showed that the correlation for the FIGRA data was poor, although the SMOGRA correlation was good.

The results from this work were also compared with other published data and the findings discussed.

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Contents

Introduction

This programme of work forms part of a Partners in Innovation project to consider the issues surrounding the 'difficult to test' or so called 'exotic products'. The project was progressed through four sector groups, each dealing with a different product or group of products. These were:

- Lighting diffusers and roof lights – Sector Group A
- Preformed insulation products – Sector Group B
- Sandwich panels – Sector Group C
- Internal fittings – Sector Group D

This report is the second stage of the work programme undertaken by sector group C, looking at sandwich panel systems. The first stage of the project was to identify and review any relevant information relating to the European reaction to fire tests, existing British Standards and large-scale experimental programmes in this area, as it had been suggested that the ISO 9705 test may not be the appropriate reference scenario for this product group. The conclusions of this review(1) were based on information available in the public domain and that supplied by the partners to the project. The data supplied covered a number of test methods and a range of scales. One of the conclusions reached was the need to undertake a series of 'back to back' tests to provide directly comparable data between the test methods and product groups. As a result of this review, a number of members of the group agreed to support an experimental programme, the generic details of which are presented below. Four systems were tested as part of this exercise and each sponsor was provided with full test reports for their own products, only the general generic details of the systems tested are presented in this report.

The members of the group for the experimental programme were:

Mr A Burd	Office of the Deputy Prime Minister (ODPM)
Mr M Payne	AEA (T)
Mr N Selves	Metal Cladding and Roofing Manufacturers Association (MCMRA)
Mr B Parlor	Rockwool Ltd
Mr R Walker	European Phenolic Foam Association (EPFA)
Mr P Trew	Engineered Panels in Construction (EPIC)

Mr L Cody	Eurisol (UK Mineral Wool Association)
Mr T Day	BRE/FRS (representing ABI interests)
Mr P Briggs	Warrington Fire Research Centre (WFRC)
Dr D A Smith	FRS/BRE
Dr S Colwell	FRS/BRE
Dr K Shaw	FRS/BRE

Sandwich panel systems

A sandwich panel consists of a core of insulating material between two facings. The core material can be a produced from products such as foamed plastics or rock fibres. The facing can be metal, gypsum board, plastic sheet, reinforced sandwich sheet or other materials. The sandwich panel forms part of a construction system and the fire behaviour depends on the performance of the system as a whole (core, facing material, flashings, fixings and framework (if used)). There is clearly a problem of scale involved when assessing fire performance as systems may perform well in bench-scale testing, but not in large-scale, where the results of structural expansion and delamination (gaps etc.) may be greater.

European harmonised system of testing and classification

In order to satisfy the requirements of the Construction Products Directive (CPD), a number of product standards have been developed by CEN Technical Committees to provide a means of CE marking products. As part of this procedure, the reaction to fire performance of these materials must be declared. In order to support this requirement, a set of four test standards has been developed to measure the reaction to fire performance of non-flooring products and a further standard defines the classification of products into Classes A1 and A2 to F. The relevant standards are detailed below:

- BS EN ISO 1716: 2002 Reaction to fire tests for building products - Determination of the heat of combustion.
- BS EN ISO 1182: 2002 Reaction to fire tests for building products - Non-combustibility test.
- BS EN 13823: 2002 Reaction to fire tests on building products - Single burning item test.
- BS EN ISO 11925 – 2: 2002 Reaction to fire tests on building products – Part 2: Ignitability when subjected to direct impingement of flames.
- BS EN 13238:2002 Reaction to fire tests for building products - Conditioning procedures and general rules for the selection of substrates.

- BS EN 13501-1: 2002 Fire classification of construction products and building elements Part 1: Classification using test data from reaction to fire tests.

Central to the system is the Single Burning Item (SBI) test BS EN 13823:2002, which is used with the other test methods to specify performance in classes A2 to D. Performance in the SBI test, at least as far as flat sheet products are concerned, was validated in terms of real scale fire behaviour by correlation with performance in the ISO 9705 Room corner test [(2)], termed the reference scenario.

Since a sandwich panel is always used as part of a construction system. Fire performance depends on the details of construction and there are a number of features of such constructions that are difficult to reproduce both in the intermediate scale SBI test and the ISO 9705 test.

The reference scenario for lining products, the room corner test, does not represent the scenario of a fire in a sandwich panel installation as many of these are free-standing and not used as linings in a room constructed from masonry. An appropriate scenario for these cases may be that used in ISO/FDIS 13784-1[(3)] as it provides the smallest realistic size for construction, and therefore potentially the worst case in terms of propensity to flashover. It also incorporates the measurement of heat release rate, smoke production rate and fire spread performance through the panels.

(It should be noted that at the time of writing the draft standard ISO/DIS 13784-1 has now been approved, and is undergoing its final editorial stages prior to publication.)

The issues of sample buildability were also highlighted by Van Hees[(4)] when comparing the fire performance of systems when installed within the ISO 9705 room and as freestanding or frame mounted systems. The view was expressed that due to the importance of the sample construction, only the free-standing or frame mounted systems could allow representative construction of the ‘end use’ conditions for these types of systems.

Experimental procedures

ISO/FDIS 13784 – 1 Room tests

General

The sandwich panel systems were all of the Type A: internal frame supported structure, as described in Clause 5.1 of ISO/FDIS 13784-1:2001[(3)]. They were constructed by mechanically mounting panels in vertical orientation on a steel box section framework with a cross section of 100mm x 100mm.

The test was carried out according to Method 2a: Enlarged hood and duct system, as described in Clause 9.4.2 of the draft standard. The specimen was placed centrally under the 9m x 9m hood of a large calorimeter with a 1.4 m diameter duct operated according to the principles of measurement given in ISO 9705. This ensured that all of the combustion products were captured by the calorimeter during the test. Data were recorded at intervals of three seconds.

Following each test, the specimen was dismantled and the facings removed from certain panels near the fire source and estimates of depth of char (by discoloration) were made.

Figure 1 shows a schematic layout of the panels on the test frame.

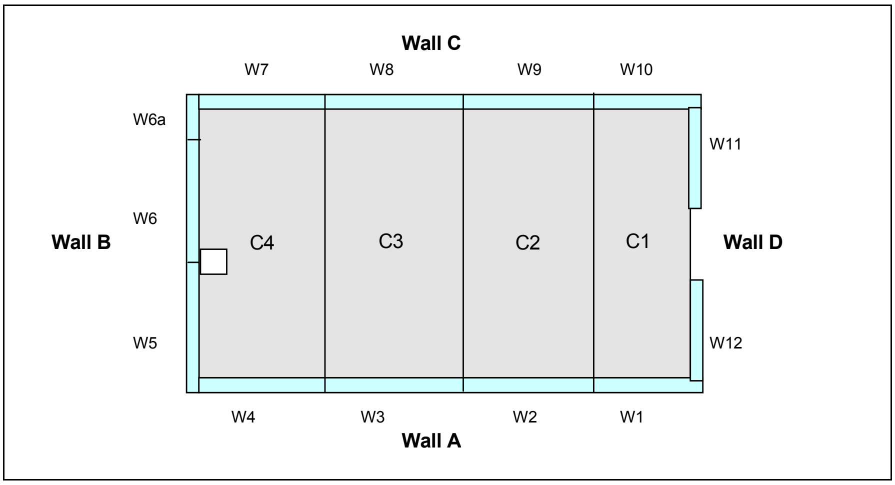

Figure 1. Schematic of typical panel layout

The following additional details are necessary to cover areas where the draft standard is as yet unclear or where a choice of protocol was offered.

Burner location

Because of the presence of a frame member, the burner could not be placed on the floor of the room and in contact with a panel. It was placed on the floor in contact with the frame at the position of a joint on the rear wall of the room.

Thermocouples and heat flux measurements

Thermocouples were located at the centre of each panel 1.8m above floor level for the walls and mid-way across the ceiling for the ceiling panels. The external thermocouples were of the sheathed type, attached to the panel surface using thermal tape. The core thermocouples were also of the sheathed type and were inserted half way into each panel via a drilled hole in the metal skin. Although unclear from the draft standard, internal surface thermocouples were also installed. The internal surface thermocouples were bare wire chromel alumel welded thermocouples made from 0.2mm wire attached to the internal panel surface with ceramic cement.

Three sheathed thermocouples were also located along the centre line of the door opening at heights of 1m, 1.5m and 1.85m above the floor in the opening, corresponding to positions 02,06 and 010 in the standard(3).

A heat flux meter (range 0-100kW/m^2) was positioned at the centre point of the floor and level with the floor surface to record the radiation from above it.

The relevant thermocouple and heat flux data from this work have been reported to each of the test sponsors but has not been included in this generic review as it does not form part of the data set required for this analysis.

Description of sandwich panel systems tested to ISO/FDIS 13784-1

Four systems were tested using the ISO/FDIS 13784-1 test procedure. The systems were supplied and installed by individual members of the PII group in the knowledge that the standard states that the connections between the panels, and between the walls and the ceiling, should be representative of those in end-use application. To the best of our knowledge, this guidance was followed by the partners. The partners were invited to consider testing panels which would be representative of the new proposed Approved Document Part L requirements. The ultimate choice of product for test was the responsibility of the individual partners.

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- Rock fibre core, steel-faced sandwich panel system – System 4 (frame mounted)

Table 1 summarises the frame and fixing mountings used in the ISO/FDIS 13784-1 Test.

Table 1 Frame and fixing details used in the ISO/FDIS 13784-1 Test.

Sandwich panel Core	**End Use application**	**Test Frame Present**	**Through Fixing to Test Frame**	**Panel Orientation**
Modified phenolic	Internal	Yes	No	Vertical
PIR	External	Yes	Yes	Vertical
PUR	External	Yes	Yes	Vertical
Rock fibre	External	Yes	Yes	Vertical

Modified phenolic foam external cladding system - System 1

The system was constructed using plastic coated steel-faced panels of nominal thickness 100mm with a modified phenolic foam core. Internal flashings were fitted to all four vertical internal corners and to both the internal and external edges of the door opening.

Rigid polyisocyanurate (PIR) and Rigid polyurethane (PUR) foam core, steel-faced sandwich panel systems – System 2 & 3

The systems were constructed using plastic coated steel-faced panels with either rigid polyurethane (PUR) or polyisocyanurate (PIR) foam cores. The external face of the panels contained a corrugated profile that produced a panel with a maximum thickness of nominally 80mm and a minimum thickness of nominally 40mm.

The panels were through-fixed to the framework. All external corners were protected with steel flashings. All internal areas where the box section of the test frame met the panels were also fitted with steel flashings.

For both the PUR and PIR systems an internal sheeting rail of width 170mm was installed at a centreline height of 1125mm on the rear wall and the two side walls, secured to the framework.

Rock fibre external cladding system – System 4

The system was constructed using nominally 113mm thick plastic coated steel-faced panels with a rock fibre core.

The panels were fixed to the framework and all external corner joints and the edges of the door opening were protected with steel flashings.

European reaction to fire tests

The reaction to fire tests were conducted following the relevant test procedures and the guidance given in the sandwich panel draft product standard(5). Each product was tested to:

- BS EN ISO 11925 – 2: 2002 Reaction to fire tests on building products – Part 2: Ignitability when subjected to direct impingement of flames.
- BS EN 13823: 2002 Reaction to fire tests on building products - Single burning item test.

Small flame test samples – BS EN ISO 11925-2 : 2002

The specimens were tested for both face and edge ignition using a flame application time of 30 seconds following the guidance given in the draft product standard(5) and the test procedure. The specimens were cut from untested panels supplied for the room tests.

SBI test samples – BS EN 13823 : 2002

The specimens were constructed in accordance with the details provided in the draft product standard(5) and the SBI test standard. Each specimen was constructed with a butt jointed corner detail covered by a steel corner flashing of dimensions 50mm x 50mm x 0.5mm fitted to the internal corner formed by the two panels. A steel corner flashing of 200mm x 50mm was fitted to the external corner, both flashings were riveted to the panel facings 40mm from the top and at 400mm centres. The specimens were engineered with a vertical joint in the main wing of the specimen identical to that used in the room tests at a distance of 200mm from the corner in accordance with the standard, fixed and sealed where necessary to correspond to the construction used in the room test. No flashings were fitted to the upper and lower edges of the specimen or to the vertical outside edges. The specimens were free-standing with an air gap of 80mm, and the test rig was in the alternative configuration.

Results and discussion

ISO/FDIS 13784 -1 – Room tests

The data for the four room tests are summarised in Table 2. Values of FIGRA were calculated from the maximum rate of heat release exactly as in the work on the development of the classification for lining materials(6). All four systems gave relatively good performances in these room tests. They would come within the requirements of Class B if judged by the same classification criteria as linings(6), thus offering only limited differentiation between product types.

Table 2: Room tests on four systems using ISO/FDIS 13784-1, Method 2a.

Type of sandwich panel system	HRR_{max} [kW]	Time to HRR_{max} [s]	SPR_{max} [m^2/s]	Time to SPR_{max} [s]	THR [MW]	TSP [m^2]	FIGRA [kW]	SMOGRA [m^2/s^2]
Modified phenolic	79.21	819	1.416	1080	35.42	867	0.09672	0.001311
PIR	43.79	877	4.385	808	10.51	1946	0.04993	0.005427
PUR	226.0	916	19.16	913	89.50	6944	0.2467	0.02098
Rock fibre	38.35	746	0.948	872	6.50	515	0.05020	0.001087

The data review undertaken prior to this experimental programme highlighted work undertaken by Van Hees(4) in which four systems were tested within the ISO 9705 test room and as free-standing or frame mounted systems. Three of the systems tested used cores which were generically similar to those investigated in the this study; rock fibre, PIR and PUR. No further details regarding the construction or specification of the materials tested as part of the Van Hees (4) study were provided and as such the data from these tests cannot be directly compared.

Van Hees(4) reported that the use of the free-standing or frame mounted room tests allowed the panels to be installed using techniques closer to typical ‘end use’ conditions than those used when installing the products within the ISO 9705 test room. The use of the free-standing or frame mounted rooms also allowed the panels to be tested in a scenario closer to typically ‘end use’ conditions than that obtained when the products were installed within the ISO 9705 test room.

Van Hees[4] reported that the free-standing or frame mounted room tests gave rise to more severe test results, typically one class higher than the results obtained with the products installed within the ISO 9705 test room when based on FIGRA analysis, with the exception of one product, which was mounted differently between the two tests.

Comparison of the data for the free-standing and frame mounted rooms between both projects raises some interesting comparisons. Whilst the cores were described as being generically similar to those investigated in this study; rock fibre, PIR and PUR, no further details regarding the construction or specification of the materials tested as part of the Van Hees [4] study were provided and as such the data from these tests can only be used for comparing generically similar products. The comparisons are not direct. None of BRE tests went to flashover whereas Van Hees data showed that both the PIR and PUR core panels flashed over during testing. One reason for this may be the configuration of the test frame and / or the burner location relative to the test specimen. As identified earlier the BRE tests utilised, the test frame suggested within ISO/FDIS 13784-1. This configuration does not allow the burner to come into direct contact with the surface of the test specimen. No details are given in the Van Hees' paper with regard to the design of the test frames used or the location of the burner in relation to the test frame. If the location of the burner or the design of the test frame was such that the burner could directly attack the panel joints, this may explain some of these differences.

European Reaction to Fire Tests

Tables 3 and 4 summarise the findings from the small flame tests and SBI tests respectively, for the samples supplied.

Table 3: Summary of small flame test data (EN ISO 11925-2:2002) for a 30 second flame application.

Type of sandwich panel system	Face Ignition	Edge Ignition
Modified phenolic	No Ignition	No Ignition
PIR	No Ignition	No Ignition
PUR	No Ignition	No Ignition
Rock fibre	No Ignition	No Ignition

Table 4: SBI test (EN 13823:2002) data on four systems.

Type of sandwich panel system	$FIGRA_{0.2MJ}$ (W/s)	$FIGRA_{0.4MJ}$ (W/s)	SMOGRA (cm^2/s^2)	THR_{600s} (MJ)	TSP_{600s} (m^2)
Modified phenolic	0	0	1.4	0.8	41.6
PIR	29.1	20.9	11.6	2.4	143.0
PUR	64.3	64.3	28.7	5.2	255.0
Rock fibre	0	0	0.4	0.4	33.0

Comparison of SBI results

Table 5 presents the Euroclasses obtained for the products tested in this study using the SBI and Small Flame tests together with data from Van Hees(4) work. The data shows that all products are class B with no flaming droplets, although the smoke classifications of S2 & S3 are reversed for the PIR and PUR products respectively, when compared with the results of Van Hees.

Table 5: European Classifications obtained for the products tested in this study using the SBI and Small Flame tests together with data from Van Hees(4) work.

Type of sandwich panel system	Euroclass (BRE)[1]	Euroclass (Van Hees)[2]
Modified phenolic	B - s1,d0	Not tested
PIR	B - s2,d0	B – s3,d0
PUR	B - s3,d0	B – s2,d0
Rock fibre	B - s1,d0	B – s1,d0

Note:

1. Indicated Euroclass is based on systems tested to SBI and Small Flame test.
2. Indicated Euroclass is based on systems tested using the SBI test.
3. Indicative comparison of the results in this table can only be made on the basis of materials which have been described as generically similar.

FIGRA Correlations

The correlation in terms of $FIGRA_{0.2MJ}$ for the SBI test and FIGRA for the ISO/FDIS 13784-1 test is shown in Figure 2.

The correlation coefficients are $R^2 = 0.66$ for $FIGRA_{0.2}$ and $R^2 = 0.77$ for $FIGRA_{0.4}$. Clearly, the correlation for $FIGRA_{0.4}$ is better than for $FIGRA_{0.2}$, but is still not especially robust. In statistical terms, this data can only be considered as a good indicator of correlation, because of the limited number of samples included within the programme of work. However, the correlation between performance in the SBI test and the ISO/FDIS 13784-1 test is not as strong as the correlation obtained with the ISO 9705 test when developing the classification for lining materials. The reason for the relatively poor correlation obtained from this work is best understood by examination of the ranking of the four products based upon the FIGRA values (lowest to highest). For the ISO/FDIS 13784-1 test, the ranking order from this work is PIR, rock fibre, modified phenolic, PUR. For the SBI test, the ranking order based on the indicative classification is rock fibre and modified phenolic, PIR, PUR.

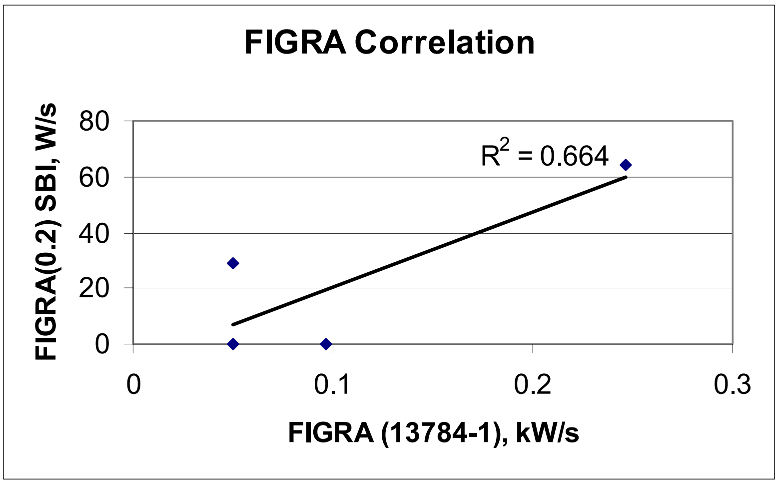

Figure 2: Graph showing the correlation between FIGRA values.

SMOGRA Correlation

The SMOGRA data for the room tests and the SBI tests is presented in Figure 3 and in this case, on the limited data available, a strong correlation was obtained ($R^2 = 0.97$). This was in contrast to the results of the SBI round robin exercise[(6)], which showed a poor correlation of SMOGRA data between the ISO 9705 test and the SBI test, attributed to the greater vitiation in the room test as flashover was approached, compared with the SBI test. In the current work the rates of heat release were much lower (500kW compared with > 1000kW) as flashover did not occur in any of the tests and this would explain why measured effects of vitiation were not observed.

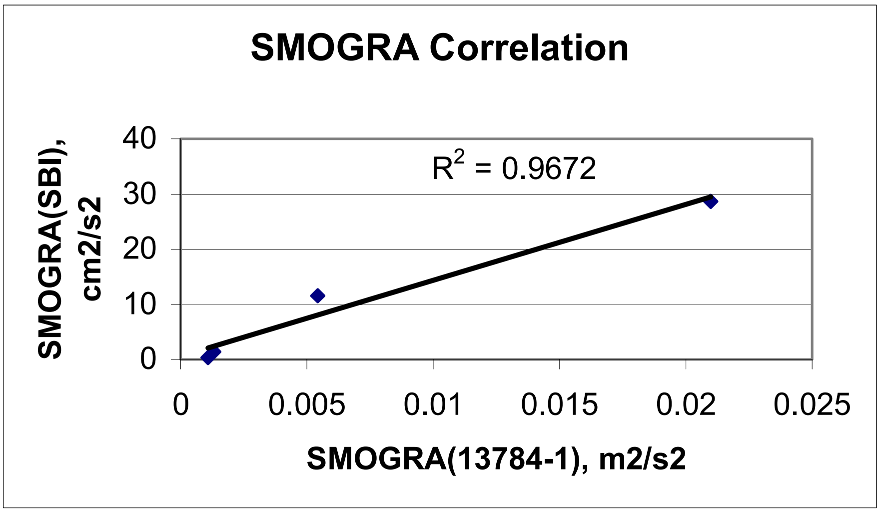

Figure 3: Graph showing the correlation between SMOGRA values.

Effect of Scaling

In the work reported, all the room test specimens were mounted on a 100mm section frame. Following the room test procedure(3) the burner was placed next to one of the side panel joints. This was not possible in the SBI tests as the burner position is fixed in the corner of the apparatus. Moreover, the specimen had to be tested without that support as there was insufficient space to accommodate the thickness of the frame, the specimen, the air gap and the backing boards in the apparatus. Instead, internal and external steel corner flashings of thickness 0.5mm were used. In addition, the presence of a 100mm frame element would introduce a significant gap between the burner and the panel itself reducing the area of flame impact. If a frame of reduced thickness were to be included, it is not obvious what the thickness of that framework should be. Furthermore, it is not obvious how a structural frame member such as the sheeting rail at half room height, which was used in two tests (PUR and PIR) and which was observed to cause a very noticeable deflection of the flame, could be effectively reproduced in the SBI test.

In summary, the features of a large-scale construction cannot always be incorporated into intermediate scale tests with the same effect. Proportional miniaturisation is not an answer, as many of the effects of fire are not linearly related to structural size. However, for reasons of pragmatism, product technical committees within CEN have attempted to propose mounting arrangements ‘indicative’ of application practise, as appropriate.

Conclusion and recommendations

A comparison was made between data obtained from this project for four sandwich panel systems using BS EN 13823 (SBI) and ISO/FDIS 13784-1 (room tests). The findings from this work were also compared with findings from a similar study[4].

1. The correlation between the FIGRA values obtained from the SBI test and the ISO/FDIS 13784 -1 room test was weak. Although the correlation for SMOGRA between both test methods was significantly better. All four products satisfied the requirements of Euroclass B.

2. The use of the ISO/FDIS 13784-1 test standard has highlighted a number of practical problems with the draft test method, including the design of the support frame and hence the location of the burner in relation to the test panels.

3. The inclusion and location of sheeting rails appeared to have a significant influence on the flame behaviour and should therefore be considered further within the context of the ISO/FDIS 13784-1 test standard.

4. Comparison between the SBI test data obtained by this work and a similar study[4] showed good agreement, with all products satisfying the requirements of Euroclass B. In this respect, the classifications achieved in terms of the SBI and ISO/FDIS 13784-1 were the same. However, there is clearly no differentiation between different product types tested in this programme.

5. The work demonstrated the difficulties in obtaining a realistic representation of real scale structural features and consequently real scale fire behaviour in the SBI test for these complex products.

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