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Health and Safety Executive
Final Report

Compartment wall/roof junction experiments

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Executive Summary

The work reported in this report was carried out by a BRE Global Project team under a Contract placed by the Ministry of Housing, Communities and Local Government (MHCLG) which was novated to the Health and Safety Executive (HSE). Its contents, including any opinions and/or conclusions expressed, are those of the authors alone and do not necessarily reflect MHCLG or HSE policy.

This Final report is delivered as part of the Ministry of Housing, Communities and Local Government (MHCLG) (formerly the Department for Levelling Up, Housing and Communities (DLUHC)) project titled "Compartment wall/roof junction experiments", MHCLG Contract reference CPD/004/120/206. This contract was novated to the Building Safety Regulator (hereafter referred to as the client) of the Health and Safety Executive (BSR HSE), HSE contract reference 1.11.4.4436, effective date 1 April 2023. This work was originally part of the call-off element (Part 2 - Experimental fire testing and reporting) of the "Investigation of Real Fires" Project, MHCLG Contract Reference CCZZ18A04.

This programme of experiments provided indicative evidence of the performance of a compartment party wall and three modern roof construction types with respect to Schedule 1 requirement B3(2) of the Building Regulations 2010 (As amended). The programme comprised eight experiments. Each roof construction was formed using timber joists and either an independent timber deck or a composite timber deck bonded to an insulation board. The compartment party wall was 215 mm wide aerated concrete blockwork. The fire stopping material, where fitted, was mineral fibre or cellular glass.

The scenarios included:

1. No fire stopping between the head of the compartment party wall and the underside of a timber deck.
2. Fire stopping between the head of the compartment party wall and underside of the timber deck.
3. Additional fire stopping between top of the timber deck and the underside of the roof membrane.
4. A variant of scenarios 1, 2 and 3 with more insulation between the flat roof joists (creating a hybrid deck construction).
5. Fire stopping (under two different compressions) between the head of the compartment party wall and the underside of a foil faced thermoset composite insulation board / deck.
6. No additional fire stopping above a timber deck of an inverted roof with thermoplastic insulation being allowed to pass across the compartment party wall.
7. Additional fire stopping above a timber deck of an inverted roof, preventing thermoplastic insulation from passing across the compartment party wall.

The study considered three roof construction types:

i. Construction type 1 – *thermally insulated deck*

Comprising tissue faced rigid thermoset polyisocyanurate insulation board on an independent timber deck

ii. Construction type 2 – *composite deck*

Comprising foil faced rigid thermoset polyisocyanurate insulation board with a composite timber deck

iii. Construction type 2 – *inverted roof*

Comprising thermoplastic insulation on an independent timber deck

Where fire stopping is only provided between the head of a compartment party wall and the underside of an independent timber deck and thermoset insulation is allowed to carry across a compartment party wall, there is the potential for elevated temperatures to occur above the centreline of the wall and between the centreline and the unexposed face of the wall.

The presence of additional fire stopping between the independent timber deck and the underside of the waterproof layer prevented elevated temperatures reaching the centreline of the compartment party wall. This observation applied to 100 mm thick thermoset insulation in Construction type 1 – *thermally insulated deck.*

Thermally thick constructions with composite deck (or thermally thick constructions generally) may require further investigation to determine if flaming or smouldering combustion can give rise to elevated temperatures close to or beyond the centre line of compartment party walls or if charring of the insulation prevents this mechanism of fire spread.

Fire stopping between the head of a compartment party wall and the underside of an independent timber deck of an inverted roof, together with additional fire stopping between the independent timber deck and the underside of the waterproof layer, prevented elevated temperatures reaching the centreline of the compartment party wall, when the insulation was thermoplastic. This observation applied to 160 mm thermoplastic insulation in Construction type 3 – *Inverted roof*.

It should not be assumed that this conclusion will apply to thermally thicker constructions without further research. Evidence should therefore be sought to explore the effect of constructing thermally thick and thermally *very* thick roof constructions up to and across party walls and whether such constructions under some circumstances may allow fire to spread across the line of a party wall. If re-visiting this, it would be worthwhile considering the effect of wind in driving fire up to and potentially over party walls

It is not known if fire would spread across a party wall if the insulation used was thinner than the insulation used in these experiments, and this may only become apparent following additional research.

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1 Introduction

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Background

MHCLG requested that BRE Global conduct indicative experimental work to inform internal discussions within the technical policy team with regard to paragraphs 5.12 to 5.15 of Approved Document B: 2019 edition incorporating 2020 amendments (AD B: 2019 edition (incorporating 2020 amendments) Volume 1 and Diagram 5.2 (reproduced at Figure 1).

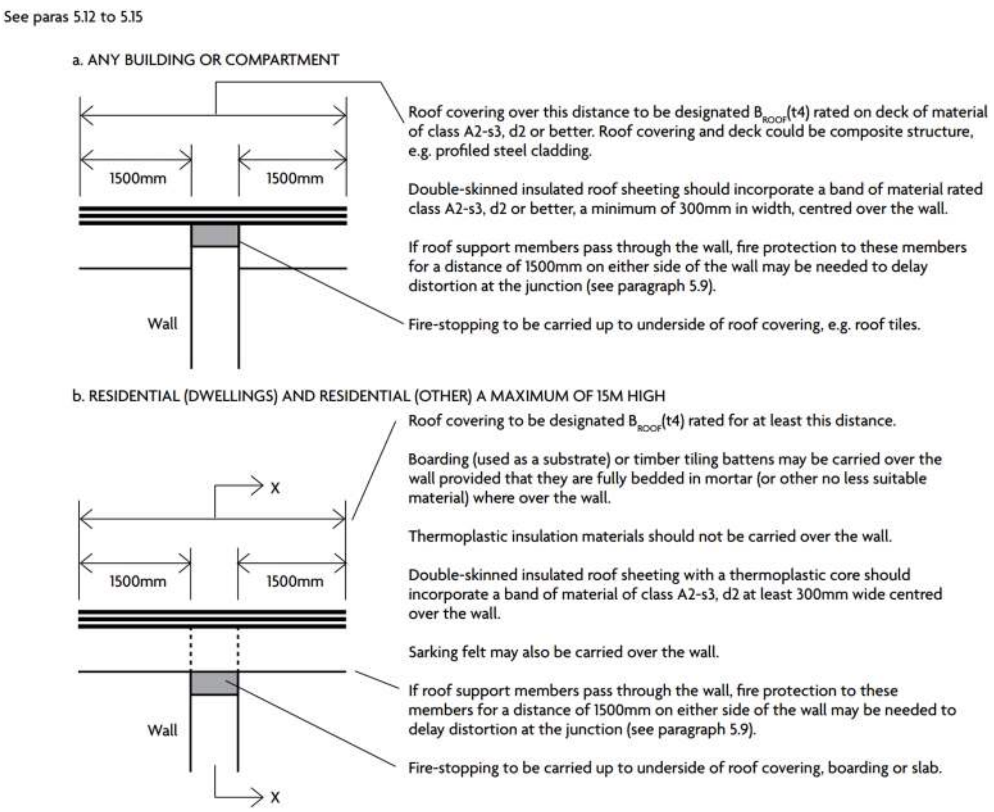


Figure 1 – Extract from Diagram 5.2 from AD B: 2019 edition (incorporating 2020 amendments) Volume 1

The guidance clauses and this diagram in Volume 1 are substantially replicated in AD B: 2019 edition (incorporating 2020 amendments) Volume 2.

The statutory requirements

The Schedule 1 requirements are:

1. Requirement B3 (2) regarding the need to resist fire spread between buildings

> A wall common to two or more buildings shall be designed and constructed so that it adequately resists the spread of fire between those buildings[...]

2. Requirement B3 (3) regarding use of compartmentation

> [...] to inhibit the spread of fire within the building, measures shall be taken[...] comprising either or both of –
> (a)sub-division of the building with fire-resisting construction
> (b)[...]

3. Requirement B3 (4) regarding unseen spread of fire and smoke

> The building shall be designed and constructed so that the unseen spread of fire and smoke within concealed spaces in its structure and fabric is inhibited

The guidance in both AD B Volume 1 and Volume 2 includes the following wording:

> A compartment wall should achieve both of the following.
>
> a. Meet the underside of the roof covering or deck, with fire-stopping to maintain the continuity of fire resistance.
>
> b. Be continued across any eaves.
>
> To reduce the risk of fire spreading over the roof from one compartment to another, a 1500mm wide zone of the roof, either side of the wall, should have a covering classified as $B_{ROOF}(t4)$, on a substrate or deck of a material rated class A2-s3, d2 or better, as set out in Diagram 5.2a.

This programme of compartment wall / roof junction experiments was required by MHCLG to consider specifically the questions that arise as a result of the guidance in a. above.

MHCLG suggested that there were differing opinions in industry, as to how abutment details should be formed to suit the differing roofing methods. One recurring theme centred around the expression ‘roof covering’ and what is meant by it. To some, roof covering is the topmost layer covering the roof, to others, particularly where ‘boarding’ is used in buildings not exceeding 15 m high, the fire stopping can stop at the deck.

The differing opinions can be expressed using a simple drawing – see Figure 2.

Figure 2 shows pictorially, the problem industry was having in determining the level a compartment wall should be taken up to and fire stopped.

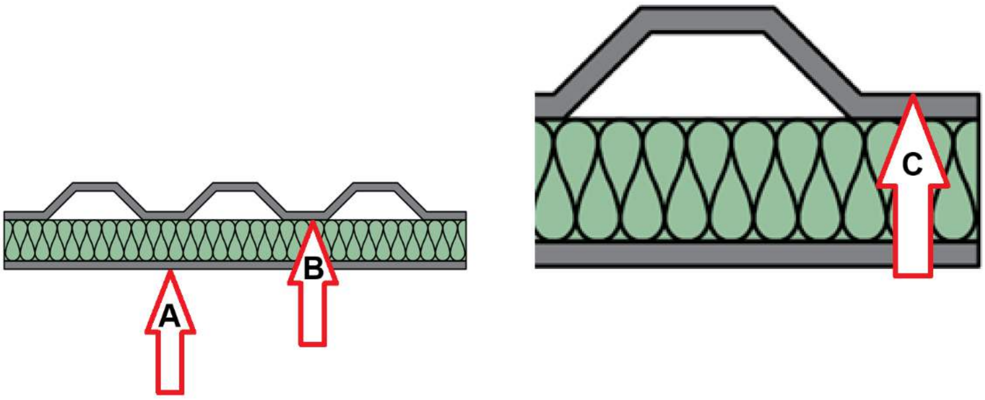


Figure 2 – Simplified diagram highlighting the difficulty in determining whether A or B represent the roof 'deck' and whether B or C represents the roof 'covering'

Note: In order to create this diagram, BRE Global adapted part of Diagram 8.4 : *Provisions for cavity barriers in double -skinned insulated roof sheeting*, from AD B Volume 1

The statutory guidance refers to the need for the roof to achieve a B_{ROOF}(t4) classification, and this is also cited as practical guidance when complying with the schedule 1 requirement B4(2) namely:

> **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.**

Current guidance in AD B

The 'relaxation' shown in Diagram 5.2 b. for buildings up to 15 m high (in Figure 1 (above)) does not apply to the following purpose group classifications:

- Residential (institutional),
- Shops and Commercial,
- Industrial, and
- Storage (including other non-residential).

For buildings up to 15 m above ground, the guidance in AD B is that fire stopping at the head of the wall should be:

"[…] carried up to underside of roof covering, boarding or slab."

Scope

Cold deck constructions were ruled out from this study. The principle of a cold deck roof is that a layer of insulation is located directly above the ceiling with a ventilated void above that. The ventilated void is at least 50 mm high. A cold deck roof would not be allowed to pass across, and above, a compartment wall where the ventilation path traverses it.

The study looked at two warm deck types and an inverted roof type, and in all cases, the method of construction involved timber framing and timber decks. These roof types were selected to provide a common, representative and modern roof design. Given that the study sought to address Schedule 1 requirements B3(2) and B3(4) there was no point in considering constructions on concrete decks, which readily allow compartment walls to be properly fire stopped to their soffits. For consideration of B3(3) see the discussion in Section 2 Experimental concept (below).

The roof construction types considered were:

Type 1. A thermally insulated deck – using 100 mm tissue faced polyisocyanurate board mechanically fixed to an 18 mm oriented strand board (OSB) deck, Experiments 1 to 4.

Type 2. A composite deck – using 120 mm foil faced polyisocyanurate insulation bonded, as a composite product, to a 9 mm OSB deck, with an additional layer of 15 mm plywood, Experiments 5 and 6.

Type 3. An inverted roof – using 160 mm thermoplastic and an 18 mm OSB deck, Experiments 7 and 8.

The most common substrate for an inverted roof is a concrete deck, whether as a monolithic slab (in a concrete framed building) or, as a composite slab (in a steel framed building). Inverted roof construction on such substrate will be even more common in buildings with a total height greater than 15 m above ground level.

MHCLG sought evidence of the implication of going against the guidance in AD B Volume 1 and 2 at diagrams 5.2b and 8.2b respectively, regarding the use of thermoplastic insulation. It was for this reason that MHCLG choose the construction type 3 – *inverted roof*, to provide this indicative evidence.

BRE Global checked that it was possible to construct an inverted roof on a timber deck, and thus, this study was able to maintain consistency i.e. all experiments comprised timber joisted construction and use of timber decking.

A reasonably foreseeable development opportunity may be likely to occur where an existing low-rise building (flats above shops) is to be vertically extended – see Figure 3. In this instance, one might see a timber roof construction, to keep the weight of the new storey down and thereby avoid the disruption of underpinning the pre-existing foundations. The use of a timber roof could also help a developer demonstrate to the Local Planning Authority that the form of construction was largely sustainable.

Figure 3 – A typical development opportunity where the building (after the work is complete) would remain less than 15 m tall and therefore the guidance at b., in Figure 1 above, would apply

Validation of concept

BRE Global reached out to the London District Surveyors Association (LDSA) to nominate a small 'cohort' of London borough building control bodies prepared to assist BRE Global in sense checking the two warm deck roof types proposed.

Note: Prior to MHCLG asking for an inverted roof construction using thermoplastic insulation, it was intended to consider four experiments on roof construction type 1 – *thermally insulated deck* and either four experiments on roof construction type 2 – *composite deck* or two on a composite deck and two on a type involving a metal sandwich panel construction. The final two experiments were decided and confirmed (to be roof construction type 3 – *Inverted roof*) as the project evolved.

Four London Borough Building Control Bodies offered to assist. BRE Global asked this 'cohort' of London boroughs if both warm deck types (as originally envisaged) were in use in their boroughs and whether they had seen such types used on developments up to 15 m high. The feedback received suggested that the two warm deck types selected were common with type 1 being more popular than type 2 but neither were routinely seen on developments at circa 15 m high.

The London boroughs 'cohort' suggested the study might wish to consider hybrid roof constructions of roof construction type 1 – *thermally insulated deck*. The expression hybrid is used when a layer of rigid foamed plastic (typically, a foil faced polyisocyanurate insulation board) is pushed up tight to the soffit of the roof deck from below (i.e. between the firrings). This is a deprecated practice, where the additional layer is overly thick and if the insulation is inserted without a dewpoint calculation being performed and or if the layer is ill-fitting giving rise to cold(er) spots.

The London boroughs 'cohort' also suggested that this study might wish to consider service penetrations on either side of a compartment wall and that this study should extend to combustible framed compartment walls, not just masonry walls.

The consideration for service penetrations would include ventilation ducts e.g. from a kitchen's mechanical extract system, or a whole flat heat recovery system and or soil and vent pipes. This risk arises from modern design in congested zones[1] where there are back to back bathrooms or kitchens, either side of a party wall. This situation may arise in a development opportunity as shown in Figure 3 (above).

The programme investigated eight experiment fire scenarios.

The eight scenarios consisted of:

1 Construction type 1 – *thermally insulated deck*
No fire stopping between the head of the wall and the underside of the timber deck. This scenario was the 'control' experiment.

2 Construction type 1 – *thermally insulated deck*
Fire stopping provided between the head of the wall and underside of the timber deck. The fire stopping was under approximately 10 mm of compression.

3 Construction type 1 – *thermally insulated deck*
As scenario 2 but with the inclusion of further fire stopping between the upper surface of the deck and the underside of the waterproofing layer.

4 Construction type 1 – *thermally insulated deck*
As scenario 2 but with the inclusion of additional foil faced thermoset insulation pushed up to the underside of the decking. Sometimes referred to as a hybrid roof construction.

5 Construction type 2 – *composite deck*
Fire stopping between the head of the wall and the underside of the foil faced thermal insulation. The fire stopping was under approximately 10 mm of compression.

6 Construction type 2 – *composite deck*
Fire stopping between the head of the wall and the underside of the foil faced thermal insulation. The fire stopping was under nominal compression.

7 Construction type 3 – *inverted roof*

[1] Congested zones is a term usually considered in external walls. See BRE Global report P118434-1006 (M6D6V3) Volume 1 (of 2): Construction Technologies, Design and Usage, October 2024. The roof / party wall may be congested where there is a grouping of vent pipes and extract ducts.

Fire stopping between the head of the wall and the underside of the timber deck. The fire stopping was under approximately 10 mm of compression. The inverted roof insulant was thermoplastic.

8 Construction type 3 – *inverted roof*
As scenario 7 but with the inclusion of additional fire stopping between the isolation fleece and the underside of the waterflow retention layer.

<u>Mode of failure of compartment wall integrity</u>

The potential mode of failure at the head of a compartment wall is likely to occur as is depicted in Figure 4.

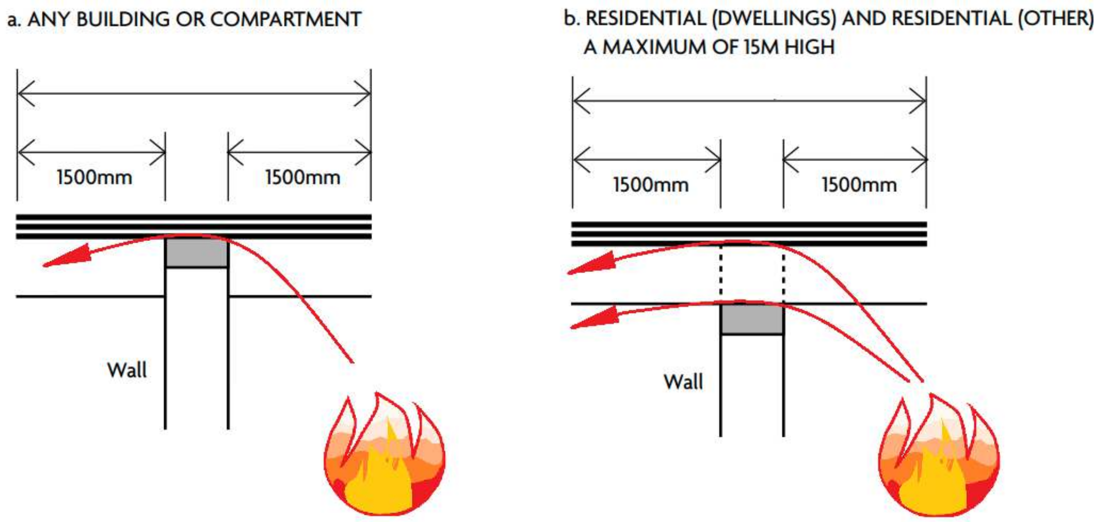


Figure 4 – Routes of fire spread that this study sought to consider – this image is adapted from Figure 1 (above)

The study was not intended to provide answers to questions that might arise under either (or both limbs) of the Schedule 1 requirement B4 (2), namely a building's ability to resist:

1. fire spread over [its] surface, and
2. fire spread via penetration of fire from one building to another.

2 Experimental concept

The key part of the wall under consideration in Diagram 5.2b of AD B Volume 1 (and Diagram 8.2 of AD B Volume 2) is the head detail. Accordingly, the concept was developed to consider just the last couple of courses of masonry party walls and differing roof constructions and to expose the junction to the heating and pressure conditions as set out in the fire resistance test standard BS EN 1363-1:2020 [1].

It was also considered that for the purposes of these indicative tests, timber joists would bear onto and continue beyond the ‘party wall,’ and decking would also pass across the ‘party wall’.

The results would indicate the potential for full scale compartment party wall and roof junctions to perform if subjected to the same heating and pressure conditions, and therefore inform the guidance with respect to Schedule 1 requirements B3(2) and B3(4).

Future programmes of work may be conceived to provide indicative evidence of the performance of a non-loadbearing compartment wall and roof junction, where the wall is provided to sub-divide a building. Accordingly, future results would indicate the potential for full scale compartment wall and roof junctions to perform if subjected to the same heating and pressure conditions, and therefore inform the guidance with respect to Schedule 1 requirements B3(3) and B3(4).

Note: When non-loadbearing compartment walls (which incorporate deflection head details) are tested to BS EN 1364-1:2015 [2], the test protocol does not have a pass / fail criteria for the performance of the deflection head. The test for non-loadbearing walls does not result in the deflection head detail being loaded. Accordingly, and prior to devising an experimental programme for non-loadbearing compartment walls (used to subdivide buildings), one would first need to consider how such walls are currently tested in the standard 3.0 m x 3.0 m wall furnace and what the pass / fail criteria for the deflection head might look like.

3 Experimental methodology

The programme was undertaken using the BRE Global 1.5 m cube intermediate furnace, shown in Figure 5.

Figure 5 – A photograph of a sample undergoing installation onto the 1.5 m cube intermediate furnace

Figure 5 shows the masonry string course, onto which the joists of the sample were bearing as well as the masonry infilling between joists. The masonry string course was built off the steel front wall of the furnace, and was representative of a compartment party wall. The different roof constructions were lifted onto the furnace, in effect creating the ‘furnace lid’. Masonry was then used to infill the spaces between the joists. Mineral wool fire stopping was or was not provided (see the eight scenarios listed in Section 1 Validation of concept (above) and Section 4 Experimental programme (below).

The representative compartment wall was selected to be equivalent to typical 215 mm thick party wall constructions, i.e. representative of a solid Fletton wall or 215 mm thick aerated concrete ‘party wall’ grade blocks, which would ordinarily be subjected to pre-completion sound testing[2].

Figure 6 is a simplified schematic drawing (showing just two joist bays) of how the experiment was originally conceived, i.e. that roof samples would be built on the roof of the furnace. Rather than build the side and rear walls from masonry for each experiment, the experimental design was changed to include a steel frame into which the roof constructions were built. For ease of viewing, Figure 6 does not show the steel frame (into which the roofing was built), nor the roofing (above firrings) or the plasterboard ceiling.

The frame was designed to be lifted onto the intermediate furnace to bear on the rear and side walls and overhang the furnace’s front wall.

[2] To enable comparison, all the indicative compartment walls were formed in this way. Perhaps future experimental testing could include cavity walls and timber framed walls, to give the study greater breadth.

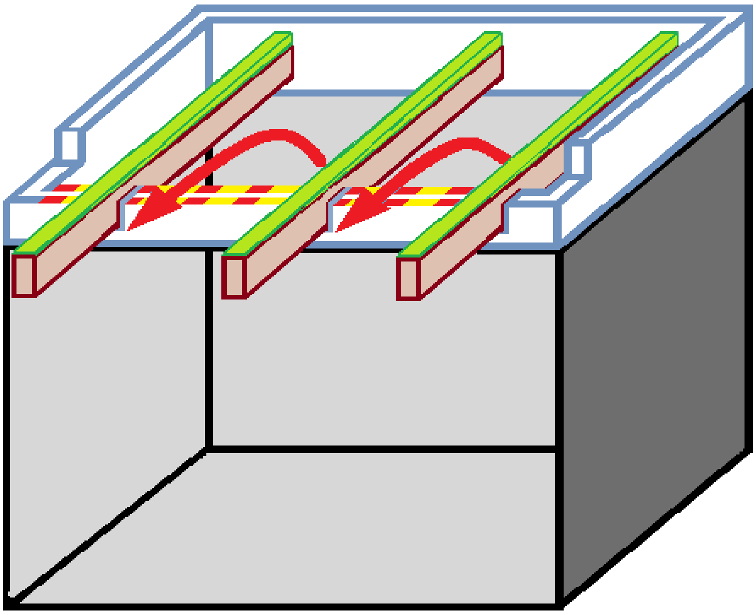


Figure 6 – Simplified schematic drawing of the furnace and roof 'rig', with yellow/red chevrons indicating the line of fire stopping under consideration and the red arrows the anticipated route of fire spread

Figures 7 to 9 (below) show how the roof construction type 1 – *thermally insulated deck* would look when sat on the furnace once all preparation was complete and Figure 10 shows the side and rear edge detail. The key elements of the roof build-up shown in Figures 7 to 10 (inclusive) are described in detail in Section 3.2 and itemised in Figure 12.

The overhanging construction at the front of the furnace, allowed a glass viewing pane to be fixed to the 'soffit' of the projecting joists see Figure 8 so that the head of the wall could be observed. In practice, during the experiment, there was too much condensation on the pane to enable a good view of the underside of the deck on the unexposed face.

Using the intermediate furnace allowed the experiments to be conducted in a consistent manner following the principles of the BS EN 1364-1:2015.

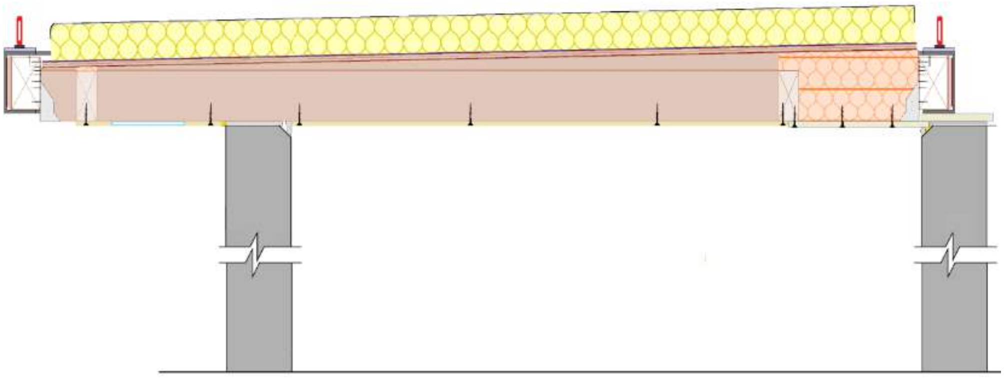


Figure 7 – A longitudinal section through the furnace, showing the frame bearing on the rear wall of the furnace and the overhang at the front wall of the furnace. Note: For clarity, the indicative compartment wall, rising off the front wall of the furnace is not shown

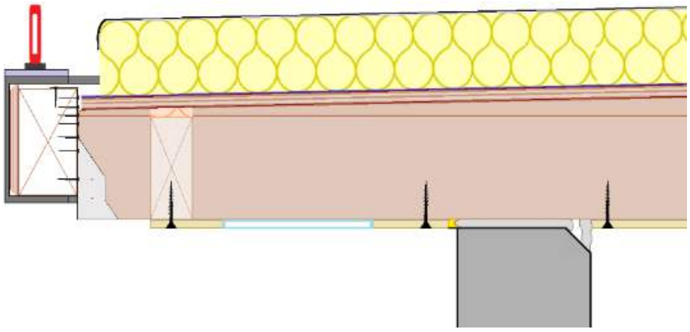


Figure 8 – Front wall detail showing how the seal was achieved on the unexposed side of the compartment wall using plasterboard and a glass viewing pane. Note: For clarity, the indicative compartment wall, rising off the front wall of the furnace is not shown

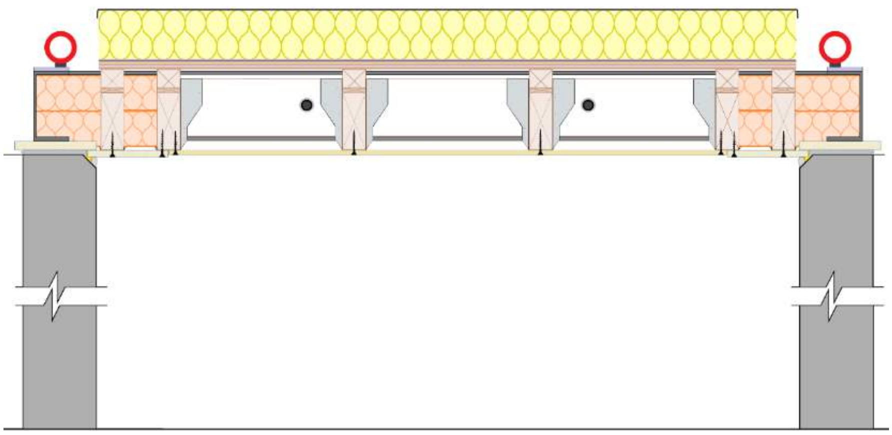


Figure 9 – Transverse section through the furnace, showing the original concept for the frame bearing onto the side walls of the furnace

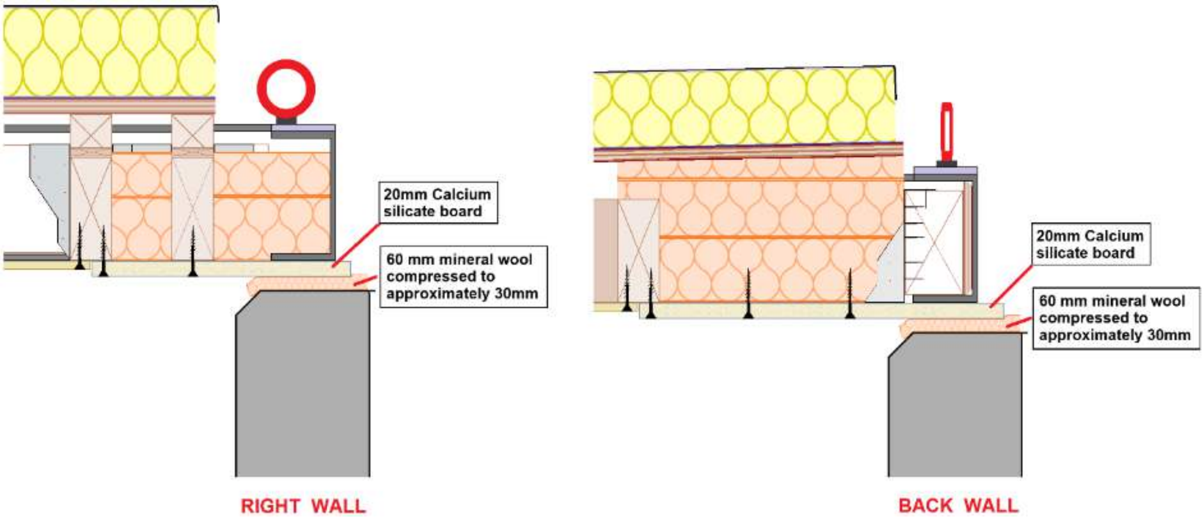


Figure 10 – Transverse section showing final construction detailing at side walls

Figure 11 shows the underside of a typical test sample during construction.

Figure 11 – A roof sample laid on its side showing the calcium silicate boarded perimeter and the plasterboard 'ceiling' in the centre.
The red lines indicate where the compartment wall will rise between the three joist bays

3.1 Pass / fail criteria

There were no established pass / fail criteria for this experimental work. The intention was to gather comparative data and observations from a series of consistent and repeatable experiments.

In terms of desired 'performance', a residential party wall needs to achieve 60 minutes (stability: integrity: insulation (R:E:I)). Research conducted by the Building Research Establishment in the 1980s [3] showed that aerated concrete (7 N/mm^2) 215 mm wide, would achieve in excess of 60 minutes R:E:I, however, it is the junction between the masonry and roof that is typically the point of failure, hence the purpose of this study.

Three nickel chromium / nickel aluminium (K-type) thermocouples, each soldered to a 12 mm diameter copper disc and secured using a 30 mm square insulating cover pad, were placed on the decking above each of the three overhanging joist bays to monitor the temperature profiles in these regions, logging temperatures every 30 seconds:

i) One on the deck, 25 mm forward of the exposed edge of the party wall below

ii) One on the deck 50 mm back from the exposed edge i.e. over the party wall below, and

iii) One on the deck 25 mm back from the unexposed edge of the party wall below.

As the programme of experiments progressed the location of the thermocouples was refined. For experiments 1 and 2 the thermocouples were set out as described above – see Section 5, Figure 16 (below) which shows the placement of these thermocouples for Experiment 1. The intention was to capture temperatures on the timber deck as fire approached the exposed edge of the compartment party wall and to determine the temperature gradient, in each joist bay, across the party wall – see a worked example of the temperature gradient in Section 5, Figure 17 (below).

After Experiment 2, the locations of the thermocouples were adjusted so as to be located in line with and above the exposed edge, the centre, and the unexposed edge of the compartment party wall. This was seen as a betterment, since it was quicker to build (reduced human error in setting out) and required one step less when processing the data i.e. there was no need to interpolate to determine temperatures at the exposed edge, centre, and unexposed edge of the party wall.

The samples were subjected to 60 minutes of thermal exposure. The furnace temperature was measured by means of four plate thermometers arranged symmetrically in the furnace with their measuring junctions 100 mm from the exposed face of the front wall. The furnace was controlled so that the mean temperature followed the time/temperature curve specified in BS EN 1363-1:2020. The furnace pressure followed the principles of BS EN 1363-1:2020.

BS EN 1364-1:2015 refers to the criteria contained in BS EN 1363-1:2020. Section 11.3 of BS EN 1363-1:2020 sets the performance criteria for insulation whereby, if the average of five thermocouple readings on the unexposed face of a wall record a temperature rise (above initial average temperature) in excess of 140°C or if any single thermocouple records a temperature rise (above initial average temperature) of 180°C, this would constitute an insulation 'failure'. Visible flaming on the unexposed side of a test sample would also usually constitute an integrity failure of the test. Insulation failure is automatically assumed when integrity criterion ceases to be satisfied.

For each of the indicative experiments, thermocouple readings at the three measurement points were taken to determine if the averages exceeded 140°C rise or if any single thermocouple reading reached 180°C rise at any point up to the end of the 60-minute test.

It was found that three of the indicative experiments did not run for the full 60-minute duration. These trials were terminated early due to safety concerns, for example where flaming occurred over the entire surface of the sample or flaming emerged at the side or rear of the test sample.

3.2 Roof type 1 (Experiments 1 to 4)

Construction type 1 – *thermally insulated deck*, shown in Figure 12 is a thermally insulated deck, comprising 100 mm thick tissue-faced polyisocyanurate board mechanically fixed to an oriented strand board (OSB) deck.

Sample Build Up:

1. 1.2 mm thick non-reinforced Ethylene Propylene Diene Terpolymer (EPDM), on
2. Solvent adhesive, on
3. 100 mm thick tissue faced polyisocyanurate core rigid board insulation*, on
4. 300 µm polyethylene vapour control layer, on
5. 18 mm thick oriented strand board deck, on
6. 44 mm wide firrings (laid to approximately 1:50 fall), on
7. 44 mm wide x 120 mm deep timber joists
8. With 12.5 mm thick gypsum ordinary wallboard ceiling
9. With fixings sealed using gypsum fine surface filler.

**The rigid insulation board was fixed using 85 mm deep nylon insulation fixings and 5 mm diameter 70 mm long screws through deck, and into the firring and joists.*

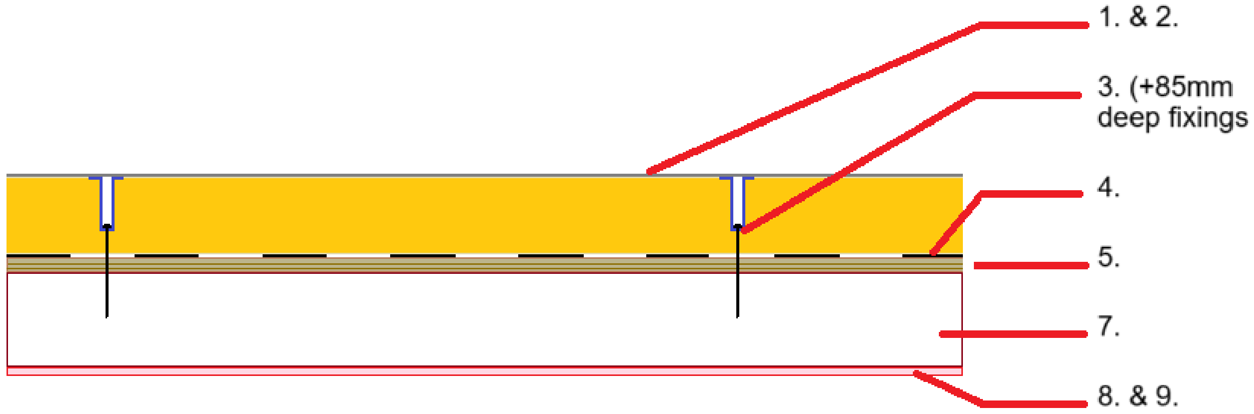


Figure 12 – Construction type 1 – *thermally insulated* deck comprising 100 mm thick tissue-faced polyisocyanurate board mechanically fixed through an oriented strand board (OSB) deck (firrings not shown for ease of drawing)

3.3 Roof type 2 (Experiments 5 and 6)

Construction type 2 – *composite deck*, shown in Figure 13 is a composite deck, comprising 120 mm thick foil faced polyisocyanurate insulation bonded to a 9 mm OSB deck with an additional layer of 15 mm thick plywood.

Sample Build Up:

1. 1.2 mm thick non-reinforced Ethylene Propylene Diene Terpolymer (EPDM), on
2. Water based adhesive, on
3. 15 mm thick hardwood ply, on
4. 129 mm thick insulated decking board (with 120 mm thick foil faced polyisocyanurate core rigid board insulation and a 9 mm thick OSB deck,* on
5. Mastic beads, on
6. 44 mm wide firrings (laid to approximately 1:50 fall), on
7. 44 mm wide x 120 mm deep timber joists
8. With 12.5 mm thick gypsum ordinary wallboard ceiling
9. With fixings sealed using gypsum fine surface filler.

**The 15 mm thick hardwood ply was fixed through the 129 mm thick insulation board using 195 mm-long helical twist fixings, into the firrings and joists.*

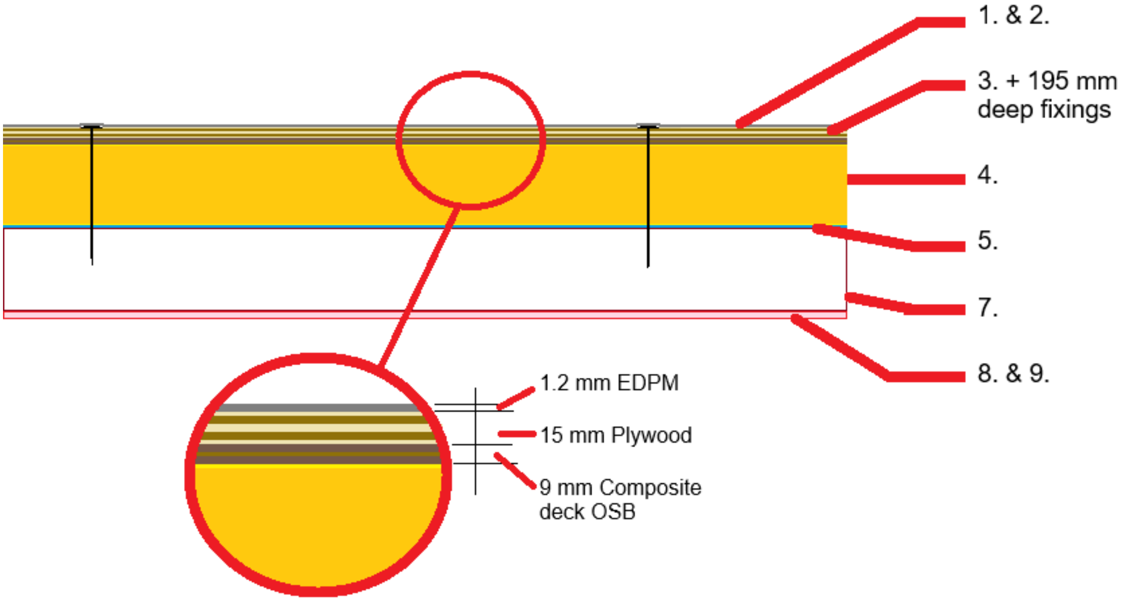


Figure 13 – Construction type 2 – *composite deck*, comprising 120 mm thick foil faced polyisocyanurate insulation bonded to a 9 mm OSB deck (not plywood as shown) with an additional layer of 15 mm thick plywood (firrings not shown for ease of drawing)

The integral OSB deck of construction type 2 – *composite deck,* was only 9 mm thick.

A problem BRE Global had was that the manufacturer of the EPDM advised that the product had not been tested in combination with a composite deck insulation board. The manufacturer did however have test evidence, when the product was placed on an 18 mm thick deck, alone. In that test it achieved a B_{ROOF}(t4) class of performance in accordance with BS EN 13501-5:2016 [4].

It was important to the experimental programme that the membrane and roof build-up (system) was capable of achieving a B_{ROOF}(t4) class of performance. Accordingly, BRE Global decided to add a second deck. The problem was knowing what thickness.

Would simply adding another layer of 9 mm OSB be sufficient to achieve the same performance as was achieved when the EPDM was tested on a single 18 mm deck?

Time was of the essence. BRE Global decided to use 15 mm thick plywood. This resulted in the deck being 24 mm thick.

An indicative test, conducted in April 2022, using the methodology given in CEN/TS 1187-4:2012 [5][3], confirmed no penetration (at the end of the 60-minute test) had occurred, which was indicative of a B_{ROOF}(t4) class of performance as described in BS EN 13501-5:2016.

[3] The methodology in terms of the time to penetration given in BS 476-3:2004 + A2:2007 [6] is identical to the methodology in CEN/TS 1187-4:2012.

3.4 Roof type 3 (Experiments 7 and 8)

Construction type 3 – *inverted roof*, shown in Figure 14 is an inverted roof, using 160 mm extruded polystyrene and an 18 mm OSB deck.

Sample Build Up:

1. 50 mm thick washed river stone, on
2. 0.4 mm thick waterflow reducing layer, on
3. 160 mm thick extruded polystyrene insulation, on
4. 300 g/m^2 isolation fleece, on
5. 1.2 mm thick Ethylene Propylene Diene Terpolymer (EPDM), on
6. Water based adhesive, on
7. 18 mm thick oriented strand board decking, on
8. 44 mm wide firrings (laid to approximately 1:50 fall), on
9. 44 mm wide x 120 mm deep timber joists
10. With 12.5 mm thick gypsum ordinary wallboard ceiling
11. With fixings sealed using gypsum fine surface filler.

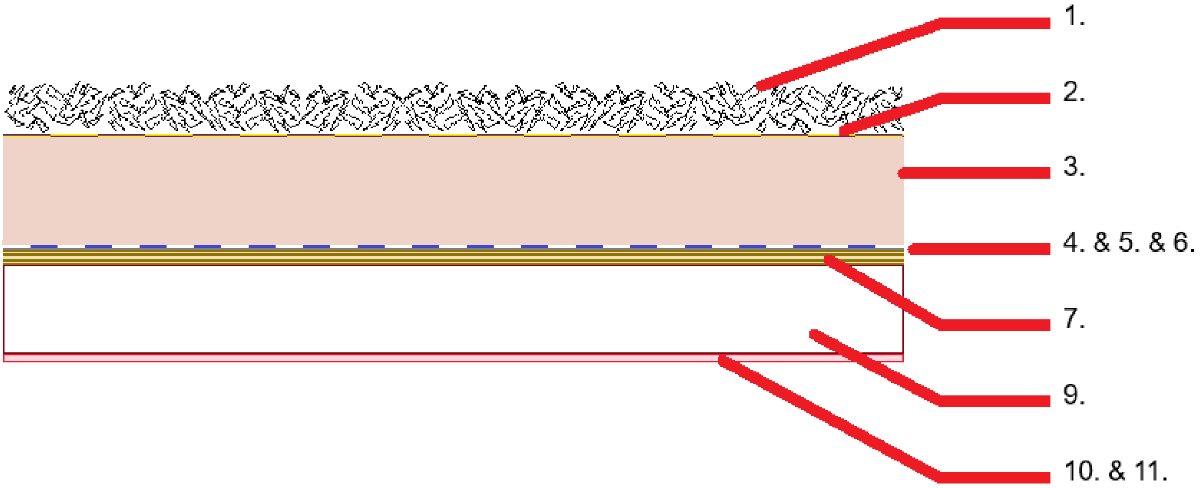


Figure 14 – Construction type 3 – *inverted roof*, comprising 50 mm of ballast, 160 mm thick extruded polystyrene insulation which is placed on a fleece isolation layer laid dry over the EPDM (firrings not shown for ease of drawing)

4 Experimental programme

The programme of experimental work conducted to date is shown in Table 1.

Table 1 – The experimental programme

Experiment	**Roof type** Including location of insulation	**Description** Including location of fire stopping
1	Construction type 1 – *thermally insulated deck* See Section 3.2 PIR insulation carried across party wall	A control experiment – no discernible fire stopping provided Compartment wall raised to the underside of the deck without fire stopping **See Figure 15 right column (middle photograph)**
2	Construction type 1 – *thermally insulated deck* See Section 3.2 PIR insulation carried across party wall	Variant of Experiment 1 – fire stopping provided Compartment wall raised and fire stopped using mineral wool (with a density of 60 kg/m^3) to the underside of the deck The fire stopping was compressed by 10 mm (nominal) **See Figure 19 right column (middle photograph)**
3	Construction type 1 – *thermally insulated deck* See Section 3.2 PIR insulation interrupted so as not to carry across the party wall	Variant of Experiment 1 – fire stopping provided Compartment wall raised and fire stopped exactly as Experiment 2 including the nominal compression of the fire stopping **See Figure 24 right column (middle photograph)** Additional fire stopping using 160 kg/m^3 mineral wool was located between the 300 μm polyethylene vapour control sheet and the underside of the EPDM roof covering **See Figure 24 right column (top photograph)**
4	Construction type 1 – *thermally insulated deck* See Section 3.2 PIR insulation carried across party wall and additional layer under deck	Variant of Experiment 1 – fire stopping provided Compartment wall raised and fire stopped exactly as Experiment 2 including the nominal compression of the fire stopping **See Figure 27 left column (middle photograph)**

Experiment	Roof type	Description
5	Construction type 2 – *composite deck* See Section 3.3 PIR insulation carried across party wall	Fire stopping provided Compartment wall raised and fire stopped using mineral wool (with a density of 60 kg/m^3) to the underside of the foil facer (vapour control layer) of the composite insulation board The fire stopping was compressed by 10 mm (nominal) **See Figure 31 right column (middle photograph)**
6	Construction type 2 – *composite deck* See Section 3.3 PIR insulation carried across party wall	Variant of Experiment 5 – fire stopping provided Compartment wall raised and fire stopped as Experiment 5 with one difference. The difference was that the fire stopping was barely compressed 3 mm (nominal) **See Figure 34 left column (middle photograph)**
7	Construction type 3 – *inverted roof* See Section 3.4 Thermoplastic insulation carried across party wall	Fire stopping provided Compartment wall raised and fire stopped using mineral wool (with a density of 60 kg/m^3) to the underside of the deck The fire stopping was compressed by 10 mm (nominal) **See Figure 37 right column (top photograph)**
8	Construction type 3 – *inverted roof* See Section 3.4 Thermoplastic insulation interrupted so as not to carry across the party wall	Variant of Experiment 7 – fire stopping provided Compartment wall raised, fire stopped (and nominally compressed) exactly as Experiment 7. **No image available** Additional fire stopping using 150 mm-high non-combustible cellular foamed glass insulation (Marketed as achieving an A1 classification to BS EN 13501-1) located directly above the line of the compartment wall **See Figure 40 left column (top photograph)**

5 Experimental findings

5.1 Experiment 1

Figure 15 is a selection of build and burn photographs. The double red lines provide a visual cue as to whether visible flaming reached the exposed edge of the party wall or spread further.

Figure 15 – A selection of build and burn photographs for Experiment 1

Figure 16 shows the thermocouple locations.

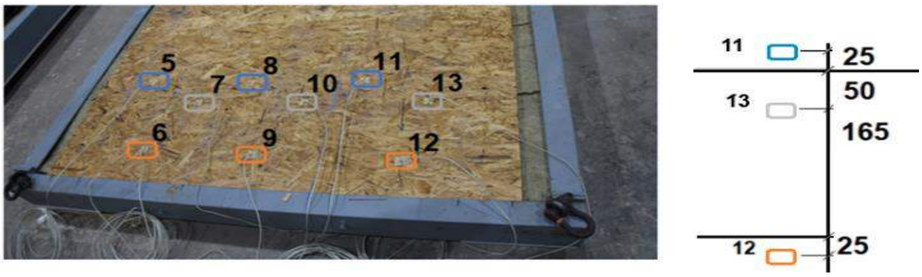
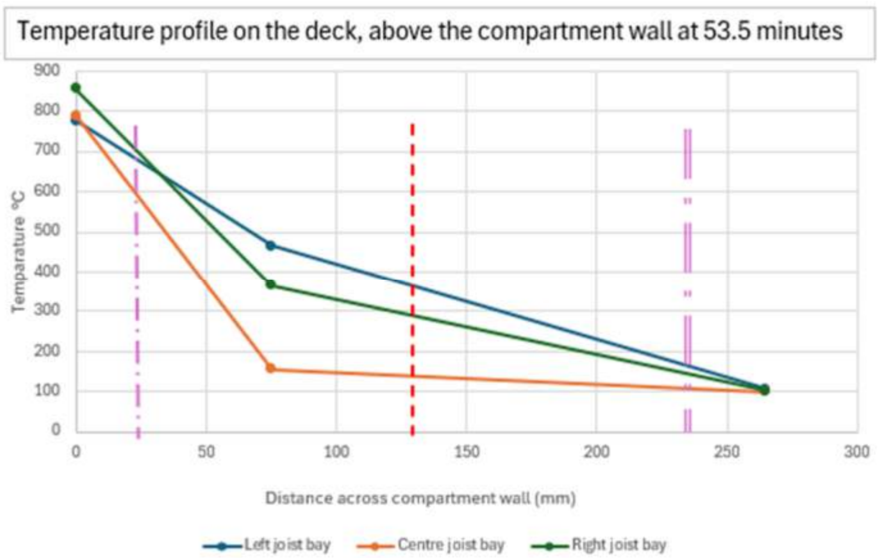


Figure 16 – Photograph of the deck showing the thermocouples and sketch indicating the key dimensions relative to the exposed and unexposed edges of the compartment wall beneath

In Figure 16, thermocouples 5, 8 and 11 were located 25 mm forward of the exposed edge. Thermocouples 7, 10 and 13 were located 50 mm back from the exposed edge. Thermocouples 6, 9 and 12 were located 25 mm back from the unexposed edge. The location of thermocouples (on plan) in the right joist bay, is shown in the sketch to the right of the photograph in Figure 16.

Figures 17 and 18 show temperature profiles on the deck.



Key:

The single lilac dot and dash line is the exposed edge of the compartment wall.

The double **lilac** dot and dash is the unexposed edge of the compartment wall.

The **red** dashed line is the centre of the compartment wall.

Figure 17 – Temperature profiles on the deck above the compartment wall at 53.5 minutes (test termination) created from data prior to correcting for ambient air temperature

	The blue temperature gradient is the left joist bay							
	The orange temperature gradient is the center joist bay							
	The green temperature gradient is the right bay							
	TC7 in °C	TC6 in °C	diff in °C	dist' to TC6 in mm	Unexposed edge in mm	∆ temp	Temp at unexp edge in °C	Ambient correction -11°C
At 53.5 mins	465.4	106.1	359.3	190	165	312.02	153.38	142.38
					Centreline in mm	∆ temp	Temp at centreline in °C	
					57.5	108.74	356.66	345.66
	TC10 in °C	TC9 in °C	diff in °C	dist' to TC6 in mm	Unexposed edge in mm	∆ temp	Temp at unexp edge in °C	
At 53.5 mins	155.6	100.5	55.1	190	165	47.85	107.75	96.75
					Centreline in mm	∆ temp	Temp at centreline in °C	
					57.5	16.675	138.93	127.93
	TC13 in °C	TC12 in °C	diff in °C	dist' to TC6 in mm	Unexposed edge in mm	∆ temp	Temp at unexp edge in °C	
At 53.5 mins	365.10	101.20	263.90	190.00	165.00	229.18	135.92	124.92
					Centreline in mm	∆ temp	Temp at centreline in °C	
					57.5	79.86	285.2	274.24

Figure 18 – Excerpt from Excel data sheet showing the calculations of the temperatures above the centreline of the wall and the unexposed edge of the wall at 53.5 minutes (test termination) and corrected to show temperature rise above ambient

5.2 Experiment 2

Figure 19 is a selection of build and burn photographs. The double red lines provide a visual cue as to whether visible flaming reached the exposed edge of the party wall or spread further.

Figure 19 – A selection of build and burn photographs for Experiment 2

Figure 20 shows the thermocouple locations.

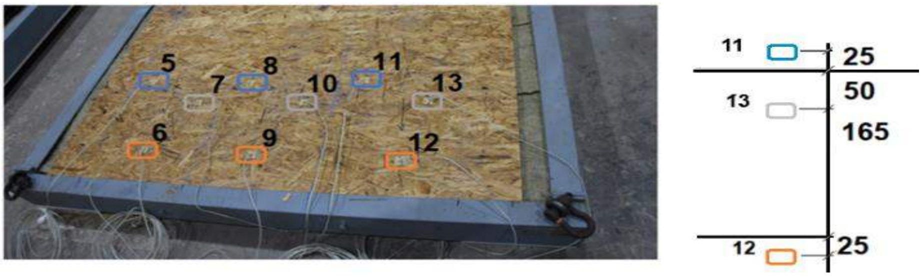
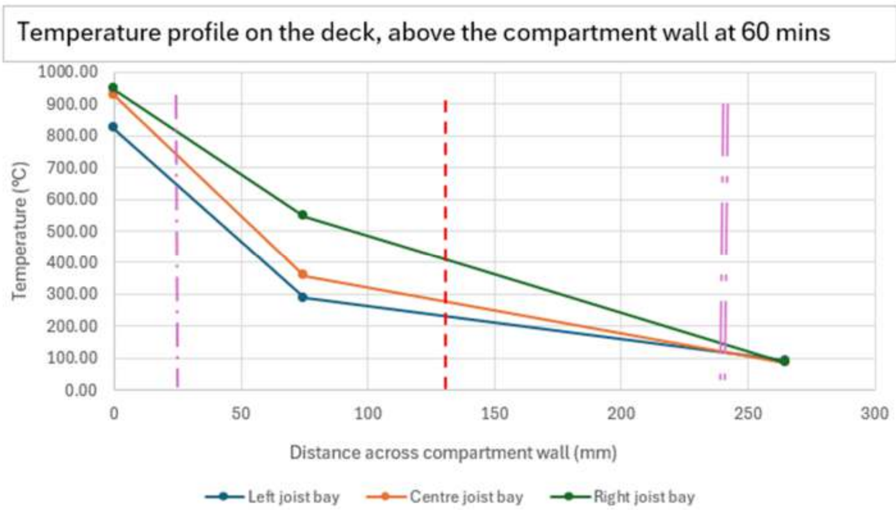


Figure 20 – Reproduction of Figure 16 showing the thermocouples and sketch indicating the key dimensions relative to the exposed and unexposed edges of the compartment wall beneath. Note: The same layout of thermocouples as Experiment 1 was adopted for Experiment 2 but there was no separate close-up photograph available.

Figures 21 and 22 show temperature profiles on the deck.



Key:

The single lilac dot and dash line is the exposed edge of the compartment wall.

The double **lilac** dot and dash is the unexposed edge of the compartment wall.

The **red** dashed line is the centre of the compartment wall.

Figure 21 – Temperature profiles on the deck above the compartment wall at 60 minutes, created from data prior to correcting for ambient air temperature

The green line, in Figure 21 represents the temperature profile in the right joist bay. This bay is further analysed in Figure 23 (below), using simple linear interpolation (a conservative approach), to indicate the approximate position, on top of the deck, where the temperature could be assumed to be in the region of 180°C.

The blue temperature gradient is the left joist bay
The Orange temperature gradient is the centre joist bay
The green temperature gradient is the right bay

TC7 in °C	**TC6 in °C**	**∆ temp (°C)**	**Distance to TC6 in mm**	**Unexposed edge in mm**	**∆ temp**	**Temp at unexp edge in °C**	**Ambient correction -16°C**
288.1	90.3	197.8	190	165	171.77	116.33	100.33
				Centreline	**∆ temp**	**Temp at centreline in °C**	
				57.5	59.86	228.24	212.24
TC10 in °C	**TC9 in °C**	**∆ temp (°C)**	**Distance to TC9 in mm**	**Unexposed edge in mm**	**∆ temp**	**Temp at unexp edge in °C**	
358.5	84.2	274.3	190	165	238.21	120.29	104.29
				Centreline	**∆ temp**	**Temp at centreline in °C**	
				57.5	83.01	275.49	259.49
TC13 in °C	**TC12 in °C**	**∆ temp (°C)**	**Distance to TC12 in mm**	**Unexposed edge in mm**	**∆ temp**	**Temp at unexp edge in °C**	
545.6	84.6	461	190	165	400.34	145.26	129.26
				Centreline	**∆ temp**	**Temp at centreline in °C**	
				57.5	139.51	406.09	390.09

Figure 22 – Excerpt from Excel data sheet showing the calculations of the temperatures above the centreline of the wall and the unexposed edge of the wall at 60 minutes, including corrections for ambient air temperature

	TC13 in °C	TC12 in °C	∆ temp (°C)	Distance between these thermocouples mm
	545.6	84.6	461	190
Ambient corrected	529.6	68.6	461	190

Thermocouple TC12 is at 68.6°C. It only needs to be raised 111.4°C to reach 180°C. How far back from the unexposed edge does this occur?

∆ temp (°C)	**Distance (mm)**	
461.00	190	
111.4	X	X= 46 mm from TC12

TC 12 is located 25mm beyond the unexposed edge so 25mm should be deducted
46 mm - 25 mm
At 21 mm back from the unexposed edge the temperature is 180°C

Figure 23 – Excerpt from Excel data sheet, using linear interpolation (a conservative approach) indicating that at 21 mm back from the unexposed edge, the temperature on the top surface of the deck could be in the region of 180°C

5.3 Experiment 3

Figure 24 is a selection of build and burn photographs. The double red lines provide a visual cue as to whether visible flaming reached the exposed edge of the party wall or spread further.

Figure 24 – A selection of build and burn photographs for Experiment 3

Figure 25 shows the thermocouple locations.

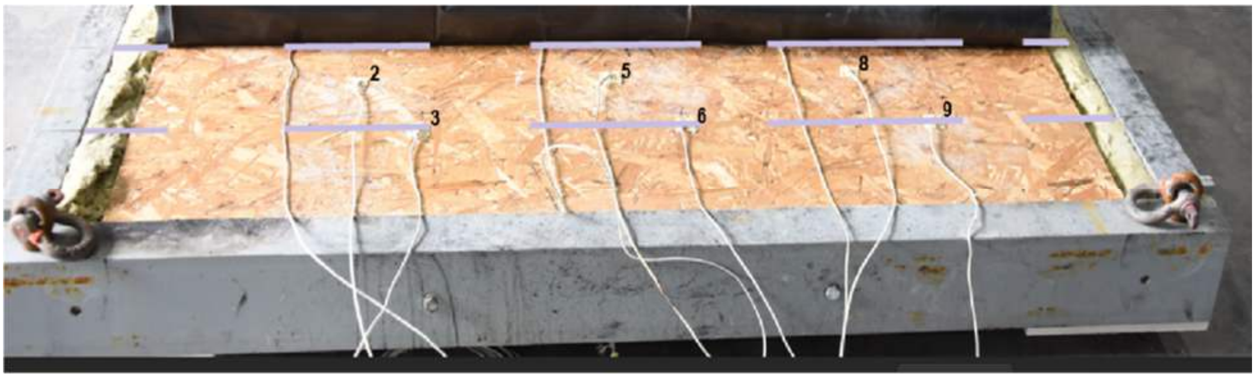
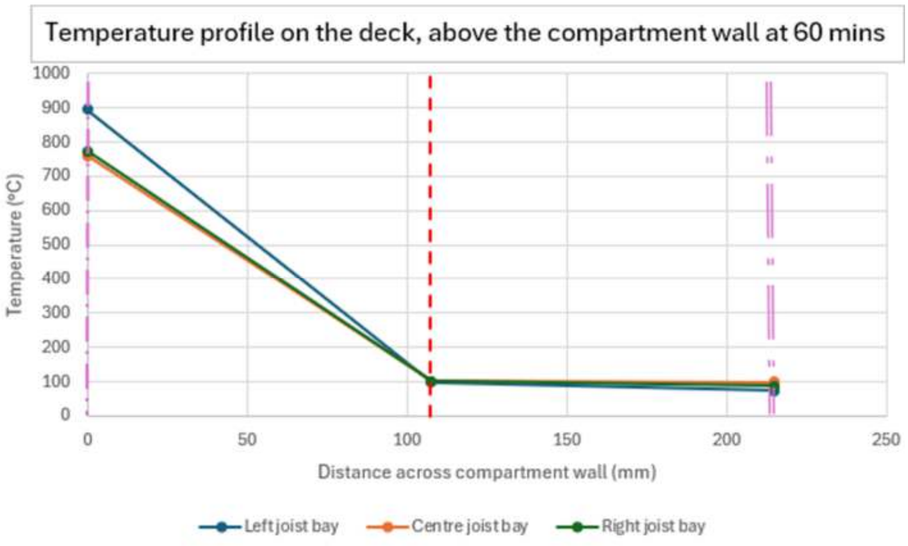


Figure 25 – Photograph of the deck showing the location of the thermocouples located directly above the edges and the centreline of the 215 mm wide wall below

The reason for locating the thermocouples in this manner was to remove the need to interpolate to determine the temperatures on the timber deck above the centreline and the unexposed edge of the wall beneath (this revised layout of thermocouples was adopted for all the remaining experiments).

Linear interpolation still had its place in this experimental programme for example, in Experiment 4 it was used to determine the approximate position, on the top of the deck, where the temperature could be assumed to be in the region of 180°C.

Figure 26 shows the temperature profiles on the deck.



Key:

The single lilac dot and dash line is the exposed edge of the compartment wall.

The double **lilac** dot and dash is the unexposed edge of the compartment wall.

The **red** dashed line is the centre of the compartment wall

Figure 26 – Temperature profiles on the deck above the compartment wall, created from data without the need to correct for ambient air temperature since the temperatures at the centreline and unexposed edge were all less than 140°C

5.4 Experiment 4

Figure 27 is a selection of build and burn photographs. The double red lines provide a visual cue as to whether visible flaming reached the exposed edge of the party wall or spread further.

Figure 27 – A selection of build and burn photographs for Experiment 4

Figure 28 shows the thermocouple locations.

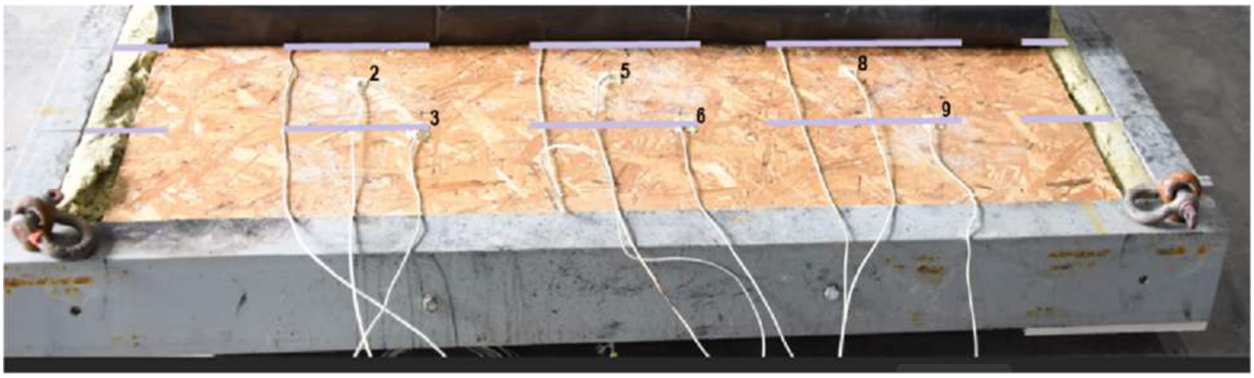
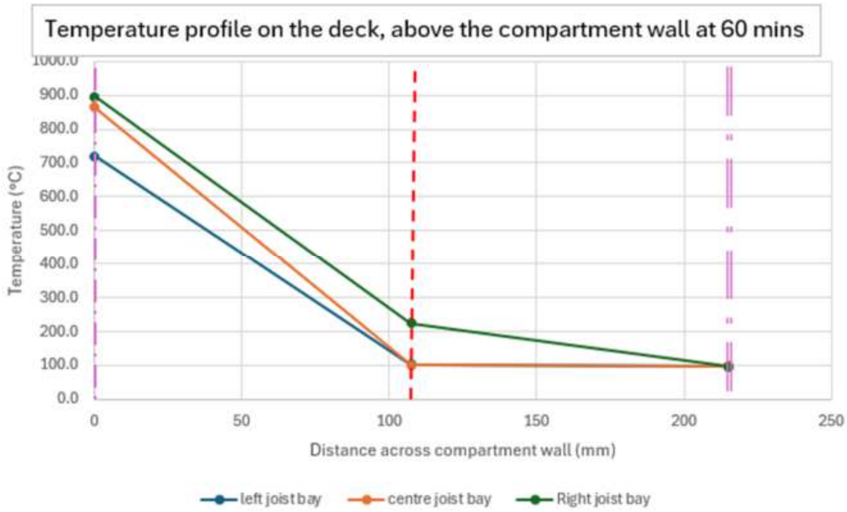


Figure 28 – Photograph of the deck showing the location of the thermocouples. Note: The same layout of thermocouples as Experiment 3 was adopted for Experiment 4 but there was no separate close-up photograph available.

Figure 29 shows the temperature profiles on the deck.



Key:

The single lilac dot and dash line is the exposed edge of the compartment wall.

The double **lilac** dot and dash is the unexposed edge of the compartment wall.

The **red** dashed line is the centre of the compartment wall.

Figure 29 – Temperature profiles on the deck above the compartment wall created from data prior to correcting for ambient air temperature

The green line, in Figure 29, represents the temperature profile in the right joist bay. This bay is further analysed in Figure 30 (below), using simple linear interpolation (a conservative approach), to indicate the approximate position, on top of the deck, where the temperature could be assumed to be in the region of 180°C.

	TC8 in °C	TC9 in °C	diff in °C	dist' to TC9 in mm
	224.6	97.1	127.5	107.5
Ambient corrected	210.6	83.1	127.5	108.5

The unexposed edge is already at 83.1°C. It only needs to be raised 96.9°C to reach 180°C. But how far back from the unexposed edge does this occur?

Δ temp (°C)	dist (mm)	
127.5	107.5	
96.9	X	X = 81.7mm away from the unexposed edge.

Figure 30 – Excerpt from Excel data sheet using linear interpolation (a conservative approach) indicating that at 82 mm back from the unexposed edge, the temperature on the top surface of the deck could be in the region of 180°C

5.5 Experiment 5

Figure 31 is a selection of build and burn photographs. The double red lines provide a visual cue as to whether visible flaming reached the exposed edge of the party wall or spread further.

Figure 31 – A selection of build and burn photographs for Experiment 5

Figure 32 shows the thermocouple locations.

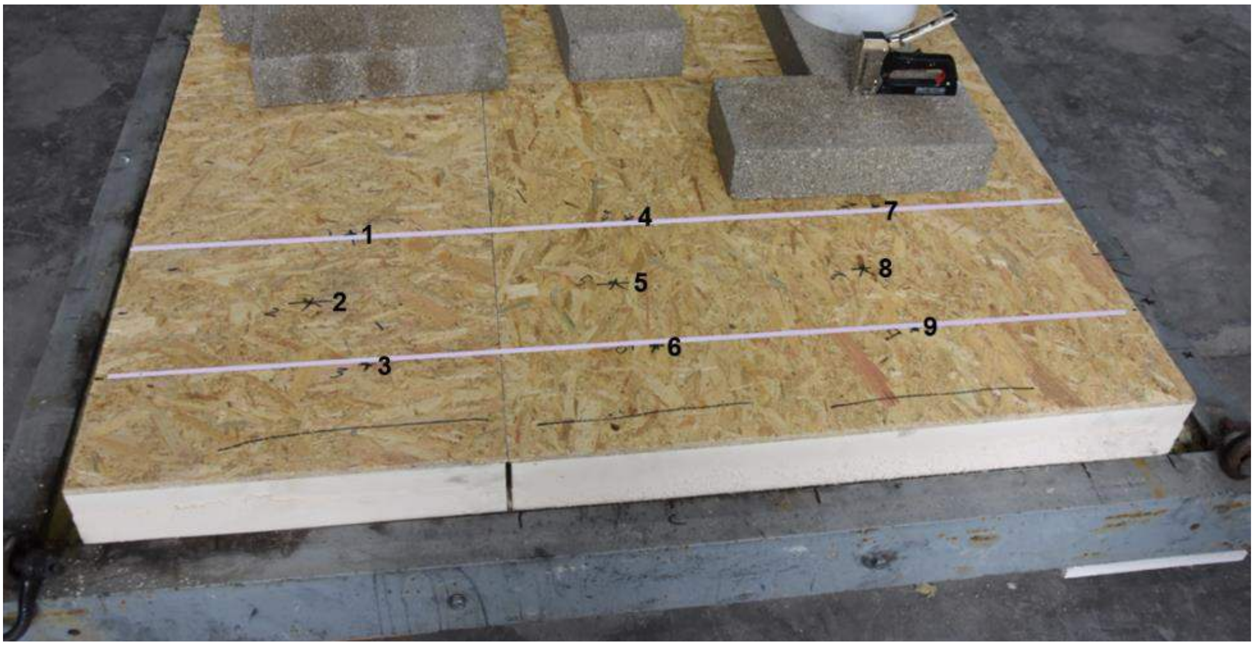
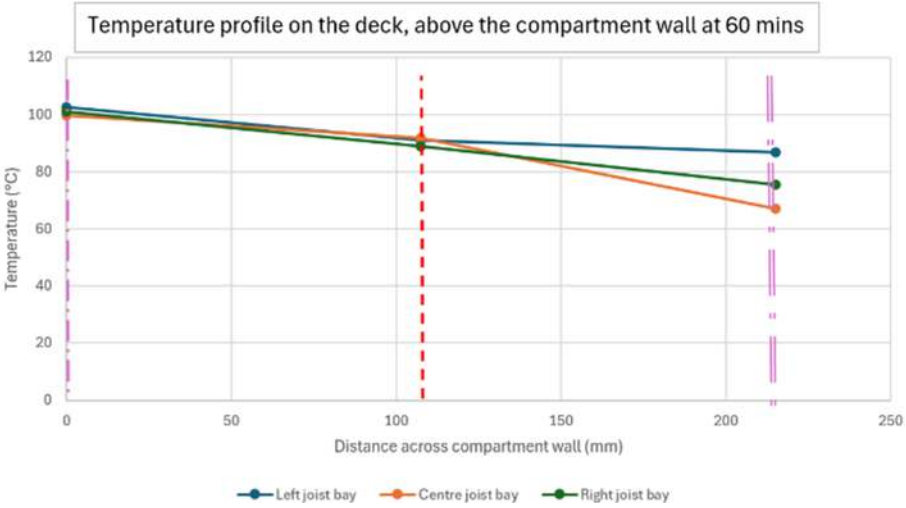


Figure 32 – Photograph of the deck of the composite board showing the location of the thermocouples

Figure 33 shows the temperature profile on the deck of the composite board.



Key:

The single lilac dot and dash line is the exposed edge of the compartment wall.

The double **lilac** dot and dash is the unexposed edge of the compartment wall.

The **red** dashed line is the centre of the compartment wall

Figure 33 – Temperature profiles on the deck of the composite board created from data without the need to correct for ambient air temperature since the temperatures at the centreline and unexposed edge were all less than 140°C

5.6 Experiment 6

Figure 34 is a selection of build and burn photographs. The double red lines provide a visual cue as to whether visible flaming reached the exposed edge of the party wall or spread further.

Figure 34 – A selection of build and burn photographs for Experiment 6

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Figure 35 shows the thermocouple locations.

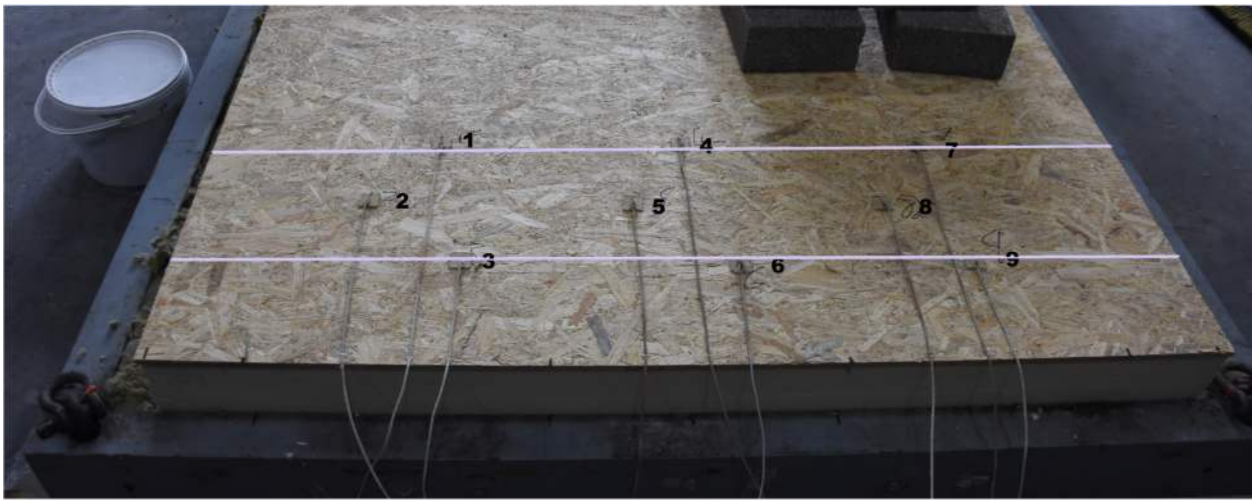
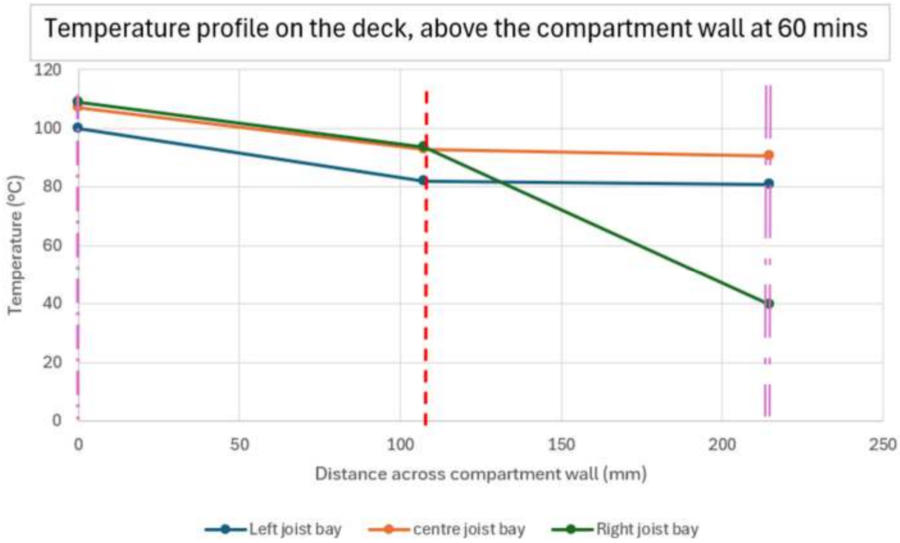


Figure 35 – Photograph of the deck of the composite board showing the location of the thermocouples

Figure 36 shows the temperature profiles on the deck.



Key:

The single lilac dot and dash line is the exposed edge of the compartment wall.

The double **lilac** dot and dash is the unexposed edge of the compartment wall.

The **red** dashed line is the centre of the compartment wall.

Figure 36 – Temperature profiles on the deck of the composite board created from data without the need to correct for ambient air temperature since the temperatures at the centreline and unexposed edge were all less than 140°C

5.7 Experiment 7

Figure 37 is a selection of build and burn photographs. The double red lines provide a visual cue as to whether visible flaming reached the exposed edge of the party wall or spread further.

Figure 37 – A selection of build and burn photographs for Experiment 7

Figure 38 shows the thermocouple locations.

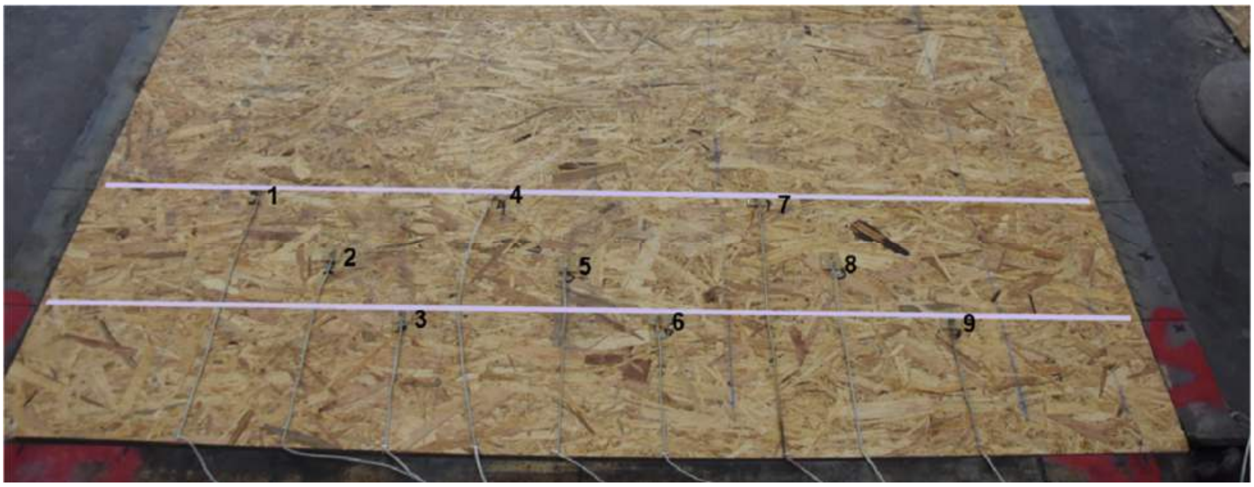
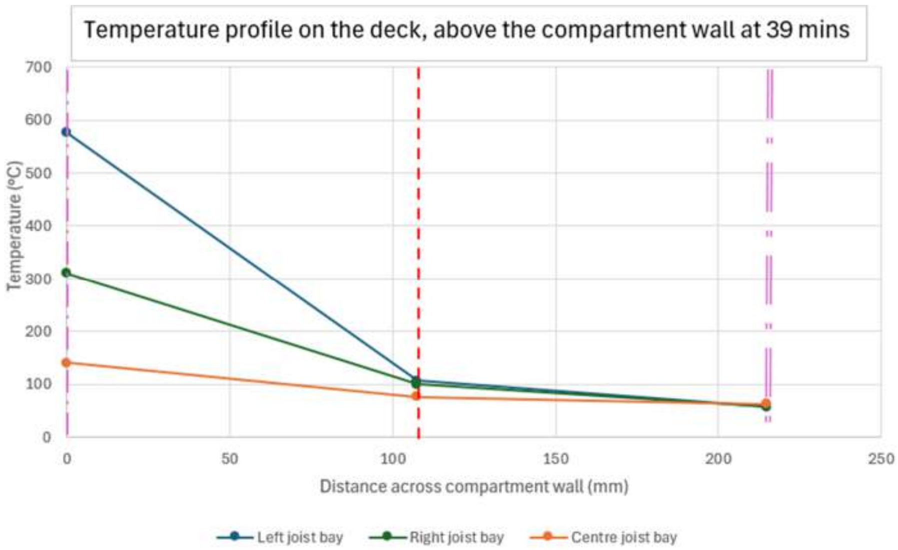


Figure 38 – Photograph of the deck showing the location of the thermocouples

Figure 39 shows the temperature profiles on the deck.



Key:

The single lilac dot and dash line is the exposed edge of the compartment wall.

The double **lilac** dot and dash is the unexposed edge of the compartment wall.

The **red** dashed line is the centre of the compartment wall.

Figure 39 – Temperature profiles on the deck created from data without the need to correct for ambient air temperature since the temperatures at the centreline and unexposed edge were all less than 140°C

5.8 Experiment 8

Figure 40 is a selection of build and burn photographs. The double red lines provide a visual cue as to whether visible flaming reached the exposed edge of the party wall or spread further.

Figure 40 – A selection of build and burn photographs for Experiment 8

Figure 41 shows the thermocouple locations.

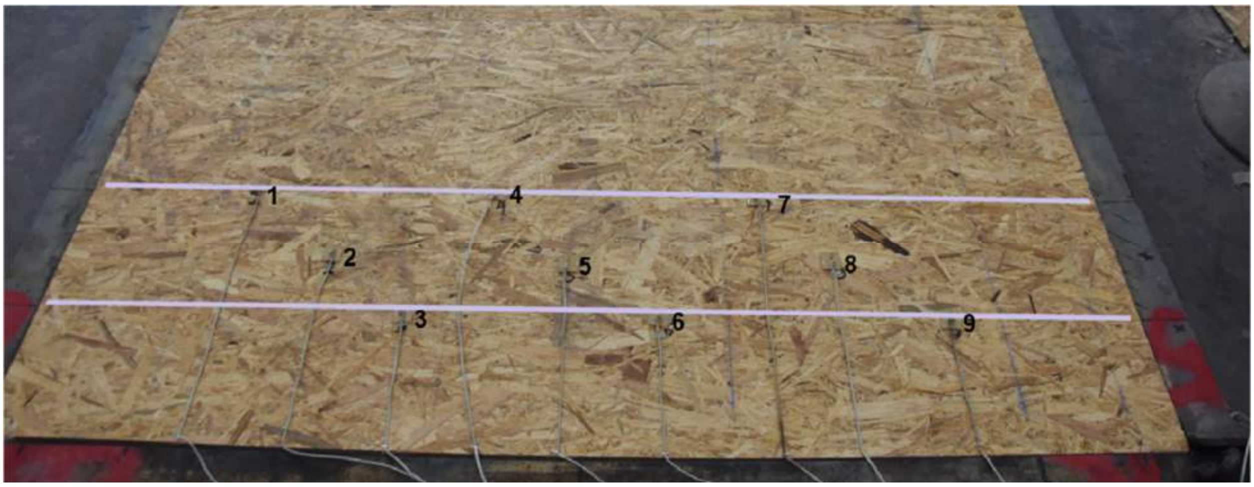
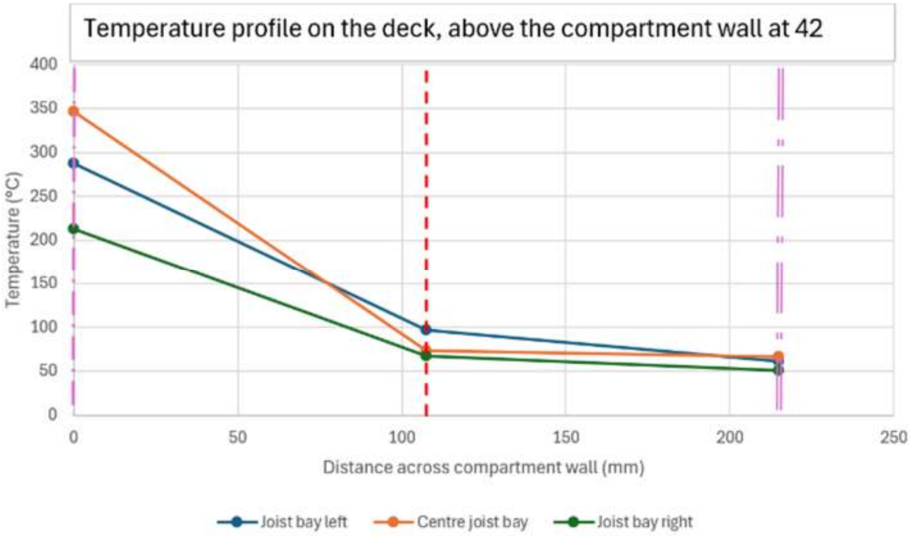


Figure 41 – Photograph of the deck showing the location of the thermocouples. Note: The same layout of thermocouples as Experiment 7 was adopted for Experiment 8 but there was no separate close-up photograph available

Figure 42 shows the temperature profiles on the deck.



Key:

The single lilac dot and dash line is the exposed edge of the compartment wall.

The double **lilac** dot and dash is the unexposed edge of the compartment wall.

The **red** dashed line is the centre of the compartment wall.

Figure 42 – Temperature profiles on the deck created from data without the need to correct for ambient air temperature since the temperatures at the centreline and unexposed edge were all less than 140°C

6 Analysis of experimental results

As discussed in Section 3, this experimental programme was undertaken on the basis of developing an understanding of roof system design and compartmentation based on ad hoc fire performance experiments and not based a series of established 'tests' with pass and fail thresholds. However, the thresholds from 'standard' testing can allow for 'benchmarking' comparisons to be made between different constructions when exposed to a standard cellulosic heating curve for walls.

In order to have comparable evidence, the application of the thresholds described in Section 3 and visual observations have been applied to the data sets to provide a common basis for comparison.

6.1 Experiment 1: Thermally insulated deck 100 mm thick tissue-faced polyisocyanurate board mechanically fixed to an OSB deck

Masonry nominally touching the underside of the deck. No firestopping.

<u>Duration 53.5 minutes (test termination)</u>

Above the centre of the wall below			Above the unexposed edge of the wall below		
Visible flaming	One or more thermocouple readings >180°C (above ambient)	Average of readings >140° C (above ambient)	Visible flaming	One or more thermocouple readings >180° C (above ambient)	Average of readings >140° C (above ambient)
			No	No	No

6.2 Experiment 2 (variant of Experiment 1)

Fire stopping between the head of the compartment wall and underside of board deck under compression.

<u>Duration 60 minutes</u>

Above the centre of the wall below			Above the unexposed edge of the wall below		
Visible flaming	One or more thermocouple readings >180°C (above ambient)	Average of readings >140° C (above ambient)	Visible flaming	One or more thermocouple readings >180° C (above ambient)	Average of readings >140° C (above ambient)
			No	No	No

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6.3 Experiment 3 (variant of Experiment 1)

Fire stopping between head of wall and underside of deck under compression.

Additional fire stopping between deck and underside of waterproof membrane.

Duration 60 minutes

Above the centre of the wall below			Above the unexposed edge of the wall below		
Visible flaming	One or more thermocouple readings >180°C (above ambient)	Average of readings >140° C (above ambient)	Visible flaming	One or more thermocouple readings >180° C (above ambient)	Average of readings >140° C (above ambient)
No	No	No	No	No	No

6.4 Experiment 4 (variant of Experiment 1)

As Experiment 2, but with an additional 40 mm thick foil faced polyisocyanurate insulation board pushed to the underside of the deck.

Fire stopping between head of wall and underside of deck under compression.

Duration 60 minutes

Above the centre of the wall below			Above the unexposed edge of the wall below		
Visible flaming	One or more thermocouple readings >180°C (above ambient)	Average of readings >140° C (above ambient)	Visible flaming	One or more thermocouple readings >180° C (above ambient)	Average of readings >140° C (above ambient)
No		No	No	No	No

6.5 Experiment 5: A composite deck using 120 mm thick foil faced polyisocyanurate insulation bonded to a 9 mm OSB deck with an additional layer of 15 mm thick plywood on top of the 9 mm OSB surface

Fire stopping between head of wall and underside of foil facer under compression.

Duration 60 minutes

Above the centre of the wall below			Above the unexposed edge of the wall below		
Visible flaming	One or more thermocouple readings >180°C (above ambient)	Average of readings >140° C (above ambient)	Visible flaming	One or more thermocouple readings >180° C (above ambient)	Average of readings >140° C (above ambient)
No	No	No	No	No	No

6.6 Experiment 6 (variant of Experiment 5)

Fire stopping between head of wall and underside of foil facer slight compression to not being under compression at all in places.

Duration 60 minutes

Above the centre of the wall below			Above the unexposed edge of the wall below		
Visible flaming	One or more thermocouple readings >180°C (above ambient)	Average of readings >140° C (above ambient)	Visible flaming	One or more thermocouple readings >180° C (above ambient)	Average of readings >140° C (above ambient)
No	No	No	No	No	No

6.7 Experiment 7: Inverted roof on OSB deck, using 160 mm thick extruded polystyrene

Fire stopping between head of wall and underside of decking under compression.

Duration 39 minutes (test termination)

Above the centre of the wall below			Above the unexposed edge of the wall below		
Visible flaming	One or more thermocouple readings >180°C (above ambient)	Average of readings >140° C (above ambient)	Visible flaming	One or more thermocouple readings >180° C (above ambient)	Average of readings >140° C (above ambient)
	No	No		No	No

6.8 Experiment 8 (variant of Experiment 7)

Fire stopping between head of wall and underside of decking (under compression).

Cellular glass fire stopping used between EPDM waterproof layer and underside of water control layer.

Duration 42 minutes (test termination)

Above the centre of the wall below			Above the unexposed edge of the wall below		
Visible flaming	One or more thermocouple readings >180°C (above ambient)	Average of readings >140° C (above ambient)	Visible flaming	One or more thermocouple readings >180° C (above ambient)	Average of readings >140° C (above ambient)
No	No	No	No	No	No

6.9 Experiments stopped early

6.9.1 Experiment 1

This was stopped due to flaming over the whole sample sitting directly above the furnace. Flames also spread laterally.

6.9.2 Experiment 7

This was stopped due to flaming reaching the front of the sample, having passed beyond the unexposed edge of the compartment wall.

6.9.3 Experiment 8

This was stopped due to flaming over whole sample sitting directly above furnace. Flames also spread laterally.

7 Discussion

Questions arise when considering combustible battening, decking or other elements of roof build-ups passing across a compartment (party wall).

Question 1:

> *“When considering B3(2) compliance, Is the objective to prevent combustion of the battening, decking or other elements beyond the centreline of a compartment (party wall)?”*

In BRE Global’s opinion, this would seem a reasonable proposition, because, if successful, it could be said that the roof system and fire stopping detailing prevented fire spreading from one building to another.

Question 2:

> *“When considering B3(2) compliance, Is the objective to prevent combustion of the battening, decking or other elements, from reaching the ‘far side’ or the unexposed edge?”*

In BRE Global’s opinion, this may not be a reasonable proposition. Battening, decking and other elements of construction beyond the centreline of a compartment (party) wall will de facto, belong to the neighbouring demise (i.e. another building).

Given that the schedule 1 requirement B3(2) is that walls should be constructed so that they:

> *“[…] adequately resist […] the spread of fire between […] buildings*”,

It is BRE Global’s opinion that the objective considered in Question 1 should apply. BSR HSE will need to consider this when arriving at any conclusions from this indicative round of experiments.

<u>Limitation of the research Schedule 1 Requirement B3(3)</u>

Both questions (above) appear relevant when considering internal compartment walls, where they are provided to comply with B3(3). This is discussed in Section 2 above, at Paragraphs 4 and 5.

The following may seem incongruous but a necessary consideration:

In BRE Global’s opinion, a non-loadbearing wall, with a deflection head detail, first needs to be shown to perform under deflection loading. At present, non-loadbearing walls are not subjected to any deflection head appraisal, when tested in accordance with BS EN 1364-1:2015. Following successful bespoke load testing (to ‘activate’ the deflection head) and prove the requisite period of fire resistance can be achieved, such walls could then be experimented on to indicate performance in the same manner as this set of experiments.

Note: The application of load to challenge the performance of the deflection head would be bespoke. Such a bespoke approach could utilise the test frames that are used when conducting testing to BS EN 1365-1:2012 [7] but being bespoke the experiment would fall outside of both BS EN 1364-1 and 1365-1. Consideration would need to include how and when the loading (to activate the deflection head) is applied and what would constitute satisfactory performance.

Finally, consideration would still need to be given as to the point at which a non-loadbearing compartment wall fails as fire passes across it i.e. at the exposed edge, the centreline or the unexposed edge.

BRE Global believes this level of consideration would be needed for non-loadbearing compartment walls prior to conducting indicative experiments as per this programme of work.

Lastly, a loadbearing compartment wall (but not a party wall) could be tested for compliance with B3(3) indicatively, as per this series of experiments but again the point at which it fails i.e. whether at the exposed edge, the centreline or the unexposed edge would need consideration.

Limitation of the research Schedule 1 Requirement B3(4)

One of the failings of current testing to BS EN 1364-1:2018 or BS EN 1365-1:2012 is that there is no pass / fail criteria for smoke spread when conducting standard testing. As this experimental work is predicated on standard testing of a wall (albeit the top couple of courses), the parameters for pass / fail for a standard test need to be established.

Accordingly, the second limb of B3(4) that:

> *"[…] the building shall be designed and constructed so that the unseen spread of […] smoke within concealed spaces [like ceiling voids][…] is inhibited"*

cannot be measured unless there are bespoke pass / fail criteria at indicative level. This would require further consideration.

Experiment 1

The indicative results suggest thermally insulated decks with 100 mm thick tissue-faced polyisocyanurate board mechanically fixed to a timber deck, require fire stopping. In BRE Global's opinion, the ad hoc results suggest that relying on a close fit between the head of the compartment wall and underside of the deck is not sufficient to prevent fire spread over the compartment wall.

Experiments 2 and 4

Even where fire stopping is used, below the timber deck, an advancing flame front (together with elevated temperatures above 180°C) or elevated temperatures (but without an advancing flame front) were observed up to the centre line of the compartment wall. Using linear interpolation, it was possible to see that elevated temperatures continued to occur on the deck beyond the centre line of the compartment wall below, and in the case of Experiment 2, it was determined that elevated temperatures on the deck existed in very close proximity to the unexposed edge of the compartment wall below.

Experiment 3

Provision of fire stopping below and above the timber deck proved to be effective at preventing flaming (together with elevated temperatures) or elevated temperatures (but without the flaming) from occurring up to the centreline of the compartment wall.

Experiments 5 and 6

The composite deck construction using 120 mm thick foil faced polyisocyanurate insulation bonded to a 9 mm OSB deck proved to be effective at preventing flaming (together with elevated temperatures) or elevated temperatures (but without the flaming) from occurring up to the centreline of the compartment wall. However, experiments 5 and 6 were different from all other experiments in that once fire broke through the plasterboard ceiling, it then had to burn through 120 mm thick foil faced polyisocyanurate insulation before impinging on the underside of the 9 mm thick deck. In both these experiments, the thermocouples were located on top of the 9 mm thick OSB deck, prior to the layer of 15 mm thick plywood being lain. The waterproof layer was bonded with adhesive to the 15 mm thick plywood.

The essential difference between Experiment 5 and Experiment 6 was that in Experiment 5 the fire stopping was under approximately 10 mm of compression, whereas in Experiment 6 it was under nominal compression (of the order of 3 mm). The temperatures on the deck above the centreline and the unexposed edge of the wall below were broadly comparable between Experiment 5 and Experiment 6. The conclusion being that even at a nominal 3 mm compression the mineral fibre stopping was effective.

Experiments 1 to 4 and 7 and 8

These experiments were like one another in that once fire broke through the plasterboard ceiling it was then able to impinge on the underside of the 18 mm thick deck. Experiment 3 varied this slightly as there was a piece of 40 mm thick foil faced polyisocyanurate beneath the deck (for the hybrid variant). The common theme in these six experiments was that once the ceiling fell the fire was able to impinge on the underside of the 18 mm thick deck immediately, or (in the case of Experiment 3) presently, thereafter.

The focus for all eight experiments was to visually observe flame spread and to obtain data. The data would suggest whether elevated temperatures occurred either as an average or individually and where this occurred over the width of the party wall. To achieve this in a consistent manner, thermocouples were placed on the deck of each construction, to gather a temperature gradient at 60 completed minutes or test termination.

With hindsight, the thermocouples in Experiment 5 and Experiment 6 might have been better placed either at the underside of the deck, or in conjunction with an additional line of thermocouples in the body of the insulation. Thermocouples placed in the body of the insulation may have helped to determine if fire was spreading through it, whether by flaming combustion or smouldering combustion. Thermally thick construction types may experience fire spread through the body of the insulation before visible flaming can be seen on the upper surface (above a timber or other deck).

Two mechanisms of burning are suggested in Figure 43 (below) to highlight this. In BRE Global's opinion, the middle image might be considered typical (or preconceived) as the typical pattern of burning. The image shows that as burning spreads away from its origin it may give rise to the V-pattern or part V-pattern over a party wall.

The bottom image is offered for discussion purpose at this stage. With thermally thick constructions, there may be some element of hollowing-out (before flaming is visible above a timber or other deck). Hollowing out may be considered to be fire spread depending on extent. In countering this, it must be recognised that some insulants may char and not give rise to such hollowing-out.

If Experiments 5 and 6 were repeated, BRE Global would consider reducing the additional deck to either 9 mm or 12 mm and inserting an additional line of thermocouples in the depth of insulation (to obtain data).

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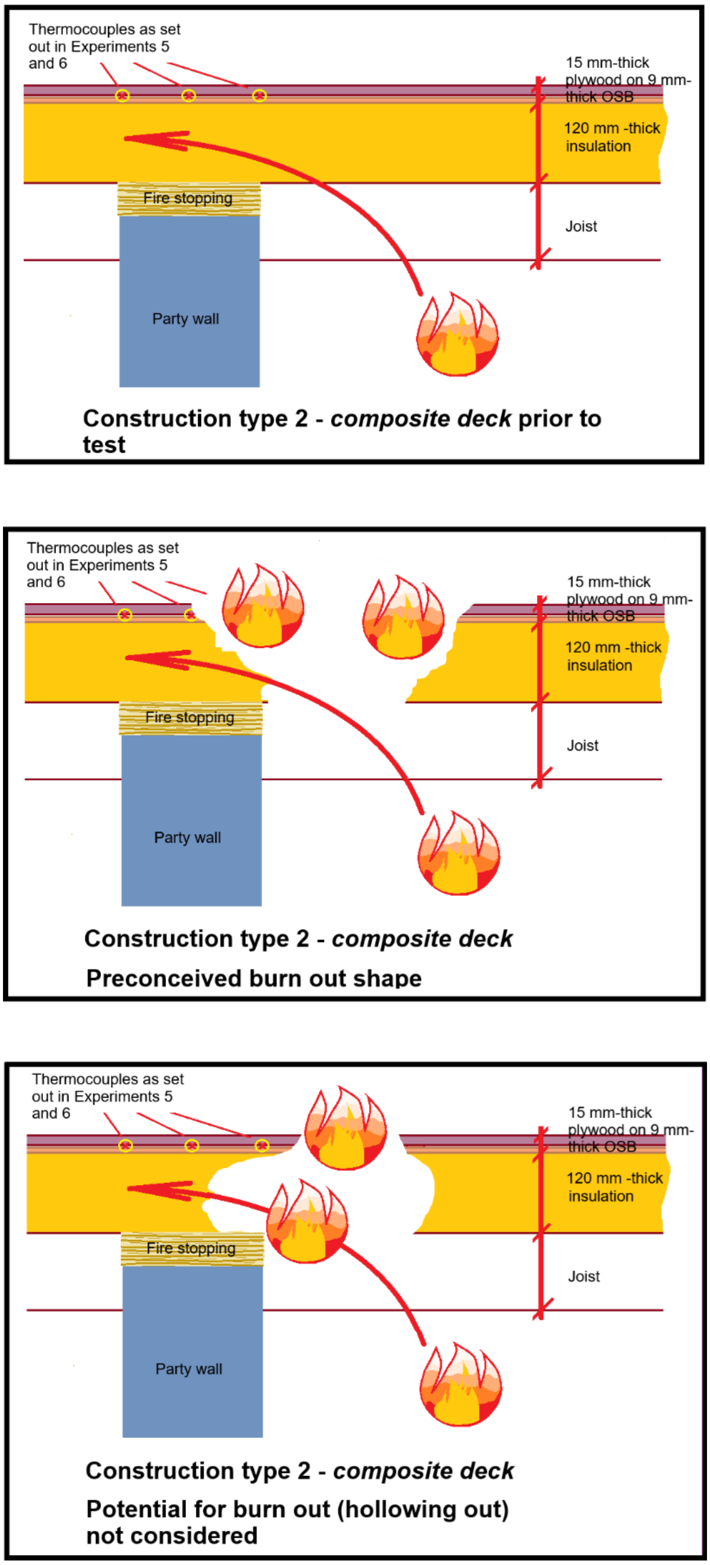

Figure 43 – Potential patterns of burning with the middle image suggesting a typical V-pattern that may occur as fire 'leans' over a party wall, and the bottom image suggesting a potential pattern that may warrant further investigation, in thermally thick constructions incorporating a deck above

Experiments 7 and 8

Whilst flaming was observed to have passed across the full width of the compartment wall, the temperature readings did not exceed the comparison threshold values.

Provision of fire stopping below and above the timber deck proved to be effective at preventing flaming (together with elevated temperatures) or elevated temperatures (but without the flaming) from occurring up to the centreline of the compartment wall.

Experiment 7 showed that fire spread through the thermoplastic insulation very rapidly. It appears that the surface thermocouples did not respond in real time as the thermoplastic insulation was consumed and or as it melted and slumped into the furnace. The thermocouples may have experienced a thermal lag.

In BRE Global's opinion, the observations made for thermally thick constructions under Experiments 5 and 6 may above apply here. If this work were to be expanded upon, there may be benefit in inserting an additional line of thermocouples in the depth of insulation (to obtain data) for inverted roofs comprised of thermally thick thermoset insulation.

8 Conclusions

The two questions in Section 7 need to be borne in mind when BSR HSE considers these conclusions.

Based on the eight ad hoc experiments conducted to date, the conclusions of this study are as follows.

Experiment 1

The findings suggest thermally insulated decks with 100 mm thick tissue-faced polyisocyanurate board mechanically fixed to a timber deck, will require fire stopping.

Relying on a close fit between the head of a masonry party wall and the underside of the timber deck of a warm deck roof construction does not appear to be sufficient in resisting fire spread across the party wall.

Over two of the three bays, fire spread was observed via combustion of the timber deck and the insulation above the timber deck.

In the last bay, fire spread by the combustion of material above the deck.

Experiments 2 and 4

Fire stopping below the timber deck alone may result in flaming occurring up to the centre line of the compartment wall and elevated temperatures may occur beyond the centre line. The elevated temperatures may occur close to the unexposed edge.

Smouldering combustion is thus likely beyond the centreline of the compartment wall. The two questions that introduced Section 7 Discussion, are also relevant here:

Question 1:

> *"When considering B3(2) compliance, Is the objective to prevent combustion of the battening, decking or other elements beyond the centreline of a compartment (party wall)?"*

And

Question 2:

> *"When considering B3(2) compliance, Is the objective to prevent combustion of the battening, decking or other elements, from reaching the 'far side' or the unexposed edge?"*

Experiment 3

Provision of fire stopping below the timber deck, as well as above it, effectively prevented fire spread from one side of a compartment wall to the other in this example. It also prevents fire and / or elevated temperatures arising at the centreline of the compartment wall.

Note: This experiment considered 100 mm thick thermoset insulation. This result should not be assumed to apply to thermally thicker constructions without further indicative research to consider if fire could spread by 'jumping' across the stopping above the deck via the insulation.

Experiments 5 and 6

This type (comprising a composite deck with a foil faced polyisocyanurate insulation bonded to a 9 mm thick OSB deck with an additional layer of 15 mm thick plywood) performed well in this scenario with no flaming being observed above the compartment wall and with temperatures on the deck, around the centre line and above the unexposed edge, being the lowest across all the experiments, but this may be a combination of the location of thermocouples and the construction being thermally thick beneath the deck.

Experiments 7 and 8

Whilst flaming was observed to spread across the full width of the compartment wall in Experiment 7, the temperature readings did not exceed the threshold values.

This suggests that the current guidance in AD B, that thermoplastic insulation should not be carried over a compartment wall, remains appropriate.

This is additionally supported by the difference in performance between Experiment 7 and Experiment 8. In Experiment 8, the provision of fire stopping below and above the timber deck proved to be effective at preventing flaming (together with elevated temperatures) or elevated temperatures (but without the flaming) from occurring up to the centreline of the compartment wall.

Note: This experiment considered 160 mm thick thermoplastic insulation. This result should not be assumed to apply to thermally thicker constructions without further indicative research. Evidence should therefore be sought to explore the effect of constructing thermally thick and thermally *very* thick roof constructions up to and across party walls and whether such constructions under some circumstances may allow fire to spread across the line of a party wall. If re-visiting this, it would be worthwhile considering the effect of wind in driving fire up to and potentially over party walls.

It is not known if fire would spread across a party wall if the insulation used was thinner than the insulation used in these experiments, but this would only become apparent following additional research.

9 Recommendations for further work

The two questions in Section 7 need to be borne in mind when considering the need for future work.

In BRE Global's opinion, recommendations for further work are as follows:

1. These experiments should be conducted at full scale, to validate these conclusions.
2. The effect of wind, passing across the roof surface, should be considered.
3. The effect of co-locating extract ducts and / or soil and vent pipes either side of a compartment wall, should be considered for a sensitivity analysis. Fire breakout may occur more quickly as it is unlikely fire collars will be fitted beneath a roof. Fire may re-enter the building via downwards fire spread through neighbouring extract ducts and / or soil and vent pipes.
4. The effect of introducing a wider margin of roof beyond a compartment wall should be considered. This would enable a study of the rate of flame spread and whether there is any penetrative flame spread that occurs within 60 minutes, or whether the mechanism of flame spread is essentially surface spread of flame.
5. Combustible framed compartment walls party walls should be considered for further B3(2) study.
6. Cavity compartment party walls should be considered for further B3(2) study.
7. Non-loadbearing compartment walls (with and without deflection head details) should be considered for further B3(3) studies.
8. The impact of large-scale installations of roof mounted systems and equipment such as photo voltaic and solar arrays.

10 References

1. British Standards Institution, BS EN 1363-1:2020 Fire resistance tests. Part 1. General requirements, BSI, London, 2020.
2. British Standards Institution, BS EN 1364-1:2015 Fire resistance tests for non-loadbearing elements. Part 1. Walls, BSI, London, 2015.
3. Morris W A, Read R E H and Cooke G E. Guidelines for the construction of fire-resisting structural elements, Building Research Establishment report BR 128, 1988, ISBN 0-85125-293-1 See Table 1 (construction 10(a)).
4. British Standards Institution, BS EN 13501-5 Fire classification using data from external fire exposure to roof tests, BSI, London, 2016.
5. CEN, CEN/TS 1187-4:2012. Test methods for external fire exposure to roofs, BSI, London, 2012.
6. British Standards Institution, BS 476-3:2004 + A2:2007 Fire tests on building materials and structures. Classification and method of test for external fire exposure to roofs, BSI, London, 2004.

Report Ends