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External Fire Spread – Part 2 Experimental research

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External fire spread – Part 2

Introduction

BRE Global carries out fire investigation activities on behalf of the Department for Communities and Local Government (DCLG) by investigating issues that may have implications for Building Regulations and the guidance that supports Building Regulations, such as the Approved Documents.; the contract 'Investigation of Real Fires' under which this work was carried out was completed in 2015 but has been renewed until 2018. An important element of this contract is to ensure that findings from fire investigations are made available to the fire community, and other stakeholders.

There have been a number of fires, both historic and more recent, which have raised concerns regarding fire spread over the external walls of multi-storey buildings and have consequently resulted in the introduction of guidance documents and test procedures to assess the fire performance of external wall construction.

Part 1 of this article [1] discussed previous and current guidance for external fire spread and also discussed several case studies of external fire spread since the introduction of the BS 8414 test series [2] and [3].

Following the conclusions of Part 1, it was agreed with DCLG to carry out an experimental scoping study focusing on the issue of external fire spread, maintaining some similarity to Ashton and Malhotra's work, carried out in 1960 [4] but also calls upon BR 135 [5] and BS 8414 [2].

Objectives

The aim of this research was to carry out three experiments to assess the performance of different external façades including non-fire rated double glazing, when exposed to a fire from below, representative of the external face of some buildings to inform DCLG Building Regulations and Standards Division.

It should be noted that this work did not test the performance of specific products/systems and was not a comprehensive research study but rather a scoping study and as such, the results need to be considered within this context.

Methodology

BRE Global carried out three large-scale experiments in the BRE Burn Hall using different types of external façade systems of types used in residential properties that incorporate both non-fire rated double glazing units (same type in all experiments) and spandrel panels of varying combustibility.

Experimental rig

An experimental rig was designed and installed (Figure 1). This utilised one of the existing BRE Global BS 8414 test rigs [3]; a schematic of the BS 8414 test rigs can be found in BR 135 [5]. The intention of this experimental work was to evaluate potential fire spread from one building storey to another and therefore it was unnecessary to clad the entire height and return wing of the BS 8414 test rig.

A steel frame, 2850 mm wide by 2300 mm high was fabricated using 30 mm steel channel with 3 mm thick steel. This frame was installed onto the test rig, as shown in Figure 2, at the level directly above the fire source, approximately 2.7 metres from the ground and 700 mm from the top of the hearth. The frame was fitted to the leading edge of the concrete lintel resting on top of the lintel (see Figure 1) representing an external façade which is flush with the floor slab below. The frame was designed with two sections; the lower section contained the spandrel panel to be tested and the upper section contained the double-glazed units.

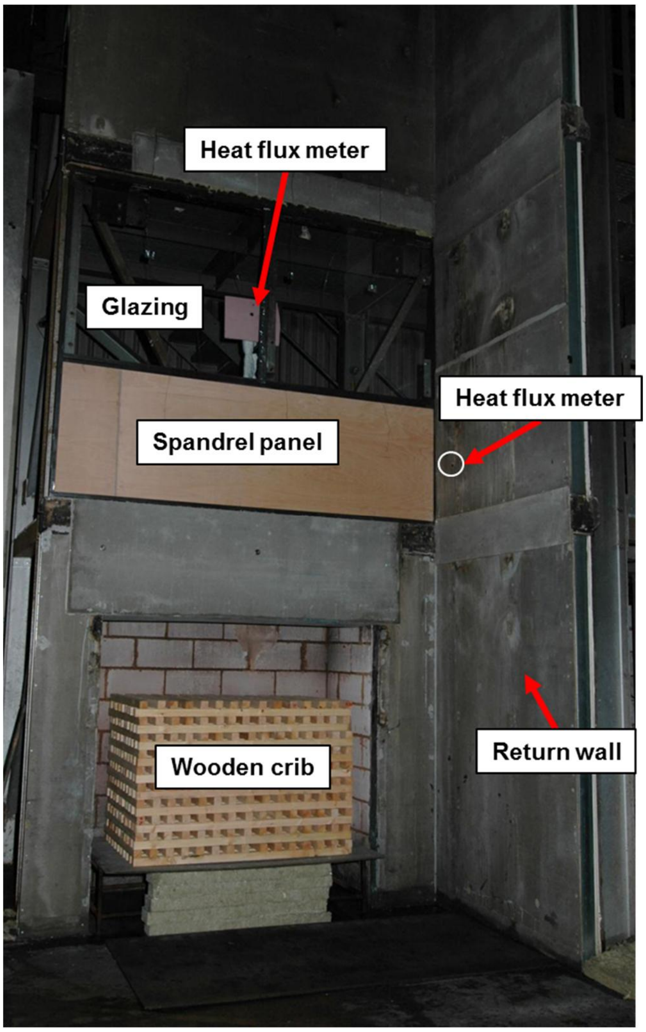

Figure 1 – Annotated image showing the front elevation of experimental set up

For each experiment, the resulting area exposed to the fire conditions was 1300 mm high x 2790 mm wide for the glazing and 880 mm high x 2790 mm wide for the spandrel panel. Two panels of glass were used due to the size and weight of the panels.

The spandrel panels were sealed into the frame by packing the channel with stone fibre wool insulation and the glazing units were sealed with glazing gasket, where necessary. Approximately 200 mm behind the spandrel panel, a sheet of standard 12.5 mm plasterboard (~ 500 mm x 2400 mm wide) was installed for mounting instrumentation on but also as a target to assess the potential damage (if any) from radiant heat or fire (Figure 2).

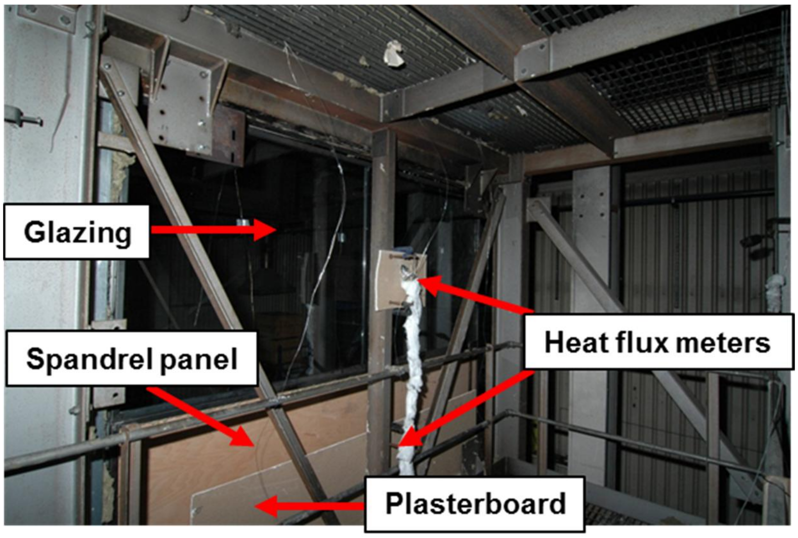

Figure 2 – Image of rear elevation behind the steel frame on level one of the test rig i.e. the level above the hearth

Materials

The following items were sourced by BRE Global and installed into the experimental frame:

- A cement fibreboard of dimensions 925 mm high x 2400 wide mm x 9 mm thick. A 450 mm wide section was cut from a second panel to fill the frame width and these sections were joined together using fire cement. This board could achieve a 60 minute fire resistance rating when installed in accordance with the details in the relevant BS 476 test report [7]. For the purposes of reporting this panel will be referred to as "fire resisting" from herein.
    - NOTE: BRE Global was not able to source an off-the-shelf fire resisting external board – the board that was used is sold for internal use. The panel is capable of achieving 60 minutes fire resistance when installed within a complete system and tested to BS 476-21:1987 [8]. However, for the purposes of this programme of work, the panel was not installed as per the test report.
- A sheet of structural hardwood plywood of dimensions 925 mm high x 2440 mm wide x 9 mm thick. A 400 mm wide section was cut from a second panel to fill the frame width and these sections were joined together using fire cement. It was anticipated that the reaction to fire performance would be Class 3 (National class), assuming a density greater than 400 kg/m^3.
    - NOTE: There was no available evidence of the fire rating of this panel, hence Class 3 is assumed based upon guidance provided in Approved Document B [9]. For the purposes of reporting, this panel will be referred to herein as "Class 3".
- A compressed stone-fibre spandrel panel with an organic binding agent of dimensions 925 mm high x 2900 mm wide x 8 mm thick. This panel, as part of a specific system for external facades, demonstrates a reaction to fire performance of Class B-s2,d0, according to EN 13501-1:2007 [6].
    - NOTE: For the purposes of this experiment, only the spandrel panel (a single component part of the system), and not the complete system was used. Therefore, the reaction to fire performance for this panel has been assumed as "Class B-s2,d0" but this was not confirmed as part of this programme of work.

- Six non-toughened non-fire resisting double-glazed units were manufactured by a glazing supplier using 4 mm float glass with a 10 mm cavity filled with argon. This gave a complete thickness of 18 mm. The dimensions of the glazing panels were 1420 mm wide x 1350 mm high.

Instrumentation

Temperature and heat flux were measured.

The experimental rig was instrumented with twelve 1.5 mm diameter Type K steel sheathed thermocouples. The thermocouples were arranged as shown in Figure 3. Thermocouples measuring temperatures at the glazing level were placed equidistantly. The thermocouples measuring temperatures at the spandrel panel were placed in similar locations, horizontally, to the thermocouples at the glazing level.

Thermocouples at the front of the rig were intended to record the gas/flame temperatures that the panels and glazing were exposed to, rather than solid surface temperatures. The thermocouples at the rear of the rig were approximately 300 mm from the spandrel and glazing and 1550 mm from the base of the frame; this was to record temperatures likely to be achieved within a room, hence they were not fitted to the rear side of the panels.

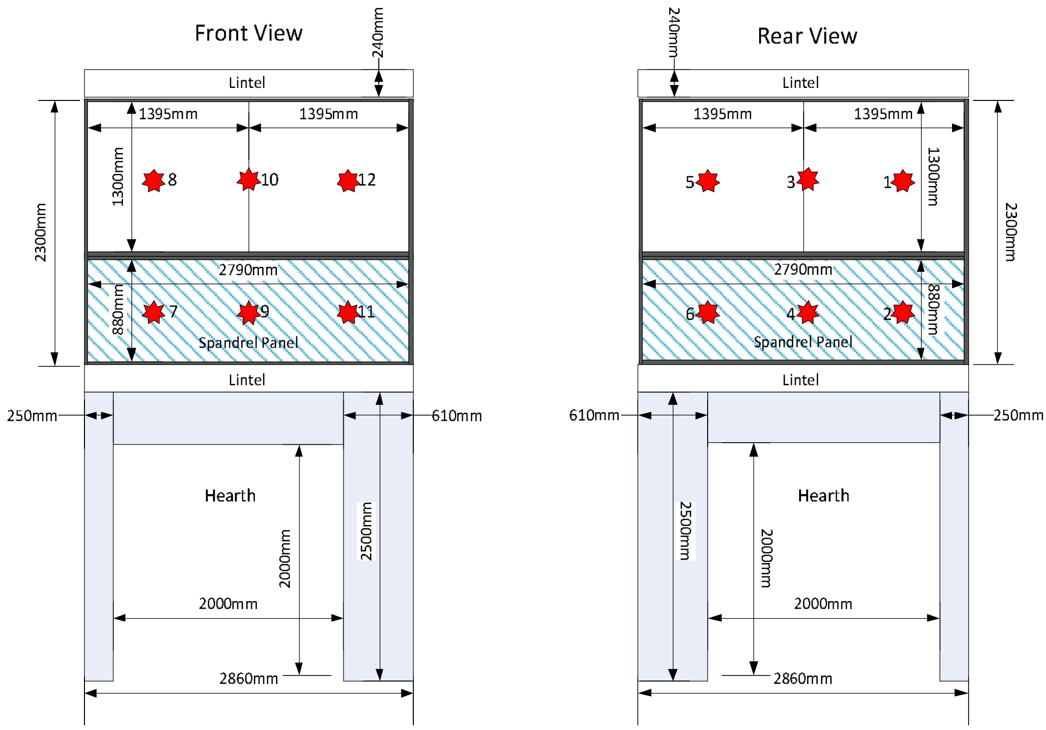

Figure 3 – Approximate locations of thermocouples in the structure

Three water-cooled heat flux transducers (heat flux meters) were also fitted at various locations on the rig to measure targeted heat fluxes and to aid the assessment of the severity of the fire (Figure 1 and Figure 2). The locations were as follows:

- One Schmidt-Boelter thermopile type sensor, mounted in the return wing of the BRE Global BS 8414-2 test rig, was located approximately 365 mm from the base of the spandrel panel and approximately 245 mm from the corner of the test rig, flush with the wall surface, with a side-on view of the fire plume. The meter was calibrated to 100 kW/m^2.

- One Gardon type sensor was located approximately 180 mm behind the spandrel panel and approximately 365 mm from the base of the frame, approximately central to the frame, protruding out approximately 10 mm, from the plasterboard (used for positioning), with a face-on view of the fire plume. The meter was calibrated to 20 kW/m^2.
- One Gardon type sensor was located approximately 300 mm behind the double-glazing unit and approximately 1550 mm from the base of the frame, approximately central, flush with the plasterboard (used for positioning), with a face-on view of the fire plume. The meter was calibrated to 50 kW/m^2.

Experimental method

Three experiments were carried out to assess the performance of the spandrel panel and glazing unit when exposed to a fire from an opening below. The fire source was a wooden crib as described in the BS 8414-2 [3] test method to be representative of a fully flashed-over fire in a compartment breaking out of a window and impinging on the external façade above. The following experiments were carried out:

- Experiment 1 – “Fire resisting” panel and non-fire resisting double-glazing unit.
- Experiment 2 – “Class 3” (plywood) spandrel panel and non-fire resisting double-glazing unit.
- Experiment 3 – “Class B-s2,d0” (stone fibreboard) spandrel panel and non-fire resisting double-glazing unit.

Each experiment was continued until the experimental rig was thought to be at risk of damage.

Findings

Observations made for all three experiments are summarised in Table 1.

The maximum flame length for all three experiments was estimated at 3.3 metres from the underside of the hearth i.e. to the top of the glazing (Figure 4). The glazing failed in all three experiments.

NOTE: Failure of glazing was defined as both panes of glass (i.e. full thickness of a double-glazed panel) falling out of the frame allowing flames through to the back of the rig.

Table 1 - Summary of observations

Experiment Number	Time (minutes:seconds)						
	Duration of fire	**Flaming at 2 metres**	**Flaming at maximum length**	**Failure of first glazing panel**	**Failure of full glazing system**	**Involvement of spandrel panel**	**Burn through of spandrel panel**
1	15:00	02:38	04:30	06:15	08:40	N/a	N/a
2	11:54	02:57	10:30	04:54	08:08	03:08	11:04
3	26:40	06:30	04:00	13:40	20:30	N/a	N/a

N/a = not applicable

Figure 4 – Image showing maximum achieved flame length of approximately 3.3 m

The severity of the fire to which each system was exposed was similar as shown by the measured data presented in Table 2 and Figure 5. It should be noted that the moisture content of the crib wood was not measured prior to the experiments which is a possible explanation for the differences in fire growth in the three experiments. The growth of the fire for Experiment 3 was slower than that of Experiments 1 and 2 but ultimately, a similar peak heat flux at the return wall was achieved.

The slower growth rate, for Experiment 3, explains the differences in failure times of glazing and time to reaching maximum flame lengths.

The peak heat flux at the return wall for Experiment 2 was lower than that for Experiments 1 and 3; this was due to the shorter duration of the fire due to the failure of the spandrel panel and also the failure of the panel resulted in a change of air flow which impacted on the position of the fire plume relative the heat flux meter.

Table 2 – Summary of peak heat flux and temperatures for all three experiments

Experiment Number	Peak heat flux (kW/m^2)			Peak temperature (°C)			
	Return Wall	Glazing	Spandrel	Front Spandrel	Front Glazing	Rear Spandrel	Rear Glazing
1	120	25	7	848	746	17	112
2	82	27	N/a	729	759	28	486
3	140	17	10	850	698	29	116

N/a – Heat flux meter was damaged during the experiment rendering the data unusable.

Table 3 compares the severity of the fire at the time of failure of the first glazing panel in each experiment. The heat flux quoted is from the return wall of the rig with a side view of the fire plume and has not been corrected for the view factor. It is only indicative of the heat flux to which the glazing was exposed and not an accurate measurement of the direct heat flux on the glazing at that time.

Table 3 – Comparison of the heat flux measured at the return wall fire at the time of the failure of the first glazing panel for each experiment

Experiment Number	Heat flux (kW/m^2)	Time (mins)
1	51	6.8
2	22	4.9
3	47	13.7

This comparison shows that there are similarities to be drawn between the failure of the glazing with Experiments 1, the “fire resisting” spandrel and Experiment 3, the “Class B-s2,d0” spandrel.

As shown in Table 2, the glazing in Experiment 2 failed earlier than in the other experiments. Given that, as shown in Figure 5, the rate of fire growth for Experiments 1 and 2 are comparable, the reason for this earlier failure of the glazing is, in our opinion, due to the involvement of and eventual burn through of the “Class 3” spandrel panel contributing to and changing the local dynamics of the fire. That is, the involvement of the spandrel panel in Experiment 2 may have changed the angle of trajectory of the fire plume relative to location of the heat flux meter in the return wall resulting in the difference of recorded data.

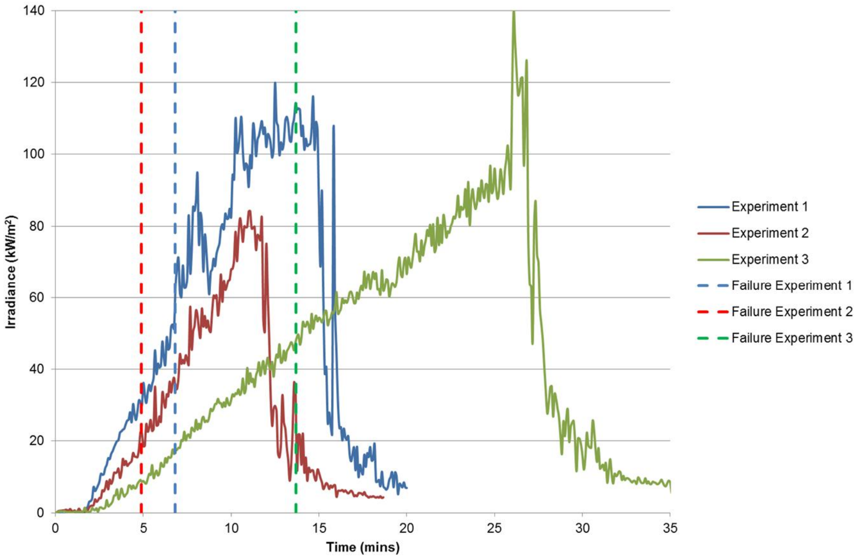

Figure 5 – Comparison of heat flux against time for the return wall for all three experiments showing the first failure point of glazing at vertical dashed lines

The highest measured temperature behind the panel system was recorded for Experiment 2. This was due to the failure of the spandrel panel allowing flames into the space behind, whereas, in Experiments 1 and 3 the panels remained intact and hence the temperatures recorded, due only to failure of the glazing, were significantly lower.

Conclusions

A limited series of three fire experiments was carried out to assess the performance of three different external facades including non-fire rated double glazing when exposed to a fire from below.

The conclusions are:

- In all three experiments the double-glazing panels failed. Failures in glazing, such as those which occurred during these experiments, provide a potential route for external fire spread from one flat to another regardless of the design of the external façade.
- The “fire resisting” and “Class B-s2,d0” panels performed in similar manner; in both experiments the glazing failed but the panels remained intact for the duration of the fire.
- The non-fire rated, “Class 3” panel became involved in the fire before the failure of the glazing and later burnt through. This early involvement of the panel appears to have contributed to the severity of conditions imposed on the glazing by introducing a flame source directly beneath it and in direct contact with it. This increased severity then caused the glazing to fail under conditions which appeared less severe than would otherwise have been the case.

It should be noted that there were several limitations to this programme of work namely:

- Only spandrel panels i.e. single components of a system and not entire systems were assessed.
- Only one type of non-fire rated double glazing was assessed and it is recognised that there are several different types of glazing used in multi-storey buildings. This would need to be addressed by separate experimental work.
- The experiments were carried out under laboratory controlled conditions. Environmental factors such as wind conditions were not part of this work and these can change the dynamics of a fire.

Overall, the findings from this research show that there is a clear and demonstrable need to ensure that buildings are designed and constructed so that the fire spread across the external surface and within the external façade is inhibited, as required by the Building Regulations. There is adequate guidance available in the public domain to allow this to be achieved.

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BRE staff have carried out fire investigations in support of the Building Regulations (and its precursors) on an ad hoc basis since 1948, and with a dedicated team since 1974. BRE has been wholly owned by the BRE Trust since its privatisation in 1997. BRE's fire investigation team is independent and provides world class fire investigation services to a wide range of clients, including insurers, legal firms, fire and rescue services, police and government departments.

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