

## Testing of steel wall systems for use in bushfire flame zone areas

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### ABSTRACT

Buildings in bushfire prone areas must be positioned or designed to resist the effects of a bushfire, which may include flame impact directly on the building envelope. In April 2010, an experimental steel framed steel clad building was tested under flame zone conditions using an outdoor bushfire flame front simulator. The roof and floor systems withstood the exposure with minimal damage, while the wall system showed some thermal and structural failures. Further wall tests were conducted using the Radiant Panel Test Facility at CSIRO Highett, Victoria. This facility can subject smaller building elements to the same radiant heat and flame contact profile as the outdoor simulator. Four wall panels were tested in August 2011 using a variety of insulation details. All panels included a steel frame, steel wall cladding on steel battens and plasterboard internal lining. Insulation materials were mineral fibre batts, standard plasterboard with glasswool batts and a rigid phenolic foam panel with and without fire-resistant plasterboard. Thermocouples measured flame, cavity, batten, stud, and plasterboard surface temperatures. The test results are described and compared with those from the full-scale outdoor simulator test. The implications for the performance design of steel-framed houses to resist severe bushfire exposures are discussed.

### KEYWORDS

Bushfire; Fire; Flame-zone; Framing; Steel; Wall

### INTRODUCTION

The National Association of Steel-framed Housing (NASH) has a longstanding commitment to research-based building solutions in residential and low-rise construction. This is particularly evident in bushfire resistant construction, where the research effort to develop more effective and economical methods of construction is ongoing. NASH is a leading participant in this type of research, working with CSIRO and industry partners to develop solutions and conduct a variety of bushfire resistance tests on steel floor, wall and roof systems constructed from familiar, readily available and easily installed products and materials.

Following the 2009 Victorian bushfires, NASH investigated different methods of providing a non-combustible, robust and durable bushfire building solution for severe bushfire exposure conditions. It was considered that a conventional steel roof together with steel trusses, steel wall studs with steel external cladding and exposed steel sub floor should be able to survive in the flame zone of a real bushfire.

To progress this concept, NASH devised a project with the following aims:

- design a low-rise predominantly non-combustible steel test building utilising a wide variety of common building materials and methods,
- assess the performance of such a building system using full-scale testing; and
- provide supporting evidence for Building Authority approval as an Alternative Solution under the BCA Performance Requirement (ABCB, 2011).

In the first phase of this project, NASH engaged the CSIRO to conduct a full scale fire test using the Bushfire Flame Front Simulator at the NSW Rural Fire Service Eurobodalla Training Centre near Mogo, NSW. (CSIRO, 2011) (ASEC, 2010). It is the only facility in the world that can model the immersion of a full scale vehicle or structure in a high-intensity bushfire flame front turnover.

The full scale test proved highly successful in confirming the concept of utilising non-combustible floor, wall and roof systems to provide a robust barrier to protect the habitable space from flame zone conditions. However it also highlighted changes that could be made to improve the performance of the wall system using techniques that did not involve specialised or expensive products or materials. As a result, four improved wall systems were developed for testing.

This paper presents the results of testing these wall systems using the Radiant Panel Test Facility at CSIRO Ecosystems Science at Highett, Victoria. (CSIRO, 2011). An advantage in using this facility is that it allowed the wall systems to be exposed to the same radiant heat and flame contact profile that was used for the full scale test.

## **REGULATORY REQUIREMENTS**

The level of bushfire attack on a building is governed by State planning regulations that include reference to AS 3959 (Standards Australia, 2009) as well as other standards and planning instruments. The performance requirement in the Building Code of Australia (BCA) 2011 for bushfire areas states that for a Class 1 building or an associated Class 10a building “that is constructed in a designated bushfire prone area must be designed and constructed to reduce the risk of ignition from a bushfire while the fire front passes.” (ABCB, 2011). The associated Functional Statement states that the “building constructed in a designated bushfire prone area is to provide a resistance to bushfires in order to reduce the danger to life and reduce the risk of the loss of the building.” (ABCB, 2011).

For BCA 2011, compliance with AS 3959-2009 is a Deemed-to-Satisfy Provision for each of the above building classes in all jurisdictions except for Class 1 and 10a in South Australia. Slight variations to class applicability apply in New South Wales.

AS 3959-2009 specifies that for houses designated as being in the Flame Zone, systems should either meet deemed-to-satisfy provisions or pass a test to AS 1530.8.2 (Standards Australia, 2007).

Alternative performance solutions to the Deemed-to-Satisfy Provisions are possible, provided it can be demonstrated to the relevant Building Authority that they satisfy the same Performance Requirements as the Deemed-to-Satisfy Provisions or that they are at least equivalent.

### FLAME ZONE THERMAL EXPOSURE PROFILE

For the most meaningful assessment of the performance of a building system under simulated bushfire conditions, the thermal exposure profile should align as closely as possible with the expected conditions in an actual bushfire.

A flame zone exposure profile has been proposed by Leonard (CSIRO, 2010) and consists of three phases:

- pre-radiation,
- flame immersion and
- post radiation

The profile is based on a worst case scenario and is similar to – but exceeds - the profile recently adopted as the basis for testing of private bushfire shelters. The pre-radiation profile was derived from modelling a range of fire scenarios using various assumptions detailed in methods given in Appendix B of AS 3959-2009. In some cases more conservative assumptions were used; for example:

- The flame body was assumed to have an emissive temperature of 1200 °K rather than 1090 °K.
- Vegetation setback from the house was zero rather than 10 m.

The flame immersion time was derived from modelling a range of fire scenarios using the detailed method in AS 3959-2009 as well as experimental data from bushfires. A 110 s flame immersion time was determined to be the worst case scenario. The post flame immersion radiant heat profile was based on the burning decay rate from heavy forest fuel fires.

The CSIRO exposure profile comprises 47 minutes of radiant heat during which the bushfire flame front approaches, immerses and then recedes from the building. The profile is shown in Figure 1.

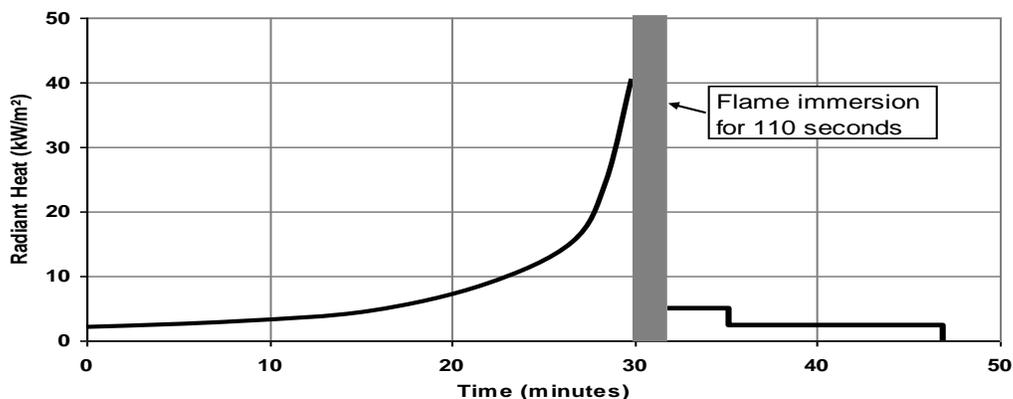


Figure 1 CSIRO Thermal Exposure Profile

The exposure profile is significantly different to that used in AS 1530.8.2 which uses a furnace heat up profile lasting 30 minutes to simulate flame zone conditions.

The advantages of the exposure profile are:

- The radiant heat and flame exposure is more representative of an actual bushfire. i.e. it is more appropriate for design testing as opposed to AS 1530.8.2 which is a comparative test;
- Allows the same exposure profile to be used for full scale and laboratory testing simplifying the comparison and combination of the test results;
- Of similar form but exceeds the ABCB Performance Standard for Private Bushfire Shelters (ABCB 2010);
- The simulator's flame body closely matches flame characteristics of real bushfire in its:
  - Flame temperature which exceeds 1000 °C;
  - Soot mass fraction giving radiant heat emission similar to bushfire flame fronts;
  - Turbulence & rapid thermal cycling within the flame due to air entrainment and mixing;
  - Heating in an environment where the oxygen in the surrounding air is available to interact with the exposed structure as in real bushfire exposures.

In comparison the 30 minute exposure in AS 1530.8.2, while intentionally severe due to its duration, is performed in a low oxygen furnace having a progressively rising temperature profile with no rapid transitions and approaches ~850°C. This may create issue for:

- Materials that fail or slump in the 850 °C to 1000 °C range, or are susceptible to thermal shock, such as glass including some fire rated glazing systems;
- Flammable materials that may be modified by a reduced oxygen environment and not behave as they may in a bushfire exposure.

## LABORATORY WALL TESTING

The Radiant Panel Test Facility can test building elements up to approximately 1000 x 1000 mm under radiant heat only or radiant heat plus flame immersion. It can model the same radiant heat exposure and flame contact profiles as the outdoor simulator. The main components of this test facility are:

- A stationary 1500 x 1500 mm gas fuelled radiant panel providing an effective constant radiant heat source. The variation in radiant heat with distance is shown in Figure 2;
- A computer controlled carriage which allows the position of the test specimen relative to the radiant panel to be varied. The system can be pre-programmed so a time varying radiant heat profile can be applied to the test specimen by moving the carriage position;
- A 900mm wide burner below the face of the radiant panel providing flame immersion in the gap between the radiant panel and the test specimen over the area of interest.

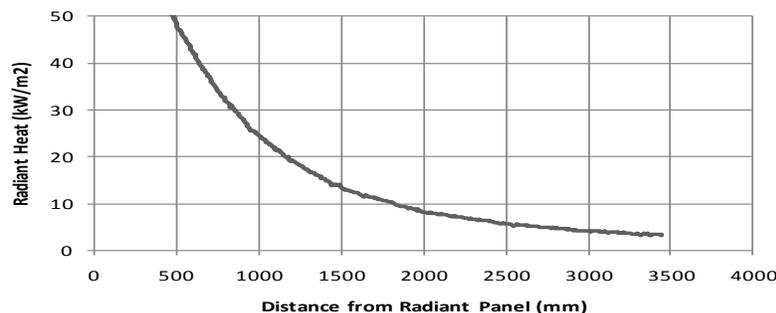


Figure 2 Variation in radiant heat with distance from the radiant panel

## WALL PANEL CONSTRUCTION

All wall panels used:

- A light gauge steel frame complying with the NASH Standard Part 1 (NASH, 2005) measuring 1.8 m by 1.8 m consisting of top and bottom plates and 4 studs nominally spaced at 600 mm centres with solid noggings at mid height
- 10 mm interior plasterboard lining with a horizontal joint 1200 mm above the bottom plate and a vertical joint over a stud. The joints were taped and bedded. The plasterboard was fixed with screws and stud adhesive in accordance with AS/NZS 2589 (Standards Australia, 2007).
- 3 horizontal steel battens were screwed through the exterior stud lining into the studs at the top, mid height and base of the wall to support the external cladding.
- Vertically orientated corrugated steel external cladding screwed to the battens at each corrugation top and bottom and at every second corrugation at mid height. L shaped flashing sections were positioned under the top and bottom of the sheets to reflect the flashing details used in practice
- Mineral wool insulation strips to seal the ends of the cavity behind the external cladding to simulate the conditions in a continuous wall.

Each individual wall panel involved a different insulation system as summarised below.

- **Test 1: Mineral Wool Only** - R2.5 (90 mm) mineral wool batts (80 kg/m<sup>3</sup> density) between studs with sarking on the external face of the studs.
- **Test 2: Glasswool and Plasterboard** - R1.7 (75 mm) glasswool batts between studs with 10mm plasterboard on the external face of the studs. An additional horizontal steel batten was used to cover the horizontal joint in the plasterboard.
- **Test 3: Phenolic Insulation Board and FR Plasterboard** R2.9 13 mm fire resistant plasterboard on the external face of the studs with 40 mm phenolic insulation board over the top.
- **Test 4: Phenolic Insulation Board Only** – R2.8 40 mm phenolic insulation board on the external face of the studs.

A typical test panel is shown in Figure 3

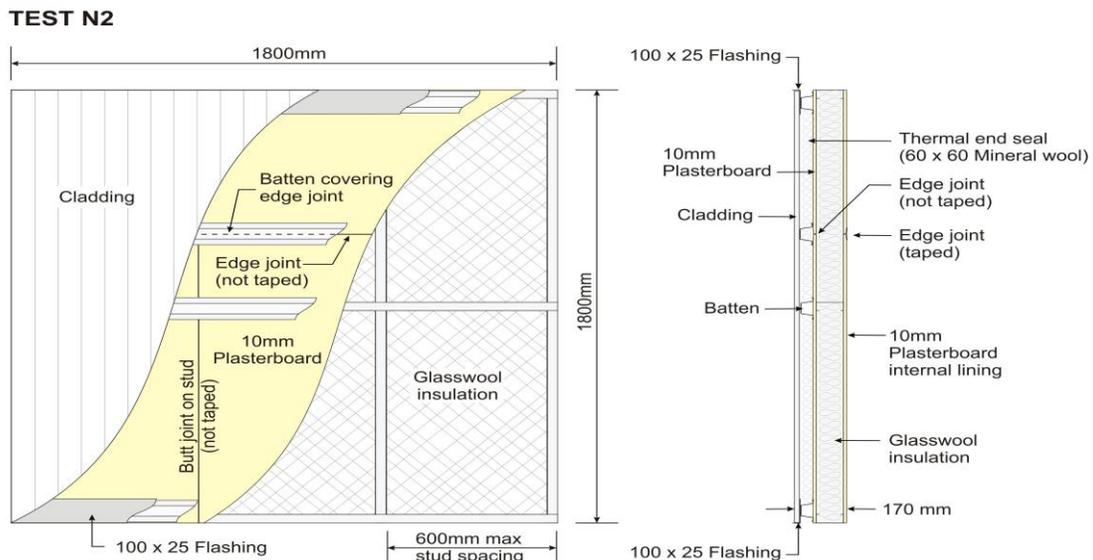


Figure 3 Glasswool and Plasterboard panel construction detail

## PANEL TESTING AND RESULTS

The test panels were instrumented in the same manner as the outdoor tests to measure flame body, cavity, batten, stud, and plasterboard surface temperatures. During the flame immersion phase the temperature on the external cladding closely matched that experienced during the full scale tests (900-1200 °C) while the temperature on the inside surface of the steel cladding was approximately 100 °C less. The temperature on the internal wall surface was <50 °C during all tests, as shown in Figure 5.

The external linings used on the external face of the stud wall frame in Tests 2, 3 and 4 restricted any temperature rise in the wall frame to less than 160 °C, as shown in Figure 4. This is significantly less than the ~900°C peak temperatures the wall frame experienced during the full scale test. Visual assessment of the walls after testing found the insulation, steel wall frame and interior plasterboard in excellent condition. The only exception was Test 1 using mineral wool and no lining over the studs where the high stud temperature caused some distortion.

All wall systems performed significantly better than the walls in the full scale test, providing a barrier from embers, flames or smoke entering through to the interior of the building due to the cool stable temperatures of the interior plasterboard and stud flanges they were fixed to.

The Plasterboard and Glasswool wall system (Test 2) generated the least smoke while the Phenolic Foam and FR Plasterboard wall system (Test 3) transmitted the least heat through the wall. The high degree of air tightness achieved in these building designs limit the potential for external smoke and any smoke development in the wall cavities to enter the occupied spaces within the house. Whilst external smoke and off-gassing are not currently regulated for housing design, they represent a significant issue for survivability under extreme bushfire exposures.

Generally the repair of a wall affected by flame zone conditions would only require replacement of the external cladding and battens and the sheeting on the external face of the frame. However, replacement depends on the extent of damage in each individual case and most exposures will be less than the worst case modelled in these tests. In balancing cost vs performance of alternatives, systems that minimise or localise damage to structural components are likely to represent the best value solutions.

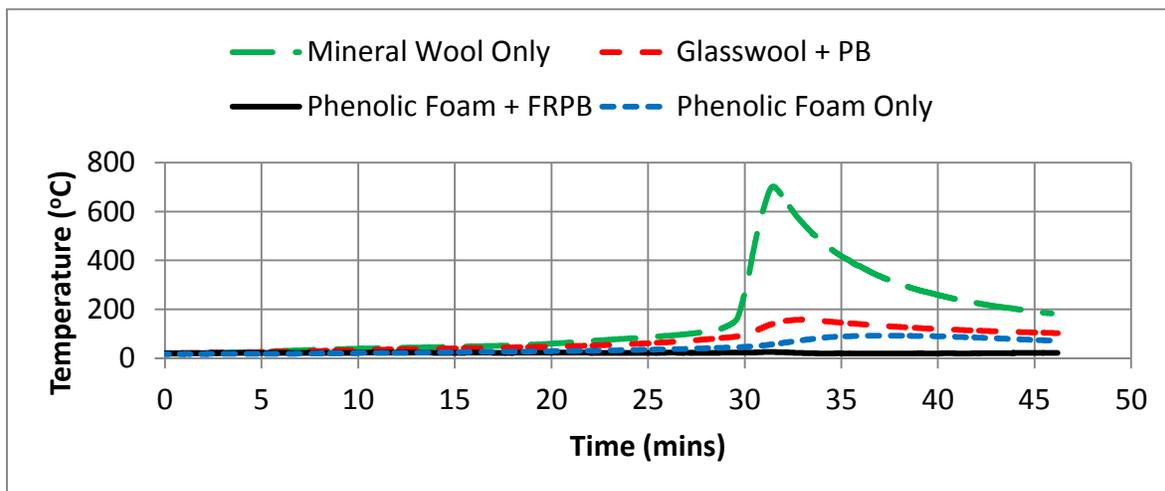


Figure 4 Stud Exterior Flange Temperatures

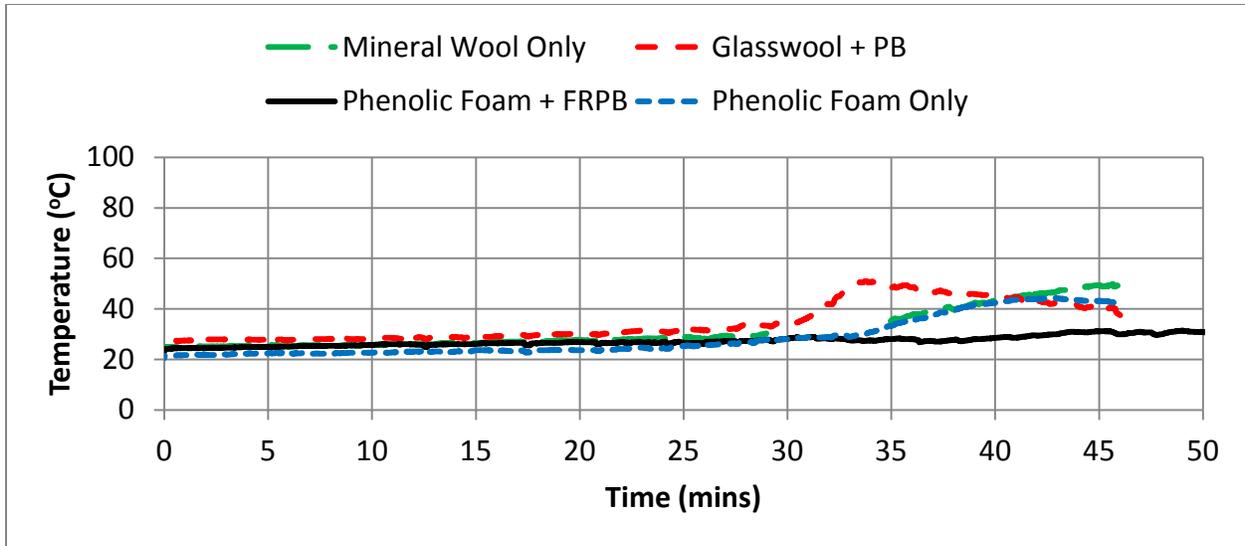


Figure 5 Interior Wall Surface Temperatures

### COST COMPARISONS

Since one of the overall project objectives is to prove the viability of conventional, economical building solutions for bushfire prone areas, a comparison was made of the best performing wall system with conventional brick veneer construction. The steel cladding system with plasterboard thermal barrier is significantly cheaper than brick veneer construction in all mainland capital cities, as shown in Figure 6.

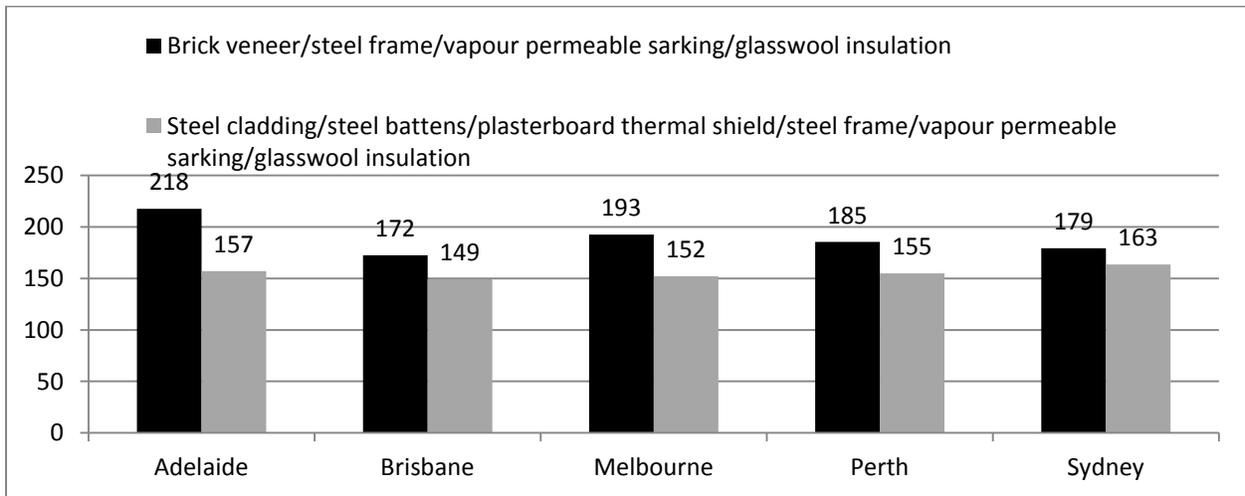


Figure 6 Comparison of Brick Veneer vs Steel + Plasterboard Costs \$ per sqm wall

Source: Rawlinsons 2011 and selected industry data

### CONCLUSIONS

The combination of laboratory and full scale outdoor testing using the same thermal exposure profile is a highly effective technique for developing and testing appropriate Alternative Solutions to comply with BCA requirements. The NASH research program confirms that readily available, economical,

easily installed, non-combustible materials may be used successfully for Australian residential and low-rise construction in Flame Zone areas.

All wall systems were able to be laboratory tested using the same radiant heat and flame contact profile as used during the 2010 full scale house test. All four wall systems tested provided excellent insulation from the effects of flame zone conditions, with a maximum temperature recorded on any of the interior wall surfaces of <50°C

All systems tested provided a barrier from embers, flames or smoke entering through to the interior of the building. In all cases the condition of the interior plaster wall was not affected. All systems except the mineral-wool only case provided satisfactory thermal protection to the wall frame structure. The Plasterboard and Glasswool wall system generated the least smoke, while the Phenolic Foam and Plasterboard wall system provided the best thermal insulation. All systems other than the Mineral Wool Only prevented the frame becoming heat affected.

Generally the repair of a wall affected by flame zone conditions would only require replacement of the external cladding and the sheeting on the external face of the frame, even under “worst case” conditions. In balancing cost vs performance of alternatives, systems that minimise or localise damage to structural components are likely to represent the best value solutions.

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