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An experimental study of solid timber external wall performance under simulated bushfire attack

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ABSTRACT

With the increasing threat of climate change there is a need to use renewable and green materials such as timber for house constructions. Timber is not generally regarded as a suitable material for the construction of homes in bushfire (or wildland fire) prone areas. However, our understanding of the performance of solid timber wall constructions under bushfire conditions is still limited. The objective of this research was to conduct a pilot experimental study of a solid timber wall system to assess its performance under severe bushfire attack conditions typical in Australia's bush land. Eight log wall specimens with and without various protection coatings were exposed to thermal radiation field produced by a gas-fired radiation panel at the BRL A40 level in accordance with the relevant Australian test standard. The heat flux on the exposed surface and temperatures on both the exposed and unexposed surfaces were measured. Flaming combustion and self-extinguishment were observed on most of the specimens while the external radiant heat varied from 40 kW/m^2 to 16 kW/m^2. The charring depth of the log walls was also measured. The performance of the solid timber walls was evaluated against the relevant standard. The experimental work showed that solid log wall assemblies are resistant to severe bushfire threat and timber can be a suitable material for building in bushfire prone areas if sufficiently thick and well sealed.

1. Introduction

With the current focus on global climate change and cataclysmic bushfires, the use of a renewable resource such as timber as a building material creates a quandary. The use of renewable material is an important part of life cycle management of buildings [1] for sustainability. Timber is an environmentally advantageous building material; timber has low embodied energy, it contributes to the carbon balance, it reduces CO_2 emissions when replacing other energy intensive building materials and it is a renewable resource [2]. However, timber is also a combustible material, and the current Australian standards for building in bushfire prone areas impose strict limitations in its use for house construction.

The fire performance of solid timber wall construction in Australian bushfires is an area with very limited research. Current Australian standards for the construction of homes in bushfire prone areas do not consider the use of timber as a suitable material in high to extreme bushfire risk areas unless it is rated as fire-retardant (treated or naturally) timber. This form of construction refers to timber cladding (15–20 mm) on timber stud walls. There is some consideration of solid timber wall construction in the Australian Standard AS 3959 [3], however it appears that the standard is referring to the treated pine log construction commonly referred to as "log homes" found in Australia.

In North America there has been a surge in popularity of machined timber log homes referred to as "engineered log" homes over the past twenty-five years. These homes use various profiles of log. Presented in Fig. 1 are two profiles which have a tongue-and-grove (T&G) configuration. These logs vary in thickness from 90 mm to 200 mm and are usually sealed in the tongue-and-groove with compressible PVC closed cell foam sealant tape. Timber species also vary from softwoods such as Western Red Cedar (*Thuja plicata*) or Pine (*Pinus* spp.) through to hardwoods such as Oak (*Quercus* spp.). This form of building has been growing in popularity in Australia, using an indigenous species such as White Cypress (*Callitris glaucophylla*).

The "log homes" most people are familiar with are constructed using round log panels, usually treated with copper chrome arsenic (CCA). These are considerably different to the log panels with tongue and-groove (T&G) joins as shown in Fig. 1. The round logs

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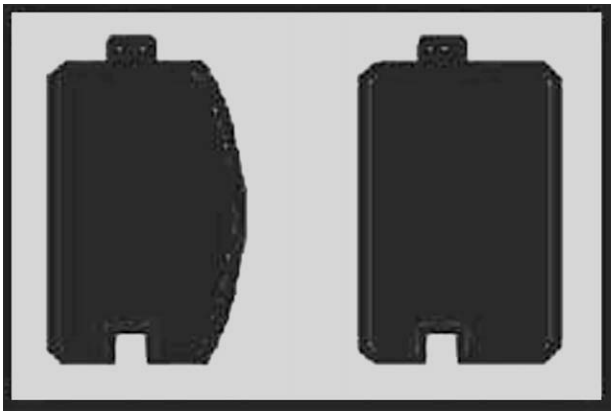

Fig. 1. Engineered T&G log profiles.

have minimal surface contact between logs, are not load bearing, and are generally constructed of a timber that develops heavy checks (cracks) up to 10 mm. When building elements are tested according to the Australian standard AS 1530.8 [4], the formation of an opening through which a 3-mm gauge probe can be inserted constitutes a failure.

The wall system studied in this research has a wide contact surface between the logs, and is bolted through with threaded rod from top to bottom. The system has, therefore, load-bearing capacity. Once the corners are morticed, tenoned and fitted with seals to ensure a tight waterproof fit and the load is applied, the wall system is gap-free.

The White Cypress timber is prone to fine surface checking as it dries, however the checks are generally less than 1 mm, and will close up entirely once the heartwood has dried [5].

The fire performance of heavy timber depends on the charring rate of the particular timber, and the exposure (one to four sides) [6]. If the timber is sufficiently thick, as in the case of a log wall construction, the progress of the pyrolysis and combustion is slowed by the growth of the char layer which shields the unburnt layer. Charring rates in the order of 0.8 mm/min for light dry wood, 0.6 mm/min for medium density softwood and 0.4 mm/min for heavy moist wood have been cited in the literature [7] under the ASTM E119 [8] standard test conditions. It has been reported by Forest Product Laboratory [9] that for a range of species, the charring rate under the external heat flux of 55 kW/m^2 varies between 0.78 and 1.38 mm/min. In the AS 1530.8 test, the specimen has a single-sided exposure to the fire source. For a thickness of 90 mm with a charring rate within the reported range, a log wall construction should have adequate resistance to survive the AS 1530.8 test.

The objective of the current research is to conduct a pilot experimental study to assess the performance of solid cypress T&G log wall systems against a set of criteria under a condition emulating severe bushfire attack as proposed in AS 1530.8.

2. Background

The concerns about the use of timber construction in bushfire prone areas are related to the burning of wood and the reduction in load carrying capacity of timber elements. Ample research has been conducted to study ignition of timber [10,11] from which it has been established that in order for timber to ignite the external heat flux must reach a critical level which is referred as the critical heat flux (CHF), q_c (kW/m^2). A simple expression between time to ignition, t_{ig} (s), and the external heat flux, q, is presented by Tewarson [12]:

$$\frac{1}{\sqrt{t_{ig}}} = \frac{q - q_c}{TRP} \quad (1)$$

where TRP (kW s$^{1/2}$/m^2) is the thermal response parameter of the fuel.

Research in the area of fire resistance level of solid timber has been focused on timber framed structures or lightweight timber walls and ceilings in internal building fires [13–15]. Various numerical models have been developed to study thermal degradation, char formation and combustion processes of wood materials when exposed to external heat [16–19]. On the other hand studies on the overall performance of solid timber walls are rather limited, and occurred mainly in other continents, using locally available timbers, and the "scribe-fit handcrafted" large logs with various sealant methods.

In a study conducted by Houdek and Bahyl [20] a scribe-fit log wall was tested under ASTM E119 [8] conditions to evaluate its fire resistance rating. The wall withstood 180 min from its integrity and insulation viewpoint and 172 min from the point of its load-bearing capacity. The high fire resistance capability of log walls is attributed to the formation of the charred layer [21] which offers a good insulation to the unburned log. There is no shortage of field evidence proving this attribute of log walls. For example, Phillips [22] reported a 30 h battle to extinguish the fire engulfing a log home originally built in 1819, and restored in the 1970s. An investigation conducted after the fire revealed that only the outer 25 mm of the 171-year-old log walls had charred. The char was simply sandblasted away and, the log walls restored, while the internal modern framed walls and roof structure were totally destroyed.

In contrast to building fire situation, the performance criteria of building elements against bushfire attack are not limited to heat penetration, integrity and load-bearing capacity [23], the burning characteristics and its impact on the immediate surrounding are also included [4]. These additional criteria are considered for the protection of bushfire fighting activities, as well as the property. The relevant test standard and the performance criteria are further discussed in the following section.

3. Method and specimen

This pilot experimental study involved the testing of several medium-scale log wall construction assemblies. The basic principles of the test procedure detailed in AS 1530.8 [4] were used to test a series of eight panel specimens with various finishes, however the specimen size was smaller than the prescribed 3 × 3 m size. In each test, the specimen is exposed to a thermal radiation field of specified heat flux. The smaller specimen size may help establish more uniform radiant heat flux distribution over the specimen surface. Detailed descriptions of the test specimen configuration are given in the following part of this section. A summary of the conditions of the specimens is presented in Table 1. The various surface coatings represent typical finishing conditions of the log walls in building construction.

The characteristic of bushfire attack is that the fire front traverses the landscape at a rapid speed [24]. The common type of bushfires in Australia which result in the most number of building losses in rural areas is reported to travel at a speed in the order of 18–20 km/h [25]. The immense radiant heat from the flame front is usually sustained for a few minutes followed by a period of slow decay as the fire front recedes and fuel burns out in the wake of the fire. The fire severity is also influenced by weather conditions such