Resilient Buildings: Informing Maintenance for Long-term Sustainability

Final Research Report

Part 2: Maintenance and resilience of buildings for bushfire risks

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Research Project: P1.53 Resilient buildings: Informing maintenance for long-term sustainability

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OUTLINE OF THE FINAL RESEARCH REPORT

The Final Research Report of SBEnrc Project 1.53 Resilient buildings: Informing maintenance for long-term sustainability is presented in the following set of separate documents:

Part 1: Overview of extreme events and maintenance

Part 2: Maintenance and resilience of buildings for bushfire risks

Part 3: Maintenance and resilience of buildings for flood vulnerabilities

Part 4: Development of a maintenance prevention strategy to mitigate wind-driven rainwater ingress through windows and external glazed doors in social housing

This Part 2 of the Final Report includes:

(a) An overview on bushfire attack mechanisms;

(b) A summary of building losses due to bushfire;

(c) A synopsis on Australian bushfire regulation;

(d) A conceptual framework for risk assessment;

(e) A summary of the role of maintenance for resilience of buildings; and

(f) A set of recommendations on building resilience for bushfire risks and suggestions for their implementation.

Further information and other reports: http://sbenrc.com.au/research-programs/1-53/

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EXECUTIVE SUMMARY

SBEnrc project P1.53 Resilient Buildings: Informing Maintenance for Long-term Sustainability aimed to examine the role of maintenance in making buildings more resilient to extreme weather events, cyclones/storms, bushfires and floods, using technical knowledge to inform policy and practice. The focus was on existing low-rise public buildings. Part 2 examines bushfire attack mechanisms, building losses, regulation, risk assessment and role of maintenance in reducing the risk.

Key recommendations include:

- All buildings in designated bushfire prone areas are to be maintained to reduce the risk of ignition due to ember attack.
- A list of maintenance items is to be compiled for each individual building.
- For high risk buildings, bushfire experts are to be consulted for mitigation measures.

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1 INTRODUCTION

Bushfire is a natural phenomenon and a feature of the Australian landscape. It becomes a problem for buildings as settlements are pushed further into the bush. Research into bushfire behaviour has been conducted by the CSIRO and the Bushfire CRC for decades. The main factors that affect bushfire behaviour are:

(i) Weather: the effects of weather on bushfire behaviour are well documented. A. G. McArthur of the CSIRO (McArthur 1967) invented the Forest Fire Danger Index (FFDI) as a quantifiable estimate of the bushfire danger caused by weather variables (dryness, rainfall and evaporation, wind speed, temperature and humidity). The current fire danger rating is based on this work.

(ii) Vegetation: vegetation provide the fuel for the fire but its influence is complex. AS3959-2009 provides a guide on the classification of vegetation in order from high to low threat: (a) forest, (b) woodland, (c) shrub land, (d) scrub, (e) Malle/Mulga, (f) rainforest, (g) grassland.

(iii) Topography: ground slope influences the rate of spread of bushfire particularly if the slope and wind direction are aligned. Bushfires move faster upslope and slower downslope.

These three factors acting in combination will determine the severity of the bushfire hazard for any particular location. In Australia, the severity of the hazard is rated by a quantity called Bushfire Attack Level (BAL). The methodology for its determination is outlined in AS3959.

Australian housing and life loss statistics for the period 1939-2009 have been collected by Blanchi and shown in Table 1 (Blanchi et al. 2010), where it is seen that high risk areas are around south eastern Australia. Queensland and Western Australia are at low risk by comparison. However, a significant bushfire outbreak has occurred recently in Queensland in November 2018.

Table 1. Australian statistics for house and life loss 1939-2009 by States and Territories

Location	Number of house losses	Number of lives lossed
Victoria	6861	475
New South Wales	1530	107
Tasmania	1376	63
South Australia	548	56
Australian Capital Territory	521	5
Western Australia	212	9
Queensland	43	23
Norther Territory	1	1

To assess the contributions of maintenance to resilience of buildings in bushfire prone areas, it is necessary to understand first the bushfire attack mechanisms. This subject has been researched in Australia for a number of years and a set of salient points are summarised in Section 2.

Section 3 is concerned with the consequences of bushfire with respect to buildings. The main finding is that the majority of losses are due to ember attacks. The best way to improve the situation is to reduce the chances of ignition. This is the basic principle behind the building regulation as outlined in Section 4.

Bushfire risk is location specific and a risk assessment will need to be made for each location. This is outlined in Section 5. Maintenance could play a very important role in reducing the chance of ignition caused by ember attacks, as explained in Section 6 where practical maintenance measures for the buildings and the areas surrounding the buildings are also provided.

2 BUSHFIRE ATTACK MECHANISMS

In the event of a bushfire, a building could be ignited by a range of mechanisms. This subject has been researched in Australia for many years. A summary of this research can be found in Watson et al. (2018). The more salient points are outlined below:

- Direct exposure to flames: Direct exposure to flames may occur for buildings in woodland or forest, scrub or grass, crops or a combination of these forms of bushfire vegetation. Flame exposure is a short distance event, influenced by weather condition, fuel load and slope of terrain. A driving wind behind the flame front can also deflect the flames on to an adjacent building.
- Radiation: A building may be sufficiently separated from the bushfire vegetation such that direct flame contact is not possible, but sufficiently close to the flame front that it is exposed to excessive levels of thermal radiation. This radiation level may be sufficient to ignite external cladding (if combustible), vegetation close to the building or result in the loss of windows depending on the type of glazing and window frame details. The speed at which a bushfire flame front moves is relatively rapid and exposure to radiation (and flaming) is over in a relatively short duration, with peak radiation experienced only for around 60 to 120 seconds.
- Direct ember attack: Direct ember attack is the most common cause of ignition and loss of buildings due to bushfires. Embers are generated by burning tree bark (or pine needles in the case of pine trees) if trees are present in sufficient density. Ember density decreases with distance from the bush (Chen and McAneney, 2004; Wang, 2006; Price and Bradstock, 2013; and Kilinc et. al. 2014). Once deposited, embers can form flaming ignition sources in such places as gaps, crevices, gutters, corners or decks on buildings; and ground vegetation, shrubs or unburnt bushland (McArthur et al. 1986; Blanchi and Leonard, 2008).

  Under extreme circumstances, embers can travel a long distance (1 to 10 km). Short distance embers (within 1 km of a fire front) are often found in prolific numbers and tend to have greater impact. Typically this mechanism is responsible for over 90% of ignitions leading to building loss in an urban environment. More severe fire weather and persistent wind conditions will cause deeper penetration of embers into an urban environment, well over the indicative distances described above (Leonard and Blanchi, 2005).

  Ember attack can be prevalent before the arrival of a fire front, during the arrival of the fire front, and always for a period after the fire front has passed.

Factors affecting ember intensity include:

- Proximity to burning vegetation or buildings.
- Wind speed and duration.
- The effects of hotness and dryness of wind on the moisture content of fine fuels.
- Vegetation type.
- Presence or absence of objects between the ember source and buildings that can trap or block embers.

- Secondary radiation: A neighbouring building or adjacent structure on fire may lead to secondary radiation. Examples of adjacent structures include treated pine retaining walls and timber fences located close to the subject building. Combustible goods stored close to the subject building can also be subject to ember attack. If a neighbouring building or object catches fire, then the duration of burning may be between 15 -20 minutes which is significantly longer than the duration of a passing flame front. The resulting radiation may be significant depending on the separation distance between this building/object and the subject building. The presence of plants and shrubs having a high level of combustibility (e.g. cypress bushes) located close to the building can present an issue, if ignited, since the resultant radiation may be sufficient to cause window breakage or ignition of combustible external materials.

3 BUILDING LOSSES DUE TO BUSHFIRE

The contents of a building combined with the combustible building elements represent a fuel load much higher than is generally found in the forest. The completeness of building destruction in the aftermath of bushfire events is frequently observed (Leonard and Blanchi 2005). Buildings that are only partially damaged are found relatively rarely and in each case the partial damage is usually attributed to occupant or fire brigade activity in suppressing the fire and preventing further burning (McArthur 1997, Leonard and Blanchi 2005).

Assisted by wind, the burning embers, radiant heat and flames may (i) enter the building and directly ignite its contents, (ii) enter the building envelope and ignite combustible elements within the cavities of the building envelope and later ignite the building contents, (iii) cause the building façade or façade elements to break, distort or yield, leading to one of the above processes, and/or (iv) ignite the façade of the building leading to one of the above processes.

These mechanisms usually operate in combination, although they can also work in isolation. Flame exposure, radiant heat and ember attack have prevalent length scales. Typical upper limits for each of these three mechanisms for severe bushfires in southern Australia are given in Table 2.

Table 2. Indicative distances between hazardous vegetation and loss from bushfire, for severe bushfires (Ahern and Chladil 1999; Leonard, Blanchi et al. 2009)

Mechanism	Typical upper distance for 80% of all house losses (m)	Typical upper distance for house ignition from forest (m)
Ember attack	100	700
Radiant heat exposure	70	160
Flame exposure	50	100

The distance of a building to the bush is therefore an important parameter in assessing the risks of losses and ignition.

Bush fire intensity and hence building losses can be enhanced by wind. It has been observed that high wind is usually associated with days of high fire danger. The combined effects of wind and fire may lead to structural failure well below the ultimate design wind speed. This issue has not been investigated in detail anywhere.

4 AUSTRALIAN BUILDING REGULATIONS REGARDING BUSHFIRES

The performance requirements for construction in *designated bushfire prone areas* (defined in States and Territories Regulations) are given in:

- GP5.1 of NCC Volume 1 - for Class 2 and 3
- P2.3.4 of NCC Volume 2 - for Class 1 and 10a.

The wordings of these Clauses are identical – as follows: 'A building that is constructed in a designated bushfire prone area must, to the degree necessary, be designed and constructed to *reduce the risk of ignition* from a bushfire, appropriate to:

- potential for ignition caused by burning embers, radiant heat or flame generated by a bushfire; and
- intensity of the bushfire attack on the building.'

The draft NCC 2019 introduces Verification Method GV5 based on an ignition probability threshold of 10% under the influence of appropriate bushfire design action. The methodology for determining the bushfire design action assigns an Annual Probability of Exceedance to each Importance Level, which is basically the same as for design wind actions. The Importance Levels 1 to 4 are determined not only from an asset perspective but also considering the occupancy. For example, a small motel or boarding house is IL 2, a large hotel is IL 3 and an aged care building subject to a "defend in place" strategy is IL 4.

The following Deemed-to-satisfy provisions are also provided:

- for Class 2 and 3: AS3959
- for Class 1 and 10a: AS3959 or NASH Standard 'Steel Framed Construction in Bushfire Area'. There are State and Territory variations to this Clause, particularly from South Australia.

AS3959 has outlined a method of determining the Bushfire Attack Level (BAL) for a site, with a step-by-step procedure including factors such as climate, slope of ground and vegetation variations and a detailed calculated procedure.

5 BUILDING RISK ASSESSMENT

5.1 A framework for a building risk assessment

Three major parameters to be considered in a risk assessment for building resilience to bushfire are:

(i) Location Hazard characteristics: There are a number of parameters that contribute toward the hazard characteristics of the site. The BAL assessment procedure of AS3959 is a fair description of the site hazard characteristics.

(ii) Property Bushfire Resistance characteristics: These include at least two groups of parameters: ones that affect the building itself and ones that affect the surrounding area.

  a. AS3995 has given a list of factors to be considered in building design in Sections 5- 9 of that document.
  b. Factors that affect the surrounding area should include:
    i. areas within the property boundary where factors such as garden, fences, combustible materials, other buildings on site are of concern
    ii. areas outside the property boundary where factors such as other buildings, access routes, water supply are relevant.

(iii) Vulnerability of the occupants: The two key parameters are the number of occupants and their mobility. These are related to both NCC Building Classification (Class 2 – 9) and NCC Importance Level (1- 4). The Building Classification has its origin in the Fire provisions and the Importance Level in the Structural provisions. The mobility of the occupants will need to be carefully considered, as it is a key factor in bushfire emergency.

Other factors that might need to be considered include:

(i) Fire brigade intervention: it is reasonable to assume that fire brigade intervention is not likely on a high bushfire danger day as its service will be demanded everywhere.

(ii) Smoke exposure: while smoke does not affect the building, it could affect the people, their safety and ability to fight fire.

For the design of the building, the first two parameters above can be combined to form a Building Vulnerability assessment (Table 3) that can be further combined with Occupant Vulnerability to provide an overall Risk Matrix (Table 4).

Table 3. Example of a Building Vulnerability assessment

Location Hazard	Property Bushfire Resistance		
	High (H)	Medium (M)	Low (Low)
High (H)	M	H	H
Medium (M)	L	M	H
Low (L)	L	L	M

Table 4. Example of a Risk Matrix for a building in a designated bushfire prone area

Building Vulnerability	Occupant Vulnerability		
	L	M	H
H	M	H	H
M	L	M	H
L	L	L	M

5.2 Risk treatment

In the above matrices, the only parameter that maintenance can have an influence over is the Property Bushfire Resistance. By increasing the Property Bushfire Resistance, we can lower the building vulnerability (Table 1), hence lowering the overall risk to the building and its occupants (Table 2).

While maintenance can contribute to lowering the risk of ignition for all buildings within the designated bushfire prone areas, ‘high risk’ buildings, such as hospitals, may need additional consideration such as access, fire-fighting facilities, evacuation route, etc. These are more complex issues that may need expert advice and are not covered here.

Using the risk assessment process to identify ‘high risk’ buildings could be problematic for maintenance personnel; however, a preliminary assessment is possible by identifying as ‘high risk’ the buildings within one or two hundred metres from the bush, or buildings containing people with limited mobility such as aged care facilities or hospitals. A more rigorous risk assessment can then be used on these buildings by bushfire experts.

6 ROLE OF BUILDING MAINTENANCE

6.1 Locations of ignition points on buildings

Maintenance has a key role in reducing the risk of ignition due to ember actions. Gaps around the edges of the roof or along the roof's ridge, eaves and the roof-line provide pathways for the entry of embers into a roof space. The same is true with respect to ventilation openings into spaces below suspended floors if there are combustible surfaces against which embers can accumulate. Open vents can also allow the entry of embers into the interior space, and evaporative coolers, due to their combustible filters, are susceptible to ember attack, especially if they are not operating at the time of the fire and the filters are dry. The accumulation of embers against exterior combustible surfaces can also result in ignition. Gaps greater than 3 mm are sufficient to allow the entry of some types of ember. Hence the standard requirement to have vents and weep holes screened with metal mesh with a maximum aperture of 2 mm unless they have an aperture less than 3 mm. The external façade shall be prevented from having gaps greater than 3 mm. Doors and windows are required to have a protective metal mesh with maximum aperture of 2 mm.

The following lists provide the locations of observed ignition points derived from three surveys (Blanchi and Leonard, 2005). The lists are a useful source for identifying inspection points for maintenance.

- External ignition points
  - Timber decks;
  - Eave fascia boards and/or gutters;
  - Timber window frames;
  - Timber stairs;
  - Timber door frames;
  - Rough-sawn western red cedar cladding;
  - Gapped board around stumps;
  - Exposed timber beams (eave structure);
  - Veranda, supporting beam;
  - Doormats;
  - Fabric veranda roofs;
  - Timber shingle roofs;
  - Plastic roof panels;
  - Veranda/pergola;
  - Timber frame behind air conditioning unit;
  - Bitumen roof membrane;
  - Canvas awning;
  - Timber wall frame elements;

- Plastic veranda roof;
- Weather boards.

- Ember entry points:
  - Door jams;
  - Windows that are not tight fitting;
  - Gaps in roofing systems;
  - Gaps in under floor enclosure;
  - Gaps in flooring systems;
  - Flues and chimneys;
  - Gaps in building facades, particularly at the interface of boards or sheets and where they terminate at corners or other building elements.

- Ember accumulation points:
  - Re-entrant corners;
  - Roof valleys;
  - Gutters;
  - Unprotected sub-floor areas;
  - Wall cavities;
  - Roof cavities;
  - Under decks;
  - Between decking boards above bearers;
  - Door thresholds
  - Window frames
  - Corner of decks adjacent to walls or glazing.

6.2 Measures in surrounding areas to reduce building vulnerability

The following set of suggested measures in its surroundings for reducing a building's vulnerability to bushfire is adapted from Watson et al. (2018):

(i) Increase the set-back distance where feasible. The set-back distance is the distance separating the bush from the building. If the vegetation fuel in this space is reduced or eliminated with maintenance then the building will be less vulnerable to bushfire

(ii) If a building on an adjacent allotment is located closer than 6 m from the subject building, mitigate the likelihood of spread to the subject building through the provision of barriers to reduce the incident radiation.

(iii) Ensure fences within 3 m of windows and combustible external wall elements are non-combustible.

(iv) Limit the location of nearby combustible objects (e.g. timber retaining walls, stacked fire wood, etc.) in relation to windows and any combustible external wall elements.

(v) Manage the location and type of local vegetation with respect to trees, bushes and ground cover. Make sure that more combustible plants are located a sufficient distance from windows or combustible external materials.

(vi) Remove leaf litter from gutters and roofs.

7 RECOMMENDATIONS

The findings from this research have led to the following recommendations:

i. All buildings in *designated bushfire prone areas* are required to be maintained to reduce the risk of ignition due to ember attack.

ii. A list of maintenance items is to be compiled for each individual building.

iii. For high risk buildings, relevant bushfire experts are to be consulted for more accurate risk assessments and suitable means/measures to lower the risks for the building and its occupants.

Suggestions for implementation of recommendations

(a) A checklist of maintenance items for an individual building can be compiled from the information supplied in this report. Each building is different and not all items listed in Section 6 above are necessarily appropriate. This checklist can be added to the maintenance schedules used in current practice.

(b) A general checklist of all relevant items for bushfire need to be compiled and incorporated into the proposed 'Framework for specifying building maintenance' provided in Research Report Part 1.

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