STRUCTURAL DESIGN OPTIONS FOR RESIDENTIAL BUILDINGS IN BUSHFIRE AREAS

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Today’s presentation

• Overview
• Bushfire design challenge
• Performance requirements
• Bushfire actions and building response
• Basic design options
• Other considerations
• Case Study
• Summary & conclusions
Conference theme

Designing buildings to resist bushfire attack. Is it . . . . .

• A public policy matter – not for the engineer?

• A regulatory obligation – doing the bare minimum?

• A commercial opportunity – delivering the best value solution?

• A professional challenge – *what role might the engineer choose to play?*
Overview

- Residential buildings are subject to a range of design actions - one of these is “bushfire action”
- Each state regulates where and to what degree it must be taken into account
- Performance-based bushfire design is difficult – most designers will use DTS path
- Until 2014, only one DTS solution available – now there are two, and each is deemed to meet NCC performance requirements
- How do they compare, and what factors are relevant to the comparison
- What might this mean for the role of the designer
- Qualitative assessment – not presenting right or wrong answers
Building design challenge

- Bushfires inflict combined actions
- Materials react in different ways
- Building components can interact with each other
- Minor damage or modification can compromise the system
- Performance is as good as the system’s weakest link
P2.3.4 Bushfire areas

A Class 1 building or a Class 10a building or deck associated with a Class 1 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 the —

a) potential for ignition caused by burning embers, radiant heat or flame generated by a bushfire; and

b) intensity of the bushfire attack on the building.
Key elements of required performance

“To the degree necessary” . . .

“reduce risk of ignition” in relation to . . .

• Potential for ignition
• Intensity of bushfire attack

• What are the specific actions?
• What magnitude are they?
• What must the building do - or not do - in response?
Nature of bushfire attack

Embers
- Responsible for > 75% of house loss
- Lengthy duration (hours)
- Essentially harmless to humans
- Present in every attack
- *Hard to quantify*

Radiant heat
- Quite short duration (minutes)
- Deadly to humans
- Common but rarely extreme
- *Easy to quantify (distance, flame body temp)*

Flame contact
- Very short duration (seconds)
- Sudden thermal shock, piloting
- Rare occurrence from forest sources
- *Quantification not that relevant*
Quantification of requirements

• When the actions and permissible action effects associated with performance requirements are unquantified, that job is usually left to standards writing committees

• This establishes a de facto substitute for the “missing” requirement

• For bushfire attack, several iterations have resulted in present scale adopted in DTS design standards [BAL –Low to BAL-FZ]

• Only one of the three actions - radiant heat flux - has been specifically quantified, and this is not the one that causes most house loss

   *So . . . how do buildings actually fail under bushfire attack?*
Common failure sequences

• Embers create local litter fire adjacent to vulnerable glazed element, breaching the element and reaching the inside

• Embers ignite a local significant fuel source (fence or vegetation) sufficiently close to a vulnerable glazed element

• Embers create local fire at roof level, progressing to fascia and eaves fire and spreading to roof structure

• Radiant heat from fire front compromises combustible cladding, cracking windows leading to internal fire

• Radiant heat from fire front compromises windows leading to internal fire

• Brief flame impingement pilots dried combustible exterior elements leading to window or cladding breach and internal fire
Interrupting the failure sequence

Different materials are affected in different ways
  • Discolouration
  • Local distortion
  • Strength reduction
  • Integrity loss
  • Ignition
  • Combustion

• Will the element be structurally compromised during or after the event?
• Can it be prevented from igniting?
• Can it be protected from critical thermal stresses?
• Will it lose critical properties gradually or suddenly?
• If it fails, what might happen next?

*Different standards writing bodies have approached these questions in different ways*
NCC 2016 - DTS solutions

Deemed-to-satisfy solution - AS 3959

Deemed-to-satisfy solution - NASH Standard
AS 3959 and NASH Standard

Australian Standard®

Construction of buildings in bushfire-prone areas

NASH STANDARD
STEEL FRAMED CONSTRUCTION
IN BUSHFIRE AREAS
2014
What happens with two DTS solutions?

- Quite common to have multiple DTS solutions in NCC
- Independent, parallel compliance paths of equivalent status
- May cross-reference each other, but
- Can’t be “cherry-picked”

**So, how do they differ, and . . .**

**How does the designer choose?**
AS 3959 design approach

- Fire and ember-resistant cladding
- Unregulated structure
- Incremental radiant heat tolerance

Heat and ember resistant windows & doors

The building envelope provides all required resistances
NASH Standard design approach

- Non-combustible cladding
- Non-combustible cavities
- Ember-proof lining
- Weather and vermin-resistant envelope
- Heat and ember resistant windows & doors

The external structure contributes to required resistances
BAL-12.5 to BAL-40 sites

**AS 3959**
- Steel or tiled roofing, fully sarked
- Steel or timber wall & roof framing
- Increasing stringency on claddings
- Increasing stringency on doors, windows and screens
- Gap control < 3 mm exterior

**NASH Standard**
- Steel roofing, sarking not required
- Steel floor, wall and roof framing
- Non-combustible claddings
- AS 3959 doors, windows and screens
- Protected ember paths through ceiling
- Normal cladding fit and workmanship

*Tight control*  
*Minimum combustibles*
BAL-Flame Zone sites

**AS 3959**
- FRL or tested floor system
- External walls masonry or tested system
- FRL or tested windows & doors
- Prescribed or tested roof system
- FRL or tested eaves system
- Verandah & deck system non-combustible or tested
- Gap control < 3 mm

**NASH Standard**
- Steel floor system, protected external stumps
- Masonry or steel clad walls
- FRL or tested windows & doors
- Steel roofing with foil + FG roofing blanket
- Non-combustible eaves system
- Non-combustible verandah & decking
- Normal cladding fit and workmanship

*Reliance on tested systems*

*Reliance on non-combustibility*
Other relevant considerations

• Preventing ignition from a precisely defined radiant heat action meets the minimum requirement, but . . .
• What about distortion, deterioration, overload (mis-classification)?
• Should the designer also consider:
  • Reliability
  • Robustness
  • Resilience
  • Durability
  • Tenability
Reliability

*Probability that correctly executed solution will function adequately*

- Initial reliability
- Durability
- Maintenance
- Modifications
- Subsequent construction
Robustness

*Proportional response to “overload event”*

- Absence of “weak links”
- Dimensionally stable materials when thermally loaded
- Protected vulnerable elements
- Overload due to mis-classification (under-design) or exceptional event
Resilience

*Capacity to return to service after overloading event*

- Maximised post-fire habitability
- Minimum cost to restore habitability
- Minimum cost to return to full service
- Cumulative effect on multiple houses in one suburb or town
Durability

*Persistence of service performance over time*

- Degradation over time of bushfire-relevant properties
- Visibility/detectability of degradation
- Cost to prevent degradation
- Repairability of degradation (practicality, cost)
- Risk of delayed maintenance or repair
Tenability

_Defendability of an attended house . . . Tricky subject!_

• Whether by conscious decision or lack of a safer alternative, house may become a “defended refuge”
• Capacity of house to perform in that situation may involve other factors beyond those applying to unattended survival
• An appropriately prepared house based on non-combustible construction is potentially more defendable than one that may progressively fail

_Housing is not intended to act as Class 10c private bushfire shelter!_
Case Study: Retirement village dwellings

- North-west of Melbourne (Bacchus Marsh)
- Within BPA but well away from forested areas
- Now required to be designed for BAL-12.5 (earlier stages were not)

- Single storey slab-on-ground
- Some steel, some tiled roofing
- Brick and other wall claddings
Original specifications

• Timber roof trusses and wall framing
• Timber roof and ceiling battens
• Tile and sheet roof to specific buildings
• Predominantly brick external walls
• Timber external feature panelling
• Unspecified pergola roofing
• Unspecified roof and wall insulation
• Unspecified downlights and ceiling access panels
• Unspecified vents and service ducting in roofspace
**AS 3959 details**

- Steel or tile roofing
- Full sarking of roof system
- Covering or replacement of lower 400 mm of any combustible wall cladding
- Non-combustible pergola roofing
- Treatment of vents, weepholes and gaps

**NASH Standard details**

- Steel roofing
- Steel roof trusses, battens and wall framing
- Non-combustible wall cladding
- Steel or polycarbonate pergola roofing
- Fibreglass or other non-combustible insulation
- Non-combustible roof vents and service ducting
Comparison of solutions

• Basic material choices are slightly more limited with NASH solution
• Durability or “persistence of function” slightly greater with NASH solution
• Reliability of solutions essentially the same
• NASH solution is slightly more robust if attack is more severe

• NASH solution dwellings less likely to become fire source
• NASH solution likely to be more resilient with faster, lower cost repair
• Tenability in a retirement village setting unlikely to come into play
Summary

• The main game is embers (except for glazing)
• The main defence is non-combustibility
• Designers have choices: DTS (AS 3959 or NASH) or Performance
• Each DTS standard meets minimum requirements, but by how much?
• In particular cases reliability, robustness, resilience, durability and tenability may be significant design considerations
• Non-combustible cladding and structure is simple, verifiable and cost-effective
• Structural engineers can play a role in promoting an awareness of how well different building solutions perform beyond minimum requirements
Thank you. Questions?