17

Fire Safe Design of Timber Structures

Compliance with the National Construction Code

Technical Design Guide issued by Forest and Wood Products Australia

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Table of Contents

Introduction

Timber is used for many building applications and has numerous advantages over other building products, including; its environmental sustainability credentials, light-weight compared to most structural materials, speed of construction, and aesthetics.

This has led to an increased interest in the use of structural timber for mid-rise buildings (up to an effective height of 25m) and high-rise buildings in Australia in addition to the more established applications for low-rise buildings and single dwellings.

Changes to the National Construction Code (NCC) in 2016[1] and 2019[2] introduced for the first time in Australia, *Deemed-to-Satisfy* (DTS) pathways for demonstrating compliance for mid-rise timber buildings based on the concept of fire-protected timber. Refer Figure 1 for the NCC height limits that correspond to low, mid, and high-rise construction.

Low-rise timber buildings
typically are buildings of:
Type B or C construction (1 or 2 storey)

Mid-rise timber buildings
have an effective height of not more than 25 metres.
Typically, they are 3-8 storeys high (the maximum number of storeys depends on the floor-to-floor height)

High-rise timber buildings
have an effective height greater than 25 m.

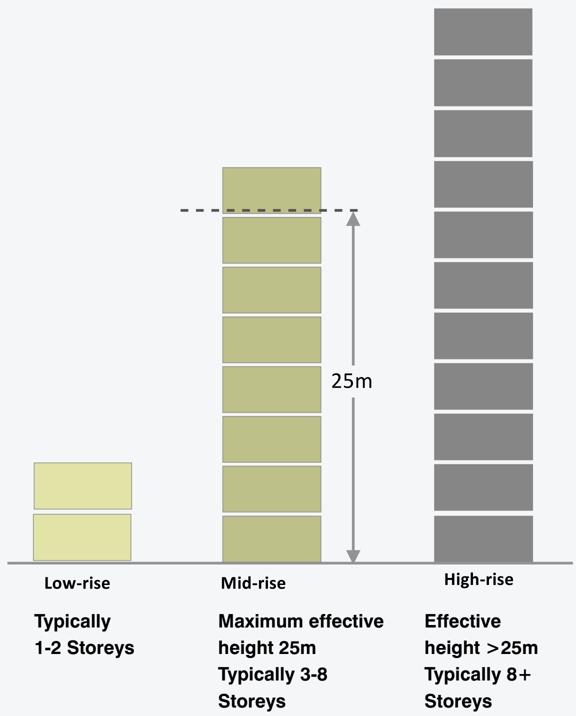


Figure 1: NCC height limits corresponding to Low, mid, and high-rise timber buildings.

Note: The NCC provides a relaxation allowing some 3-storey Class 2 or 3 buildings to be of timber frame construction

Detailed Guidance on the application of NCC [3] *Deemed-to-Satisfy Provisions* to low-rise and mid-rise timber buildings are provided in the following WoodSolutions Technical Design Guides.

- WoodSolutions Technical Design Guide 1 Timber-framed Construction for Townhouse Buildings (Class 1a)
- WoodSolutions Technical Design Guide 2 Timber-framed Construction for Multi-residential Buildings (Low-rise Class 2 & 3) – under revision at the time of preparation of this Design Guide
- WoodSolutions Technical Design Guide 3 Timber Framed Construction for Commercial Buildings Classes 5, 6, 9a & 9b – under revision at the time of preparation of this Design Guide (This guide is temporarily unavailable as it is being revised).
- WoodSolutions Technical Design Guide 37R [4] - Mid-rise Multi-residential buildings (Class 2 and 3)
- WoodSolutions Technical Design Guide 37C [5] - Mid-rise Commercial and Education buildings (Class 5,6,7,8 and 9b,including Class 4 parts)

- Wood Solutions Technical Design Guide 37H [6] - Mid-rise health-care buildings (Class 9a and Class 9c)
- WoodSolutions Technical Design Guide 42 [7]. - Timber Aged Care Buildings (Class 9c).

Note: Guide 42 describes an alternative DTS pathway to the fire-protected timber solution for Class 9c aged care accommodation

This Guide (Design Guide 17-2021) introduces fire safe design approaches for timber structures in Australia. The primary focus is compliance with the NCC Volume One which provides requirements for the technical design and construction for all multi-residential, commercial, industrial, and public assembly buildings and their associated structures (Class 2 to 9 buildings) but some content can also be applied to single dwellings and associated structures.

Other design objectives may also apply and are discussed where appropriate, highlighting the need for building designers to consider all relevant legislation and design objectives throughout the building life-cycle in a holistic manner.

Document Overview

This Guide is intended to provide an introduction to the fire safety design of timber buildings in compliance with the NCC Volume One. It is suitable for a broad range of practitioners and students including;

- Fire Safety Engineers
- Building Certifiers
- Structural Engineers
- Fire Authorities
- Architects, and
- Building Consultants

This Guide is part of a series of three guides that have been written in 2021 to reflect the significant changes to fire safety regulations and recent research relating to the performance of timber when exposed to fire. This Guide provides a general review of the NCC compliance pathways and Assessment Methods before focussing on how these pathways and Assessment Methods can be applied to timber buildings and elements of construction to verify compliance with the NCC.

The other two design guides in the series are listed below and have greater technical content more suited to fire and regulatory specialists such as fire safety engineers, building certifiers and fire authorities.

- Wood Solutions Technical Design Guide 18 - Fire Safe Design of Timber Structures - Methods of Analysis and Supporting Data (2021) provides more detailed information relating to the design and *Assessment Methods* described in this Guide along with supporting data predominantly used during the development of the compliance pathways for timber
- Wood Solutions Technical Design Guide 19 – Fire Safe Design of Timber Structures - Worked Examples of Performance Solutions (2021) provides worked examples of the analysis and *Assessment Methods* that can be applied to typical *Performance Solutions*.

Below is a summary of the content of this design guide.

Chapter 1 includes an overview of the design process to provide a context for the application of the NCC. The need to consider a broad range of other drivers and constraints based on applicable legislation and stakeholder requirements and the importance of considering implementation, commissioning and through life performance of buildings is also discussed.

Chapter 2 provides a general introduction to compliance pathways under the NCC, including DTS and *Performance Solutions*, and Assessment Options.

Chapter 3 describes the NCC compliance pathways available for timber buildings

Chapter 4 describes the various options available for the design of Structural Elements and Barriers to resist fire. It also describes how structural design loads are derived for fire conditions and default load levels can be established for fire testing and other methods of assessment based on NCC referenced design standards.

Chapter 5 reviews the high level *Assessment Methods for Performance Solutions* relating to the fire performance of timber buildings including *Verification Methods* CV1 to CV4 and comparative and absolute assessments against the *Performance Requirements*. In relation to absolute assessments proposed, changes to the NCC relating to the quantification of *Performance Requirements* are described.

Chapter 6 reviews the NCC *Assessment Methods* for verification of compliance of DTS Solutions relating to timber elements of construction. These *Assessment Methods* should also be applied, as appropriate, to the detailed documentation for *Performance Solutions*.

Additional information, definitions and references are provided in the Appendices.

1

Building Design Process

1.1 Addressing Critical Drivers and Constraints During the Design Process

When undertaking a fire safety design for any building it is critical for the designer to understand the objectives of key stakeholders and the key drivers and constraints that apply to the project.

Critical drivers and constraints should be identified through consultation with key stakeholders at the start of the design process, from which the essential design criteria can be derived. These should be the focus throughout the development of the design and incorporated in the design documentation.

Identifying key drivers and constraints early in the design process facilitates the adoption of a holistic approach to design such that synergies between the various drivers and constraints can be exploited and design constraints can be managed in a cost-effective manner.

Compliance with the relevant design drivers and constraints should then be checked for both the NCC drivers and constraints as well as other criteria that have been derived once the fire safety strategy has been resolved during the design process and as the supporting documentation is developed. This process is shown schematically in Figure 2.

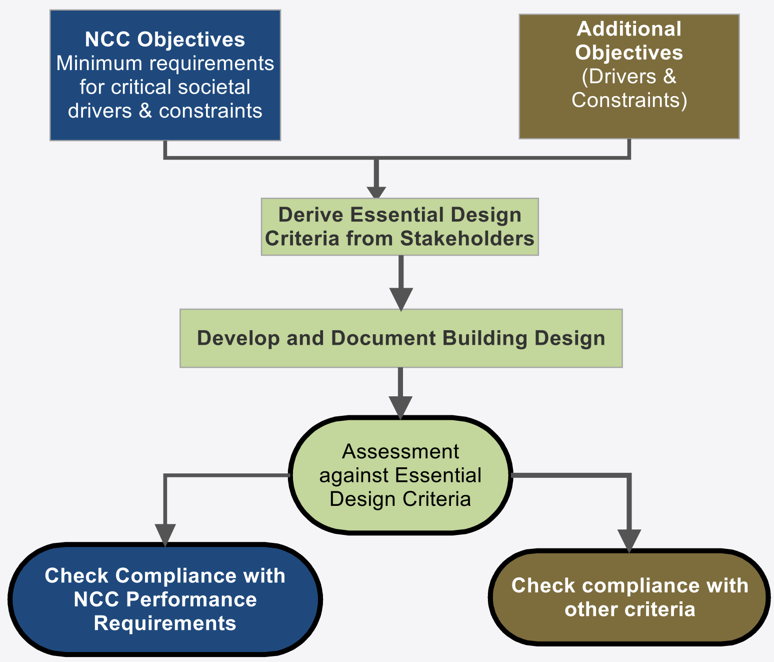


Figure 2: Addressing Critical Drivers and Constraints during the Design Process.

1.2 Role of the National Construction Code

The NCC sets minimum community standards for a range of drivers and constraints with the goal of addressing community expectations with respect to criteria such as:

- Health and Safety
- Amenity
- Accessibility
- Sustainability
- Protection of Other Property

Note: Whilst the NCC provides an essential consolidation of technical provisions relating to fire safety in buildings, which is the primary focus of this Design Guide, practitioners need to also identify and address additional drivers and constraints that may be required to be satisfied by other legislation (e.g. Disability Discrimination and Work Place Health and Safety legislation), in addition to other project stakeholder requirements and a general duty of care to provide an acceptable level of safety.

The National Construction Code (NCC) was developed to provide a uniform set of minimum technical requirements and standards for the design and construction of buildings and other structures throughout Australia. It is given legal effect by each of the State / Territory regulatory systems who are responsible for administering and regulating these matters under the Australian Constitution. As a result, administrative provisions, and to some extent technical provisions can vary between the States and Territories.

The NCC is a performance-based code which primarily applies to the design and construction of new buildings (and new building work in existing buildings) throughout Australia. The performance based NCC provides the flexibility to address other drivers and constraints in a cost-effective manner without compromising the NCC requirements.

The relationship of the NCC to regulatory and non-regulatory drivers and constraints is shown in Figure 3.

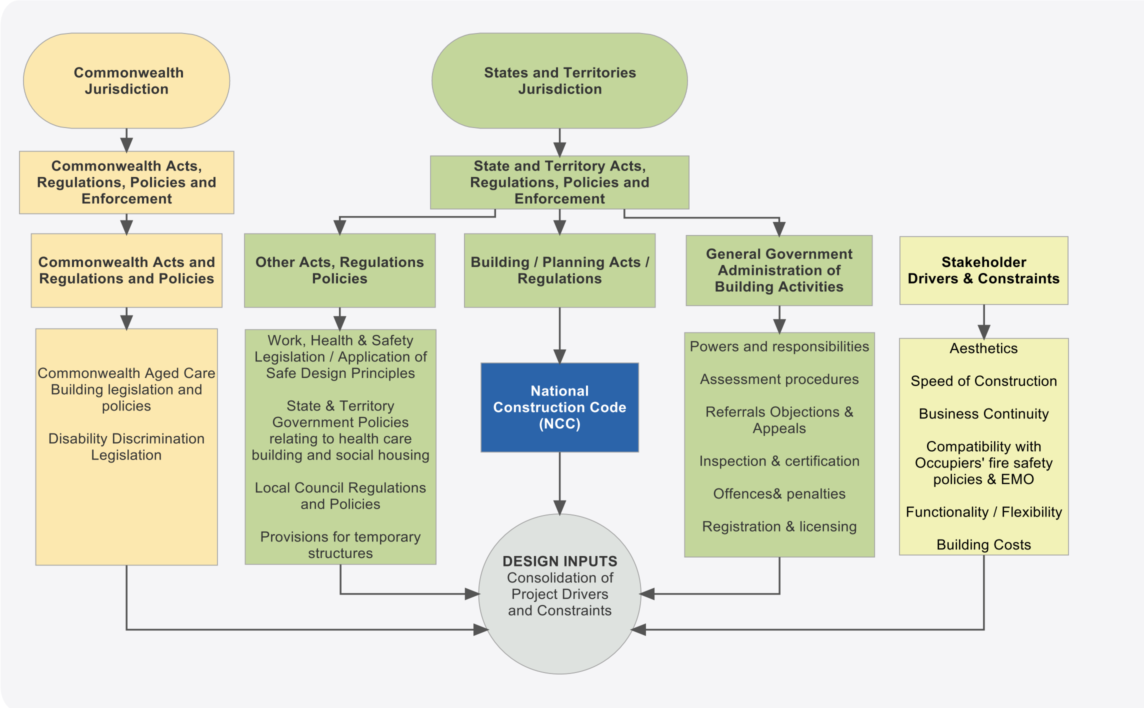


Figure 3: Relationship of the National Construction Code to other Regulatory and Non-Regulatory Drivers and Constraints.

The Structure of the NCC includes State and Territory Appendices in Schedule 1 which nominate variations that apply within a specific jurisdiction. The intent was to ensure that all technical provisions relating to the NCC scope were included in the NCC, even if State or Territory variations could not be avoided. However, additional drivers and constraints are often included in other National or State and Territory legislation and policies. In some cases, local government legislation and policies may also apply additional or different constraints.

1.3 Design for the Entire Building Life Cycle

Whilst the scope of the NCC is focussed on the design and documentation stages for new building works it does not negate the need for consideration of the performance of the building and all elements of the fire safety strategy throughout the building life cycle - refer Figure 4.

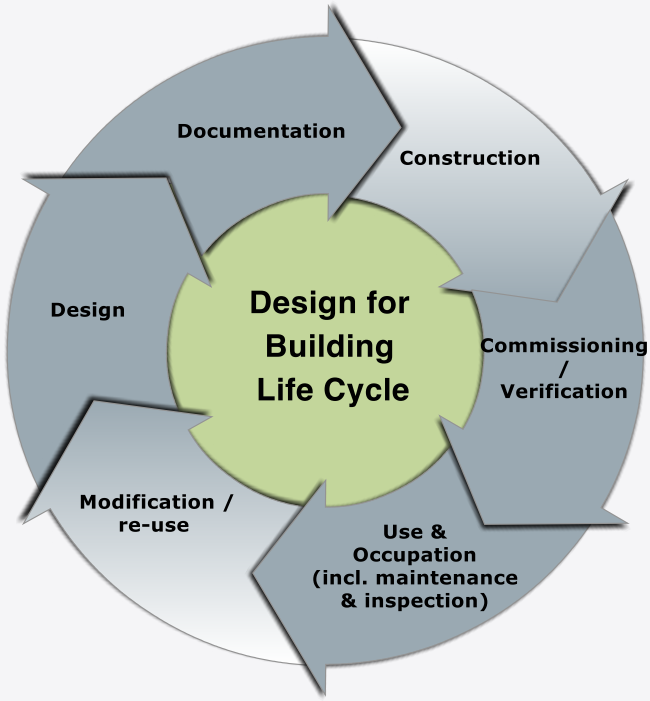


Figure 4: Schematic of typical building life cycle.

Typical examples of stages in the building life cycle where additional fire safety mitigation measures may apply are summarised below in relation to WHS Legislation which applies throughout the life of a building. Therefore, the design needs to account for construction, commissioning / verification, and expected use of a building once it is constructed and occupied including, amongst other things.

- installation and maintenance of fire safety measures without exposing people to undue risk. (e.g., provide safe access for installation of fire protection systems)
- avoiding specification of fire safety provisions which introduce additional hazards.
- addressing fire safety during construction and maintenance (whilst the NCC incorporates some fire safety provisions during the construction phase they do not fully address WHS obligations. Refer Wood Solutions Design Guide 20 - Fire Precautions During Construction of Large Buildings[8]
- facilities for subsequent safe inspection and testing of fire protection measures during occupation
- compatibility of the fire safety strategy with the Emergency Management Organisations (EMO) and related evacuation procedures and staff training post occupation.

The fire safety design does not stop once the fire safety strategy has been developed. The strategy needs to be translated into detailed design documentation and the process will typically involve a number of practitioners such as the following;

- Structural Engineers
- Fire Protection Engineers / Practitioner
- Services Engineers
- Building Designer
- Fire Safety Engineer (or other specialist practitioners for non-fire safety matters)
- EMO consultants / manages (if appointed)

Coordination with design team members throughout the development of the design documentation is critical to a good outcome.

The design also needs to consider the availability of fire protection systems and the availability of *Evidence of Suitability* which will need to be submitted to the *Appropriate Authority*. This is particularly important for some innovative *Performance Solutions* which may depart from the use of systems that comply with commonly applied standards.

1.4 Documentation and Control of Critical Information

Background to Documentation and Control of Critical Information

The Building Confidence Report [9] included recommendation 20 "that each jurisdiction requires that there be a comprehensive building manual for commercial buildings that should be lodged with building owners and be available for successive purchasers". At the time of writing the ABCB had issued a discussion paper identifying potential options for implementation of the recommendation. Options identified included application of the recommendation to all Class 2 to 9 buildings and options placing responsibility on either the Building Surveyor or Building Owner for assembling a Building Manual.

As the provision of accurate and comprehensive information is critical to achieving and maintaining compliance and acceptable levels of safety through the life of a building, the process shown in Figure 5 is suggested, which integrates the design and documentation and construction processes with the development of a Building Manual. The Building Manual can be either an electronic folder as will be necessary for many major projects or may be a printed document. It is prepared initially by the design team, and then further developed during the construction process to address design changes and more detailed information about specific building products, equipment, and other safety measures. The manual should be treated in the same way as other *Evidence of Suitability* and submitted to the *Appropriate Authority* as part of the package of information on which fire safety compliance is verified. The process should be applied to all NCC and other safety provisions but focusses on fire safety here in line with the context of this Technical Design Guide.

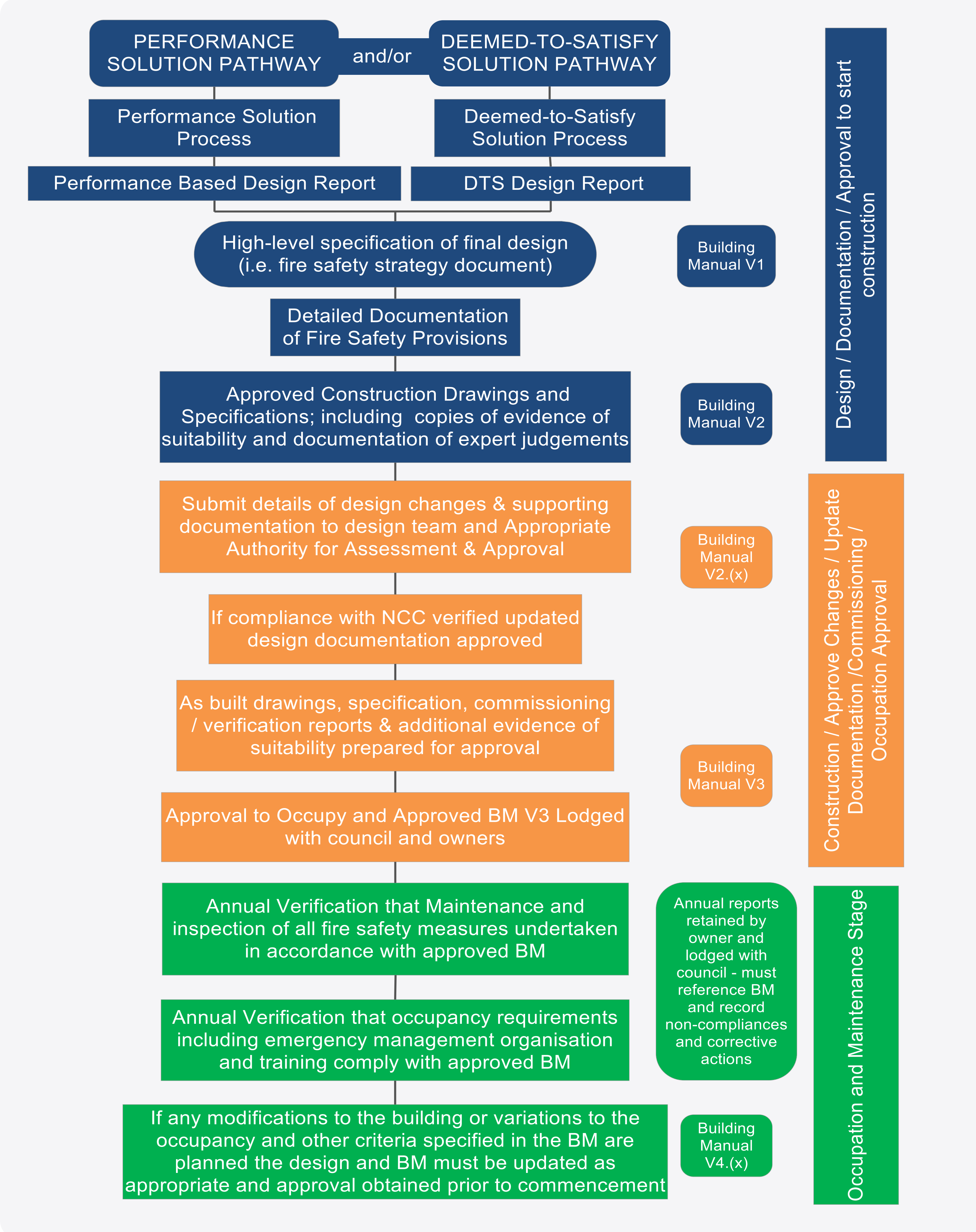


Figure 5: Documentation and Control of Critical Information.

Design and Documentation Prior to Construction

The processes stages shaded in blue relate to the design and documentation phases of the building life cycle and the building design team should take responsibility for the preparation of Versions 1 and 2 of the Building Manual. If a fire safety engineer is appointed, to a project it should be their responsibility to produce the fire safety parts of the Building Manual. Where the *DTS Solution* Pathway is adopted for simple projects a Fire Safety Engineer may not be appointed in which case the responsibility would generally fall on the lead designer (typically the architect) who would assemble the required documentation from other members of the design team or delegate the role to a member of the design team.

Whichever compliance pathway is adopted the initial outcome will be a high-level specification of the final design which is commonly referred to as the fire safety strategy. The strategy defines the combination of measures that are required to satisfy the fire safety objectives and includes physical and human measures.

i.e., the strategy should clearly identify constraints that apply to the use of the building, required fire safety measures including maintenance and inspection regimes, and requirements for the building Emergency Management Organisation including emergency procedures and training to facilitate an efficient and safe emergency evacuation of a building in conjunction with physical fire safety measures.

It is reasonably simple to provide this in the format of a Building Manual as Version 1 which should be submitted to the *Appropriate Authority* for approval before developing the Detailed Design Documentation. If a *Performance Solution* is adopted a complete copy of the performance-based design report should be included in an Appendix to the Manual. Further information relevant to the development of documentation at this stage is given in Chapter 5 Assessment Methods for Performance Solutions and Chapter 6 NCC Assessment Methods for DTS Solutions and Detailed Documentation of Fire Safety Provisions.

Construction, Commissioning and Verification Prior to Handover

It is acknowledged that in complex projects minor and sometimes major changes to a design may be required during the construction process. Minor changes to the design can have a significant impact on fire safety and therefore it is critical that the Building Manual and Performance Based Design Report are updated by the design team and approved by the *Appropriate Authority* to reflect any changes. These should be issued as revisions to Version 2 of the Manual with each revision being uniquely identified (i.e., V2.1, V2.2 etc)

Evidence of Suitability and other documentary evidence for the specific materials and systems used should be included in Appendices to the Manual. Further information relevant to the development of documentation at this stage is given in Chapter 6.

At the end of the construction phase the Building Manual should be updated to Version 3. The updated Version 3 should include as built drawings and updated supporting documentary evidence of compliance reflecting the actual construction including additional documents such as product technical statements and installation / inspection reports referring to the specific products supplied and installations. Any modifications to maintenance and inspection regimes should also be made at this stage.

The completed version 3 of the Building Manual and supporting documents such as “as built drawings” and *Evidence of Suitability* should be submitted to the *Appropriate Authority* to obtain approval to Occupy. Where progressive handovers occur progressive revisions of the Building Manual Version 3 can be issued at each handover stage.

The approved Building Manual and associated documents should be lodged with the building owners and retained by the *Appropriate Authority*. If processes are in place a copy should also be lodged with the relevant council so that it can be used as the basis for building inspections and audits and copies can be available for future occupants / owners if the originals are misplaced.

Use and Occupation including Maintenance and Inspection

The Building Manual includes requirements for annual maintenance and inspection of all fire safety measures and verification that occupancy requirements including emergency management organisation and training comply with intended designs.

Annual reports must be prepared that document inspection, maintenance and other compliance checks and record non-compliances, faults and corrective actions undertaken including the time taken for corrective actions to be implemented. These reports should also be retained by the owners and if processes / regulations are in place lodged with the relevant council / authority.

Modifications and Redevelopment

If any modifications to the building or variations to the occupancy and other criteria specified in the BM are planned the design and BM must be updated as appropriate and approval obtained prior to commencement. The modified design must be consolidated in a new version of the building manual (e.g., version 4) and the processes described in the above sections should be followed through the design, construction and occupancy phases of the redevelopment or refurbishment. A change in the Class of Building would also require modification of the Building Manual.

Lodgement, Format and Updating of the Manual

It is important that the Building Manuals are provided in a format that can be easily updated in the future using file formats that can be opened and edited without costly proprietary software or access to passwords. Locked PDF files or equivalent file types can also be provided to provide an historic record of a particular version of the document. Similarly, as built drawings and supporting documentation should use easily accessible file formats for future editing and viewing data.

A key element of the Building Manual is that it provides a consolidation of information required by the *Appropriate Authority* in order to issue a permit for commencement of construction and subsequently, on completion, to authorise occupation. When the building is occupied the Building Manual provides a useful tool for verification that the fire safety strategy is continuing to be implemented and maintained through the life of the building.

The above processes enable the building manual to be progressively developed through the construction and life of the building reducing the risk of key elements of the strategy being overlooked and reducing the need to rework existing analysis and undertake costly inspections.

Most States and Territories require design documents and annual statements to be lodged with local councils and the production of Building Manuals as outlined above is likely to simplify and standardised the lodgement process.

2

The National Construction Code (NCC)

2.1 General Structure of NCC

The NCC is Australia's primary set of technical design and construction provisions for buildings. It is a performance-based code which sets minimum levels for the safety, health, amenity, accessibility, and sustainability of certain buildings in order to satisfy relevant State and Territory building legislation.

A major advantage with the performance-based NCC is that there is no obligation to adopt any particular material, component, design factor or construction method. This provides flexibility to tailor a design to meet all the project drivers and constraints that may apply to a particular project in the most efficient manner.

For example, where project drivers require the use of a timber structure to address policies relating to sustainability, speed of construction and minimal impact on the surrounding community during construction, the use of timber is not prohibited by the NCC provided the relevant Performance Requirements are satisfied.

The NCC is published in three volumes.

NCC Volume One covers the design and construction of multi-residential, commercial, industrial, and public assembly buildings and some associated structures. This is the primary focus of this design guide.

NCC Volume Two predominately covers the design and construction of single dwellings and related structures. These are generally designed following the *Deemed-to-Satisfy* (*DTS Provisions*) and are addressed by other Design Guides but some information relating to *Evidence of Suitability* in this guide and others in the series may be relevant.

NCC Volume Three relates to the design, construction and maintenance of plumbing and drainage systems in new and existing buildings which lies outside the scope of this Design Guide.

The NCC Volume One contains amongst other things:

- *Governing Requirements*
- Technical Provisions
- State and Territory variations and additions.

The *Governing Requirements* provide the rules and instructions for using and complying with the NCC. They are vital in understanding how the technical requirements of the NCC should be applied to any particular situation.

The technical provisions are provided in Sections B to J of NCC Volume One and these Sections contain the relevant *Performance Requirements* and associated *Deemed-to-Satisfy Provisions*. The following definitions are provided in the NCC and are self-explanatory.

***Performance Requirement** means a requirement which states the level of performance which a **Performance Solution** or **Deemed-to-Satisfy Solution** must meet.*

Deemed-to-Satisfy Provisions** means provisions which are deemed to satisfy the **Performance Requirements

The majority of the fire safety content is included in Sections C, D and E and the application of these Sections to timber buildings or elements of a timber building is the primary focus of this design guide.

Section C Fire Resistance is of direct relevance to timber elements of construction and timber buildings, but Sections D and E also have relevance since the NCC applies a holistic approach to fire safety.

Additional fire safety content relating to specific applications is included in Sections G Ancillary Provisions and Section H Special use buildings and variations from the "standard" provisions in the body of the NCC are provided in State and Territory Appendices. These variations and additional provisions will not be specifically addressed in this Design Guide. Reference should be made to NCC Volume One for information on these sections and the State and Territory Appendices. Readers should note that it is necessary to check the applicability of other Sections of the NCC and State Appendices when involved in a fire safety design.

A series of schedules are included in the NCC which are referenced from the main body. These are:

- Schedule 1 State and Territory Appendices – identifying variations to the main body of the NCC
- Schedule 2 Abbreviations and Symbols – assists interpretation
- Schedule 3 Definitions – assists interpretation
- Schedule 4 Referenced Documents – assists usability
- Schedule 5 Fire–resistance of building elements – provisions for fire resistant elements of construction; of direct relevance to timber buildings
- Schedule 6 Fire hazard properties – provisions relating to the fire hazard of materials and assemblies such as wall and ceiling linings; of direct relevance to timber.
- Schedule 7 Fire Safety *Verification Method* – general comparative *Verification Method* which can be applied to timber buildings

2.2 Overview of Pathways for Demonstrating Compliance

The options for demonstrating compliance with the NCC are described in Part A2 Governing Requirements. Compliance is required with both:

- the *Governing Requirements* (Part A in NCC Volume One), **and**
- the *Performance Requirements*

As noted previously the *Governing Requirements* specify how the NCC should be used and address matters such as interpretation, reference documents, the acceptance of design and construction (including related *Evidence of Suitability* /documentation) in conjunction with the corresponding schedules

To comply with the NCC, buildings must satisfy the *Performance Requirements* in addition to the *Governing Requirements.*

Performance Requirements can be satisfied by:

a) following the *Performance Solution* pathway and demonstrating that all relevant *Performance Requirements* have been satisfied.

b) following the Deemed-to-Satisfy pathway which involves selecting an appropriate combination of *DTS Solutions* from the NCC (including materials, components, prescribed design, and construction methods), which are deemed to meet the *Performance Requirements*.

c) A combination of a) and b).

Note: Option c) is effectively a *Performance Solution* since the impact of variations from the *DTS Provisions* on the total fire safety system for the building need to be considered.

A *Performance Solution* is generally unique to each individual building and it is necessary to directly assess the *Performance Requirements*.

A *DTS Solution* comprises a combination of *DTS Provisions* which include materials, components, building layouts and configurations, and construction methods that, if used, are deemed to meet the *Performance Requirements*. In some instances, the NCC provides a choice of *DTS Provisions* that can be used to satisfy the *Performance Requirements*. To some extent this provides a level of flexibility for designers to select a combination of *DTS Provisions* to optimise a fire safety design in a manner that is consistent with all project drivers and constraints

One or more of the *Assessment Methods* specified in the NCC must be used to determine compliance with the *DTS Provisions* or the *Performance Requirements* depending on the pathway adopted. The procedures for demonstrating compliance using the DTS or Performance Pathways are compared in Figure 6.

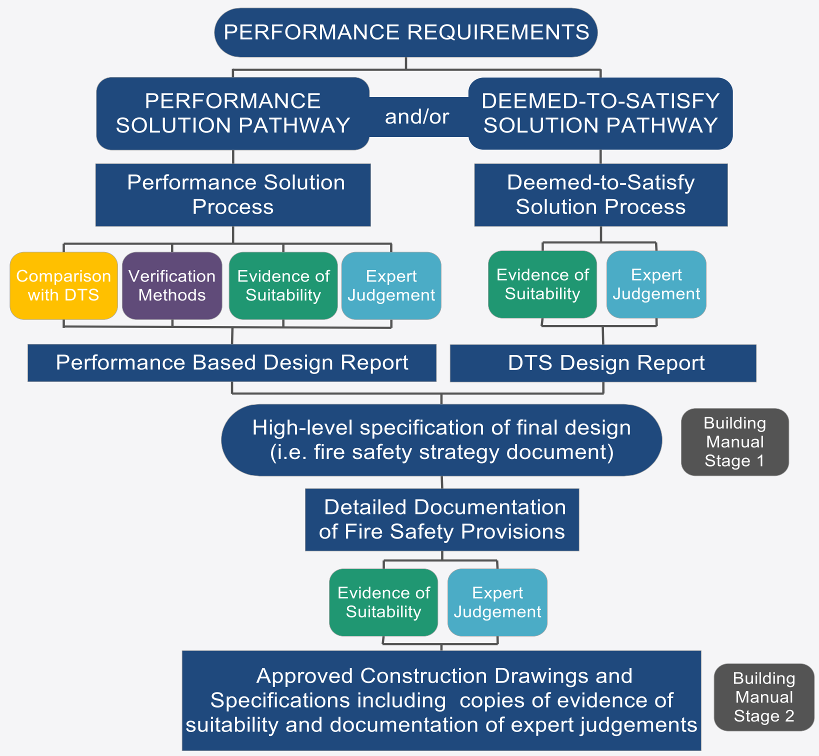


Figure 6 Overview of Procedure for Demonstrating Compliance with the NCC

The DTS and Performance Pathways follow different processes for the development and assessment of compliance of a high level specification of the fire safety design (the fire safety strategy).

At this stage, a high-level specification of the design in the form of a fire safety strategy should be submitted for approval to the *Appropriate Authority* before progressing to the detailed documentation of the fire safety provisions. The general NCC definition for the *Appropriate Authority* is provided below:

***Appropriate Authority** means the relevant authority with the statutory responsibility to determine the particular matter.*

In many instances the *Appropriate Authority* will be the appointed Building Surveyor or Certifier, but other entities can be nominated depending on the application and location.

Generally, the procedures for demonstrating compliance are similar for the *DTS Solution* and *Performance Solution* Pathways once an assessment of compliance of the *Performance Solution* against all relevant *Performance Requirements* has been undertaken or the *DTS Solution* has been selected.

If it is impractical to include specific *Evidence of Suitability* within the approved documentation at the design stage for a particular application, requirements for *Evidence of Suitability* should be specified within the approved design documentation. Once product selections have been made the required *Evidence of Suitability* shall be incorporated in the as built documentation and submitted to the *Appropriate Authority* for approval.

Note: Major design decisions should be made early in the design process to avoid unnecessary reworks of design documentation. This highlights the need for early involvement of a fire safety engineer and other critical stakeholders early in the process to ensure the fire safety design is compatible with other drivers and constraints.

2.3 Fire Safety Performance Requirements

The fire safety provisions make up a significant proportion of the content of NCC Volume One and the required performance is expressed through numerous *Performance Requirements* which tend to be interrelated encouraging the adoption of holistic approaches to fire safety designs.

This is best illustrated by considering two example *Performance Requirements*, CP1 and CP2, that are critical to the use of timber structural elements.

CP1 relates to structural stability during a fire and CP2 relates to the spread of fire. Fire safety strategies commonly address these *Performance Requirements* by specification of FRLs, provision of separation distances, specification of material fire hazard properties, non-combustibility (or fire-protected timber) and building geometry in combination with active fire safety systems, evacuation strategies and fire brigade intervention, as appropriate.

The fire safety *Performance Requirements* in NCC Volume One generally state what is to be achieved and provide a list of parameters that must be considered when determining compliance as shown in Figure 7. It can be seen that there are differences between CP1 and CP2 with respect to what is to be achieved but the parameters that have to be considered (within the dashed box) are similar.

Terms such as "to the degree necessary" are used in a number of the *Performance Requirements* of the NCC including CP1 and CP2 to provide flexibility when applying holistic approaches.

For example, timber structural elements can be used in some applications where non-combustible elements are commonly used as part of a *DTS Solution*, if other design features such as the use of fire-protected timber and / or automatic sprinkler systems are adopted to maintain structural stability appropriate to the listed parameters in CP1. These include parameters for consideration such as fire brigade intervention and any active fire safety systems installed in the building.

CP1 Structural stability during a fire

A building must have elements which will, to the degree necessary, maintain structural stability during a fire appropriate to—

(a)the function or use of the building; and

(b)the *fire load*; and

(c)the potential *fire intensity*; and

(d)the *fire hazard*; and

(e)the height of the building; and

(f)its proximity to *other property*; and

(g)any active *fire safety systems* installed in the building; and

(h)the size of any *fire compartment*; and

(i)*fire brigade* intervention; and

(j)other elements they support; and

(k)the *evacuation time*.

CP2 Spread of fire

(a)A building must have elements which will, to the degree necessary, avoid the spread of fire—

(i)to *exits*; and

(ii)to *sole-occupancy units* and *public corridors*; and

Application:
CP2(a)(ii) only applies to a Class 2 or 3 building or Class 4 part of a building.

(iii)between buildings; and

(iv)in a building.

(b)Avoidance of the spread of fire referred to in (a) must be appropriate to—

(i)the function or use of the building; and

(ii)the *fire load*; and

(iii)the potential *fire intensity*; and

(iv)the *fire hazard*; and

(v)the number of *storeys* in the building; and

(vi)its proximity to *other property*; and

(vii)any active *fire safety systems* installed in the building; and

(viii)the size of any *fire compartment*; and

(ix)*fire brigade* intervention; and

(x)other elements they support; and

(xi)the *evacuation time*.

Figure 7 Comparison of Performance Requirements CP1 and CP2 *This figure is a derivative of the performance requirements CP1 and CP2 of the NCC provided by the Australian Building Codes Board © 2020. (https://ncc.abcb.gov.au/)*

The parameters for consideration comprise a mix of

- fire hazards,
- mitigation measures,
- risk exposure (people and property) e.g.;
  - number of occupants and vulnerability (function and use of the building)
  - other property at risk.

The fire related *Performance Requirements* in sections C to E of NCC Volume One can be consolidated into a matrix as shown in Figure 8. In all, there are 25 *Performance Requirements* (ignoring the *Performance Requirement* relating to fire precautions during construction) and fifteen parameters for consideration. The filled circles in Figure 8 represent parameters specifically referenced in the *Performance Requirements* and the open circles the parameters that are inferred by the context of the *Performance Requirement*. Some of the nominated *Performance Requirements* such as DP2, DP4, and DP6 are not specific to fire emergencies and may also apply to general usage and other emergencies. The fire safety analysis should consider these *Performance Requirements* as appropriate to the fire safety design, but additional analysis may be required for other emergencies and general safety within the building.

Figure 8 highlights the significant inter relationships between the fire safety *Performance Requirements* and in most cases holistic approaches need to be adopted to assess *Performance Solutions*.

Performance Requirement	**Parameters for Consideration**														
	Function or use of the building	Fire load	Potential fire intensity;	Fire hazard;	Height of the building / num. of storeys	Its proximity to other property	Any active fire safety systems	Size of any fire compartment / floor area	Fire brigade intervention	Other elements they support	Evacuation time	Number, mobility / occupant charact.	Travel distance	Exit above or below ground	Fire Safety System
CP1 Structural stability during a fire	●	●	●	●	●	●	●	●	●	●	●	○	○		○
CP2 Spread of fire	●	●	●	●	●	●	●	●	●	●	○	○	○		○
CP3 Spread of fire and smoke in health and res. care	○	○	○	○			○				○				
CP4 Safe conditions for evacuation	●						●				●	●	○		○
CP5 Behaviour of concrete external walls in a fire		○	○	○	○										
CP6 Fire protection of service equipment				○											
CP7 Fire protection of emergency equipment	○	○	○	○			○								
CP8 Fire protection of openings and penetrations	○	○	○	○	○	○	○	○	○	○	○				
CP9 Fire brigade access	●	●	●	●			●	●							
DP2 Safe movement to and within a building											○	○	○		
DP4 Exits	●			●							○	●	●	●	
DP5 Fire-isolated exits	●			●					●						●
DP6 Paths of travel to exits	●										○	●			
DP7 Evacuation lifts	●			●							○	●	●		●
EP1.1 Fire hose reels	●			●				●							●
EP1.2 Fire extinguishers	●			●											●
EP1.3 Fire hydrants				●				●	●						
EP1.4 Automatic fire suppression systems	●			●	●			●							
EP1.6 Fire control centres	●				●			●							
EP2.1 Automatic warning for sleeping occupants					○										
EP2.2 Safe evacuation routes	●	●	●	●			●		●		○	●	●		
EP3.2 Emergency lifts					○										
EP4.1 Visibility in an emergency	●							●					●		
EP4.2 Identification of exits								○				○	○		
EP4.3 Emergency warning and intercom systems	●				●			●							

Figure 8: Matrix of Performance Requirements and Parameters for Consideration.
This figure is a derivative of Table 7.1 Handbook - Fire Safety Verification Method provided by the Australian Building Codes Board © 2020. (https://ncc.abcb.gov.au/sites/default/files/resources/2020//Handbook_Fire_Safety_Verification_Method.pdf)

This has been recognised in CV4 - Fire Safety *Verification Method* which requires a holistic comparative approach to fire safety design. The assessment process also requires consideration of any relevant *Performance Requirements* in other sections of the NCC. For example, consideration of *Performance Requirement* BP1.1 Structural Reliability is necessary in many applications where CP1 is relevant.

Note: At the time of writing the *Performance Requirements* are expressed in qualitative terms which can lead to significant variations in interpretation of terms such as "to the degree necessary". However, the fire safety *Performance Requirements* are programmed for quantification in the 2022 edition with a draft for comment being released in May 2021 that effectively:

- consolidates the *Performance Requirements* into a life safety *Performance Requirement* and a property protection *Performance Requirement*.
- provides quantified risk-based criteria against which designs can be assessed reducing the subjectivity associated with determining compliance with *Performance Requirements*
- maintains a similar list of parameters for consideration.

2.4 Performance Solution Assessment Process for the Fire Safety Strategy

A Performance Solution complies with the NCC if it is demonstrated that the solution:

- Complies with all relevant *Performance Requirements or,*
- Is at least equivalent to the *Performance Requirements*

using one or more of the following A*ssessment Methods* are used;

- Comparison with the *Deemed-to-Satisfy Provisions*
- *Verification Methods*
- *Evidence of Suitability*
- *Expert Judgement*

and

if an absolute approach rather than comparison to a DTS Solution is adopted; the relevant *Performance Requirement*(s) are identified as follows:

- Relevant *Performance Requirements* from the Section or Part of the NCC to which the Performance Solution applies.
- *Performance Requirements* from other Sections or Part of the NCC that are relevant to any aspects of the *Performance Solution* proposed or that are affected by the application of the *Performance Solution*

Performance Solutions relating to fire safety State and Territory fire safety regulations generally require *Evidence of Suitability* in the form of a report from a professional fire safety engineer in addition to any other requirements of the NCC. This is consistent with NCC A5.2 *Evidence of Suitability* -Clause 1(e) which states:

> (e) A certificate or report from a professional engineer or other appropriately qualified person that -
>
> (i) certifies that a material, product, form of construction or design fulfils specific requirements of the BCA; and
>
> (ii) sets out the basis on which it is given and the extent to which relevant standards, specifications, rules, codes of practice or other publications have been relied upon to demonstrate it fulfils specific requirements of the BCA.

It therefore follows that the primary *Assessment Method* comprises *Evidence of Suitability* in the form of a report from a professional engineer. However, such assessments commonly apply more than one *Assessment Method* and different categories of *Evidence of Suitability*.

Note: National and State based accreditation of fire safety engineers is available. When relying on a certificate or report from a fire engineer it is prudent to check the credentials of the relevant engineer and recognition of the accreditation within the State or Territory in which the building works is to be undertaken. Legislation within a State or Territory often includes requirements for insurance of some practitioners.

Required Process for Demonstrating Compliance with of a Performance Solution

In July 2021, Clause A2.2(4) formally took effect, which specifies a step-by-step process which must be undertaken when developing and demonstrating compliance of a *Performance Solution*. It is to be used in conjunction with relevant Assessment Methods.

This process will ultimately result in a report from a professional engineer as the primary *Evidence of Suitability* for a *Performance Solution* but in most instances, it will be supplemented by other *Assessment Methods* described in the following sub-sections.

The step-by-step process in centred around the Performance-based Design Brief (PBDB) which is similar to the approach specified in the International Fire Engineering Guidelines (published by the ABCB in 2005) and has been applied extensively for *Performance Solutions* relating to fire safety in Australia.

Note: Some existing documents relating to fire safety *Performance Solutions* use terms such as Fire Engineering Brief (FEB) rather than the more general term Performance-based Design Brief (PBDB) which was introduced into the NCC so that the process is not specific to fire safety.

This process confirms the need for a formal report to be issued confirming compliance with the NCC.

The four steps are summarised below.

Prepare a Performance-based Design Brief (PBDB)

A PBDB is a documented process that derives a proposed *Performance Solution* (e.g., a fire safety strategy) and defines methods of analysis, associated inputs, and acceptance criteria. The scope and content of a PBDB will depend on the scope and complexity of the proposed solution. Its purpose is to set down the basis, as discussed and usually agreed by the relevant stakeholders, on which the analysis of the proposed building and its Performance Solution will be undertaken. The main PBDB activities are summarised in the chart below:

Generally, key stakeholders in a *Performance Solution* include:

- building owner or owner's representative
- builder or project manager
- relevant design process practitioners such as
  - architects
  - engineers (structural, hydraulic, fire safety, civil etc.)
  - design specialists (ESD, HVAC etc.)
  - building design professionals
  - trade practitioners
- *Appropriate Authority*, e.g., building surveyors and certifiers
- other relevant agencies related to *Performance Solution*
  - health
  - environment
  - fire safety (e.g., fire brigades)
  - infrastructure (water, sewerage, and stormwater)
- representatives of any other relevant party.

At the end of the PBDB process, the proposed fire safety strategy should be clearly defined such that all the relevant stakeholders have a clear expectation of the likely fire safety performance of the building and clearly understand their obligations in relation to the building project and subsequently through the building lifecycle.

Carry Out Analysis

Given that each Performance Solution is unique, each proposal will require an analysis / assessment specific to the solution being considered and other relevant attributes of the building.

The methods of analysis should therefore be agreed with the stakeholders and fully documented during the PBDB stage together with required inputs, outputs, and acceptance criteria. The methods of analysis and acceptance criteria must be consistent with one or more of the NCC *Assessment Methods* and address all relevant parameters nominated in the relevant *Performance Requirements*.

Evaluate Results

The results from the analysis should be compared to the acceptance criteria. If the acceptance criteria are not satisfied the proposed *Performance Solution* may require revision and depending on the changes to the design, the methods of analysis may also need adjustment. The PBDB will need to be revised accordingly and agreed with the relevant stakeholders prior to further analysis.

Prepare Final Report

Clause A2.2(4) of the NCC requires the following information to be included in the final report.

- all relevant *Performance Requirements* and/or *Deemed-to-Satisfy* Provisions
- identification of all *Assessment Methods* used; and
- details of the PBDB, Analysis and Evaluation of results; and
- confirmation that the relevant *Performance Requirement* have been met and
- details of conditions or limitations, if any exist, regarding the *Performance Solution*.

Note: Although not explicitly stated in clause A2.2, it is necessary for the final report to include, or cross reference, a detailed specification of the fire safety strategy which has been assessed for compliance with the NCC. This could be in the form of the section of a Building Manual addressing fire safety.

Whilst it is necessary for the fire safety strategy to be defined in order to undertake the assessment of a *Performance Solution* it is critical that the strategy is adequately documented to avoid key components, conditions or limitations being overlooked which could compromise the design. This documentation should not just be limited to a specification of physical fire safety measures and the building layout but should also address matters such as:

- evacuation strategies and the related requirements for an emergency management organisation and occupant training.
- installation, commissioning, and maintenance of equipment.
- expectations relating to fire brigade intervention.
- other critical conditions, limitations, and design features such as assumed occupant characteristics.

2.5 Deemed-to-Satisfy Solution Process

For a DTS Solution only *Evidence of Suitability* and *Expert Judgement* are applicable.

Design using *DTS Solutions* requires selection of an appropriate combination of DTS Provisions.

For more complex buildings the number of combinations of DTS Provisions can be large. Under these circumstances applying a simplified PBDB process to identify the most appropriate combination of *DTS Provisions* that is consistent with other stakeholder drivers and constraints can be beneficial.

This could be integrated into the initial design brief stage of a project if members of the design team have been appointed.

At the end of this process a DTS Design Report can be prepared which;

- clearly defines the fire safety strategy
- identifies all relevant *Deemed-to-Satisfy Provisions* (i.e., selected DTS options)
- identifies *Assessment Methods* for the *DTS Solutions* and
- confirms that the relevant *Performance Requirement* can be met through compliance with the relevant *DTS Provisions*
- details of conditions or limitations, if any exist, regarding the *DTS Solution*.

Similar to a *Performance Solution*, the document should not be limited to physical fire safety measures but should also address matters such as:

- evacuation strategies and the related requirements for an emergency management organisation and occupant training
- installation, commissioning, and maintenance of equipment.
- expectations relating to fire brigade intervention
- other critical conditions, limitations, and design features

2.6 Assessment Methods

The following definition of *Assessment Method* is provided in the NCC:

Assessment Method means a method that can be used for determining that a Performance Solution or Deemed-to- Satisfy Solution complies with the Performance Requirements.

The NCC groups *Assessment Methods* into four categories as shown in Table 1. One or a combination of these *Assessment Methods* may be adopted to assess compliance with the NCC in conjunction with other procedures specified in the *Governing Requirements*.

Table 1: Summary of NCC Assessment Methods.

Assessment Method	Applicability
Evidence of Suitability	Applies to performance and DTS Solutions
Expert Judgement	Applies to performance and DTS Solutions
Comparison with the Deemed-to Satisfy-Provisions	Applies only to Performance Solutions
Verification Methods	Applies only to Performance Solutions

A brief overview of each of the *Assessment Methods* follows. Further information on the general application of the various *Assessment Methods* is provided on the ABCB website which can be accessed from the following link. ***Australian Building Codes Board (abcb.gov.au)*** Application of the Assessment Methods to Timber Buildings is addressed in Chapter 6.

Comparison with DTS Solution

This *Assessment Method* involves a comparative analysis to demonstrate that a *Performance Solution* is better than, or at least equivalent to, the *Deemed-to-Satisfy Provisions*. The NCC definition for equivalent is:

Equivalent means equivalent to the level of health, safety and amenity provided by the Deemed-to-Satisfy Provisions.

To carry out this comparison, the applicable *Deemed-to-Satisfy Provision(s)*, and *Performance Solution* both need to be subject to the same level of analysis using the same methodology. This provides the building designer and Appropriate Authority with a defined benchmark or level for the *Deemed-to-Satisfy Provision* and the *Performance Solution*.

Following a comparative method determines whether the *Performance Solution* provides the same level of health, safety, amenity, or sustainability as using a *Deemed-to-Satisfy Solution*. If it is found that the *Performance Solution* is equal to or better than the *Deemed-to-Satisfy Provision*, then the *Performance Solution* proposal satisfies the NCC *Performance Requirements*.

The comparative Assessment Method is the basis for NCC *Verification Method* CV4 - Fire Safety *Verification Method* (FSVM), which provides guidance amongst other things in relation to the range of fire scenarios that must be compared. *Verification Method* CV 4 / DV4 / EV1.1, the fire safety *Verification Method* is discussed in more detail in Section 5.3.

Verification Methods

Verification Methods are tests, inspections, calculations, or other methods providing a means for demonstrating a *Performance Solution* complies with the relevant *Performance Requirements*. Some *Verification Methods* are prescribed within the NCC and may take a number of forms but generally include a quantifiable benchmark or predetermined acceptance criteria that the solution must achieve.

It is permitted to use *Verification Methods* not prescribed within the NCC; however there must be agreement with the *Appropriate Authority* and other relevant stakeholders that the *Verification Method* is acceptable. This can be incorporated within the PBDB process. Parts C to E include the following *Verification Methods* that may have direct relevance to the fire safety of timber buildings.

CV1 Fire spread between buildings on adjoining allotments
CV2 Fire spread between buildings on the same allotment
CV3 Fire spread via external walls
CV4 / DV4 / EV1.1 Fire Safety *Verification Method*
DV2 Access to and within a building
These *Verification Methods* and their application to timber buildings are discussed further in Chapter 5

Expert Judgement

The NCC definition of *Expert Judgement* is provided in the following text box:

> ***Expert Judgement*** *means the judgement of an expert who has the qualifications and experience to determine whether a* ***Performance Solution*** *or* ***Deemed-to-Satisfy Solution*** *complies with the Performance Requirements.*
>
> *Explanatory Information: Contemporary and relevant qualifications and/or experience are necessary to determine whether a* ***Performance Solution*** *complies with the* ***Performance Requirements****. The level of qualification and/or experience may differ depending on the complexity of the proposal and the requirements of the regulatory authority. Practitioners should seek advice from the authority having jurisdiction or* ***Appropriate Authority*** *for clarification as to what will be accepted.*

It is frequently necessary to make judgements when determining compliance with the NCC and particularly when determining compliance with qualitative *Performance Requirements*. Even when other *Assessment Methods* are being applied it is still often necessary to make judgements with respect to inputs and acceptance criteria.

Note: In engineering disciplines the term engineering judgement is commonly used when making decisions or judgements rather than expert judgment. The process may be formal, intuitive, or deliberate or, in most cases, a combination of the three.

Different types of experts may need to be registered with State and Territory accreditation bodies, registrars or nominated national accreditation bodies.

In general, in the field of fire safety, a professional fire safety engineer is required to carry out the *Performance Solution* process which includes;

- Preparing the PBDB in conjunction with relevant stakeholders
- Undertaking the analysis
- Evaluating the results
- Preparing a final report determining compliance and defining the fire safety strategy

As a professional fire safety engineer (registered with a professional body and / or the relevant State or Territory) a practitioner would meet the general requirements for qualifications and experience to determine compliance and may be expected to have the competence to make more routine engineering judgements associated with undertaking a fire safety engineering analysis and evaluating the results.

Note: What is legally defined as an expert will differ for individual States and Territories.

As indicated in the Explanatory information provided in the NCC the qualifications and experience required for a particular project differ depending on the complexity of the proposal and requirements of the *Appropriate Authority*.

Ultimately, it is the role of the *Appropriate Authority* to determine whether a particular person undertaking an *Expert Judgement* is considered an expert. Each situation is different, so the capacity of the expert (practitioner) to make appropriate judgements must be individually assessed on a project-by-project basis.

Therefore, it is important before appointing a fire safety engineer to clarify the extent of their expertise and likely acceptability to the *Appropriate Authority* and other relevant stakeholders.

If significant *Expert Judgements* are required beyond that associated with routine fire safety engineering design practice, extra confidence can be obtain to some extent if the PBDB stakeholders include people with expertise in the field of fire safety and/or an independent Peer Review is commissioned. Techniques such as sensitivity analyses can be used to further inform expert / engineering judgements.

Note that typically under State and Territory laws, the *Appropriate Authority* cannot be part of the design process as they are to independently assess the proposal. Therefore, they cannot provide an *Expert Judgement* for a matter they are considering for approval.

Evidence of Suitability

The NCC provides numerous options under the *Assessment Method* category of *Evidence of Suitability* which can be selected depending on the application. Many of the *Evidence of Suitability Assessment Methods* are most suited to the assessment for compliance with the NCC of the detailed documentation (drawings and specifications) and therefore can apply to both *Performance Solutions* and *DTS Solutions*.

Note: When defining the fire safety strategy for a ***Performance Solution*** *it is important that the required performance of components of the fire safety strategy are specified in a form that can be readily developed into detailed design documentation by a competent practitioner and subsequently assessed for compliance. Required maintenance procedures should also be identified. This can be achieved by, as far as practical, referencing appropriate Australian and International Standards and nominating required* ***Evidence of Suitability*** *in a form that is consistent with DTS Solutions. Such approaches reduce the risks of misunderstandings and errors being introduced during the development of design documentation and construction of the building and facilitate the maintenance of the systems and components throughout the building life.*

There are specific requirements for *Evidence of Suitability* for the following fire related properties of a material or systems which will be addressed specifically in Chapter 6 since they are directly relevant to timber:

- Fire-resistance of building elements
- Fire-hazard properties
- Resistance to the Incipient Spread of Fire

In addition, the following options are available for other applications:

- A current CodeMark Australia or CodeMark Certificate of Conformity.
- A current Certificate of Accreditation.
- A current certificate, other than those described above, issued by a certification body stating that the properties and performance of a material, product, form of construction or design fulfil specific requirements of the BCA (NCC Volumes One and Two).
- A report issued by an Accredited Testing Laboratory that -
  - demonstrates that a material, product, or form of construction fulfils specific requirements of the BCA (NCC Volumes One and Two); and
  - sets out the tests the material, product or form of construction has been subjected to and the results of those tests and any other relevant information that has been relied upon to demonstrate it fulfils specific requirements of the BCA (NCC Volumes One and Two).
- A certificate or report from a professional engineer or other appropriately qualified person that -
  - certifies that a material, product, form of construction or design fulfils specific requirements of the BCA (NCC Volumes One and Two); and
  - sets out the basis on which it is given and the extent to which relevant standards, specifications, rules, codes of practice or other publications have been relied upon to demonstrate it fulfils specific requirements of the BCA (NCC Volumes One and Two).
- Another form of documentary evidence, such as but not limited to a Product Technical Statement, that -
  - demonstrates that a material, product, form of construction or design fulfils specific requirements of the BCA (NCC Volumes One and Two); and
  - sets out the basis on which it is given and the extent to which relevant standards, specifications, rules, codes of practice or other publications have been relied upon to demonstrate it fulfils specific requirements of the BCA (NCC Volumes One and Two).

The NCC defines a Product Technical Statement as:

a form of documentary evidence stating that the properties and performance of a building material, product or form of construction fulfil specific requirements of the NCC, and describes -

(a) the application and intended use of the building material, product, or form of construction: and

(b) how the use of the building material, product or form of construction complies with the requirements of the NCC Volume One and Volume Two; and

(c) any limitations and conditions of the use of the building material, product, or form of construction relevant to (b).

*Note: Seeking a Product Technical Statement in addition to, for example, relevant test reports from an **Accredited Testing Laboratory** can provide added confidence that the test reports provided relate to the specific products provided the Product Technical Statement references the test reports. It is strongly recommended not to solely rely on product technical statements.*

3

Structural Timber Building NCC Compliance Pathway Options

3.1 Overview of Fire Properties of Timber

This brief overview of the fire properties of timber in this section provides a simple explanation of the engineering principles underpinning the compliance pathway options for the fire safety of timber buildings.

In common with all structural building materials, timber construction has advantages that can be optimised and disadvantages that can be managed to achieve an acceptable level of safety.

When exposed to a severe fire, timber will decompose releasing volatiles, but a char layer is formed which provides a degree of protection to the underlying timber such that timber elements having a large cross section can exhibit high levels of inherent fire resistance. There will be a heat affected zone between the char and unaffected timber where some pyrolysis may occur, and the mechanical properties of the timber will be modified. The process is depicted in the simplified schematic shown in Figure 9.

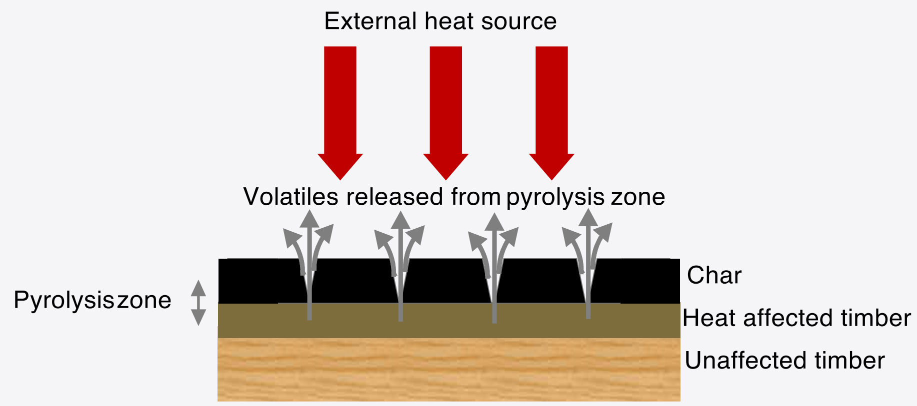


Figure 9: Schematic showing a section through a Burning Section of Timber.

Some of the more critical considerations for the fire safety design of timber buildings can be summarised as follows:

- Timber is combustible and may therefore;
  - contribute to the fire load within an enclosure unless it is fully encapsulated.
  - influence fire growth when used as an exposed timber wall and ceiling linings or the surfaces of elements of construction such a cross laminated timber are exposed. Most structural timbers and wood products with a density above 400kg/m^3 are expected to be classified as Group 3 in accordance with AS 5637 [10] but with appropriate fire retardant treatments this can be improved to Groups 1 or 2.
  - Combustion may continue after burnout of the contents under certain circumstances further reducing the loadbearing capacity of an element or sub-assembly.
- As timber burns it produces a protective char insulating the core of the element and reducing the burning rate.
  - Elements of construction with large cross-sections (Massive timber) can therefore achieve high inherent fire resistance levels without additional fire protection and
  - Protected massive elements are less susceptible to sudden structural failures if a protection system fails due to the high inherent fire resistance of the timber element.
- The coefficient of thermal expansion of timber is relatively low compared to other common building materials. This tends to reduce deflections and induced stresses due to differential heating during fire scenarios.

3.2 NCC Compliance Pathways for Timber Buildings.

The NCC *DTS Provisions* apply a simple risk-based approach based on the rise in storeys to determine the minimum Type of fire resisting construction and also apply area / volume constraints as shown in Table 2.

Table 2: Types of Construction Required by NCC Vol. One.

Rise in storeys or effective height	Multi-residential		Office	Retail	Car Park/ Storage	Factory / Laboratory	Hospitals / Assembly / Schools
	Class 2	Class 3	Class 5	Class 6	Class 7	Class 8	Class 9
4 or more	A	A	A	A	A	A	A
3	A	A	B	B	B	B	A
2	B	B	C	C	C	C	B
1	C	C	C	C	C	C	C

Note: Clause 2.2 of the NCC also applies area and volume limits on fire compartments based on the Type of Construction

Type A construction is the most fire resisting form of construction and the general DTS solutions for Type A construction impose severe limitations on the use of timber through the additional prescription of masonry and concrete construction and non-combustibility for some structural elements required to achieve a prescribed Fire Resistance Level (FRL). Type B construction, whilst not requiring as high FRLs as Type A construction, applies similar constraints to the use of timber.

Type C construction is applicable to most low-rise buildings. It is the least fire resisting form of construction and places few fire related restrictions on the use of structural timber members.

However, the NCC does include some DTS pathways that permit the more general use of structural timber members under specific circumstances where Type A and B construction is required. Table 3 summarises these compliance pathways. The cells highlighted in green indicate available DTS options which are described in the following sections. The blue cells indicate applications where there are no DTS solutions prescribed in the NCC and therefore a *Performance Solution* (PS) is the only pathway for compliance.

Table 3: NCC Compliance Pathways for Timber Buildings.

Rise in storeys or effective height	Multi-residential		Office	Retail	Car Park/ Storage	Factory / Laboratory	Hospitals / Assembly / Schools
	Class 2	Class 3	Class 5	Class 6	Class 7	Class 8	Class 9
Effective height (EH) > than 25m	PS	PS	PS	PS	PS	PS	PS
8 (EH<25)	FPT	FPT	FPT	FPT	FPT	FPT	FPT
7 (EH<25)	FPT	FPT	FPT	FPT	FPT	FPT	FPT
6 (EH<25)	FPT	FPT	FPT	FPT	FPT	FPT	FPT
5 (EH<25)	FPT	FPT	FPT	FPT	FPT	FPT	FPT
4	FPT / TFC	FPT / TFC	FPT	FPT	FPT	FPT	FPT
3	TFC	TFC	FPT	FPT	FPT	FPT	FPT
2	TFC	TFC	Type C	Type C	Type C	Type C	FPT
1	Type C	Type C	Type C	Type C	Type C	Type C	Type C

It should be noted that:

- a *Performance Solution* can be applied to any height and Class of building and may consider an innovative structural fire safety design or consider non-structural fire safety provisions that vary from the DTS solutions. In either case it is necessary to ensure the fire safety system as a whole satisfies the required levels of safety.
- The Fire-Protected Timber (FPT) pathway can be selected as an alternative to Type C construction or the timber frame concession (TFC) pathways for low rise buildings.

Type C Construction

Type C construction is generally restricted to buildings with a rise in storeys of 1 or 2 depending on the building Class as indicated in Table 3. Lower area limits also apply to Type C construction compared to Type A and B construction.

Due to the relatively low height and area restrictions applied to Type C buildings the DTS requirements for the fire performance of structural elements are substantially relaxed from the general requirements that apply to Type A and B construction.

For example:

- The number of elements requiring to be of fire-resistant construction (required to achieve FRLs) is reduced.
- Lower FRLs for external walls which are located more than 1.5 metres from a fire-source feature are specified and only requiring a maximum FRL of 90 minutes for any criterion.
- Most building elements in a building required to be of Type C construction are not required to be non-combustible, or of concrete or masonry.

There are few restrictions on the use of timber structural members and exposed structural elements can be used subject to compliance with *Fire-hazard Properties*, fire resistance requirements and other DTS requirements.

The following WoodSolutions Design Guides provide detailed information relating to compliance using the Type C construction DTS compliance option.

- WoodSolutions Technical Design Guide 2 Timber-framed Construction for Multi-residential Buildings – under revision at the time of preparation of this Design Guide
- WoodSolutions Technical Design Guide 3 Timber Framed Construction for Commercial Buildings Classes 5, 6, 9a & 9b

Timber Framed Concession (TFC)

The NCC DTS requirements in Specification C1.1 for Type A and B construction have general provisions that require elements such as external walls, common and non-loadbearing fire-resisting wall and shafts to be built from non-combustible materials and loadbearing internal and fire walls to be built from concrete or masonry which restrict the use of timber structural elements.

However, the NCC Specification C1.1 Clauses 3.10 and 4.3 provide concessions permitting the use of timber framed construction subject to specific conditions.

In summary the concessions:

- permit timber framed construction to be used for Class 2 and 3 buildings (multi-residential buildings) having a rise in storeys up to 3 provided other materials used in the wall construction such as thermal insulation satisfy the NCC DTS requirements relating to non-combustible construction.
- allow the use of timber framed construction to be extended to buildings with a rise in storeys of four if
  - the lowest *storey* is used solely for the purpose of parking motor vehicles or for some other ancillary purpose; and
  - the lowest *storey* is constructed of concrete or masonry including the floor between it and the Class2 or 3 part of the building above; and
  - the lowest *storey* and the *storey* above are separated by construction having an FRL of not less than 90/90/90 with no openings or penetrations that would reduce the *fire-resisting* performance of that construction except that a doorway in that construction may be protected by a –/60/30 *self-closing* fire door.

i.e., 3 levels of timber framed construction on top and fire separated from a one storey concrete structure used for ancillary purposes.

- if a sprinkler system complying with Specification E1.5 is provided (other than a FPAA 101D or FPAA 101 H system), the FRLs are reduced for a number of elements of construction.

The concessions are reproduced in full in Appendix B.

The concession was originally introduced for Class 2 buildings, based on extensive research and quantitative risk assessments undertaken at Victoria University of Technology and described by Beck[11] performed in the early 1990s with supplementary testing and literature reviews undertaken to justify the extension to Class 3 buildings in 2011[12].

The following WoodSolutions Design Guide provides detailed information relating to compliance using the Timber-framed Concession DTS compliance option.

- WoodSolutions Technical Design Guide 2 Timber-framed Construction for Multi-residential Buildings (Low-rise Class 2 & 3) – under revision at the time of preparation of this Design Guide.

Fire-protected timber (FPT)

The elements of the fire-protected timber concession are shown in Figure 10. The following definitions from the NCC are needed to interpret and apply the concession.

***Fire-protected Timber** means fire-resisting timber building elements that comply with Volume One Specification C1.13a*

***Massive timber** means an element not less than 75 mm thick as measured in each direction formed from solid and laminated timber.*

The definition for *Massive timber* was introduced to allow relaxations to the Fire-protected Timber requirements for timber elements with large cross-sections that do not include cavities to account for the removal of the risk of cavity fires and the beneficial effects of timber with larger cross-sections.

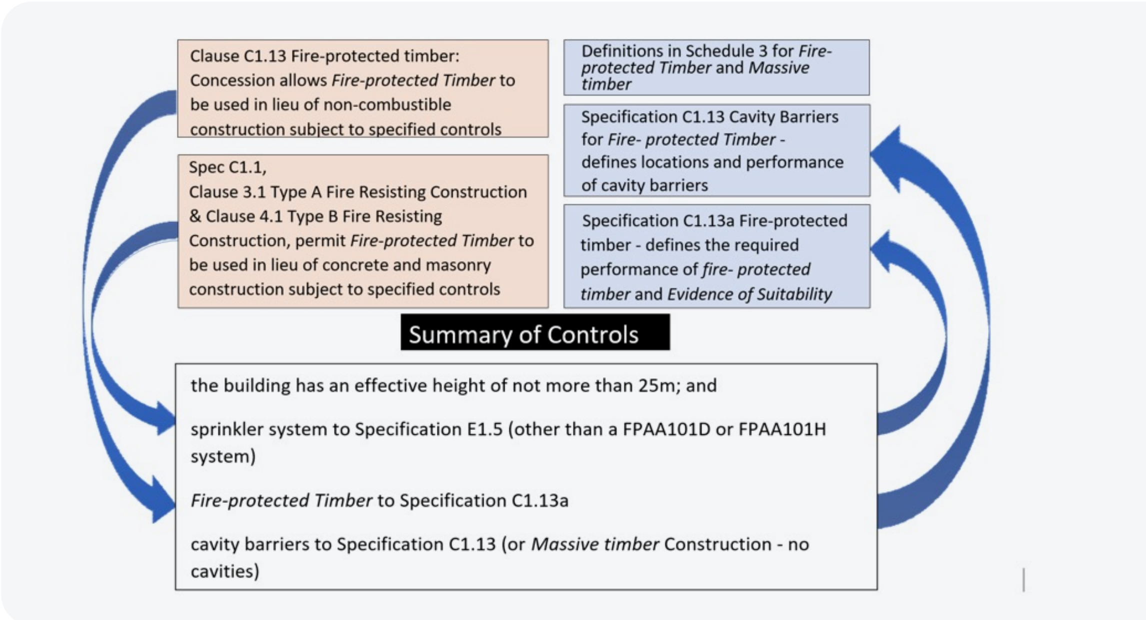


Figure 10: Fire Protected Timber Concession Structure.

The fire-protected timber concession is primarily triggered by clause C1.13 which allows *Fire-protected Timber* to be used in lieu of non-combustible construction, but it is supplemented with content in Specification C1.1 Clauses 3.1 and 4.1 which also allow the use of fire protected timber in lieu of concrete or masonry construction.

Clause C1.13 and Specification C1.1 Clauses 3.1 and 4.1 restrict the use of *Fire-protected Timber* construction under the DTS pathway to buildings with an effective height of not more than 25m and apply the following additional controls;

- a sprinkler system to Specification E1.5 (other than a FPAA101D or FPAA101H system) must be provided
- *Fire-protected Timber* must comply with Specification C1.13a
- cavity barriers must be provided in accordance with Specification C1.13 and
- if cavity insulation is provided it must be non-combustible.

The general requirements for *Fire-protected Timber* construction are provided in Specification C1.13a clause 2.1 which is presented in the text box below:

2.1 General requirements

(a) Fire-protected Timber must -

(i) utilise a non-combustible ***fire-protective covering*** *fixed in accordance with the system requirements to achieve an FRL not less than that required for the building element; and*

(ii) have a ***non-combustible fire-protective covering*** *fixed in accordance with system requirements -*

(A) to achieve a Resistance to the ***Incipient Spread of Fire*** *of not less than 45 minutes when tested in accordance with -*

(aa) for horizontal elements — Section 4 of AS 1530.4; and

(bb) for other elements - the relevant test procedures from Section 4 of AS 1530.4 applied to the element lining; or

(B) which consists of not less than 2 layers of 13 mm thick, fire-protective grade plasterboard.

(b) For the purposes of (a), the ***non-combustible fire-protective covering*** *provided under (a)(ii) may form all or part of the* ***non-combustible fire-protective covering*** *provided under (a)(i).*

Further details relating to appropriate *Evidence of Suitability* is discussed in Section 6

As noted above the general requirements can be relaxed under certain circumstances if *Massive timber* elements are employed. The *Massive timber* requirements for Fire Protected Timber construction are provided in Specification C1.13a clause 2.2 which is presented in the text box below:

2.2 Massive timber

(a) ***Fire-protected timber****, where the timber is* ***massive timber****, need not comply with Clause 2.1 if the fire-protected timber -*

(i) utilises a ***non-combustible fire-protective covering*** *fixed in accordance with system requirements to achieve an FRL not less than that* ***required*** *for the building element; and*

(ii) has a ***non-combustible fire-protective covering*** *fixed in accordance with system requirements -*

(A) so as the temperature at the interface between the protection system and the timber does not exceed 300°C during a fire resistance test performed in accordance with Clause 3 for the application and periods listed in Table 1; or

(B) not less than that specified by Table 1; and

(iii) has either -

(A) any cavity -

(aa) between the surface of the timber and the fire-protective covering; or

(bb) between timber elements within the fire-protective covering,

filled with ***non-combustible insulation****; or*

(B) no cavity -

(aa) between the surface of the timber and the ***fire-protective covering****; or*

(bb) between timber members within the ***fire-protective covering****.*

(b) For the purposes of (a), the non-combustible ***fire-protective covering*** *provided under (a)(ii) may form all or part of the* ***non-combustible fire-protective covering*** *provided under (a)(i).*

Refer to Table 4 for a copy of Table 1 from specification C1.13a Performance Solutions for high-rise buildings

Table 4: Specification C1.13a Table 1 Interface temperature and minimum fire protective grade plasterboard thickness from the NCC.

Application	Time – without timber interface exceeding 300°C (mins)	Minimum thickness of fire-grade plasterboard (mm)
Inside a fire-isolated stairway or lift shaft	20	13
External walls within 1 m of an allotment boundary or 2 m of a building on the same allotment	45	2 x 13
All other applications	30	16

Further details relating to appropriate *Evidence of Suitability* including determination of interface temperatures are provided in Section 6.

The *Fire-protected Timber* concession was originally introduced for Class 2, 3 and 5 buildings in 2016 and extended to other classes in 2019. The following WoodSolutions Design Guides provide detailed information relating to compliance using the Fire-protected Timber Option.

- WoodSolutions Technical Design Guide 37R [4] - Mid-rise Multi-residential buildings (Class 2 and 3)
- WoodSolutions Technical Design Guide 37C [5] - Mid-rise Commercial and Education buildings (Class 5,6,7,8 and 9b,including Class 4 parts)
- Wood Solutions Technical Design Guide 37H [6] - Mid-rise health-care buildings Class 9a and Class 9c

Details of the supporting analysis have been provided in WoodSolutions Technical Design Guide 38 Fire Safety Design of Mid-rise Timber Buildings - Basis for the 2016 changes to the National Construction Code. [13] to provide background information when developing *Performance Solutions*.

Miscellaneous applications

The previous sections outlined the primary DTS Options for Timber Structures in the NCC however there are applications where timber construction can be used for specific structural and non-structural applications in accordance with the NCC DTS Provisions for applications where the NCC permits combustible structural elements or materials and does not restrict materials to concrete or masonry.

Typical examples include wall and ceiling lining materials and timber flooring where *Evidence of Suitability* can be provided to show that the required *Fire-hazard Properties* have been satisfied.

In relation to timber structures a typical example is the DTS solution for Class 9c aged care accommodation which adopted a sprinkler and smoke detection based strategy enabling some relaxations with respect to FRLs, compartmentation and requirements for non-combustibility. Details of this approach are provided in

- WoodSolutions Technical Design Guide 42 [7]. - Timber Aged Care Buildings (Class 9c).

For these miscellaneous applications in particular interpretations of the NCC should be checked with the *Appropriate Authority* early in the design process to ensure any restrictions on the use of timber have not been overlooked.

3.4 Performance Solutions Compliance Options

In theory there are no constraints, if the *Performance Solution* pathway is adopted, to demonstrate compliance of timber structures with the NCC irrespective of the height of a building, provided it can be demonstrated that the relevant *Performance Requirements* have been satisfied.

However, as building heights increase the time required for evacuation increases considerably and the timing and effectiveness of fire brigade intervention is reduced. To manage the impact of these effects and take account of the larger populations within high-rise building that are at risk if structural collapse occurs, it is generally necessary to increase the reliability of the performance of the structure when exposed to fire conditions, in addition to requiring automatic fire suppression systems.

Performance Solutions for high-rise buildings

A common approach for high-rise buildings is to enhance the *Fire-protected timber* construction provisions by increasing the efficacy of the protection system (e.g., increasing the thickness of materials protecting a timber element) and reliability (improved fixing methods, supervision, and quality assurance systems) in addition to the provision of automatic sprinkler systems potentially with enhancements as the risk increases with increasing height. To differentiate these enhancements from the DTS fire protected timber systems that apply to DTS mid-rise building solutions the term "encapsulated timber" is commonly adopted.

Exposed structural timber

It is a common wish to expose some structural timber elements as an architectural statement.

Exposure of timber structural elements can:

- impact the rate of growth of a fire
- increase the effective fire load (potentially increasing the fire severity) and
- increase the risk of structural collapse due to continuing smouldering combustion reducing the residual cross-section of timber fixings and performance of connections

It should be noted that most structural timbers and wood products with a density above 400kg/m^3 are expected to be classified as Group 3 in accordance with AS 5637 [10] but with appropriate fire retardant treatments this can be improved to Group 2 and therefore exposed timber linings are permitted under current *DTS Provisions* for some applications. Where this applies the impact of growth rate and to some extent an allowance for an increase in fire severity may have been incorporated within the DTS solutions, but this will need to be adequately demonstrated when assessing the *Performance Solution*.

The risk of continuing flaming or smouldering combustion potentially leading to collapse is specific to timber structural elements and will need to be considered as part of a *Performance Solution* when timber is ignited during a fire scenario. Based on the work of Crielaard [14] heat fluxes above 5 to 6kW/m^2 are required for smouldering combustion to continue. From the AFAC Fire brigade Intervention Model Manual [15], Fire Brigade personnel with full PPE and BA would be able to withstand an incident heat flux of 3kW/m^2 for 10 minutes and 4-4.5kW/m^2 for approx.1 minute. The timing (or heat flux levels) at which smouldering combustion is assumed to cease and / or the fire brigade could start suppressing any residual smouldering combustion should be determined during the PBDB process when considering the subject building. For small enclosures suppression activities could commence from outside the enclosure and therefore the timing is less sensitive to the heat flux within the fire enclosure.

4

Design Process for Fire Resistant Structural Elements and Barriers

4.1 Overview of Design Process of Structural Elements and Barriers

The process for the design of structural elements and barriers to resist exposure to fire involves the three stages listed below:

- Derivation of the Design Fire,
- Heat transfer Analysis (including assessment of insulation performance for barrier systems), and
- Structural Analysis (including an assessment of the formation of gaps and openings for assessment of integrity of barriers).

A flow chart showing the key stages of the process is shown in Figure 11 based on the flowchart from NCC Fire Safety Verification Method (FSVM) Handbook Annex [16] which was derived from a chart originally prepared for structural design by Buchanan[17].

The three stages can be consolidated in some applications depending on the adopted methods of analysis and selected compliance pathways.

For example, the NCC DTS solutions generally specify a nominal design fire based on the standard heating regime of AS 1530.4 with the performance of elements of construction expressed in terms of fire resistance levels (FRLs.)

The NCC defines the Fire-resistance level (FRL) as the grading periods in minutes determined in accordance with Schedule 5 of the NCC, for the following criteria—

(a) ***structural adequacy****; and*

(b) ***integrity****; and*

(c) ***insulation****,*

and expressed in that order.

A dash means that there is no requirement for that criterion. For example, 90/–/– means there i s no requirement for an FRL for integrity and insulation, and –/–/– means there is no requirement for an FRL.

The required period of exposure to the standard heating regime is varied to address different fire exposure conditions with heat transfer and functional performance being evaluated by subjecting a representative specimen to a fire resistance test or other methods permitted by the NCC such as calculation in accordance with AS 1720.4 [18]

The Design Guide: Structural Fire Safety, produced by the Conceil International du Bâtiment (CIB W14) [19], identified three types of Heat Exposure Models (Design Fires) and three types of Structural Response Models based on single elements, sub-assemblies or entire structures. The matrix produced by CIB W14 has been compacted and cross referenced with NCC performance pathways and required *Evidence of Suitability* as shown in Table 5.

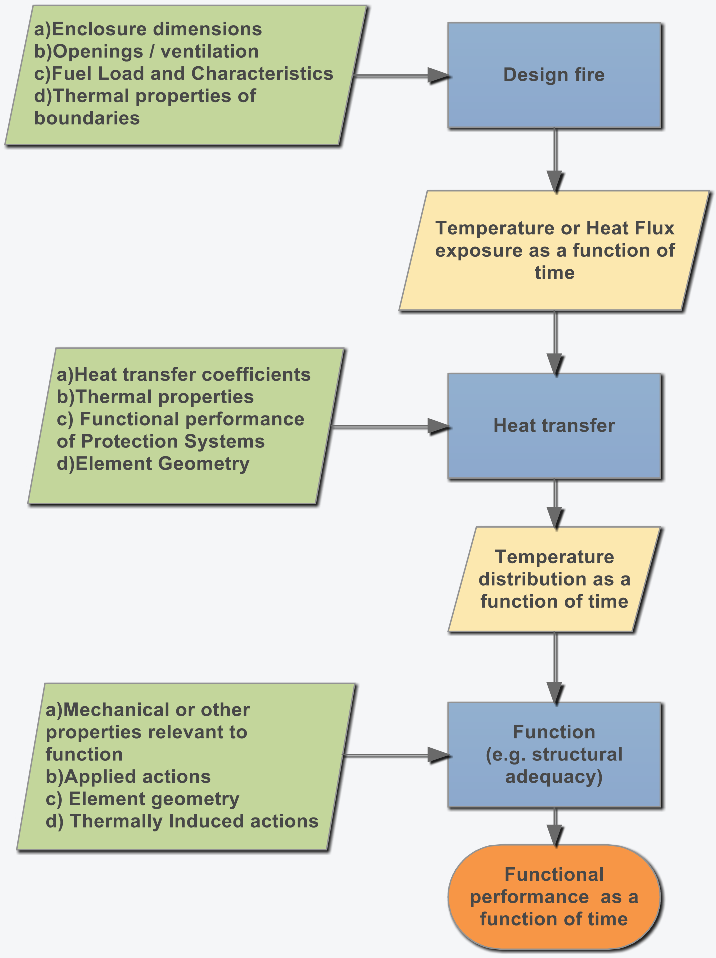


Figure 11: Design Process for Fire Resistant Structural Elements and Barrier Systems.

Table 5: Performance Pathways and Evidence of Suitability compared to Design Fire and Extent of Structural Analyses.

Compliance Pathway	Design fire	Extent of Structural Analysis	Evidence of Suitability
Deemed-to-Satisfy	AS 1530.4 standard heating regime	- Generally individual elements - Occasionally sub-assemblies	NCC Schedule 5 (test or assessment from an Accredited Testing Laboratory (ATL) or permitted calculations)
Simple Time Equivalence *Performance Solution*[1]	Equivalence to AS 1530.4 standard heating regime	- Generally individual elements - Occasionally sub-assemblies	NCC A2.2- demonstration of compliance / *Evidence of Suitability* [2] and NCC Schedule 5 (test, assessment from an ATL or permitted calculations)
More Complex *Performance Solution*	Parametric curve or other theoretical or experimentally derived design fire	Varies with application, could be single elements, sub-assemblies, or whole structure	NCC A2.2- demonstration of compliance / *Evidence of Suitability* [2] and NCC Schedule 5 (test, assessment from an ATL, permitted calculations or natural fire tests, or alternative heating regime tests

*Note 1 Time equivalence is the simplest **Performance Solution** option and relates the expected real fire exposure to a time of exposure to the standard (AS 1530.4) heating regime. Where timber elements are exposed or may become exposed the fire load must be adjusted to take account of the additional contribution from the timber.*

*Note 2 **Evidence of Suitability** will also need to include a report from a competent person (e.g. a professional engineer) assessing compliance of the fire safety strategy with the relevant **Performance Requirements** where the **Performance Solution** Pathway is followed. Additional **Evidence of Suitability** will also be required to verify the performance of key structural elements / components.*

The appropriate methods of analysis should be selected based on the compliance pathway adopted. The extent of analysis required for the design fire(s), heat transfer and structure (or other required function) must be determined having regard to the requirements of the specific project and agreed by the relevant stakeholders as part of the Performance Based Design Brief (PBDB) process.

4.2 Design Fires

Deriving Fire Exposure

If a DTS pathway is followed, the performance of structural elements exposed to enclosure fires is generally expressed in terms of the period of time the element continues to support the applied load when exposed to the standard heating regime of AS 1530.4 as noted in Table 5. If the element also serves a fire separating function integrity and insulation criteria are also applied. The standard heating regime of AS 1530.4 has common origins and is similar to many other international fire resistance test method heating regimes such as ISO 834 [20]

Note: The term nominal heating regime is sometimes used as an alternative to standard heating regime.

The duration for which the performance criteria are required to be satisfied when exposed to the standard heating regime can be varied to account for the differences between the expected thermal exposure (gas temperature and radiant incident heat flux together with appropriate boundary conditions) applicable to the application and exposure to the standard test conditions. The AS 1530.4 standard heating regime is compared to average enclosure fire temperatures from a typical natural fire test using timber cribs as the fire load in Figure 12 highlighting the differences in the enclosure temperatures.

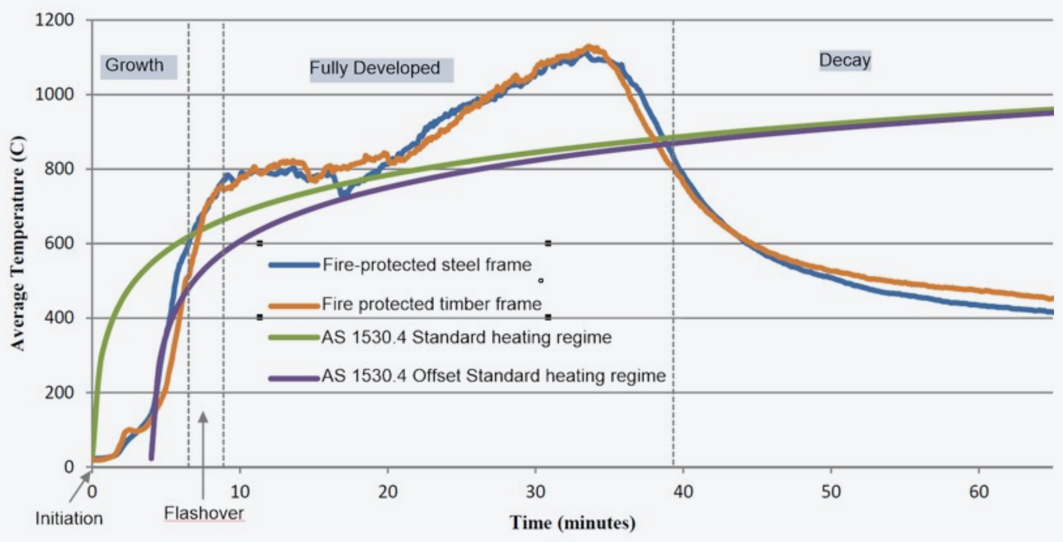


Figure 12: Average enclosure temperatures compared to the AS 1530.4 heating regime for timber and steel wall and ceiling members protected by fire grade plasterboard.

If a performance pathway is followed, a design fire or a number of design fires representing a distribution of potential critical fire scenarios should be defined that take account of the fire dynamics including potential contributions from timber structural elements if exposed (i.e. unprotected timber elements).

If unprotected timber elements are exposed, the rate of pyrolysis and combustion processes are dependent upon the thermal exposure and environmental exposure (oxygen content) which may also need to be taken account. Schmid [21, 22] suggested the introduction of the term "fire exposure" which accounts for both thermal and environmental exposures. Fire exposure is discussed further in Design Guide 18.

It is common to subdivide an enclosure fire into the following four stages when undertaking fire engineering analyses:

- Incipient
- Growth
- Fully Developed
- Decay

In some applications, it may be necessary to extend the analysis and consider a cooling phase if the behaviour of elements of construction, after extinction of the contents (moveable fire load) and combustible elements, is to be considered. Typically, this may be necessary where degradation of elements of construction occurs after extinction of the contents due to thermal inertia, degradation on cooling (e.g. Dimia et al [23]) and / or combustion of elements of construction (e.g. McGregor [24]).

A schematic example of an enclosure fire is shown in Figure 13.

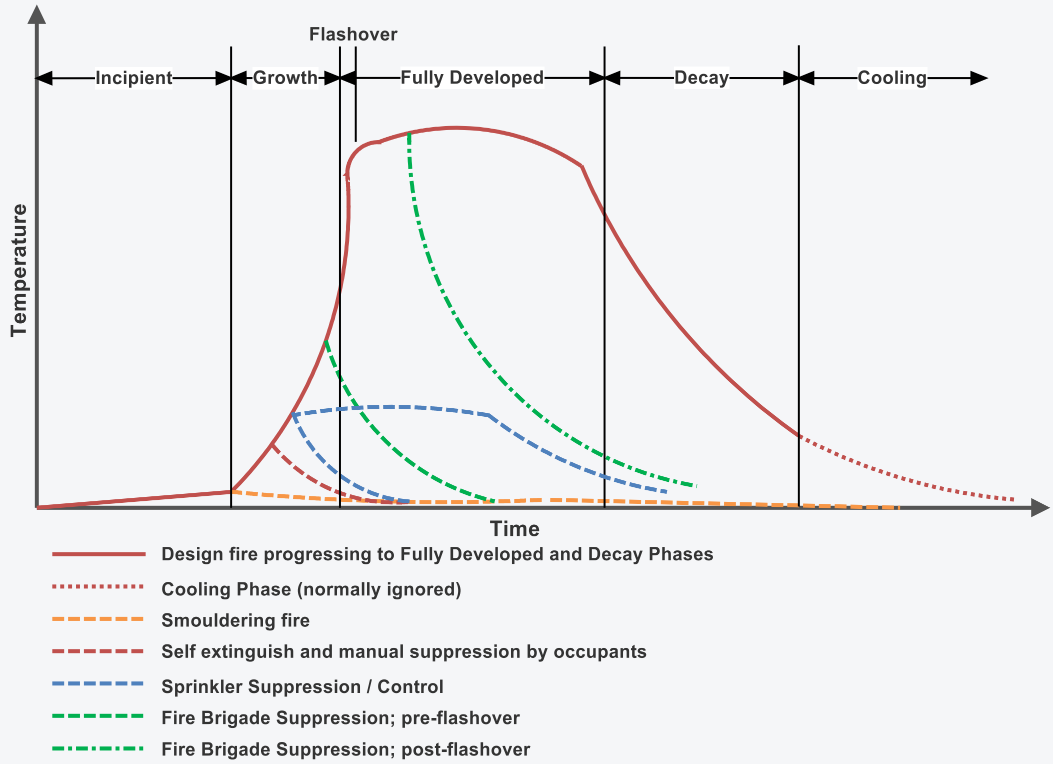


Figure 13: Design Fire Stages and Interventions.

The incipient phase is commonly used for evaluation of a smouldering fire (SF); for example, the SF scenarios in sleeping areas in the NCC Fire Safety *Verification Method* (FSVM) [25]. The exposure of elements of construction during the incipient phase is expected to be negligible and can generally be ignored when modelling the impact of a design fire on an element of construction. However, when undertaking a holistic analysis of a structure, and considering matters such as occupant evacuation and fire brigade intervention, it may be appropriate to determine the probability and timing of detection and alarm during the incipient phase. The incipient phase may also require investigation if there is a risk for fire initiation and spread through concealed spaces.

After the incipient stage, a fire may transition to a flaming fire corresponding to the fire growth stage. The characteristics of the *Design Fire* during this stage can be determined from one or more of the following sources if a performance pathway is followed:

- Full scale enclosure fire tests /experiments
- Furniture calorimeter tests
- Cone calorimeter tests
- Statistical data / fire incidents
- Calculation / fire modelling

Depending on the methods of analysis and *Design Fires* adopted, it may be necessary to quantify the exposure of an element (and its response) to a growing fire although in many calculation methods or fire models the growth phase may be incorporated within a fully developed fire model.

Also shown in Figure 13 are typical interventions by occupants, fire brigade and automatic suppression / control systems (e.g., sprinklers) that can modify the exposure of the element of construction.

Identifying Fire Scenarios for Analysis

There are many fire scenarios / fire scenario clusters that are unlikely to compromise the performance of a structure or structural elements and therefore the required analysis can reasonably be restricted to a limited number of fire scenarios / fire scenario clusters.

For example, in a small or medium sized enclosure a fully developed fire is required in order to challenge the structural adequacy of the elements of construction or structure as a whole but only a proportion of fires will progress to flashover.

Typically, once ignition occurs:

- a fire may simply smoulder and self-extinguish or be suppressed by the occupants
- progress to a small flaming fire but not spread beyond the object first ignited or be suppressed by the occupants
- if an automatic suppression system is provided and operates successfully the fire may be suppressed
- if the fire growth rate is relatively slow and the fire brigade are notified relatively quickly the fire may be manually suppressed before flashover occurs.

If probabilities are determined for these events, it is possible to derive the probability of a flashover fire occurring by means of a simple event tree similar to that shown in Figure 14.

The event tree can be extended to consider the effectiveness of structural fire protection if provided and fire brigade intervention. When defining the effectiveness of structural fire protection systems, it is important to consider the probability and consequences of gross defects such as the omission of protection or substitution with materials providing little protection. These types of gross defects are not adequately modelled by a simple assumption such as a normal distribution but can be addressed either by means of a separate branch in the event tree (scenario cluster) as in the example above or a two-peak distribution as applied in the analysis supporting the mid-rise DTS fire protected timber building solutions in the NCC which is described in more detail in WoodSolutions Design Guide 38 [13].

The probability of fire brigade suppression activities being successful after flashover can be introduced to the event tree. If fire brigade intervention is unsuccessful and the element cannot withstand burnout structural failure will occur.

Generally, with respect to safety of occupants and fire fighters the scenarios involving a gross defect will result in a premature and potentially unexpected failure presenting the greatest hazard to occupants although the probability of occurrence may be low.

To help interpret the results objectively it is generally necessary to undertake a risk assessment so that both the frequency and outcomes can be considered.

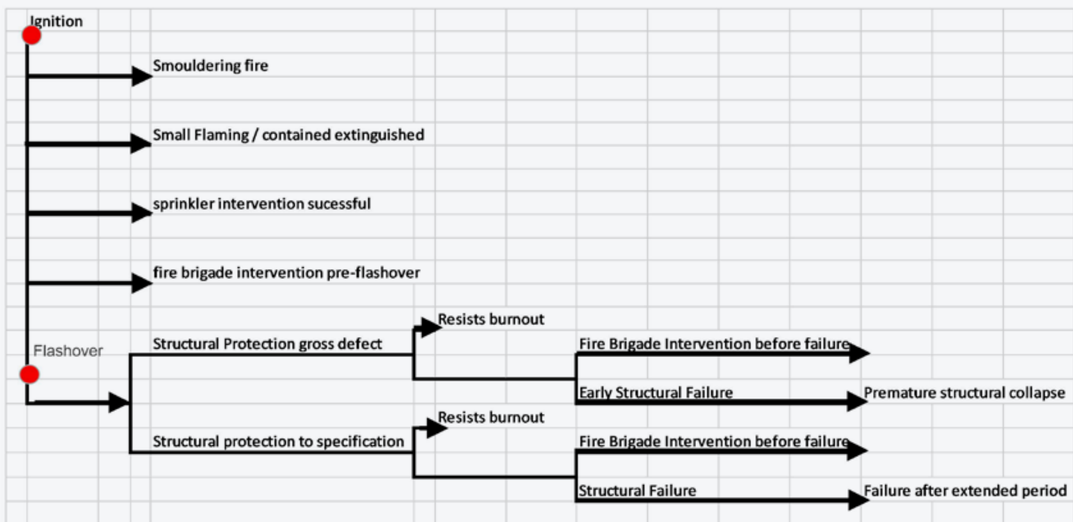


Figure 14: Simple event tree structure for evaluation of structural performance when exposed to fire.

4.3 Heat Transfer

This process uses the fire exposure determined during the first stage to derive a temperature distribution with respect to time for individual elements, sub-assemblies or the whole structure depending upon the design approach adopted.

There are a range of methods available for determining temperature distributions including:

- empirical correlations for simple lumped thermal mass or char rate calculations
- finite element analysis
- application of data from standard fire tests or natural fire experiments.

In some applications char oxidation, char layer contraction and delamination may need to be considered.

The methods should be appropriate to the application under consideration and appropriate validation of the methods undertaken.

Variations in material properties and quality of installations should be accounted for. In some scenarios this may require consideration of major variations representing unauthorised or incorrect substitution of materials or use of inappropriate fixings, for example, to determine the robustness of the overall fire safety strategy. This can be addressed through the consideration of fire scenario clusters as described in Section 4.2.

Further details of heat transfer analysis for timber elements and *Fire-protected Timber* elements exposed to fully developed fires are provided in Technical Design Guide 18.

4.4 Functional Performance

There are a range of methods that can be used to check the functional performance of individual elements, sub-assemblies or the whole structure. In addition to determination of the time to structural failure for elements providing a separating function, criteria relating to integrity and insulation may also apply.

Analysis options include:

- simple hand calculations using prescribed critical temperatures or char rates and effective residual section for timber elements (e.g. AS 1720.4[26] method)
- finite element modelling or calculations using material properties
- application of data from standard fire tests or natural fire experiments

Where necessary, the interaction of elements of construction, including thermally induced deflections and stresses should be evaluated to determine if the structure has adequate robustness. Detailed modelling of the whole or major parts of the structure under a range of fire scenarios may be required.

Note: Timber tends to be less prone to thermally induced actions during a fire due to its low coefficient of thermal expansion relative to other common building materials, but care should be taken with detailing timber construction to avoid generating significant thermally induced stresses or where this cannot be avoided the analysis should account for the thermally induced actions.

In some cases, it may be appropriate to either directly apply experimental / fire test data where the heating regime and applied loads are representative of the case under consideration, or the impact of variations can be predicted based on fire engineering principles.

Applied Loads for the Fire Limit State

The structural loading of elements of construction under fire limit state conditions is prescribed in AS 1170.0 [27] which requires the design actions (loads) for the fire limit state to be determined based on the following actions:

$G + \psi_l Q +$ (thermal actions arising from the fire) where:

G is the permanent action (dead load including self-weight)
Q is the imposed action (live load)
ψ_l is the long-term factor (0.4 for residential, offices, parking, and retail and 0.6 for storage and other occupancies).

Further details of determination of the functional performance of timber elements are provided in Technical Design Guide 18.

4.5 Determination of default loading for fire tests

It is common practice for test sponsors to nominate test loading for specimens when undertaking fire resistance tests on loadbearing elements of all types of material. In many cases the test loads are calculated using relevant structural design codes and characteristic material properties but the basis of the derivation of the test load is often not clearly stated in test reports other than to note the applied load was nominated by the test sponsor.

It is useful to express a fire test load (or design load capacity under fire conditions determined by calculation) in terms of the ratio of the fire test load to the design capacity of the member under “normal use (ambient) conditions” This load ratio can be used to compare loading levels simplifying the process of interpreting test results (*Evidence of Suitability*) for relevant structural design codes and the National Construction Code.

Design Codes for other structural materials such as AS4100 [28] use the ratio of design action on the member under design load for fire to the design capacity of the member at room temperature to determine load levels for testing and or analysis.

A similar approach can be adopted for timber elements but under Australian design codes (e.g.AS 1720.1 [29]) the design capacity of a member at room temperature varies with the load duration factor (k_1). This was identified by Nicholls [30] who observed that in order to compare load cases and determine load levels for fire testing, it was necessary to take into account the duration of load factor for strength (k_1) in addition to the load combinations required to be considered by AS/NZS 1170.0 [27]. The original approach proposed by Nicholls has been further developed and is described in this section.

To provide a benchmark that is independent of the load duration factor, the load duration independent design capacity R_b is determined by calculating the design capacity in accordance with AS 1720.1 at ambient conditions assuming $k_1 = 1$ which will be designated as the ***ambient benchmark design capacity***.

The action (or load) that can be resisted in the fire situation can be expressed as a proportion of the ambient benchmark design capacity and is represented by the symbol LR_{fb}. The appropriate value of LR_{fb} is now determined taking into account potential load combinations and the load duration factors given in AS 1720.1

Load Cases for Load Duration factors.

Table G1 from AS 1720.1-2010 [29] provides load duration factors for typical load combinations for the strength limit state. Table 6 is an extract from Table G1 of AS 1720.1 with wind and earthquake actions excluded.

Table 6: Load Duration factors For Typical Load Combinations for Strength Limit State from AS 1720.1 [29].

Type of load (action)	AS/NZS 1170.0 specified load combination*	Load duration factor	
		Solid Timber	Joints
Permanent action (dead load)	1.35 G	0.57	0.57
Permanent and short-term imposed actions	1.2 G +1.5 Q		
(a) Roof live load—Distributed		0.94	0.77
(b) Roof live load—Concentrated		0.97	0.86
(c) Floor live loads— Distributed		0.80	0.69
(d) Floor live loads— Concentrated		0.94	0.77
Permanent and long-term† imposed action	$1.2\ G + 1.5\ \psi_l Q$	0.57	0,57
Fire	$G + \psi_l Q$	0.94	0.77

** The notation used in this Table is drawn from AS/NZS 1170.0.*

† Long-term in this context is the terminology in AS/NZS 1170.0 for the quasi-permanent component of imposed action.

Determination of Default Fire Test Load Conditions

The derivation of default fire test load conditions has been demonstrated below.

The following cases will be considered:

Case	Description	Load combination	k_1
1	Permanent action (dead load)	1.35 G	0.57
2	Permanent and short term-imposed actions	1.2 G +1.5 Q	0.8 - 0.97
3	Permanent and long-term imposed action	$1.2\,G + 1.5\,\psi_l Q$	0.57
	Fire	$G + \psi_l Q$	0.94

ψ_l = 0.4 (from Table 4.1 of AS/NZS 1170.0:2002 [27] for residential, offices and retail buildings and 0.6 for other building uses).

AS 1720.1 requires member capacity for various design actions to be determined as follows and should be greater than the design action or applied load

$Rd = \Phi\, k_{mod}\, f'_o\, X \geq G + \psi_l Q$

Where:

R_d = the design capacity
Φ = capacity factors
k_{mod} = product of modification factors
$f'_o\, X$ = characteristic capacity appropriate to the action effect

Capacity factors and modification factors other than load duration factor (k_1) are generally the same for ambient temperature and fire design cases and will not therefore influence the load ratio LR_{fb}.

Therefore, the maximum capacity for fire for determining the LR_{fb}.ratio will be:

$(G + \psi_l Q)/k_1$, or

$(1+0.4\alpha)$ G/ 0.94, assuming k_1=0.94, ψ_l = 0.4 and α=Q/G

Case 1 Permanent action dead load only

The maximum design load under ambient conditions (R_b) occurs when:

$1.35G = R_b \times 0.57$
Therefore $R_b = 1.35G / 0.57 \approx 2.37G$
The maximum load condition under fire conditions = $(1+0.4\alpha)$ G/ 0.94
Therefore $LR_{fb} \approx (1+0.4\alpha) / 0.94/2.37 = (1+0.4\alpha) / 0.397$

The LR_{fb} ratio with the ratio of live to dead loads is plotted for a range of Q / G ratios in Figure 15.

Case 2 Permanent and short term-imposed actions

The maximum load condition under ambient conditions occur when:

$1.2\,G + 1.5\,Q = R_b \times 0.8$

If the ratio of Q/G = α

$(1.2+1.5\,\alpha)\,G = 0.8\,R_b$

Therefore $R_b = (1.2+1.5\,\alpha)\,G / 0.8$

$LR_{fb} = (1+0.4\,\alpha)\,G / 0.94\,((1.2 +1.5\,\alpha)\,G / 0.8)$

$= 0.8\,(1+0.4\,\alpha) / 0.94\,(1.2+1.5\,\alpha)$

The LR_{fb} ratio with the ratio of live to dead loads is plotted for a range of Q / G ratios in Figure 15.

Case 3 Permanent and long-term imposed action

The maximum load condition under ambient conditions occur when:

$1.2\,G + 1.5 \times 0.4 \times Q = R_b \times 0.57$

If the ratio of Q/G = α

$(1.2+0.6\,\alpha)\,G = 0.57\,R_b$

Therefore $R_b = (1.2+0.6\,\alpha)\,G / 0.57$

$LR_{fb} = (1+0.4\,\alpha)\,G / 0.94\,((1.2+0.6\,\alpha)\,G / 0.57)$

$= 0.57\,(1+0.4\,\alpha) / 0.94 / (1.2+0.6\,\alpha)$

The LR_{fb} ratio is plotted for a range of Q / G ratios in Figure 15

Critical Load Combinations

Typically, when undertaking a design for ambient temperatures the design capacity will be checked for the relevant cases which will typically include cases 1 to 3. For design at ambient temperatures the critical load case for determining the design capacity of a member will be the one that applies the greatest design action and hence load. The critical design case can vary with the ratio of live to dead load when each case is also divided by the k_1 value shown in Table 6 appropriate for that load case..

For all cases the structural loading for fire conditions is the same; i.e. $(1+\psi_l\,\alpha)$ G, k_1=0.94

LR_{fb} is proportional to the ratio of imposed load when exposed to fire conditions (divided by k_1) over the design capacity or maximum applied design load under each of the ambient condition load cases (divided by k_1).

Therefore, the critical case for design at ambient temperatures, (i.e. the case that applies the greatest load under ambient conditions) will yield the lowest LR_{fb} ratio which is shown as the solid grey line in Figure 15.

This yields a maximum load ratio (LR_{fb}) of 0.494 which has been rounded to 0.5 to provide a maximum value for determination of fire test loads. Case 2 was also checked using a k_1 value for structural design of 0.97 in lieu of 0.8 which will not increase the minimum LR_{fb} above 0.494.

A LR_{fb} value of 0.5 will be conservative in many applications particularly where the sizing of structural elements is dominated by factors such as serviceability rather than load capacity. The option for test sponsors to specify other load levels for specific applications should therefore be retained but the LR_{fb} ratio should be clearly stated to avoid confusion.

Examples have been provided in Appendix C of two common end conditions to demonstrate the importance of clearly defining the end conditions to calculate the appropriate test load.

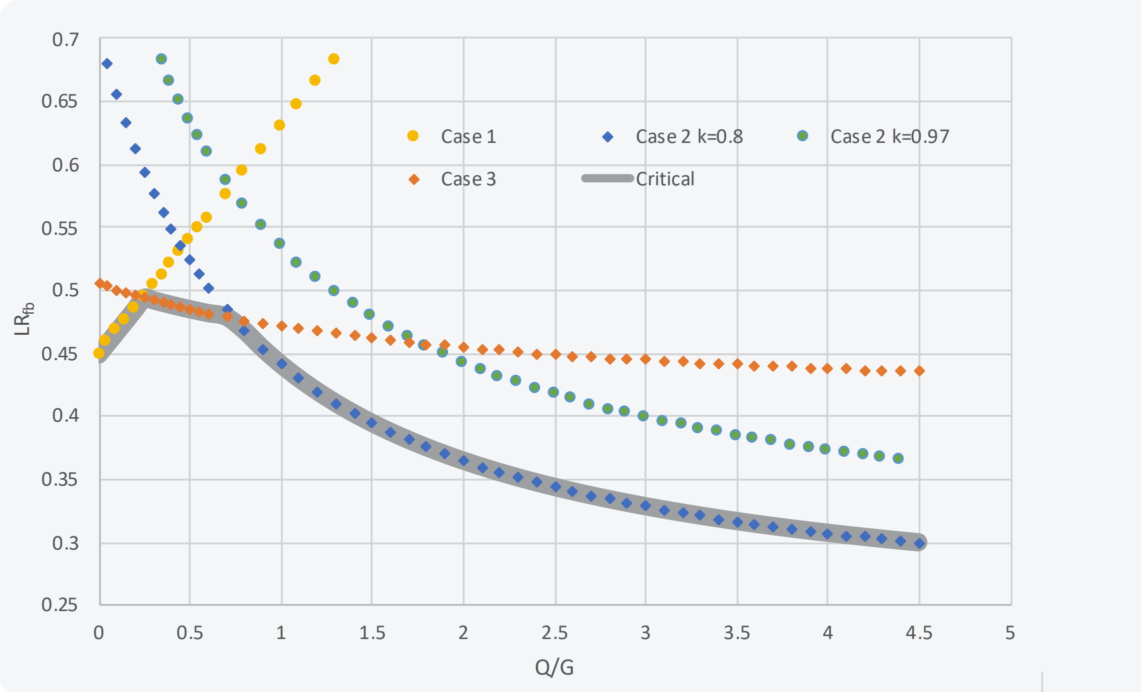


Figure 15: LR^{fb} ratio plotted against the ratio of live to dead loads (Q / G).

Default Load Ratio for Fire Testing

Where a fire test is being undertaken for general application, unless the design loads under fire conditions can be clearly defined, the following approach is recommended for structural elements

To provide a benchmark that is independent of the load duration factor, the load duration independent design capacity R_b is determined by calculating the design capacity in accordance with AS 1720.1 at ambient conditions assuming k_1 = 1 which will be designated as the ambient benchmark design capacity.

LR_{fb} is the ratio of design action or fire test load applied to the element to the ambient benchmark design capacity.

For general application of fire test data load-bearing elements should be fire tested at a load ratio (LR_{fb}) of at least 0.5

5

Assessment Methods for Performance Solutions

5.1 Fire Spread between Buildings

Performance Requirements and DTS Solution

The *Performance Requirement* that relates directly to fire spread is CP2 (see text box below for an extract from NCC Volume One: 2019) and sub-clause CP2(a)(iii), which has been highlighted in a bold font, specifically relates to fire spread between buildings:

CP2 Spread of fire

(a) A building must have elements which will, to the degree necessary, avoid the spread of fire—
(i)to exits; and
(ii)to sole-occupancy units and public corridors; and
(iii)between buildings; *and*
(iv)in a building.

(b) Avoidance of the spread of fire referred to in (a) must be appropriate to—
(i)the function or use of the building; and
(ii)the fire load; and
(iii)the potential fire intensity; and
(iv)the fire hazard; and
(v)the number of storeys in the building; and
(vi)its proximity to other property; and
(vii)any active fire safety systems installed in the building; and
(viii)the size of any fire compartment; and
(ix)fire brigade intervention; and
(x)other elements they support; and
(xi)the evacuation time.

The above text is derived from performance requirement CP2 provided by the Australian Building Codes Board © 2020. The original content is provided in the NCC 2019 Ammendment 1

The development of a *Performance Solution* which impacts on the risk of fire spread between buildings is not straight forward because the nature of the hazard from buildings and vulnerability of buildings on the same or adjacent allotments may change independently from the subject building (the building for which the *Performance Solution* is being developed). For example, an adjacent allotment may be unoccupied when a *Performance Solution* is being verified but subsequently a new building may be built on the adjacent allotment.

It is therefore necessary to take account of potential developments within the allotment boundaries and on adjacent allotments. Various methods have been adopted internationally and all methods have their strengths and weaknesses.

In Australia this is addressed through the DTS pathway, by specification of non-combustible construction for external walls for high rise and medium buildings (Type A and Type B construction respectively) together with prescribed separation distances (from adjacent buildings on the same allotment and from allotment boundaries), limitations placed on unprotected openings in external walls supplemented by other general measures such as specification of automatic sprinklers in all buildings above 25m effective height.

Verification Methods CV1 and CV2

Verification Methods CV1 and CV2 provide a means of addressing the uncertainty regarding further developments if the performance pathway is followed. *Verification Methods* CV1 and CV2 place controls on the heat flux the subject building is permitted to impose on an adjacent building, as well as the heat flux that the subject building is required to resist from adjacent structures. To address potential hazards outside the subject building's allotment boundaries, heat flux limits are specified relative to the boundary position in Table CV1 in the NCC; whilst the limits relating to buildings on the same allotment are specified in Table CV2 of the NCC. For convenience Tables CV1 and CV2 have been consolidated in Table 7 below:

Table 7: Limiting Heat Fluxes for verifying Compliance with CP2(a) (iii) (consolidation of NCC Tables CV1 and CV2. *The original content was provided by the Australian Building Codes Board © 2020 from NCC 2019 Amendment 1*

Column 1	Column 2	Column 3
Distance from Boundary (m)	Distance between buildings on the same allotment (m)	Limiting heat flux(kW/m^2)
0	0	80
1	2	40
3	6	20
6	12	10

CV1 indicates compliance with CP2(a)(iii) has been verified when it is calculated that -

(a) a building will not cause heat flux in excess of those set out in Column 3 of Table 7 at the location on an adjoining property set out in Column 1; and

(b) when located at the distances from the allotment boundary set out in Column 1 of Table 7, a building is capable of withstanding the heat flux set out in Column 3 without ignition.

CV2 indicates compliance with CP2(a)(iii) to avoid the spread of fire between buildings on the same allotment has been verified when it is calculated that -

(a) a building is capable of withstanding, without ignition, the heat flux set out in Column 3 of Table 7 at the distance set out in Column 2 from a building on the same allotment; and

(b) a building will not cause heat flux in excess of those set out in Column 3 of Table 7 when the distance between the buildings on the same allotment is set out in Column 2.

The fire safety engineer still has to determine appropriate inputs which should be agreed with the *Appropriate Authority(ies)* and other relevant stakeholders on the PBDB team. Typical required inputs include:

- the size and intensity of the fire source from the subject building is required to calculate the incident heat flux on an adjacent building or allotment. This generally requires consideration of fire dynamics within the fire compartment, the effectiveness of compartmentation, and the additional exposure from a plume extending beyond the compartment together with fire propagation over the façade of the building if combustible cladding materials are used. If fire spread between floors occurs or other failures of internal compartmentation occur multiple fire sources may need to be considered.
- the likely exposure period and time to ignition when determining if ignition will occur when a building is exposed to the nominated incident heat fluxes. Above a critical heat flux of nominally 10-12.5kW/m^2, exposed timber products may ignite with the time to ignition varying with the incident heat flux, potential ignition sources and material properties of the target material.
- assessed levels of reliability of fire safety preventing fire spread between buildings. Acceptable probabilities of fire spread between buildings have been included as a metric in the draft quantification of the *Performance Requirements,* released for public comment in May 2021.

Note: Material properties and methods for predicting ignition times are available in Wood Solutions Technical Design Guide 18 - Fire Safe Design of Timber Structures - Methods of Analysis and Supporting Data (2021) and from the WoodSolutions website. Data sources and information relating to enclosure fire tests are also provided in Technical Design Guide 18.

Appendix C of AS 5113 [31] includes a test method that exposes external wall elements to radiant heat flux which can be used for the assessment of building to building fire spread.

When checking whether a subject building will cause heat fluxes greater than those listed in Column 3 of Table 7, the incident heat flux at each distance should be checked.

When checking whether a subject building can withstand the heat fluxes listed in Column 3 of Table 7, the distance from a boundary or adjacent building on the same allotment may lie between the nominated distances in columns 1 and 2. No guidance is provided within the NCC with respect to interpolation of values for buildings located at intermediate distances although various approaches have been suggested including:

- the use of a standardised heat source,
- simple linear interpolation, or
- conservatively rounding down the distance to the next value in Table 7.

If it is necessary to consider intermediate distances, the relevant fire safety engineer will need to justify the approach taken.

Where existing buildings are located close to the subject building, the analysis should also check the risks of fire spread to, or from, the subject building with respect to adjacent existing buildings since the existing buildings and separation distances may not comply with current NCC provisions.

5.2 Fire spread via external walls

Performance Requirements and DTS Solution

The Performance Requirement that relates directly to fire spread is CP2 with subclauses CP2(a)(iii) and CP2(b)(iv) having relevance to external walls. (Refer to the text box in Section 5.1 for an extract of CP2).

The NCC DTS pathway primarily addresses fire spread via external walls by means of the use of non-combustible materials and physical separation of openings within external walls using spandrel panels, horizontal projections, or separation distances to reduce the risk of a fire spreading between floors via an external fire plume for mid-rise and high rise buildings of Type A or B construction

Openings between the slab perimeter and curtain walling are also required to be fire protected to reduce the risk of early fire spread inside curtain walling.

Concessions allow the use of fire protected timber for external walls and relax the requirements for spandrel panels and horizontal projection provisions under the DTS pathway for some sprinkler protected buildings; but protection at the perimeter of the slab to the face of curtain walling is still required.

If the fire separation between levels of the building is insufficient and automatic sprinkler systems are not provided or are ineffective, external fire spread to an upper level can occur as shown in Figure 16. Without intervention, the secondary fire may develop to a fully developed fire and the process may be repeated leading to progressive fire spread to multiple floors. This process is sometimes referred to as leapfrogging.

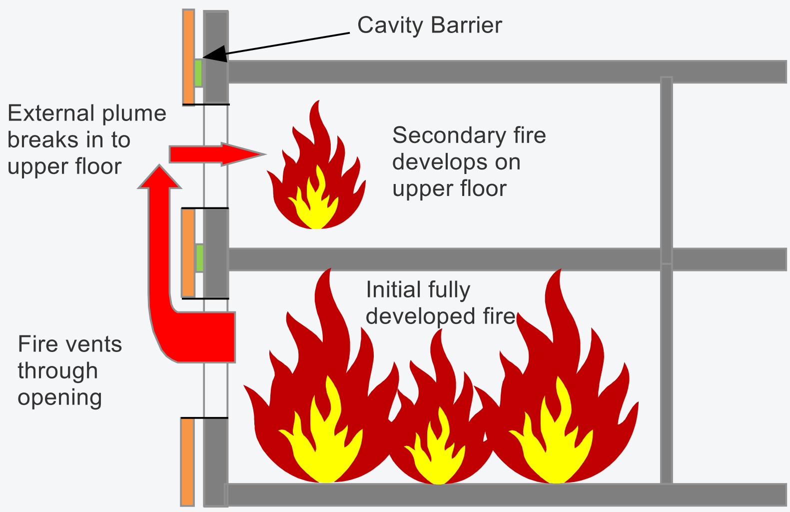


Figure 16: Fire Spread via a plume from a fully developed fire.

In configurations where the fire resistant floor slabs do not extended through the external wall, cavity barriers are required. If these cavity barriers are missing or faulty, fire and smoke spread to the level above can occur rapidly between the slab edge and external facade as shown in Figure 17.

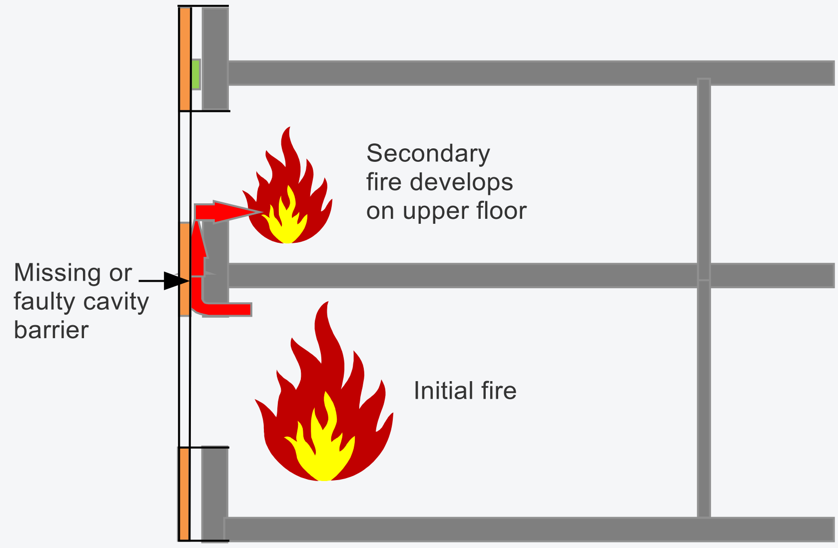


Figure 17: Fire spread path if fire protection at slab perimeter is inadequate.

Combustible External Walls and CV3

The risk of external fire spread can increase if combustible cladding systems are used without appropriate mitigation measures and this has been highlighted by many recent major fires involving combustible facades that facilitated rapid spread between floors of high-rise buildings.

For example, if high risk combinations of materials are used, rapid fire spread over large areas of a building façade can occur potentially breaking into multiple levels prior to full evacuation and overwhelming automatic fire suppression systems. Multiple fires will also compromise the effectiveness of fire brigade intervention. The initial fire source may be external, typically occurring in waste materials at ground level or on balconies in addition to a fully developed fire breaking out of a building.

Typical scenarios are shown schematically in Figure 18

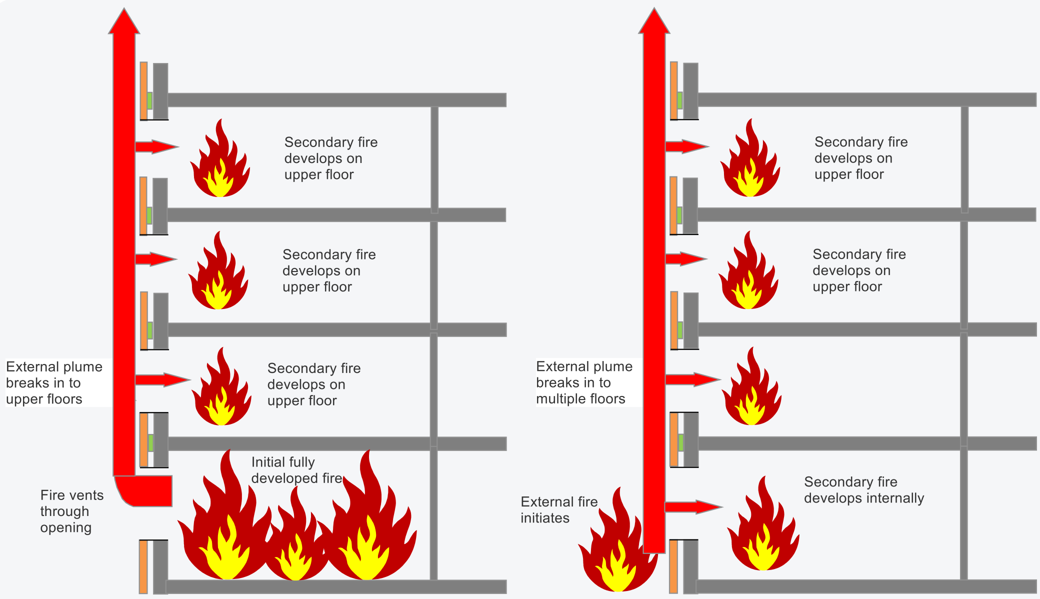


Figure 18: Fire Spread to multiple floors with highly combustible materials forming facade.

The current NCC does not provide *Deemed-to-Satisfy Solutions* for combustible cladding systems

Therefore if, for example, external timber screening is applied to external walls of buildings of Type A or B construction the *Performance Solution* pathway will need to be followed because the timber screening is combustible.

Verification Method CV3 provides a means of demonstrating compliance with CP2(a)(iv) in relation to combustible facades / combustible external walls but other *Assessment Methods* are also permitted.

The text box below is an extract from the NCC 2019 showing CV3 and a brief overview of the *Verification Method* follows:

CV3 Fire spread via external walls

Compliance with CP2 to avoid the spread of fire via the external wall of a building is verified when -

(a) compliance with CP2(a)(iii) to avoid the spread of fire between buildings, where applicable, is verified in accordance with CV1 or CV2, as appropriate; and

(b) the external wall system -

(i) has been tested for external wall (EW) performance in accordance with AS 5113; and

(ii) has achieved the classification EW; and

(iii) if containing a cavity, incorporates cavity barriers and these cavity barriers have been included in the test performed under (i) at the perimeter of each floor; and

(c) in a building of Type A construction, the building is protected throughout by a sprinkler system (other than a FPAA101D or FPAA101H system) complying with Specification E1.5 and has -

(i) sprinkler protection to balconies, patios and terraces, and where overhead sprinkler coverage is not achieved alongside the external wall, sidewall sprinkler heads are provided at the external wall for the extent of the balcony, patio, or terrace where overhead sprinkler coverage is not achieved; and

(ii) for a building with an effective height greater than 25 m -

(A) monitored stop valves provided at each floor level arranged to allow the isolation of the floor level containing the stop valve while maintaining protection to the remainder of the building; and

(B) the sprinkler system being capable of providing sufficient flow to serve the design area required by AS2118.1 for the relevant hazard class on each floor level plus the design area required by AS 2118.1 for the floor level above, except where the former level is -

(aa) the floor level below the uppermost roof; or

(bb) any floor level that is wholly below ground; and

(d) in a building of Type B construction, the building is -

(i) a Class 5, 6, 7 or 8 building or Class 4 part of a building; or

(ii) a Class 2, 3 or 9 building that -

(A) is protected throughout by a sprinkler system (other than a FPAA101D or FPAA101H system) complying with Specification E1.5; or

(B) has any openings in external walls separated by a slab or other horizontal construction complying withC2.6(a)(iv) as if the building were of Type A construction.

Clause (a) applies to the spread of fire between buildings rather than vertical fire spread via the external wall and requires *Verification Methods* CV1 and / or CV2 to be applied. Combustible materials may increase the radiant heat emitted from a building fire and potential for direct flame impingement if buildings are close together. Combustible materials are also susceptible to ignition if a major fire occurs in an adjacent building unless adequately protected or adequate separation distances from fire sources are provided. Refer to Section 5.1 for further information relating to CV1 and CV2.

Clause (b) requires that the external wall system to be tested for external wall (EW) performance in accordance with the requirements of AS 5113 [31] and achieve the EW classification.

CV3 differs from many other *Verification Methods* in the NCC in that it places a heavy reliance of a large-scale fire tests rather than calculations when carrying out the analysis and evaluation phases; although significant expert / engineering judgement will be required to ensure that the test is representative of the proposed installation.

AS 5113:2016: Classification of External walls of buildings based on reaction-to-fire performance, nominates appropriate test methods and specifies the required performance criteria that have to be satisfied to achieve the EW classification.

Fire tests can be performed to ISO 13785-2[32] or the BS8414 series [33, 34]. Generally, the BS8414 test methods are adopted since a number of accredited testing laboratories in Australia have facilities to test to BS 8414. However it should be noted that the AS 5113 test and performance criteria vary significantly from the criteria specified in the UK by Approved Document B [35] through reference to BR135 [36]. For example, AS 5113 specifies;

- performance criteria that apply throughout the 60 minute test duration
- criteria to debris falling from the test specimen
- more stringent criteria with respect to fire spread / incipient spread of fire.

The AS 5113 performance criteria for tests performed to BS8414 are summarised in Table 8 together with the intent of the criteria

Table 8: AS 5113 Criteria and Intent.

Intent:	Criteria
Reduced risk of fire spread to two or more levels above the floor of origin	Temperature 50mm from façade, 5m above opening shall not exceed 600°C
Reduced risk of incipient spread of fire to two or more levels above the floor of origin	Internal temperatures of materials and cavities 5m above opening shall not exceed 250°C
Reduced risk of fire spread to two or more levels above the floor of origin and lateral flame spread	Flame spread must not extend beyond the nominated specimen size
Reduce risk of fire spread to floors below	Continuous flaming on the ground for more than 20s from debris or molten material shall not occur
Control of debris falling from the test specimen	Total mass of debris shall not exceed 2kg
Reduce risk of fire spread to the floor above through wall if not fire resistant	Non-fire side temperatures measured 900mm above the opening shall not rise by more than 180K, flaming on the non-fire side should not occur and through openings should not occur

Clause (c) Applies to Type A construction (mid- and high-rise buildings) and additionally requires sprinkler protection including protection of balconies. For buildings with an effective height greater than 25m, additional enhancements to fire sprinklers are specified to enhance both the reliability of the sprinkler system and reduce the probability of the sprinkler system being overrun if fire spread to the next floor occurs.

Clause (d) applies to Type B construction (low-rise buildings) and for Class 2, 3 or 9 buildings requiring either sprinkler protection or having any openings in external walls separated by a slab or other horizontal construction complying withC2.6(a)(iv) as if the building were of Type A construction.

Notwithstanding the direct application of a fire tested system and additional mitigation measures specified in CV3, the fire safety engineer should consider the applicability of tested systems to the specific installation and the holistic design of the building to determine if any further mitigation measures are required and nominate requirements for commissioning and ongoing maintenance of fire safety systems.

In addition to information on data and methods in WoodSolutions Design Guide 18 useful information relating to the exposure of facades from mass timber compartment fires and a comparison with standard test method exposures, including BS8414, has been published by Brandforsk. (Sjöström [37])

5.3 Fire Safety Verification Method (CV4 / DV4 / EV1.1)

Verification Method CV4 / DV4 EV1.1 is also known as the Fire Safety *Verification Method* (FSVM) and is included in Schedule 7 of the NCC. It provides a process for the design and assessment of fire safety *Performance Solutions*. Whereas other fire safety *Verification Methods* (CV1-CV3) focus on specific applications such as spread of fire between buildings, the FSVM is suitable for general application and adopts a holistic approach to fire safety which is consistent with the structure of the NCC *Performance Requirements*. This is recognised by the *Verification Method* being cross-referenced in Sections C, D and E.

For further detail, reference should be made to the Fire Safety *Verification Method* Handbook [25] and supporting Annex[16] which includes data sheets providing useful supporting data and descriptions of methods.

The FSVM applies the following *Governing Requirements* to provide a *Verification Method* that is consistent with NCC compliance pathways for Performance Solutions;

- The concept of equivalence is applied whereby a similar (reference building) complying with the *DTS Provisions* is defined and the level of safety for the Proposed Performance Solution must be at least equivalent to that of the reference building. This approach provides a quantifiable benchmark against which compliance of a *Performance Solution* can be verified once the appropriate reference building has been selected.
- The FSVM must only be used by a *professional engineer* or other appropriately qualified person recognised by the *Appropriate Authority* as having qualifications and/or experience in the discipline of fire safety engineering. Thus, the *Evidence of Suitability* for the total fire safety strategy will be in the form of a report from a professional engineer consistent with other pathways for *Performance Solutions.*

The FSVM specifies a minimum of twelve design scenarios for consideration that are described in Table 9. Each design scenario is considered in one or more locations to compare the proposed solution against a reference building complying fully with the NCC DTS requirements and that is considered by the PBDB stakeholders to provide an acceptable level of safety.

This approach ensures that common critical design scenarios are considered but does not prevent additional design scenarios being considered if they are identified during the PBDB process.

Table 9: NCC Fire Safety Verification Method Design Scenarios. *This table is a derivative of Schedule 7 of the NCC 2019 Amendment 1 provided by the Australian Building Codes Board © 2020. (https://ncc.abcb.gov.au/)*

Ref	Design Scenario	Design Scenario Description
BE	Fire blocks *evacuation route*	A fire blocks an *evacuation route*
UT	Fire in a normally unoccupied room threatens occupants of other rooms	A fire starts in a normally unoccupied room and can potentially endanger a large number of occupants in another room
CS	Fire starts in concealed space	Flame spread must not extend beyond the nominated specimen size
	A fire starts in a concealed space that can facilitate fire spread and potentially endanger a number of people in a room	Continuous flaming on the ground for more than 20s from debris or molten material shall not occur
SF	Smouldering fire	A fire is smouldering in close proximity to a sleeping area
IS	Fire spread involving internal finishes	Interior surfaces are exposed to a growing fire that potentially endangers occupants
CF	Challenging fire	Worst credible fire in an occupied space
RC	Robustness check	The objectives of the NCC should be satisfied if failures of a critical parts of the fire safety systems fail
SS	Structural Stability and other properties	Building does not present risk to other properties in a fire event. Consider risk of structural failure
HS	Horizontal fire spread	A fully developed fire in a building exposes the external walls of a neighbouring building (or potential building) and vice versa
VS	Vertical fire spread involving cladding or arrangement of openings in walls	A fire source exposes a wall and leads to significant vertical fire spread
FI	Fire brigade intervention	Facilitate fire brigade intervention to the degree necessary
UF	Unexpected Catastrophic Failure	A building must not unexpectedly collapse during a fire event

The fire safety *Verification Method* process is shown in Figure 19 which has been extracted from the FSVM Handbook. Essentially the process is broken down into two stages the (1) Performance Based Design Brief and the (2) Performance Based Design Risk Assessment (Report). Each of these stages and the individual processes are described in detail in the Handbook.

Further data and worked examples demonstrating the use of the FSVM for timber structures are provided in the following WoodSolutions Technical Design Guides

- Wood Solutions Technical Design Guide 18 Fire Safe Design of Timber Structures - Methods of Analysis and Supporting Data (2021)
- Wood Solutions Technical Design Guide 19 Fire Safe Design of Timber Structures - Worked Examples of *Performance Solutions* (2021)

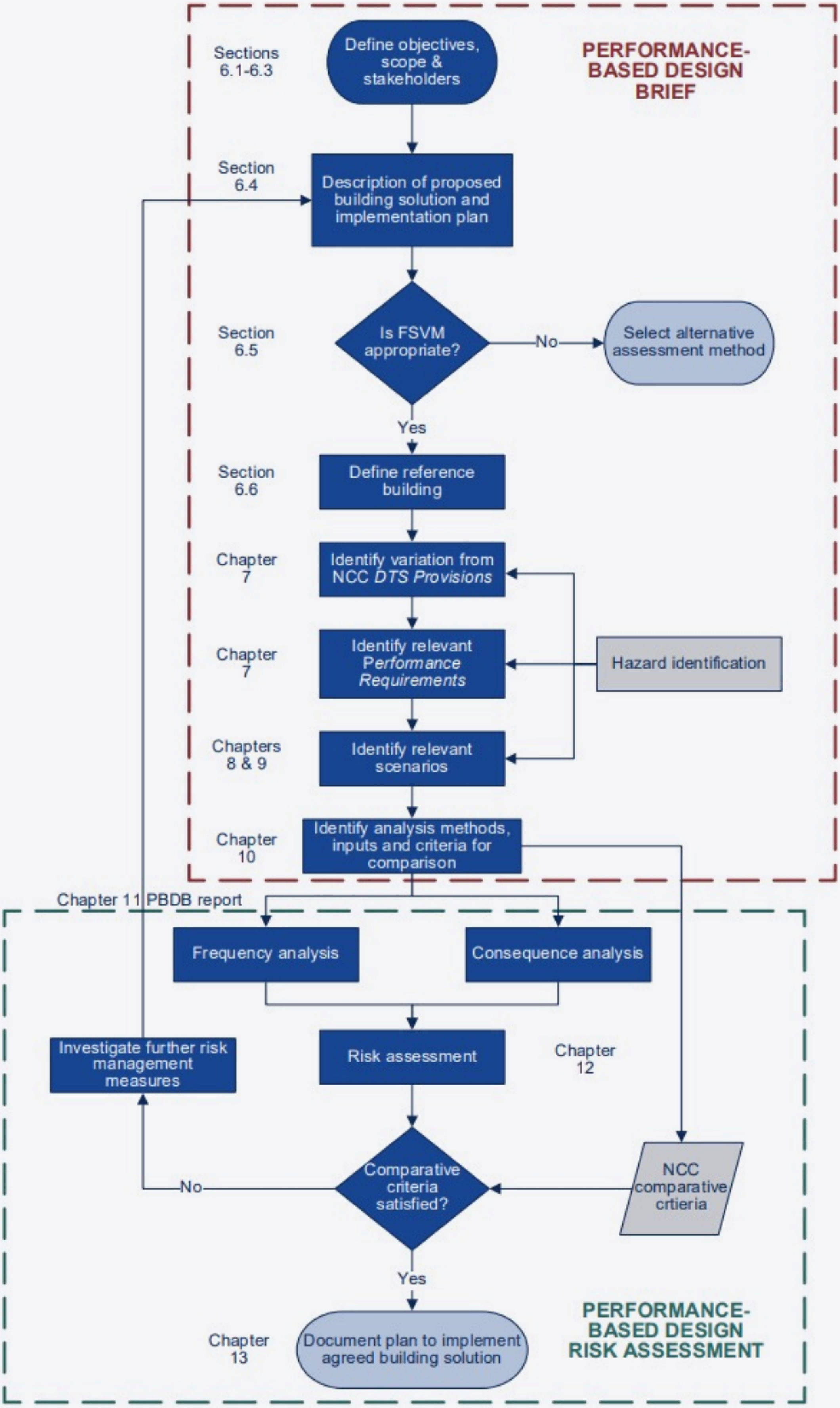


Figure 19 Fire Safety Verification Method Process (from the Fire Safety Verification Method Handbook). *The FSVM process flow chart was provided by the Australian Building Codes Board © 2019. Original content hosted on the ABCB website. (https://ncc.abcb.gov.au/sites/default/files/resources/2020//Handbook_Fire_Safety_Verification_Method.pdf)*

5.4 Absolute Assessment and Quantification of NCC Performance Requirements.

The NCC adopts a holistic approach to fire safety based on early work on a fire safety system approach described by Beck [11, 38, 39], the Draft National Safety Systems Code [40] and various Fire Code Reform Centre projects which informed the development of the performance based Building Code of Australia (NCC); and subsequent fire safety engineering guides prepared in Australia and internationally.

The holistic approach to fire safety recognises that the optimum fire safety solution for a building can only be identified by considering the interactions between fire safety sub-systems such as passive fire protection / structural design, active fire protection systems, fire brigade intervention and occupant behaviour and response etc.

It is therefore necessary for any quantification of the fire related Performance Requirements to be expressed in terms that facilitate holistic approaches to enable optimum solutions to be developed that are compatible with other design drivers and constraints.

It is planned to include quantified *Performance Requirements* for fire safety in the NCC 2022 and draft quantified *Performance Requirements* were released for public comment in May 2021 in the Public Comment Draft of the NCC 2022 [41]. A brief overview of the proposed approach is described below but it should be noted that these provisions may be subsequently modified after public comment. The copyright for the information, from which the information below has been derived, is owned by the Commonwealth of Australia and published by the Australian Building Codes Board © 2021.

Essentially there are two categories of criteria relating to:

- Life Safety; and
- Fire Spread

with the criteria for both categories requiring to be satisfied.

Quantified Life Safety Criteria

With respect to life safety, criteria are expressed in terms of tolerable individual and societal risks with upper and lower limits being specified.

If the lower tolerable limits (individual and societal) are not exceeded by the proposed Performance Solution, the individual and societal risk criteria can be considered to be satisfied.

If the upper tolerable limits (individual or societal) are exceeded by the proposed Performance Solution, the individual or societal risk criteria have not been satisfied and modifications to the proposed solution will be required.

If the individual and / or societal risks presented by the proposed *Performance Solution* lie between the lower and upper allowable risk limits, the proposed *Performance Solution* can be considered to meet the *Performance Requirements* for life safety, if it can be demonstrated that the individual and / or societal risk presented by the *Performance Solution* is less than or equal to that presented by a similar Deemed-to-Satisfy compliant reference building that is considered to represent a tolerable risk.

The following list identifies matters for consideration when undertaking the risk assessment and, whilst it is not definitive, it provides a useful check of some of the more common parameters that must be considered.

A comparison with the Performance Requirements in the NCC 2019 edition shows that the majority of the parameters are included within the current Performance Requirement structure but are consolidated into a single list.

(a) hazards, building characteristics and occupant characteristics including—

- (i) function or use of the building; and
- (ii) fire load; and
- (iii) potential fire intensity; and
- (iv) height of the building; and
- (v) number of storeys; and
- (vi) location in alpine areas; and
- (vii) proximity to other property; and
- (viii) size of any fire compartment / floor area; and
- (ix) other elements providing structural support; and
- (x) number, mobility and other occupant characteristics; and
- (xi) travel distance; and
- (xii) exit above and below ground; and

(b) prevention / intervention measures against hazards as applicable including—

- (i) control of linings, materials and assemblies to maintain tenable conditions for evacuation; and
- (ii) occupant intervention using firefighting equipment (fire hose reels and fire extinguishers); and
- (iii) automatic fire suppression; and
- (iv) fire brigade intervention, including- -
  - (A) fire brigade access; and
  - (B) fire hydrants; and
  - (C) fire control centres; and
  - (D) automatic notification of Fire Brigade; and
  - (E) emergency lifts; and

(c) means of managing the consequences, including—

- (i) maintaining building structural stability; and
- (ii) avoiding spread of fire to exits; and
- (iii) protection from spread of fire and smoke to allow for orderly evacuation as appropriate or as part of defend in place strategies or provisions of temporary refuges for occupants requiring assistance to evacuate; and
- (iv) behaviour of concrete external walls in fire; and
- (v) barrier protection from high hazard service equipment; and
- (vi) protection of emergency equipment; and
- (vii) fire protection of openings and penetrations; and
- (viii) provision of exits; and
- (ix) construction of exits; and
- (x) provision of fire isolated exits; and
- (xi) provisions for paths of travel to, through and from exits; and
- (xii) evacuation lifts; and
- (xiii) automatic warning for sleeping occupants; and
- (xiv) safe evacuation routes; options for consideration include one or more of the following if necessary:
  - (A) smoke detection; and
  - (B) smoke management systems; and
  - (C) automatic suppression; and
- (xv) visibility in an emergency including emergency lighting; and
- (xvi) identification of exits including exit signage; and
- (xvii) emergency warning and intercom systems.

Spread of Fire Criteria

The spread of fire criteria were broadly derived from *Verification Methods* CV1 to CV3 and Deemed-to-Satisfy criteria relating to maximum compartment sizes with probability criteria included with the aim of maintaining similar levels of redundancy to current NCC provisions.

The relevant parameters from those identified for life safety should be considered.

It should be noted that both life safety and spread of fire criteria apply and satisfying the spread of fire criteria does not necessarily mean that the tolerable life safety criteria have been satisfied with respect to structural fire resistance for example.

6

NCC Assessment Methods for DTS Solutions and Detailed Documentation of Fire Safety Provisions

6.1 Overview of Assessment Methods for DTS Provisions and Detailed Documentation

Depending upon the compliance pathway, the proposed fire safety strategy will be described in either a Performance-based Design Report or a DTS Design Report which may be incorporated in an early version of a Building Manual. Whichever pathway is selected, the strategy then needs to be translated into detailed documentation for the required fire safety measures supported by *Evidence of Suitability* and *Expert Judgement* as shown in Figure 20.

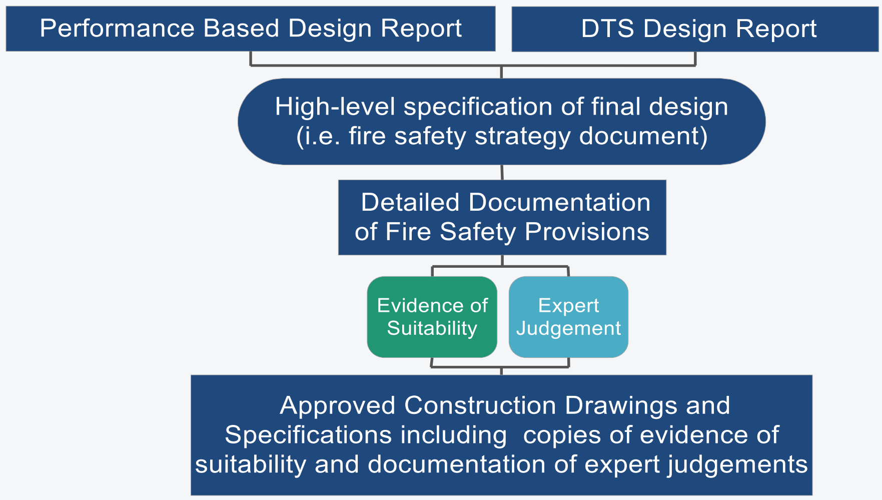


Figure 20: Overview of Procedure for Demonstrating Compliance with the NCC.

The design process for fire resistant timber structural elements is described in Chapter 4. Typically, when adopting the *Performance Solution* pathway, it is necessary to consider the fire dynamics of the compartment fire to determine the fire exposure, undertake heat transfer analysis and then determine the element or structure's functional performance.

Once this stage is undertaken, it is then necessary to specify the products and systems for construction purposes in a manner that is easily understood by product suppliers and installers and that enables the compliance with the specifications to be reliably determined by the design team and appropriate authorities. It is also important to specify the products and systems such that if an installation is damaged, it is possible to source materials that can reinstate the performance and for which appropriate *Evidence of Suitability* can be provided.

A practical way of achieving this is to express the performance of systems using terms, procedures and test methods that are consistent with NCC *DTS Provisions*.

For example, when expressing requirements for fire-protected timber or encapsulation of timber to prevent ignition, the required performance can be expressed in terms of the resistance to incipient spread of fire, non-combustibility, and the fire resistance performance of the protected timber member. Where consideration of delamination or self-extinguishment of exposed timber is a critical criterion, the fire exposure may be expressed in terms of an equivalent fire resistance test exposure / low oxygen concentration for a ventilation controlled fire followed by a controlled cooling rate with higher oxygen concentrations simulating transition to a fuel controlled regime with a greater tendency to support smouldering combustion. Further information on treatments of delamination and self-extinguishment are provided in Design Guide 18.

The remainder of this chapter focusses on specification of timber-based materials and elements of construction using Evidence of Suitability in a manner consistent with the following NCC DTS Provisions.

- A5.4 / Schedule 5 Fire-resistance of building elements
- A5.6 Resistance to the Incipient Spread of Fire
- Specification C1.13a Fire Protected Timber Requirements
- A5.5 Fire hazard properties
- Schedule 2 Definition of Non-Combustible

6.2 A5.4 / Schedule 5 Fire Resistance of Building Elements

Application and Definitions

Clause A5.4 of the *Governing Requirements* requires that the Fire Resistance Level (FRL) must be determined in accordance with Schedule 5 if the *Deemed-to-Satisfy* pathway is adopted. Where a *Performance Solution* can specify the fire resistance performance of an element in terms of an FRL, clause A5.4 should be applied.

Note: Where the resistance to fire of elements of construction is not expressed in terms of FRL, appropriate means of independent verification of performance should be specified (including performance criteria)

The definitions in the text box below (from NCC 2019 [3]) are relevant to the following discussion:

Fire-resisting-

- *For the purposes of Volume One, applied to a building element, means having an FRL appropriate for that element.*
- *For the purposes of Volume Two, applied to a structural member or other part of a building, means having the FRL required for that structural member or other part.*

Fire-resistance level (FRL) *means the grading periods in minutes determined in accordance with Schedule 5, for the following criteria—*

(a) structural adequacy; and

(b)integrity; and

(c)insulation,

and expressed in that order.

A dash means that there is no requirement for that criterion. For example, 90/–/– means there is no requirement for an FRL for integrity and insulation, and –/–/– means there is no requirement for an FRL.

Standard Fire Test *means the Fire-resistance Tests of Elements of Building Construction as described in AS 1530.4*

The Standard Fire Test

The standard fire resistance test method is AS 1530.4[42]. It requires a representative specimen of an element of construction to be exposed to the "standard" time/temperature regime shown in Figure 21. Typically, vertical specimens 3m x 3m and horizontal specimens 4m x 3m are tested unless the use of smaller specimens is permitted. Refer Figure 22 and Figure 23 for examples of typical loadbearing timber floor and wall tests. Loadbearing elements are normally subjected to typical load combinations that apply to the fire limit state although other loads can be applied for example if lower loadings are applicable to limit defections.

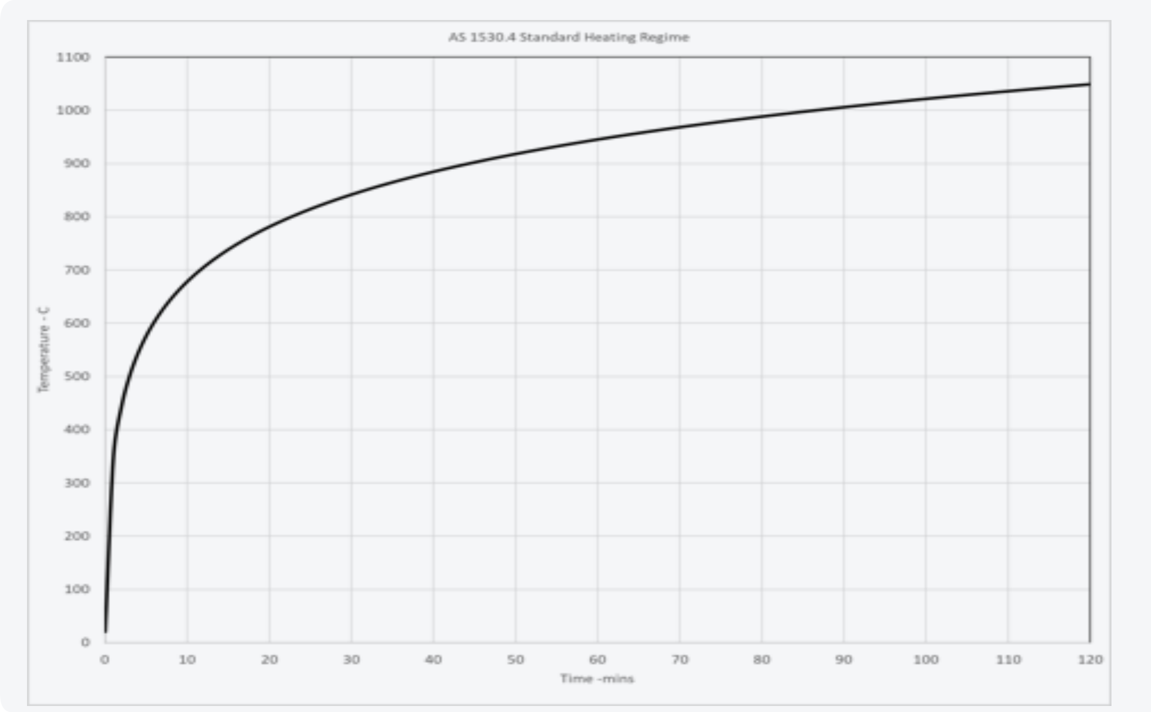


Figure 21: Standard Heating Regime of AS 1530.4.

Non-fire side after 90 minutes of test

Fire-exposed face after removal from the furnace

Figure 22: Loadbearing Light-weight timber framed floor FRL of 90/90/90 RISF>60mins at end of test.

Non-fire side after 180 minutes with full test load applied

Fire Exposed face 4 minutes after removal from furnace (Test was continued to 227 minutes under reduced load)

Figure 23 Loadbearing Timber Stud wall with cavities filled with high-performance mineral fibre FRL 180/180/180 RISF>120mins

Observations are made on the performance of the specimen while it is subjected to thermal and, where applicable, physical loading and the elapsed times at which failures under various criteria occur are recorded.

The most common performance criteria are summarised below:

Structural adequacy - The ability of a load-bearing element of construction to support a load

Integrity - The ability of an element of construction to resist the passage of flames and hot gases from one space to another

Insulation - The ability of an element of construction to maintain a temperature on the surface that is not exposed to the furnace, below the limits specified in order to prevent the spread of fire.

Other criteria such as radiant heat flux and *Resistance to the Incipient Spread of Fire* may be applied to specific circumstances.

Schedule 5 Clause 2 sets out the procedures for determining the FRL of building elements.

These procedures can be grouped as follows.

- Prescribed forms of construction (none of the prescribed forms of construction relate to timber construction and therefore no further discussion of this approach is provided in this publication).
- Performance determined by exposure to a standard fire test
- Nominated Design Standards / Specifications

Schedule 5 Clause 2 of the NCC is reproduced in the following text box.

Schedule 5 Clause 2 Rating

A building element meets the requirements of this Schedule if—

(a) it is listed in, and complies with Table 1 of this Schedule; or

(b) it is identical with a prototype that has been submitted to the ***Standard Fire Test****, or an equivalent or more severe test, and the FRL achieved by the prototype without the assistance of an active fire suppression system is confirmed in a report from an Accredited Testing Laboratory which -*

(i) describes the method and conditions of the test and the form of construction of the tested prototype in full; and

(ii) certifies that the application of restraint to the prototype complied with the Standard Fire Test; or

(c) it differs in only a minor degree from a prototype tested under (b) and the FRL attributed to the building element is confirmed in a report from an Accredited Testing Laboratory which -

(i) certifies that the building element is capable of achieving the FRL despite the minor departures from the tested prototype; and

(ii) describes the materials, construction and conditions of restraint which are necessary to achieve the FRL; or

(d) it is designed to achieve the FRL in accordance with -

(i) AS/NZS 2327, AS 4100 and AS/NZS 4600 if it is a steel or composite structure; or

(ii) AS 3600 if it is a concrete structure; or

(iii) AS 1720.4 if it is a timber element other than ***Fire-protected Timber****; or*

(iv) AS 3700 if it is a masonry structure; or

(e) the FRL is determined by calculation based on the performance of a prototype in the Standard Fire Test and confirmed in a report in accordance with Clause 3; or

(f) for ***Fire-protected Timber,*** *it complies with Specification C1.13a where applicable.*

The emphasis of Schedule 5 relates to structural elements but there are numerous other elements to which the standard fire test applies either by direct reference in the NCC or via reference documents such as 1905.1 (fire doors) or AS 4072.1 (service penetrations and fire dampers). Elements addressed by AS 1530.4 include:

- Walls,
- Floors, roofs, and ceilings
- Columns
- Beams Girders and Trusses
- Doorsets and Shutter Assemblies
- Service penetrations and control joints
- Fire damper and air transfer grille assemblies
- Uninsulated glazing
- Critical Services.

For elements other than structural elements, the most common options for determining FRLs are standard fire testing and subsequent assessments of minor variations from the tested prototype by *Accredited Testing Laboratories*.

Performance Determined by Exposure to a Standard Fire Test

There are three options for determining the FRL of timber elements of construction by exposure to the standard fire test:

1) The element is identical with a prototype that has been submitted to the Standard Fire Test, or an equivalent or more severe test, and the FRL achieved by the prototype without the assistance of an active fire suppression system is confirmed in a report from an Accredited Testing Laboratory. In most cases there will be variations from the tested prototype which is addressed by the following approaches.

2) The element differs in only a minor degree from a tested prototype as described above and the FRL attributed to the building element is confirmed in a report from an Accredited Testing Laboratory which -

   (i) certifies that the building element is capable of achieving the FRL despite the minor departures from the tested prototype; and

   (ii) describes the materials, construction and conditions of restraint which are necessary to achieve the FRL; or

3) The FRL of an element is determined by calculation based on the performance of a prototype in the Standard Fire Test and confirmed in a report in accordance with Clause 3 which allows building elements to vary with respect to:

   - length and height if it is a wall; and
   - height if it is a column; and
   - span if it is a floor, roof or beam; and
   - conditions of support; and
   - to a minor degree, cross-section and components; and

   demonstrates by calculation that the building element would achieve the FRL if it is subjected to the regime of the Standard Fire Test in relation to -

   - structural adequacy (including deflection); and
   - integrity; and
   - insulation; and

   the calculations must account for

   - the temperature reached by the components of the prototype and their effects on strength and modulus of elasticity; and
   - appropriate features of the building element such as support, restraint, cross-sectional shape, length, height, span, slenderness ratio, reinforcement, ratio of surface area to mass per unit length, and fire protection; and
   - features of the prototype that influenced its performance in the Standard Fire Test although these features may not have been taken into account in the design for dead and live load; and
   - features of the conditions of test, the manner of support and the position of the prototype during the test, that might not be reproduced in the building element if it is exposed to fire; and
   - the design load of the building element in comparison with the tested prototype.

Option 3 is used relatively infrequently since, based on its content, it is generally restricted to structural elements and it is more common for a “field of application” to be defined in an assessment from an *Accredited Testing Laboratory* using options 1 and 2 with the tests being designed to yield the necessary information for the assessment.

*Note: **Where Evidence of Suitability** is in the form of a report or reports from an **Accredited Testing Laboratory** the designer should:*

- *Obtain complete copies of the relevant report(s) issued by the laboratory which must:*

  (i) describe the method and conditions of the test and the form of construction of the tested prototype in full; and certify that the application of restraint to the prototype complied with the Standard Fire Test,

  and where variations from the tested prototype are considered;

  (ii) identify the variations from the tested prototype, describe the materials, construction and conditions of restraint which are necessary to achieve the FRL and certify that the building element is capable of achieving the FRL despite the minor departures from the tested prototype.

- *Check the reports are complete and are current.*

  Note: Most assessments of variations issued by NATA accredited laboratories nominate a termination date after which the assessment must be reviewed. From May 2022 the NCC will require tests to be undertaken to the current edition of the NCC or the performance of the element to be assessed by an Accredited Testing Laboratory against the current edition of a standard.

- *Check that the relevant laboratory is accredited for the relevant test and retain documentation from this check for submission to the **Appropriate Authority**. (This information can be obtained from the NATA web site; https://nata.com.au/accredited-facility)*

- *Retain appropriate documentation from an appropriately qualified person (including their qualifications and experience) determining that the design details and subsequently installation are either identical to the tested prototype or comply with the variations and conditions nominated in an assessment of a variation from the tested prototype*

- *Provide the above information in the Building Manual or equivalent Document (Refer Section 1.4)*

Element designed to achieve an FRL in accordance with a nominated design standard

Schedule 5 allows elements of construction to be designed to achieve prescribed FRLs in accordance with nominated design standards which include AS 1720.4 Timber structures—fire resistance for structural adequacy of timber members [18]

Typically, these designs are undertaken by professional structural and or fire engineers or other appropriately qualified persons and evidence of compliance should be provided as described in the text box below.

Evidence of compliance is typically a report from a professional engineer or appropriately qualified person which:

- *certifies that the form of construction is likely to fulfill the specific requirements of the NCC (e.g., FRL 120/–/–), and*
- *sets out the basis on which it is given and the extent to which relevant standards, specifications, rules, codes of practice, other publications, tests, and inspections have been relied upon to determine it fulfills the specific requirements of the NCC.*

A complete copy of the report and any supporting documents including details of the experience and qualifications of the report author should be included with the design documentation forwarded to the Appropriate Authority. The designer should be satisfied that the author has the appropriate expertise and experience before forwarding the documentation. These documents should also be included in the Building Manual.

Where confirmation is required after installation any tests and inspections should be documented in addition to the above information and provided in the appropriate version of the Building Manual.

Other Evidence of Suitability

If any other form of *Evidence of Suitability* is presented to demonstrate compliance with FRLs for a *Deemed-to-Satisfy Solution*, it does not waive the need comply with Schedule 5.

Therefore, product certification and accreditation and any other evidence must be supported by documentation complying with the requirements of Schedule 5 (e.g., a complete copy of the original test reports and / or reports from an Accredited Test Laboratory).

Where manufacturers or installer statements of compliance are made, they may provide some level of additional confidence that the supplier has confirmed the performance of the product, but the supporting documentation must still include complete copies of test reports, assessment reports, inspections and reports from professional engineers or an appropriately qualified person as appropriate.

6.3 Evidence of Suitability - Resistance to the Incipient Spread of Fire

The NCC defines Resistance to the Incipient *Spread of Fire* as follows

Resistance to the Incipient Spread of Fire, in relation to a ceiling membrane, means the ability of the membrane to insulate the space between the ceiling and roof, or ceiling and floor above, so as to limit the temperature rise of materials in this space to a level which will not permit the rapid and general spread of fire throughout the space.

Resistance to the Incipient Spread of Fire is determined by subjecting a ceiling system to a standard fire resistance test (AS 1530.4). Temperatures are monitored on the upper surface of the ceiling at prescribed positions and if the measured temperatures are maintained below the maximum permitted temperature (250°C), a *Resistance to the Incipient Spread of Fire* can be assigned, which is the time in minutes for which temperatures were maintained below the prescribed temperature or the end of the test whichever is less.

The above criteria are also consistent with criteria for limiting interface temperatures for light-weight fire-protected timber elements (refer Section 6.4 and Appendix D *Evidence of Suitability for Fire-protected Timber* for further details) or the derivation of levels of protection for *Performance Solutions* requiring encapsulation to prevent ignition of timber structural elements.

Similar to elements required to achieve an FRL; a ceiling is deemed to have a *Resistance to the Incipient Spread of Fire* to the space above if:

- it is identical with a prototype that has been submitted to the Standard Fire Test and the *Resistance to the Incipient Spread of Fire* achieved by the prototype is confirmed in a report from an Accredited Testing Laboratory that
  - describes the method and conditions of the test and form of construction of the tested prototype in full and
  - certifies that the application of restraint to the prototype complies with the Standard Fire Test; or
- it differs in only a minor degree from a prototype and the *Resistance to the Incipient Spread of Fire* attributed to the ceiling is confirmed in a report from an Accredited Testing Laboratory that:
  - certifies that the ceiling is capable of achieving the Resistance to the *Incipient Spread of Fire* despite the minor departures from the tested prototype; and
  - describes the materials, construction and conditions of restraint that are necessary to achieve the *Resistance to the Incipient Spread of Fire*.

Evidence of Suitability must therefore be in the form of a report or reports from an *Accredited Testing Laboratory* as detailed for elements required to achieve FRLs Refer Section 6.2 for further details.

6.4 Evidence of Suitability Fire-protected Timber

The NCC provisions include enhanced requirements for fire-protected timber elements of construction in addition to the prescribed FRL to compensate for the relaxation of the requirements for elements of construction to be non-combustible or of masonry or concrete construction. The requirements for fire protected timber are provided in Specification C1.13a of the NCC and include requirements for:

- Non-combustible coverings to be used
- Extended application of the *Resistance to the Incipient Spread of Fire* criteria to walls as well as ceilings.
- Modified *Resistance to the Incipient Spread of Fire* criteria for application to *Massive timber* construction
- Use of cavity barriers within some elements of construction
- Where cavities are present any insulation within the cavities must be non-combustible

Generally, the requirements for E*vidence of Suitability* for fire-protected timber are consistent with those for fire-resistant building elements except that:

- calculation of the FRL in accordance with methods such as AS 1720.4 is not permitted. (i.e., FRL performance has to be determined on the basis of AS 1530.4 fire tests), and
- *Evidence of Suitability* verifying coverings and insulation are non-combustible is required, and
- *Evidence of Suitability* that the resistance to incipient spread of fire or modified criteria have been satisfied (for walls and ceilings) is required, and
- *Evidence of Suitability* for internal cavity barriers if they are required for the form of timber elements selected.

Most of the above *Evidence of Suitability* will be in the form of test reports from *Accredited Test Laboratories*. Further details and discussion relating to appropriate *Evidence of Suitability* for fire-protected timber are provided in Appendix D. An example of a data sheet nominating appropriate *Evidence of Suitability* for an external wall is also provided in Appendix E.

6.5 Fire Hazard Properties

Introduction to fire hazard property tests and evidence of suitability

The guide to the NCC states "A material's fire hazard properties are an indication of its susceptibility to the effects of flame or heat, particularly during the early stages of a fire". Perhaps a clearer understanding of the intent of controlling fire hazard properties can be obtained from consideration of the definition of fire hazard in the NCC, provided in the text box below:

***Fire hazard** means the danger in terms of potential harm and degree of exposure arising from the start and spread of fire and the smoke and gases that are thereby generated.*

Therefore, it is reasonable to conclude that the intent of controlling the fire hazard properties of materials is to minimise the potential harm and degree of exposure resulting from ignition and spread of fire and the generation of smoke and hot gases. The relevant *Performance Requirement* is CP4 which, is consistent with this interpretation, is summarised below:

CP4 Safe conditions for evacuation

To maintain tenable conditions during occupant evacuation, a material and an assembly must, to the degree necessary, resist the spread of fire and limit the generation of smoke and heat, and any toxic gases likely to be produced, appropriate to—

(a) the evacuation time; and

(b) the number, mobility and other characteristics of occupants; and

(c) the function or use of the building; and

(d) any active fire safety systems installed in the building.

Application:

CP4 applies to linings, materials and assemblies in a Class 2 to 9 building.

Wood products are a popular choice for floor wall and ceiling linings and may be applied as attachments to structural elements or in the case of exposed *Massive timber* elements the fire hazard properties also apply to the exposed timber elements.

The majority of the NCC Deemed-to-Satisfy Fire Hazard Properties requirements are specified in Specification C1.10 of NCC Volume One and the nominated tests and performance / classification criteria are summarised below:

As the classification of these materials is by means of test, *Evidence of Suitability* will normally be in the form of a test or classification / assessment based on one or more tests prepared by a test laboratory. Whilst the NCC does not prescribe the use of an *Accredited Testing Laboratory* for fire hazard property tests, the laboratory accreditation process provides added confidence in the results obtained. It is therefore recommended that the *Evidence of Suitability* obtained is in the form of a report from an *Accredited Testing Laboratory*.

The following sections describe common test methods used by the *DTS Provisions* which in many cases are also appropriate for specification of required performance that have been derived for *Performance Solutions*.

Fire hazard properties – floor linings AS ISO 9239.1

AS ISO 9239.1 [43] Reaction to fire tests for floorings Part 1: Determination of the burning behaviour using a radiant heat source is the prescribed test method. It is an intermediate scale test simulating the thermal radiation levels likely to impinge on the floor of a corridor from the hot layer from a fire in an adjacent room or compartment. The test specimen is placed in a horizontal position below a gas-fired radiant panel inclined at 30°. A pilot flame is applied to the hotter end of the specimen. Results are expressed in terms of, the critical heat flux at extinguishment and smoke density versus time.

Critical Heat Fluxes of not less than 1.2, 2.2, or 4.5 kW/m^2 are prescribed by the NCC depending on the application.

Smoke developed index of not greater than 750 percent-minutes applies in buildings not protected by nominated types of sprinkler system.

Most commonly used wood products do not exceed the Smoke Developed Index limit of 750 percent-minutes and achieve Critical Heat Fluxes greater than 2.2 kW/m^2 with a minimum timber thickness of 12mm when mounted on an appropriate substrate or 17mm with an airgap behind the boards. It should be noted that some timber species achieve Critical Heat Fluxes greater than 4.5 kW/m^2 or greater than 2.2kW/m^2 with thicknesses less than the above thickness limits.

Reference should be made to WoodSolutions web-site for further information and *Evidence of Suitability.* (https://www.woodsolutions.com.au/articles/fire-test-reports)

Fire hazard properties – wall and ceiling linings AS 5637.1

AS 5637.1 [10] Determination of fire hazard properties, is a classification standard that defines how the fire hazard properties of wall and ceiling linings are classified using the following test methods as appropriate:

- AS ISO 9705 – 2003 [44] Fire tests—Full-scale room test for surface products
- AS /NZS 3837 [45] Method of test for heat and smoke release rates for materials and products using an oxygen consumption calorimeter.
- ISO 5660-1 [46] Reaction-to-fire tests — Heat release, smoke production and mass loss rate - Part 1: Heat release rate (cone calorimeter method) and smoke production rate (dynamic measurement)

The primary basis for classification of wall and ceiling linings is the time to flashover and the Smoke Growth Rate Index determined in an AS / ISO 9705 test

The lining material / system is fitted to the walls and ceiling of the test room and a heat source comprising a gas burner is located in the corner of the room and the time to flashover and smoke growth rate are determined.

Since AS/ISO 9705 tests are costly and correlations have been developed from bench-scale cone calorimeter tests for some materials, AS 5637.1 provides a pathway for classification to be based on cone calorimeter tests performed in accordance with AS 3837 tests and ISO 5660-1 but only if there are correlations for the materials. Detailed guidance is provided in AS 5637.1.

Wall and ceiling linings are assigned a Group number based on the time to flashover in a room test as follows with additional smoke criteria being applied if buildings are not protected by a nominated fire sprinkler system.

- Group 1 Materials do not reach flashover when exposed to 100kW for 600s followed by exposure to 300kW for 600s.
- Group 2 Materials reach flashover following exposure to 300kW within 600s after not reaching flashover when exposed to 100kW for 600s.
- Group 3 Materials reach flashover in more than 120s but within 600s when exposed to 100kW.
- Group 4 Materials reach flashover within 120s when exposed to 100kW.

The NCC DTS provisions specify the required Group Number, depending on the location within a building, class of building and presence of a nominated sprinkler system.

The Smoke Growth Rate Index should be not more than 100 if a building is not protected by a nominated sprinkler systems. If bench scale cone calorimeter tests are permitted to be used for classification an average specific extinction area limit of 250 m^2/kg is applied instead of the Smoke Growth Rate Index.

*Note: The **Evidence of Suitability** should be in the form of a report providing a classification to AS 5637.1 and if reliance is placed on cone calorimeter tests the report must identify that there are appropriate correlations to estimate the time to flashover.*

Most commonly used wood products achieve Group 3 performance with either a Smoke Growth Rate Index less than 100 or an average specific extinction area less than 250 m^2/kg although the Group Number can be reduced to 1 or 2 with appropriate fire-retardant treatments. Reference should be made to WoodSolutions web-site (https://www.woodsolutions.com.au/articles/fire-test-reports) for further information and *Evidence of Suitability*.

*Note: The NCC **DTS Provisions** prohibit the use of fire retardant coatings to modify the fire hazard properties and therefore a **Performance Solution** is required for these applications*

Fire Hazard properties other materials AS 1530.3

AS 1530.3 [47] *Methods for fire tests on building materials, components and structures Part 3: Simultaneous determination of ignitability, flame propagation, heat release and smoke release* is the prescribed test method used for control of various miscellaneous materials under the DTS Provisions. The method was originally developed for evaluation of wall and ceiling linings but was superseded by the Group number classification system. It has been retained in the NCC for various miscellaneous applications but there is little information to justify the performance levels specified.

The test method examines the reaction of a sample of the material, 600mm x 450mm, of normal in use thickness, orientated vertically when subjected to radiant heat and exposed to a piloted ignition source. The specimen progressively moves towards the radiant panel with a small flaming ignition source applied to volatiles.

The following indices are derived:

- Ignitability (range 0 to 20)
- Spread of Flame (range 0 to 10)
- Heat Evolved (range 0 to 10)
- Smoke Developed (range 0 to 10)

The lower the index the better the performance.

The NCC only applies the following two criteria;

- Spread of flame (indices of 0, 5 and 9 are commonly applied)
- Smoke developed (indices of 2 to 8 are commonly applied)

For common timbers, the Spread of Flame Indices are generally less than 9 and Smoke Developed Indices are generally 5 or less.

Reference should be made to WoodSolutions web-site (https://www.woodsolutions.com.au/articles/fire-hazard-properties-c110-materials-and-assemblies) for further information.

Schedule 6 of the NCC is required to be applied by Specification C1.10, where the outer layers of an assembly screen their core materials (e.g., composite panel).

Schedule 6 requires a determination of the ability to prevent ignition and screen the core material from free air by exposing a sample of minimum size 900mm x 900mm to the standard heating regime of AS 1530.4 for a period of 10 minutes. The specimen must include all types of joints, perforations and recesses or the like for pipes, light switches, or other fittings.

6.6 Non-combustible materials and construction – AS 1530.1

The specification of non-combustible materials and construction has broader application than the fire hazard properties and can relate to the reaction of materials to fire during the fully developed phase as well as the early stages of the fire. The NCC defines non-combustible as follows:

Non-combustible means

- **applied to a material - not deemed combustible as determined by AS 1530.1 - Combustibility Tests for Materials; and**
- **applied to construction or part of a building - constructed wholly of materials that are not deemed combustible.**

AS 1530.1[48] Methods for fire tests on building materials, components and structures Part 1: Combustibility test for materials is the prescribed test method. A specimen (45mm diam x 50mm high), is inserted into a specimen holder which is then placed within a pre-heated furnace at an initial temperature of approximately 750°C.

Temperatures are measured by the furnace and both specimen thermocouples and recorded until the test is terminated in accordance with the standard. Mass loss is also measured and sustained flaming from the specimen is observed.

A material is classified as combustible if any of the following occur:

- The mean duration of sustained flaming (for periods longer than 5s) is other than zero. (i.e., if sustained flaming for longer than 5s occurs)
- The mean furnace thermocouple temperature rise, exceeds 50°C.
- The mean specimen surface thermocouple temperature rise exceeds 50°C.

Wood products are combustible when tested to this method, but the combustibility criteria are applied to fire-protective coverings and insulation materials associated with fire-protected timber and may apply to other encapsulation systems adopted for Performance Solutions.

A

Appendix A - Abbreviations and Definitions

Abbreviations

ABCB – Australian Building Codes Board

DTS – *Deemed-to-Satisfy*

FPT – *Fire-protected timber*

MRISF – Modified *Resistance to the Incipient Spread of Fire*

NCC – National Construction Code

PBDB – Performance-based design brief

RISF – *Resistance to the Incipient Spread of Fire*

TFC – Timber-framed Concession

Definitions

Definitions in italics are defined terms within the NCC and these definitions were provided by the Australian Building Codes Board © 2020.

Appropriate Authority means the relevant authority with the statutory responsibility to determine the particular matter.

Assessment Method means a method that can be used for determining that a *Performance Solution* or *Deemed-to- Satisfy Solution* complies with the *Performance Requirements*

Deemed-to-Satisfy Provisions means provisions which are deemed to satisfy the *Performance Requirements*.

Deemed-to-Satisfy Solution means a method of satisfying the *Deemed-to-Satisfy Provisions*

Evidence of Suitability means, in the context of the NCC, one of the nominated types of Evidence of Suitability nominated as being acceptable in the NCC for the relevant application(s)

Encapsulated timber means timber which is encapsulated by *fire-protective coverings* to prevent the underlying timber igniting for either a prescribed time period when exposed to a prescribed fire exposure, or in relation to fully encapsulated timber, for the entire fire duration, including the fire growth, fully developed, decay cooling phases.

Expert Judgement means the judgement of an expert who has the qualifications and experience to determine whether a *Performance Solution* or *Deemed-to-Satisfy Solution* complies with the *Performance Requirements*.

Explanatory Information: Contemporary and relevant qualifications and/or experience are necessary to determine whether a *Performance Solution* complies with the *Performance Requirements*. The level of qualification and/or experience may differ depending on the complexity of the proposal and the requirements of the regulatory authority. Practitioners should seek advice from the authority having jurisdiction or *Appropriate Authority* for clarification as to what will be accepted.

Note: In engineering disciplines the term engineering judgement is commonly used when making decisions or judgements rather than expert to indicate that the judgements made are typical of those made routinely by a competent professional engineer. The process may be formal, intuitive, or deliberate or, in most cases, a combination of the three.

Fire-hazard Properties means the following properties of a material or assembly that indicate how they behave under specific fire test conditions:

(a) *Average specific extinction area, critical radiant flux,* and *Flammability Index*, determined as defined in Schedule3.

(b) *Smoke-Developed Index, smoke development rate* and *Spread-of-Flame Index*, determined in accordance with Schedule 6.

(c) *Group number* and *smoke growth rate index* ($SMOGRA_{RC}$), determined in accordance with Specification C1.10 of Volume One.

Fire-protected Timber means *fire-resisting* timber building elements that comply with Volume One Specification C1.13a of the NCC

Fire Protective Covering – in the context of fire-protected timber in the NCC means a non-combustible covering complying with the requirements of specification C1.13a. Note this differs from the standard definition provided within the NCC for fire protective coverings.

Fire-resistance level (FRL) means the grading periods in minutes determined in accordance with Schedule 5 of the NCC, for the following criteria—

(a) structural adequacy; and
(b) integrity; and
(c) insulation,

and expressed in that order.

Note: A dash means that there is no requirement for that criterion. For example, 90/–/– means there is no requirement for an FRL for integrity and insulation, and –/–/– means there is no requirement for an FRL.

Fire Resisting for the purposes of Volume One of the NCC, applied to a building element, means having an FRL appropriate for that element.

Fire safety strategy means a strategy that defines the combination of measures that are required to satisfy the fire safety objectives and includes physical and human measures

Fire Safety Engineer or Fire Engineer means a professional fire engineer with appropriately qualifications and experience. Note: National and State based accreditation of fire safety engineers is available. When relying on a certificate or report from a fire engineer it is prudent to check the credentials of the relevant engineer and recognition of the accreditation within the State or Territory in which the building works is to be undertaken. Legislation within a State or Territory often includes requirements for insurance of practitioners such as Fire Safety Engineers

Governing Requirements means rules and instructions for using and complying with the NCC

Massive timber means an element not less than 75 mm thick as measured in each direction formed from solid and laminated timber

Modified *Resistance to the Incipient Spread of Fire* means the modified criteria used to determine the performance of fire protective coverings applied to *Massive timber*

Performance Solution means a method of complying with the Performance Requirements other than by a Deemed-to-Satisfy Solution.

Performance Requirement means a requirement which states the level of performance which a *Performance Solution* or *Deemed-to-Satisfy Solution* must meet.

Performance-based design brief (PBDB) means the process and the associated report that defines the scope of work for the performance-based analysis, the technical basis for analysis, and the criteria for acceptance of any relevant *Performance Solution* as agreed by stakeholders.

Resistance to the Incipient Spread of Fire, means the ability of the membrane to insulate the space between the ceiling and roof, or ceiling and floor above, so as to limit the temperature rise of materials in this space to a level which will not permit the rapid and general spread of fire throughout the space. Note: This definition is expanded to include walls in Specification C1.13a

Verification Method means a test, inspection, calculation, or other method that determines whether a *Performance Solution* complies with the relevant *Performance Requirements*.

B

Appendix B - Timber Framed Concessions from NCC Specification C1.1

The following clauses from the NCC were provided by the Australian Building Codes Board © 2020.

3.10 Class 2 and 3 buildings: Concession

(a) In a Class 2 or 3 building with a *rise in storeys* of not more than 3 -

(i) notwithstanding C1.9(a) and (b) and C2.6, timber framing may be used for -

(A) *external walls*; and

(B) *common walls*; and

(C) the floor framing of lift pits; and

(D) non-*loadbearing internal walls* which are *required* to be *fire-resisting*; and

(E) non-*loadbearing shafts*, except *shafts* used for the discharge of hot products of combustion; and

(F) spandrels or horizontal construction provided for the purposes of C2.6; and

(ii) notwithstanding Clause 3.1(d) of Specification C1.1, for *loadbearing internal walls* and *loadbearing fire walls* -

(A) timber framing may be used; and

(B) *non-combustible* materials may be used.

(b) A Class 2 or 3 building having a *rise in storeys* of not more than 4 may have the top three storeys constructed in accordance with (a) provided -

(i) the lowest *storey* is used solely for the purpose of parking motor vehicles or for some other ancillary purpose; and

(ii) the lowest *storey* is constructed of concrete or masonry including the floor between it and the Class 2 or 3 part of the building above; and

(iii) the lowest *storey* and the *storey* above are separated by construction having an FRL of not less than 90/90/90 with no openings or penetrations that would reduce the *fire-resisting* performance of that construction except that a doorway in that construction may be protected by a –/60/30 *self-closing* fire door.

(c) In a Class 2 or 3 building complying with (a) or (b) and fitted with a sprinkler system (other than a FPAA 101 D or FPAA 101 H system) complying with Specification E1.5, any FRL criterion prescribed in Table 3 -

(i) for any floor and any *loadbearing* wall, may be reduced to 60, except any FRL criterion of 90 for an *external wall* must be maintained when tested from the outside; and

(ii) for any non-*loadbearing internal wall*, need not apply if -

(A) it is lined on each side with 13 mm standard grade plasterboard or similar *non-combustible* material; and

(B) it extends -

(aa) to the underside of the floor next above; or

(bb) to the underside of a ceiling with a *resistance to the incipient spread of fire* of 60 minutes; or

(cc) to the underside of a *non-combustible* roof covering; and

(C) any insulation installed in the cavity of the wall is *non-combustible*; and

(D) any construction joint, space or the like between the top of the wall and the floor, ceiling or roof is smoke sealed with intumescent putty or other suitable material; and

(E) any doorway in the wall is protected by a *self-closing*, tight fitting, solid core door not less than 35 mm thick.

4.3 Class 2 and 3 buildings: Concession

(a) In a Class 2 or 3 building with a rise in storeys of not more than 2 -

(i) notwithstanding C1.9(a) and (b), timber framing may be used for -

(A) external walls; and

(B) common walls; and

(C) the floor framing of lift pits; and

(D) non-loadbearing internal walls which are required to be fire-resisting; and

(E) non-loadbearing shafts, except shafts used for the discharge of hot products of combustion; and

(ii) notwithstanding Clause 4.1(e) of Specification C1.1, for loadbearing internal walls and loadbearing fire walls -

(A) timber framing may be used; and

(B) non-combustible materials may be used.

(b) A Class 2 or 3 building having a *rise in storeys* of not more than 2 may have the top storey constructed in accordance with (a) provided -

(i) the lowest *storey* is used solely for the purpose of parking motor vehicles or for some other ancillary purpose; and

(ii) the lowest *storey* is constructed of concrete or masonry including the floor between it and the Class2 or 3 part of the building above; and

(iii) the lowest *storey* and the *storey* above are separated by construction having an FRL of not less than90/90/90 with no openings or penetrations that would reduce the *fire-resisting* performance of that construction except that a doorway in that construction may be protected by a –/60/30 *self-closing* fire door.

(c) In a Class 2 or 3 building complying with (a) or (b) and fitted with a sprinkler system (other than a FPAA 101D or FPAA 101 H system) complying with Specification E1.5, any FRL criterion prescribed in Table 4 -

(i) for any *loadbearing wall*, may be reduced to 60, except any FRL criterion of 90 for an *external wall* must be maintained when tested from the outside; and

(ii) for any non-*loadbearing internal wall*, need not apply, if -

(A) it is lined on both sides with 13 mm standard grade plasterboard or similar non-combustible material; and

(B) it extends -

(aa) to the underside of the floor next above if that floor has an FRL of at least 30/30/30 or is lined on the underside with a *fire-protective covering*; or

(bb) to the underside of a ceiling with a *resistance to the incipient spread of fire* of 60 minutes; or

(cc) to the underside of a *non-combustible* roof covering; and

(C) any insulation installed in the cavity of the wall is *non-combustible*; and

(D) any construction joints, spaces and the like between the top of the wall and the floor, ceiling or roof is smoke sealed with intumescent putty or other suitable material.

C

Appendix C - Example Calculations of Fire Test Loading for a Timber Stud Partition

Examples have been provided for two common end conditions to demonstrate the need to clearly define the end conditions and adjust the test load accordingly.

Example 1 - Bottom nail joint to timber plate upper pinned joint

Bottom nail joint to timber plate upper pinned joint

Design to AS 1720.1

MGP10 Timber studs 90mm x 45mm

b=45 mm; d=90mm, A_c = 4050mm^2

Noggings provided at approx. 750mm centres. Buckling expected about major axis.

Length of Stud between supports (L) – Taken as from pin joint to interface with the surface of sill plate = 2.936m.
Studs nailed to plates.
From Table 3.2:
Studs in light framing g_{13}= 0.9
Studs restrained at both ends in position only g_{13}=1.0
One end typical light framing detail other held in position only (pinned joint) therefore g_{13}=0.95 adopted
$L_{ax} = L \cdot g_{13} = 2.79$m
$S_3 = L_{ax} / d \approx 31.0$

Characteristic Stress for Compression parallel to grain (f_c') 18MPa	App H Table H3
Material Constant Seasoned Timber ρ_c=0.96	Table 3.3
$\rho_c\, S \approx 29.7$	
Stability Factor $k_{12} \approx 0.227$	For $\rho_c\, S \leq 10$; k12 = 1.0 For $10 \leq \rho_c\, S \leq 20$; $k_{12} = 1.5 - 0.05\rho_c\, S$ For $\rho_c\, S \geq 20$; $k_{12} = 200 / (\rho_c\, .S)^2$
$\Phi = 0.7$	Category 2 MGP from Table 2.1
$k_1 = 0.57$	Permanent and long-term imposed action from Table G1
$k_4 = 1$	Seasoned clause 2.4.2.3
$k_6 = 1$	No temp extremes in normal service Clause 2.4.3
Design capacity in compression parallel to the grain $N_{d,c} \approx 6.6$kN (ambient)	$N_{d,c} = \varphi k_1\, k_4\, k_6\, k_{12}\, f_c'\, A$ - Clause 3.3.1.1
Load duration independent ambient design capacity $R_b = N_{d,c}$ = 11.6 kN / Stud	k_1=1 for Load duration independent design capacity
LR_{fb} ratios of 0.5 adopted for general application.	Based on analysis of load combinations
Test Load = $N_{d,c}$ x R =11.6 x 0.5 ≈ 5.8kN / stud	Under fire conditions

Example 2 - Both ends nail joint to timber plates fixed to test frame that does not allow rotation

Both ends nail joint to timber plates fixed to test frame that does not allow rotation

Design to AS 1720.1

MGP10 Timber studs 90mm x 45mm

b=45 mm; d=90mm, A_c = 4050mm^2

Noggings provided at approx. 750mm centres. Buckling expected about major axis.

Length of Stud between supports (L) – Taken as from interfaces with the surface of sill and head plate = 2.91m.
Studs nailed to plates.
From Table 3.2:
Studs in light framing g_{13}= 0.9
L_{ax} = L . g_{13} = 2.91 x 0.9 m =2.62
S_3 =L_{ax} / d ≈ 29.1

Characteristic Stress for Compression parallel to grain (f_c') 18MPa	App H Table H3
Material Constant Seasoned Timber ρ_c=0.96	Table 3.3
ρ_c S ≈ 27.9	
Stability Factor k_{12} ≈ 0.257	For ρ_c S ≤10; k12 = 1.0 For 10 ≤ρ_c S ≤20; k_{12} = 1.5 − 0.05ρ_c S (c) For ρ_c S ≥20; k_{12} = 200 / (ρ_c .S)^2
Φ = 0.7	Category 2 MGP from Table 2.1
k_1 = 0.57	Permanent and long-term imposed action from Table G1
k_4 = 1	Seasoned clause 2.4.2.3
k_6 = 1	No temp extremes in normal service Clause 2.4.3
Design capacity in compression parallel to the grain $N_{d,c}$ ≈ 7.5 kN (ambient)	$N_{d,c}$ = φk_1 k_4 k_6 k_{12} f_c' A - Clause 3.3.1.1
Load duration independent ambient design capacity R_b = $N_{d,c}$ = 13.1 kN / Stud	k_1=1 for Load duration independent design capacity
LR_{fb} ratios of 0.5 adopted for general residential application.	Based on analysis of load combinations
Test Load = $N_{d,c}$ x R =13.1 x 0.5 ≈ 6.55 kN / stud	Under fire conditions

Appendix D - Evidence of Suitability for Fire-protected Timber

General Requirements

There are three components to the performance of *Fire-protected Timber* that need to be satisfied:

- fire-protective coverings must be non-combustible.
- the protected element must achieve the required Fire Resistance Level (FRL)
- the protected element must achieve the required *Resistance to the Incipient Spread of Fire* (RISF).

In addition, for timber framed and lightweight construction where there are cavities within the elements of construction the following apply,

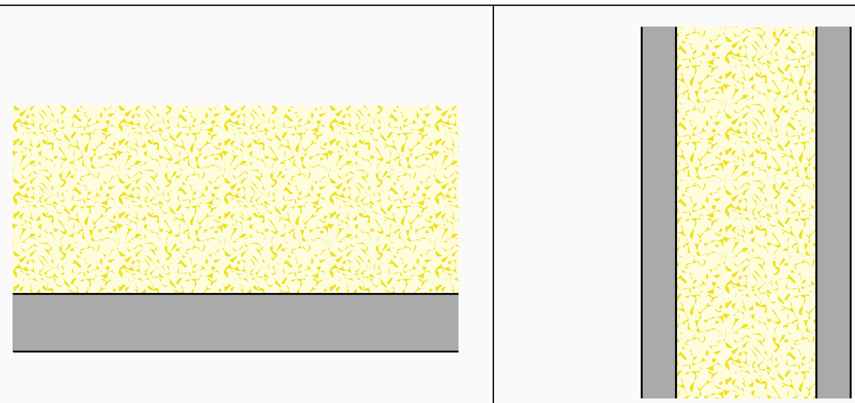
- any cavity insulation must be non-combustible
- internal cavity barriers must be provided.

Non-Combustible Fire-Protective Covering

Unless the NCC deems a material or element of construction to be non-combustible, non-combustible means:

- Applied to a material – not deemed combustible as determined by AS 1530.1 – Combustibility Tests for Materials.
- Applied to construction or part of a building – constructed wholly of materials that are not deemed combustible.

If the fire-protective covering is a composite or multi-layer system, each layer must be non-combustible. It is not acceptable to undertake a single combustibility test on the composite or just the facing materials and claim the fire-protective covering is non-combustible. Typical examples of multi-layer systems are shown in Figure D1.



Multi-layer system – each layer must be non-combustible	Composite panels – each layer of the composite must be non-combustible
Commonly fire resistant board supporting non-combustible lightweight insulation used in ceilings protecting floors/beams	Commonly non-combustible lightweight insulating core between non-combustible durable facings used for external claddings

Figure D1: Example of multi-layered fire-protective coverings (all layers).

Clause C1.9(e) of the NCC allows the following materials, though combustible or containing combustible fibres, to be used wherever a non-combustible material is required:

- plasterboard
- perforated gypsum lath with a normal paper finish
- fibrous-plaster sheet
- fibre-reinforced cement sheeting
- pre-finished metal sheeting having a combustible surface finish not exceeding 1 mm thickness and where the Spread-of-Flame Index of the product is not greater than 0
- sarking-type materials that do not exceed 1 mm in thickness and have a Flammability Index not greater than 5
- bonded laminated materials where:
  - each laminate is non-combustible
  - each adhesive layer does not exceed 1 mm in thickness
  - the total thickness of the adhesive layers does not exceed 2 mm
  - the Spread-of-Flame Index and the Smoke-Developed Index of the laminated material as a whole does not exceed 0 and 3, respectively.

All materials forming the fire-protective covering are either permitted to be used in accordance with NCC Clause C1.9(e) or determined to be non-combustible by testing to AS1530.1. Appropriate *Evidence of Suitability* should therefore be a AS 1530.1 test report from an accredited testing laboratory or a determination that the fire-protective covering is one of the materials listed in C1.9(e).

Fire Resistance Level

A *Fire-protected Timber* element must achieve the required FRL specified in the NCC for the particular application. The fire resistance of a *Fire-protected Timber* element has to be determined in accordance with Schedule 5.2(b) and (c) of the NCC.

Generally, Schedule A5.2(b) requires a prototype to be submitted to the Standard Fire Test (AS 1530.4), or an equivalent or more severe test, and the FRL achieved by the prototype, without the assistance of an active fire suppression system, is confirmed in a report from an Accredited Testing Laboratory which:

- describes the method and conditions of the test and the form of construction of the tested prototype in full
- certifies that the application of restraint to the prototype complied with the Standard Fire Test;
- or differs in only a minor degree from a prototype tested under Schedule 5.2(b) and the FRL attributed to the building element is confirmed in a report from an Accredited Testing Laboratory which:
- certifies that the building element is capable of achieving the FRL despite the minor departures from the tested prototype; and
- describes the materials, construction and conditions of restraint which are necessary to achieve the FRL.

The option to use AS 1720.4 char-based calculation methods to determine the fire resistance is not permitted for *Fire-protected Timber.* This is because concerns were expressed with respect to the suitability of the AS 1720.4 approach for certain types of adhesives and connections forming parts of engineered timber products. The proprietary nature of *Massive timber* panel products and lack of standardisation of adhesives and other critical materials used in their construction at the time meant that there was insufficient data available at the time to demonstrate the suitability or otherwise of AS 1720.4.

Resistance to the Incipient Spread of Fire

Determine Applicable *Resistance to the Incipient Spread of Fire* Requirements

The *Resistance to the Incipient Spread of Fire* (RISF) as applied to fire protected timber elements means the ability of the covering to insulate voids and the interfaces with timber elements so as to limit the temperature rise to a level that will not permit ignition of the timber and the rapid and general spread of fire throughout any concealed spaces. The performance is expressed as the period in minutes that the covering will maintain a temperature below the specified limits when subjected to a test in accordance with AS 1530.4.

The general requirement for *Fire-protected Timber* is an RISF of 45 minutes.

The NCC permits a relaxation to the RISF requirements for massive *Fire-protected Timber* elements providing both the following additional criteria are satisfied.

- the minimum timber panel thickness is not less than 75 mm
- there are no cavities between the surface of the timber and the fire protective covering or between timber members.

The 75 mm dimension relates to the inherent fire resistance achieved when using a timber panel member. If the relaxation conditions are satisfied, the Modified Resistance to the *Incipient Spread of Fire* (MRISF) criteria are applicable.

Figure D2 shows the process for determining the applicable *Resistance to the Incipient Spread of Fire* requirements. The general requirement for Fire-protected Timber is a RISF of 45 minutes.

The relaxed requirements for *Massive timber* construction without voids and cavities is a MRISF that applies a higher interface temperature limit (300°C) and the time periods for which the temperature limit applies varies according to the application in accordance with Table D1.

Table D1: Modified Resistance to the Incipient Spread of Fire required performance for applications where criteria are relaxed (Massive timber construction without voids and cavities).

Application	**Modified *Resistance to the Incipient Spread of Fire* (MRISF)**
Inside a fire-isolated stairway or lift shaft	20 min
External walls within 1 metre of an allotment boundary or 2 metres of a building on the same allotment	45 min
All other applications	30 min

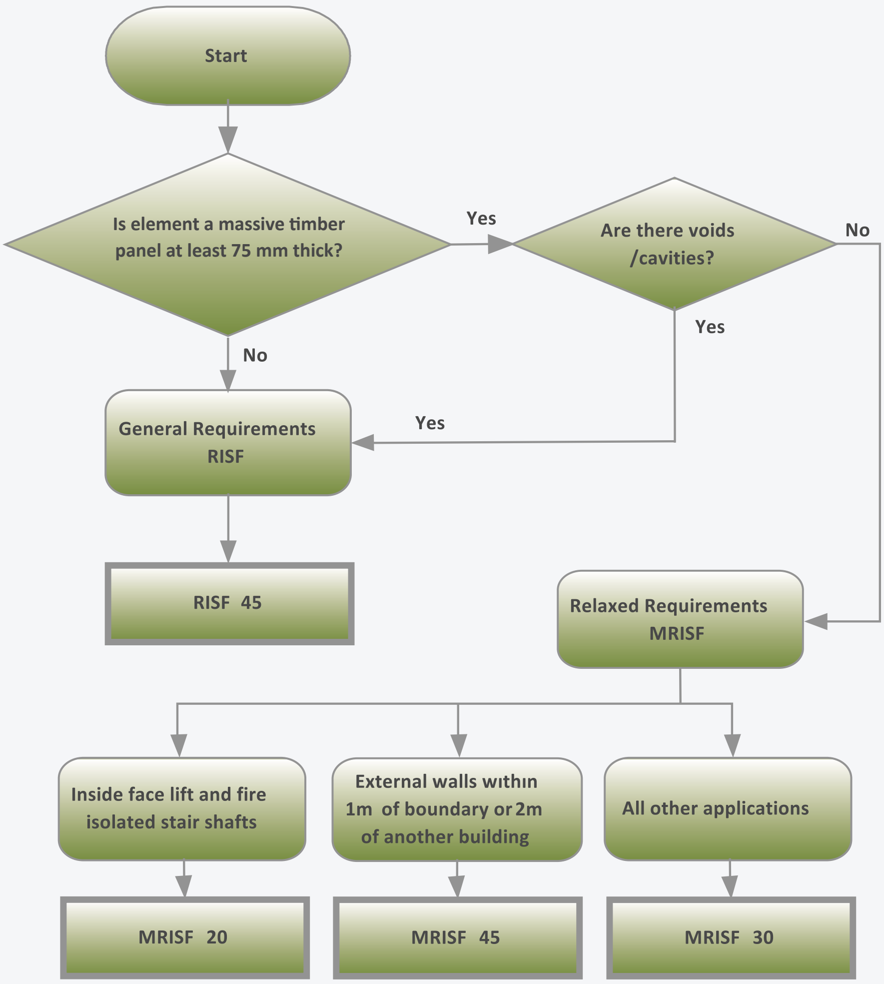


Figure D2: Determination of Resistance to the Incipient Spread of Fire acceptance requirements.

Evidence of Suitability Options for Resistance to the Incipient Spread of Fire

Three paths are permitted to demonstrate compliance with the RISF requirements;

- simultaneous determination during a full-scale fire resistance test
- smaller-scale fire resistance test (at least 1 metre x 1 metre specimen)
- selection of *Deemed-to-Satisfy* fire-resisting grade plasterboard coverings.

Simultaneous determination during a full-scale fire resistance test

When a fire resistance test is undertaken to determine the FRL of an element, additional instrumentation can be included in the test to also determine the RISF or MRISF performance, providing a cost-effective approach for new protection systems.

Smaller-scale fire resistance test

There are a large number of systems that have been tested previously to determine their FRLs but in many cases prior to 2016 insufficient data will have been recorded to determine the RISF or MRISF performance. Under these circumstances, the use of a smaller specimen (not less than 1 m x 1 m) is permitted to obtain supplementary data to determine the RISF or MRISF of the system in a cost effective manner. The fire-protective covering should be fixed in the same manner as that used for the original test that determined the FRL of the system.

Deemed-to-Satisfy Fire-Protective Grade Plasterboard coverings

Specification C1.13a deems fire-protective grade plasterboard facings, if fixed in accordance with the requirements to achieve the required FRL of the element and of the required thickness, to also satisfy the requirements for *Resistance to the Incipient Spread of Fire* (RISF) or *Modified Resistance to the Incipient Spread of Fire* (MRISF). Table D2 shows the minimum requirements for plasterboard coverings.

Table D2: Fire-protective grade plasterboard coverings Deemed-to-Satisfy RISF requirements.

Requirements	Application	Performance criteria	Minimum DTS fire-protective grade plasterboard
General Requirements	All applications	RISF 45min	2 layers x 13 mm thick
Relaxed requirements for timber panels not less than 75 mm thick without cavities voids or cavities voids filled with non-combustible material	Inside a fire-isolated stairway or lift shaft	MRISF 20 min	1 layer x 13 mm thick
	External walls within 1 metre of an allotment boundary or 2 metres of a building on the same allotment	MRISF 45 min	2 layers x 13 mm thick
	All other applications	MRIFS 30 min	1 layer x 16 mm thick

Resistance to the Incipient Spread of Fire (RISF) Test Procedures

The test procedure for determining the *Resistance to the Incipient Spread of Fire* (RISF) of horizontal elements during a full-scale fire resistance test is provided in Section 4 of AS 1530.4. Specification C1.13a of the NCC requires the relevant procedures from AS 1530.4 Section 4 to be applied to other elements.

AS 1530.4 requires walls to be full size or not less than 3 m high x 3 m wide and floor/ceiling systems to be full size or not less than 4 m long x 3 m wide. Floor systems are exposed to the standard heating conditions from the underside and fire-resisting walls are exposed from one side. Asymmetrical walls generally require two tests to evaluate the response to exposure to fire from either side unless the side exposed to fire is specified.

Smaller-scale specimens (not less than 1 m x 1 m) can be used to retrospectively determine the RISF performance of a floor or wall system that has previously achieved the required FRL in a fire resistance test satisfying the minimum size requirements specified in AS 1530.4. This requirement is included to evaluate the "stickability" (retention) of fire protective coverings which generally require full-scale specimens to evaluate the sensitivity to differential expansion / shrinkage and reduction in mechanical performance, amongst other things.

For universal application of results the minimum cavity depth should be fire tested.

To determine the RISF, five thermocouples with insulating pads as prescribed in AS 1530.4 are fixed to the inner face of the fire-protective covering system. They are placed at approximately the centre and the centre of each quarter section as shown in Figure D3. When testing corrugated specimens, increase the number of thermocouples to six to provide an equal number of thermocouples at the maximum and minimum specimen thickness.

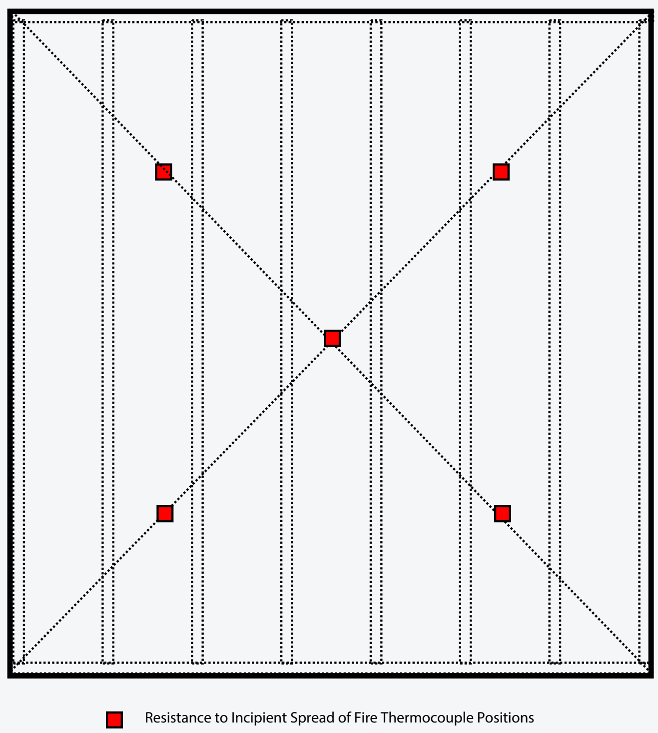


Figure D3: Elevation of a wall showing RISF thermocouple positions

Sections through typical specimen configurations are shown in Figure D4 to illustrate the correct surfaces to apply thermocouples to determine the RISF. For F*ire-protected Timber*, the temperature has to be maintained below the prescribed temperature on the surface of the fire-protective covering facing the void and at the interface with timber elements within the wall or floor. If a wall or ceiling system is protected by a board system, for example, the temperatures are measured on the board surface within the cavity even if non-combustible insulation is applied between the timber studs or beams. However, if the non-combustible insulation forms a continuous layer between the timber elements and the board the thermocouples (t/c) should be applied to the surface of the insulation as shown in Figure D4.

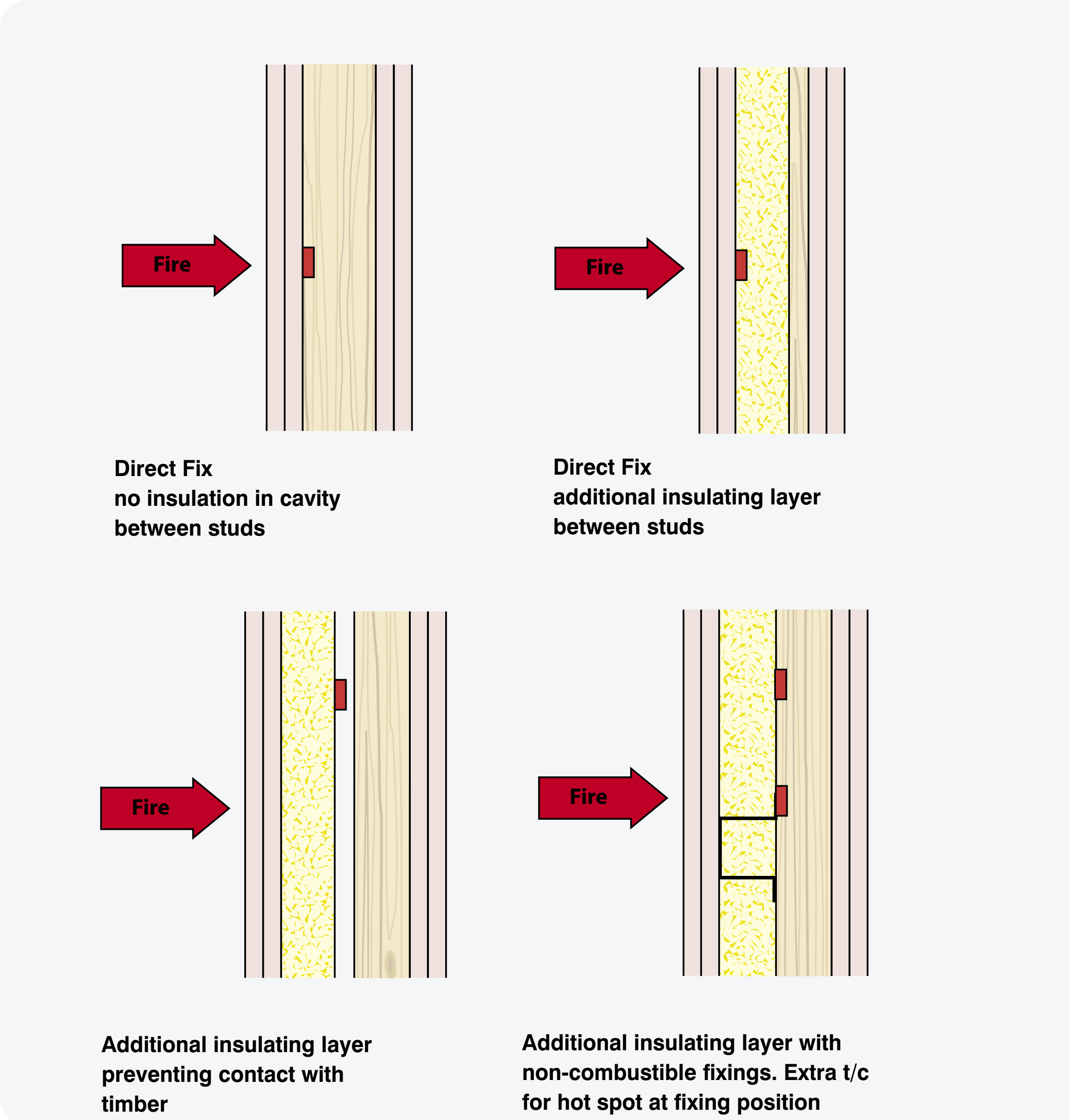


Figure D4: Resistance to the incipient spread of fire thermocouple positions for typical specimen configurations.

Failure in relation to the RISF is deemed to occur when the maximum temperature of the thermocouples described above exceeds 250°C.

Smaller scale specimens 1 m x 1 m can be used to determine the performance of services penetrations in *Fire-protected Timber.* Typical examples of thermocouple configurations for various types of service penetrations are shown in Figure D5. Additional thermocouples are shown to allow the simultaneous determination of the FRL of the service penetration system.

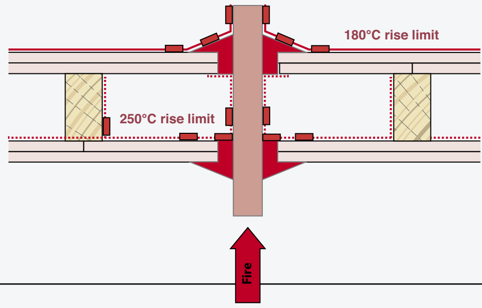
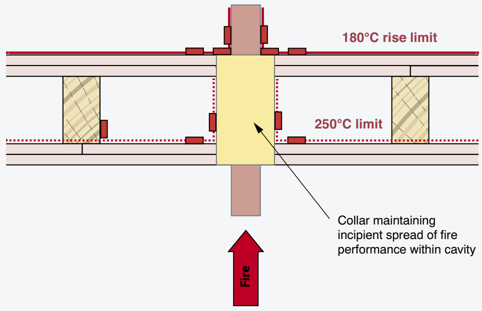
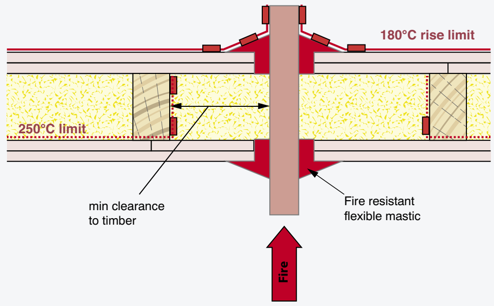
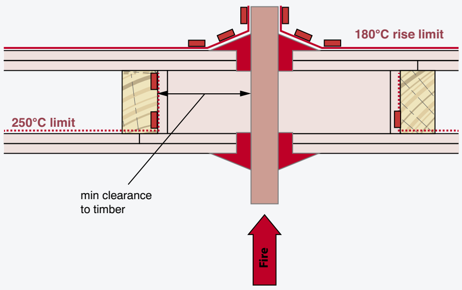
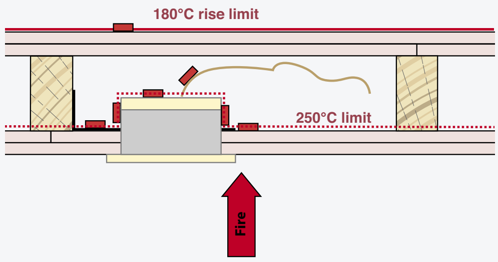
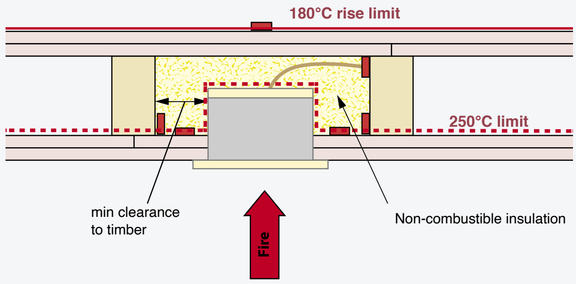
Cable/metal pipe penetration protected with fire-resistant mastic.	
Plastic pipe protected by insulating collar system.	
Cable/metal pipe penetration protected with fire resistant mastic and non-combustible cavity infill. The critical interface for RISF for the service penetration system is the surface of the insulation where it is in contact with timber elements. Note: plasterboard surface is the critical surface for determining the RISF of the wall system	
Cable/metal pipe penetration protected with fire-resistant mastic and cavity lined with non- combustible board. The critical interface for RISF for the service penetration is the surface of the lining board where it is in contact with timber elements.	
Proprietary GPO outlet protection system. Note: Thermocouples applied to cable surface connected to the GPO, on fixing bracket and adjacent element.	
GPO outlet with non-combustible cavity infill protection. The critical interface for RISF is the surface of the insulation where it is in contact with timber elements. Note: plasterboard surface is the critical surface for determining the RISF of the wall system	

Figure D5: Typical thermocouple positions for determining the RISF of service penetrations.

The thermocouples positions must satisfy the following requirements:

- At not less than two points about 25 mm from the edge of the hole made for the passage of the service.
- Attached to adjacent structural members and those elements that support the penetrating service.
- At points on the surface of the penetrating service or its fire stopping encasement, as follows:
  - at least two thermocouples about 25 mm from the plane of the general surface of the covering and non-combustible insulation
  - where the seal or protection around the service is tapered or stepped, two additional thermocouples beyond the step or the end of any taper if it is expected that the temperatures will be higher at these points.
- Where practicable, at two points on the seal or protection around the service.
- One in the centre of the surface of the penetration nominally parallel to the plane of the fire protective covering if it terminates within the cavity (e.g., GPO outlets or down lights).

Failure in relation to the RISF is deemed to occur for the service penetration when the maximum temperature of the thermocouples described above exceeds 250°C.

Modified Resistance to the *Incipient Spread of fire* (MRISF) Test Procedures

The MRISF is applicable to *Massive timber* panels having a thickness not less than 75 mm if there are no voids/cavities through which fire and smoke can spread. The MRISF, amongst other things, relaxes the failure temperature from 250˚C to 300˚C to reflect the reduced risk of fire spread through cavities and higher inherent fire resistance of timber with larger cross-sections. The test procedures are described in Section 3 of Specification C1.13a of the NCC and are summarised below:

Tests must be carried out in accordance with AS 1530.4, or an equivalent or more severe test, on the timber element with the proposed non-combustible fire protective coverings fixed in a representative manner.

Smaller scale specimens (not less than 1m x 1m) can be used to retrospectively determine the MRISF performance of a system that has previously achieved the required fire resistance level in a fire resistance satisfying the minimum size requirements specified in AS 1530.4. If a fire protection system incorporates joints, the test specimens must incorporate representative joints.

Testing to evaluate the MRISF performance must measure the temperatures at the following locations:

- at joint positions in the protection systems
- at least 200 mm from any joint
- at any other locations if, in the opinion of the Accredited Testing Laboratory, the interface temperature may be higher than the above positions.

Temperatures at each of these locations must be measured by a minimum of two thermocouples complying with Appendix C1 and Section 2 of AS 1530.4 as appropriate.

Where the fire protective covering is not in contact with the timber (e.g., multi-layer system), the surface of the fire-protective covering is deemed to be the interface.

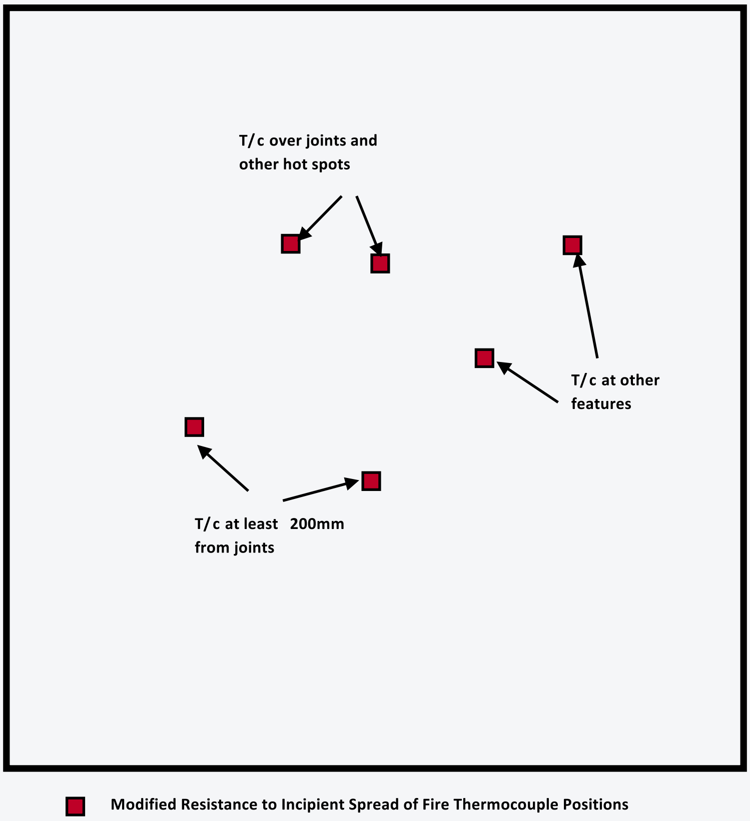


Figure D6: Elevation of a wall showing modified RISF thermocouple positions.

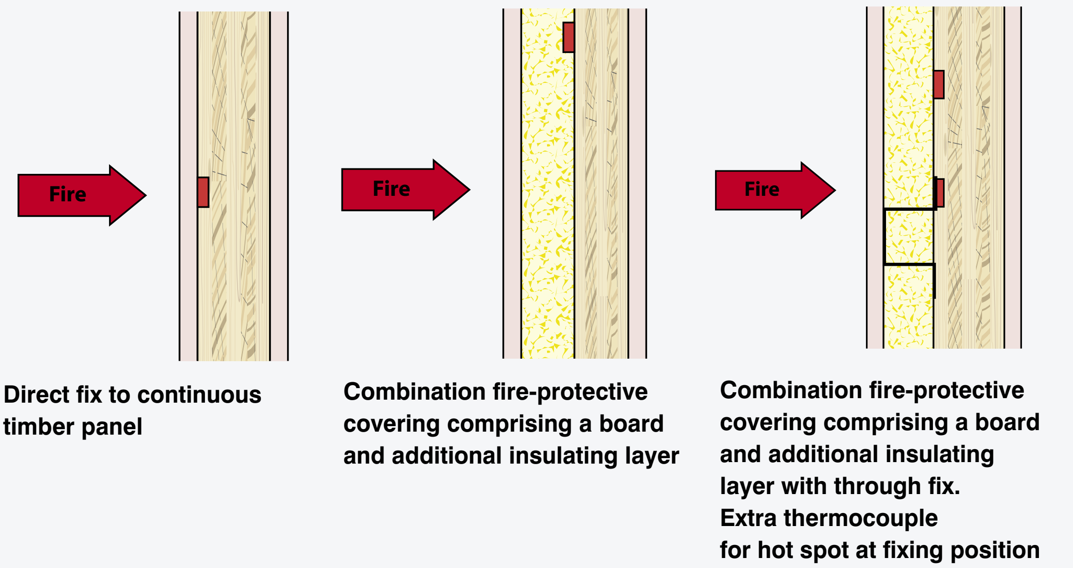


Figure D7: Modified RISF thermocouple positions for typical specimen configurations.

Failure in relation to the MRISF is deemed to occur when the maximum temperature of the thermocouples described above exceeds 300°C.

Smaller scale specimens 1 metre x 1 metre can be used to determine the performance of services penetrations in *Fire-protected Timber*. Typical examples of thermocouple configurations for various types of service penetrations to determine both the MRISF and FRLs are shown in Figure D8.

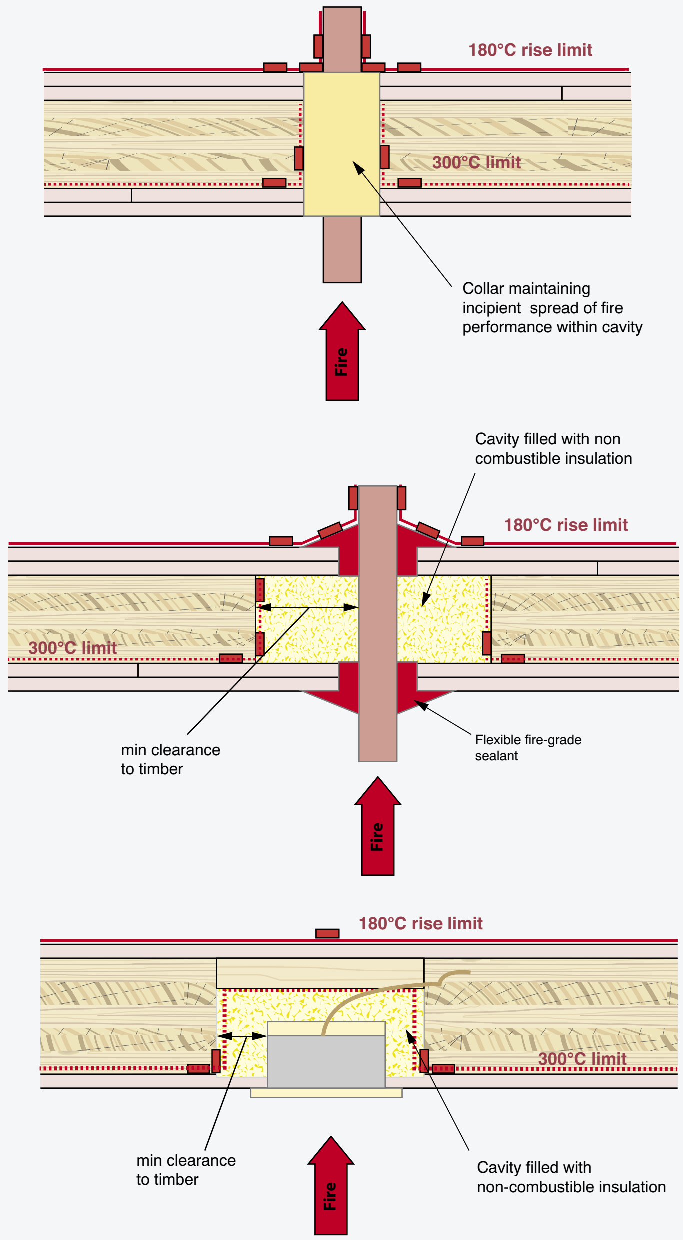


Figure D8: Typical thermocouple positions for determining the MRISF of service penetrations.

Evidence of Suitability for Cavity Barriers in *Fire-Protected Timber* Construction

Specification C1.13 of the NCC sets out the requirements for cavity barriers in *Fire-protected Timber* re-protected timber construction. The following compliance options are provided for cavity barriers:

- the cavity barrier system must achieve the FRLs specified in Table D3 when mounted in timber elements
- comprise timber of minimum thickness as specified in Table D3 and with density equal to or greater than the structural timbers in the proposed application or
- comprise polythene-sleeved mineral wool or non-sleeved mineral wool slabs or strips placed under compression and of minimum thickness as specified in Table D3 or
- for cavity barriers fitted around doors and windows, steel frames are also Deemed-to-Satisfy the requirements for cavity barriers provided that the steel frames should be tightly fitted to rigid construction and mechanically fixed. It should, however, be noted that if the windows or doors are of fire-resistant construction, the windows or door system needs to be capable of achieving the required fire resistance when mounted in the wall system, notwithstanding the requirements for cavity barriers.

Table D3: Cavity barrier requirements for Fire-protected Timber.

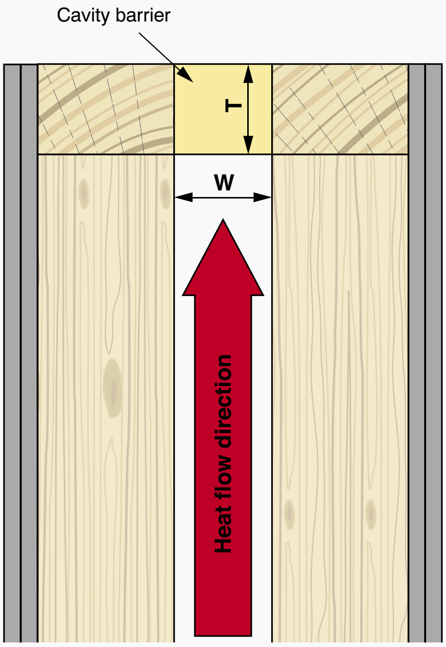
Requirements	**FRL required for element cavity barrier is fitted to (minutes)**	
	–/90/90 or less	**greater than –/90/90**
Cavity Barrier Required FRL – minutes	–/45/45	–/60/60
Timber required minimum thickness	45 mm	60 mm
Mineral wool required minimum thickness	45 mm	60 mm

The minimum thicknesses of protection are required to be measured in the direction of heat flow. The role of a cavity barrier is normally to prevent a fire spreading from the cavity on one side of the cavity barrier to the other. The top plate of a double stud partition (Detail A of Figure D9) is a typical example of this where the direction of heat flow for the cavity barrier would be from the underside to the upper face of the barrier.

The other role for cavity barriers is to reduce the risk of fire spread to cavities occurring around openings for doors and windows within a fire-resisting wall. This configuration is shown as Detail B in Figure D9. For this scenario, the heat flow is from the occupied area of the building through the framing to the cavity. In the Figure, the thickness dimension is identified as 'T'.

Proprietary cavity barrier systems may provide more practical options than the *Deemed-to-Satisfy Solutions* for some applications. To encourage the development and use of these systems a compliance path has been provided through the specification of FRLs. For smaller cavity barriers, the performance should be determined by testing the cavity barrier as a control joint system in accordance with Section 10 of AS 1530 using timber members as the separating element. Specification C1.13 permits the results from such a test to be used for applications where the *Fire-protected Timber* is constructed from timber with a nominal density at least equal to the tested timber.

Detail A
Cavity Barrier at the Head of a double stud partition



Detail B
Cavity Barrier around door opening

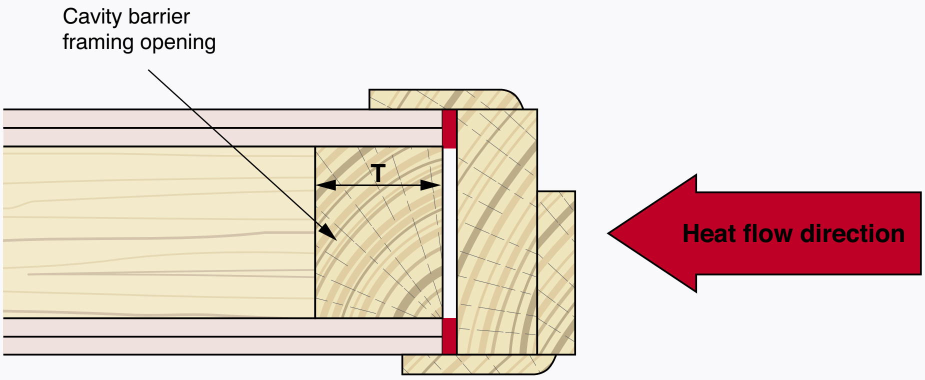


Figure D9: Heat flow direction for cavity barriers.

Typical test configurations are shown in Figure D10. The selection of the test configuration(s) depends on how the cavity barrier will be mounted. If it is symmetrical (e.g. fitted at the mid-depth of a timber member), Detail A is appropriate. If the cavity barrier system is not symmetrical both details B and C should be tested unless the most onerous configuration can be determined by the test laboratory or the cavity barrier use is restricted to one configuration. A report from an Accredited Testing Laboratory should state the field of application for the cavity barrier based on the test results.

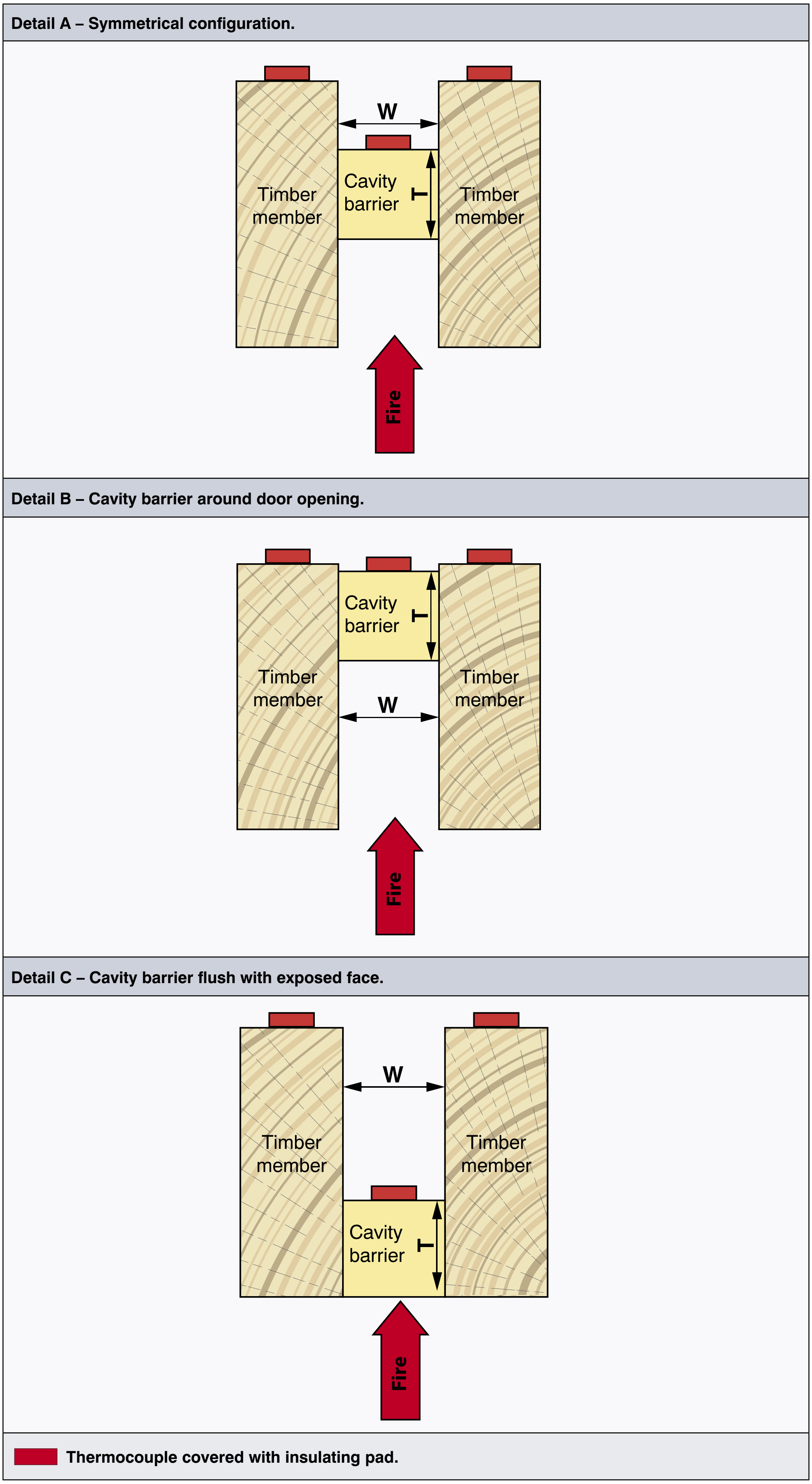
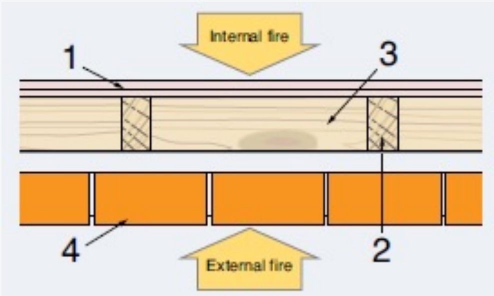


Figure D10: Typical cavity barrier test configurations.

E

Appendix E – Example Data Sheet Identifying Evidence of Suitability

External Brick Veneer Timber framed wall system



1 Fire protective grade plasterboard, 2 x 13 mm thick

2.Timber framing in accordance with Evidence of Suitability

3 Cavity. – Cavity insulation may be required to achieve sound ratings and R –value (insulation must be non-combustible)

4 Outer brick veneer 90 mm thick

Typical Performance

Fire-protected timber	FRL90/90/90: RISF45: NC
Sound transmission and insulation	R_w 50: R_w+C_{tr} 50
Thermal resistance	R Value 3.3 m²K/W
Damp and weatherproofing	NCC performance requirement FP1.4
Structural tests	NCC specification C1.8 Clause 3.4

Evidence of Suitability

Fire-protected timber:	
Internal Fire Exposure	FRL Test or assessment report from an Accredited Testing Laboratory complying with NCC A5.4 – (Lab XYZ Report Ref 123) RISF – 45 (NCC Spec C1.13a DTS)
External Fire Exposure	FRL Test or assessment report from an Accredited Testing Laboratory complying with NCC A5.4 or design in accordance with AS 3700 RISF – 45 (AS 3700 design for insulation or test or assessment report from an Accredited Testing Laboratory)
Non-combustibility	Plasterboard NCC C1.9(e)(i) DTS Fire-protected timber NCC C1.13 Concession Cavity Insulation AS 1530.1 test Brickwork – NCC C1.9 / C2D10(4) n iii (planned introduction in 2022) DTS

Sound Transmission and Insulation No NCC requirement for external walls in NCC but commonly specified for inner city locations. Report from a laboratory or acoustics engineer stating performance achieved.

Thermal Resistance R-Value Report complying with NCC Clause A5.2

Weatherproofing Statement of compliance with relevant requirements of AS 3700 and report confirming applicability of AS 3700 – complying with NCC Clause A5.2.

Structural tests for lightweight construction Report complying with NCC Clause A5.2 expressing results of tests in accordance with NCC specification C1.8.

Primary Distributors Plasterboard Supplier xyz

Note: The above is an example of how summaries can be developed to identify necessary Evidence of Suitability for fire protected timber elements. A document similar to the above could be included in a product technical statement from a manufacturer. Selection of systems that are fit for purpose and the provision of Evidence of Suitability to the satisfaction of the Appropriate Authority is the responsibility of the designers and product suppliers. Forest and Wood Products Australia Limited (FWPA) and the authors of this Guide make no warranties or assurances with respect to the fitness for purpose of the systems described in this Guide.

F

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