Fire Safety Principles for Massive Timber Building Systems

GUIDELINE

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PROCEDURAL

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This guideline should be reviewed by the doctrine owner by 22 October 2029.

Contents

About AFAC and AFAC Doctrine

AFAC

The Australasian Fire and Emergency Service Authorities Council (AFAC) is the Australian and New Zealand National Council for fire, emergency services and land management. It is a collaborative network of fire, emergency services and land management agencies that supports the sector to make communities safer and more resilient.

AFAC Doctrine

AFAC develops doctrine to support the practice of emergency management. The information in doctrine publications is evidence-based and drawn from academic research and the collective expert knowledge of member agencies. Doctrine is regularly reviewed and represents the official AFAC view on a range of topics.

Doctrine does not mandate action; rather, it sets aspirational measures. Publishing nationally agreed views, shared approaches and common terminology enhances cooperation and collaboration within and between agencies and jurisdictions.

Types of AFAC Doctrine

AFAC Doctrine is classified as follows:

Capstone doctrine – includes publications, such as 'strategic intents', that are high-level accounts of the concepts of emergency management operations and service delivery. They describe the principles of what is practical, realistic and possible in terms of protecting life, property and the environment.

Fundamental doctrine – includes 'positions', which AFAC members are expected to support, as well as 'approaches' and some 'frameworks'. Fundamental doctrine may become agency or jurisdictional policy on a matter if adopted by individual services or jurisdictions.

Procedural doctrine – includes 'guidelines', some 'frameworks' and 'specifications'. AFAC members are expected to be aware of procedural doctrine. A guideline is an advisable course of action; a framework provides a linking of elements to create a supporting structure to a system and specifications are a detailed description of a precise requirement to do something or build something.

Technical doctrine – includes 'technical notes', 'training material' and the *Australasian Inter-Service Incident Management System* (AIIMS). Technical doctrine provides guidance of a technical nature: the how to do something, or the technical meaning relative to a situation.

About this document

This publication is a guideline. At the time of publishing it is supported by the following:

- *Fire Safety in the Built Environment* (AFAC 2019)

Acknowledgements

AFAC and its member agencies have been supported in the development of this guideline by input from industry organisations such as Forest Wood Products Australia.

Source of authority

Approved by AFAC Council on 22 October 2024.

Purpose

The primary objectives of this guideline are to:

- identify the relationship between fire authorities' guidance and the *National Construction Code's* (NCC) limitations of deemed-to-satisfy (DTS) clauses in relation to the use of massive timber building systems
- describe the specific issues relating to occupant life safety and fire brigade intervention in buildings incorporating massive timber building systems
- facilitate consistent advice from AFAC members to the construction industry.

Scope

This guideline is predicated on establishing principles for the safe design of buildings using massive timber building systems. It is not a prescriptive document. Rather, it seeks to inform fire agencies about the current principles for fire safety design with engineered timber products. The adoption of the guiding principles detailed herein, coupled with a comprehensive design process agreed to by the local fire authority, should ensure a reliable design outcome in terms of fire safety by the design and construction stakeholders.

The intention of the document, when read, understood and applied, is to reduce the likelihood and consequence of fire, assist with firefighting intervention and protect life, property and environment from fire.

This guideline is not a statutory document and should be given due consideration by each stakeholder as it relates to their role and responsibility in planning, designing, consulting, assessing or determining the case of any building that utilizes massive timber construction.

Application of this guideline does not automatically provide an acceptable solution that avoids the involvement of fire authorities in the process. Fire authorities should always be involved early in the consultation phase of any development or risk management process.

The use of massive timber building systems in buildings or building parts classified under the National Construction Code has not been specifically addressed in this guideline. This guideline promotes the analysis of hazards, achievement of fire safety outcomes and developing a coherent strategy that delivers the satisfactory fire performance including brigade intervention, irrespective of classification or occupancy types. Discussions of buildings' particular classifications have been omitted at this stage as the fire engineering issues associated with using massive timber building systems and building classification (e.g. special fuel load, special occupancy requirements) warrants further research.

NOTE: It is the responsibility of the designer to ensure compliance with the required jurisdictional legislation. Every project is unique and the information in this document should be used as a guide only. The designer should justify design solutions using Performance Based Design Briefs and processes outlined in the Australian Fire Engineering Guidelines.

Statement of engagement

This guideline was developed through consultation and contribution from members of AFAC's Built Environment Technical Group (BETG) and external bodies.

Audience

This guideline is intended to be used by fire authorities to support a collaborative approach with any person conducting a business or undertaking, designer, owner, development proponent (e.g. builder, fire engineer), planning consultant, regulatory authority, or authority having jurisdiction (AHJ).

Definitions, acronyms and key terms

In this document the following terms have specific meanings.

AHJ – Authority having jurisdiction: An organisation, office, or individual responsible having the regulatory authority for enforcing requirements of legislation, codes, standards and orders.

Burnout: The end of an uncontrolled fire in a compartment after all the available fuel has been consumed, and the room temperatures drop to allow firefighters safe access to carry out fire suppression activities. (Buchanan & Östman, 2022, p. 55) Noting that after this stage structural capacity can still decrease.

Char layer: The Char layer is produced when the wood material is exposed to external heat and is transformed into solid carbonaceous residue (Buchanan & Östman, 2022, p. 65).

Combustible: Has the same meaning as Schedule 1 of the National Construction Code (NCC). Applied to:

(a) a material — means combustible as determined by AS 1530.1; and

(b) construction or part of a building — means constructed wholly or in part of combustible materials (Commonwealth of Australia and the States and Territories of Australia, 2022).

Contribution of timber: The explicit emphasis that the timber used in the building's construction must not contribute additional fuel to any conceivable fire scenario, and the timber must not contribute to any effect that is worse than would occur in a non-combustible compartment.

Deemed-to-satisfy provisions: Has the same meaning as Schedule 1 of the NCC. Provisions which are deemed to satisfy the Performance Requirements (Commonwealth of Australia and the States and Territories of Australia, 2022).

Delamination: The consequence when a layer of laminated engineered timber separates from the parent member due to the heat transfer and or combustion effects in the compartment. This exposes fresh fuel and loses the charring's insulating effect, potentially intensifying the fire and its burning duration.

Delamination is applicable in exposed timber but may also be applicable in fire-protected timber.

Debonding: The effect of laminated engineered timber separating at its adhesive layer due to effects of a fire event. It is synonymous with delamination.

Designed containment: The concept of preventing fire spread to adjacent compartments using internal and external containment measures.

Engineered wood product: A composite wood product manufactured to achieve specific and consistent performance suitable for engineering design.

Exposed timber: Exposed timber elements have no protection and therefore rely on the properties of the timber section to withstand the effects of fire. As opposed to fire-protected timber that is defined by a building code (NCC, NZ BC) and protected by a non-combustible material.

Fire brigade intervention: The terminology used to determine the time taken by the fire brigade to arrive at the building and any likely action of its officers (e.g. whether they will undertake a search and rescue operation, and the likely time for that operation). Beyond this period, the specific considerations of massive timber building systems may impact on further actions such as fire investigation.

Fire compartment: Has the same meaning as Schedule 1 of the NCC. Either:

(a) the total space of a building; or

(b) when referred to in—

   (i) the Performance Requirements — any part of a building separated from the remainder by barriers to fire such as walls and/or floors having an appropriate resistance to the spread of fire with any openings adequately protected; or

   (ii) the Deemed-to-Satisfy Provisions — any part of a building separated from the remainder by walls and/or floors each having an FRL not less than that required for a fire wall for that type of construction and where all openings in the separating construction are protected in accordance with the Deemed-to-Satisfy Provisions of the relevant Clauses of the National Construction Code (Commonwealth of Australia and the States and Territories of Australia, 2022).

Fire-protected timber: The term applied to the method of protecting timber element with a non-combustible/protective material to avoid the timber becoming involved in a furnishings fire. Fire-resisting timber building elements that comply with Specification 10 (Commonwealth of Australia and the States and Territories of Australia, 2022).

Fire resistance level: Has the same meaning as Schedule 1 of the NCC.

Furnishings fire: The furnishings fire establishes a difference between a fire that involves the compartments contents (furnishings) and a fire that may involve the structure. This may be referred to as 'movable fuel load' in some jurisdictions. Also refer to contribution of timber.

Massive timber: An element generally 75mm or greater in thickness from: cross-laminated timber (CLT), glue laminated timber (GLT) or Glulam, laminated veneer lumber (LVL), nail laminated timber (NLT) and dowel laminated timber (DLT).

Massive timber building systems: Wall, floor, column and roof construction using engineered wood products, their connections and the way they work together in buildings.

Performance solution: Has the same meaning as Schedule 1 of the NCC. A method of complying with the Performance Requirements other than by a Deemed-to-Satisfy Solution (Commonwealth of Australia and the States and Territories of Australia, 2022).

Self-extinction: In this document, self-extinction refers to the phenomenon where the flaming on the surface of the timber member ceases. Extinction is a limit condition of flame spread and, in this context, it is the limit point where the supply of fuel vapour to the flame from the massive timber section falls below the fuel vapour amount needed for flaming. 'Self-extinction' can be a misleading term because it can be used to describe the end of flaming combustion, the end of the decay stage, or the end of smouldering combustion. (Buchanan & Östman, 2022, p. 57). This document is only referring to the end of the flaming combustion.

Sole occupancy unit: Has the same meaning as Schedule 1 of the NCC. A room or other part of a building for occupation by one or joint owner, lessee, tenant, or other occupier to the exclusion of any other owner, lessee, tenant, or other occupier and includes—

(a) a dwelling; or

(b) a room or suite of rooms in a Class 3 building which includes sleeping facilities; or

(c) a room or suite of associated rooms in a Class 5, 6, 7, 8 or 9 building; or

(d) a room or suite of associated rooms in a Class 9c building, which includes sleeping facilities and any area for the exclusive use of a resident *(Commonwealth of Australia and the States and Territories of Australia, 2022).*

Introduction

This guideline is based on the available research, terminology and design approaches using massive timber building systems for the built environment. As engineered timber building products are subject to ongoing development, this guideline endeavours to establish the common terminology and the foundation principles. Subsequently, this guideline compiles AFAC agencies' experiences of the research projects and construction approaches for timber buildings. AFAC has endeavoured to describe the products and the design principles that are associated with the construction approaches using those products.

The research related to engineered timber and associated products are large and ongoing. AFAC has listed the foundation research that has informed fire safety approaches to this point. As research about massive timber construction and fire safety continues, AFAC advocates that users of this guideline and fire agencies in general follow this progression in construction material research.

Doctrine concepts

Background

Massive timber building systems refers to a variety of different products and is generally used to distinguish this construction method as different from traditional lightweight timber frame construction methods. These systems are built from engineered timber elements that are generally 75mm or greater in thickness and include cross-laminated timber (CLT), glue laminated timber (GLT) or Glulam, laminated veneer lumber (LVL), nail laminated timber (NLT) and dowel laminated timber (DLT) (WS Technical Design Guide 16: Massive Timber Construction Systems, 2018, p. 4).

Massive timber building systems are claimed to possess an inherent level of fire resistance similar to solid timber, due to the thickness of the product allowing for charring while maintaining a suitable thickness of unaffected timber capable of supporting the required structural loads. This inherent fire resistance is based on the principle of a timber section developing a char layer that insulates the internal timber and supports a process of self-extinction as the energy transfer to overcome the thickening char layer acts to extinguish the combustion of timber.

AFAC member agencies have evaluated two types of applications for massive timber design and their building systems, referred to as fire-protected timber and exposed timber.

1. Massive timber design approaches

The two approaches of design for massive timber are described in the following sections.

1.1. Fire-protected timber

The process of preventing massive timber sections from becoming additional fuel for a building fire has been managed in the fire-protected timber approach of the National Construction Code (NCC). Protecting the surface of massive timber sections is detailed by the NCC, Specification 10 as a DTS solution.

Alternatively, designers may wish to use a Performance Solution, such as partial protection with DTS element and protection with another material element. Fundamentally, the protective layer(s) prevents the timber in contributing to the fire event, prevents structural degradation of timber and the design demonstrates that the protection shall remain intact for the necessary period to achieve that purpose.

1.2. Exposed timber

The exposed timber approach typically adopts or endeavours to address how the self-extinction phenomena of the timber elements perform within the fire scenarios. Particularly as exposed timber construction presents many surfaces of timber and available fuel load, any fire safety design must determine whether self-extinction is achievable, and whether those conditions are appropriate within the fire scenarios. Self-extinction and its impact and effects within the fire scenario needs to be determined by way of a comprehensive technical analysis.

An approach that provided fire authorities with necessary confidence in a fire safety design project was where the analysis of fire safety strategy also combined with the separation of the hazards concept (explained below). Self-extinction was analysed in the period after the furnishings fire had decayed and was used to separate burning period sequences of the available fuel. This allowed the design to demonstrate that there was a period where self-extinction occurred on a timeline in the fire scenario. The fire sequence was that as the furnishings fire decayed, the exposed timber burned until the imposed heat flux degraded to below a critical value. The self-extinction demonstration in this case identified that further contribution of exposed timber and prolonged burning did not occur. Importantly, the self-extinction analysis was coupled with the analysis of the fire dynamics of the compartment, since self-extinction methodologies were not fully ratified and required due caution within the design.

The separation of hazards concept identified the hazards associated for timber and fire safety design and employed the analysis to prevent and control the causes of each of the potential hazard events. When the causes are effectively controlled, thereby preventing the hazard event, the other hazard events can be analysed. Separating these hazards was undertaken in the design analysis to ensure that components with the potential to fail the fire safety strategy are investigated.

The fire safety strategy is a performance statement that defines the goals and objectives established for the building and the necessary functionalities of all the interdependent systems for the fire scenarios. Where the systems and components are prevented from failing, then the fire safety strategy is designed to achieve the intended outcome.

The following illustration (see Figure 1) is provided from an example approach as applied from an early timber design project. This approach was considered necessary by the peer reviewer and the fire authority as the self-extinction design methodology was incomplete and subject to uncertainty. Six hazard events are identified in Figure 1. The analysis of self-extinction is located under the hazard event: 'Timber construction prevented from contributing to fire'. The analysis of self-extinction in this project considered causes of sustained pyrolysis that prevented self-extinction, and the causes (sources) of re-radiation that delayed self-extinction. Ultimately the time-based scenario of the separation of hazards, and the fire modelling and flame spread analysis was determinative for this project's fire safety design to be approved.

The fire safety strategy for a building essentially delivers the outcomes fire authorities need to see, e.g., the occupants escape to safety before they may be injured; firefighters are able to intervene and conduct their operations; the building, where in part or as a whole, does not unexpectedly collapse due to fire and whilst occupants are still within the building; and external fire spread is limited. For the massive timber building systems, an additional strategy of separating the hazards demonstrates that the building can deliver fire safety outcomes commensurate with a conventional DTS building and is therefore a fire-safe building through its own performance.

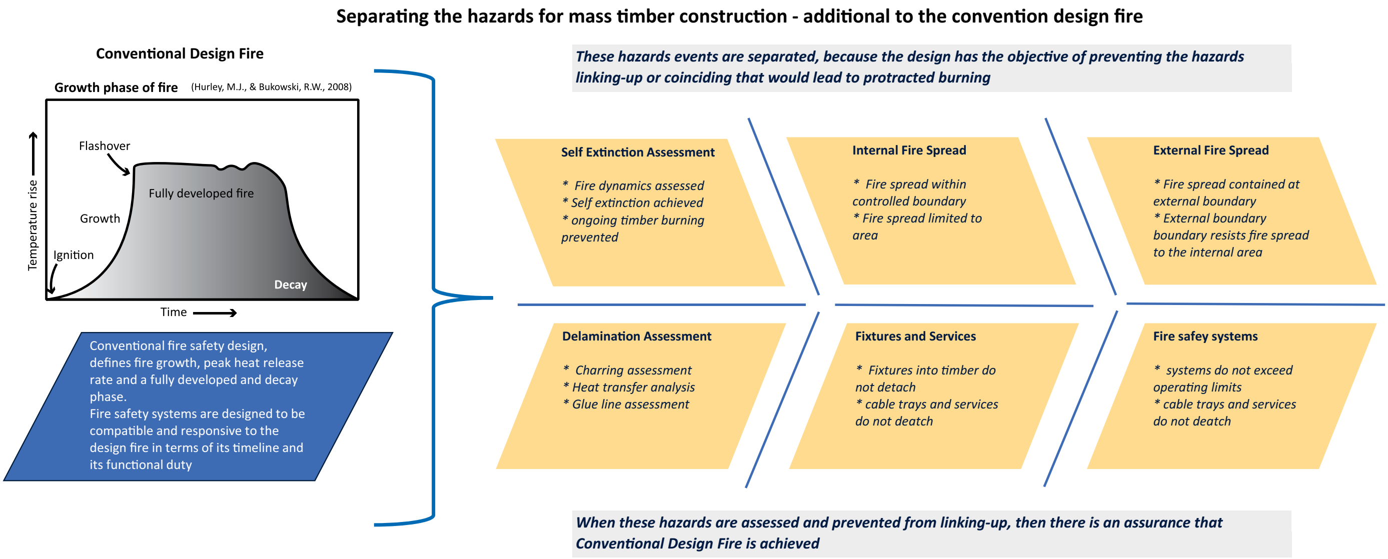

Figure 1. Separation of hazards - fishbone diagram

2. Guiding principles for fire safety design

Building designers may wish to undertake their building designs adopting either fire protection or exposed timber methods or combinations of both. Within this context of design flexibility, AFAC and its member agencies submit the following principles to be appropriately addressed in the building design, whether the DTS or performance solution approaches are undertaken.

2.1. Contribution of timber

The timber is potentially an additional fuel load above that of the building's furnishings fuel load. The design must therefore prevent the timber from contributing this additional fuel to a fire and worsening or prolonging the duration period of the fire. If exposed timber elements are used in a building, its contribution to fuel load shall be appropriately assessed and hazards resulted from this additional fuel load be identified and considered in the fire safety design.

2.2. Fire resistance

The conventional approaches to fire resistance are essentially based on the premise that the compartment boundary is non-combustible or inert and does not contribute fuel to the fire. Massive timber construction elements obviously contradict this premise, and therefore a modification to the determination of fire resistance of the boundary needs to be undertaken. Fire resistance is not generally translatable in exposed massive timber building systems design and should be replaced by the concept of designed containment.

2.3. Charring assessment

The assessment of charring through the critical layers of timber provides indication of element behaviour and potential failure through delamination. Consider multiple approaches using iterative calculation of fire severity and experimental values for converging around an appropriate time interval for charring. Currently available methods for calculation are detailed in Fire safe use of woods (2022, Buchanan & Östman)

2.4. Failure assessment

Assessing the conditions that lead to failures associated with massive timber building systems, e.g., protective layers falling off and delamination of CLT. The failure assessment is also applicable to embedded connections and supported attachments. The outcome of the failure assessment is that appropriate measures are implemented that safeguard against failure conditions occurring.

2.5. Burnout assessment

Assessment of the compartment for burnout of the total available fuel load under the most arduous conditions occurring in the compartment.

2.6. Hazard analysis for fire safety strategy

The Australian Fire Engineering Guidelines (AFEG) states that a systematic review should be conducted to establish potential fire hazards (both normal and special) of a building under evaluation. A hazard is the outcome of a particular set of circumstances that has the potential to give rise to unwanted consequences. Regarding building fires, a 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.

The fire related hazards in a building can arise from the layout of the building including its location with respect to adjoining properties, construction materials, activities undertaken in the building, possible ignition sources and fuel sources.

One of the first stages in reviewing potential fire hazards for a project is to examine available fire incident data for facilities having the same or very similar form and usage. This data may be international in origin and therefore must be used with care to establish possible hazards and a realistic measure of the possible unwanted consequences of fire. There is unlikely to be any relevant available data for many years given the emerging nature of massive timber design.

Every hazard has a risk associated with it. The risk arising from a hazard is the frequency of an event involving that hazard, times, the expected consequences. A hazard may be controlled, but there will always be an event frequency of occurrence and therefore always a positive value of risk associated with the hazard.

Whilst the frequency of hazardous events (probability) is considered during the hazard analysis, AFAC member agencies will be specifically concerned for the consequence analyses of fire events. AFAC member agencies, as design stakeholders, will need evidence that in the event of credible worst-case fires, that a massive timber building will perform satisfactorily.

3. Hazard considerations

The following are considerations of the hazards introduced by massive timber building systems.

3.1. Fire sprinkler protection

Sprinklers are recognised to reduce the probability of a fire event reaching unwanted conditions, nevertheless they do not eliminate all the probability. Given the uniqueness of massive timber building systems, a purposeful fire safety strategy that manages the consequences is necessary and does not focus on the reduction of probability. For this reason, sprinklers are therefore deemed to be a redundancy to the core fire safety strategy for the purposes of analysis.

3.2 Delamination

A failure mode of massive timber products is delamination. Delamination is controlled by fire duration and severity which is determined by ventilation and fuel load. Ventilation conditions need to be designed so that the heat flux decays to enable self-extinction in the shortest possible time. The combination of the assessment of the fuel load and the ventilation conditions establishes a worst-case condition for delamination assessment.

The delamination of massive timber elements results in timber contributing to the fire regrowth after initial decay. This can result in further delamination and the continuation of the fire until structural integrity is lost. This represents a hazard for firefighters and adjacent buildings. Therefore, this scenario needs to be prevented. Only if it can be demonstrated that delamination can be avoided during the entire period between ignition and self-extinction then separation of hazards can be done. The absence of delamination is assessed by conducting a heat transfer analysis into all structural elements affected by the fire to demonstrate that the temperature at the interface between the exposed layer and the next layer of the massive timber does not degrade the adhesives .

3.3 Charring

In the absence of delamination, then, the conventional FRL analysis can be applied. For example, the charring rates can be calculated using conventional approaches to guarantee structural integrity according to the member's residual sectional strength for the periods prescribed by DTS solutions.

It should also be noted that self-extinction does not mean charring has finished or that heat impacting the residual timber has finished. (Buchanan & Östman, 2022)

3.4 Furnishings

In the presence of a furnishings fire (movable fuel load), exposed timber may ignite, and flames will spread on the surface of the structure. The analysis should display the evolution of the fire with the interaction between the burning of the furnishings and that of the exposed timber structure. The subsequent burning of massive timber sections from a furnishings fire can be identified through separated energy criteria. An appropriate ignition criterion is recommended to monitor flame spread over the timber structure while an appropriate self-extinction criterion from research can aid the determination of where the exposed timber structure will cease burning after furnishings fuel load has been fully consumed (burn-out). The separation of hazards can only be done if complete self-extinction is demonstrated from such an approach.

3.5 Fire growth rate

The fire growth rate, fire size, building characteristics and fire safety measures determine the available safe egress time (ASET). To ensure that fire growth rate of the massive timber is not worse than a conventional building, the comparative modelling of the fire growth in a building constructed of non-combustible material (e.g. concrete or steel) and of exposed timber may be necessary if the comparative approach is taken.

If extended travel distances are a component of the building design, it will be necessary for an ASET vs required safe egress time (RSET) analysis to be performed for the conventional hazards introduced into the building. It then needs to be demonstrated that the fire growth with and without exposed timber will remain the same for at least twice the RSET. A reasonable and appropriate factor should be used that considers the variability of egress data within the calculation. Only when it can be demonstrated that the fire growth remains the same for the appropriate factor of safety for the RSET will the hazards be considered adequately separated.

NOTE: **Extended travel distance will also impact fire brigade intervention times and must be included in those calculations.**

NOTE: **For determination of all reasonable and appropriate factors and values, consultation with the relevant fire authority is recommended during the Performance Based Design Brief stage.**

3.6 External spread

The presence of exposed timber will inevitably introduce additional fuel to the fire. During a fully developed fire, much of this fuel will likely burn outside the compartment if ventilation is limited. The spill plume from compartment should be modelled for all scenarios (fires at multiple locations) to demonstrate that the additional timber fuel for the external flames, will not result in external fire spread. Typically, a fire safety strategy is governed by the assumption that fire will remain at the floor of fire origin. Therefore, only if it is demonstrated that external spread will not occur, then both hazards (additional fuel and available fire spread pathway) can be separated. An analysis of the spill plume should be conducted to demonstrate that, for all scenarios studied, external elements will be protected with the heat flux from the spill plume. The receiving element should use appropriate and reasonable values to demonstrate glazed openings do not fracture and fall out and for the timber elements (at or around the openings) within the level above do not ignite.

3.7 Smouldering fires

Smouldering fires represent a hazard. The impact of smouldering on the load resisting capacity of the structure is a concern for fire authorities and can occur for hours following a flaming fire. This can have consequences for the final extinguishment and the prevention of the reignition of timber elements. Furthermore, the overhauling work that firefighters undertake to ensure smouldering has ceased is made challenging.

A sensitivity analysis with sufficient ignition locations that cover all critical scenarios should be conducted. This sensitivity analysis should include critical conditions for external flames, critical conditions for delamination, critical conditions for charring and critical conditions for structural integrity.

If all the failure and burning conditions are satisfied, then the hazards introduced by the massive timber as a construction material can be separated from the conventional hazards of buildings. Once these failure and burning conditions have been demonstrated within a fire safety analysis for the building, it can be concluded that the massive timber construction has no detrimental impact on the fire safety strategy greater than a conventionally constructed building.

4. Issues for design consideration, building approval and building operation

The use of massive timber building systems introduces combustible materials into the construction of buildings. The use of combustible construction materials has the potential to introduce a number of issues, including (but not limited to):

- building elements with reduced fire resistance levels (FRLs) with respect to structural adequacy, insulation, and integrity
- combustible materials within fire-isolated egress paths
- combustible materials within concealed spaces
- higher fuel loads within fire compartments
- combustible materials in balcony areas that may have unprotected penetrations through the floor (e.g. downpipes and floor wastes) and significant ignition sources (e.g. gas, electric, wood or coal barbecues)
- exposed combustible building elements during construction.

For the reasons identified above, the use of combustible materials within certain structures is limited or prohibited entirely by the NCC based on the type of construction required. Table 1 reproduces the types of construction required for certain buildings as identified by NCC 2022 Clause C2D2.

Generally, construction types A and B limit or prohibit the use of combustible materials due to the potential for rapid horizontal and vertical fire spread and the impact on occupant tenability during egress and the impact on the ability for fire brigade intervention. The designers have a deemed-to-satisfy compliance approach under the NCC as per Specification 10 Fire-protected timber, however if Specification 10 is only partially applicable to the design, then the compliance pathway will need to be subject to a performance solution.

A performance solution must demonstrate compliance with the NCC performance requirements in accordance with NCC, Part A2G2. In these circumstances, the use of massive timber building systems in buildings must be comprehensively assessed by a fire engineer. It then must be shown to satisfy the NCC performance requirements to the satisfaction of the authority having jurisdiction before the building may be considered compliant.

Consequently, all the itemised considerations should be incorporated into the fire engineering documentation that is developed in order to demonstrate how the buildings fire safety strategy is achieved.

5. Fire engineering documentation

In general, the regulatory framework does not permit the use of combustible materials for elements of buildings that require types A and B construction. Therefore, details of the massive timber building system proposed should be provided to the relevant fire authority during the fire engineering design phase in addition to the supporting information that the system is appropriate to facilitate occupant egress and fire brigade intervention. This information may include, but should not be limited to:

- panel construction details (including adhesive details) and method of production
- construction method details (e.g. connections, fixings, penetrations)
- compliance/adherence with international standards or codes if applicable (e.g. EuroCodes) without 'cherry picking' from multiple standards
- calculations for fire endurance and containment to validate fire resistance
- calculations for panel charring rate with consideration to AS 1720.1, AS 1720.4 and published literature
- test information identifying that the proposed panel construction can achieve the required FRL.

The fire engineering report should consider building design features associated with the use of the massive timber building system that may have an impact on occupant egress and fire brigade intervention, including (but not limited to):

- the potential for fire spread between combustible building elements and combustible façades

- the use of appropriate construction joints to limit the spread of fire and maintain required FRLs
- the use of appropriate penetration sealing systems to limit the spread of fire and maintain required FRLs
- location and construction of building parts with certain classifications and significant fire loads (e.g. carpark areas which can present a significant fire load should be incorporated into the lowest storeys of the building and constructed of conventional steel and concrete)
- fire spread through concealed spaces.

6. Material considerations

Research conducted on the fire resistance properties of massive timber building system panels has identified several factors that can impact the fire performance, including (but not limited to):

- wood type
- thickness of layers
- number of layers
- orientation of layers
- orientation of the panel (e.g. wall, ceiling, floor)
- adhesive used between adjoining layers
- fixing methods (mechanical or adhesive used between adjacent boards)
- longitudinal joining of boards.

Where AS 1530.4 test results are used to demonstrate that a panel construction meets a specific FRL, consideration should be given to the material properties identified above when comparing the tested panel construction and the proposed design panel construction. The panel manufacturer should be consulted for further advice.

Additionally, the methods to be used for connecting the panels require equally rigorous consideration and justification to ensure these areas do not introduce potential weak spots in the structure that may facilitate fire or smoke spread or lead to premature structural failure of one or multiple panels.

7. Firefighting considerations

The use of massive timber building systems introduces issues that have the potential to detrimentally impact on the ability for fire brigade intervention in the event of fire, including (but not limited to):

- the potential for structural collapse during search and rescue activities and firefighting activities as a result of smouldering and continued heat propagation, and water pooling on floor and in concealed spaces
- faster fire growth, greater heat release rates, and possibility of multiple flashovers
- the potential for external fire spread requiring additional resources to control

Table 1: Type of construction required (Commonwealth of Australia and the States and Territories of Australia, 2022), Clause C2D2).

Rise in storeys	**Class of building**	
	2, 3, 9	**5, 6, 7, 8**
4 or more	A	A
3	A	B
2	B	C
1	C	C

- the potential for increased production of smoke, carbon monoxide and heat reducing the ability to conduct efficient and effective search and rescue and firefighting activities
- the potential for increased demand/load on automatic suppression systems and hydrants for fire suppression
- the potential for fire spread in concealed spaces.

Conditions expected within the building during fire brigade intervention should be clearly demonstrated as part of the fire engineering assessment and discussed with the appropriate fire brigade to determine if their operational requirements are met.

8. Fire safety systems

In areas where fire sprinklers are not specifically required by the DTS provisions of the NCC, the installation of a suitable sprinkler system is considered necessary. In Australia, the NCC Clause C2D13 requires a sprinkler system to Specification 17 (The FPAA101D or 101H systems are not suitable fire suppression systems for massive timber building construction). AFAC recommend sprinkler protection be extended to cover all areas of the building, including fire-isolated stairs.

Smoke seals and closers should be provided to all sole occupancy unit entrance doorways and waste room doors within any residential tower.

Reliable, monitored, early warning detection systems are expected throughout buildings utilising massive timber building systems. The detection system should be designed to minimise the potential for unwanted/false alarms.

For buildings greater than 25m in effective height, each storey is expected to be provided with not less than two exits in addition to any horizontal exits.

9. Structural design

Buildings utilising massive timber building systems should include an appropriate level of structural redundancy throughout and particularly in areas that are potentially critical for occupant egress and fire brigade intervention (e.g. stair wells).

The adequacy of all structural panel connections consisting of steel plates or pins are to be verified by a structural engineer as part of the fire safety design.

Connections to be appropriately protected, by means such as timber plugs with appropriate depth into timber layers, or have connections recessed into members such that appropriate depth of timber provides protection to connections.

The structural engineer, in combination with the fire engineer, should provide the fire authorities with the assurance that the structures are designed for additional loads, structural capacity of fire-weakened structure, distortion, expansion effects, water ponding and will not collapse on firefighters during the design fire scenario period and the extended cooling phase period thereafter.

Consideration should be given to long-term structural integrity when massive timber building systems are used in humid and wet environments such as buildings with swimming pools.

10. Concealed spaces

Service penetrations within concealed spaces are to be provided with a suitable penetration sealing system to inhibit the spread of smoke to other fire compartments and maintain the required fire separation/containment barrier of the building element penetrated. Any concealed spaces including sub-floors, must be provided with smoke detection and sprinkler protection. Where concealed spaces are too shallow to provide smoke detectors and/or sprinklers, they must be lined with a non-combustible lining and not be permitted to contain any combustibles or ignition sources.

11. Egress and emergency evacuation

Where required, building management needs to formulate, document, and implement an emergency evacuation plan for all occupants, including those with mobility impairment, consistent with the fire engineering report and include occupant/staff training in accordance with the requirements of AS 3745.

12. Fire precautions during construction

Here, the NCC Clause E1D16 should be complied with in full. A site-specific fire safety risk management plan is to be prepared by the developer in consultation with the fire engineer to identify and address risks that will exist during the construction process. The fire safety risk management plan must include arson prevention measures.

Prior to commencement of construction, an additional report is to be prepared demonstrating effective consideration of the previous two points. The report is to obtain agreement from appropriate stakeholders.

A fully operational fire hydrant system, appropriate to the size and orientation of the building and building site, is to be made available on-site, at ground level, from the commencement of construction.

In the event that any sprinkler, hydrant or fire detection systems are fully isolated, or isolated in part, as a result of staged building work or maintenance, additional fire safety measures and procedures are to be implemented to maintain an appropriate degree of safety. The de-isolation and re-activation of these systems must occur prior to the close of business each day.

13. Fire safety systems installation and commissioning

All fire safety measures documented within the fire engineering report are to be installed in accordance with the relevant Australian Standards. Sprinkler systems are to be provided with monitored isolation valves on each level of the building within the emergency egress stairs.

Sprinkler systems are also to be provided with end-of-line testing capacity on each level of the building.

At the commencement of the construction phase and prior to occupation, the building and all fire safety measures are to be inspected by the fire safety engineer to ensure that the fire safety measures have been reasonably implemented in accordance with the fire engineering report.

Prior to occupation of the building, integrated testing and commissioning is to be undertaken on all fire safety systems. Similarly, prior to occupation of the building, the relevant fire authority is to inspect the functional operation of the fully installed fire safety systems.

NOTE: In jurisdictions where fire authorities are not required to inspect the functional fire safety systems, it is beneficial for them to be invited.

14. Maintenance and management

All parts of emergency egress paths, including the egress stairs, corridors, lift lobbies, and entry areas, are to be kept free of combustibles (e.g. furniture). Balconies, regardless of floor area, are not to be used for storage or contain combustible or flammable products (e.g. barbecues) unless sprinkler protected.

The management measures identified in the previous two points are to be recorded as essential safety measures for the building, to be maintained regularly in accordance with the fire engineering report or relevant Australian Standards.

All fire safety systems are to be maintained in accordance with relevant Australian Standards.

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15. Further reading

For documents associated to the issues around fire safety related to massive timber buildings, AFAC suggests the following:

- Australian Fire Engineering Guidelines
- National Construction Code – Building Code of Australia
- Australian Standards
  - AS 1684.1-4 Residential Timber Framed Construction
  - AS 1720.1 Timber structures, Part 1: Design methods
  - AS 1720.4 Timber structures, Part 4: Fire resistance of timber elements
  - AS 2118.1 Automatic fire sprinkler systems, Part 1: General systems
  - AS 3745 Planning for emergencies in facilities
- Fire Safe Use of Wood in Buildings: Global Design Guide
- New Zealand Building Code
- Wood Solutions Technical Design Guides:
  - 03. Timber Fire Design Compliance for Low-rise Office (Class 5) and School (Class 9) Buildings
  - 15. Fire Design
  - 17. Fire Safe Design of Timber Structures- Compliance with the NCC
  - 18. Fire Safe Design of Timber Structures- Methods of Analysis and Supporting Data
  - 19. Performance Solution Fire Compliance- Internal Linings

Also:

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