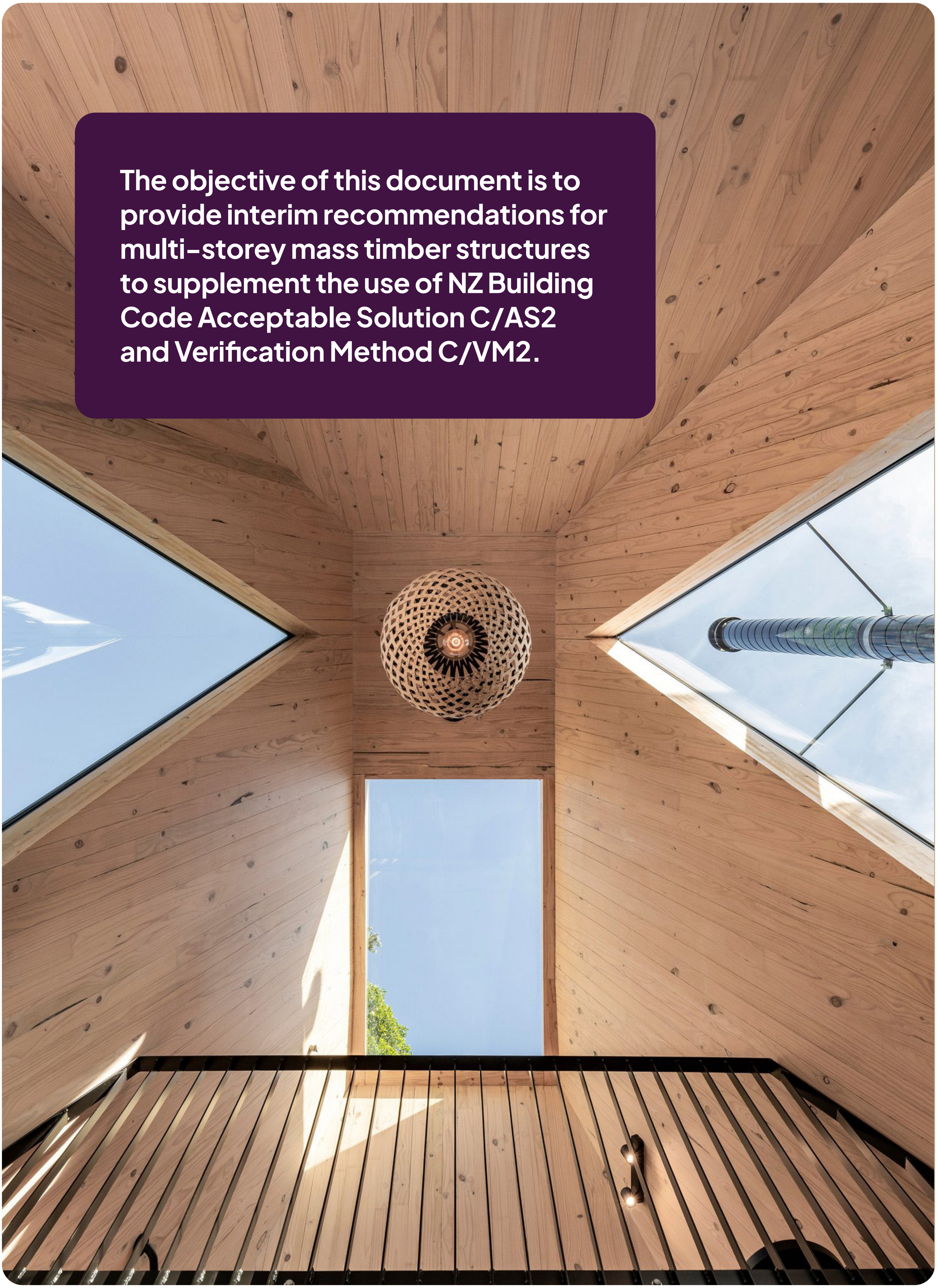
Timber Unlimited

Fire safety in multi-storey mass timber structures

RECOMMENDATIONS TO SUPPLEMENT C/AS2 & C/VM2

The objective of this document is to provide interim recommendations for multi-storey mass timber structures to supplement the use of NZ Building Code Acceptable Solution C/AS2 and Verification Method C/VM2.



1. Introduction

Rationale

- The reason for this proposal is to address three principal concerns regarding fire safety in mass timber buildings, in the unlikely event that firefighter access is delayed, and sprinklers (if installed) are ineffective:

    1. Large areas of exposed structural timber can add significantly to the fire load.
    2. Charring may continue after a severe fire appears to be extinguished.
    3. The strength of wood decreases with temperature, starting at temperatures below 100°C.

- Recent advances in timber materials, including Cross Laminated Timber (CLT), have resulted in mass timber being considered for a wide range of buildings. New Zealand Building Code (NZBC) documents C/AS2 and C/VM2 do not contemplate the extensive use of mass timber, so using these documents without specific consideration of mass timber may produce fire safety outcomes that do not meet the performance requirements of the NZBC.

Use of this document

- This document provides recommendations for an emerging area of building construction and is published by Timber Unlimited. It is not published as guidance under s175 of the Building Act. It is recommended practice produced by a team of experts after reviewing recent national and international research. The advice is likely to change as more information becomes available. The flowchart in Appendix D may be of assistance to readers.

Background

- A recent international book, *Fire Safe Use of Wood – Global Design Guide (2022)* provides much information on the design of timber buildings for fire safety. To expand the use of this guide into common practice in New Zealand, Timber Unlimited has commissioned a New Zealand Commentary and these recommendations.

  Further discussion and detailed justification for the recommendations in this document will be provided in the Commentary to be published late in 2023.

What buildings do the interim guidance recommendations apply to?

- This document applies to all mass timber buildings with escape heights greater than 4 metres, where charring could significantly add to the fuel load and reduce the structural capacity.
- It is expected that buildings with escape height not more than 4 metres will be subject to normal design procedures, with no additional recommendations. Buildings with escape heights above 25 metres are beyond the scope of this document.

The following types of building are included:

- Buildings with mass timber structural frames, walls or floors (either exposed or protected).
- Buildings with a mix of concrete and mass timber (e.g. concrete core walls and timber gravity structure).
- Buildings with a mix of structural steel and mass timber (e.g. structural steel braced frames with CLT floors).
- Buildings with timber-concrete composite floors (with vertical structure of any material).
- Buildings with a mix of mass timber and light timber frames (e.g. light timber walls and mass timber floors).

This document applies to risk groups SM, SI, CA, and WB as defined by C/AS2.

- Risk groups WS (high rack storage) and VP (vehicle parking) are outside the scope of this document.
- There are no additional recommendations for mass timber residential buildings designed using C/AS1.
- There are no additional recommendations for light timber frame buildings (such as those covered by NZS 3604) provided that there are no large areas of exposed structural mass timber.

2. Prescriptive design of mass timber buildings using Acceptable Solution C/AS2

For mass timber buildings with escape height greater than 4 m, a prescriptive design based on C/AS2 should contain the following supplementary measures in 2.1 to 2.2. Additional items in 4.1 to 4.8 are recommended for buildings designed using C/AS2 or C/VM2.

2.1. FRR and areas of exposed wood

Where CAS2 requires building elements to be fire rated, the life and property ratings should be taken from Table 1 below but not be less than those given in Table 2.4 of C/AS2. The FRR values in Table 1 apply to both life ratings and property ratings. Encapsulation materials provided to limit the fuel load may also contribute to the fire resistance.

Table 1.
Permitted area of exposed mass timber and minimum FRR
For Risk Groups SM, SI, CA, WB[4]

	Unsprinklered building		Sprinkler-protected building[1]	
	Exposed wood	Minimum FRR[5]	Exposed wood	Minimum FRR[5]
Escape Height up to 4 metres (1 and 2 storeys)[6]	WU	As in C/AS2	WU	As in C/AS2
Escape Height more than 4 m and up to 10 metres (3 and 4 storeys)[6]	W100	60[2]	WU	60[3]
Escape Height more than 10 m and up to 18 metres (5 and 6 storeys)[6]	W0	90	W200	60
Escape Height more than 18 m and up to 25 metres (7 and 8 storeys)[6]	Not recommended		W100	60

Notes to Table 1:

1. Sprinklers must be installed to a recognised standard as required by C/AS2 (e.g. NZS 4541).
2. The minimum FRR of 60 minutes in category W100 requires a Type 4 or Type 5 fire alarm system to be installed, otherwise the minimum FRR becomes 90 minutes, unless all wood is encapsulated (category W0).
3. If exposed wood is in category W100, the minimum FRR is specified in C/AS2 Table 2.4.
4. For Risk Group WB, refer to Note 2 in C/AS2 Table 2.4.
5. The minimum FRR applies to all structural and non-structural elements which are required to be fire-rated.
6. The escape height governs over the number of storeys, which are shown only for guidance.

Refer to Section 2.2 for exposed mass timber categories WU, W200, W100 and W0. The permitted amount of exposed timber considers factors such as the expected occupant egress time, risk to firefighting operations and adjacent property, reflecting the increased consequence of failure with increasing building height.

Risk Groups and building types that are not covered by this Guidance Document are not excluded from using mass timber. This document is simply guidance and has no regulatory enforcement status. Designers are free to use mass timber in buildings not within the scope of this document using either C/VM2 or an Alternative Design (or a combination of the two), provided that they achieve the satisfaction of the regulatory authorities.

2.2. Exposed mass timber categories

Category WU

- Unlimited area of exposed mass timber surfaces.

Category W200

- The maximum area of exposed timber in any firecell is 200% of the floor area, shared across multiple surfaces.
- This could be all of the ceiling exposed and some of the walls, or a combination of both.
- In addition, structural timber beams and columns may also be exposed provided that the additional exposed surface area is no more than 10% of the floor area.

Category W100

- The maximum area of exposed timber in any firecell is 100% of the floor area on an elevated horizontal surface (timber floor soffit), OR 40% of the floor area on vertical surfaces (timber walls), OR a pro-rata combination.
- As an example, a pro-rata combination of exposed area could be 75% of the ceiling plus a wall area equal to 10% of the floor area, as permitted in Type IV-B construction in the US International Building Code (IBC).
- In either case structural timber beams and columns may also be exposed provided that the additional exposed surface area is no more than 10% of the floor area.
- In this category there must be a 3 m separation distance (measured parallel to the floor) between exposed timber on adjacent walls to prevent interactive burning of walls in internal corners.

Category W0

- Full encapsulation. No exposed mass timber is permitted, hence no addition to the fire load. FRR should be as per C/AS2, table 2.4 or calculated using C/VM2.

All categories other than WU

- All non-exposed mass timber must be encapsulated to limit the surface temperature of the timber to 300°C for the specified FRR period from C/AS2 Table 2.4 or Table 1.
- The top surface of a structural timber floor is considered to be encapsulated if it is protected by a layer of non-combustible material at least 15mm in thickness. A layer of combustible floor covering is permitted over the non-combustible protective layer.

3. Verification Method design of mass timber buildings using principles of C/VM2

For buildings with escape heights above 4 metres, a design based on the principles of C/VM2 should contain the following supplementary measures in 3.1 to 3.5. Additional consideration should also be given to the items in 4.1 to 4.8 as these are recommended for buildings designed using either C/AS2 or C/VM2.

3.1 Relaxation for buildings with escape height up to 10 metres

For sprinklered buildings with escape height up to 10m, the floors may be inter-connected and the mass timber may be fully exposed without including it in the fuel load calculations provided that:

- The design complies with C/VM2 requirements for a building with no mass timber, and
- Safe paths are encapsulated on the surface exposed to fire threat, and
- The fire resistance is no less than 60–minutes, and
- The following firefighting requirements are met:
  - FENZ hose run distance to any point on the floor is less than 75 m as measured from FENZ vehicular access, or where full building coverage is achieved from a single internal building hydrant, and
  - Where hydrants are required, the safe path stair is provided with a firefighting lobby with the hydrants located in the firefighting lobby, and
  - Vehicular access requirements are agreed with FENZ.

Note: The recommendations in 3.2 to 3.5 do not apply to buildings satisfying the above criteria.

3.2 All mass timber buildings (encapsulated or exposed timber)

- Where fire resistance for burnout is required, the fire severity calculation must take into account the ventilation and the thermal properties of the firecell boundaries, and calculate the depth of charring of exposed timber during the full fire exposure, including the decay period.
- Thermal properties for the bounding surfaces of the firecell must be consistent with the thermal properties of encapsulation materials and in proportion to the surface area of encapsulation.
- For buildings with escape height > 18 m, the minimum fire load energy density (FLED) for the moveable fuel, after applying the F_m factor, is 400 MJ/m^2.
- For buildings with escape height > 18 m, modelling the full design fire must be for the most severe fire exposure considering full and partial (50%) breakage of windows, within the limits of Equation 2.2 of C/VM2.
- The top surface of a structural timber floor is considered to be encapsulated if it is protected by a layer of non-combustible material at least 15mm in thickness. A layer of combustible floor covering is permitted over the non-combustible protective layer.

3.3 Fully encapsulated mass timber buildings

- Buildings with fully encapsulated mass timber may be designed in accordance with C/VM2 Section 2.4 using the time-equivalent method as for non-combustible materials.
- All mass timber must be protected to prevent charring for the calculated FRR period by limiting the surface temperature of the timber to 300°C.

3.4 Buildings with partially encapsulated timber or with some exposed timber surfaces

- Where fire resistance for burnout is required, the design FLED must include the fuel load of charring of exposed timber floors, walls, ceiling, columns, beams and diagonal bracing.
- The fuel load must include calculated charring of mass timber under protective linings (partial encapsulation).
- The F_m factor applies only to the introduced (movable) fuel load (design FLED in Table 2.2 in C/VM2).
- All mass timber not included in charring calculations must be fully encapsulated for the calculated FRR period.
- In normally occupied spaces there must be a 3 m separation distance (measured parallel to the floor) between exposed timber on adjacent walls to prevent interactive burning of walls in internal corners.

3.5 Notes for C/VM2 design

- The lower limit on FLED takes into account the likely fire load and uncertainty about the fire dynamics and possible contribution of charring wood to the fire load, especially important for taller buildings.
- The partial breakage of windows is included here to recognise the consequence of the uncertainty when quantifying fire severity for tall buildings.
- The calculation of fire severity may require an iterative calculation such as that described in Chapter 3 of the *Fire Safe Use of Wood – Global Design Guide*.
- The fire engineer must ensure that the fire load calculations are consistent with the surface areas of timber completely exposed, areas fully encapsulated, and those areas which are only partially encapsulated. The timber surface contributing to additional fire load includes non-structural mass timber elements as well as structural timber elements.
- The time-equivalent formula in C/VM2 (including any modification to the design FLED proposed in this document) may be used to calculate the equivalent time of exposure to the standard fire, for fire resistance ratings of non-timber structural elements, and non-structural elements such as fire doors, penetrations etc.

4. Additional considerations for mass timber buildings using C/AS2 or C/VM2

A design based on C/AS2 or C/VM2 should contain the following supplementary measures in 4.1 to 4.8.

4.1 Fire protected (safe path) stairwells and lift shafts with firefighter lift control

- Mass timber may be exposed on the inside surfaces of lift shafts and stairwells, provided that the spaces are sprinkler-protected and the surface finish materials comply with Building Code Clause C3.4.
- For single-stairway buildings with an escape heights > 18 m (sprinklered) or > 10 m (unsprinklered) the outside surface of mass timber walls around the stairwell must be encapsulated.

4.2 Penetrations and fire-stopping

- Designers must check that penetrations and fire stopping solutions are suitable for use with mass timber construction.

4.3 Gaps in construction

- Gaps at joints and in exposed areas of timber should be minimised to prevent spread of fire through assemblies and to prevent increased charring and challenges to firefighting. Gaps of any size passing through a fire-rated assembly, or surface gaps more than 5mm wide must be filled with an intumescent mastic or other recognised fire stopping sealant.

4.4 Vertical services

- Non-encapsulated service risers and vertical shafts containing building services should be fire stopped at every floor level.

4.5 Structural fire resistance

- Structural fire resistance must be demonstrated (by calculation or test results) to show that all structural members and connections have the capacity to resist the applied loads for the required time of fire resistance as stated in this document.
- Structural calculations must consider increased local charring of timber in contact with metal fixings.
- For buildings with escape heights > 18 m (sprinklered) or > 10 m (unsprinklered), free-standing columns and load-bearing walls inside firecells must be fully encapsulated, or alternatively the structural design calculations must consider the maximum internal temperatures induced by the fire. This recommendation is beyond the requirements of AS/NZS 1720.4 so specialist structural fire engineering input is required. More guidance will be given in the Commentary to the *Fire Safe Use of Wood – Global Design Guide*.

4.6 Fire-resistant adhesive

- For buildings with escape heights > 18 m (sprinklered) or > 10 m (unsprinklered), CLT floor panels must be manufactured with fire-resistant adhesive tested in accordance with Annex B of ANSI/APA PRG 320, or Annex B of prEN 1995-1-2:2025, unless it is demonstrated that the effective depth of charring will not reach the first glueline.

4.7 Buildings with a place of safety inside the building:

- Evacuation zone boundary fire separations constructed from mass timber are required to be fully encapsulated.

4.8 Fires during construction

- Comprehensive plans to manage the risks and consequences of fires during construction are essential for all mass timber buildings taller than two storeys, as described in the *Fire Safe Use of Wood – Global Design Guide.*

Appendix A. Definitions and glossary

Burnout

As defined in Clause A2 of NZBC: "Burnout – Means exposure to fire for a time that includes fire growth, full development, and decay in the absence of intervention or automatic suppression, beyond which the fire is no longer a threat to building elements intended to perform load-bearing or fire separation functions, or both."

Full encapsulation

- Full encapsulation will ensure that there is no significant charring which could add to the fuel load or reduce structural performance for the full duration of the design fire.
- Full encapsulation is required to limit the wood temperature to 300°C.
- Manufacturers of protective lining materials are able to provide information on the encapsulation performance of their materials derived from standard fire resistance tests.
- Test methods and acceptance criteria for encapsulation will be given in the Commentary to the *Fire Safe Use of Wood – Global Design Guide.*
- Encapsulated walls may have small service penetrations which allow some local charring, provided that the fire resistance rating of the assembly is not compromised and there is no significant increase in fuel load.
- Note: It should be recognised that the strength of wood will start to reduce at temperatures below 100°C and pyrolysis will start to occur at temperatures over 200°C, resulting in damage to protected wood well before charring occurs at about 300°C. For this reason, a severe fire may damage the timber behind encapsulation, and encapsulation will likely need removal by firefighters to prevent ongoing charring.

Partial encapsulation

- Partial encapsulation is protection not sufficient to provide full encapsulation. Partial encapsulation will mitigate surface flame spread and provide a delay to the onset of charring, but it may not prevent charring of the underlying timber later in the fire.
- Wood surfaces with partial encapsulation will start charring when the wood temperature under the protective layer reaches about 300°C and will char at an increased rate after the protective material falls off. Any charring under partial encapsulation, or after the protective layers fall off, will add to the available fuel load, increasing the severity and duration of the expected fire.
- The design time for partial encapsulation will depend on the fire design strategy used for the building.

Escape height

(as defined in C/AS2)

Effective depth of charring

(as defined in AS/NZS 1720.4 Clause 2.6)

Fire Resistance Rating

(as defined in C/AS2)

Appendix B. Concerns about fire safety in timber buildings, with possible mitigation measures.

- The recommendations in this document reflect concerns with large, post-flashover fires which may increase the fire risk to life safety and property in buildings. These types of fires are less frequent in sprinklered buildings, but still must be designed for.
- These concerns have mostly been addressed in this document. One item requiring more research is hazard due to larger external flaming where there are no specific mitigation measures currently proposed. This and other items of concern will be covered in more detail in the Commentary to the *Fire Safe Use of Wood – Global Design Guide*, based on the results of recent international research.

Appendix C. Collaboration

For buildings of any material, design for fire safety requires collaboration between the fire engineer, the architect, the structural engineer, other consultants and the approving authorities. The required level of collaboration increases for mass timber buildings because the decisions of one party can greatly affect the requirements of others.

Input from the fire safety engineer:

- The decision whether to follow the Acceptable Solution C/AS2 or the Verification Method C/VM2 for fire design is likely to be made early in the design process. A design to C/VM2 (or a full performance-based design) takes more design effort than a C/AS2 design.
- The main reasons for adopting a C/VM2 design pathway are usually to get more freedom in the building design, such as interconnected floor areas, rationalised means of escape, lower fire resistance provisions and other trade-offs.
- At a later stage of most designs, there will be additional input from a fire protection engineer and a passive fire engineer.

Input from the structural engineer:

- For structural fire design of most mass timber elements, the structural engineer needs to know the effective depth of char in the design fire. For C/AS2 design, this will be a simple calculation based on the standard charring rate for 30, 60, or 90 minutes, with or without a protective layer of gypsum board. Charring calculations are not normally necessary for CLT panels because the manufacturers provide load-span tables for protected and unprotected assemblies.
- Where calculation of fire severity is carried out including exposed timber, as described in Chapter 3 of the *Fire Safe Use of Wood – Global Design Guide*, the fire engineer will provide the structural engineer with the effective depth of char to use in the structural calculations. Note that the effective depth of char may be greater than that obtained from the equivalent fire severity calculations. The structural engineer may need to discuss this with the fire engineer and with CLT providers to assess the structural capacity of CLT.

Input from the architect:

- For most buildings, the architect's drawings show the finishes on all surfaces, including intumescent paint and gypsum plasterboard of various types and thicknesses. Co-ordination is essential because different types of gypsum plasterboard may be required by the fire engineer to control the fuel load, by the structural engineer or CLT provider to achieve structural fire resistance, and/or by the architect to provide a desirable architectural finish, noise control, and reaction to fire requirements.

Input from the builder and QS:

- The builder, the material suppliers, and the quantity surveyor all need to be involved in this decision-making because selected details will greatly affect the buildability and the cost of construction.

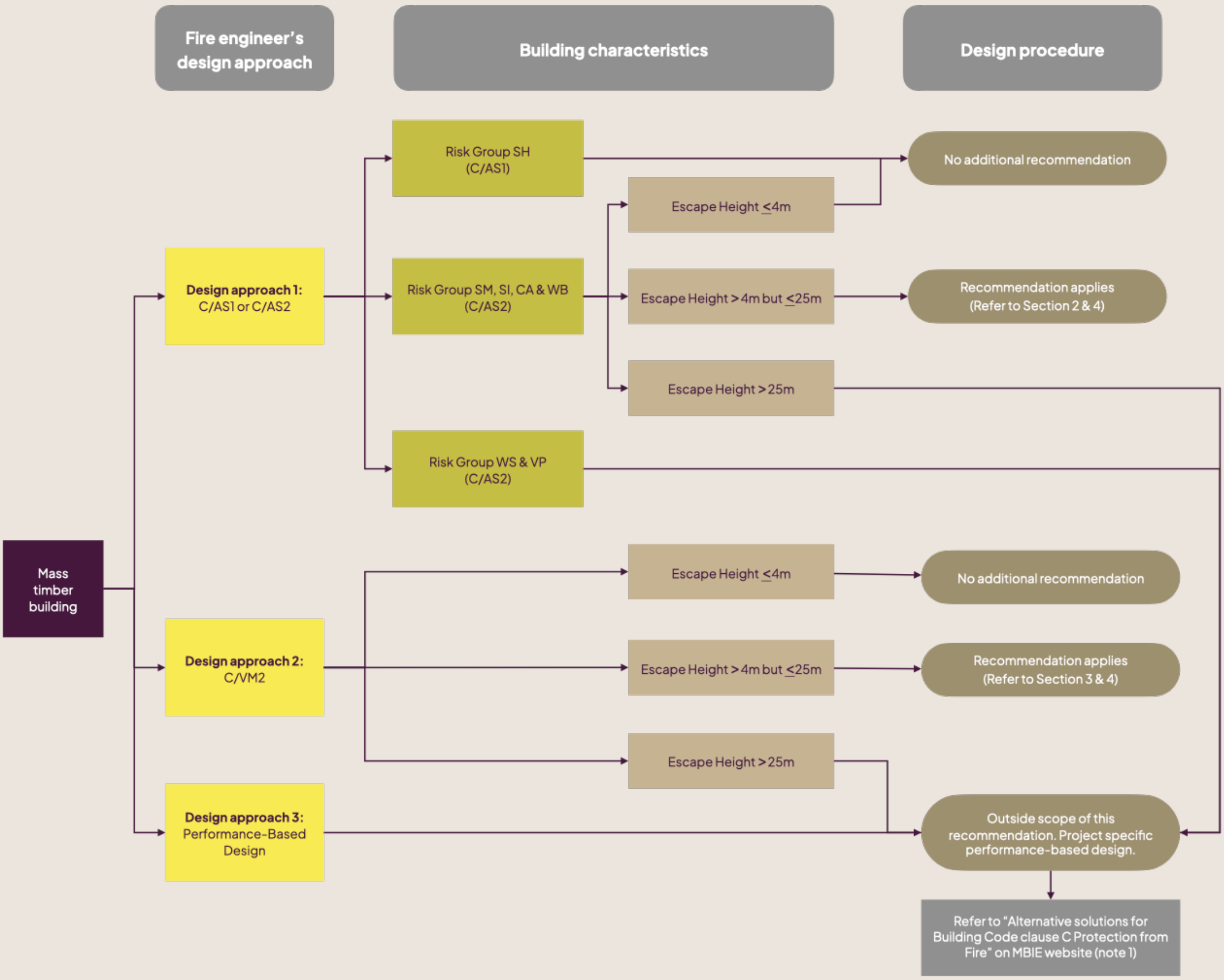
Input from the regulatory authorities:

- A building consent will not be issued by the Building Consent Authority (BCA) unless they are satisfied that the building meets the requirements of the New Zealand Building Code. The lead consultants should be talking to the BCA early in the design process. Discussions with Fire and Emergency New Zealand (FENZ) will also be required for some buildings.

Appendix D.
Design flowchart

The flowchart below gives a graphical representation of the major steps in deciding how to use this document.

This document could be used as part of an alternative solution design approach as shown below.



Note 1:
Link to Alternative solutions for Building Code clause C Protection from Fire

Appendix E. Disclaimers

This document is intended for information only. While we have made reasonable endeavours to ensure accuracy of the information set out here, it is not specific to your project, is not intended to be a substitute for specific specialist advice on any matter and should not be relied on for that purpose. We are not responsible for the accuracy or completeness of any information provided in this document and if you choose to use this document and/or use such information, you do so at your own risk. Accordingly, the information set out here is provided without warranties of any kind including accuracy, timeliness or fitness for any particular purpose. To the fullest extent permitted by law, we exclude liability for any loss, damage or expense, direct or indirect resulting from any person or organisation's use of or reliance on this document.

Timber Unlimited is a collaboration between Wood Processors and Manufacturers Association of New Zealand, New Zealand Timber Design Society, BRANZ Limited and Scion, hosted by Scion. We are helping create a future where the benefits of building in wood are widely understood and building owners and property developers commission wooden buildings.

FENZ supports the recommendations in this document. However, each building will be considered in light of its own facts, circumstances and context.

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