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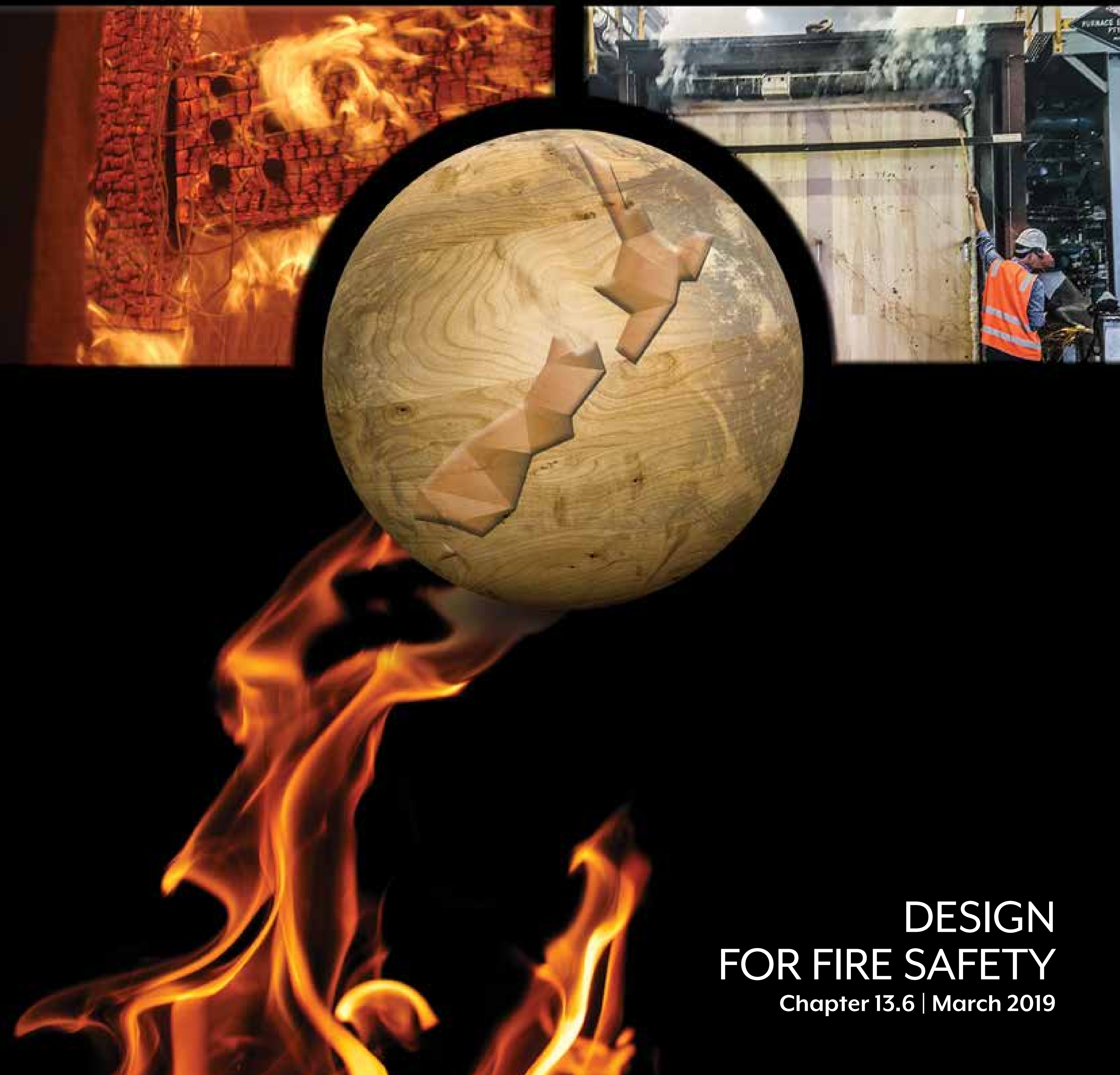

DESIGN FOR FIRE SAFETY

Chapter 13.6 | March 2019

Wood Processors & Manufacturers
Association of New Zealand

NZ Wood Design Guides

A growing suite of information, technical and training resources, the Design Guides have been created to support the use of wood in the design and construction of the built environment.

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Author: Andy Buchanan : PTL Structural Consultants

WORKING GROUP

Colleen Wade: BRANZ
Greg Barnes : Holmes Fire
Hans Gerlich: Winstone Wallboards
Tony Parkes: PFITS Consulting

NZ WOOD DESIGN GUIDE SUPPORT GROUP

WPMA Project Manager: Andy Van Houtte
WPMA Promotions Manager: Debbie Fergie
WPMA Technical Manager: Jeff Parker
Design Co-ordinator: David Streeten

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INTRODUCTION

Because wood burns, many people assume that all timber buildings have poor behaviour in fires. However, where necessary, timber buildings can be designed with excellent fire safety for the occupants, and sufficient fire resistance to prevent spread of fire or structural failure.

Timber structures tend to fall into two distinct categories; "heavy timber" structures and "light timber framing". Heavy timber structures are those where the principal structural elements are beams, columns, or panels made from sawn timber, glue laminated timber (glulam), laminated veneer lumber (LVL), or cross laminated timber (CLT). Light timber framing consists of timber stud and joist construction, typical of New Zealand house construction.

Large sized timber members, whether sawn timber or engineered wood products, have the inherent ability to provide fire resistance because surface charring of the wood allows an insulating layer to form that provides some protection to the underlying timber. In light timber framed structures, appropriate protective lining materials (e.g. gypsum plasterboards) can provide excellent fire resistance.

The contribution from timber building materials to the overall fire load depends on the surface area of timber exposed to the fire. With limited amounts of timber exposed, it is small compared with the contribution of the combustible contents which constitute the main fire load. However, a significant contribution will be made where large surface areas of timber walls, ceilings or the underside of timber floors become involved in the fire.

Charred timber roof framing still intact following a fire.

HISTORY OF FIRES IN TIMBER BUILDINGS

Many building regulations limit the use of timber as a building material, because of the combustibility of wood. A precondition for increasing the use of timber in buildings is the provision of adequate fire safety. A growing number of countries around the world are changing their building codes to allow for taller timber framed structures.

History has recorded some disastrous urban fires including huge fires in Toyko (1657, 1923), London (1666), San Francisco (1906) and Melbourne (1919). These fires predominantly occurred in low rise timber buildings, spaced closely together. Following such disasters, building standards have been introduced with restrictions on the use of timber in buildings to prevent major conflagrations. In particular most modern building codes have requirements which reduce the spread of fire across property boundaries to adjacent structures.

(above) The Great Fire of London, 1666.
(right) Ballantynes (Christchurch) Fire, 1947.

As our understanding of severe fires has increased, with the development of new materials, new technology, and new legislation, confidence in the use of wood as a major construction material has increased significantly. This is supported by increased knowledge of the inherent charring capacity of heavy timbers in severe fires. All building materials experience negative impacts from fire; steel buckles, concrete spalls and wood burns. By understanding these material properties and selecting the appropriate specification of systems, timber buildings can perform as well, if not better, in fires than other materials.

WOOD-BASED STRUCTURAL MATERIALS

In addition to solid sawn timber, the main wood-based structural materials are glulam, LVL, and CLT, often called "engineered wood products". Most engineered wood products are manufactured and used in large sizes, so that they can be considered to be "heavy timber" when calculating fire resistance.

Glued laminated timber (glulam) is made from sawn timber boards glued together in straight or curved members of almost any size or shape.

Laminated veneer lumber (LVL) is a panel product made from thin veneers peeled from logs. Most LVL is made with all the veneers oriented with the grain in the longitudinal direction to produce high strength and stiffness. Some manufacturers produce "cross-banded" LVL where two or more veneers are oriented in the perpendicular direction, for increased stability and increased resistance to splitting. Most LVL is made in a continuous process, giving panels up to 12 metres long, 1200mm wide, with a thickness from 45mm to 100mm.

Cross laminated timber (CLT) is made from sawn timber boards glued together in transvere layers at 90° to each other, rather like thick plywood, to make large panels up to 3 metres wide and 15 metres long. The most common layups are three-ply, five-ply, or seven-ply, so the finished thickness of typical panels is from about 40 mm (3 thin layers) to 300 mm (7 thicker layers).

A wide range of wood-based panel products including plywood, particle board, MDF (medium density fibreboard) are also used in building construction. Most of these products have similar fire performance to solid wood or engineered wood, provided that they are thick enough. Components with thin panels (such as wood I-joists or plywood box-beams) have little fire resistance because thin panels can burn through very quickly.

All engineered wood products are glued together with adhesive, which can have variable fire performance. Adhesives such as phenol, resorcinol, melamine formaldehyde, phenol-resorcinol or poly-phenolic adhesives are not affected by high temperatures (up to 300°C), hence their effect on charring rates can be ignored. An intermediate range of products including some polyurethane adhesives and some urea-based adhesives can have poorer fire performance, but recent advances in adhesive formulations are resulting in greatly improved fire resistance. Advice should be sought from manufacturers if necessary. Non-structural adhesives such as PVA are largely ineffective in fire.

As a general rule, well designed wood buildings can provide similar levels of fire safety as steel or concrete buildings. However, because wood burns, there are often limits on the size and surface finish of large exposed areas of internal wood products, which do not apply to non-combustible materials. With regard to fire resistance, heavy timber structures can be designed with fire resistance comparable to steel and concrete structures.

LVL. Credit Carter Holt Harvey (CHHWP).

Sawn Timber (Douglas Fir).

CLT. Credit Xlam.

FIRE BEHAVIOUR

Design of buildings for fire safety is a complex topic requiring integration of a large number of sometimes conflicting requirements. When wood burns, as with the burning of any other material, combustion is an exothermic chemical reaction releasing a large amount of heat when the combustible gases are oxidised. Many solid materials melt and evaporate to produce combustible gases when they get hot, but wood is different because it goes through a process of pyrolysis to produce the combustible gases without going through a gaseous phase. All combustion requires oxygen from the air. The combustion reaction always produces carbon dioxide, CO_2, and sometimes carbon monoxide, CO, when there is incomplete combustion.

The threat to life safety usually occurs in the early stages of a fire when occupants close to the fire can be trapped due to rapid flame spread on combustible surfaces, or be overcome by smoke. Fire resistance is required at later stages in the fire to prevent fire spread or structural collapse which could threaten occupants or fire-fighters elsewhere in the building, or threaten adjacent property or the general public.

Figure 1 shows the time temperature curve for a typical fire with no fire-fighting intervention. **Table 1**, below the curves in **Figure 1** shows the significance of the first three phases of fire development.
The transition between the growth phase and the burning phase is known as flashover, when most exposed combustible materials ignite, and burn temperatures rise suddenly. The temperature and duration of the burning phase, often referred to as a fully developed fire, is limited by the amount of fuel and the available area of ventilation openings.

Once most of the available fuel has been consumed, the fire will enter the decay phase, and temperatures will drop. After all the combustible material has been consumed, the fire will go out. This phenomenon, called burnout, is likely in non-combustible buildings, but may never occur in massive timber structures without firefighter intervention, because smouldering combustion of large timber members could continue indefinitely until the structure collapses.

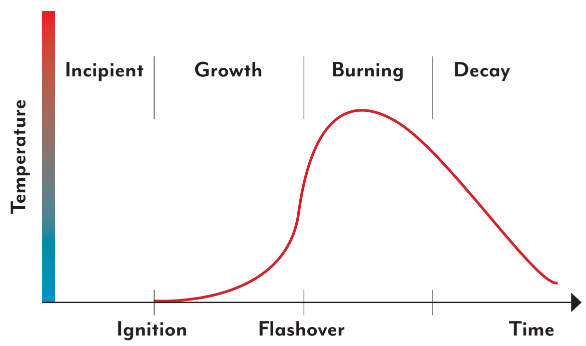
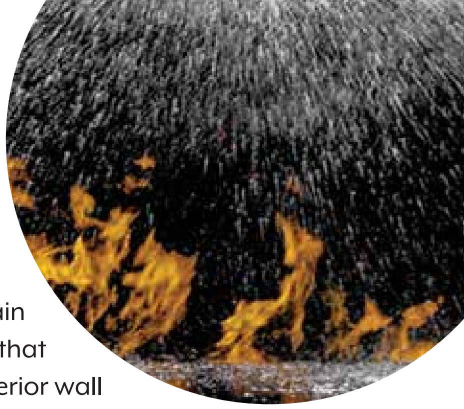


Figure 1. Time temperature curve for full process of fire development.

	Incipient Period	Growth Period	Burning Period	Decay Period
Fire Behaviour	Heating of fuel	Fuel controlled burning	Ventilation controlled burning	Fuel controlled burning
Human Behaviour	Prevent ignition	Extinguish by hand, escape	Fatal	
Detection	Smoke detectors	Smoke detectors, heat detectors, etc.	Visible smoke and flame from openings	
Active Control	Prevent ignition	Extinguish by sprinklers or fire fighters. Control smoke	Control by fire fighters	
Passive Control	Control of materials	Select materials with resistance to flame spread	Provide fire resistance, to contain the fire and prevent collapse	

Table 1. Summary of periods of typical fire development

EARLY FIRE HAZARD



Design for fire safety should initially concentrate on detection and control of fires at the earliest possible time, while allowing for the possibility of the fire getting out of control. An automatic fire sprinkler system will greatly reduce the probability of a fire from reaching flashover. Wood is a combustible material so large areas of exposed timber surfaces may allow the fire to spread rapidly in the growth phase of a fire. Design features to limit this early fire hazard include installation of automatic fire sprinklers, and limiting the total exposed surface area of combustible products, especially ceilings and upper walls.

To control the early fire hazard, building codes contain provisions to ensure that products used as interior wall and ceiling linings do not promote rapid surface spread of fire. These provisions are intended to allow time for the safe evacuation of occupants and for fire fighting operations. The New Zealand Building Code specifies Group Numbers for surface finishes in different occupancies, as described later.

FULLY DEVELOPED FIRES

Fire safety in a fully developed fire is heavily dependent on fire resistance, to ensure that the fire does not spread and the structure does not collapse.

Use of the standard fire resistance test for determining structural performance is based on the assumption that the severity of a real fire will be similar to that of the standard fire, shown in **Figure 2**. Most real fires are more like the time temperature curve shown in **Figure 1**, which may be very different from the standard fire, with higher temperatures early in the fire, a constant burning period and declining temperatures during the decay phase.

The Verification Method C/VM2 of the New Zealand Building Code allows the use of a "time equivalent formula" to calculate the duration of standard fire exposure which is equivalent to a burnout of all the fuel in a firecell. This time equivalent formula was developed for steel structures, so it cannot be used with accuracy for timber structures.

Specified minimum fire resistance ratings are given in Acceptable Solutions and are deemed to meet the requirements of the New Zealand Building Code. These can be used for almost all buildings, but critical applications such as tall timber buildings will require performance-based fire design. Design for complete burnout may not be possible without guaranteed sprinkler control or some level of firefighter intervention.

Fully Developed House fire.

FIRE RESISTANCE

Fire resistance of building elements is normally determined through full-scale testing, by exposing a test specimen to the time temperature curve shown in **Figure 2**. Calculation methods are beginning to replace fire resistance testing, but some tests will always be required.

Where necessary to limit fire spread and ensure structural adequacy in the burning phase, some building elements must be provided with fire resistance to prevent the spread of fire, and to carry the imposed loads. The standard fire resistance test is not an accurate representation of real fires because the maximum temperatures may be different and there is no decay phase.

However such tests are a useful tool for designers, code officials, and material suppliers to ensure that a certain level of fire safety is provided. Prescriptive requirements, such as the NZBC Acceptable Solutions, take account of the difference between anticipated building fires and furnace test conditions.

The three criteria for fire resistance testing are structural adequacy, integrity and insulation, always specified in that order. “Structural adequacy” is sometimes called “stability”, which can be misleading because the criterion is for strength, not stability. To meet the structural adequacy criterion, a structural element must perform its load bearing function and carry applied gravity loads for the duration of the test fire, without structural collapse. The integrity and insulation criteria are intended to test the ability of a barrier to contain a fire, to prevent fire spreading from the room of origin. To meet the integrity criterion, the specimen must not develop any cracks or fissures which allow smoke or hot gases to pass through the assembly. To meet the insulation criterion the temperature of the cold side of the fire barrier must not exceed a specified limit, usually an average temperature increase of 140°C or a local maximum increase of 180°C (above the ambient temperature).

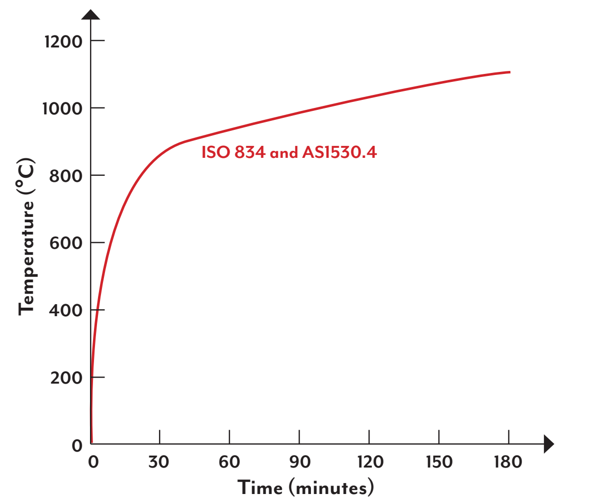


Figure 2. Time temperature curve for standard fire resistance tests.

All fire rated construction elements must meet one or more of the three criteria. **Table 2** shows which criteria must be achieved (shown with an X) for different construction elements. Note that traditional fire resistant glazing need only meet the integrity criterion because it is not load bearing and it cannot meet the insulation criterion, but some new glazing systems can also provide insulation. A typical load bearing wall may have a specified fire resistance rating of 60/60/60, which means that a one hour (60min FRR) rating is required for structural adequacy, integrity and insulation. If the same wall is non-load bearing, the specified fire resistance rating would be - /60/60. A fire door with a glazed panel may have a specified rating of - /30/ - , which means that this assembly has an integrity rating of 30 minutes, with no fire resistance for structural adequacy or insulation. For more detail on these topics, see *Structural Design for Fire Safety* (Further Reading).

	Structural adequacy	Integrity	Insulation
Partition		x	x
Door		x	x
Load bearing wall	x	x	x
Floor – ceiling	x	x	x
Beam	x		
Column	x		
Normal fire resistant glazing		x	
Insulated fire resistant glazing		x	x

Table 2. Failure criteria for fire resistance of construction elements

CHARRING OF WOOD

When large timber members are exposed to a severe fire, the timber constituents decompose into pyrolysis gases which react with oxygen to generate flames, heat and combustion products such as carbon dioxide, carbon monoxide and a solid char layer. The developing layer of charred wood helps to insulate the solid wood below. In many cases, the char layer does not burn away because there is insufficient oxygen in the flames near the surface for oxidation of the char to occur. However, during the decay period of the fire when oxygen levels increase, oxidation of char can result in smouldering combustion and some continuing erosion of the char thickness.

When the wood below the char layer is heated above 100 ˚C, the moisture in the wood evaporates. Some of this moisture travels out to the burning face, and some travels into the wood, resulting in an increase in moisture content in the heated wood a few centimetres below the char front. The boundary between the char layer and the remaining wood is quite distinct, corresponding to a temperature of about 300˚C. There is a layer of heated wood about 35 mm thick below the char layer, and the inner core remains near ambient temperatures. For structural calculations the loss of strength of heated wood below the char layer can be accounted for with a zero-strength layer, which is specified as 7.0 mm in many building codes (e.g. Eurocode 5). The heated wood above 200°C is known as the pyrolysis zone, because this wood is undergoing thermal decomposition into gaseous pyrolysis products, accompanied by loss of weight and discolouration, as shown in **Figure 3**.

Charred CLT. Credit Xlam.

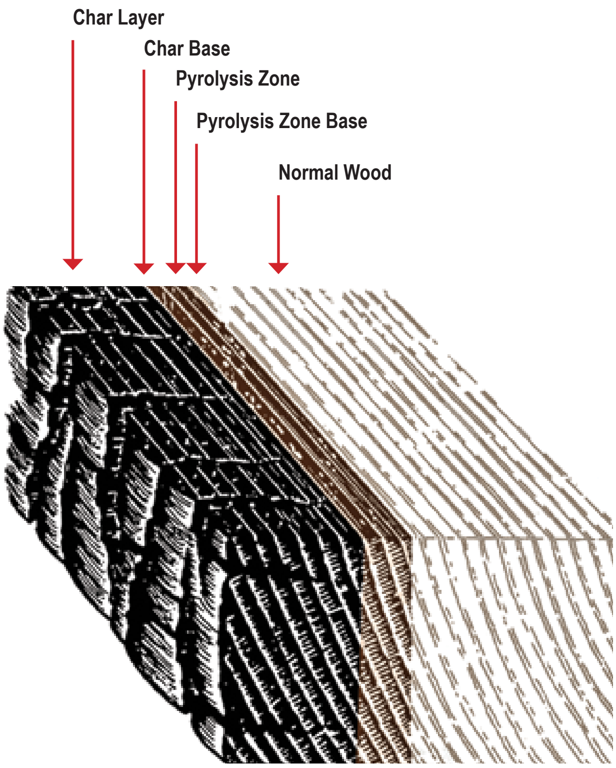


Figure 3. Time temperature curve for full process of fire development.ar layer and pyrolysis zone in a timber beam (Buchanan and Abu, 2017)

COMPARATIVE FIRE RESISTANCE OF STRUCTURAL MATERIALS

Crown Movers steel portal building post fire. (inset) Glulam floor beams showing significant charring of timber.

All building materials suffer some damage when exposed to heat, however, massive (heavy) construction in all materials has better fire performance than light or slender construction.

The natural insulating properties of timber can provide built-in fire resistance. Large timber members burn slowly, and form char on the surface. The unburnt timber retains strength and stability during a fire. Because timber is dimensionally stable at elevated temperatures, failure will not occur until the cross section has been reduced to a critical minimum size. This predictable behaviour allows fire fighters to operate safely for some time in a burning building of heavy timber construction. When a fire is brought under control before major damage has occurred, heavy timber members may still be useable, subject to cosmetic repairs. However, the original fire resistance is lost and the building fire-safety design may need to be revisited.

Engineered wood products (glulam, LVL, and CLT) have a fire performance comparable to heavy sawn timber members of equivalent size, provided that the products are glued with approved thermosetting adhesives which will not delaminate during fire exposure. New Zealand LVL manufacturers all use thermosetting resorcinol adhesives, so LVL members have equivalent fire resistance to solid wood. When LVL is remanufactured into larger components, information should be obtained about the adhesive used for re-gluing. When temperature sensitive adhesives such as some one-component polyurethane adhesives are used, there is a possibility of glueline failure allowing surface lamellae to fall away prematurely, especially with thin lamellae on the fire-exposed surface. This can allow fresh timber to ignite resulting in regrowth, a second flashover, and a prolonged burning period. There are many factors affecting this type of behaviour in real building fires including the ventilation and fuel load in the building.

Steel is a good conductor of heat, so unprotected structural steel can suffer rapid temperature rise and loss of strength when exposed to a fire. The rate of temperature increase is greatest for thin sections with a large surface area exposed to the fire. Similar to timber elements, heavy steel sections with a small exposed surface area have slower temperature rise than thinner steel sections with a large exposed area. Structural steel can be protected with a wide range of different applied materials, some of which are expensive.

Cold drawn pre-stressing steels are particularly susceptible in fire because they tend to revert to mild steel at elevated temperatures. Aluminium has poor fire resistance as it starts to weaken and melt at much lower temperatures than steel.

Reinforced concrete structures generally have good fire resistance, even though concrete loses strength at high temperatures. Concrete is generally a good insulator, so fire design of reinforced concrete is based on the cover concrete remaining in place to protect the reinforcing steel. Some concrete is susceptible to explosive spalling of the cover concrete, but this has not been a serious problem with concrete made from typical New Zealand aggregates.

Precast floor panels spalling due to fire.

CODE REQUIREMENTS FOR FIRE SAFETY

BUILDING ACT

Fire safety in New Zealand buildings is controlled by the Building Act 2004 which requires that buildings be designed and constructed to provide safety to occupants and fire fighters in the event of a fire, and to prevent fire spread to other property. The Building Act requires that the requirements of the Building Regulations, known as the New Zealand Building Code (NZBC) be met. The Building Code specifies objectives, functional requirements and performance for fire safety in each of six categories:

- **C1 | Objectives of clauses C2 to C6**
- **C2 | Prevention of fire occurring**
- **C3 | Fire affecting areas beyond the fire source**
- **C4 | Movement to place of safety**
- **C5 | Access and safety for firefighting operations**
- **C6 | Structural stability**

The requirements in the Building Code are mandatory requirements which can be achieved in three different ways, as described in the Approved Documents published by the Ministry of Business, Innovation and Employment (MBIE):

1. Following an Acceptable Solution published in the Approved Documents, or
2. Following an Approved Verification Method, or
3. Relying on “Alternative Solution” using specific fire engineering design to demonstrate compliance with clauses of the Building Code.

Most buildings are designed using an Acceptable Solution, with the use of Verification Methods and Alternative Solutions generally used only in large or complex buildings or for building renovations. Because the New Zealand Building Code is a performance-based code, it does not specify materials or construction methods, but concentrates on the required performance. This generally allows timber to be used on a “level playing field” with other materials, provided that the performance requirements are met.

ACCEPTABLE SOLUTIONS

The Acceptable Solutions published by MBIE include prescriptive methods of meeting the performance requirements of the Building Code. Most designs for fire safety are done by specialist fire engineers using the relevant Acceptable Solution.

The Acceptable Solutions are presented as seven separate documents, each addressing a different type of fire risk. It is possible that this list of Acceptable Solutions may change as a result of a current review.

- **C/AS1** | typical houses, small multi-unit dwellings and outbuildings.
- **C/AS2** | multiple-unit accommodation buildings such as apartments, hotels, and motels.
- **C/AS3** | buildings where care or detention is provided – i.e. where there is a delay to evacuation.
- **C/AS4** | public access buildings such as schools, recreation centres, cinemas, shops, restaurants etc.
- **C/AS5** | many workplaces such as offices, workshops, factories and low-level storage facilities.
- **C/AS6** | high-level storage areas in buildings such as warehouses, trading and bulk retail.
- **C/AS7** | vehicle parking and storage.

Each of the seven Acceptable Solutions are structured according to the following seven similar parts:

- **Part 1** | General
- **Part 2** | Firecells, fire safety systems and fire resistance ratings
- **Part 3** | Means of escape
- **Part 4** | Control of internal fire and smoke spread
- **Part 5** | Control of external fire spread
- **Part 6** | Firefighting
- **Part 7** | Prevention of fire occurring

The Acceptable Solutions specify minimum fire resistance ratings for walls and floors of buildings, depending on the occupancy, the height of the building and the active fire protection measures installed. In most cases the required fire resistance is in the range from half an hour to 2 hours, easily achieved with timber construction.

In addition to fire resistance of structural elements, the Acceptable Solutions specify requirements for surface finishes of walls, floors and ceilings, to control the early spread of fire and production of smoke in certain buildings. These requirements become important if exposed wood panelling or other wood-based materials are used as finishing materials, especially for crowd occupancies in unsprinklered buildings.

VERIFICATION METHODS

There are two Verification Methods for fire safety:

1. **Verification Method C/VM1** only applies to solid fuel appliances, so it is not referred to in this guide.
2. **Verification Method C/VM2, Framework for Fire Safety Design**, is a comprehensive document which provides a means of compliance with the New Zealand Building Code Clauses C1-C6 Protection from Fire.

ALTERNATIVE SOLUTIONS

In some cases where the Acceptable Solution would require expensive or unwieldy outcomes, specific fire engineering design can be used to produce a more satisfactory result that can be demonstrated to comply with the Building Code. Such design must be carried out by a suitably qualified professional engineer and be presented as an “Alternative Solution”. Alternative Solutions are less often used than the Acceptable Solutions.

NZS 3603 AND AS 1720

The current New Zealand Standard for timber design is NZS 3603:1993 (Timber Structures Standard) which is a verification method for complying with Section B1 Structure of the NZBC. This standard is currently being replaced by NZS AS 1720.1 (Design Methods for Timber Structures), which is an interim New Zealand version of AS 1720.1 in the expectation that the Australian and New Zealand timber design standards will be combined into a joint Australian / New Zealand standard in the next review cycle.

Section 9 of NZS 3603 sets out methods for determining the fire resistance of load bearing timber elements and assemblies, including calculation of the reduced cross section after charring. The replacement standard NZS AS 1720.1 makes no reference to fire resistance because that will be specified in the new Joint Standard AS/NZS 1720.4:2018 (Fire Resistance of Timber Elements) which is an update of AS 1720.4, currently under revision, to be adopted for use both in Australia and New Zealand. Many of the requirements of AS/NZS 1720.4:2018 have come from Eurocode 5.

The guidance for structural fire calculations of timber structures in this guide is based on the most recent draft-for-comment of AS/NZS 1720.4.

The objective of AS/NZS 1720.4 is to provide a method for determining the fire resistance of sawn timber, timber as poles, plywood, laminated veneer lumber (LVL), or glued-laminated structural timber as an alternative to the test method specified in AS 1530.4. The main differences from NZS 3603 are the addition of a 7mm zero-strength heat-affected layer, and design methods for protected timber and protected connections. Rounding of beam corners due to charring was included in NZS 3603 but is not required to be considered in the new standard.

Neither of these new standards will refer to Cross Laminated Timber (CLT) because the production and design of CLT structures is not considered sufficiently mature. Structural design of CLT structures will have to be carried out from first principles. Guidance for fire design of CLT is given later in this document.

FLAME SPREAD REQUIREMENTS

INTERIOR WALL AND CEILING LININGS

Fire properties of internal lining materials of walls and ceilings are regulated because certain types of finish can contribute significantly to an increase in fire hazard reducing the time available for the occupants to safely escape.

Requirements for the minimum fire properties of lining materials for walls and ceilings are given in Clause 3.4(a) of the New Zealand Building Code (NZBC). This specifies a maximum Material Group Number which ranks the degree to which the material contributes to early fire development. The required Group Number for a wall or ceiling lining can vary from 1 (best) to 4 (worst). The NZBC requires the lining material to be Group 1, Group 2 or Group 3 depending on the occupancy type, location in the building and whether fire sprinklers are installed.

C/VM2 Table A1 allows lining materials of solid wood or wood products to be assigned as Group 3 without providing evidence of testing. These wood products must be at least 9 mm thick and have a density of at least 400 kg/m^3 or 600 kg/m^3 for particleboards. This also applies if the wood is coated with waterborne or solvent borne coatings no more than 0.4 mm film thickness with an application of no more than 100 g/m^2. Wood products not meeting this description will require testing to determine their Group Number.

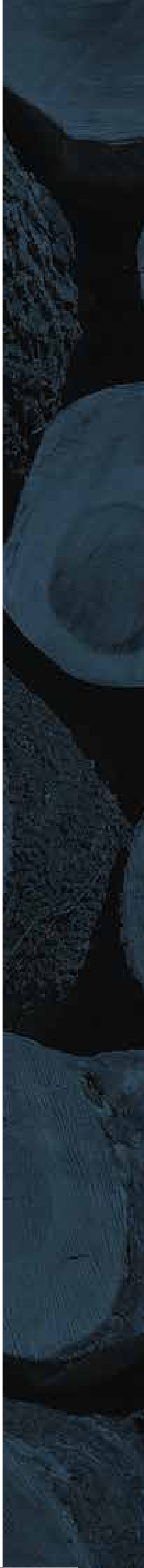
In order for wood products to be assigned as Group 1 or Group 2, they are usually required to be chemically treated, or be coated with a surface fire-retardant. While such products improve the early fire performance by making the wood surface more difficult to ignite, and reducing flame spread, they are not able to increase the fire resistance because they do not prevent charring in a severe fire.

In New Zealand fire retardant timber coatings have been used to improve the early fire hazard performance, and products using pressure-impregnation methods may also be used. Fire retardant treated timber currently is commonly specified and more readily available in other countries than it is in New Zealand and has the advantage of being more durable for interior applications compared to coatings.

In buildings without fire sprinklers, where a Group 1 or Group 2 surface is required, there is also a requirement to meet smoke production criteria. Where this has been achieved the classification is given as Group 1-S or Group 2-S as applicable.

Group Numbers can be determined from any of the following fire test methods:

- **ISO 9705** – this is a full-scale room test in which the lining material to be classified is installed on three walls and the ceiling, using the installation methods proposed for the building. A gas burner heat source in the corner of the room subjects the lining materials to flame and heat. The rate of heat release from the burning walls and ceiling is then measured over a test period up to 20 minutes and a Group Number is assigned.
- **ISO 5660** – this is a less expensive bench-scale fire test on a small 100 x 100 mm sample of the finished lining material. However, it may provide a more conservative evaluation of the Group Number compared to the larger ISO 9705 test. In some cases, a similar fire test AS 3837 may be used, however it is recommended that expert advice be sought to evaluate the test results for obtaining a Group Number for use in New Zealand.
- **EN 13501-1:2007+A1:2009** – This is a classification standard used in Europe based on one or more of the following fire test methods EN ISO 1182, EN ISO 1716, EN 13823, and EN ISO 11925-2. The classification levels assigned are A1, A2, B, C, D, E and F (from least to most combustible). The NZBC Acceptable Solutions allow the following Group Numbers to be assigned based on the European classes.
    - **Group 1 = A1, A2 or B**
    - **Group 1-S = A1 or A2**
    - **Group 1-S = B + smoke production s1 or s2.**
    - **Group 2 = C**
    - **Group 2-S = C + smoke production s1 or s2.**
    - **Group 3 = D (typically this applies to untreated timber products)**



Manufacturers of paint and timber coatings may undertake fire testing on timber substrates to provide test evidence for their paint or coating systems applied to timber wall or ceiling linings. C/VM2 Appendix A1.6 provides guidance on the selection of a timber substrate for the fire test. If the substrate used is solid timber, standard grade plywood, hardboard or fibre/particleboard not more than 12 mm thick, then the Group Number achieved with the specified coating will also be applicable for similar timber products more than 12 mm thick. However, the reverse does not apply – testing of coatings on a substrate thicker than 12 mm cannot be used to justify the Group Number when the coating is applied to a substrate less than 12 mm thick.

The Acceptable Solutions allow some exceptions to the requirement to meet a Group Number. With respect to timber, the exceptions include timber joinery and structural timber building elements constructed from solid wood, glulam or laminated veneer lumber (including heavy timber columns, beams, portals and shear walls not more than 3.0 m wide) but it does not extend to exposed timber panels or permanent formwork on the underside of floor/ceiling systems. These exemptions are also commonly relied on in conjunction with design using C/VM2 or Alternative Solutions.

FLOORING

There are no fire requirements for floor finishes of housing designed in accordance with C/AS1. For all other applications timber floor finishes must have a Critical Radiant Flux (CRF) of not less than that specified in Table 4.2 of the Acceptable Solutions. This requires a minimum CRF of either 1.2 kW/m² or 2.2 kW/m² depending on the occupancy and location of the flooring in the building. The CRF value is determined by testing to ISO 9239-1:2010 (Reaction to fire tests for floorings – Part 1: Determination of the burning behaviour using a radiant heat source).

C/VM2 Table B1 allows some timber products to be assigned a CRF of 2.2 kW/m² without providing evidence of testing. These timber products are – wood products, plywood or solid wood that is at least 12 mm thick and with a density of at least 400 kg/m³. Timber products not meeting this description are required to be tested to ISO 9239.1 to determine if the floor finish achieves the required CRF value. Most typical timber floor finishes are expected to satisfy the requirements in Table 4.2 of the Acceptable Solutions.

In addition to the above floor finish requirements, the Acceptable Solutions C/AS2 to C/AS6 provide additional requirements for wood or wood-based floors which are fire separations in multi-storey buildings, preventing fire from spreading down through the floor to the firecell below. In these cases the wood flooring material must be nominally 20 mm thick (19 mm particleboard or 17 mm plywood are acceptable). Most typical wood floors will meet this requirement with no special attention.

Exposed timber fire rated ceiling (intumescent coating). Credit Resene.

EXTERNAL CLADDING

Fire requirements relating to the combustibility of external wall cladding systems have been the focus of much scrutiny around the world and in New Zealand in recent years. MBIE issued guidance in December 2018 relating to the different fire test methods that can be applied depending on the height and occupancy of the building. It is recommended that designers discuss any requirements for buildings above 10 m with the BCA at an early stage, as there may be varying interpretations made of the current Code or Acceptable Solution requirements. Inappropriate use of combustible materials as part of facade systems (especially in tall buildings) has the potential to contribute to unacceptable fire performance as illustrated by many recent international high-profile facade fire disasters. Note - Building height means the vertical distance between the floor level of the lowest occupied space above the ground and the top of the highest occupied floor, but not including spaces located within or on the roof that enclose stairways, lift shafts, or machinery rooms.

The following material is intended to be consistent with the MBIE guidance.

Currently, in buildings greater than 10 m high with upper floors containing sleeping uses or "other property", Clause 3.2 of the NZBC requires the building be designed and constructed so that there is a low probability of external vertical fire spread to upper floors in the building. Clause 3.7 of the NZBC also requires cladding materials located within 1 m of a property boundary to be not easily ignited when exposed to radiant heat from a fire on an adjacent property.

There are specific fire test requirements for external wall cladding systems depending on the occupancy, distance to boundary, building height, and sprinkler installation.

Small amounts of timber included within or on external walls such as door and window frames are generally considered acceptable and are not subject to fire test requirements. Other minor trim and fascia that are unlikely to spread fire to the remaining parts of the external wall cladding are also permitted.

Exterior walls incorporating timber products (including timber cladding, rigid air barriers or framing) are likely to be acceptable for any building height and any occupancy type where the exterior wall system has been the subject of a façade fire test such as NFPA 285 or BS 8414 and passed the applicable criteria. In the case of these fire tests, it is particularly important that the construction of the complete wall assembly as tested is representative of that intended to be used.

External walls within 1 m of a property boundary in all buildings

Only the exterior cladding material needs to be resistant to ignition and this can be confirmed with small-scale fire tests using ISO 5660 Part 1 or AS/NZS 3837. In general, typical timber cladding products will not meet these fire requirements, unless they have been treated with special fire-retardant treatment chemicals, which are not normally available in New Zealand. If fire retardant chemicals are used to treat external timber, then it is also necessary to show that the fire performance does not degrade with exposure to the weather.

Buildings up to 10 m high

There are generally no fire test requirements for the use of timber within the external wall construction such that timber cladding, rigid air barriers, panels or framing materials are all permitted.

Exceptions may include importance level 4 buildings or multi-floor buildings incorporating staged evacuation, phased evacuation, or evacuation to a place of relative safety within the building.

Non-sleeping use buildings higher than 10 m and not higher than 60 m

If façade fire test results are not available, small-scale fire tests on the cladding material and the rigid air barrier within the external wall will be required to meet C/AS paragraph 5.8. Typical timber products will not meet these fire requirements. However, timber framing is permitted.

Sleeping use buildings 10 - 25 m high with sprinklers

If façade fire test results are not available, small-scale fire tests on the cladding material and the rigid air barrier within the external wall will be required to meet C/AS paragraph 5.8. Typical timber products will not meet these fire requirements. However, timber framing is permitted.

All other sleeping use buildings higher than 10 m or any building higher than 60 m

If façade fire test results are not available, small-scale fire tests (refer the MBIE guidance for acceptable test methods) on various components (such as cladding, rigid air barrier, framing and insulation) within the external wall will be required. Typical timber products will not meet these fire requirements. However, timber framing is permitted if used in conjunction with a rigid air barrier that has limited combustibility and can also provide thermal protection to the timber frame.

FIRE DOORS

Fire doors are typically constructed from timber with a core of either vermiculite mineral, laminated veneer lumber, or reconstituted wood fibre depending on the fire rating required. The complete door-set for a fire door includes a jamb that may be made of steel, or timber (up to -/60/), fire rated edge seals, and specific door hardware including a self-closer which allows the door to fully close and latch shut. Fire doors, as a minimum, are required to meet the Integrity criterion for fire resistance, but sometimes the Insulation criterion may also be required.

All installed fire rated doors must have certified fire tags attached to the doorset to provide evidence of compliance to NZS:4520. A smoke control door will have an SM added to the FRR designation, e.g., -/60/30 SM and to achieve the SM classification, the door must be either a fire door with smoke seals or else be a solid core door (if timber, not less than 35 mm thick) fitted with smoke seals. There is no test for smoke leakage in the New Zealand Building Code documents. Timber doors are exempt from surface finish requirements.

FIRE RESISTANCE OF HEAVY TIMBER COMPONENTS

Although fire resistance must usually include all three requirements of structural adequacy, integrity and insulation, calculations are only available for structural adequacy. Standard calculation methods for fire resistance are based on consistent results of many full-scale fire resistance tests.

STRUCTURAL CALCULATIONS

The new joint standard AS/NZS 1720.4 provides a design method to achieve structural fire resistance of exposed timber members based on the charring rate. The method only applies to timber members whose smallest dimension is at least 75 mm because smaller members may char at a faster rate. After deducting the depth of charring, and an additional 7mm heat-affected layer, the residual section shown in **Figure 4** is required to support the fire design loads specified in the Loadings Standard AS/NZS 1170. The corners of the residual beam will become rounded as the charring proceeds, and this was allowed for in NZS 3603:1993, but is not required to be considered by AS/NZS 1720.4.

Fire testing of light timber framed walls at BRANZ. Credit BRANZ.

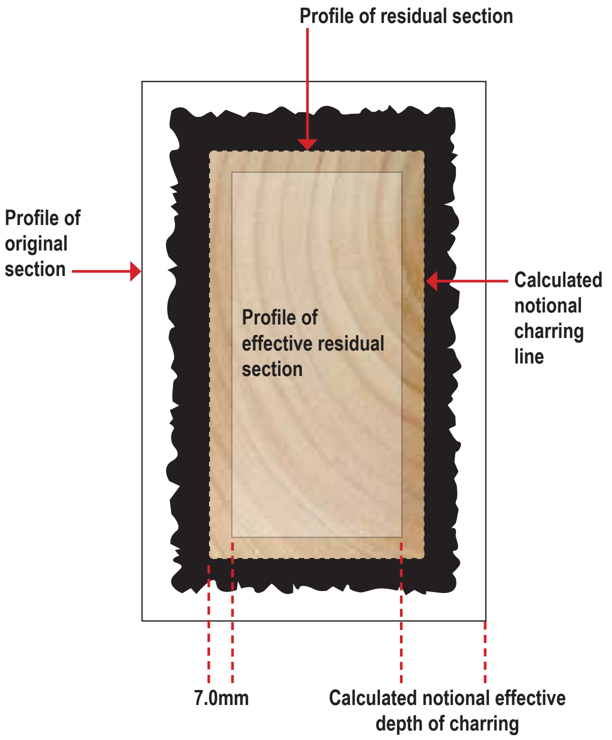


Figure 4. Loss of cross section due to charring

AS/NZS 1720.4 gives an equation to calculate the charring rate based on wood density. For radiata pine grown in New Zealand, the specified charring rate is required to be 0.65 mm per minute, based on a notional density of 550 kg/m^3 at 12% moisture content. This charring rate applies to sawn timber, round timber and all engineered wood products made with New Zealand grown radiata pine. To allow for heat affected wood under the char layer, an additional layer 7.0 mm thick must be subtracted from the charred cross section.

These calculations should be used with a strength reduction factor of ϕ=1.0 and a duration of load factor k1 = 1.0 (brief loads) in addition to any other appropriate reduction factors. The likelihood of instability in beams or columns must be taken account of with the appropriate buckling factor for the reduced cross section and any potential loss of lateral restraint. No deflection limits are specified for fire design, so the designer should aim for performance that will allow the structural elements to fulfil their load carrying function and to provide fire separation for the duration of the fire. The effect of anticipated deformations on insulation and integrity of the barrier must be assessed and allowed for.

All the above calculations are related to standard fire resistance ratings as specified in the various Acceptable Solutions. They may not necessarily be appropriate to support Alternative Solutions where a different level of fire severity is assumed, such as a parametric fire.

CROSS LAMINATED TIMBER (CLT)

CLT is not explicitly referred to in AS/NZS 1720.4, so guidance is needed for structural fire design. CLT panels which are glued with adhesive which does not delaminate during fire exposure have similar fire performance to other glued wood panels, so they can be designed in the same way.

However, some CLT manufacturers use polyurethane adhesives which are vulnerable to delamination at high temperatures, in which case a modified design procedure is required. The recommended design procedure (following the Technical Guideline for Europe) is to assume that the charred layer falls off when the glueline temperature reaches 300˚C, followed by charring at double the normal rate for charring of the next 25 mm of wood, after which the normal charring rate continues. When using this procedure, CLT panels with thick outer layers will perform much better than those with thinner outer layers.

Some CLT manufacturers, including XLam, provide load-span tables for fire resistance of structural walls and floors, derived from expert opinion assessment of full scale fire resistance test results, removing the need for specific structural fire calculations. These load-span tables are recommended for use.

SOLID TIMBER FLOORS

Solid timber floors of uniform thickness such as slabs of glulam, CLT or nail laminated timber rely on the timber thickness for both structural adequacy and integrity. These timber floors can be designed from first principles using calculations of the charring rate. It is important to seal any gaps between individual flooring units which could allow an integrity failure. Tests on timber box-beam floors, stressed-skin floors, and T-beam floors have shown that fire resistance for structural adequacy can be calculated in the same way. The rate of charring on the outer surface of hollow timber construction is not affected by the presence of internal voids. To prevent an insulation failure, the thinnest section of the floor should be checked to ensure that at least 30 mm of timber remains in place. Information from glulam and CLT manufacturers, and other proprietary literature, provide details on fire resistance of manufactured flooring for various spans.

PROTECTED TIMBER

Fire-resistant protective insulating materials can be used to increase the fire resistance of structural timber members by delaying the onset of charring. Insulating materials can also be used to increase the fire resistance of timber connections. The principal insulating materials are solid panels such as wood, gypsum plasterboard or calcium silicate board. Intumescent paint can also be used. Fire-resistant protective insulation must be fixed or applied in accordance with manufacturers' specifications. Note that most intumescent coatings cannot be used on exterior surfaces because of poor durability after exposure to the weather. Gypsum plasterboard is particularly useful as a fire resisting material because of the energy required to drive off the water of crystallisation within the material. The use of heavier, thicker, or multiple layers of plasterboard will increase the fire resistance even more. Most plasterboard products must be protected from the weather.

In order to calculate the fire resistance of protected timber, using the methods given in the current draft of AS/NZS 1720.4, it is necessary to estimate the time at which the temperature of the wood surface under the protection will reach 300˚C, and the possible time at which the insulation is likely to fall off. This information can be obtained from the manufacturers of protective materials.

If the insulation is expected to remain in place for the duration of the fire resistance period, the calculations should be based on charring starting under the insulation when the temperature of the wood surface reaches 300˚C, followed by charring at the normal rate of 0.65 mm/min. If the fire-resistant protective insulation is expected to fall off during the fire resistance period, the charring rate after falling off should be taken as twice the normal charring rate until the next 25 mm of wood has charred, after which the charring rate will revert to the normal rate.

If glued-on solid wood or wood-based panels are used to provide additional fire protection to structural timber, charred layers are not expected to fall off, provided that suitable adhesives are used.

INSULATION CRITERION FOR SOLID WOOD PANELS

For separating elements such as walls and floors, it is essential to ensure that the containment function is maintained throughout the fire resistance period, by checking that the insulation and integrity criteria are achieved. The insulation criterion is usually assessed by results from full-scale fire resistance tests. For solid wood or glued wood elements, AS/NZS 1720.4 allows the insulation criterion to be calculated for the nominated fire resistance period, by ensuring that the thinnest part of the separating element has a residual thickness of at least 30 mm. No effect of a zero-strength layer needs to be included in the calculation. This minimum thickness of 30 mm is based on empirical data for the heat affected region below the char layer in a number of full-scale fire tests. This calculation will also apply to CLT panels.

INTEGRITY CRITERION FOR SOLID WOOD PANELS

The fire resistance of containment elements such as walls and floors, requires that integrity must be maintained throughout the fire exposure. Integrity cannot be calculated, so it must be obtained with reference to satisfactory results of full scale fire resistance tests. An expert opinion from a fire testing laboratory may be useful if the precise assembly has not been tested. It is not possible to assess integrity in a small scale test because the test specimen is not subjected to the same thermal stresses, shrinkage and distortion as in a full scale test.

OPEN GAPS NOT PERMITTED

To ensure that integrity is maintained, there must be no open gaps in the assembly. Closed gaps are permitted, provided that they have narrow dimensions. Open gaps and closed gaps are discussed on the next page.
In order to ensure prevention of integrity failures, the designer must ensure that there are no open gaps between panels which could allow flames or hot gases to travel from one firecell to another during the specified

fire exposure. Even small open gaps can allow the passage of smoke and hot gases through a fire barrier, especially if there is differential pressure between the two sides of the barrier. Higher air pressure due to hot gases is most likely in the upper region of any firecell, causing potential for vertical air flow through floor panels to the room above, or horizontal air flow through the top of wall panels to adjacent rooms. Any joints which can be looked through, or which allow air flow from one side to the other must be considered to be open gaps, and must be protected in some way, regardless of the width of the gap.

Construction to prevent movement of hot gases through panel joints can be done in several alternative ways. Ideally there should be intimate close contact between panels, with fire resistant caulking put into all joints during construction. If open gaps remain after construction, they must be closed. Possible options include:

1. Closing one side of the gap with non-structural lining material.
2. Caulking the gap with intumescent sealant, preferably on both sides of the panel.
3. Inserting a shim of plywood or similar wood material tightly into the gap.
4. Packing the joint tightly with a ceramic fibre blanket, especially for wider gaps.

CLOSED GAPS PERMITTED

If a gap between solid wood panels is closed on the non-fire side, the width of the closed gap on the fire side must be small enough to prevent charring inside the gap and to prevent fire exposure of the closing material. A closed gap could occur if a joint between panels is covered with a non-structural sheet of material such as gypsum plasterboard, or with a plywood spline between the panels, as shown in **Figure 5**. The plywood spline should be fixed with fire resistant adhesive to fill any tolerance gaps. Gypsum plasterboard should be installed as a continuous taped and stopped lining to avoid joints between sheets. Note that any movement between solid wood panels during a seismic event is likely to damage the plasterboard.

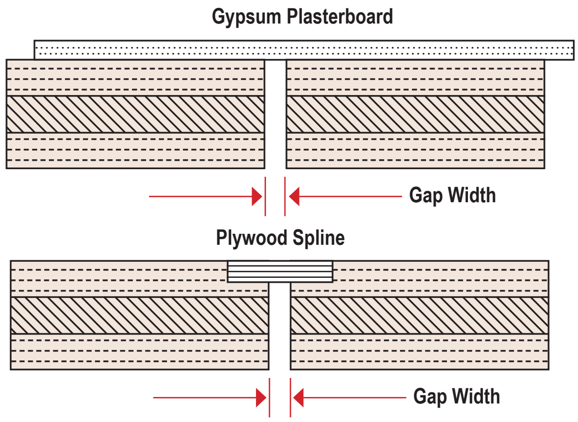


Figure 5. Closed gaps in solid wood panels, fire attack from below

The maximum permitted width of a closed gap is 5mm because charring does not generally occur in dead-end gaps less than 5 mm wide between timber members, where there is no possibility for the flow of hot gases. A closed gap wider than 5mm will allow the edges of the panel and the closing material to be exposed to fire temperatures, resulting in charring or degradation leading to a possible integrity failure. Hence any closed gap wider than 5mm must be filled. The best material is an intumescent caulking compound, provided that it completely fills the gap. Other options are tight-fitting wood material (sawn timber or plywood), or an approved non-combustible material.

PENETRATIONS THROUGH SOLID WOOD PANELS

Any fire resisting barrier is only as good as its weakest link. Any holes or penetrations for services must be constructed such that the fire performance is not reduced. CLT manufacturers' literature gives details of tested and approved protection for penetrations. Proprietary materials such as intumescent paints and putties, fireproof mastic, and ceramic fibre blankets are available for sealing openings and penetrations. Self-sealing fire collars are available for plastic pipe penetrations. Recent Canadian testing has shown that solutions for service penetrations in light timber framesare equally effective for protecting penetrations through solid wood panels.

CONNECTIONS IN HEAVY TIMBER STRUCTURES

GLUED JOINTS

Fully glued timber to timber joints using thermosetting resin adhesives have the same fire performance as solid timber, with charring occurring at a predictable rate on exterior surfaces. Glued steel to timber connections will not be affected by fire if sufficient protection is provided to ensure that the glueline does not exceed its approved temperature.

STEEL DOWEL CONNECTIONS

The fire behaviour of steel dowel-type fasteners such as nails, screws, bolts, or dowels depends on the temperature of the steel during the fire. High temperatures affect the strength of the fastener itself, and can lead to charring or loss of strength of wood in contact with the fastener. Fasteners with a small surface area exposed to fire (such as the end of a steel dowel) will heat up slowly compared with steel plate connectors. Dowel-type fasteners will not be affected by fire if they are fully embedded in the timber to the calculated depth of charring, as shown in **Figure 6**. The residual holes resulting from such embedment should be filled with timber plugs glued into place or fire resistant mastic.

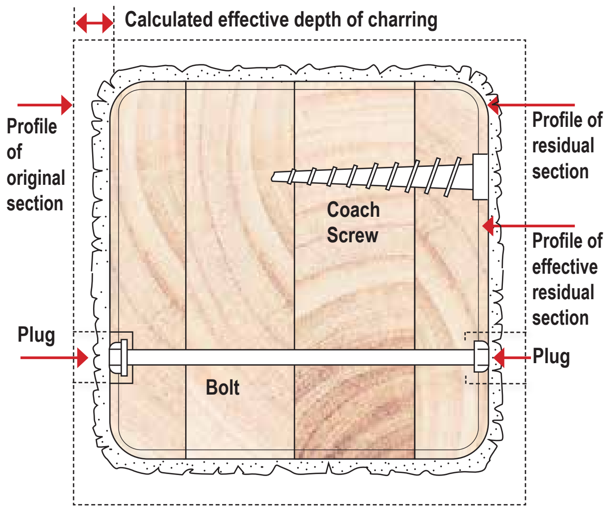


Figure 6. Protecting steel dowel-type fasteners with embedment, from BS5268.

Alternatively, dowel-type fasteners can be protected with insulating materials such as solid wood, gypsum plasterboard or intumescent paint to achieve the required fire resistance. To be equivalent to full embedment, the protective insulation should be thick enough to prevent the end of the dowel fastener from exceeding 300˚C before the end of the fire resistance period. Manufacturers' specifications should be consulted where possible.

STEEL PLATE CONNECTORS

Steel plate connectors and similar fasteners with a large area of thin steel plate exposed to a fire will heat up much more rapidly than heavy steel brackets or dowel-type fasteners. When they get hot, exposed steel plates fixed with nails or screws will conduct heat into the wood, causing softening or charring which will reduce the load carrying capacity. Brackets which are only for location during construction do not need fire protection. All components which are stressed under load, such as connection brackets and bolted or nailed gusset plates should be protected with insulating materials to achieve the required fire resistance. Protective insulation coverings include wood products, gypsum plasterboard, or intumescent paint. As guidance, the protective insulation covering should be thick enough to prevent the temperature of the steel plate under the protection exceeding 250°C before the end of the fire resistance period, from the draft AS/NZS1720.4. Higher temperatures can be used with supporting evidence, but not more than 300˚C because the nails or screws will start to char the adjacent wood when they exceed this temperature.

The temperature under wood products used as protection can be calculated based on the charring rate, but information from manufacturers will be required for other materials such as gypsum plasterboard or intumescent paint. All protection products must be applied and fixed in accordance with manufacturers' specifications.

FIRE RESISTANCE OF LIGHT TIMBER FRAMING

Unprotected light timber framing has negligible fire resistance, but protective layers can be used to provide many hours of fire resistance. Light timber framing is widely used in low-rise buildings, mostly one to four storeys for residential occupancy, and less often for commercial construction. Light timber framed walls and partitions are usually constructed with studs of sawn timber or LVL. Floors consist of plywood or particle board sheeting nailed or screwed to joists which may be sawn timber or engineered products such as glulam, LVL, wood I-joists or parallel chord trusses. **Figure 7** shows a perspective view of a single storey timber framed house. Multi-storey light timber frame construction uses similar components.

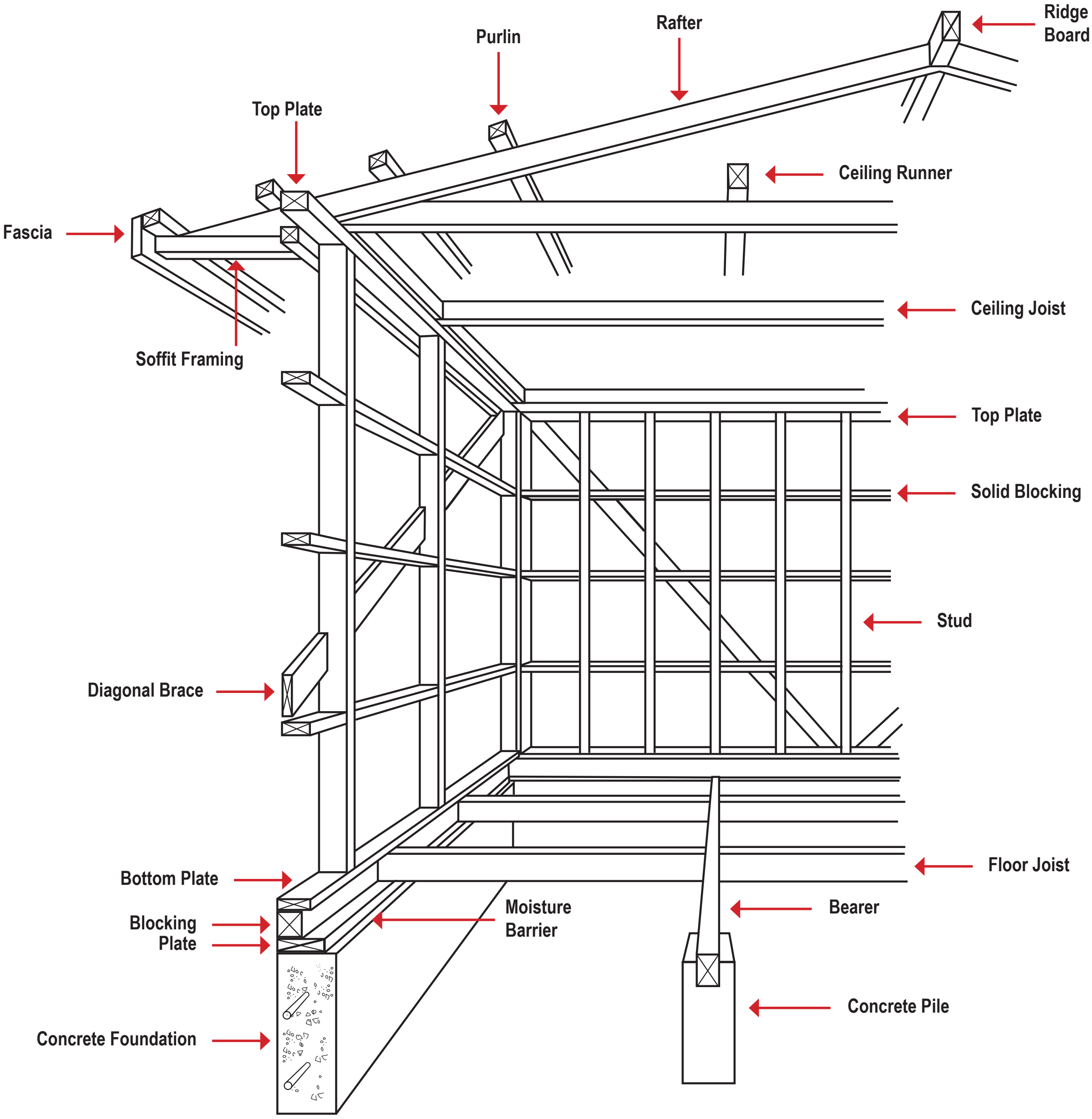


Figure 7. Typical light timber house framing.

TIMBER STUD WALLS

Light timber framed (LTF) walls and partitions consisting of vertical studs lined with gypsum plasterboard can be designed to have excellent fire resistance, and may be used wherever fire-resisting partitions or fire walls are required. A full-scale fire resistance test of a light timber framed wall is shown in images below.

The lining thickness, method of fixing and stopping, spacing of studs and nogs (dwangs) all affect the fire resistance, so construction must follow an approved specification. Designers should refer to literature from lining manufacturers for specifications of approved assemblies. Proprietary non-load-bearing timber stud partitions have fire resistance ratings of up to 3 hours, while load bearing timber stud walls have ratings up to two hours.

A typical fire resisting timber stud wall is shown in **Figure 8**. A wide range of similar solutions are provided in manufacturers' literature. Most LTF wall assemblies are rated for two-way fire exposure (a fire on either side of the assembly), but some special assemblies are only rated for one-way fire exposure. If used as an external wall, a suitable weather resistant cladding will be necessary on the exterior face.

In some cases a loadbearing wall, supporting a fire rated floor, is not itself a fire separation and is located entirely within a firecell. In this case fire exposure can be from both sides simultaneously and specific design is required to select suitable protective linings.

Figure 8. Typical fire-rated light timber frame wall assembly. GIB® Fire Rated Systems, 2018.

Full scale fire resistance test of a light timber framed wall. Credit BRANZ.

Full-scale fire resistance test of a light timber framed wall. Credit BRANZ.

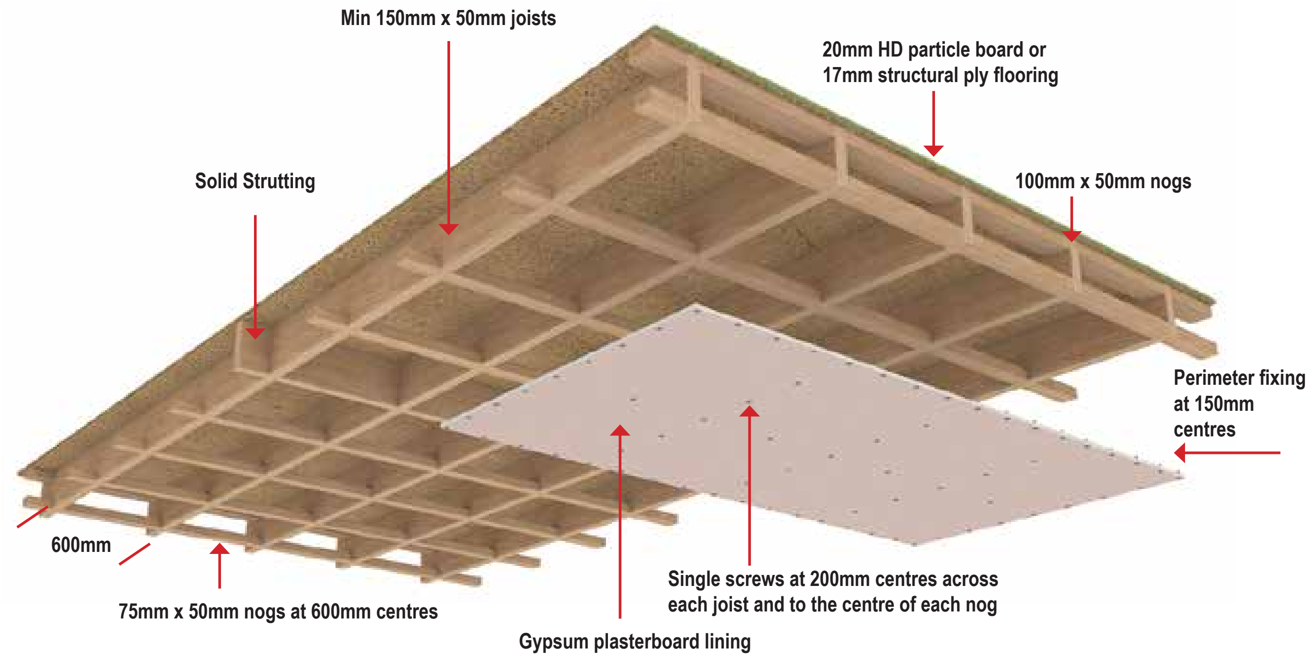


Figure 9. Typical fire-rated light timber floor assembly. GIB® Fire Rated Systems, 2018.

TIMBER JOIST FLOORS

The fire resistance of conventional timber flooring (timber joists with plywood or particle board sheeting) is achieved by fixing a fire resistant lining on the underside. Timber joist floors with gypsum plasterboard ceilings can be designed with fire resistance ratings up to 2 hours. To achieve the approved rating it is essential that the manufacturers' specifications be complied with, including flooring material, size of joists, thickness of lining materials, and method of fixing. Designers should refer to lining manufacturers' literature for specifications of approved assemblies.
Typical fire-rated timber joist floor construction is shown in **Figure 9**.

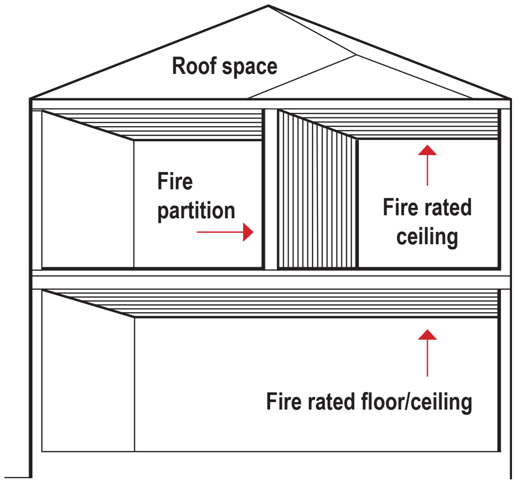
RECESSES, PENETRATIONS AND ALTERATIONS

Any fire resisting barrier is only as good as its weakest link. Any recesses or penetrations must be constructed such that the fire performance is not reduced. Manufacturers' literature gives details of many tested and approved assemblies using gypsum plasterboard and other lining materials. Whenever alterations are carried out in timber buildings, it is essential that fire resisting linings remain intact or be reinstated to the same standard. A large number of proprietary materials such as intumescent paints and putties, fireproof mastic, and ceramic fibre blankets and ropes are available for sealing gaps.

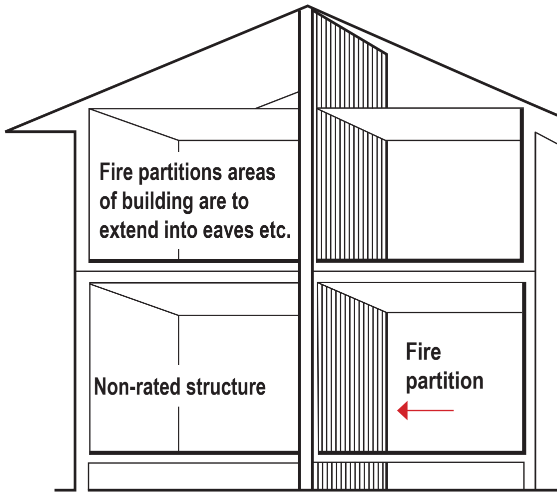
FIRE STOPPING

All fire rated timber construction must continue to perform its function in a fire, carrying the applied loads and not permitting the spread of fire. Careful detailing and sound workmanship is necessary to achieve the integrity required to prevent spread of fire. Fire and structural requirements are often in conflict with acoustic requirements, which also requires careful detailing. Architectural detailing must ensure that there are no hidden cavities or concealed spaces which would allow the unseen movement of fire or smoke between firecells, especially at floor to wall junctions. This fire stopping is often achieved with extra timber framing or timber blocking with a minimum nominal thickness of 50 mm. The sketches in **Figure 10** are recommended fire stopping details for timber frame construction, based on Standards Magazine, 1986 (see Further Reading).

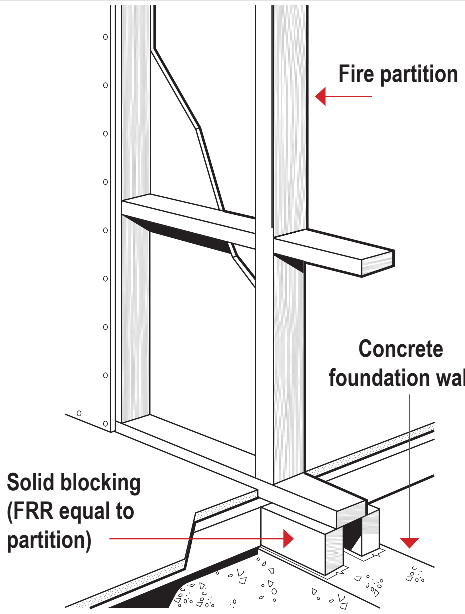
Figure 10. Typical fire stopping details.



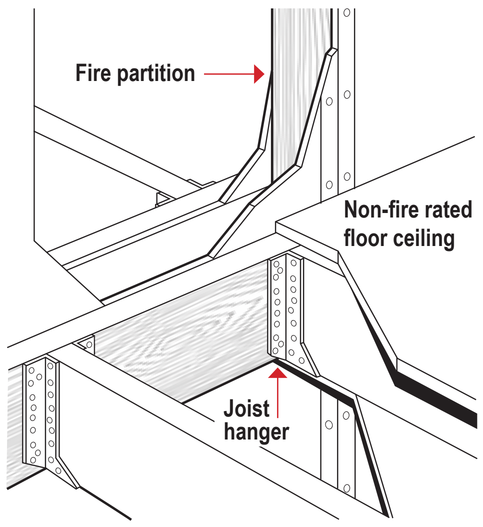
Fire partition between fire-rated floor and ceiling.



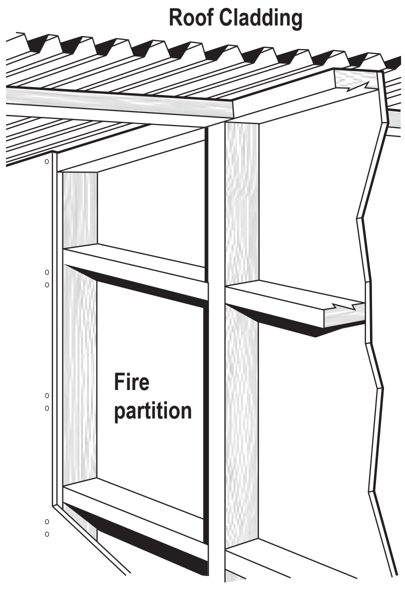
Fire partition in non-rated structure.



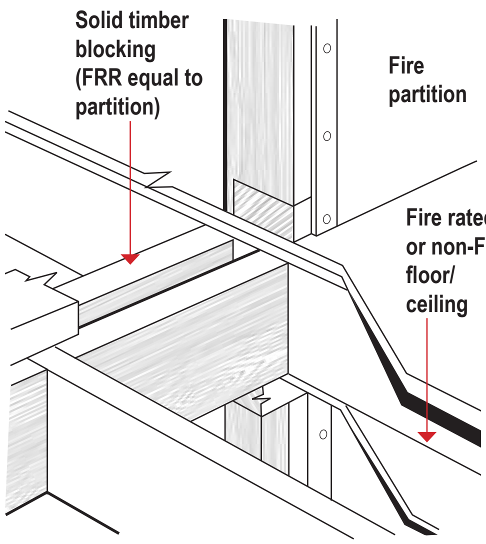
Fire stopping below ground floor level.



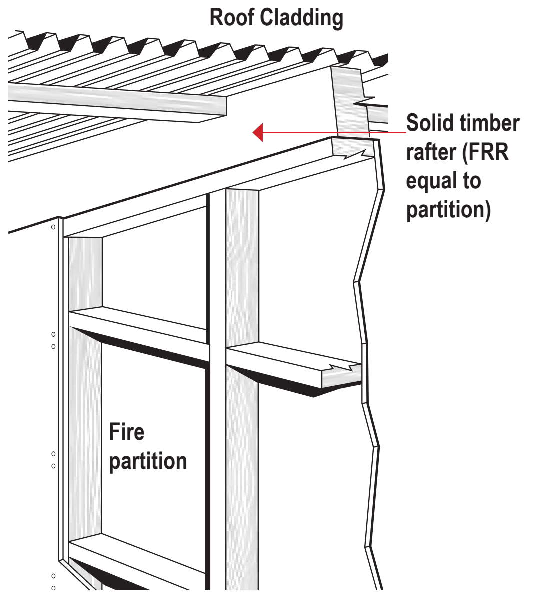
Fire stopping at intermediate level.



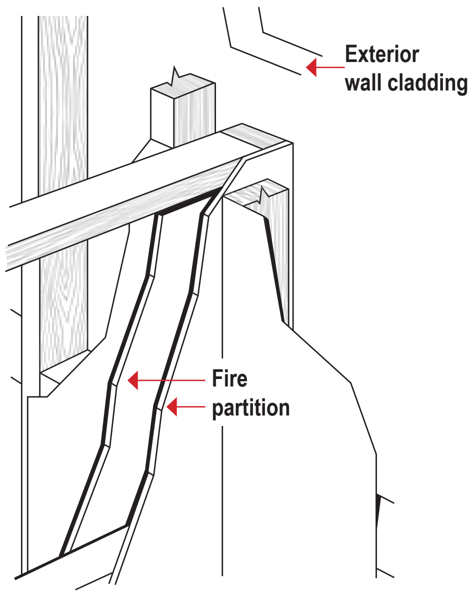
Fire stopping at roof.



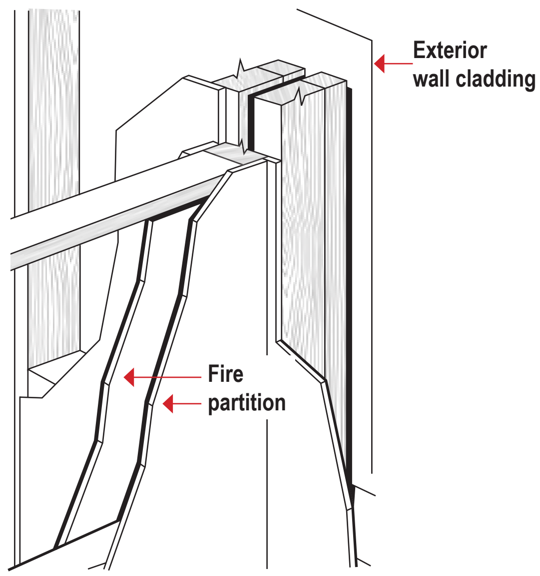
Fire stopping at intermediate level.



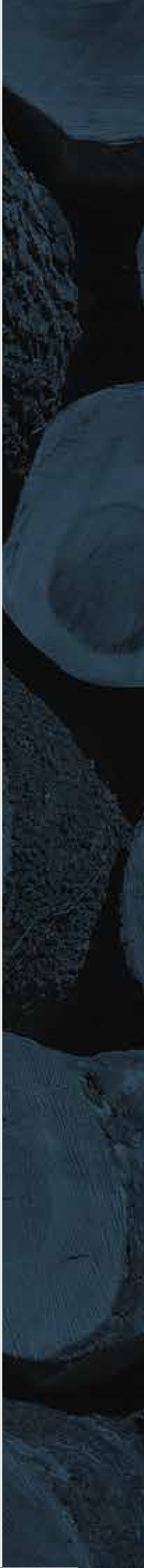
Fire stopping at roof level.



Fire stopping at exterior walls.



Fire stopping at exterior walls.



STABILITY OF EXTERNAL WALLS

There has been some confusion in the industry about conflicting requirements for lateral stability of external walls of single storey buildings and at the top floor of multi-storey buildings during and after fires. The problem in single storey buildings is very different to tall buildings because repair or demolition of tall buildings may take much longer, and the possible consequences of collapse are much greater.

These concerns have been addressed in the MBIE discussion document (MBIE, 2017), and future changes to the MBIE Approved Documents are likely.

A common interpretation of existing regulations is that external walls, which could lose their lateral support from an unprotected roof system failing in a fire, must be designed as cantilevers to resist a face load of 0.5 kPa to prevent the wall from collapsing inwards or outwards, both during and after a fire. No design load needs to be applied to those external walls which are attached to the main structure, and are designed to be pulled inwards during or after a fire.

These external wall requirements do not apply to buildings which comply with Acceptable Solutions that do not include specific provisions to address the lateral stability of boundary walls.

ADVANCED CALCULATION METHODS

Appendix B of the draft AS/NZS 1720.4 gives guidance for the use of Advanced Calculation Methods for structural fire design of timber buildings. This includes calculation of expected fire severity, the resulting temperature distribution inside structural members or the residual strength of timber structures. Advanced calculation methods should be based on fundamental physical behaviour in such a way as to lead to a reliable approximation of the expected behaviour of the structural component under the specified fire conditions.

FIRE SEVERITY

Estimation of fire severity is normally done by the fire engineer in consultation with the client and the BCA. Most fire designs require a fire resistance rating for a specified time of exposure to the standard test fire. In some special circumstances it may be appropriate to consider a realistic non-standard "parametric" fire exposure including a decay phase with provision for a full burnout of the fire compartment. This would be based on the actual compartment geometry, the available ventilation, surface linings, interior partitions and shape of the floorplate. An estimate of the amount of timber in the construction that contributes to the fuel load should be made and be included in any calculations.

Note that Annex A of Eurocode 5 provides methods of calculating the charring rate of timber subjected to a range of parametric fires, but this design method is not recommended because it has not been verified sufficiently to become an accepted design method. One problem is that the zero strength layer may continue to increase in thickness even though the rate of charring decreases. The charring rates from AS/NZS 1720.4 should be used until new information from current international research becomes available.

As described earlier, design for complete burnout of heavy timber buildings may not be possible without some guaranteed level of firefighter intervention.

STRUCTURAL RESPONSE

Advanced calculation methods for structural design normally require a finite element analysis of the fire-exposed structural timber elements and connections. For guidance on thermal and mechanical properties of timber at elevated temperatures, refer to Eurocode 5, Annex B. For further information on the thermal and mechanical material properties of structural timber elements for finite element modelling, refer to Structural Design for Fire Safety and the paper by Werther et al. (2012).

FIRE SAFETY DURING CONSTRUCTION

Although not a building code requirement, fire safety during construction can be a particular hazard for large timber buildings. Very large losses have occurred on some overseas building sites because of very large fire loads due to the lack of linings and large areas of exposed timber. The fire engineering design of large timber buildings should include the possibility of a fire during construction managing the risk by:

1. Ensuring that suitable site security and insurance cover are in place.
2. Requiring the main contractor to put in place a fire safety plan for the entire period of construction, from delivery of the first timber elements until the fire sprinkler system is operating.
3. Preventing ignition and mitigatingany possible fire risk.
4. Implementing early installation of fire safe construction.

A useful NZ document is *Guidelines for Fire Safety on Construction Sites* produced by STIC in 2012.

SUMMARY

The significant features of timber construction in fire can be summarised as follows:

1. **Timber has the unique property of forming a charcoal layer on the surface, which slows down the rate of burning, so large structural timber members retain strength and shape for considerable time in a fire.**
2. **Structural elements made from engineered wood products (glulam, LVL and CLT) have fire performance comparable to solid wood members of equivalent size provided that the adhesives have good performance at high temperatures.**
3. **The fire resistance of timber increases as the structural size increases and as the ratio of exposed surface area to cross section area decreases.**
4. **When a fire is brought under control before major damage occurs, heavy timber members may still be useable, subject to cosmetic repairs and structural analysis.**
5. **Light timber framed structures can achieve excellent fire resistance with the use of suitable fire resistant lining materials such as gypsum plasterboard.**
6. **There are restrictions on large exposed areas of timber linings. Most structural timber elements, such as heavy beams and columns, are exempt from surface finish requirements, so they can be used without specialist treatment. Specialist surface coatings are available for use wherever necessary.**
7. **Exterior timber cladding located further than 1 m from a boundary and not higher than 7 m (to the topmost floor) can generally be used without requiring any special fire treatments or protection for limiting vertical fire spread. Requirements for cladding in other situations need to be considered carefully and are subject to change.**
8. **Heavy timber structures can be designed to have fire resistance similar to steel and concrete structures but design for complete burnout may not be possible without guaranteed sprinkler control or some firefighting intervention.**

Woodspan PLT Floor being installed. Credit Taranakipine.

Motat Aviation Display Hall. Credit Carter Holt Harvey (CHHWP).

FURTHER READING

Charring Rates of Timber by P.C.R. Collier. BRANZ Study Report No 42. Building Research Association of New Zealand. 1992. https://www.branz.co.nz/cms_show_download.php?id=0ef894f9af0b665d62b7004df771889dbfddf136

CLT Handbook - Canadian Edition
https://research.thinkwood.com/en/permalink/catalogue819

Consultation on fire safety proposals: Changes to the Building Code, Amendments to Verification Method, Guidance for Alternative Solutions. MBIE, May 2017. www.mbie.govt.nz/building-and-energy/building/investigations-and-reviews-for-safer-buildings/protection-from-fire/

Design of Fire Walls and Fire Partitions to Ensure Stability and Integrity. Standards Magazine 32(8):14-19, August 1986. Standards New Zealand, Wellington.

Design of Loadbearing Light Timber Framed Walls for Fire Resistance by P.C.R. Collier. BRANZ Study Report No 43. Building Research Association of New Zealand. 1992.
https://www.branz.co.nz/cms_show_download.php?id=8e5fe7f10987eec097bd9788483f26816270a702

Eurocode 5: Design of Timber Structures, Part 1-2: General — Structural Fire Design. EN 1995-1-2 (with 2006 corrigendum). European Committee for Standardization, Brussels

Fire Engineering Design Guide, Third Edition, edited by M.J.Spearpoint. University of Canterbury, Christchurch, 2008.

Fire safety challenges of tall wood buildings – Phase 2: Task 4 Engineering methods. D. Brandon. Fire Protection Research Foundation, Quincy, MA, 2018

Fire Safety in Timber Buildings: Technical Guideline for Europe. SP Report 2010:19. SP Technical Research Institute of Sweden, 2010, http://www.jrc.ec.europa.eu

GIB® Fire Rated Systems. Winstone Wallboards Ltd. Auckland. 2018. www.gib.co.nz

Guide to Passive Fire Protection in Buildings. BRANZ Ltd., March 2017. https://www.branz.co.nz/passivefire

Guidelines for Fire Safety on Construction Sites produced by STIC in 2012
http://www.timberdesign.org.nz/design-aids/

MBIE's Building Performance website at www.building.govt.nz

Parametric Study of Modelling Structural Timber in Fire with Different Software Packages. N. Werther et al. Seventh International Conference on Structures in Fire, Zurich, Switzerland, 2012

SFPE Handbook of Fire Protection Engineering. Society of Fire Protection Engineers, Bethesda, MD, USA. 2002.

Structural Design for Fire Safety, 2nd Edition. A.H. Buchanan and A.K. Abu. John Wiley & Sons Ltd, UK. 2017.

CLT Handbook - US Edition
https://www.thinkwood.com/products-and-systems/clt-handbook

Full scale fire test on light timber framing.