Fire design of tall timber buildings

Timber is an attractive material choice for use in tall buildings, and its use is growing. However, as it is a combustible material, there are concerns around fire safety and specific fire design is required.

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THE MOMENTUM and demand to build taller buildings using timber continues to increase in New Zealand as well as around the world, largely driven by a desire to build energy-efficient, sustainable and low-carbon buildings. Innovative timber structures potentially allow for reduced construction time and cost. They also provide architecturally attractive solutions where the timber can be exposed to view.

Engineered mass timber beams and columns, including glue-laminated timber (glulam) or laminated veneer lumber (LVL) as well as panellised construction such as cross-laminated timber (CLT), are increasingly viewed as a viable alternative to traditional concrete and steel structures.

Examples of tall timber buildings

There are several notable examples of tall timber buildings overseas, including

Artist's impression of Auckland City Mission on Hobson Street.

IMAGE – AUCKLAND CITY MISSION

the 18-storey Brock Commons residential building at the University of British Columbia completed in 2017. It has a floor structure using CLT panels supported on glulam columns. The fire protection strategy included encapsulating the structural timber with three layers of gypsum plasterboard to achieve a 2-hour fire resistance rating.

The 18-storey Mjøstårnet building in Norway completed in 2019 exposes more of the structural timbers than at Brock Commons, with careful design to ensure the structure is able to withstand a complete burnout of the fire load without collapse. This required encapsulated fire-retardant treated timber in some places.

In New Zealand, the tallest mass timber building is the 9-storey Auckland City Mission currently under construction using CLT walls and floors.

Fire sprinklers are considered essential in all tall buildings. In addition, standard practice is to ensure that, in the unlikely event that the sprinklers are not effective, the structure is able to withstand a severe fire without risk of collapse even after the occupants have safely evacuated.

Concerns about fire performance

There are, however, some concerns from fire experts regarding the fire safety and fire performance of tall timber buildings since timber is clearly a combustible material and our understanding of building performance in real fires is still evolving.

What are these and how can they be addressed or mitigated?

Traditional fire design based on standard fire resistance tests may be unsuitable

Fire design of timber structures has typically involved oversizing members based on an assumed charring rate in a standard fire resistance test. Members are designed such that the undamaged timber remaining beneath the char layer is able to support the required loads. However, standard fire resistance tests were developed with non-combustible structures in mind. The construction only needs to meet the test criteria for the defined period, and there is no consideration as to what happens during the decay period of a real fire. Furthermore, standard fire resistance tests do not account for the additional fuel provided by the building elements.

In practice, careful fire engineering is needed to limit damage to the structure in a real fire to ensure it can self-extinguish without the risk of structural collapse during or after the fire. This often requires some of the timber to be encapsulated with protective boards or coatings to ensure the timber structure ceases to burn after the building contents have burned away.

Some engineered wood may delaminate in a fire

In CLT panels without fire-resistant adhesives, it has been observed in fire experiments that the charred timber layers can delaminate during a fire and fall away, exposing fresh timber that sustains the burning process.

This concern is being eliminated as most CLT manufacturers now use fire-resistant adhesives so that char layers do not fall away prematurely and the panels behave in the same way as solid timber.

Risk of external vertical fire spread increases

It has been observed that fires in enclosures with large amounts of exposed timber surfaces lead to larger and more extensive external flames projecting from window openings in the external wall compared to when the enclosure surfaces are non-combustible. This requires greater consideration to be given to the façade design and materials selection to prevent fire spread up the façade.

Acceptable Solution requirements for tall buildings fire resistance may be inadequate

There is an expectation that a building structure will be stable and not collapse before the occupants can safely escape and firefighters can carry out search and rescue activities. The New Zealand Building Code requires that there is a low probability of injury and illness to occupants and firefighters and of damage to adjacent household units or other property.

While the term 'low probability' is not quantified, it is generally accepted in all tall buildings that a combination of active and passive fire protection measures will be necessary. Active measures such as fire sprinklers reduce the likelihood that a severe fire will occur. However, they are not 100% effective. A small probability remains that a severe fire could occur where fire-rated construction would be called upon to contain the fire.

In most countries, the required fire resistance ratings increase with building height. This ensures that the probability of failure in fire reduces as the building height increases, generally in line with societal expectations.

However, in New Zealand, this increase with height is essentially non-existent. For example, in the case of the two previously mentioned sprinklered 18-storey residential buildings in Canada and Norway where a 2-hour fire resistance rating was required, the New Zealand Acceptable Solution C/AS2 would only require a fire rating of 30 minutes for the primary structure, regardless of height.

This concern applies to all tall buildings, but it is particularly relevant for tall buildings constructed from combustible materials.

Developing international guidelines

Funding from the Building Research Levy is supporting New Zealand experts to participate in an international effort to write a state-of-the-art guide for the fire design of timber buildings.

The guide is being developed by leading fire experts from 10 countries with Dr Andrew Buchanan, PTL Structural Consultants, as editor and Dr Colleen Wade, Fire Research Group, as a chapter author. Publication of the new guide is planned for 2022.