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The influence building codes and fire regulations have on multi-storey timber construction in Australia.

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Extended abstract

Timber is an environmentally friendly building material that is both renewable and reusable, though being combustible by nature meant historically it has been viewed in some parts of the world as an inferior structural material to steel and concrete in multi-storey construction. Buildings are responsible for a substantial amount of material and energy consumption. The environmental properties of materials aren't traditionally a design or construction priority and typically cost, performance characteristics and aesthetics have governed the choice of structural materials. This trend is beginning to change as the issues associated with climate change continue to come to the forefront and governments and industry look for ways to assuage its effects. Choosing environmentally sustainable building materials is beginning to become a client and tenant expectation and industry is starting to follow suit. Life Cycle Assessment studies have outlined when timber is used as an alternative structural material to steel and concrete the overall environmental impact of the building can be reduced.

In Australia timber products have generally not been considered a viable option for multi-storey construction. Two major barriers to increased market share of timber use in non-residential construction in Australia are overall designer confidence and fire performance. As a result there are limited examples of multi-storey timber framed buildings in Australia with concrete and steel primarily being used for structural elements. This has also been largely determined by the evolution of Australian building codes, where building codes have evolved on a state-by-state basis. They were largely based on English building codes, where the prescriptive requirements of the building code were typically not favourable to timbers use in multi-storey construction. This originates from the "Great Fire of London" where it was decreed that all buildings would be made of non-combustible materials such as stone and masonry. In Australia on July 7, 1997 performance based codes were introduced in the Building Code of Australia (BCA). Performance based Alternate Solutions were introduced to allow innovative new structural systems and designs that didn't meet the standard Deemed-to-Satisfy compliance criteria an opportunity to obtain approval under the BCA.

This paper critically analyses the impact the BCA has on multi-storey timber buildings in Australia specifically in relation to fire, acoustic, structural and energy requirements. The paper also identifies the Sections/Parts of the BCA that would typically require a performance-based Alternate Solution in order for a timber building to gain code approval. One of the original purposes of performance-based codes was to facilitate cost savings in building construction. In Australia any building 4

storeys or higher requires an Alternate Solution and this actually has the potential to significantly increase costs, due mainly to increased design fees. The methodology adopted for the study was case study, and two building case studies were used to demonstrate the impact that building regulations in Australia have on the viability of large multi-storey timber buildings. The first case study is a virtual design of an 8-storey Cross Laminated Timber (CLT) residential building in Victoria, Australia. The second building case study is a redesign of a previously constructed 9 storey concrete office building in NSW, Australia, which uses laminated veneer lumber (LVL) as its structural elements. The two building case studies were used to demonstrate the Sections/Parts of the BCA requirements that typically require an Alternate Solution and the two building case studies were able to outline the different requirements in obtaining building code approval between the different states in Australia. Data collection was achieved through document analysis and semi-structured interviews with a number of building professionals. The interviews were transcribed and a thematic analysis was performed to establish relevant issues and comments in regards to the Sections/Parts that would typically require an Alternate Solution for timber use in the BCA. Also through the use of the case studies it was outlined that there are different code requirements for CLT and LVL. As there is no mention of CLT in the BCA or any Australian Standard, a multi-storey building proposing to use CLT would potentially require a structural Alternate Solution, which is typically very rare for anyone to do in Australia. The timber office-building case study was able to demonstrate the fact that in Australia there are no requirements for acoustic performance, though in residential buildings there is. It is important to note that even though are no acoustic code requirements, there is still an expectation from a tenants' comfort perspective.

A number of strategies have been suggested to potentially allow easier more cost effective avenues for timber to obtain building code approval in Australia. Firstly CodeMark certification was looked at as a possible option. It is described as a third party scheme that has been developed to support the use of new and innovative building products, through the use of an internationally recognised process. Products can be assessed for compliance with the requirements of the building codes of Australia and New Zealand. The main issue with CodeMark certification is that it requires significant testing and associated costs to achieve a certificate of compliance, and even though timber elements such as LVL and CLT have the potential to achieve certification, the high associated costs is typically the responsibility of manufacturers. Though manufacturers would be hesitant to outlay the costs if they aren't going to see an increase in demand for their product and designers are hesitant to use the timber in large buildings due to increased complexity in achieving code compliance. Secondly Proposals to Change the BCA was looked at as another avenue to allow the BCA to be more accommodating to timber construction. This option was deemed to be more of a long-term solution to the issue.

The paper is able to demonstrate that currently under the BCA there are a number of options available for timber buildings to be constructed essentially to any height, provided that a performance based design is developed to meet the necessary Alternate Solution performance requirements. This paper also outlined the difference code requirements between different states i.e. NSW and Victoria. It also outlined there are different code requirements between residential and commercial timber construction and also between CLT and LVL. With the rising costs of steel, concerns over carbon emissions of building products and increasing site constraints timber has the ability to provide not only a more environmentally sustainable product though due to its prefabricated light weight nature it has the ability to potentially increase productivity, decrease construction waste and limit OHS issues on site due to the

lower number of workers needed to construct the building. It has been demonstrated that current buildings codes in Australia allow timber buildings to essentially be constructed to any height and as more efficient designs and cost effective code compliance options such as CodeMark certification are developed the use of timber in multi-storey buildings in Australia can become a more viable alternative to steel and concrete buildings.

Keywords: Timber, fire regulations, building codes, Alternate Solutions, CodeMark certification

1. Introduction

Timber has great potential opportunities in multi-storey buildings due to its high strength to weight ratio, light prefabricated nature and its environmental attributes. Engineered wood products are starting to gain interest within the construction sector, as they have more uniform mechanical and physical properties compared to solid sawn structural timber products [1]. Two potential areas for timbers use are commercial offices and residential construction. Multi-storey office buildings typically consist of large open plan spaces with long span floors supported on beams and columns Laminated Veneer Lumber (LVL) has potential to be used for the structural elements in such buildings. LVL can be either a solid section or fabricated into a hollow section for use in new innovative post-tensioned technology, which improves seismic performance and can provide the ability to achieve longer spans with smaller beam depths [2]. Multi-storey residential buildings typically consist of relatively short span floors supported on walls from the previous floor, generally with a significant number of separate rooms on each floor. Cross Laminated Timber (CLT) has been successful throughout Europe and is being earmarked as having the greatest potential to compete with steel and concrete in North America [3]. CLT allows for rapid construction erection and extremely close tolerances, though CLT has some issues such as it uses a significant amount timber that is not subjected to any mechanical forces and it has limited unsupported spanning capabilities.

Buildings are responsible for a substantial amount of material and energy consumption and whilst environmental properties of materials aren't traditionally a design or construction priority [4], with cost, performance characteristics and aesthetics being the main items that decide material selections in buildings [5]. However, as climate change continues to come to the forefront and governments look for ways to assuage its effects such as passing legislation to address the issue, choosing sustainable environmentally friendly building materials is beginning to become owner and tenant expectations. All levels of government in Australia are beginning to introduce legislation to mitigate the impacts of climate change; recent studies [6] outline how a Carbon Pollution Reduction Scheme if implemented could have a large impact on the building construction industry in Australia in the future. The greatest contributor to greenhouse gases and in turn climate change is carbon dioxide (CO_2) emissions, where 30 – 50% of total CO_2 emissions throughout the world are produced by the construction and operation of buildings [7]. The selection of materials used in the buildings has the potential to reduce energy consumption and CO_2 emissions in buildings and there have been a number of reports [8,9] that have demonstrated timber to be a more environmentally friendly material than steel and concrete. This is because trees have the unique ability to sequester carbon dioxide from the atmosphere, which is in turn stored in wood materials once they have been manufactured and they typically require less energy during manufacturing. The National Association of Forest Industries [10] showed that Australian forests have the potential ability to provide 20% of Australia's total carbon abatement targets by 2020.

In Australia timber products have generally not been considered a viable option for multi-storey construction. Bayne and Taylor [5] found that historically two of the major barriers to increase market share of timber use in non-residential construction in Australia are overall designer confidence and fire performance. This lack of confidence in using timber amongst designers stems from a multitude of issues such as, lead times, cost implications, connection details, availability, commercial risk, lack of assistance, inadequate training in timber design and poor marketing [5]. A number of authors [11,12] have highlighted that fire regulations are typically the major obstacle to the use of timber in multi-storey buildings.The culture of multi-storey timber buildings has a long history throughout the United States and Europe. Many four-storey and higher timber buildings have been constructed in those countries such as Murray Grove and the Norwich Academy in the UK. Throughout Europe timber-framed walls have been utilised to achieve fire separation between apartments in residential buildings, though in Australia under prescriptive requirements typically fire-separating walls between abutting residential building have to be constructed out of a non-combustible materials. In Australia there are limited examples of multi-storey timber framed buildings with concrete and steel being primarily used for structural elements. This has been largely determined by the evolution of Australian building codes. Building codes within Australia have evolved on a state-by-state basis, and were largely based on English building codes, where the prescriptive requirements of the building code does not like timber buildings in multi-storey buildings which historically dates from the "Great Fire of London" when it was decreed that all buildings would be of non combustible materials such as stone and masonry.

In this study, the objective was to look at how code regulations impact the use of timber in multi-storey buildings in Australia and to determine whether or not an 8-storey timber residential and a 9-storey timber office building could be constructed in Australia and also to identify how the Building Code of Australia (BCA) influences such buildings. This paper does not intend to outline what is involved or how to develop a Performance Based design but rather outline what Section/Parts of the BCA that affect timber buildings and in turn require a Performance based Alternate Solution. The study also endeavours to show where different compliance regulations exist in the BCA for different building classes and also different states i.e. NSW and Victoria have their own amendments to building regulations and through the use of the case studies these differences are able to be pointed out in reference to multi-storey timber buildings.

2. Building Code of Australia (BCA)

The BCA was first released in 1991 in Australia and was prescriptive in nature, such that there was no opportunity for new and innovative buildings to be constructed if they didn't meet the prescribed Deemed-to-Satisfy provision. Then in 1997 performance based alternatives were introduced, to allow designers to deviate from prescriptive provisions, provided that testing and other analysis can be documented to establish that an Alternate Solution is able to satisfy code's performance requirements.

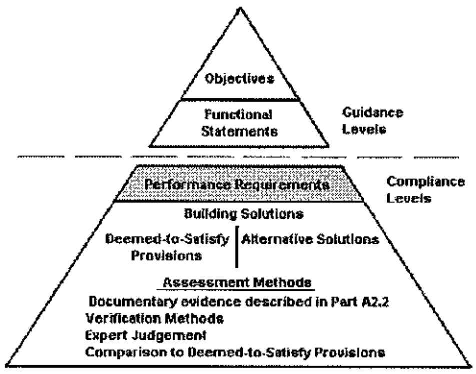
2.1 BCA Structure

The way the BCA is set up currently is that buildings have to comply with all sections/parts outlined, with some Australian Standards also referenced in the BCA as being mandatory requirements. As illustrated in Figure 1 meeting the performance requirements of the BCA can achieve by one of two ways,

1. Deemed-to-Satisfy provisions are the traditional prescriptive measures where minimum requirement set out in the BCA must be complied.

2. Alternate Solutions allow new innovative buildings designs to be established and provided the designers/builders can demonstrate the adequacy of the design it has the potential to meet performance requirements as set out in the BCA. Currently under the BCA any timber building greater than 4 storeys in height has to be designed through the use of an alternate solution.

Fig. 1 BCA structure



(Source BCA 2010)

There are a number of different types of buildings and these are catergorised in the BCA under different classes, as outlined in Table 1. In Australia it has been outlined there are significant opportunities for timber construction in class 2 – 9 buildings, with class 2 and class 9b and 9c being a prime area of opportunity for increased use due to their inherent scale and function. A survey of building professionals and timber suppliers to establish what factors helped or hindered the sale and use of timber in class 2 to 9 buildings. The study outlined that building regulation requirements were considered to be one of the key factors that hindered the use of timber in buildings [13].

Table 1 BCA building classes

Building Class	Building Function
1	Single dwelling unit, detached or attached, not one above another
2	Residential building with 2 or more sole occupancy units, usually one above another
3	Hotels, motels, boarding houses etc
4	Residential part of classes 5, 6, 7, 8 or 9
5	Office building
6	Shops, restaurants, showrooms etc
7	Car parks, store buildings or wholesalers
8	Factory and laboratory
9	Public buildings: 9a health care, 9b public assembly, 9c aged care
10	Ancillary building

2.2 Performance based – Alternate Solutions

Performance based Alternate Solutions provide timber buildings in Australia that don't meet the prescriptive Deemed-to-Satisfy requirements an avenue to become code compliant. In order to comply with all Sections/parts of the BCA it is necessary to determine whether an Alternative Solution meets all the relevant BCA performance requirements by:

a) Identifying the relevant Deemed-to-Satisfy provisions of each BCA section/part that is to be the subject of the Alternative Solution;
b) Identifying the performance requirements from the same sections/parts that are relevant to the identified Deemed-to-Satisfy provisions; and
c) Identifying performance requirements from other sections/parts that are relevant to any aspects of the Alternative Solution proposed or that are affected by the application of the Deemed-to-Satisfy provisions that are the subject of the Alternative Solution.

Section A0.8 Alternate Solutions outlines that an Alternate Solution must be assessed according to one or more of the assessment methods, which are outlined below

a) Evidence to support that the use of a material, form of construction or design meets a Performance Requirement or a Deemed-to-Satisfy Provision; and/or
b) Verification Methods such as;
    - The Verification Methods in the BCA or
    - Other methods that the local government or other appropriate authority accepts; and/or
    - Comparison with the Deemed-to-Satisfy Provisions; and/or
    - Expert Judgement.

An alternate solution will only comply with the BCA if the assessment methods listed above have been adequately satisfied and used appropriately to determine compliance with performance requirements. Also where many Alternative Solutions fail is in not ensuring that associated Deemed-to-Satisfy and Performance provisions throughout the BCA are also considered where a proposal might impact upon it.

To meet the fire requirements under the BCA any timber building 4 storeys or higher in height requires an Alternate Solution in order to be compliant under the BCA. This in turn could potentially turn people away from developing multi-storey timber buildings, as associated design consultancy fees would be high for "one off" projects. In developing an Alternate Solution a performance based design approach is needed and an engineer is responsible for developing a design that will have the ability to meet the specified performance requirements. In todays building design in Australia, sound insulation and acoustic performance particularly in residential buildings tends to govern the choice of timber-framed construction to a greater extent than fire requirements, particularly from a clients perspective where they are living in a class 2, 3 or 9c multi-storey residential building [14]. This is evident as acoustic/sound issues are a day-to-day issue where as fires are a potential risk, which are not guaranteed to occur. This is why under current BCA legislation there are performance requirements for acoustic design in residential buildings whereas in commercial buildings there are currently no acoustic/sound performance requirements in class 5,6, 9a and 9b buildings [15]. Hence for a residential building an Alternate Solution will need to be developed for a residential building though not for an office building.

3. Methodology

In this study, the objective was to look at how code regulations impact the use of timber in multi-storey buildings in Australia and to determine whether or not an 8-storey timber residential and a 9-storey timber office building could be constructed in Australia and also to identify how the Building Code of Australia (BCA) influences such buildings. This paper does not intend to outline what is involved or how to develop a Performance Based design but rather outline what Section/Parts of the BCA that affect timber buildings and in turn require a Performance based Alternate Solution. The study also endeavours to outline where different compliance regulations exist in the BCA for different building classes and also different states i.e. NSW and Victoria have their own amendments to building regulations and through the use of the case studies these differences are able to be pointed out in reference to multi-storey timber buildings.

Two case study buildings have been used to outline the process of obtaining building code compliance and to specifically outline, which sections of the BCA require Alternative Solutions for timber structural systems. Multi-storey timber buildings are a relatively new technique, and as the investigation is focused on contemporary phenomena within real life contexts the case study as empirical inquiry is found to be a suitable option [16]. Data collection was achieved through document analysis and semi-structured interviews with building professionals including a building consultant who was well versed and specialised in BCA compliance, a senior fire engineer with 15 years experience and project manager with extensive experience in the management of both residential and commercial office buildings were also interviewed to obtain their views on the BCA in relation to timber buildings. The interviews were transcribed and a thematic analysis was performed to establish relevant issues and comments with specific performance based applicable to timber in the BCA and these findings are incorporated into the case studies.

4. Case Studies

4.1 Case Study 1 – Class 2 Residential building - CLT panel structural system

This virtual building design is an 8 storey residential building with levels 2 – 8 constructed out of CLT using platform construction, with the ground floor constructed out of concrete. The building has a proposed location of Victoria, Australia. This building design would be classed as a class 2 building and the Sections/Parts of the BCA that may typically require an Alternate Solution are outlined in Table 2. Designers i.e. fire engineers, acoustic specialists etc are employed to develop solutions to meet the requirements set out in 2.2 Performance based – Alternate Solutions. Then once the Alternate Solution design has been produced it is then forwarded to review by the Building Appeals Boards in Victoria, which has an independent statutory board of industry representatives who have an aim to achieve building safety, amenity and sustainability outcomes matched to community goals.

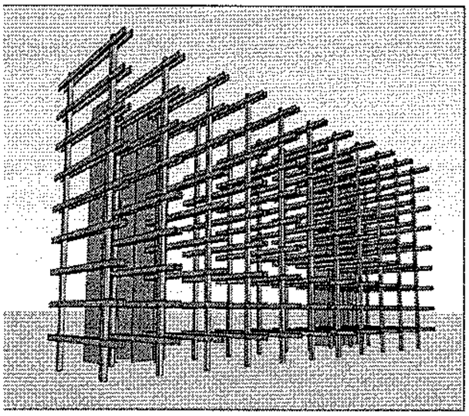
These designs are then presented to the Building Appeals Board in Victoria who make judgements on the solutions and whether they adhere to the performance requirements. The decision cannot be appealed (except on a point of law). Some variations in the Victorian legislation that is relevant to timber are that internal load bearing walls do not require fire rating and may be combustible, and also apartment entry doors do not have to be fire rated. This building has been designed to be less than 25m in overall height as it is much easier to achieve approval in regards to fire safety of the building. Also in conjunction with the Building Appeals Board the chief officer of the fire brigade has 10 days to respond to the Alternative Solution and he has jurisdiction to disapprove of the design if it was deemed to not meet the necessary requirements.

Table 2 BCA Alternate Solutions for case study buildings

BCA Performance Requirement	**CASE STUDY 1**	**CASE STUDY 2**
Part B1 - Structural Provisions	✔	
Section C – Fire Resistance	✔	✔
Section D – Access & Egress	✔	✔
Part F1 – Damp and Weatherproofing	✔	✔
Part F5 – Sound Transmission and Insulation	✔	
Section J – Energy Efficiency	✔	

4.2 Case Study 2 – Class 5 Office building – LVL post and beam structural system

Fig. 2 Buildings timber structural system



This building case study is a virtual redesign of a building that has previously been constructed in concrete. The building is situated in NSW, Australia and the timber redesign building is based on a series of gravity only frames and lateral load resisting shear walls as shown in Figure 2. LVL has been proposed for use as the timber structural elements for the building. This building design would be classed as a class 5 building and the Sections/Parts of the BCA that may require an Alternate Solution are outlined in Table 2. Designers i.e. fire engineers, acoustic specialists etc are employed to develop solutions to meet the requirements set out in 2.2 Performance based – Alternate Solutions. Then once relevant engineers i.e. Fire Engineers have developed the required Alternate Solution design for the building and an expert peer review is required, who comments on the design and essentially gives the design the OK from a technical viewpoint. Then finally the design has to be given the go ahead by the NSW fire brigade service and finally has to be signed off by the building certifying authorities.

A few things to point out in case study 2 that are different to case study 1 are; firstly as the office building is recognised as a class 5 building under the BCA, as is outlined in Part FC class 5 buildings don't require any acoustic requirements. However, even though under building regulations there aren't any minimum requirements, clients do expect a certain level of acoustic performance and comfort and this in turn should be reflected in the building design, particularly for the floors and walls. Another key potential issue for this building design in comparison to building case study 1 is that as it is over 25m in height and is classed as a high rise building there are a number of additional fire engineering requirements including sprinklers throughout, stair pressure, fire isolated stairway, emergency lift, zone smoke control system etc. Also there may potentially be issues with the NSW fire brigade giving a timber building over 25m the go ahead as they may have concerns to the safety of their fire fighters as typically when a building is over 25m they fight fires in buildings from the inside as their hoses and ladders don't have capabilities to fight fires in buildings over 25m.

5. Strategies

5.1 CodeMark Certification

The Australian Building Codes Board (ABCB) in consultation with the New Zealand Department of Building and Housing (DBH), State & Territory governments, industry groups and prospective certification bodies set up the CodeMark certification scheme. It is a third party scheme developed to support the use of new and innovative building products, through the use of an internationally recognised process in which products can be assessed for compliance with the requirements of the building codes of Australia and New Zealand. The certification allows a product to essentially gain approval under Deemed-to-Satisfy provisions of the BCA, which through the issue of a certificate of conformity is able to provide confidence and certainty to regulatory authorities and also the market. In order to obtain CodeMark certification an organisation must apply through a certification body such as SAI Global, Global-Mark Pty Ltd and CertMark Australasia. The requirements for evaluation & certification of products are set out in the CodeMark scheme rules and essentially any organisation can obtain approval provided it is able to demonstrate to the certification body that their particular product meets the relevant requirements. Certificates of Conformity can be achieved for a material, form of construction or design and in order to achieve conformity existence and maintenance of a 'Product Quality Plan, testing of a sample or samples that are representative of the Product that are used or installed. Also factory and/or construction site audits are typically required to ensure that compliance is being achieved and is capable of being maintained [17].

In regards to timber use as structural elements in multi-storey buildings CodeMark certification has the ability to help reduce costs and time associated with such projects across a range of performance requirements. If a Certificate of Conformity is achieved for a timber system in relation to fire performance requirements it would then negate the need for a fire engineer to develop an Alternate Solution on future buildings, which is a costly and time consuming process. The issue at present is that there are relatively high costs involved to achieve CodeMark certification (circa $50,000 to $100,000) and in relation to timber it would most probably need to be the manufacturer who is responsible for this investment; keeping in mind that manufacturers aren't going to spend the time and money to achieve certification if it isn't going to result in an increased demand for their products/systems. In essence it is catch 22 situation as building designers in Australia as outlined in survey results [13] see building regulations requirements as one of the key factors that hinders the use of timber in class 2 – 9 buildings. In turn CodeMark certification could be a good avenue to provide an easier way to achieve BCA compliance in multi storey timber buildings, though unless designers show an interest and increased demand for timber buildings above 4 storeys in height, timber manufacturers aren't necessarily going to invest the money into CodeMark certification. Also an important thing to note is that Certificates of Conformity are only valid for 3 years.

5.2 Change to BCA Legislation

The ABCB has a process in place called 'Proposals for Change' (PFC), which allows technical proposals the opportunity to change the BCA. In order to maintain appropriate thoroughness and consistency the Council of Australian Governments regulatory principles is used. In order for a PFC to be considered there must be a:

- A description of the proposal
- An explanation of the problem it is designed to resolve
- How the proposal is expected to solve the problem
- Who will be affected and how they will be affected; and
- Any consultation that has taken place

If a proposal is considered to have merit the Building Code Committee (BCC) may recommend that the proposal be included in the next draft for public review. If the BCC considers the proposal as being complex in nature, it may suggest that further research, analysis and consultation is performed. Proposing to change the BCA to be more receptive to timbers use in multi-storey buildings was considered by one of the building consultants interviewed as being a medium to long-term goal, whereas CodeMark certification is more short-term objective.

6. Conclusion

It has been demonstrated that currently under the BCA there is an avenue available for timber buildings to be constructed essentially to any height. This is provided that a performance based building design is developed that meets the necessary Alternate Solution performance requirements and is then signed off and given the go ahead by the Fire Brigade and the Building Certifier who essentially at the end of the day assumes the liability of signing off the design. At present in the BCA there are a number of areas where timber does not meet the Deemed-to-Satisfy requirements and the development of Alternate Solutions is usually a costly exercise. In order to address this issue strategies including CodeMark certification and proposals to change the BCA to be more accommodating to structural timbers use in multi-storey buildings have been considered as a way to provide a more cost effective and viable option over the medium to long term for structural timber to obtain code compliance.

With the rising cost of steel, concerns over carbon emissions of building products and increasing site constraints, timber has the ability to provide not only a more environmentally sustainable product but create other benefits due to its prefabricated light weight nature and subsequent ability to potentially increase productivity, decrease construction waste and limit OHS issues on site due to the lower number of workers needed to construct the building. It has been demonstrated that essentially the code allows timber buildings to be constructed to any height and as more efficient designs and cost effective code compliance options are developed the use of timber in multi-storey buildings in Australia can become a more viable alternative to steel and concrete buildings.

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