

Medium-rise structural timber apartments: Luxury or long-term carbon storage solution?



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Short Summary

The Australian construction sector contributes almost a quarter of the nation's carbon emissions and the main strategy to address this has been to reduce the operating energy of existing buildings and by regulating energy consumption of new buildings. However there has been less focus on minimising the embodied energy of new construction projects. Engineered timber products have been used in a number of large building projects to replace heavier materials as a structural alternative whilst providing benefits such as aesthetics and the capacity to store carbon. Cross-laminated timber (CLT) has found a market in apartment buildings in Europe with a growing number of projects using the product for both structural floors and walls up to 9 storeys high. Australia's first major CLT building stands 10 storeys high and is currently being marketed as a sustainable city apartment alternative to reinforced concrete. This paper looks at the perception of consumers towards this new construction innovation in an attempt to understand whether Australian residents will accept sustainable timber use in apartment living.

Keywords: Cross-laminated timber; apartments; embodied-energy; sustainable construction.

1. Introduction

Australians are gaining an increasing awareness of environmental issues and sustainable construction due to continued publicised debate and recently implemented carbon tax, rising energy prices and a string of government subsidies provided to homeowners for energy saving technologies [1][2]. Whilst much of the focus in reducing the construction industries' environmental impact has been on operating energy, there is a growing importance to minimise the embodied energy in homes and apartment buildings [3][4]. Building legislation currently controls issues relating to operating energy but it has no restrictions on the energy embodied in a new building's construction materials [5]. Shortage of land for detached dwellings in the city of Sydney (New South Wales) and the high cost of providing infrastructure to a spreading city have led to the government encouraging high-density apartment living through both state and local government policy changes and land use rezoning [6]. Apartment projects make up the majority of revenue in Australia's new construction market and this is expected to continue in the near future [7]. Apartment buildings in Sydney are predominantly built with a structure of reinforced concrete columns and floor slabs with a variety of materials used for dividing walls and facades [8]. The recent completion of Australia's first and the world's tallest structural timber apartment block has provided a reduced embodied energy option when compared to the typical concrete construction methodology [9]. It has also been marketed for its sustainable attributes whilst providing equivalent or greater facilities, aesthetics and comfort compared to inner city concrete apartments.

This paper examines the opinion of NSW residents towards environmental sustainability, the use of timber as a sustainable material in new residential construction, and their willingness to live or purchase an apartment in a medium-rise timber structural building. This paper also presents the process of data collection and analysis of an online survey. The results of the survey reveal that most of the participants prefer concrete construction in apartments even though they believe there should be an increase in the use of sustainable materials and that timber is a more environmentally sustainable material. Finally, this paper presents strategies for increasing the acceptance of timber both as a sustainable building material and as an alternative structural solution to reinforced concrete apartment construction.

2. Timber apartment construction

2.1 Australian apartment construction

Structural timber apartment construction is limited in Australia due to the market dominance of materials such as steel, reinforced concrete and masonry used in these projects. Increasing population densities requiring taller buildings, stricter building codes and standards as well as an established workforce and technologies all support the use of heavy materials in medium and high-rise apartment construction. The majority of apartment projects in NSW are built with reinforced concrete floor plates and columns. The national code of construction does not permit apartments greater than three storeys to be built out of structural timber elements so alternate design solutions are required to achieve compliance [5]. This costly and time-consuming process in addition to the strict fire and acoustic performance requirements for apartment buildings has resulted in heavy material utilisation in these types of projects until recently. Timber research and testing has shown that engineered timbers such as CLT have the capacity to perform predictably in fires in addition to providing acoustic performance that satisfies local regulations with the addition of some simple cement screeds to the floor, insulation systems and floor coverings [10][11][12]. The increased speed of construction compared to reinforced concrete has made medium-rise apartments using CLT panels appealing to developers for financial and time-saving reasons. Reduced site manpower will also assist building companies to decrease the risk of site injuries and the cost of safety compliance [13]. In addition to time, cost and safety benefits, the opportunity to source CLT panels from sustainable plantations and its capacity to store carbon during its life cycle is motivating construction companies in Europe and Australia to implement this innovative construction methodology [14][15][16].

2.2 Cross-laminated timber apartments

A few years after the erection of the eight and nine-storey CLT apartment structures named 'Bridport house' and 'Stadhaus' in London, the construction of 'Forte' has recently been completed. Forte is a ten-storey CLT apartment building in the Docklands area of the city of Melbourne, Australia. Despite being slightly taller than the preceding CLT apartment blocks, one of its main differences is its positioning in the private apartment market where it competes against similar luxury-grade concrete apartments rather than in the affordable/public housing market. The adoption for this timber building innovation in the private housing market will depend not only on providing financial benefits to developers but also on the dynamic preferences and choices of prospective investors and occupants [17]. Research in Europe has found that cost premiums associated with sustainable construction provide disincentives to purchasers, whereas a recent Australian study revealed that homeowners would pay extra for sustainable materials in new detached dwellings [18]. Housing material research reveals that consumers desire the warm and aesthetic attributes of timber but are still concerned with its perceived structural, safety and longevity issues when comparing timber with heavy materials such as concrete and masonry products [19]. Despite the existing data covering some aspects of consumer perception towards sustainability and the use of timber in residential housing, the completion of Australia's first structural CLT apartment block presents an opportunity to test how the market will view this innovative construction methodology.

3. Research method

The purpose of the research was to obtain data that reflected NSW resident's perception of sustainability in residential building, their understanding of timber as an environmentally beneficial material and their inclination towards occupying and owning medium-rise timber apartments. The data would be analysed and results used to develop strategies to increase the acceptance of timber as an environmentally sustainable alternative for heavy building materials in apartment construction. Online questionnaire surveys were used to allow for rapid distribution, wider coverage and to increase the efficiency of data collation and analysis. The sample group was chosen to provide a mix of residents occupying and/or owning units or detached dwellings and having a background of either construction or non-construction related employment. Construction related participants were contacted through construction companies, industry associations and professional affiliations. Non-construction workers were accessed through friends, family and work colleagues and snowballing technique was used to increase the size of this group. The survey was distributed via a link embedded in an email sent to participants to enable completion of the surveys at their own convenience and to maintain anonymity. The potential participants were then reminded 2 weeks after initial distribution by email, phone and personal contact except in the case of surveys distributed through industry associations and snowballing. Final response rate was estimated at 15% with 310 responses received. The questionnaire included sections on demographics, attitudes to sustainable construction, material preferences for medium-rise units and willingness to pay a premium for these dwellings. The survey commenced in December 2012 and data was collected for approximately 3 months.

4. Observation and analysis

Participants in the questionnaire were occupants and residents of both units and detached dwellings in NSW with the majority coming from suburban areas surrounding the city of Sydney (84%). This figure was made up of those living in inner Sydney (59%) and outer Sydney (41%). Close to half of the participants came from a construction related profession (48%) and the remaining 52% had no construction background. Construction professions/workers included project managers, property professionals, developers, architects, engineers, builders, quantity surveyors and trades in order of greatest representation to least. Females were underrepresented as they made up only 35% of participants whereas there is an equal amount of men and women in NSW between the ages of 18 and 64 [20]. A comparison of the age distribution of the survey participants with the NSW population shows a similar percentage spread and this is presented graphically in Figure 1.

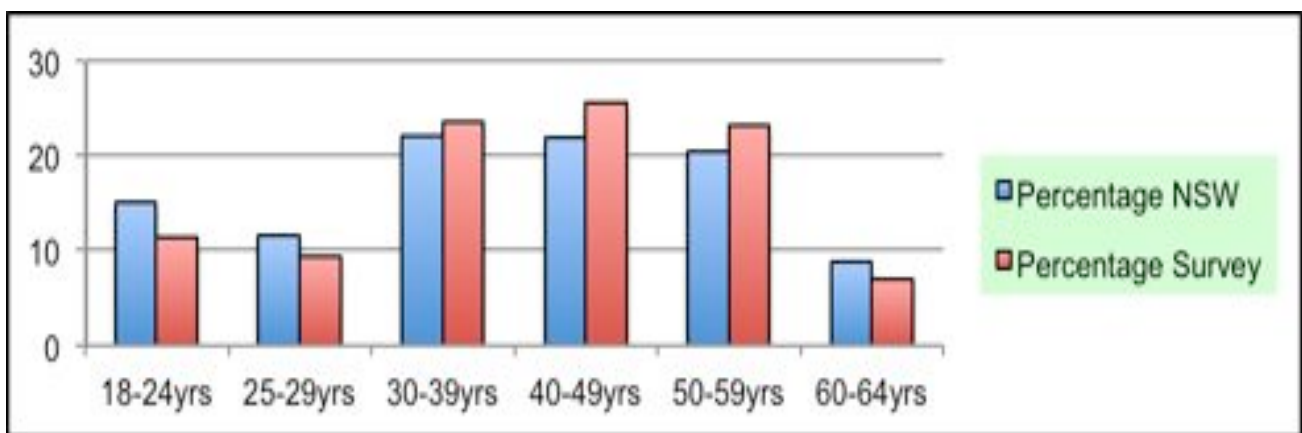


Figure. 1: Age distribution comparison between survey participants and NSW population

4.1 Sustainability and sustainable building materials

Participants were asked whether society should focus more on sustainability and whether there should be an increase the use of sustainable building materials in residential construction. They were also asked if they believed that timber was an environmentally sustainable building material.

There was almost full agreement that society should focus more on sustainability (90%) and that sustainable materials should be used to build new residences (94%). Undecided votes for these questions were 7% and 4% respectively with negative responses for each question totalling just 3%. Two thirds (65%) of participants favoured timber as an environmentally sustainable building material with 29% unsure and 6% rejecting the proposition. Age, gender, construction background made little difference to the responses with a maximum variation of 9% above or below the mean.

4.2 Home occupants attitudes towards medium-rise structural timber units

Participants were also asked seven questions specifically about their perception of living and owning a unit in a ten-storey structural timber apartment. These included the reasons for preferring to live in a concrete or timber unit and some of the benefits and concerns they would have about the timber structure. They were also requested to nominate whether they would expect to pay more for a unit in a timber residential apartment block or a typical reinforced concrete apartment block and how much extra they would expect to pay.

4.2.1 Willingness to live or purchase a unit in a timber apartment block

21% of respondents would prefer to live in a 10-storey timber structural unit over one built with reinforced concrete which is just over double the proportion of people willing to purchase a unit in a timber apartment block (10%). 36% of the females surveyed were willing to live in a timber unit but only 12% of the males. This percentage gap increased when it came to purchasing, with 20% of females and just 6% of males willing to buy into medium-rise timber construction. Participants with a construction background were less willing to live in a timber unit block (16%) and even less would like to purchase (7%) whereas 26% of non-construction workers would live in timber units and 14% would buy. Age groupings also provided different rates of willingness to live and buy timber units with both the 25-29yr and 60-64yr age groups varying significantly from other age groups. These results along with those mentioned above are found in Table 1.

Table 1: NSW residents' preference for timber over concrete units.

Demographic group	Prefer to live in timber medium rise unit to a concrete unit (%)		Prefer to purchase a timber medium rise unit to a concrete unit (%)	
	Timber	Concrete	Timber	Concrete
All responses	21	79	10	90
Male	12	88	6	94
Female	36	64	20	80
Construction	16	84	7	93
Non-construct.	26	74	14	86
<u>Age group</u>				
18-24	19	81	8	92
25-29	5	95	11	89
30-39	25	75	9	91
40-49	23	77	12	88
50-59	25	75	14	86
60-64	16	84	6	94

4.2.2 Willingness to live or purchase a unit in a timber apartment block

As recorded in Table 1 there were only a small percentage of participants willing to purchase a timber apartment (10%). Reasons provided for the choice of buying a unit with a structure composed of timber over concrete included sustainability, aesthetics and acoustics. The reason for participants choosing concrete structure for units is listed in Figure 2 and these have also been

analysed by work background. The top three reasons for all participants to choose concrete units were structural performance, fire resistance and its tested performance. Participants with construction background showed the greatest concern for the fire resistance, tested product, financial and acoustic characteristics. Non-construction workers selected structural capability, maintenance, durability and insect resistance as the most important characteristics.

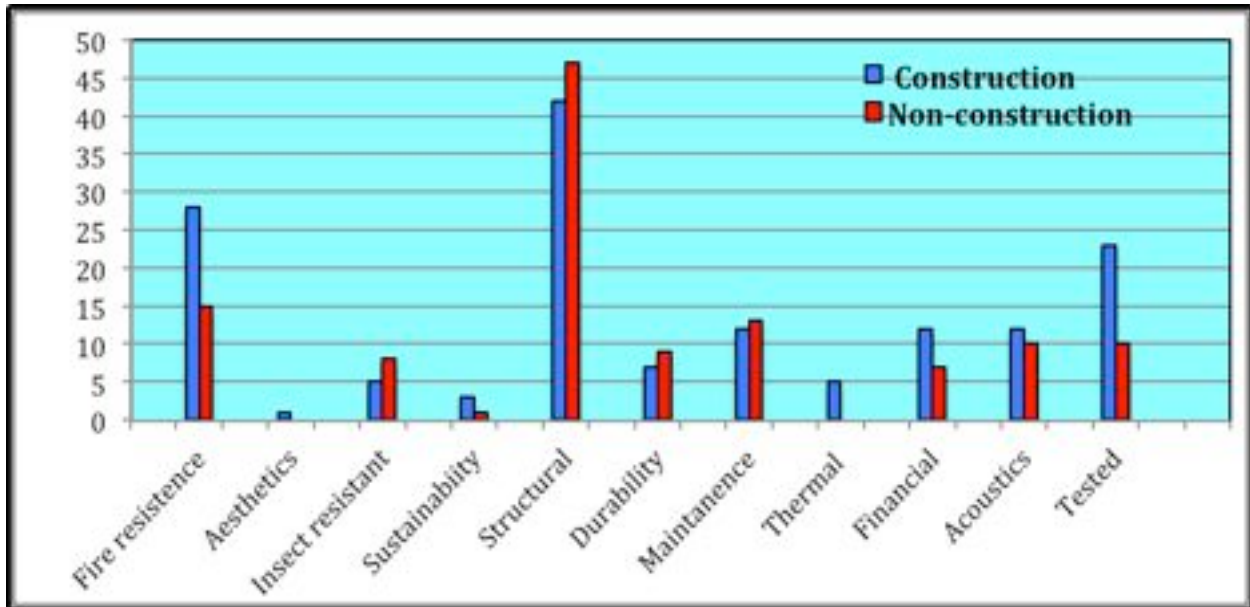


Fig. 2: Reasons to purchase concrete over timber structure in medium-rise apartments (by number)-Comparison by construction or non-construction industry background.

4.2.3 Benefits and concerns of living in a timber apartment

Participant's opinions of some of the benefits and concerns associated with living in a ten storey timber unit block was analysed, with sustainability, aesthetics and less expensive being the most commonly chosen benefits. Following these came indoor air quality, acoustics and structural attributes. Other benefits mentioned included pioneering project, innovation, and thermal comfort. The top three concerns for prospective occupants were fire resistance, insect attack and structural stability, and to a lesser degree water damage, purchase price and acoustics. Participants raised maintenance, deforestation, thermal mass capabilities and high strata levies as other concerns of less importance. These results are presented in Table 2.

Table 2: Main benefits and concerns of potential occupants of a tall timber apartment.

Benefits	No. Chosen	%	Concerns	No. Chosen	%
Sustainability	163	35	Fire resistance	173	34
Aesthetics	158	34	Insect	118	23
Inexpensive	65	14	Structural	106	21
Indoor air quality	48	10	Water damage	46	9
Acoustics	24	5	Expensive	24	5
Structural	10	2	Acoustics	8	8
TOTAL	468	100	TOTAL	508	100

In regards to participants expectations of whether timber units should be cost comparable to concrete units there was little difference between the percentage of those who believed that timber should cost more (37%) and those that thought concrete should be more expensive (38%). The remaining 25% considered that the unit cost should be the same regardless of the structural material. These proportions are presented in Figure 3.

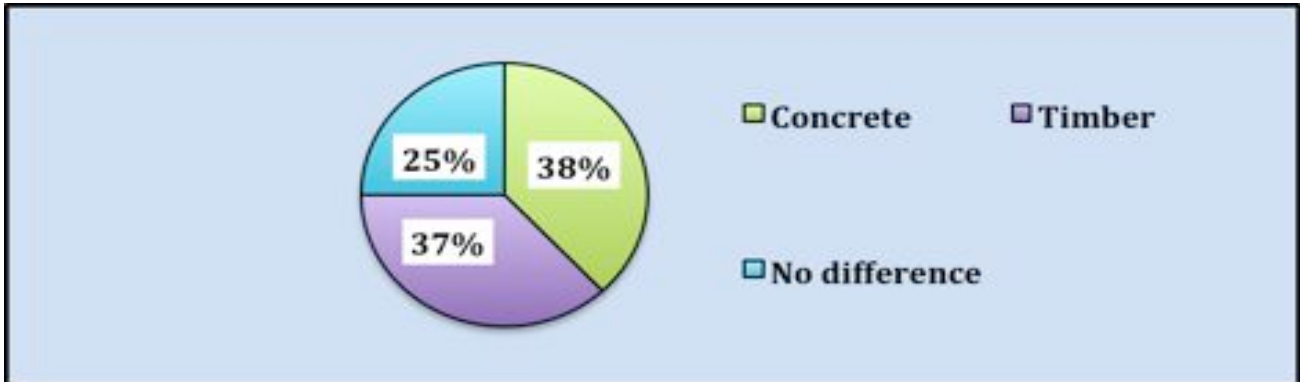


Fig. 3: Would you expect to pay more for a timber or concrete unit

The participants who chose either timber or concrete units to be more expensive to purchase were also asked how much extra they would expect to pay for that type of unit. They were given 7 options: these included \$5000, \$10,000, \$15,000, \$20,000, \$25,000, \$30,000 and a participant-determined premium. Only the first 5 options were selected and the percentages of each selection are shown in Table 3. The median expected additional cost for both the timber unit and concrete unit was similar with figures of \$15,600 and \$16,000 despite dissimilar distributions around the mean.

Table 3: Additional amount expected to be paid for a concrete or timber unit

Amount above typical unit price	Concrete %	Timber %
\$5000	13	4
\$10,000	15	32
\$15,000	20	24
\$20,000	43	28
\$25,000	9	12
\$30,000	0	0
Other amount	0	0
TOTAL	100	100

5. Discussion

A mixed section of NSW home occupants with both construction and non-construction work backgrounds are strongly in favour of increasing societies' action on sustainability in general and specifically increasing the use of sustainable materials for residential building. The majority believe that timber is an environmentally sustainable building material however they demonstrated a reluctance to either live or purchase a unit in a medium-rise structural timber apartment block in favour of the traditional reinforced concrete structure. This represents a separation between their ideals and their intended actions. This could be related to a number of the factors listed below.

- Misperceptions surrounding structural adequacy of timber in taller buildings due to the lack of information distributed about medium-rise timber construction technologies.
- Fear of the combustible nature of timber in tall buildings despite legislative requirements related to the protection and escape of occupants being mandatory in all Australian apartment buildings.
- Familiarity and acceptance by the construction industry and general public of reinforced concrete apartment construction which has been proven to fulfill all building codes and standards and has predictable costs, experienced designers and trades people in the market.

- Projection of common negative perceptions of residential timber performance such as insect and water damage onto larger residential timber construction projects.

In addition to these issues potential occupants, investors and owners need to be assured that they will not pay increased maintenance costs, strata levies and receive an acceptable return on their investment. A number of strategies are suggested below to address the fore mentioned barriers to the acceptance of medium-rise structural timber construction.

1. Increase marketing to educate the demand side of the market about the structural capacity, fire resistance, acoustic and thermal benefits and suitability of timber for use in apartment construction to compliment the recent media campaign that promotes the aesthetic and environmental benefits of timber.
2. Produce a clear and simple report on the effects of carbon tax on the price of timber, concrete, steel and other heavy materials used in the residential building industry.
3. Publicly showcase innovative construction methods that seek to reduce the environmental impact of the construction industry.
4. Include innovative timber building design and construction technologies into university curriculum to educate future construction professionals on sustainable building options.

All these strategies aim to increase the education of both construction professionals and the general public regarding the benefits of timber use in medium-rise apartment construction in order to help dispel persistent misconceptions about negative timber characteristics. They also reveal the need to address the embodied energy issues in construction to compliment the continuing efforts to reduce the operating energy in Australia's building stock as part of the nations carbon reduction strategy. This study will be followed by a set of qualitative interviews that target the supply side of the apartment market with interviews to a broad range of construction professionals.

7. Conclusion

Heavy materials such as steel, concrete and masonry dominate the current market for medium and high-rise apartment construction in Australia. Advances in engineered timber and innovative design has seen CLT used in a growing number of projects in Europe and the first ten-storey timber apartment block in Australia. Although CLT construction has been shown to deliver advantages of speed, safety, cost and carbon reduction when compared to reinforced concrete, the private consumer market for apartments built of timber is yet to be convinced of these benefits. Ongoing education on the benefits of timber to both the general public and construction professionals is required if structural timber apartment construction is to become a long-term environmentally sustainable alternative to current construction methods.

8. Acknowledgements

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