Wood in multi-storey construction in Christchurch in 2019 – an assessment of progress since 2014

David Evison, School of Forestry, University of Canterbury, September 2019

Research commissioned by the Ministry for Primary Industries.

1. Introduction

This research was carried out at the request of the Ministry for Primary Industries and builds on earlier work by the author. A pilot survey on attitudes to the use of wood by building professionals was conducted in 2011 (McGregor et al., 2011) and a broader survey of the key players (owners, builders, engineers and architects) involved in the construction of four wooden buildings in Christchurch was implemented in 2013 and 2014, at the request of MPI (Evison, 2015) . A further assessment of use of mass timber in multi-storey construction was carried out for New Zealand and Australia in 2018 (Evison et al., 2018).

This current research was carried out in July to September 2019, in Christchurch. The purpose of the research is to provide an assessment of progress since the 2014 survey. This report has been organised to identify:

- what has changed and what has improved.
- what is still work in progress.
- what can the government do to improve outcomes for building using wood.

The principal findings have been that:

- Architects and engineers are more familiar with the range of engineered timber products on the market than they were five years ago, and there are increasing examples of materials being combined (timber to timber and timber to concrete and steel), to produce cost effective and customer-focused designs;
- While there is now a core of experienced architects, quantity surveyors and builders, there remains a need to support those who are exploring the opportunities of engineered timber, and the regulators, for whom engineered timber is still a new technology;
- Timber suppliers are moving to provide full service packages (from material construction to delivery), to compete more effectively with other construction materials.

2. Methods and data

A semi-structured interview process was used. The guide for the interview is shown in Appendix 1. In general the conversation was guided by the points the interviewee wanted to make, rather than the template. The time taken for each interview depended on the particular circumstances of the interview – they varied from around 15 minutes when the discussion was part of a field visit, to about 2.5 hours when there was a specific appointment to discuss the topic.

A “weight of evidence” approach was taken when identifying the key themes as the output from this work. While all of the findings are derived from the expertise and knowledge of those interviewed,

and the generous commitment of time by all participants is gratefully acknowledged, any errors or omissions are those of the author. Helpful feedback from Dr Parnell Trost, of MPI, on earlier versions of this document and the survey instrument is acknowledged.

The interviewees were largely Christchurch-based, but their views were frequently based on experience in other parts of New Zealand and the world.

3. What has changed over the past five years?

There has been significant progress since 2013/14 in the use of timber in non-residential construction in Christchurch. There is growing confidence in the building industry that wood is a material with significant advantages, including

- lightweight buildings with good seismic properties.
- Quick to construct.
- Environmental benefits.
- Innovative designs.

3.1 Availability of building products

A much larger range of engineered timber products is now available than in 2013/14, and architects and specifiers are seeking to optimise the combination of materials being used – particularly the ability to reduce cost by using cheaper materials where the more expensive option is not required. The four buildings studied previously (Evison, 2015) were all post and beam construction. Now structural wood panels – Cross Laminated Timber[1] (CLT) and Parallel Laminated Timber[2] (PLT) are becoming commonly used, and there is a broader use of new and existing products.

For example, whereas the shear walls in the Trimble Building (completed in 2014) were made solely from Laminated Veneer Lumber[3] (LVL), in the Kaikoura Council building (completed in late 2016) they were made with LVL and CLT. This was a more cost-efficient option. Also while mass timber is still the key material, in some parts of these buildings, conventional 2X4 framing or LVL framing materials are being used as the most suitable material from both an engineering and a cost perspective.

Along with these trends there is now a better appreciation of the capability and operational requirements of these different products, and of the connection technology for constructing in these new materials. One difference between timber and steel or concrete is a greater need to protect it from the elements during construction. Because this has not been an issue for concrete or steel, building practises may need to be modified in some ways to accommodate engineered timber materials. For example, wrapping (with plastic) or coating (with a protective paint) beams and columns that will be exposed to the weather during construction has become common practice. However there is now a better appreciation of the capabilities of different materials to cope with exposure to the weather.

For example, CLT can stand a lot more moisture during the construction phase, whereas LVL must be protected. Learnings are that sometimes wrapping doesn't work – contractors on site rely on it too

[1] A wood panel product made from gluing layers of solid-sawn lumber together. Each layer of boards is usually oriented perpendicular to adjacent layers and glued on the wide faces of each board, usually in a symmetric way so that the outer layers have the same orientation.

[2] PLT Panels are glue laminated, structural panels. Lamina are glued so that the grain runs parallel to the panel span direction. Lamina may be finger-jointed or solid.

[3] A structural product manufactured from thin peeled veneers of wood glued with a durable adhesive with the grain running parallel to the main axis of the member. Panels of LVL are cut into structural members which have high strength and stiffness.

much. Effective protection is more about behaviour of contractors on site. Build quickly and cover seems to be one principle that will work. This is clearly different to both concrete and steel where both are highly tolerant of wet conditions, and there are no consequences to delays in weather-proofing buildings.

Figure 1: Use of cross laminated timber and treated framing timber in a multi-storey building

While there is still a need for further work on building connection joints (timber to timber, and timber to concrete and steel), there are standard connections available from overseas manufacturers, so that it is much less of an issue than it was in 2013/14. Having readily-available solutions for connections is a significant advantage, because standard solutions reduce both cost and uncertainty.

Figure 2: Use of CLT for a lift well

There has been a broadening of the applications where wood is used – for example in stair and lift wells (Figure 2 above). While it may be technically feasible to use wood in a wide variety of applications, it is also well accepted that buildings are, and should be, made from a range of materials, with the final product being a composite construction.

3.2 Precision manufacturing equipment and expertise

Computer Controlled (CNC) machining and prefabrication capacity has been increasingly adopted by LVL, CLT and Glulam[4] manufacturers, and prefabrication companies. The major LVL manufacturers have direct access to this equipment and there are other companies with this equipment and capability also. While there is anecdotal evidence that not all prefabrication companies have been a success (for example the liquidation of building firms (Tallwood, Welhaus) in 2019), there are also some good examples of this working well.

There are some important implications of the introduction of this sort of equipment in a number of regions of New Zealand.

- It facilitates sophisticated designs – there are examples of buildings that have been built using this sort of equipment that could not have feasibly been built in any material other than wood;
- It provides repeatability and scalability (this equipment can provide components machined to very impressive tolerances, and can provide multiple components of the same type quickly;
- It facilitates the emulating of the design-prefabricate-build model used by the steel industry in construction;
- It supports supply chain integration (discussed below).

The increase in capacity also means that engineered timber products are readily available in all regions, and are available to architects, engineers and builders in their operations.

3.3 Supply chain integration

Along with increasing capability and product knowledge, the interviews found that the approach to project design, manufacturing and construction has been changing. The nature of timber construction has encouraged greater engagement (and team planning) between the key players in the design and production process (who include the project engineer, architect, manufacturer/timber supplier, builder and client's Quantity Surveyor). This 'design for manufacture' approach is realising benefits through the project cycle, from better and more efficient design through to savings in construction and project completion time.

There are examples where this model has extended to the engineering peer reviewer. It appears that there are strong benefits to involving the peer reviewers at the concept stage. Improvements suggested by the peer reviewer are incorporated into the design. The peer review is submitted along with the building consent. There are examples where this model has been used successfully, and examples where engaging peer review late in the process may have caused less efficient design and construction.

---

[4] Glulam is a product made from assembling and gluing pieces of dimension timber (e.g. 100 X 500 mm) together to make a beam or column of specified dimensions and engineering properties. While it is a technology that has been available in New Zealand for a long time (for example, use for the structure of municipal swimming pools is quite common), the addition of CNC equipment has allowed a further level of sophistication in this industry, and has facilitated the combining of different engineered wood products with the objective of supplying the most cost-effective engineering structures to the client.

There is evidence that the leading suppliers of engineered timber are matching the service model provided by the steel and pre-cast concrete competitors, of full service provision. Whereas previously there was concern that the wood industry had not adapted to the requirements of the construction industry (Evison, 2015), this has now happened.

A full service supplier would provide:

- Material construction;
- Product manufacturing;
- Delivery;
- Provision of craneage; and
- The supply of temporary supports.

Engineered wood panels are a very impressive product with significant inherent benefits. However the ability for this material to successfully out compete the materials currently favoured in the industry (steel and reinforced concrete) depends on the total product service offering being competitive, not just the building material.

Figure 3: Erection of timber panels on site provided by panel manufacturer

This service approach will act in direct competition with tilt slab concrete. The Hornby Club was originally designed as a concrete tilt slab building. The timber supplier was able to offer a full service approach and demonstrate that there are significant benefits in terms of erection time, cartage, foundations, and the ability to allow other trades on to the site early.

Figure 4 below is an example of what can be achieved for multi storey residential construction using engineered wood. Survey respondents have stated there is significant interest in this type of construction from some of the major construction companies.

Figure 4: Multi storey rest home in CLT

Figure 5: CLT used for exposed wood finish in hall ways

Figure 6: CLT in the Hornby Club

3.4 Differing levels of expertise among building professionals

There are now firms with significant expertise in the design and construction of wooden buildings of a variety of different types. There are at least four New Zealand engineering firms who seem to be generally accepted as having a high degree of skill and experience in timber engineering. They are developing a culture of building excellence in wood. These firms are building a significant international reputation and are involved in many international projects.

However while there is significant professional interest in wood as a construction material – perhaps particularly amongst young engineers, there is still a need for greater experience in some of these professionals. Whether there are any specific actions that might improve this situation is an open question. However, a funded mentoring scheme might ensure there is a deliberate connection between the professional leaders in this area, and those who aspire to specialise or achieve a high level of technical competence in timber engineering.

There appears to be a need for greater expertise among the approvers and regulators in the building regulatory authorities. A lack of expertise in this area means that peer reviews will be requested more often, so upskilling this group would provide significant benefits to building cost and time. Funding to provide the approvers and regulators with sufficient knowledge and familiarity that they have confidence to approve timber designs without the need for peer review would also assist the uptake of this technology.

3.5 The benefits of wood in construction can be demonstrated in recent buildings

A number of the positive features of wood construction, raised in the 2013/14 survey, have now been demonstrated, and are being validated, in actual operating examples, including the strong seismic properties of lightweight timber construction, advantages across a range of soil conditions and quieter building site conditions.

4. In what areas is further progress required?

4.1 Post and beam construction

For multi storey office buildings post and beam construction has not replaced steel or reinforced concrete yet. The Beatrice Tinsley building on the University of Canterbury campus is one example of a new building where the post tensioned technology has been used (and refined).

Where this technology has been used the feedback is generally very positive in terms of staff well-being and general feelings of safety. The large shear walls were mentioned as being somewhat inconvenient, however the main point to be made is that the major selling point for these buildings – safety and resilience in major earthquakes - has not yet been tested.

Figure 7: Post and beam construction – Beatrice Tinsley

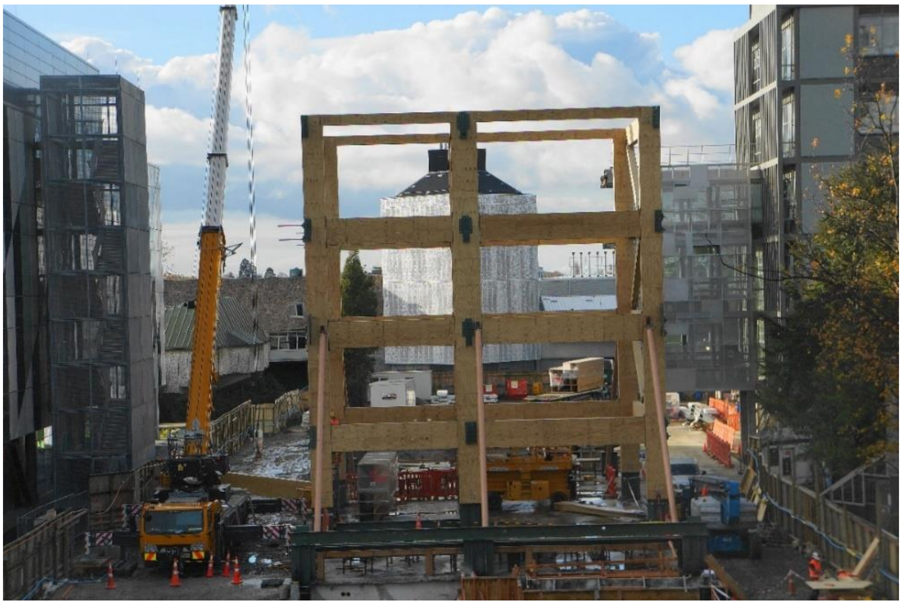


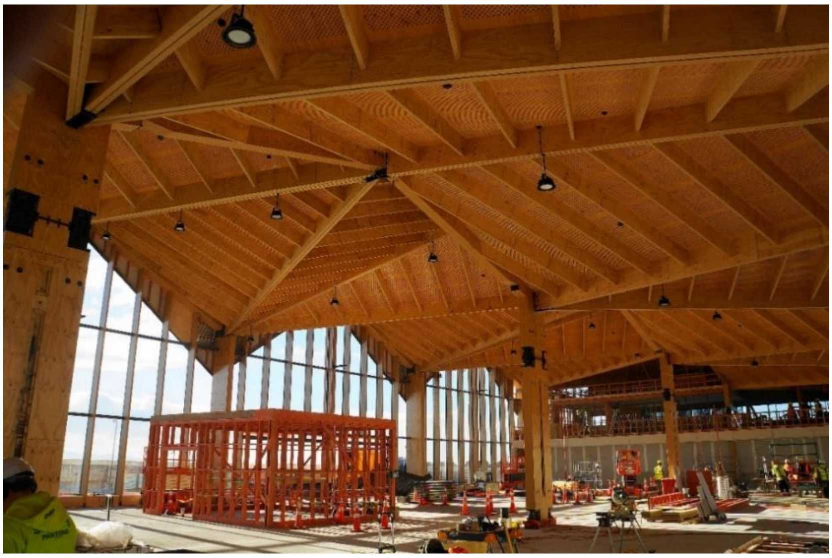
Figure 8: Post and beam construction – Beatrice Tinsley

4.2 "Architectural" building opportunities are still to be fully realised

There is a major opportunity for wood in what may be called "architectural" buildings. As Taggart (2011) and others have stated, wood with computer controlled manufacturing is very amenable to unconventional shapes and sizes. This means that design features can be developed with timber that would not be feasible in other materials, or would require additional supports.

The new Nelson Airport terminal is an illustration of this form of architectural building. While a more traditional design could have been less expensive, the additional cost relates to the architectural design rather than the wood componentry.

Figure 9: Innovative LVL design – Nelson Airport terminal



An important point from the interviews was that the use of wood in architectural applications does not need to use highly innovative designs – for example the Cathedral Grammar building used traditional wood joints and Arvida's Park Lane retirement complex has a standard design lay-out.

Figure 10: Innovative design – Cathedral Grammar

Source: https://www.contract-construction.co.nz/project/cathedral-grammar-junior-school/

Figure 11: Accoya used in the exterior cladding of the Park Lane Arvida building

The braided rivers building project, proposed for Cathedral Square in Christchurch, with sculptured wooden columns and supports, has not gone ahead to date but would be an excellent example of an architectural building that would brand the city, and demonstrate the potential of engineered timber. https://www.braided.co.nz/ .

4.3 Supply industry conditions and capacity constraints

There is a need for a local supply of cross laminated timber, due to concerns about availability and timber treatment. In general overseas suppliers are limited by the size of a 40 foot container (13m X 3.3 m). Open topped containers can allow for greater width. There have been situations where the local industry has not been able to supply. Note also that lenders (if funding is required to build a building) will see it as a risk if there is only one supplier available for a particular product.

The diversity of products in New Zealand is creating some options and reducing risk of a small number of suppliers. For example Parallel Laminated Timber or GLT (glue laminated timber) in panel form can be used in place of CLT in some applications. Prefabricated panels may be a substitute for CLT in some applications.

In general there is a need for a greater diversity of supply across a range of materials. Survey respondents were divided on whether the local products were more expensive than imported products however encouraging a larger local processing capacity is very likely to increase both competition and innovation. Additional suppliers of CLT, plywood and potentially OSB[5] would be very helpful for the local construction industry.

[5] OSB or oriented strand board is a structural wood based panel, which is a substitute for plywood in many applications. It can be manufactured from small logs or other residue material. The logs are flaked, producing a thin piece that is rectangular in shape. This allows it to be oriented in the manufacturing process to confer desirable structural properties. Usually three layers of pre-glued flakes are laid down on a moving mat with the outside layers being oriented in the longitudinal direction with the middle layer oriented at right angles. The mat is then run through a hot continuous press, subject to heat and pressure.

5 What can the government do?

- Upskill regulators – often if the regulators don't understand wood they will require a peer review;
- Provide funding for industry-led research – not all projects may be amenable to student postgraduate study, and a mechanism for funding research projects by practitioners would be useful;
- It would be helpful if the major government demand nodes (for example, Housing New Zealand, Ministry of Education) specified prefabricated construction;
- Encourage the building of high quality architectural buildings in wood. These will be unique inspirational buildings that will make a branding statement about a particular city, region or even New Zealand as a whole;
- Provide information showing the benefits of wood, and promote to architects;
- Provide ways to upskill the large number of engineers who are interested in timber design, but don't yet have the skills;
- Encourage wood processing targeting specific products required by engineers and architects to build multi-storey buildings. Encourage a competitive processing sector which can stimulate product development and efficient process management.

6. Conclusion

Designers and engineers now have a wider range of materials available to them. The most noticeable change from 2015 is the availability of CLT, PLT and GLT structural panel products. The increase in the availability of prefabricated composite panels is also striking. Engineers are now finding that combining different timber products, including LVL beams and columns, a variety of prefabricated and engineered panels, the use of standard wood-based panels such as plywood and OSB, and stick framing (both LVL and radiata pine sawn timber) can provide a more efficient and cost-effective designs. This has also led to import of a number of products that could easily be made in New Zealand (e.g. OSB).

There are currently two levels of expertise in the industry, there is a core of highly-skilled people with a significant level of experience and knowledge in timber construction, and a larger number with interest and enthusiasm but a lack of expertise. Specialists are still learning how to get the best out of wood as a construction material. Product development and greater use of different products according to engineering properties, requirements and cost has made significant progress.

Prefabrication is much improved but much more progress can be made. In particular it is not clear that this segment of the industry is yet getting the benefits of a long period of running at capacity, and therefore has not yet had the opportunity to fully prove the contribution it can make to the construction industry. A deliberate strategy to utilise this capacity for specific projects would be timely.

The tender process doesn't necessarily provide the best outcome for increasing the use of timber in buildings – design and build offers the best opportunity to get the best design, and design for manufacture and construction. There is a growing awareness of the benefits of this approach, however the standard operating model for developers is to first commission the design then tender the construction as a subsequent step.

The "full service" model, where the timber manufacturer is also involved in design, prefabrication logistics and erection on site, is a good "value add" case study. This model demonstrates the main elements of true value add. It includes an element of design, as well as an augmented product which includes service elements. It also demonstrates how a new entrant in a particular sector needs to emulate the offering of the incumbents (steel and concrete) if it is to be successful. The ability to emphasise and ensure constructability at time of design, is very important to ensure that new projects in wood are successful for the suppliers as well as the clients.

7. References

Evison, D. C. (2015). Survey of key decision-makers involved in the construction of multi-storey timber buildings in Christchurch during 2013 and 2014. *New Zealand Timber Design Journal*, *22*(4), 15-22. Retrieved from https://www.researchgate.net/

Evison, D., Kremer, P., & Guiver, J. (2018). Mass Timber Construction in Australia and New Zealand - Status, and Economic and Environmental Influences on Adoption. *Wood and Fiber Science*, *50*(Special Issue), 128-138. Retrieved from https://wfs.swst.org/index.php/wfs/article/view/2713

McGregor, R., Evison, D., & Ozanne, L. (2011). A Pilot Survey of Structural Engineers' Perceptions Regarding Specification of Laminated Veneer Lumber in Single-Storey Industrial Buildings. *Sesoc Journal*, *24*(1), 25-29.

Taggart, J. (2011). Towards a culture of wood architecture. Abacus editions, Vancouver, Canada

Appendix 1: Survey instrument 2019

Coverage: Key Decision Makers in the Design and Construction Chain

- **Building owners;**
- **Architects;**
- **Engineers; and**
- **Builders.**

Background on survey participant

Experiences with multi-storey timber construction

Number of projects

1. **Review of progress on key findings from last report (2013/14). What has changed in the past five years with respect to:**
   a. Simplifying the design process and increasing design expertise
   b. Interface between research and engineering practice and further research needs
   c. Promotion of wood use, as an element in the construction process
   d. Assessment of manufacturing and prefabrication capability
   e. Information for architects
   f. How aware are you of developments in connection technology and options? To what extent is connection technology constraining use of engineered timber in construction projects?
   g. What are the key attributes of engineered timber that

      i. Encourage its use
      ii. Act as a deterrent to use

2. **Construction industry perception of engineered wood products**

   How aware are decision makers of / how important are:
   a. The full life cycle costs of composite buildings, compared to those constructed predominantly in concrete or steel?
   b. Time savings that can be achieved in construction and tenanting the building; and
   c. The seismic advantages of this form of construction (particularly the timeframe for repair and tenant re-entry).

   What is the level of understanding within the engineering and construction industry of the changes in building practices that are required to work with engineered timber components?

3. **Current issues**

What are the current concerns of practitioners?

a. Performance of material in construction. What are the issues in constructing using wood, compared with steel or concrete

   i. Would a specification of tolerances for wood be useful?
   ii. Performance of wood when exposed to wet weather and guidelines for construction
   iii. Dimensional stability

b. Capacity of processing plants to supply
   i. CLT
   ii. LVL
   iii. Sawn timber
   iv. Other

c. Competitiveness of New Zealand manufacturing
d. Product development and product range
e. Fire engineers vs structural engineers and the gap in the middle
f. Development of the understanding of how to build in wood
g. Supply chain development and integration – use of Building Information Modelling

4. What additional guidance are decision makers looking for to support the greater use of engineered timber in design solutions and construction?