SURVEY OF KEY DECISION-MAKERS INVOLVED IN THE CONSTRUCTION OF MULTI-STOREY TIMBER BUILDINGS IN CHRISTCHURCH DURING 2013 AND 2014

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1 INTRODUCTION

A survey was conducted in December 2013 and January 2014 to gather feedback from building owners, architects, engineers and builders responsible for four Christchurch buildings recently constructed using engineered wood products. The survey was carried out to assist the Ministry for Primary Industries (MPI) prioritise its work programme on engineered wood products, and to identify opportunities to raise awareness, and encourage the use of engineered wood products. Those surveyed can be described as "lead users":

> *"those who…face needs that will be general in a marketplace – but face them months or years before the marketplace encounters them, and… expect to benefit significantly by obtaining a solution to those needs…"* (Herstatt and von Hippel, 1992)

Three out of four of these buildings use recently-developed technologies, including post-tensioned timber frames and shear walls, and timber-concrete-composite (TCC) floors. A number of factors have contributed to increased interest in construction using wood including the following:

- The establishment of Timber Engineering professorships at University of Canterbury and University of Auckland in 2005, the development of various technologies to use wood in the place of structural steel and reinforced concrete, and construction of the Nelson-Marlborough Institute of Technology demonstration building in 2010.
- The establishment of the Structural Timber Innovation Company (STIC), a joint venture company which sponsored timber engineering research and development, developed design guides, and conducted education and promotion initiatives based on the STIC demonstration building.
- The Canterbury earthquake sequence that started in September 2010 heightened concerns about building safety and resilience, the impact of liquefiable soils on building design and the benefits of designing and constructing lightweight low-damage buildings.

The requirements of the clients, the recommendations of the professionals involved and the constraints and attributes of each site had a role in the final selection of building material, and in two cases led to less wood use than was originally conceived.

2 RESEARCH METHOD

Seventeen semi-structured interviews were conducted with four building owners, four architects, four structural engineers and five builders, with most being and almost all were face to face. Each interview took between 30 and 90 minutes. Survey responses and an interpretation of verbatim comments are included in this report. The survey instruments were developed with the help of key informants from the University of Canterbury College of Engineering and Ministry for Primary Industries.

3 RESULTS

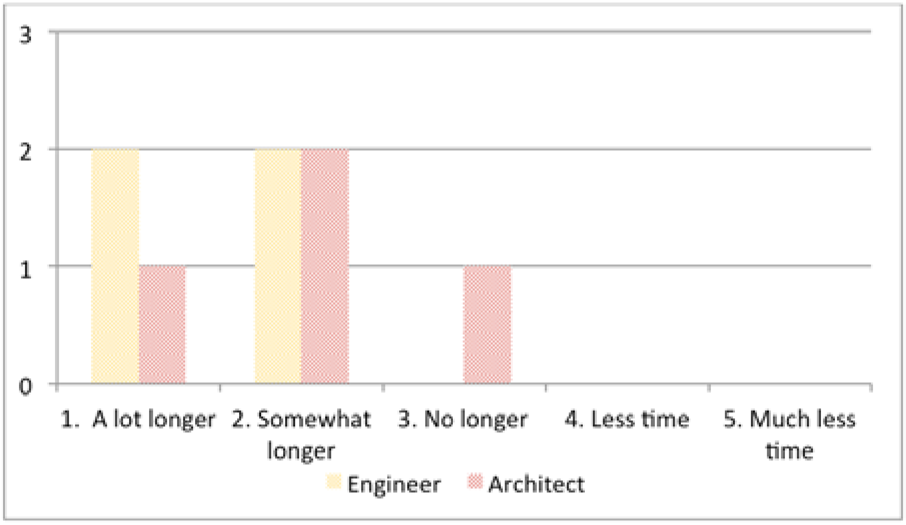
A number of common themes that emerged in the discussion with survey respondents are summarised below.

3.1 Support for simplifying the design process, and increasing design expertise

Engineers consistently highlighted the need to reduce the design cost for timber buildings, and that design time and complexity were major issues when using wood (Figure 1). Currently engineers are obliged to work out one-off solutions using performance-based design methods, which entail greater time and cost than code-based designs. The result is designated an "alternative design", which needs to be peer reviewed. One respondent felt that you need very experienced structural engineers to design in wood. Architects noted that design took longer because they were, "going back to the research". They said, "…it takes longer when there are unknowns…for example big spans…jointing details…", which meant that, "…timber sizes and spans had to be engineered…."

By contrast, one architect stated that design time was less with timber than with steel due to, "…lots more detailing with steel for fire protection…" One respondent suggested that subsidising peer review costs would be helpful as this cost is currently the responsibility of the designer.

Figure 1: *Did it take longer to design this building in wood than it would have taken in steel or concrete?*



There was very strong support for upgrading the New Zealand timber design standard NZS 3603 (1993). Although design stress data are available from LVL manufacturers, the current standard doesn't include LVL, and the information it contains is very generic. Engineers commented, "The timber standard is 60 years behind concrete - the first serious concrete standard was done in 1935". It was also noted that, "Timber is a first generation standard". One builder stated, "Code design is the place to start…the timber code is woefully behind current research, compared with steel and concrete". Another builder said, "Engineers do not trust timber because they don't have a standard". To support the use of structural timber in construction that goes beyond the prescriptive methods provided in NZS 3604 (2011), wood needs to compete effectively with concrete and steel. For example, both steel and concrete have comprehensive standard connection guidelines – thereby providing better ways to design compliant connections. These guidelines reduce design time and cost and professional risk for the engineers. In general, both engineers and architects agree that design time was longer for the timber buildings studied. There are a number of actions that should be taken to reduce design costs by providing or upgrading the following:

- Standards
    - Design code (NZ standard)
    - Material specifications (NZ standards)
- Design guides (that specifically support the new standards)
- Standard details

These actions were strongly supported by the engineers surveyed. All engineers surveyed responded it would be "very helpful":

- to have post-tensioning systems based on engineered wood included in building codes and standards, and
- to have standard detailing available for engineered timber during in the design process.

The lack of an up-to-date design standard and supporting documents means that design takes longer, is more expensive, and, because of liability concerns, may be more conservative than is actually required. The consequence may be a more complicated design, and require more complex fabrication and construction methods. Therefore the lack of standard solutions and guidance at the design stage has the potential to increase costs throughout the entire value chain. Good design also requires collaboration and consultation with fabricators and builders, as well as engineers and architects, and these from an early stage in the design process.

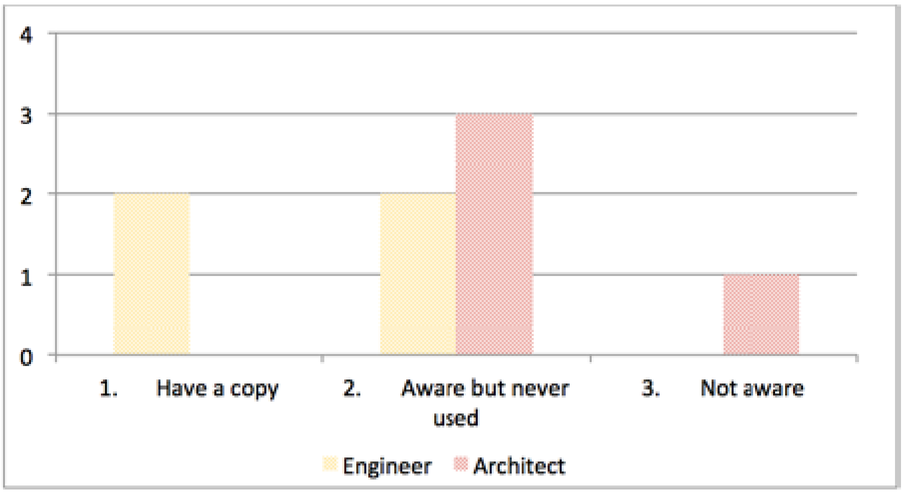
3.2 The interface between research and engineering practice, and further research needs

There is a natural tension between the professional engineer developing expertise in timber design to create a competitive advantage, and the desire of producers and researchers to disseminate information as widely as possible to get a quicker uptake of the technology (i.e. more buildings built). A number of respondents also highlighted the gap between research results and what a practicing structural engineer can action and use.

There are major benefits in having an independent organisation that is responsible for managing the interface between researchers and practitioners, and there is currently no organisation doing this for wood. While STIC clearly played an influential and valuable role in the implementation of research results, the poor uptake of its design guides was surprising. Some respondents expressed a strong view that design guides should be more freely available[1]. None of the architects surveyed used the design guides produced by STIC (Figure 2), however some were in direct contact with STIC and University of Canterbury researchers. Some of the engineers surveyed noted they had direct discussions with researchers at University of Canterbury and STIC, which may have obviated the need for design guides. A number of respondents felt the role of a design guide was to provide more detail on how to meet a standard, and that a design guide was less useful if the underlying standard was not available. The limited funding "life" of STIC meant that it was not possible to develop a new timber standard as part of that project.

An independent organisation responsible for the promotion of new technologies can also identify gaps in knowledge that researchers can fill. In two of the buildings studied, less wood was used than originally conceived. A detailed gap analysis of the reasons for this change would be useful to determine additional research that may be required. It was suggested that timber floors (including timber/concrete composite systems) are expensive and there are not many options (as opposed to precast concrete and steel where there are lots of options. For example one respondent suggested the requirement was for a, "… clean and simple floor that is cheap and repeatable, with 6-10 m spans..."). Another respondent said that timber concrete composite floors are "…not cost effective…"[2].

Figure 2: *Are you aware of EXPAN timber design guides for post-tensioned multi-storey buildings?*



The use of shear walls was rejected by some clients and their architects, because they impeded sight lines within a building and also to the outside. The steel

[1] I have been informed that the design guides produced by STIC under the Expan brand name are freely available to registered users, and that registration is also free-of-charge. Part of the contention here seems to be that EXPAN required the signing of a waiver of liability, which led to some respondents rejecting their use. This reinforces the need for a new standard as a first step, as this would provide greater comfort (in the sense of reducing professional risk) to the design engineer.

[2] There appears to be some conflicting evidence on this point, with some data from quantity surveyors suggesting that TCC floors are competitive.

K-brace system that was used as a substitute for the shear wall system in one of the buildings surveyed could be replicated in timber, once the required research and design work is done.

Engineers (and builders) are concerned about the amount of time that structural timber components might be exposed to the weather before the building is closed in. More work on protective coatings and methods of weatherproofing was suggested by a number of respondents. Further research on the long-term performance of timber, including creep in beams and deflection of floor systems, and on acoustic performance and dynamic performance of long span floors was also suggested.

3.3 Promotion of wood use

The building owners and architects surveyed were generally positive about specifying wood in future projects. All building owners were initially motivated to build in wood because of interest in the new technology, general environmental awareness, or a desire for an innovative solution related to low-damage earthquake performance. Some building owners and developers mentioned that the system was not as well developed as they expected (which led to increased design and construction costs), however as a group they remain positive about the technology. The architects and building owners surveyed were generally very positive about the use of timber in multi-storey buildings.

Recent earthquake activity in Christchurch has increased the emphasis on building resilience and building in wood is seen to be an advantage because building repairs are expected to be relatively easy and quick for timber buildings. One owner stated he would promote the safety and resilience benefits of the technology strongly to tenants. All the architects surveyed stated that low-damage design was something clients were currently aware of and asking for. One respondent also stated the low-damage requirement was "starting to fade now", and three out of four architects thought that low-damage design will be an important differentiating factor for building in seismic zones in the future. All architects indicated that seismic performance and the opportunity to feature wood in the finished structure were determining factors in the use of wood on their projects.

The comment that the interest from clients in low-damage design was "starting to fade now" highlights the importance of ongoing promotion of the technology. A technical promotion function could be established under the banner of a pan-industry body. Earlier promotional activities of NZ Wood, under Woodco (the Wood Council of New Zealand), were enhanced by STIC for a few years, but neither is now active in the marketplace. For several years STIC was able to demonstrate the technology in the STIC demonstration building at the University of Canterbury, with the support of the engineering departments of the University of Auckland and the University of Canterbury. The universities promotional role is very compatible with their active timber engineering research and teaching functions. The funding of any promotional role requires continued industry support.

Owners felt that the benefits they recognised in the buildings did not necessarily lead to greater financial returns. One was concerned that the Green Star rating system did not give adequate recognition to timber buildings, and the insurance industry did not necessarily offer reduced premiums for low-damage buildings. Architects felt that clients' views of the environmental benefits of this technology were expressed as a liking for wood rather than specific attributes such as life-cycle cost, carbon footprint or embodied energy advantages compared with other building materials.

Figure 3 shows that the building owners and architects surveyed are at least as likely to specify wood in future buildings as they were previously. The two building owners who responded "no change" also said that applied only up to 3 storeys. The three architects that expressed "no change" also said they were strong advocates for wood. Two architects also said that you must have the "right client" for a wooden building. Architects surveyed felt that wood was most appropriate for buildings of 2-5 storeys (Figure 4). Some thought that taller buildings could be built from wood when the technology was more mature.

Builders' opinions of the appropriate height for timber buildings varied greatly, and one builder felt only 1-2 storeys was appropriate. At the other extreme another builder felt greater than 10 storeys would be appropriate, "with the right design". Some did not offer an opinion on this question.

The existing buildings are a valuable promotional and informational tool that may not be fully utilised. Existing tenants and building owners should have readily-available material on the features of their buildings. One builder suggested there was a need for, "…education for the whole system. People don't understand the value and benefit…". Building owners

Figure 3: *As a result of your experience with the current project, has your likelihood of specifying wood in the structure changed?*

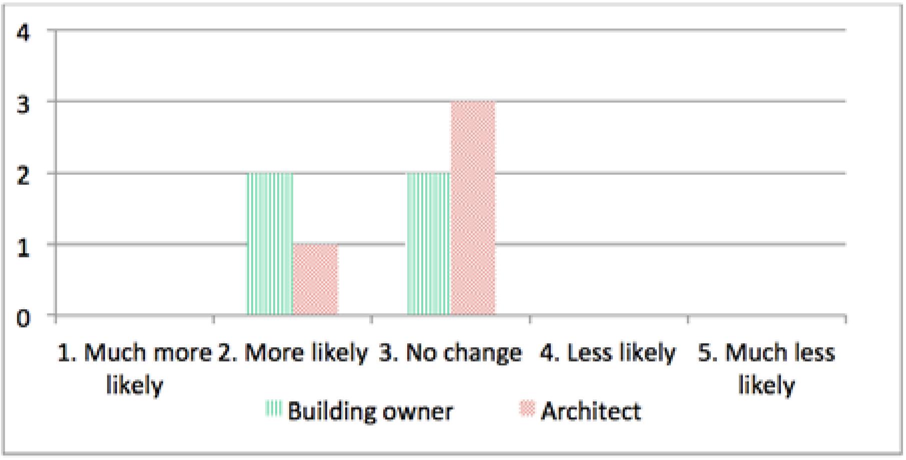
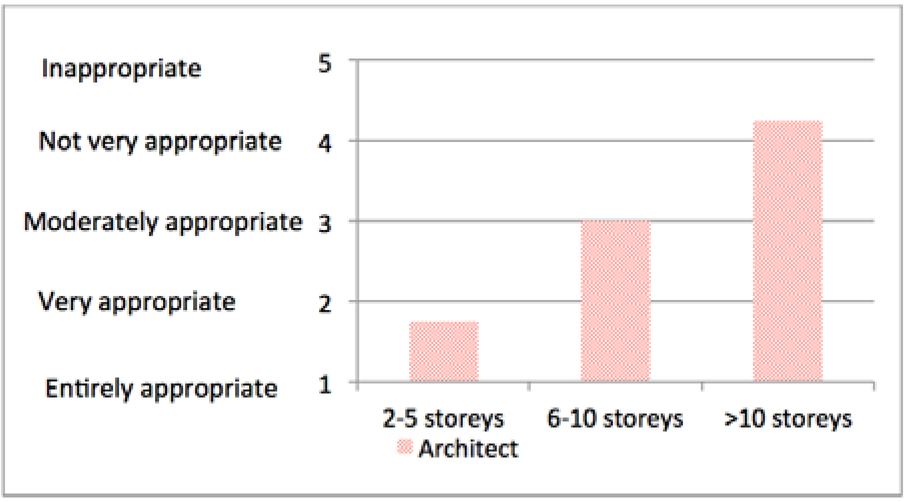


Figure 4: *How appropriate do you think wood is for buildings of different heights (architects only)?*



frequently mentioned the importance of aesthetic benefits of wooden buildings.

Builders and architects were asked to identify benefits from using wood and barriers to greater wood use, to provide insights into how wood could best be promoted. Results from these queries are provided in Table 1 and Table 2 for Architects and Builders, respectively.

Three out of four builders were very positive about the use of wood. The one who was not positive stated that, with the current state of expertise and knowledge in the industry, there were no benefits and some major drawbacks to wood. The same builder commented, "…it would be hard to contemplate a design that is cost-effective and simple enough to erect".

A number of respondents stated that on a "like-for-like" basis costs were very similar, and noted that the new timber technologies produce high-performance buildings, and a similar standard of performance in concrete would cost the same. They also noted that there was, "…a lot more steel going into buildings in Christchurch now than previously…", and that it was important to compare costs for timber buildings with current costs of concrete and steel buildings of an equivalent specification and not historical costs. Figure 5 reflects these views.

3.4 Assessment of fabrication and construction capability

The level of sophistication and expertise within the manufacturing and fabrication industries was seen as a major issue by both engineers and builders, with other respondents echoing their concerns. One respondent used a Melbourne-based prefabricator, and expressed

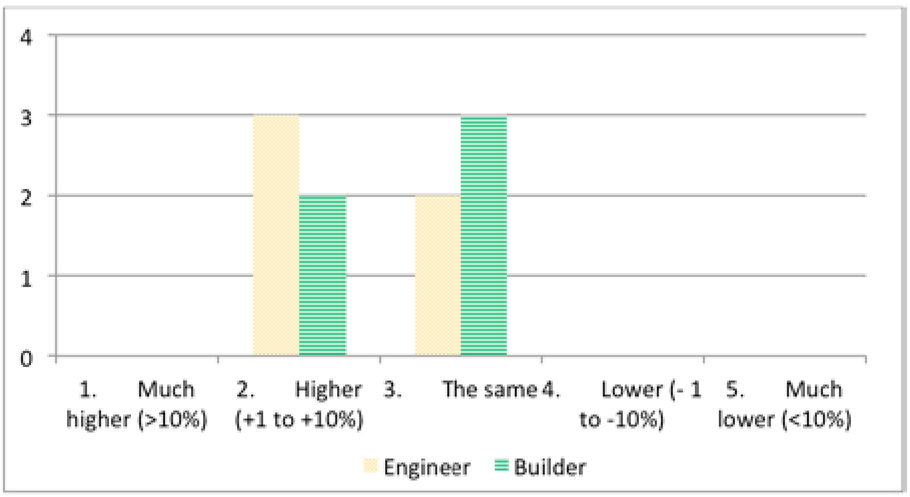
Table 1: Architects' perceptions of benefits of, and barriers to use of wood in construction

Benefits	*Barriers*
Resilient structure using STIC system	Large structural members and wide shear walls (interfering with lines of sight and vistas)
Light weight reduces foundation costs	Perception of higher cost
Cost-effective if fabricated properly	Appearance of LVL may turn some clients off (industrial-looking product)
Faster construction time	Lack of knowledge among architects
Sustainability story	Perceived fire performance
Local design using local materials	Lack of a track record - seen as experimental until more buildings are built
Aesthetics / natural appearance	

Table 2: Builders' perceptions of benefits of, and barriers to use of wood in construction

Benefits	*Barriers*
Ability to do more off-site, which leads to less resources required on-site (smaller cranes, fewer contractors, etc.)	Incorrect perception that it is much higher in cost (in fact possibly only slightly higher costs)
Less risk of construction error	Architects' expectations of timber "look". One respondent highlighted that the LVL should be presented to prospective clients as a natural product complete with defects such as knots and other imperfections
Should be promoted to developers and landlords who wish to create a natural environment	If alternatively the product is presented as being free of visual imperfections, then it is likely costs will be too high and expectations will not be met
Ease and speed of construction (with the right staff), it can be much quicker than concrete	Slow construction, not cost effective
Easy for follow-on trades	Too complex

Figure 5: *How would the total out-turn cost of the engineered timber structure in this building compare with a structure in steel or concrete with equivalent amenity, performance and visual specification?*



a view that the New Zealand prefabricators are not competitive in technology, expertise or approach. While respondents were pleased that two fabricators had recently purchased new technology cutting equipment (CNC routers), they also stressed that the issues were not just related to technology. They felt the fabrication industry needs to have a better understanding of engineers' requirements, and how to meet those needs.

Structural wood component fabrication needs to be aligned to the processes for building approval, such as producer statements. Fabricators need to adopt the subcontracting business model, rather than a supplier model. One respondent noted: "there are long-term liabilities in the building industry. Timber prefabricators are not aware of how to manage these liabilities". It was noted that: "the manufacturing industry doesn't have the sub-contractor mind-set. Risks are huge if industry doesn't have the right expertise. Current New Zealand industry does not have the required mind-set, technical expertise or equipment"

Most builders highlighted concerns with the existing pre-fabrication capability, including skill, mind-set, equipment, location and logistical issues. Performance issues were also mentioned, and fabrication costs need to come down, in order for timber buildings to be competitive. From a builder's viewpoint, the problems with fabrication also often related to the lack of local (i.e. Christchurch) manufacturing facilities. This led to a lower level of understanding between the fabricator and the builder, increased logistical issues (trucking cost and availability) and increased scheduling problems between manufacture and construction. Three out of the four architects expressed concerns about the capability of the timber fabrication industry.

The steel fabrication industry may be a good model to follow here – steel fabricators have the capability to feed digital information from 3D drawings directly into their cutting machines. The fabricator will manufacture and assemble components, transport them to the site and erect them. This makes the builder's job simpler in a number of ways, including reduced coordination of subcontractors, all warranties are provided, scheduling and also that delays are internalised by the steel fabricator. The building industry is accustomed to the routine provision of the required warranties and certification, and a subcontractor relationship model, and the timber industry needs to recognise this by adopting a similar model.

A number of respondents noted that it may not be necessary for the wood industry to emulate this model in full, because builders routinely employ carpenters, who are accustomed to working with wood. On the other hand, builders are not always used to working with wooden components that are engineered to high tolerances, and one suggestion was to, "…use a skilled carpenter not a formwork carpenter, when building with this technology". By contrast with the fabrication industry, there was much greater confidence in building contractors with two respondents indicating no concerns and the other two stating that there were no concerns, "if you got the right contractor".

3.5 Information for architects

Some respondents suggested that providing material for architects' continuing professional development courses (such as those provided by the NZ Institute of Architects) on the use of wood in multi-storey buildings would increase architect's willingness to design in wood. A number of respondents highlighted that a timber building fostered a feeling of well-being for occupiers, and a number commented on the impact of the NMIT building on them personally. Timber aesthetics were described almost universally as a major selling point for timber in both the conceptual stage and in the build, and for the building occupiers. The less-tangible benefits of wood have been documented as described by Taggart (2011), and should be better understood by the architectural profession.

4 CONCLUSIONS

The updating of the New Zealand timber design standard and supporting documentation was consistently seen as a very high priority by those surveyed. Completing this action will provide benefits for reducing the cost of design and construction, and will assist the uptake of the new technology by reducing uncertainty and professional risk.

The four buildings studied in Christchurch represent a significant increase in the practical experience required to build engineered timber buildings efficiently and competitively. It is important that this momentum is maintained so that the full benefits of building in wood are realised. Many of the respondents to the survey made the point that costs will reduce as more buildings are built. One of the engineers commented that while the first building took longer and required a higher level of expertise, the next one would not.

Post-tensioned timber technology for multi-storey buildings is generally seen as innovative, environmentally friendly, and a good fit with the branding of high technology companies. Respondents felt that more buildings should be built in wood, but noted an industry-wide perception that building in wood entailed significantly higher costs. The wood industry needs to be able to counter that perception with clear and simple messages based on the experience to date. It is important to ensure that cost comparisons are made on a like-for-like basis – the new low-damage timber technology produces a high-performance building, and the cost comparison should use an equivalent specification in concrete or steel. It would also be helpful to raise the level of the debate by highlighting that the best buildings are always going to be a composite of a variety of materials – a “wooden” building also uses steel and concrete.

The aesthetic appeal of a wooden building for tenants and their clients was identified a number of times, and the benefits for the workplace during construction are also a common theme. One builder cited “the calming effect that timber has on people” on the building site. Another builder said the building site was “usually very quiet on site. Nice environment to work in. Quality and safety are improved…” Builders and subcontractors providing services and fit-out for these buildings tend to find working with wood helpful and easy.

The fabrication industry needs to develop the required skills and experience to support the design and construction of timber buildings. The steel and concrete industries - who are the competition for wood – have much more experience in meeting the demands of the construction industry, and should be the benchmark for the wood fabrication industry.

The adoption of this New Zealand technology development which utilises a New Zealand-grown resource with strong environmental credentials, requires the removal of some significant barriers and better understanding of benefits. Facilitating design and fabrication, and promotion of the benefits of wood construction to owners and occupiers are the key enablers of increased adoption of this technology.

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