

CROSS LAMINATED TIMBER IN NEW ZEALAND: INTRODUCTION, PROSPECTS AND CHALLENGES

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ABSTRACT

Cross Laminated Timber, better known by the short form CLT, has been gaining increasing popularity particularly in Europe and North America for the last two decades. In recent years it has been manufactured and used as a building material in other parts of the world including New Zealand. A brief overview of the initial research and introduction of CLT in New Zealand is presented here. The prospects of further production and applications are discussed along with the associated challenges.

INTRODUCTION

CLT was first developed in Austria in the early 1990s and quickly gained popularity in central and northern Europe within the next few years. It is now well established as a building material in many countries in Europe and North America. Research on CLT in New Zealand started only in the last decade, but the material is receiving increasing interest from researchers and practitioners. This paper provides a summary of recently completed and ongoing research initiatives and describes some of the engineering challenges. Material and design demands are also discussed along with structural systems and concepts proposed to meet them. Completed and planned projects demonstrate the applicability of CLT in New Zealand. The market potential and some of the opportunities and hurdles are identified.

RESEARCH

Fortune and Quenville first investigated the feasibility of production of CLT with New Zealand grown Radiata pine [9]. They had CLT panels successfully fabricated with timber sizes commonly available in New Zealand and in line with those commonly produced in Europe. The panels were subjected to four point bending tests to establish Modulus of Elasticity (MOE) and bending strength. The panels exhibited typical behaviour and

failure modes during the tests. Attempts were also made to predict bending strength based on MOE results from acoustic testing. The study showed that it is possible to manufacture CLT panels with predictable characteristics from locally-grown timber. The allowable stress values found were in excess of that specified by a major European producer, although the sample size was not large enough to be able to predict the characteristic strength for the panels.

Millen and Carradine performed further investigations on compressive and flexural characteristics of CLT produced in New Zealand [13,14]. The effect of heterogeneous stiffness in CLT on joint stress under high compression loads was also investigated (Figure 1a). Full-scale joints were tested following the guidelines of AS/NZS 4063.1:2010 but the heterogeneous nature of CLT did not seem to have any significant influence on the joint strength [19].

Flexural behaviour of New Zealand grown and manufactured CLT was investigated through bending tests with panels representative of the New Zealand CLT industry product, constructed from Radiata Pine, Douglas-Fir and Mountain Ash (Figure 1b). Analytical work was undertaken to predict the characteristics and the predictions matched well with the experimental results which confirmed the average stiffness values determined from the experiments.

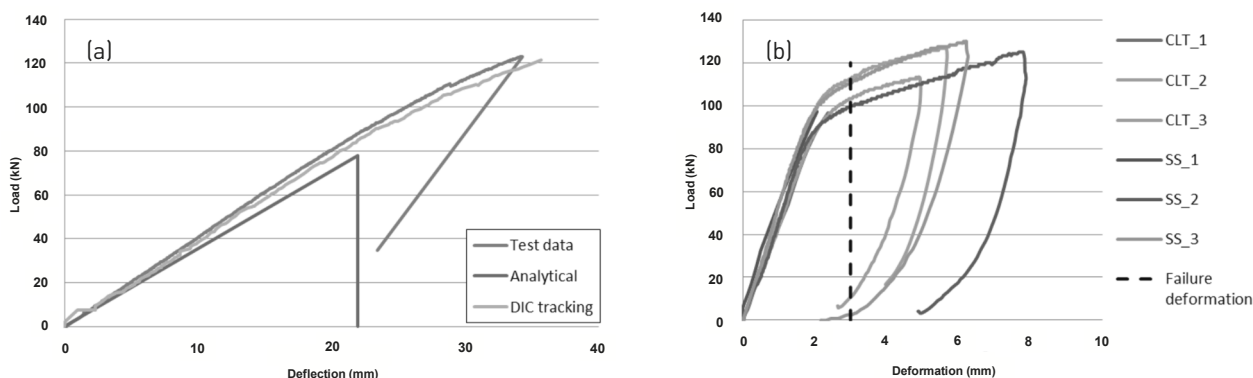


Figure 1. Load-deformation of pine CLT in a) perpendicular to grain compression [13] and b) flexure [14].

The strength of the panels tested exceeded their expected capacity and the brittle tension failure confirmed the expected failure mechanism to be considered in design. It was also suggested that the manufacturers can use the analytical approach to produce panels with more predictable properties thereby increasing the likelihood of meeting the quality standards with the manufactured product. This can save cost through reducing chances of failure in meeting the requirements checked after manufacture.

In recent years there has been significant research, particularly at the University of Canterbury on structural systems with engineered wood products with self-centring and energy dissipating capability for seismic applications. Although most of that uses Laminated Veneer Lumber (LVL) or Glulam, focus has also been put into CLT in more recent investigations. After the initial stages with small scale tests and subassemblies, complete structural systems and arrangements were studied as a solution potentially applicable in practical structures.

Dunbar *et al.* (2014) tested two half-scale two-storey post-tensioned CLT stairwells under bi-directional quasi-static seismic loading [8]. The “high seismic option” (Figure 2a) consisted of post-tensioned CLT walls coupled with energy dissipating U-shaped Flexural Plates (UFP) attached between wall panels and square hollow section steel columns at the corner junctions. An alternative “low seismic option” (Figure 2b) used the same post-tensioned CLT panels, with no corner

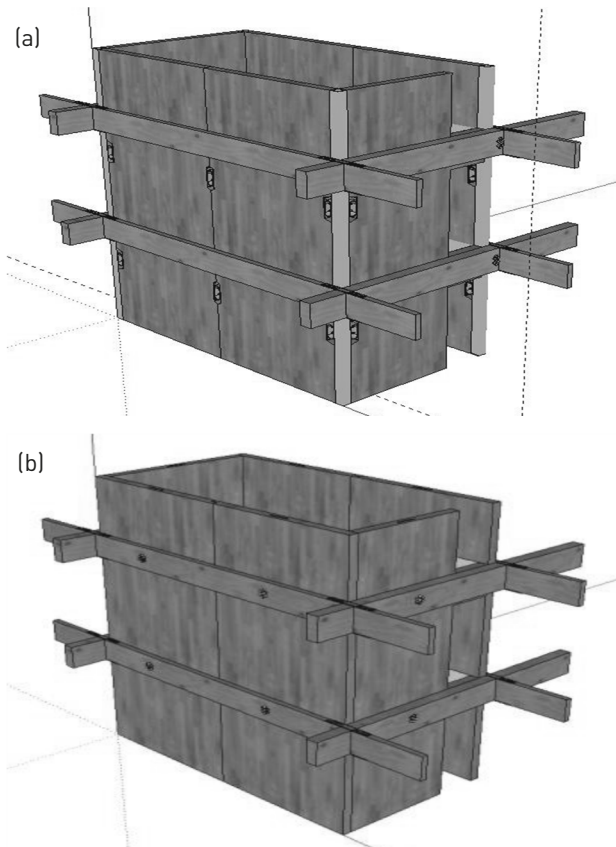


Figure 2. a) High seismicity option and b) Low seismicity option for post-tensioned CLT rocking walls [7].

columns or UFPs. The panels were connected by screws to provide a semi-rigid connection, allowing relative movement between the panels to produce some level of energy dissipation.

Desirable seismic performance was achieved with the use of core-walls made from post-tensioned CLT panels providing low damage re-centering behaviour (Figure 3). For the low seismic option, the best behaviour was observed when a very small number of screws were used to connect the panels allowing the panels to rock individually. The ‘pin’ connection of the loading beams and walls behaved as intended allowing rotation to minimise the vertical displacement of the floor beams. In the high seismic tests, the corner columns were found to work well as a shear key in addition to providing support for the floor beams. The vertical displacement of the floor beams was much less than the low seismic option as expected. The results of these tests provide confidence in using post-tensioned CLT core-walls for open-plan multi-storey timber buildings.

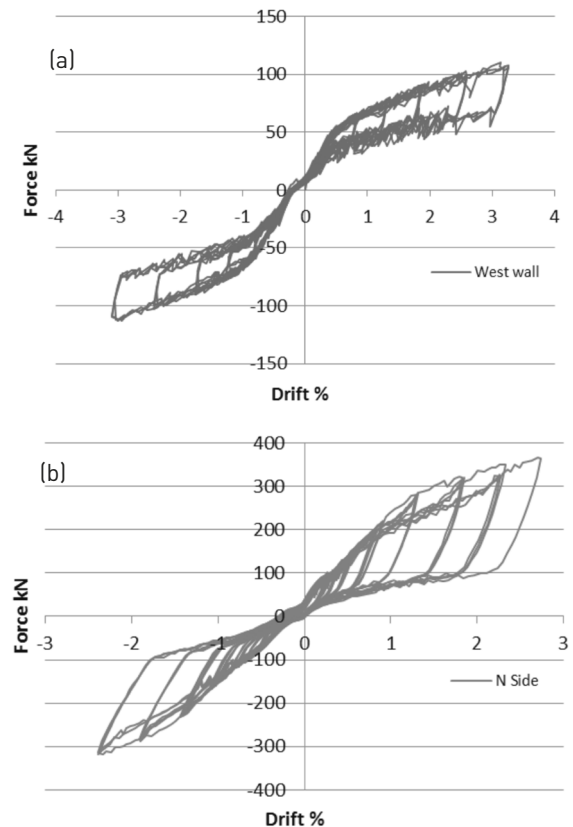


Figure 3. Hysteretic behaviour of a high seismic stairwell a) coupled walls and b) a single wall [8].

MANUFACTURING AND APPLICATIONS

The first commercial manufacturer of CLT in New Zealand started production in 2012. It manufactures CLT panels for roof, floor and wall diaphragms in commercial and residential buildings. Commissioning of the factory began in April 2012 and commercial production started around the middle of the same year.



Figure 4. Image of proposed Kaikoura District Council Building [6].

Establishment of the first CLT manufacturer is expected to expand the local market. Availability of technical information (e.g. Cross Laminated Timber Design Guide by XLam NZ 2012) should also help prospective professionals with applications.

The first application of CLT panels in the NZ market was in a residential building on Waiheke Island in 2012 [11]. Compared to conventional solutions it was an economical option because of the remoteness of the location, reduction in the number of structural members used as well as savings in time and cost of erection. The project also underlined the potential level of interest from building owners and designers in building with CLT.

Following the extensive research on post-tensioned timber the first application of the technology with CLT is the new Kaikoura District Council Building [6]. The proposed facility will be a three storied all-timber structure and will have a number of CLT shear walls with post-tensioning. The external walls are constructed with CLT panels which are detailed to provide no bracing as the rocking shear walls are designed to resist the full seismic load.

Another planned application is the Kenton Site Development in Christchurch [10] where a combination of materials has been proposed. The “optimum hybrid

damage resistant design” consists of a combination of CLT floors, LVL floor beams and columns, precast concrete shear walls and steel purlins and rafters.

A recent Scion study confirmed the feasibility of CLT manufacture in NZ commercially and calculated the unit cost to be \$1146/m³ [16]. It concluded that CLT could be cost competitive against the incumbent construction materials for most building types. The potential local market is of moderate size and was found to be concentrated in a few metro areas where demand for multi-family buildings was relatively low with potential for growth.

The study also suggested assessment of the Australian market for additional opportunities. It indicated that cost competitiveness in New Zealand may be influenced by additional requirements for seismic performance. The competitiveness analysis can also include finishing elements beyond the structural components, e.g. linings.

A peer review by BRANZ of the Scion study re-examined the potential for CLT applications in New Zealand [17]. According to the study the estimated annual demand in 2012 was 38,000 m³ which is comparable to Scion estimate of 41,500 m³. The annual demand for 2018 is projected to be 46,000 m³. An additional demand of 750 m³ is expected for 1% market penetration into all

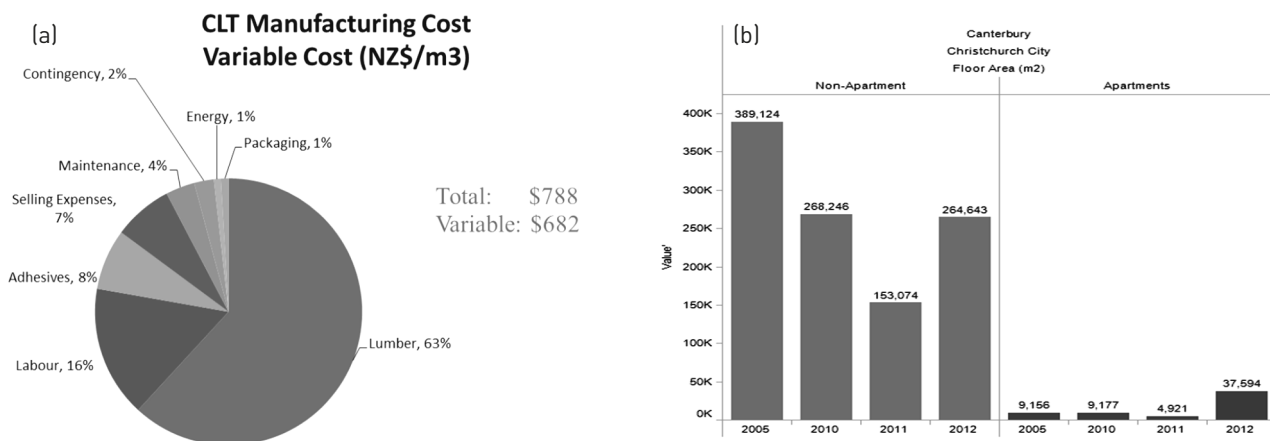


Figure 4. a) CLT manufacturing cost components and b) demands [17].

new detached houses. The figure is based on the Scion methodology of 10% market penetration where CLT is cost effective. Another 1,450 m³ is expected in non-cost effective solutions for non-residential buildings.

The BRANZ study also investigated different types of potential applications and found that CLT is most cost competitive for non-residential buildings. Most of the demand is concentrated around Auckland and Christchurch at the moment. The study also looked into the break-down of the manufacturing cost (Figure 4a) and found that about two thirds of the cost was attributed to the materials. The detailed manufacturing process for a similar plant in Canada was presented with variations in the New Zealand exercise identified.

A recently completed BRANZ research study investigated advanced residential building construction techniques for New Zealand [5]. The study included better building construction practices, possible opportunities for improvement in quality and productivity, opportunities for innovation with new materials and techniques as well as business strategies and industry transformation. CLT was identified as one of the materials with prospects of contributions in all of these areas.

A new BRANZ Research initiative has been launched recently to investigate the opportunities and to promote CLT within the New Zealand building industry. The research is planned for three years with multiple phases. Scoping and market study will be conducted in the first phase. The next phase will focus on new developments and testing with particular attention on connection details. Guidelines for practical applications are expected to be developed at the last phase. Transfer of knowledge and latest research findings to practitioners is planned during the second and third phases.

POLICIES AND PROSPECTS

The New Zealand Government's latest Research Strategy for Building and Construction has identified research needs and priorities and grouped them into a number of themes [15]. One of the items listed under building materials research is "viability and applicability of new and innovative building materials", which suggests the government is actively encouraging research and applications of new materials like CLT.

The New Zealand Forest and Wood Products Industry has a vision to reach export earnings of \$12 billion by 2022, which is more than double the figure for 2012 [20]. In the latest Strategic Action Plan the industry outlined the details to be "delivering innovative wood-based building solutions from a sustainable resource..." [20]. Investment into specific research and development is emphasised to provide growth opportunities. Some of the means to achieving that include development of new products and systems that increase productivity, compete with alternative products and open

opportunities for new markets of wood based products. Promotion and increased use of CLT elements in building construction serve all of these purposes.

In addition to expected benefits to forest growers (increased returns and reduced market risk) the action plan is expected to make the wood processors and manufacturers more successful in competition against wood substitutes. One of the actions required to achieve the target is identified as development of high value processing and manufacturing. The objective is to "transform the use of wood in building systems (off site manufacture of new building systems, new wooden products, treatments, wood modifications, etc.) through, among others, research and development of new products, systems and processes" [20]. The opportunity for CLT to become a more prominent building material is clearly visible from that statement.

The recent Scion-Wood Council of New Zealand joint study states that supply of CLT is expected to ramp up over the coming year and it presents a strong growth opportunity [18]. However developing the acceptance within the national and Australian building codes will be one of key factors in achieving longer success.

After the good performance of timber buildings in the recent Canterbury earthquakes there is renewed public confidence and interests in timber buildings [2,3,4]. The Christchurch rebuild presents an excellent opportunity for more timber buildings. That is particularly true for multi-story buildings potentially with engineered wood products. In addition to all the inherent properties of wood favouring good seismic performance, products like CLT can be pre-manufactured, saving significant time on site.

Being the nearest neighbour and with closely associated markets, the prospects of CLT manufacture in New Zealand are also influenced by acceptance of the product in Australia. CLT has been already used in two notable projects in Australia including the tallest timber building in the world at the moment, the Forte' Apartment building in Melbourne. Although all the CLT used in Australia so far has been imported from Europe there are a number of projects with CLT in planning stage at the moment which provides opportunity for current and potential new CLT manufacturers. There are also potential opportunities in growing markets in Asia for suppliers from New Zealand.

CHALLENGES FOR NEW ZEALAND MARKET

Structural systems and details have to be up to seismic requirements for New Zealand. Some of concepts developed with other materials can be used with modifications for material-specific properties. More work is necessary for the panel type elements CLT is mostly used in, to take full advantage of the latest seismic design technologies.

Proof of acceptable performance in fire is one of the biggest hurdles to acceptance into building codes and practices. That is of much greater importance for multi-story and tall structures which CLT is better suited for.

Serviceability criteria have to be met e.g. floor vibration, acoustic and flanking noise, deflection and sway.

Some of these issues can be addressed with help from research performed overseas, particularly in Europe and North America with appropriate adoption for the local products.

All of these areas have to be covered by Standards and sufficient information has to be provided in design guidelines and tools for practitioners. Collaboration between researchers and practitioners is essential for the knowledge transfer. The research institutions and professional organizations can facilitate the initiative together.

Standard fabrication details need to be worked out with sufficient details to allow application of 'off the shelf' products in regular use.

Being a relatively new material there are some unknowns regarding the long term performance of CLT. The creep of the material can be an issue for load bearing members particularly if they are part of a post-tensioned structural system. It can also be a concern under serviceability condition for other types of systems. There has been very little opportunity to investigate the long term behaviour of the panels manufactured here in the New Zealand climatic conditions, so conservative creep factors for serviceability design are recommended.

The hygrothermal properties of CLT in local conditions have to be considered throughout the building design phase. Requirements of weather-tightness of the structural members have direct implications on the design, details and costs of the buildings. Propagation of moisture and heat through the materials are significant factors in overall building performance, energy efficiency and sustainability.

Cost will be a key issue in competition with other materials, particularly in a developing market [18]. Marketing and promotion can help in gaining acceptance among professionals and users.

CONCLUSION

CLT has gained increasing acceptance in New Zealand in recent years. Initial research findings and case studies have indicated potential for applications. The current market is favorable to further applications but the commercial competitiveness has to be explored further. In addition, significant challenges such as widespread acceptance within the engineering community and availability of information have to be overcome to utilise the full potential of CLT in New Zealand.

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