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HYBRIDISED AUSTRALIAN CROSS LAMINATED TIMBER (ACLT) AND ORIENTATED STRAND BOARD (OSB) WALL PANELS – A CASE STUDY.

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ABSTRACT: This paper reports on the design and construction of the first domestically designed and manufactured CLT type building in Australia using locally produced Radiata pine. The building features a hybridised nail laminated two ply CLT and OSB wall panel with an insulation/services cavity. The design and construction of this building is undertaken for Western Australia's largest soft wood timber processor, Wespine.

KEYWORDS: Australian Cross Laminated Timber (ACLT), engineered timber, hybrid engineered timber, Orientated Strand Board (OSB), interlocking timber panels, Radiata Pine

1 INTRODUCTION

Findings from the author's doctorial studies and research undertaken by the author for New Zealand research group, *Solid Wood Innovation* (SWI), have theoretically demonstrated the potential for rough sawn multi-grade Radiata pine to be used as a structural material with the capacity to be used in developments of five and six storey buildings when laminated via a simple gun nailing lamination process [1]. This paper introduces new developments on this concept through the applied testing and prototyping of the hybridisation of a two ply CLT with an OSB structural panel to create a rigid, modular wall element suitable for a range of building types and applications. The construction of a prototype single storey office building with walls constructed using this technology is presented.

1.1 Wespine's Kiln Control Room Facility

Wespine's sawmill, located in Dardanup, two hours south of Perth in Western Australia, was the site for the first building utilising this technique. Completed in December 2013, this structure is the first Australian domestically designed, manufactured and built permanent CLT building constructed using locally grown and milled Radiata pine.

***Figure 1**: The completed Wespine Kiln Control Facility*

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2 METHODS

The development of modern prefabrication pioneered by the Scandinavian, German and Austrian timber construction sectors have clearly demonstrated the benefits of off-site construction and engineered timber structures. The development of CLT has provided the construction industry with a new material capable of performing comparably with modern concrete and steel construction. The increased load carrying capacity and dimensional stability that results from lamination, first optimised in LVL and glue laminated beams and posts and now in a panelised format, has many potential variations and hybridisations. Whilst gluing has emerged as a popular laminating methodology, the cost of establishing equipment capable of pressing, gluing and the heavy lifting of large scale panels can be a significant deterrent to conservative timber processing sectors that have yet to establish a market for heavy weight panelised timber construction elements. Small scale timber wall, floor and roof panelised elements that can be laminated using a readily available fixing method, can offer a way for innovative timber processors to introduce new value added structural timber products to the market without the large investment and risk of importing existing technologies from Central Europe or Scandinavia.

2.1 Radiata Pine

Radiata pine is the dominant coniferous plantation timber in Australia making up 76% of all coniferous forests [2]. Western Australia has approximately 400,000 ha of Radiata pine plantations with replanting rates experiencing a slight decline over the last decade (ibid). The vast majority of Australia's Radiata pine plantations were owned by state governments but are being slowly sold to private investors (ibid). This transition, in conjunction with other factors such as decreased rainfall and land availability, has contributed to the gradual slow down in

plantation expansion. Notwithstanding this, significant volumes of Radiata pine exist and will continue to provide timber for the Australian construction industry and for international export. For over 20 years, Wespine has been the primary soft wood miller for the Western Australian sawn lumber market. They perform stringent testing and machine grading, but very little value adding or production of 'engineered' timber products. Currently, Wespine's mill produces approximately 200,000m^3 of sawn structural lumber. Increasing interest in value added timber products such as CLT has the potential to create better returns on the sawn timber that falls outside their current suite of structural timber products. This material is sold to other manufacturers who produce timber pallets and MDF. Value adding through the production of engineered timber building products such as CLT has the potential to provide a new avenue for Wespine and other Australian sawmills interested in increasing their returns on timber that is not suitable for standard frame construction.

2.2 Nail Lamination

Almost without exception, most developed countries use nail guns as the primary fixing method for on-site residential timber frame construction. Gun nailing equipment is readily available and the construction industry is very familiar with its use. Panelised nailed timber plates are also becoming increasingly popular.

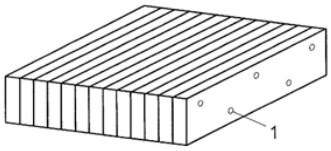

Figure 2: *Nail laminated deck plate image showing nail positions at item 1 [3]*

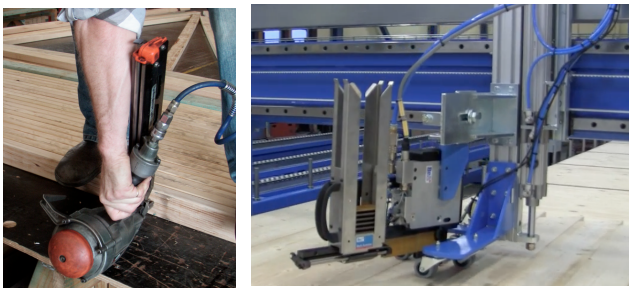

Figure 3: *Hand held nail gun and automated nail gun machine [4]*

Australia has a well established forestry, sawmill and construction sector, yet no planar laminated structural elements such as CLT are manufactured there. Currently, Australia's only large scale CLT buildings, Lend Leases' Forté building and the Melbourne Library at The Dock, have been constructed with CLT imported from Austria. Both buildings have generated significant interest in planar timber construction in Australia and it is reasonable to assume that CLT will be produced domestically in the future as a market is established and supply can be assured. Timber processors such as Boral already manufacture nail laminated timber sections using native hardwoods [5] and this demonstrates that there may be additional commercial opportunities in the development and marketing of other value added nail laminated building products. This paper argues that small scale gun nailed solid timber planar panels have the potential to promote the establishment of solid timber panelised construction in Australia and can assist in paving the way for large scale domestic CLT manufacture.

2.3 Interlocking Hybrid CLT/OSB panels

The author, in conjunction with Wespine Industries Pty Ltd and MLB Consulting Engineers, has developed a 1200mm long gun nailed cross laminated panel that hybridises with 6mm Orientated Strand Board (OSB) bracing board to create segmented structural wall panels in modular format that interlock to create a desired wall length. Each panel combines multi-grade Radiata pine (pine that falls outside the Machine Grade Pine [MGP] spectrum, but retains structural properties suitable for laminated products) in a two ply vertical and horizontal cross-laminated pattern with vertically integrated MGP10 studs at set distances and an OSB bracing element. As with all modular elemental construction, the design of the structure must conform to the modular units where possible to ensure the system is optimised.

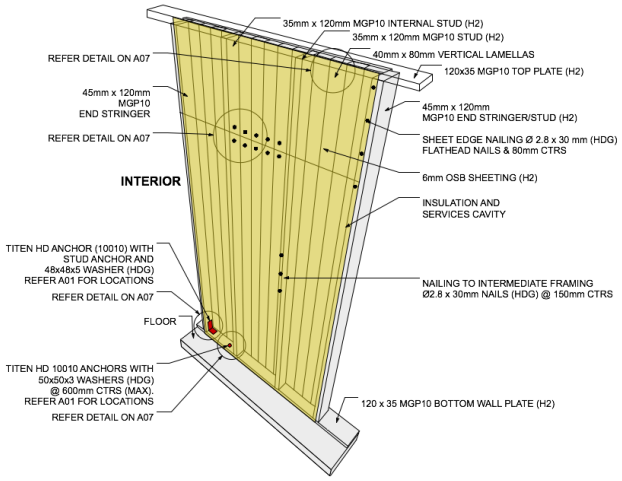

Figure 4: *Perspective views of 3ply ACLT panels developed for Wespine's new Kiln Control Room Facility.*

2.4 Designing within Modular Constraints

The use of steel nails for the primary panel lamination provided a method of making panels that was relatively quick and easy as it readily utilised locally available technology and skills. In contrast to glued CLT or aluminium nails, the steel nails create a panel that is not easily trimmed or modified. To ensure that a reasonable level of design flexibility is maintained, two panel sizes

were created to allow for variation in opening sizes and to accommodate the design brief's building size limitations. Four variants of these panels were manufactured as either full height wall sections or as the infill 'sill' sections beneath windows. To ensure that no site cutting or trimming is required, it is essential that the four panel combination was adhered to in the wall layout plan.

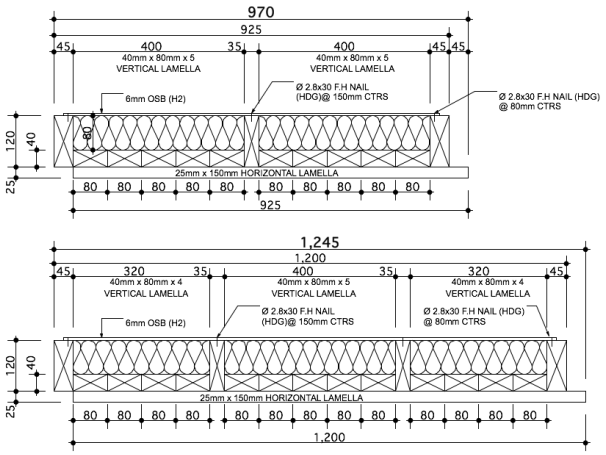

Figure 5: *Standardised panels. Type 1 & Type 2*

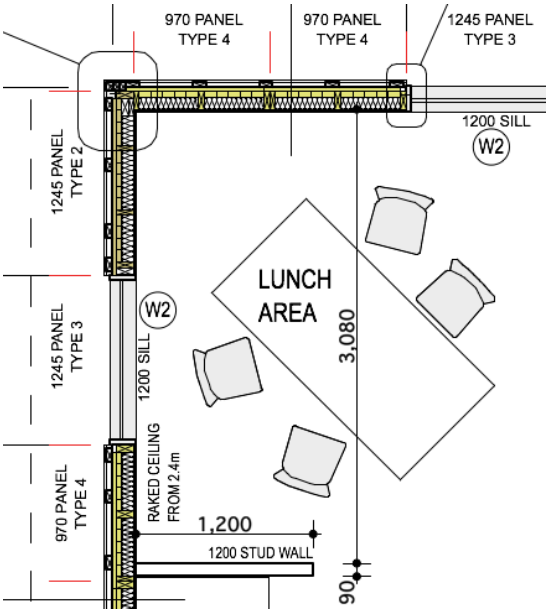

Figure 6: *Section of floor plan detailing panel type and location with colour coding and notation.*

2.5 Managing Panel Expansion and Contraction

Significant thought went into ensuring that the natural expansion and contraction experienced by the timbers was managed in order to limit the potential cracking of the internal linings. Glued CLT, such as that used in seven storey residential Älvsbacka Strand buildings in the northern Swedish city of Skellefteå, have demonstrated unsightly cracking in both the painted CLT and the direct fixed Gyprock cladding. Whilst not structural, these types of visible splitting would be unacceptable in the Australian market.

Figure 7: *Splits evident in the CLT in the Älvsbacka Strand building by White Architects and built by Martinsons*

The 6mm OSB used in the two ply ACLT wall panels for the Wespine Kiln Control Room Facility provided the stabilising element by interconnecting the individual panels on their internal face and was attached horizontally in a running bond format. Any expansion experienced by the cross laminated Radiata pine in the panels is resisted by the combination of the cross lamination and the OSB, and the inclusion of control joints filled with flexible sealant in the Gyprock sheets. This method has been successful and to date the building has not exhibited any signs of cracking.

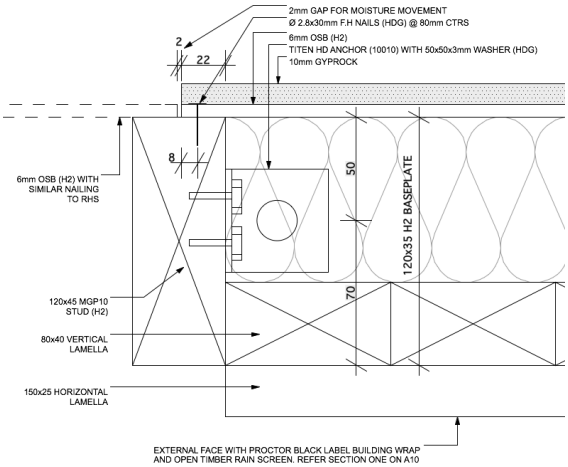

Figure 8: *Plan detail of panel with control joint*

2.6 An Alternative Panel Bracing Solution

MLB Consulting Engineers were asked to consider an alternative bracing system that utilised only nails fixing the vertical and horizontal lamella without the inclusion of OSB. The key points of their findings, presented as a theoretical solution, were as follows:

- Nails between a horizontal and vertical lamella provide a force-couple that results in lateral bracing capacity.

• The lateral displacement of the panel for ultimate limit state wind loading is limited to15mm for a 2.4m high panel (or 0.63% lateral drift). To achieve this displacement limitation, the nail strength is limited based on theoretical force-deformation relationships from NZS 3603:1992.
• Assuming the theoretical lateral stiffness of the panels is accurate, the capacity of the panel is approximately 15% higher than the OSB bracing system.
• Experimental testing is necessary to verify the lateral stiffness of the panels before the system can be used for construction.

2.7 Panel Construction

As this prototype structure was developed in conjunction with a mill that only produces a range of sawn lumber primarily for 'stick roof' construction, the manufacture of the panels at the mill was carried out by a local carpenter with the aid of one trades assistant under the supervision of a registered builder. A simple flat bed table was used in conjunction with rudimentary measuring and setting out equipment. Being a small structure with a relatively small number of each panel type, it was not deemed necessary or justifiable to build customised jigs to assist in the accurate production of the panels. To warrant the separate manufacture of a specialised jig, it was determined that a minimum of 20 panels would be required.

Figure 10: *Detail of the nailing configuration and example of manufacturing the panels by hand.*

Each panel size was built by hand, given an identifying number according to the plan and stored until needed. Once all panels had been built, as with other panelised construction systems, they were sequentially lifted and positioned in place and secured with the use of temporary props.

Figure 11: *Panels positioned and temporarily propped*

2.8 Insect Resistance

Untreated softwood timber in Australia is vulnerable to attack from termites or 'white ants' and the European House Borer. Effective management strategies used to provide protection against insect attack include the use of treated timber in conjunction with the judicial application of other preventative measures such as the inclusion of physical barriers and ensuring moisture cannot penetrate the structure. To protect against potential insect attack, the panels intended for use in buildings located south of the Tropic of Capricorn use 'Blue Pine', a treated timber using an organic compound based on pyrethroids (found naturally in chrysanthemum daisies). This treatment accords with AS/NZS 1604.1: 2002 using Tanalith T (H2 Blue) for hazard category H2. This 'off-the-shelf' approach is cost effective and is in keeping with the aim of utilising as many locally available materials and skills as possible

3 RESULTS

3.1 Wespine Kiln Control Room Facility

The design for a free standing 9m by 4.5m Kiln Control Room Facility was developed to accommodate three staff at work stations, a small meeting area and kitchenette. To ensure simplicity of construction and to fit within constraints of the site, the form of the building was a simple rectangle. This provided the necessary building area to accommodate the intended use and provided a simple building form to test the new modular panel system. Non 90 degree corners and segmented curved walls would be possible in future designs.

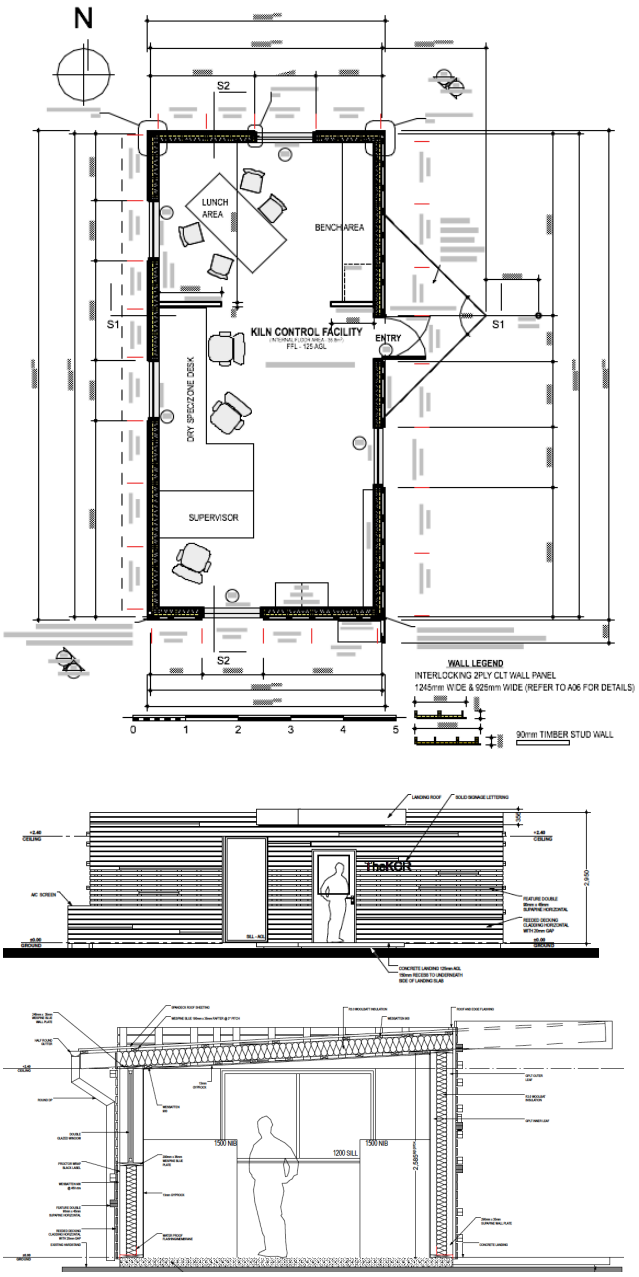

Figure 12: *Concept drawings of the first structure using the Interlocking 3ply CLT/OSB wall panel*

The area that the new structure was located in provided the inspiration from which the façade was modelled. Being a Kiln Control Room Facility, it is located next to Wespine's bank of 12 kilns. The area surrounding the kilns contains many large stacked timber packs that are waiting to be kiln dried or have just been removed from the kilns.

Figure 13: *Timber stacked for the kilns*

These large, neatly ordered stacks of sawn lumber with large heavy concrete 'charges' sitting on top were referenced in the design of the building. The horizontally orientated timber battens are designed to also act as rain screens in conjunction with Proctor Wrap Black Label building paper by giving reference to these timbers waiting to be kiln dried but with selected elements breaking free from the stack and protruding out to provide some relief to the facade.

Figure 14: *Horizontal timber cladding with Proctor Wrap Black Label building paper visible while under construction*

The entry has a large Corten clad portico roof jutting out to provide weather protection and has been rotated by 45 degrees as a play on the concrete 'charges' from the stacked timber.

Figure 15: *Portico angled at 45 degrees and clad with Corten weathering steel*

Figure 15: *The completed building. The images show the feature horizontal cladding elements. The kilns and stacked timber are in the background.*

3.2 Construction Cost and Building Time

As a one off, small building using a newly developed prototype hybrid CLT and OSB modular wall panel, the Wespine Kiln Control Room Facility cost approximately $120,000 Australian dollars to design and construct. Building time was approximately two months from slab to occupation of the structure. As can be expected, both the construction cost and build time will significantly decrease as automated panel construction techniques are developed and further concept refining is undertaken. Nail bridge machinery has the potential to be adapted to suit these types of panels and preliminary enquiries indicate that this would be a cost effective approach to improving the efficiency of panel manufacture. Identifying potential sawn timber not currently providing Wespine with an acceptable return on investment, and adapting the panels to suit a range of lamella sizes would also further reduce the construction cost.

4 CONCLUSIONS

The use of nail lamination to create solid timber cross laminated timber panels as a precursor to glue laminated CLT will assist in establishing industry confidence that planar timber construction is possible in Australia. The two ply ACLT developed for Wespine's Kiln Control Room building is a case in point that will pave the way for further developments in this field.

Figure 16: *The completed building*

ACKNOWLEDGEMENTS

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