Nelson Airport's new terminal – overview of the design of a large-span engineered timber specialist building

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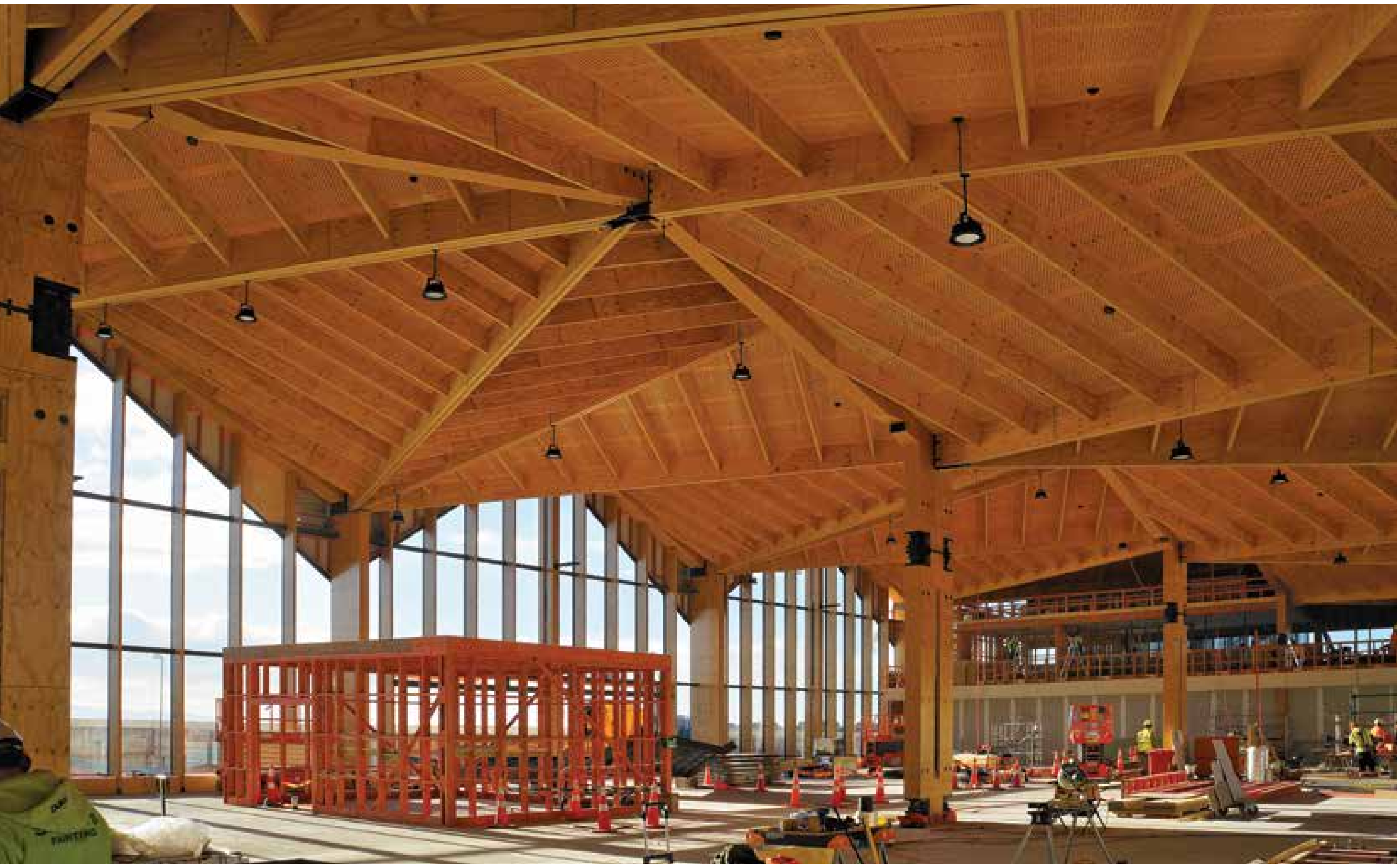


Engineered timber in the Nelson Airport Terminal under construction. Photo courtesy of David Evison

Abstract

The Nelson Airport Terminal is a new large-span building that replaces the existing terminal building at the airport. The structure and interior of the building relies on engineered timber (LVL and plywood) to achieve the open spans required and create a unique airport environment.

This paper serves to outline a significant end use for engineered timber and sets out, from a designer's perspective, the journey from initial idea to end result. The designer's perspective is clearly not the same as the producer's. In general, the designer's perspective more closely reflects the needs of the end users of the building. In providing this viewpoint, the authors hope that it facilitates a raised producer awareness of the issues facing the incorporation of engineered timber into any building and, more fundamentally, an increase in the use of engineered timber in the building stock New Zealand produces each year.

Beginning with the brief and a short description of the building, the paper goes on to discuss the design drivers for the building and how the selected drivers supported the use of engineered timber, one very major element of the design strategy. An overview of the design and construction processes, particularly dealing

with innovations such as the use of resilient slip friction joints (RSFJs) and pre-fabrication, is provided along with some preliminary learnings.

Introduction

Nelson Airport's new terminal building will be a 5000 sq m addition to the airport's aeronautical facilities and it replaces the existing terminal building first opened in 1975. At the time of writing, the first stage of the building is nearing completion while the second stage is due for completion at the end of 2019. The building uses mass timber laminated veneer lumber (LVL) and plywood in combination to provide a striking overall form to the building. Most of the terminal is on a single level, although a second level is provided at either end of the building for offices and airline lounge facilities.

The terminal building showcases timber use in a major entrance point to the Nelson region and utilises timber that is sourced locally, both to recall the place in which the airport stands and to introduce visitors to the possibilities that local industry can provide. Timber usage on this scale in airport terminals is unusual in New Zealand and rare in airport terminals around the world. Its utilisation enables the airport to differentiate itself in the most positive manner possible.

Clearly, there is evidence of a strong affinity for the creative use of timber in this building. This is not accidental at all, but has come about from a design process begun with a strong direction from both client and architect. In fact, without the support of the client to embark on a journey utilising engineered timber, nothing of the building's greatest timber features would have been viable at all.

Building starting points

The first starting point for the terminal has been the need to increase capacity to cater for the rise in passenger numbers and freight throughput at Nelson Airport. At the outset of the project in early 2015, Nelson Airport catered to approximately 800,000 passengers annually with projections of 1.2 million passengers using the terminal a decade later. The existing terminal does not have the capacity to cater for existing numbers or the projected increase in numbers. Overall predictions for growth in aviation, in New Zealand and throughout much of the world, suggest that capacity demands will further increase. Nelson Airport welcomed its one millionth annual passenger in June 2017.

Nelson Airport is served by a range of aircraft, mostly turboprops ranging from 40 to 72 seats each, although smaller aircraft are also used by regional operators. There is no jet aircraft usage and therefore no requirement for air bridges to aircraft. The number of operators at Nelson Airport has increased and now includes Air New Zealand, Sounds Air, Golden Bay Air, Originair and Jetstar. The airport caters to 46,000 flights per year and is one of New Zealand's busiest airports outside the main centres.

Initially, the design team investigated whether an expansion of the existing terminal would be feasible, or if a new terminal would best serve the airport's needs from a functional and cost perspective. The existing terminal, if it were to be kept, required such an extensive upgrade to its structure to meet modern seismic engineering codes that this option proved untenable practically and economically. The decision was eventually made by the airport to proceed with a new terminal building.

In summary, the briefed requirements for the new terminal building included:

- Design to meet the forecast demand previously outlined
- Provide a safe and functional new building
- Feature sustainability in its construction and operation
- Provide for a level of customer service better than existing
- Make extensive use of local materials
- Provide intuitive way-finding
- Maximise commercial opportunities for the airport
- Use a simple grid layout with few interruptions from columns
- Utilise a modular construction format to simplify expansion.

There are also a number of detailed operational requirements, a set of regulatory requirements related to the aviation environment, the usual Building Code compliance issues, and a number of terminal users (such as the airlines, rental car companies, food and beverage and retail providers, and others whose needs and requirements are also part of the mix).

Even at the first interview for the project we had suggested that amongst the drivers that would generate a great design to meet the needs of the airport and (most importantly) of the region the airport serves, we should use materials and products sourced from the Nelson area. One of those materials is timber. The local industry is served by extensive areas of forestry and there are well-known manufacturers (Hunter Laminates, Nelson Pine and X-Lam) domiciled in Nelson.

Making a timber building was a crucial decision. We had decided on using timber for the essential structure of the building and not merely as a decorative afterthought applied as an overlay on another structural system. Much of the conceptual development of the project then hinged on how best to utilise structural timber while meeting all the briefed needs of the project. Designing for a timber structural system became an integral part of all project processes from the outset.

Building description

The new terminal is a simple rectangular shape of 36 m width and 100 m length. It has a total floor area of approximately 5000 sq m, with an upper level at each end of the building for offices and airline lounge facilities.

The ground floor is a concrete slab raised 600 to 800 mm above existing ground levels, to protect against flooding from the increased number of climate change generated storm events already evident and expected future rises in sea level. The building sits on a series of foundation beams and driven concrete-filled steel piles. The site is classed as prone to liquefaction and allowance has been made to accommodate the potential for this. The two upper floors are concrete on steel tray supported by the main timber structure and some intermediate steel columns.

The main structural system of the building is based on the use of engineered timber. LVL columns support the roof, and its system of three-dimensional portals using beams and rafters composed of LVL combined with plywood provide diaphragm action to create a folded structural roof plane.

The external cladding of the building is a mix of aluminium curtain wall glazing fixed to the external face of the LVL structure, both main columns and intermediate LVL mullions, and coated metal profiled cladding on timber framing. Chevron-shaped overhangs on the northern façade provide the means for air extraction and are clad in aluminium panels. The roof has an undulating form, and to provide seamless waterproofing across the changing profile it uses a thermoplastic membrane system fitted on a Securock roof board sitting over rigid insulation board, vapour barrier and base deck.

Design drivers and outcomes

The design outcome meets a set of five major drivers selected as being the most fundamental parts of the brief. Before embarking on describing the journey, we need to understand how the building meets the needs of each of these project drivers:

- Safe and functional
- Modular and flexible
- Illustrates sustainability and timber technology
- Lofty and transparent
- Has a sense of place.

Designing a *safe* and *functional* building is the first priority for an airport terminal. The safe operation of the airport's buildings is just as much an industry norm as the safe operation of an airline. It is in this respect that aviation has such an enviable record, particularly with commercial aviation where the accident and incident rate is exceptionally low compared to either construction or forestry.

Safety in design is therefore a focus. Multiple initiatives have been put in place, but two examples include plant location and the use of timber pre-fabrication. To preclude the need for regular maintenance access to the roof, plant such as chillers are located at ground level. Similarly, the sub-assemblies of the timber roof elements have been designed to be pre-fabricated to a finished level prior to their erection into the roof. Providing the ability to work in a dry and safe environment at ground level, rather than at height, minimises health and safety risks.

Erection of pre-assembled 'diamond' beams and columns

The functional needs of the terminal are relatively complex and space prevents a full description. Suffice to say that the main focus is ease of use for customers, which has been addressed with the simplicity of the planning.

This simplicity is an enabler for a *modular* and *flexible* design, as the building has a rectangular plan form with minimal internal columns. This allows for flexibility – elements within the building can change and evolve over time. The aviation industry is in a state of constant change, for instance, the check-in is now more often by cellphone and the way space is used within the building will change to match industry changes.

The terminal is designed with repetitive structural bays or modules of 15 m, so that building size can be increased when required in a modular way at either end in 15 m wide by 36 m deep increments. Thus the building has both internal and external adaptability.

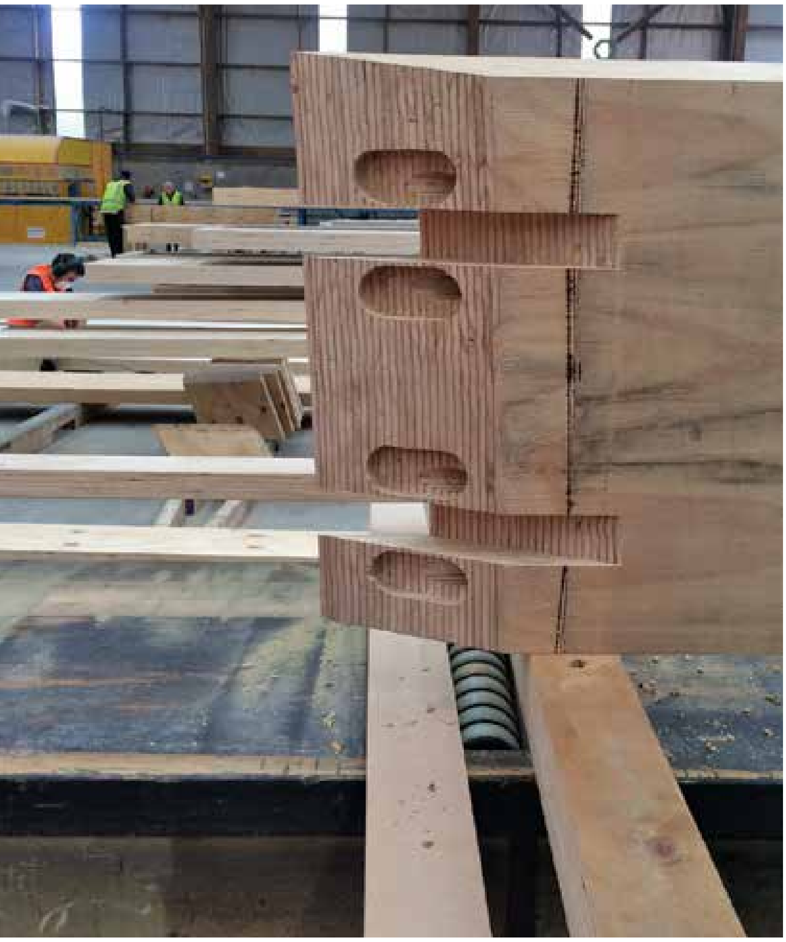
A variety of strategies have been chosen to deliver on the expectations for *environmentally sustainable design*, but chief amongst these has been the use of a mass timber structure coupled with a natural ventilation strategy.

According to calculations made by Nelson Pine Industries Ltd, the building uses approximately 610 m^3 of LVL, which equates to two hectares of forestry land or three hours of growth in the production forests of the Nelson/Marlborough region. The factory production time for the LVL is two-and-a-half days, whereas the re-manufacture and CNC machining requires 62 days. This does not account for plywood use, but does indicate the importance and added value of the re-manufacturing and fabrication process in the overall construction sequence.

Timber is a net carbon sink and the scale of the timber usage leads to the expectation that about 300 tonnes of CO_2 equivalent has been embodied in the building. A steel-framed building would require the expenditure of potentially the same level of CO_2 again. These are very, very rough calculations as the full impact has not been independently reviewed, but the scale of saving of the CO_2 equivalent in one building is considerable.

The building's ventilation system contributes to its sustainability in the same way as the use of timber. The building is designed to take advantage of the stack effect, with the building automated system (BMS) automated south side (landside) windows providing air intake and air buoyancy, driving air to the diamond-shaped windows at height in the centre of the building. These are supplemented by heat-driven solar chimneys on the north side that are incorporated into the chevron-shaped overhangs.

The chevrons provide shading, which over the course of a full year have the effect of reducing direct radiation by 23% compared to no shading. De-stratification fans are provided for mixing air within the building. A small amount of air conditioning is provided to upper floor or enclosed areas of the building – the main area of the terminal has an assisted natural ventilation scheme.



Detail of CNC shaping to LVL beam for housing metal bracket connections

The building sets out to be *lofty* and *transparent*. The loftiness enhances the customer experience and this is increased again by making the timber structure entirely visible and by emphasising the materiality of the building. The timber work is also effective beyond being structural, as the plywood ceiling panels provide visual delight, diaphragm action and, with closely-spaced drilled holes, noise attenuation within the building.

Transparency is being used to enhance way-finding for passengers and visitors. A clear path from bike, car or bus to aircraft is an easy to find navigational sequence. This complements the visible timber structure with big views of the aircraft (the central reason for the building's existence) and the distant mountains across Tasman Bay.

Providing a *sense of place* is perhaps the most ethereal of the five drivers, but actually the most crucial. Many airports are a porridge of grey, concrete, metal and glass and are often difficult to tell apart from one another. Nelson Airport wants to be the opposite of this type of standard issue. It is with a delightful sense of place that the airport wishes to differentiate itself from others and to make itself and the experience of using it positively memorable.

Nelson's Airport Terminal uses its timber materiality and its form to allude to place. Externally the roof form folds and weaves to reflect the mountains across Tasman Bay. The folds of the Arthur Range are reflected in a rhythmical series of folds in the roof itself. The repetitive folds, recognisably triangular, also have an historic reference to the triangular serrated edge plan form of the 1975 terminal building.

Externally, and particularly from the landside or city aspect, the roof appears as though multiple series of birds' wings have been joined together to reflect the soaring wings of flight itself.

Internally the warmth and texture of the timber, as well as the pattern and rhythm of the structure, is being used to create an environment that is gracious and convivial. The internal environment of the terminal is special and noticeable. It is hoped that the enjoyment of the space is such that it is relaxing in an otherwise stressful environment and that people will want to dwell longer. While an increased dwell time should also lead to better returns for the commercial operations within the terminal, the nature of the building also recognises that looking after the spirit is a fundamental aspect of the design. Timber used in this way has helped the building achieve this aim.

Design process

Design for functionality is complex in its own right. However, the terminal at a fundamental level has a relatively simple diagrammatic pattern with a check-in and baggage handling area to one end, a lounge with food and retail opportunities in the middle, and gates to the aircraft and an arrivals area with the baggage claim at the other end. Achieving operational simplicity is the beginning and the base line for the airport operator, and much thought then went into the planning to ensure the design optimised both the passenger flows and the terminal's operations.

At the same time, investigations into the form of the building took place. In one set of design investigations, sketches of multiple possibilities were generated by the team and then modelled in Rhino, a three-dimensional free-form surface modelling software package. The software was used to print out developed elevations, which could be cut and folded to make a paper model of the roof form. Multiple roof forms were created and tested for their functionality, buildability, appearance, effectiveness in supporting a natural ventilation solution for the building, and (most importantly) their contribution to an efficient structural solution.

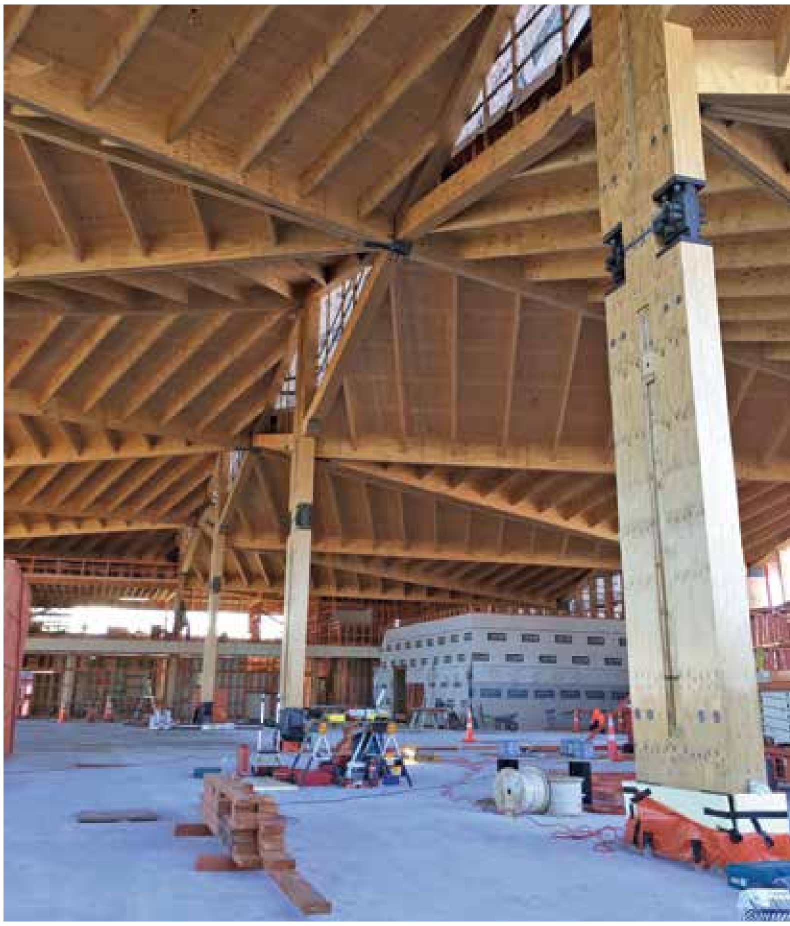
A combined design exercise between engineer and architect was required to establish how the engineering for the chosen roof form would work. The building has spans of 19 m and then 17 m to create the overall width of 36 m. Each span is a three-dimensional portal, with 600 mm deep beams using the depth of the triangular segment to achieve the portal action.

The building is designed in 7.5 m bays, but two bays of four triangular segments make up a self-supporting roof assembly of 15 m, so the effective building module is therefore 15 m wide.

Columns in the middle of the building support a series of diamond-shaped clerestories. Together the diamond shapes create a large moment frame to provide bracing in the transverse direction of the building. Columns at the front and back of the building, in contrast, are cantilevers supporting the roof and, along with LVL mullions, take wind face loads.

One of the most important structural elements is the use of Tectonus resilient slip friction joints (RSFJs) in the building. These innovative jointing systems are integrated into the columns. The RSFJs provide friction damping to withstand seismic activity and dissipate seismic energy. They have an inherent self-centering functionality in each of the three possible movement planes: up/down, east/west and north/south. This improves post-event resilience and is intended to eliminate the need for post-seismic event maintenance.

Tectonus describe the RSFJ as consisting of '2 outer plates and 2 centre plates with elongated holes. The outer plates and the centre slotted plates are grooved and clamped together with high strength bolts and disc springs. When the applied joint force overcomes the frictional resistance between the sloped bearing surfaces, the centre slotted plates start to slide and energy will be dissipated through friction during cycles of sliding.'



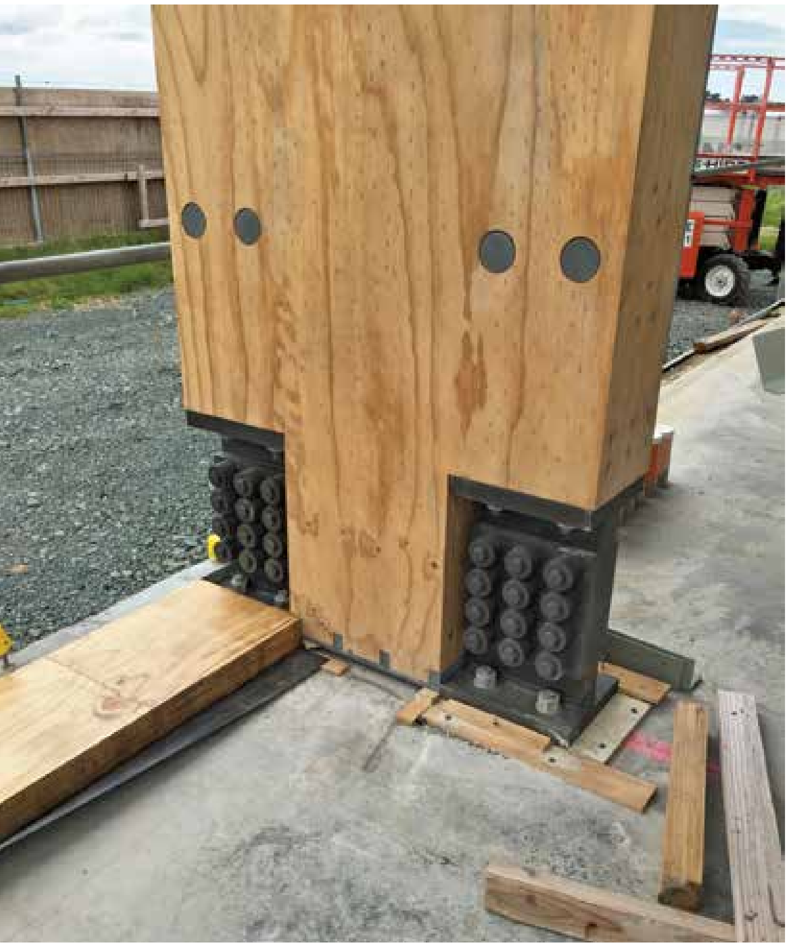
Prefabricated triangular roof sections after installation in the building

In a sense, the airport terminal is an incubator project for the use of Tectonus RSFJs. The incorporation of this new product into the structural design has made an open (relatively column-free) space viable, but it also supports New Zealand Inc as well as innovation in the construction industry.

As well as providing space in the design process to accommodate innovation, integrating a multitude of requirements required design attention. Building information modelling (BIM) was used throughout the design phases to ensure elements matched and were coordinated together. Using the models, discussions were held with Nelson Pine on supply side issues and the supply of LVL was organised.

Brief overview of construction process

A multitude of changes to all the interfaces to the terminal are required as an outcome of building a new terminal building. This includes the aircraft apron, where aircraft parking positions have changed, the services infrastructure, the pick-up and drop-off areas that have moved and the car parking, which requires an increase in size to match the terminal capacity. Also, a new control tower has been built, and while the team involved (Studio Pacific/Dunning Thornton/Gibbons) has some cross-over to the terminal team, this was an entirely separate



1200 x 300 mm LVL column with two RSFJs connected at the base

building project conducted for Airways NZ rather than Nelson Airport.

The terminal building project was combined with all the infrastructure and forecourt and car parking works into one tender package to enable full coordination across multiple project sectors. For the airport and the airlines, remaining operational is paramount and every aspect of staging needs to function to ensure safe operation continues. Four tenderers bid on the project, with the winning tender coming from a consortium composed of Naylor Love with local contractors Gibbons and civil works specialists Fulton Hogan.

As noted, the engineered timber supply had already been sourced pre-tender. However, some sub-contractors providing the timber re-manufacture, fabrication and connection brackets were formally organised after the Naylor Love/Gibbons partnership had been appointed.

Shop drawings commenced not long after the contract had been awarded. What is important at this point is the coordination of individual parts into the whole. This means the coordination of multiple sets of manufacturing information together so that the shop drawing of an individual component manufactured in one facility is assured of fitting with another component manufactured elsewhere. In using engineered timber for major structural systems, the complexity of this process can be overlooked by the inexperienced and a steep learning curve will result.

In the case of the terminal building shop drawings for the LVL, the plywood diaphragm, the Tectonus RSFJs, the metal work brackets connecting timber elements together, and the triangular sub-assemblies were required and needed comprehensive review and coordination by the contractor and consultant team.

Incorporating the newly-developed resilient fixings added another level of coordination requirements, as several cycles of prototype testing of the RSFJs were completed just as construction was commencing. Each RSFJ unit was also quality assurance (QA) proof tested for response reliability before supply to site.

The initial design called for the fabrication of two triangular roof elements together to form one roof sub-assembly for lifting into place. The contractor elected to lift one triangular sub-assembly at a time to match their craneage. This methodology resulted in design changes to connection brackets for each of the triangular sections.

At this juncture Nelson Airport and the project managers offered the contractor Hangar 3 on the airfield campus as a covered yard in which to assemble the triangular timber roof sections. Hangar 3 had been empty for a time and required some upgrading, but has proved to be a convenient place in which to work in all weathers producing the roof sub-assemblies. Each roof triangle was fully built up including the roof membrane, which had copious lap material left in place to enable jointing to the next sub-assembly. When required after hours, the sub-assemblies are transported to the site across the airport taxiways and can be delivered just in time for their incorporation into the building.

Each sub-assembly is essentially a finished product, with all services such as lighting and fire protection systems already installed and integrated. This requires considerable effort and coordination both with design and construction. Once erected and installed this finished product requires very little further work, but remains vulnerable to the elements until full enclosure is achieved.

LVL columns were re-manufactured by Nelson Pine using a cold press to create the required section thickness, typically of 90 mm or 300 mm, the latter several times thicker than standard billets. The incorporation of the RSFJs occurred on the ground and the columns were lifted and propped ready to receive roof sub-assemblies. With the install of LVL mullions between columns, follow on with curtain wall installation could occur. Where metal cladding was to be installed, full LVL/timber framing came first.

While it is relatively quick to put together columns and roof elements on-site, this is only possible after a considerable amount of time has been spent making each element first. This may seem self-evident, but the constraints are the need for covered space and carpentry resources to assemble multiple sub-assemblies at once and then the need for more covered space to store them prior to site installation. The advantages of pre-fabrication, and these are worthwhile obtaining, presume then that some logistics needs are overcome first.

Timeline

The project commenced in mid-2015 with the comparative investigation – extend and refurbish the existing terminal or build new. By the end of 2015 the decision to build new had been made and first concepts had been produced and broadly approved. Proof of concept followed in May 2016. The developed design and detailed design work leading to building consent lodgement and a construction tender was completed by January 2017. The Naylor Love/Gibbons/Fulton Hogan partnership, having won the tender, was awarded the contract and began construction in May 2017. Stage A of the terminal is due for completion in October 2018 and Stage B, the balance of the building, in late 2019.

Lessons

As with any project, there are changes that would be made if it were to be commenced again. Without construction being finished completely it is too soon to be conclusive about lessons learned. Also, further research would be needed to validate conclusions from the evidence to hand, much of which is segmented by the project roles held within the project.

Some initial reflections include:

- Client interest and commitment to a timber design strategy from the outset is of key importance, particularly because the level of innovation required may be quite high and the level of expertise in the timber industry and associated industries is not yet widespread and instantly available
- Also, crucially, the increased use of engineered timber in commercial construction will need further upskilling and coordination throughout the supply chain from log production through to building handover
- A more comprehensive use of BIM with better transfer protocols to sub-contractors would have helped services integration, potentially sped up shop drawing production for timber components and connection assemblies, and provided opportunities for visualised programming
- The use of pre-fabrication in an indoors controlled environment has clear benefits for quality control and should speed up on-site construction and reduce risk from timber exposure to the elements
- Protection of pre-fabricated timber construction exposed to the elements is an issue after erection in an open working site and it requires careful forward planning. The finished LVL had a sacrificial coating of Resene Lignaguard to provide a limited amount of protection from moisture, but the protection is time limited.

Conclusion

The use of timber as structure and form-giver is integral to the aims of the designers in showcasing: Nelson as a special place; innovation and New Zealand Inc; building in a sustainable way; the local timber industry and the potential for timber products in New Zealand building; and a space inside that exudes calm, warmth and beauty, especially for the travelling public.

A combined architectural idea and clever structural system creates the building form in this airport terminal and the building form does most of the work of creating a special identity within and a sense of place throughout the terminal. Initial reaction from the small number of visitors able to view the building prior to its early October first stage opening supports the idea that a special sense of place has been created, particularly inside the terminal.

As designers, there is an almost measurable benefit for us in coming to work to help make an object of beauty. If the generations of building occupants, users and visitors feel their spirits lifted after we and the builders have finished crafting, particularly the natural materials, then the building will have achieved well beyond its intended aim to showcase timber and its Nelson sources.

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