Timber Construction as a catalyst for innovation in Australia

Ninotschka Titchkosky
BVN Architecture
Sydney, Australia

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1. Introduction

Innovation within the Australian construction industry is relatively low compared with other developed countries globally. The construction industry in Australia has one of the highest % shares of GDP (gross domestic product) and employment but ranks third lowest in digitization and innovation of all sectors. Mass Timber Construction (MTC) is still relatively new within the Australian context, however it continues to gain momentum due to its notable advantages in reduction of on site labour, sustainability, quality and occupant wellness. Timber construction has become a catalyst for change; the use of a new material has enabled a mind shift within the architectural and construction industry not just of the structural component but all aspects of the build including the advancement of fully prefabricated facades.

BVN is one of Australia's leading architectural practices, with arguably the most timber buildings in Australia. We examine the changing nature of construction, client and architect driven promotion of timber buildings and the current limitations within the Australian context through three case studies.

2. Additive Timber Structures Our Lady of Assumption Primary School, North Strathfield, Sydney, Australia

Our Lady of the Assumption (OLA) is a new primary school that is the adaptive reuse of a previous 1970's brutalist concrete telephone exchange centre. The existing building – a typical institutional example of brutalist concrete architecture of its time - presented many challenges in its transformation into an inspirational educational space.

The ground floor was initially refurbished into classrooms in Stage 1, this stage only required minor structural modification. Stage 2 was much more significant and included adding a new level on top of the existing 3 level structure, expanding the floorplate of each existing level and creating a new portion of building, all linked with a new 4 storey atrium. A timber structural solution was fundamental to achieving these amendments as it enabled a lightweight addition to the existing structure with minimal modification of footings, which was not possible due to the ground level refurbishment. Improving sustainability and wellness benefits also supported the use of timber. The use of timber resulted in 1400 tonnes of captured CO_2, as opposed to 800 tonnes of emitted CO_2 if the project was constructed in standard concrete. The existing concrete structure is partially exposed to acknowledge the original building, the extensive use of timber in floors, wall panelling, ceiling and joinery creates a warm and welcoming atmosphere conducive to a contemporary learning environment.

Figure 1: OLA, Existing building

Figure 2: OLA, Proposed learning spaces

Figure 3: OLA, proposed four storey atrium

Figure 4: OLA, Floor slabs with integrated Lignotrend installed

2.1. Procurement

The school design and procurement processes were architecturally led, an uncommon arrangement in Australia on major projects which are generally project manager or contractor led processes. This enabled BVN to establish a project environment which supported the use of timber and demonstrate its quality, cost, structural and sustainability benefits to the school.

Typically, in Australia there is a 'knock down and rebuild' mentality with Contractors which makes additive structures or adaptive re-use often more expensive. A significant process of evaluation was undertaken to review the cost of the project and demonstrate the benefits of timber in comparison to concrete construction which was favoured by the contractor. At the time the data supporting timber was relatively limited within the Australian context. The two critical factors that made timber competitive in this case was; eliminating modification of existing footings due to the lighter weight of timber and the demonstrated saving by integrating Lignotrend acoustic ceiling into the floor slabs.

Contractors and clients find it difficult to adopt and price new construction methods if they have not experienced it previously which is a considerable barrier to the uptake of MTC. Pricing the reduction of site labour, programme time and finishing trades is challenging without prior experience, its highly likely that we will continue to see MTC become more competitive as the market gains confidence in this construction type. Further, structural and fire engineers lack the expertise required to develop solutions therefore detailed engineering needed to come from Europe and European fire testing data was used and interpreted to Australian standards and codes.

Due to the infancy of the timber industry in Australia the procurement process was also challenging as there are only a very small number of industry contractors that have established expertise in timber. In this instance a small company, CWC, was subcontracted to provide advice to the design team as well as managing the timber construction process for the head contractor. The detailed engineering for the project was done by NeueHolz with a local Australian structural and fire engineer establishing the performance criteria. Neueholz then later coordinated all timber suppliers including KLH and Lignotrend. This methodology is difficult to scale in the Australian context as it requires the early buy-in of the client into a timber solution, which can be difficult to achieve in medium to large scale projects with competitive pricing.

Figure 5: Timber and concrete structure

Figure 6: Perforated aluminium façade overlay

3. Accelerated delivery and sustainability Kambri, Australian National University, Canberra

The Australian National University, (ANU) is the number one research University in Australia. Located in Canberra on a vast site, The University had a series of activities clustered around buildings, but it lacked an identifiable 'heart' to the campus. ANU also recognised, if it was going to attract the best students, staff and researchers, it needed to become more connected to the city of Canberra and create opportunities to enhance the university life and contribute to the vibrancy of city. The vision for the project is to establish 6 new buildings around a sequence of public spaces. Each new building makes a particular contribution to the precincts activation from teaching, student life, health services, sports, culture and events to student accommodation. The project is highly ambitious and the 6 new buildings, new underground carpark (400 cars) and over 40 retail outlets needed to be delivered within an 18-month construction programme to limit the disruption to the Universities teaching programme and ensure the student accommodation could be delivered in-line with enrolments at the start of 2019.

Figure 7: Kambri, ANU development overview

Figure 8: Kambri, ANU development during construction

Lendlease won the contract to deliver the project and work with BVN to finalise the design documentation. In 2012 Lendlease delivered Australia's first CLT building and the world's tallest at the time, Forte in Melbourne. Since then they have continued to develop the capability of DesignMake as their timber design and manufacturing business.

Lendlease's investment in MTC as an organisation, enabled timber construction to be readily considered for ANU as it sat under the primary construction contract they had already been awarded and they had full control over the procurement, supply chain and processing of CLT panels locally. Two buildings were identified as being suitable for timber construction, the 450 bed student accommodation building and the Collaborative Learning Environments (teaching) building. Lendlease identified a 30% saving to the programme if timber was considered for these buildings, which would allow the project to be delivered in 18 months.

3.1. Student Accommodation

The Student Accommodation precinct comprises a pair of block tower buildings providing residential accommodation for 450 students. The two buildings, 7 and 9 levels tall, are constructed of CLT (Cross-laminated timber) throughout the accommodation levels. The student rooms sit above a connected two level concrete podium structure which provides communal lounge, social, and kitchen amenities. The CLT is a solid laminated and load bearing structure, with no additional structural provision. The use of CLT was viable as the 10m2 room module was a repeatable element across the floorplate.

Figure 9: Kambri, ANU, Student Accommodation

Figure 10: Student Room, 10m2

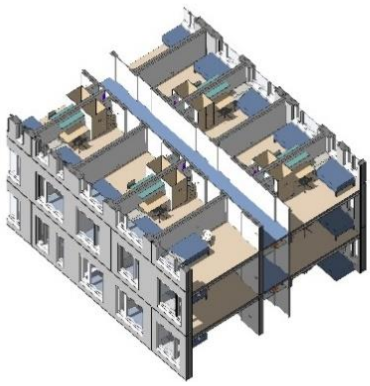

Figure 11: Typical planning module

3.2. The Collaborative Learning Environments

The Collaborative Learning Environments is a 6-storey teaching building with a range of formal and informal learning spaces linked by a circulating stair. The structure comprises exposed prefabricated glulam beams, columns and a cassette floor system. The lift and service cores are constructed from CLT walls that are exposed throughout. The ability to expose all the structural elements enables the building to take advantage of the multiple physiological, psychological and environmental benefits of wooden interiors as well as reduce cost of applied finishing materials.

Figure 12: Collaborative Learning Environment, ANU, cross section

Figure 13: Collaborative Learning Environment, ANU, view from new laneway

3.3. Accelerated Delivery

Whilst timber construction increased the coordination and design time pre-order, it accelerated the construction by approximately 30% in comparison to traditional concrete construction. The total build time was 18 months for all buildings meant labour on site peaked at around 700 people with an average build cost of $25million/month to achieve the programme. This was considered one of the largest cohorts of construction workers in Canberra since the building of Parliament House in the 1980's in Canberra.

Reducing the extent of concrete construction was a key factor in the project meeting the tight programme, the timber structure for the student accommodation was installed in approximately 3 months with a team of 13 people, 10 on the floor and 3 for the crane crew. In comparison, the estimate for concrete construction was around 50 people, including multiple trades such as scaffolders, formworkers, concrete and dry wall partition contractors. The reduced team and working hours also increased safety on site. MTC requires fewer high risk and cleaner activities such as moving reinforcing around the site and risk of fall with column pours. The constant safety risk relates to edge protection which still needs to be mitigated. The timber assembly team were part of the facade subcontractors team, there proficiency in accurate and detailed setout as well as carpentry was complimentary to the skill set required for the timber install. Despite being new to MTC the team continued to improve their sequencing to accelerate and optimise the process.

The reduction in labour considerably reduced the labour costs from 50-60% on traditional construction cost to 20-30% of the cost for MTC. With industry maturity, more suppliers entering the market and a local supply chain being developed the high materials cost around 70-80% should decrease over time. In addition, savings to other trades such as services with the simplified process of drilling into CLT as opposed to concrete should be able to be better understood and also realised in total cost savings going forward.

Figure 14: ANU, Student Accommodation

Figure 15: ANU, Student Accommodation CLT

The prefabricated timber structure, cost of scaffolding and programme pressure prompted the introduction of the first fully prefabricated rain screen façade of a mega scale in Australia. The prefabricated facade system did not require scaffolding and saved $1.2 million by eliminating it. The system was developed in the US by Island and adopted by CSR, for the project. The façade was conceived as a series of Mega-Panels that came in fully completed with windows, brick slip or aluminium finish, all waterproofing and thermal requirements. Each panel took approximately 20 minutes to install from being hooked to the crane. As the timber structure did not require a construction apron, this enabled the prefabricated façade panels to be installed in sequence with the structural installation of timber which in turn allowed finishing trades to progress immediately behind the façade installation. In concrete construction, the façade would need to be installed considerably later after the construction apron could be lifted.

Figure 16: ANU, façade panel lift

Figure 17: ANU, Student Accommodation façade over CLT

3.4. Sustainability

The ANU, Kambri development has ambitious sustainability targets using the 'One Planet' system, the quantitative measure of human demand versus the supply of nature. The project is targeting an ecological footprint equivalent to 0.6 of the Planet which is considered "World Sustainable Leadership". The One Planet system looks holistically across the project at bio capacity, operating consumption, transport and infrastructure.

The timber structure is assessed in the Buildings component of the measurement. Adopting timber structures for the Collaborative Learning Environments and the Student Accommodation reduced embodied carbon by more than 30% over traditional concrete as well as reducing construction time and increasing safety. Across the project, over 31,100 tonnes of CO_2 were avoided by specifying low carbon materials, clever design and construction. Equal to delivering the entire Student Accommodation building for zero carbon footprint. The timber framed teaching building performed better than the CLT Student Accommodation avoiding 9,673 tonnes of CO_2 versus 4,400 tonnes of CO_2. A significant advantage in the teaching building is the reduction in finishing materials as the timber structure was left exposed. No additional ceilings were added avoiding 20-60kg CO2/m2 of finished ceiling. CLT core walls replaced traditional blockwork walls having the embodied carbon/m2 avoiding 175kg CO2/m2. Unfortunately, fire engineering has not yet caught up with timber construction in Australia and fire related issues created considerable constraints in the accommodation building. This required most walls except the internal firestair shafts and lift shafts to be over clad in fire rated plasterboard. With further maturing of the industry in Australia, it is likely that more innovative solutions can be achieved in residential environments. Services still account for 25-35% of embodied carbon on projects, which suggests this is an area worth considering to further improve sustainability outcomes.

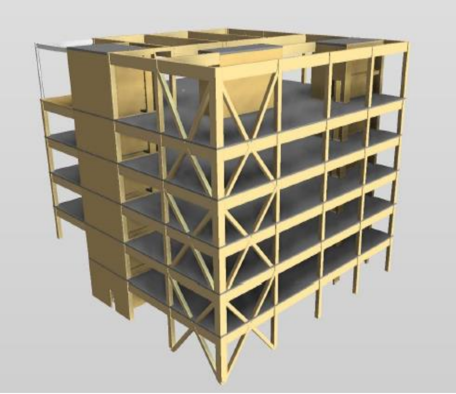

Figure 18: Collaborative Learning Environments

Figure 19: Collaborative Learning Environments interior

4. Quality, Learning and Wellness STEM School Luddenham, Sydney

Sydney is experiencing unprecedented growth in the areas west of the city driven by a new second airport and strategy to decentralise the existing Sydney CBD into 3 cities, Eastern City (Sydney's current CBD), Central City and Western City. A new school focussed on Science, Engineering and Maths (STEM) is located in the Sydney Science Park, north of the new airport in Western City. This area is currently a rural setting and will be developed over time into a 280ha fully integrated community, comprising a town centre, commercial, educational, residential, cultural and recreational spaces. In order to support future residents, a new school will be built for approximately 2000 students. The primary site for the new school is collocated with the first community of residents and research developments for the Science Park.

The STEM school inspires to be a destination school with a science and technology focus catering for all ages of the learning community. This 30,000sqm school will be one of the most sustainable and technologically advanced in Australia, Stage 1 will be operational by 2022.

Our existing relationship with the client, Catholic Education Diocese Parramatta (CEDP), and our recent timber projects for the Australian National University and OLA school, enabled us to demonstrate the quality, learning and wellness benefits for timber construction for the new school in the concept design phase. Further to this, costing analysis was completed on steel, concrete and timber construction for this project and timber was proven to be the most cost effective. The overarching aspirations of the Science Park as an innovation hub also encouraged the client to consider a different construction method.

Figure 20: Stem School street view

4.1. Designed for Modularity

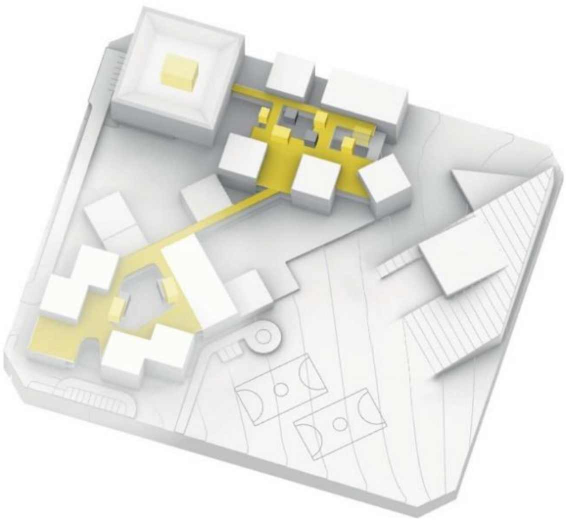

Figure 21: STEM School, Stage1 and Stage 2 Masterplan

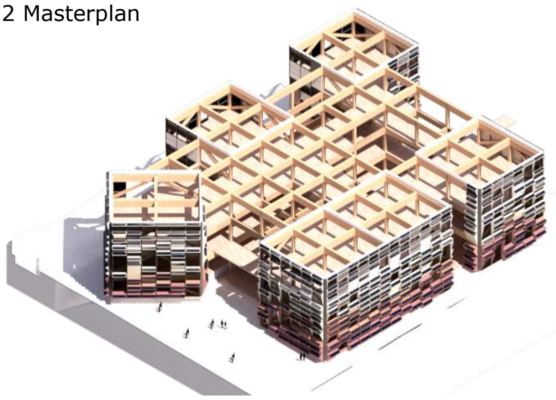

Figure 22: STEM School, Inquiry Hub

The STEM school comprises 3 buildings in Stage 1, 2 of these, The Inquiry Hub and The Research/Creative Hub are proposed to be glulam timber post and beam construction with CLT floor slabs and ribs. The school will be constructed in two stages, the second stage will be the expansion of the Inquiry Hub into the early years learning spaces. Given the known strategy of future expansion significant design time was invested in optimising a modular planning solution that would give the client a repeatable spatial framework, cost certainty and equity across the school as it evolved. This basic module is now being deployed over other new school designs for CEDP.

The Inquiry Hub, 7500m2, is the primary learning space which comprises repeated 'hubs' based on 7.5m x 7.5m grid, to manage structural spans, creating 15x15m spaces over 3 levels linked by a large atrium space. The modularity of the grid system simplified the structural complexity and allows the client to 'plug and play' future adjustments to spaces as the school evolves. The Research and Creative Hub, 4700m2, has also been designed in timber, based on the same grid module including a four storey connecting atrium and double height workshop spaces. This building was initially proposed as a steel structure but following detailed cost analysis was converted to timber which proved to be 40% less than steel and 25% less than concrete.

Figure 23: STEM School, Research and Creative Hub, south elevation

Figure 24: STEM School, Research and Creative Hub, west elevation

Figure 25 and 26: STEM School, Research and Creative Hub, interior views

4.2. Quality

Australia does not have a strong history in complex, quality construction commensurate with some other countries, therefore achieving quality in an already tight labour market within acceptable cost parameters can be extremely challenging and in many cases it precludes creative and high quality outcomes.

The site location of the new school and current lack of skilled trades in the area, suggests a prefabricated construction methodology would allow for certainty of quality and reduce programme risk or cost issues associated with limited access to skilled labour. This approach was extended to the Inquiry Hub facade system, a performance facade which has been computationally designed to limit direct solar access to the spaces in summer whilst allowing views out and generating energy from integrated photovoltaic cells. The exact geolocation and sun angles have driven the design of this innovative facade solution. Despite its complexity it has been designed for prefabrication as a rainscreen made of 2.5m modular units that are the full height of the building. The facade will be fabricated and installed as 3 storeys high megapanels that can be sequenced to follow behind the timber structure installation. The proposed installation time for the façade is approximately 14 days. The cost of the façade system is in line with standard construction methodology (approximately $1000/m2).

Figure 27: STEM School, Inquiry Hub facade detail and analysis

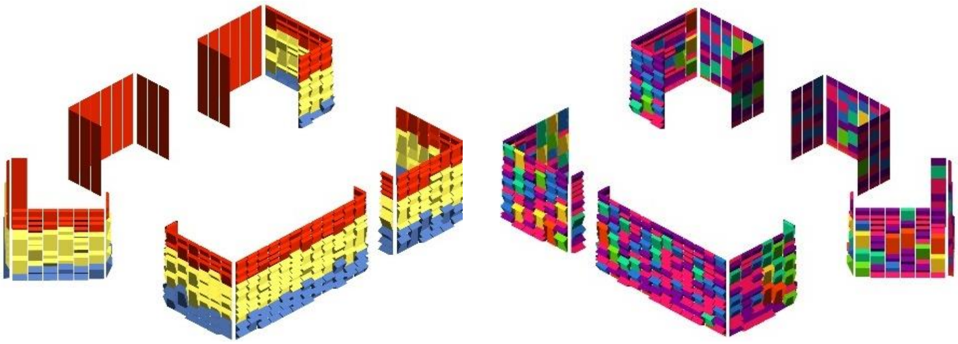

Figure 28: STEM School, Inquiry Hub facade type analysis

4.3. Learning and Wellness

The STEM schools curriculum is designed around inquiry based learning focussed on Science, Engineering and Maths. The building design is a strong reflection of this and forms part of the student's learning. MTC is still novel within Australia and therefore provides a great learning opportunity for the students to explore its unique characteristics and advantages over traditional construction of steel and concrete. The elemental nature of timber construction allows the students to understand the components and connections of the building, which will be celebrated in the design detailing. Services and infrastructure will also be exposed and also form part of student learning of building systems and performance.

The benefits to wellbeing of timber buildings has been widely documented. The use of wood in the interior of a building has clear physiological and psychological benefits that mimic the effect of spending time outside in nature. The feelings of natural warmth and comfort that wood elicits in people has the effect of lowering blood pressure and heart rates, reducing stress and anxiety, increasing positive social interactions and improving corporate image. *(Wood: Nature Inspired Design, Planet Ark).* Whilst wellbeing and learning benefits of timber have not been the fundamental drivers in the selection of timber structures these benefits have strengthen the rationale for timber use, especially within school and education projects.

Traditionally in Australia timber cladding systems have been used internally to introduce the warmth of timber and biophilic design to a project. The opportunity to use timber structurally removes the cladding layer, saving cost and reducing carbon footprint, whilst enhancing the biophilic outcome.

5. Conclusion

The first commercial timber building in Australia was completed in 2012 by Lendlease, since that time 5 Mass Timber Construction (MTC) projects have been completed and there are over 50 live projects. At this stage the MTC market is still in its infancy however, it continues to grow its market share and Australian regulations and codes are starting to be amended to address the use of timber, reducing some of the barriers to its use.

The most compelling advantage for substituting traditional steel and concrete construction for MTC is the reduction of on site labour cost, improved safety and programme acceleration. The construction industry in Australia has been decreasing in productivity since 2000, whereas studies (*A Robotics Roadmap for Australia, 2018)* have shown that Australia needs to increase productivity by 2.5% per year if we are to maintain our standard of living. The increased usage of MTC can improve, innovation, digitization and productivity within the sector. Further gains can be made due to MTC facilitating prefabricated façade systems. Capital cost savings are not yet well proven in the market, this could be addressed with increased transparency by current MTC contractors and suppliers.

The additional benefits of wellness, quality, and sustainability are also critical especially within the commercial office and education sectors who see these attributes as important to their brand and marketing of the product.

Critical challenges for the expansion of the MTC industry in Australia is establishing a local supply chain, assembling engineering expertise and addressing fire engineering standards for buildings over 25 metres and multi-unit residential. The limited pool of contractors and suppliers within the market makes competitive pricing very difficult. Australia opened its first CLT production plant in March 2016, with Lendlease's DesignMake, since then several other CLT processing plants have established in Australia all source their product from Europe or New Zealand. With on-going research, a local timber supply chain may be developed.

Nevertheless our (BVN) experience in Mass Timber Construction has clearly demonstrated the benefits of using timber, therefore we are optimistic that if the key challenges can be addressed, we will see a significant uptake of MTC in the next 5-10 years in Australia which will catalyse other innovations in the construction and design industry.

6. Project Credits

Our Lady of Assumption, Strathfield, NSW
Architect: BVN
Timber subcontractor: CWC
Structural engineering: Taylor Thompson Whitting
Timber engineering: Neueholz
Suppliers: NeueHolz, Lignotrend, KLH

Australian National University, Kambri, ACT
Architect: BVN
Head Contractor: Lendlease
Timber engineering and CLT processing: DesignMake
Timber supplier: Stora Enso
Timber Installation: ABS
Structural Engineering: Robert Bird Group
Fire Engineering: Exova Defire
Environmental consultant: The Footprint Company

STEM School, Luddenham, NSW
Architect: BVN
Project Manager: Savills
Structural Engineer: Enstruct
ESD: Stenson Varming
Timber supplier: not confirmed
Contractor: not confirmed