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THE APPLICATION OF HYBRID TIMBER SYSTEMS TO CHALLENGE CONVENTIONAL BUILDING TYPOLOGIES IN AN EMERGING MARKET: 2 CASTLE STREET 'WORKPLACE HUB'

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ABSTRACT: One of the key differentiators of mass timber workplace buildings from more entrenched methods of construction is its unique, inherent structural performance. This paper explores how the knowledge developed during the design and construction of the Oakhill Innovation Hub is being applied to evolve both education and commercial building typologies. This knowledge is being applied directly to the design process of a new office tower, the 2 Castle Street 'Workplace Hub'. The primary ambitions of the Workplace Hub presented two challenges to contemporary Australian commercial buildings. Firstly, the need for use of timber for its low carbon and high strength to weight ratio when compared to concrete, allowing for a larger building than would conventionally be possible above a rail corridor. Second is the emerging demand for 'post-Covid' workplaces where occupants have access to entirely outdoor spaces within a commercial floorplate. In isolation, each of these could be solved easily through established mass timber systems, or conventional construction, respectively. In combination, they require a structural and procurement strategy that demands growth of the Australian construction sector. This case study responds to project specifics and supports the maturity of mass timber within Australia. The design journey follows multiple lenses and design implications of a hybrid mass timber structure in a commercial/workplace context.

KEYWORDS: Hybrid, Procurement, Education, Commercial, Post-Covid.

1 – INTRODUCTION

Expectations of commercial buildings are often at odds with pure mass timber construction (MTC). Hybrid systems are an emerging solution to bridge the gap. MTC is gaining popularity in Australia, demonstrated by several landmark projects. However, most mass timber products used in these projects are from overseas, in consultation with foreign experts or limited local expertise. [1] Widespread use of mass timber still faces challenges ranging from availability to market familiarity.

Figure 1. Location of Case Studies

This paper explores how the development of a hybrid timber school project, Oakhill Innovation Hub, affected the ongoing development of a commercial tower, 2 Castle Street 'Workplace Hub'.

1.1 AIMS AND OBJECTIVES

The purpose of this paper is to compare the suitability of full timber, proprietary hybrid systems, and conventional construction for constructing education and commercial building types. We aim to address how to:

- Effectively select emerging hybrid timber construction methodologies to meet Australian market demands.
- Identify and weigh the contributing factors to the feasibility of a hybrid timber structure.
- Assess the appropriateness of emerging hybrid timber structural strategies in the Australian industry and market.

We aim to support the mainstream adoption of hybrid timber as a solution to commercial high-rise buildings within the Australian market. Projects that employ emerging MTC systems, may legitimise further development and investment. We present each case study as a precedent for future works by exploring the

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challenges and solutions of using previously untested systems.

1.2 METHODOLOGY

This case study includes a mixed-methods approach focused on the evaluation of MTC and hybrid timber systems in the context of real-world project aims. Practical work and technical research were conducted as a part of the development of each case study. Interviews were conducted with key contributors of the case study projects, primarily the architectural and consultant teams, selected based on their direct experience and contribution in delivery of hybrid timber systems.

The case study projects may be contextualised by real challenges faced by the Australian MTC industry. The results represent a small sample size of expert and industry opinions. Available technologies and industry familiarity may have changed. It is limited by design to Australia-specific challenges.

2 – BACKGROUND

Mass timber in an Australian context requires advocacy for widespread adoption. Peak bodies such as Wood Solutions provide technical guidance and lobbying. Built projects support advocacy as they legitimise untested systems, providing precedent and working through design challenges faced by products within an emerging market.

The case studies expose the need for precedents, especially for hybrid timber as they inherently rely on proprietary products, and multi-material junctions that introduce complexities in local certification and technical capability. The following subsections are contributing and limiting factors to the use of hybrid timber construction in each case study.

2.1 NEED FOR CARBON REDUCTION

Global investment and development in mass timber construction represents the growing realisation that a critical contributor to humanity's carbon emissions is the built environment (39%). The World Green Building Council (WGBC) pledges "By 2030, all new buildings, infrastructure and renovations will have at least 40% less embodied carbon". [2, p. 8] To meet such a goal, indiscriminate use of reinforced concrete (the industry standard within Australia) is no longer appropriate.

In an interview, Lendlease's Head of Sustainability Australia Ann Austin acknowledged that among available reduction pathways, the trade from concrete and steel to MTC presented a 40% embodied carbon reduction. [3]

Green Star, the Australian arm of the WGBC, currently demands a 10% minimum reduction in embodied carbon. Green Star offers credits to achieve a higher score for greater carbon reductions, but this is entirely optional. This is still a pledge to reduce, but 10% can be met with simple cement substitution, providing less pressure to the industry to consider mass timber.

In June 2022 Australia "reaffirms Australia's commitment to net zero emissions by 2050" [4]. If MTC is the answer, then our industry must reach maturity in advance of this deadline.

2.2 CHALLENGES FOR MTC

Mass timber is a recent opportunity within Australia. Our National Construction Code (NCC) only provided a formal pathway for mid-rise residential and commercial buildings (less than 25 meters in height) in 2016; in 2019 extending to all building classifications. [5]

As a result, the Australian construction industry is not yet familiar with using mass timber across a range of scales and building types. Further, functional expectations of new buildings are indexed to the structural performance and procurement models of conventional construction methods.

Despite previous success through mass timber projects such as the 2019 ANU learning hub and student accommodation project Kambri, applying business as usual procurement methodology and functional expectations does not yield the same benefits. Globally tenanted commercial buildings call for a greater degree of flexibility from wider structural grids when contrasted to owner-occupier buildings.

2.3 HYBRID SYSTEMS

'Pure' timber refers to buildings using primarily CLT and Glulam like products as the primary structural system [6]. 'Pure' mass timber projects present a trade-off between a wide range of economic, functional and environmental benefits in exchange for a significant change in mindset and front-loaded process of design and construction.

Hybrid timber construction introduces additional materials to perform specific structural tasks. This can include steel for longer spans, and concrete to support rigidity and connect elements through its reinforcement. Hybrid follows the ideology of 'using the right materials for the job', to have timber be a core component of the structural system, and outperform pure timber when longer spans, and reduced floor depths are required.

Hybrid strategies trade off some advantages of pure timber, such as the elimination of 'wet' trades (concrete) which add time and limit reusability at end of life. In exchange hybrid systems can close the gap with the market expectations and be a feasible contender against conventional construction.

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3 – OAKHILL INNOVATION HUB

Oakhill Innovation Hub is located within Oakhill College, a Catholic school established in 1937. In 2017 Oakhill College began development of their new masterplan in collaboration with URBIS, with a focus on outstanding education, innovation and sustainability. Oakhill's facilities had seen few significant upgrades since the 1970s, leading to a vision to modernise the campus to exceed their peer institutions. The plan consisted of upgrading the central connectivity of their campus, including new facilities and upgrades to adjacent structures.

Figure 2. Oakhill College Masterplan (URBIS)

BVN was engaged to design and deliver the Oakhill Innovation Hub, first stage of the masterplan. It is located at the intersection of two major axis in the masterplan, designed to house a range of STEM facilities. The 4300 m^2 building would contain contemporary science labs, hybrid fabrication workshops (timber, metalwork, textiles and robotics), both indoor and outdoor multi-purpose learning spaces.

3.1 OBJECTIVES AND CONSTRAINTS

Innovation was core to the project in all aspects, from curriculum to facilities, and architectural concept. The project team identified an opportunity for the building itself to perform as teaching tool, innovation by example. It was critical that the construction methodology be cutting edge, and the building be able to adapt to future technologies. These informed the initial concept development and influenced later decisions during tendering.

Oakhill Innovation Hub's purpose was "[t]o prepare students for the rapidly changing world, this facility will empower them to explore new ideas". [8]

Sustainability was an overarching aim of the masterplan, championed by the schools' business manager in pursuit of both environmental benefits and operational cost savings. The stakeholder group also highlighted the detrimental effects of the 2019 bushfires on air quality of the school and surrounding region. It was considered a health risk nationally [7] and was reflected in the client's requirements. In response the school sought a high level of air tightness and ability to operate within those conditions, providing adequate internal air quality for occupants.

Pursuit of innovation, environmental performance, and a desire for air tightness led to the design team proposing a mass timber strategy. Passivhaus principles [9] were also integrated into the project aims. The combination of mass timber and Passivhaus for high performance envelopes, though familiar overseas, is seeing greater local recognition [10], [11], [12]

3.2 DESIGN RESPONSE

The building mass was initially aligned parallel to the site boundary, however this raised privacy concerns with neighbouring residential zones. In response, the main volume of the building was rotated perpendicular to the site boundary and elevated to retain the east-west walkway.

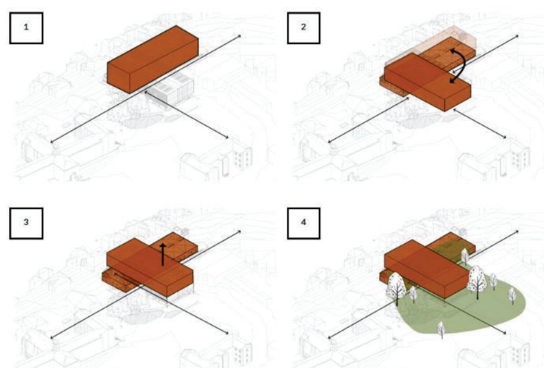

Figure 3. Massing design moves

An open-air amphitheatre emerged in the concept design, providing connection through the site, and served as the main entrance to the project.

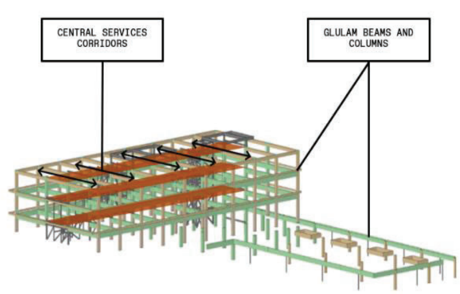

Figure 4. Indicative Structural and Services Diagram

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The concept design employed a pure mass timber structure, consisting of glulam beams and columns, with CLT floors. The main volume is broken into three zones through the column grid. The central zone containing lifts, stairs and the service 'spine' that connects to the adjacent mix of classrooms, laboratories, staff rooms and other amenities.

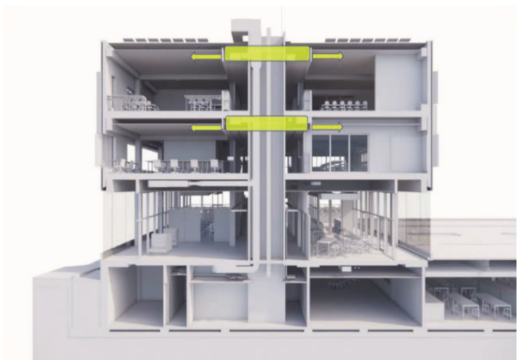

Figure 5. Cross section through labs, highlighting services spine.

In combination with the services Spine, movable and non-structural internal walls were used for long-term flexibility. The client required the internal planning could be adjusted for new technology and methods of teaching.

.3.3 PROCUREMENT

MTC benefits from resolution of servicing strategies as all penetrations can be made during the prefabrication of the structure. Uncertain servicing strategies can lead to oversized beams to account for future additions. Future flexibility is at risk due to the on-site costs of editing the CLT or GLT members being significantly higher than in factory. In the case of Oakhill Innovation Hub, the beams perpendicular to the services corridor were conservatively sized, and increased overall floor to floor height.

As the project was designed and constructed during the COVID 19, it faced the associated global supply chain challenges. The timber system was tendered early based on the concept design, about 30% documentation, to lock in certainty of price and material supply.

Of three tenderers received, one provided a full timber solution, another a hybrid solution from overseas, and the third a locally produced hybrid system. The local provider of the hybrid system was selected for a combination of price, minimised risks associated with international supply chains, and support of local manufacturing capabilities. The local provider, Viridi Group, based their proposal on their new and untested proprietary hybrid system. It combined two products, Composite Systems 'Strongfloor' and Peikko's 'Deltabeam'.

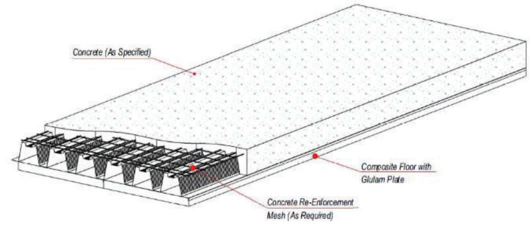

Figure 6. Viridi "Strongfloor", Indicative diagram.

The introduction of the Deltabeam afforded a 'flat slab' [14] in the service corridor and reduced overall floor to floor heights. Services coordination was disentangled from timber procurement timelines and could remain flexible after project completion.

In addition, the Viridi system removed the need for back-propping due to the permanent form work provided by the Glulam plates. Despite the introduction of a 'wet trade' of concrete, this typical drawback is avoided entirely for those familiar with the system.

Full timber strategy required K or V bracing, especially throughout the under-croft spaces. The hybrid solution removed the need for bracings, providing greater transparency throughout the building, and connectivity at the ground plane.

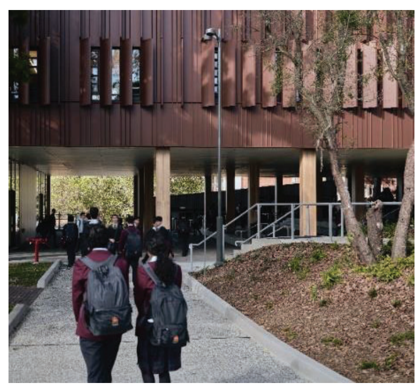

Figure 7. Photograph of through site link.

As the structure of this zone was outdoors yet protected from the building above, the timber structure needed to be service class 2 (EN1995 1-1). To meet performance requirements, GLT was sourced from Australian Sustainable Hardwoods (ASH) and used Accoya surface treatment. Columns sat atop concrete plinths to provide further protection from water.

3.3 COORDINATION

The project was redesigned using the new system and documented to 70%. These were used by the Viridi to produce shop drawings then and sent for manufacturing, prior to engagement with the head contractor.

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Though mass timber can be tendered ahead of the head contractor, it is typically fully documented. The significant difference between supply versus supply and install became apparent. The untested nature of the proprietary systems, and their intersections with other products such as the internal GLT made of Spruce and the external members from ASH.

As the design resolved, minor inconsistencies emerged between the timber ordered and required spans. The Deltabeams and Strongfloor systems could not be adjusted whatsoever. Editing GLT was possible but would lose some structural and thermal performance. These issues were resolved through close work between the project team and head contractor.

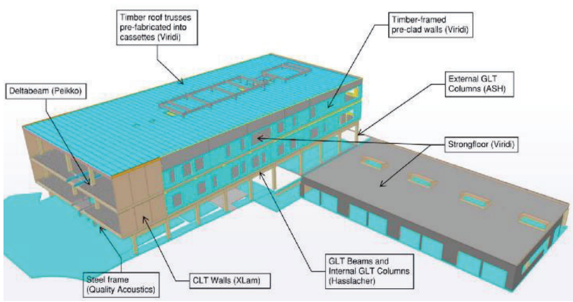

Figure 8. Breakdown of key products used for structure and façade.

The coordination between multiple products, systems, materials and manufacturers is a key challenge when some have not been used prior. The value of supply and install contracts comes from the timber contractor being responsible for facilitation between parties.

The Oakhill Innovation Hub project team addressed knowledge gaps in connections between systems though additional fire testing and structural engineering. Though higher risk at first, the coordination was possible through close collaboration.

3.4 CONSTRUCTION

Initial stages in creating the foundation slab followed conventional construction methodologies. GLT columns were attached to concrete plinths via steel connections. Once the Deltabeams were lifted into position atop the GLT columns, they were ready to bear the weight of the Strongfloor system.

As illustrated in Fig. 9, GLT beams and columns on the left were protected during construction from moisture and propped for stability. The Deltabeam on the right required no intermediate support. Once in position, CLT edge pieces were inserted acting as more permanent formwork for the concrete. Steel reinforcement mesh was positioned on the ridges of the Strongfloor.

Figure 9. Construction of Ground floor.

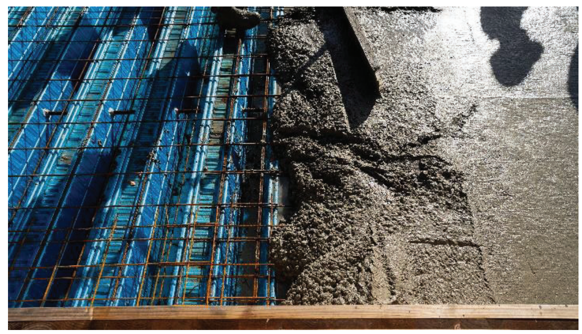

Figure 10. Concrete pour onto Strongfloor.

Figure 11. Completed structure facing services corridor.

There was no need to backprop the Strongfloor system, however, the head contractor followed typical concrete procedure so did backprop for the first-floor slab. As construction continued back props were not used as with familiarity came trust and the speed of each subsequent floor increased.

The ‘flat slabs’ visibly contrast the GLT beams in Fig. 11, where the Deltabeam runs perpendicular to the services corridor. Since the CLT and Deltabeam are flush, it allowed simplified servicing through this area and could be coordinated after timber procurement and during future systems upgrades.

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3.4 COMPLETION

The project team developed a collective understanding of the hybrid system through coordination and construction. Oakhill College's lasting impression [15] valued the project as a differentiating piece to what is in campus and their competitors, not just the timber, but also for the quality of light. Especially the southern facade that presents the internals of the building to the campus clearly communicating it is a timber building.

4 – 2 CASTLE STREET 'WORKPLACE HUB'

2 Castle Street 'Workplace hub' is approximately 24km northeast of Sydney, located adjacent to Castle hill station. The 2441 m² site and adjoining lots are zoned for mixed use, at precinct scale providing a range of office, retail, residential, wellness and entertainment facilities.

Figure 12: Rendering of north west corner.

Once complete the hybrid timber building will stand twelve storeys above ground, with three basement floors. 800m² of food and beverage activate the sloping ground plane and through site links. Nine floors of offices provide 14,000m² of commercial space and 2,500m² of open air 'Verandahs'. Design of 2 Castle Street was led by BVN, with environmental and structural strategies developed in close collaboration with ADP consulting, and BG&E.

4.1 CONTEXT

2 Castle Street was one of several co-located lots being developed by the client. In combination the precinct aimed to challenge the commercial offering of Sydney's Central Business District (CBD). The 'workplace hub' will be the commercial heart of the upcoming precinct (Fig. 13)

The project is developed to coincide with the completion of a new Metro line providing a 35-minute trip to Central Station. Metro connectivity made the site viable as a compelling alternative to Sydney CBD.

Figure 13. Aerial of project site (yellow) in context of mixed-use precinct (blue) and metro station (cyan M).

4.2 BRIEF

The brief described 2 Castle Street as a sustainably built, wellness focused project, offering high quality working environments. The client held ambitious environmental targets at both organisational and project specific scales. These requirements informed the following ambitions:

- Green Star Buildings 6 Star
- 40% embodied carbon reduction from a conventional building, informed by a potential 53% savings based on a full timber structure. [Figure 14]
- 32% energy reduction, including on-site renewables.
- Access to natural light, fresh air and connection to nature for occupants.

In addition to environmental ambitions, the project must align to commercial space best practices, including a PCA Grade A rating [16].

Table 1: Carbon Comparison prepared by ADP Consulting

Structural Options	**Materials**	***Kg CO_2 e / m²***	**Savings (%)**
Concrete (benchmark)	-New Foundation -Concrete Structure -Typical Façade and Services	1000	0
Hybrid System 1	-Reused Foundation -GLT + Composite Slab + Steel -Typical Façade and Services	608	39
Hybrid System 2	-Reused Foundation GLT + Composite Slab + Steel -Low Carbon Façade and Services	486	51
Timber Structure 1	-Reused Foundation -MTC Structure -Typical Façade and Services	467	53
Timber Structure 2	-Reused Foundation -MTC Structure -Low Carbon Façade and Services	345	65

Such expectations are based on the performance of conventional construction, leading to some bias in what is feasible and accounted for in the design response.

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4.3 SITE CHALLENGES

The site had a series of thoroughfares connecting foot traffic from the metro station through to the nearby shopping centre, directly affecting viable core placement. The case study is located above a rail reserve which imposes a maximum allowable weight (Fig. 14).

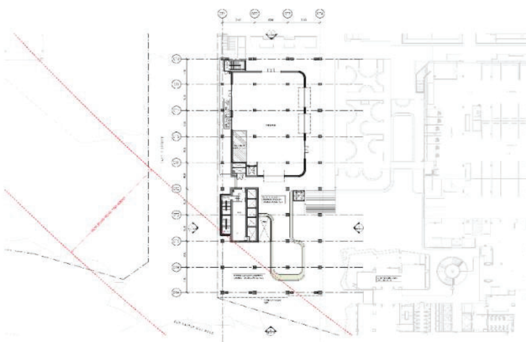

Figure 14. Ground floor plan with extents of rail reserve (red).

Nine floors of commercial space were required to meet GFA targets. Concrete could not achieve the required number of storeys, and pure timber would breach the height plane due to structural depths of beams. A hybrid solution was chosen to minimise weight, provide carbon reductions, and remain within the height constraints.

4.4 DESIGN CONCEPT

Initial design response of the Workplace Hub was a timber framed structure with side core on the southern edge, and 'Verandah' outdoor zones on the north face. Wrapping the structure was a stainless-steel net that replaced the function of a balustrade, supporting plant growth as a form of seasonal shade and connection to nature.

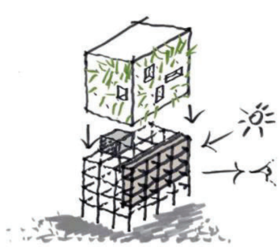

Figure 15. Early concept diagram of the 'Workplace Hub'

The Verandah challenged conventional workplace design in both its purpose and scale. As outdoor spaces are not included in lettable areas, how to monetise these spaces was a commercial challenge. Providing a wraparound balcony to each office floor was an unconventional but welcome addition to the commercial typology.

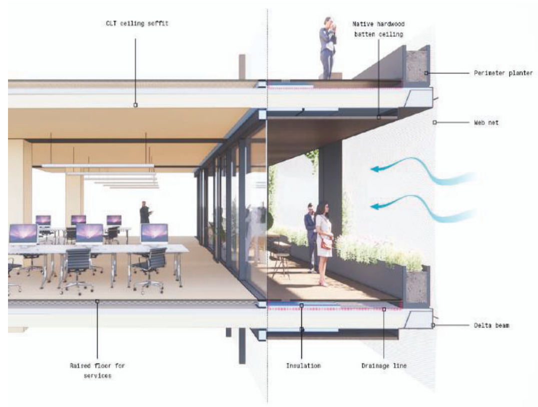

Figure 16. Sectional perspective of Verandah zone.

As acknowledged within the brief, value proposition of wellness features is more apparent in a post-Covid landscape [17], where employee experience is a metric alongside workstation efficiency. The Verandah zone provides planting and social spaces accessible to each tenant.

4.5 STRUCTURAL STRATEGY

The initial design strategy employed reinforced concrete for basement floors and core, with GLT timber frame internally, and a composite slab of CLT, steel and concrete.

Figure 17. Sectional Perspective.

As opposed to Oakhill Innovation Hub, Deltabeam was used without Strongfloor, instead using a CLT slab with a shallow reinforced concrete topping. This strategy would take full advantage of the maximum spans allowed with Deltabeam. As shown in fig. 18 concrete is poured onto the slab and into the Deltabeam with steel rebar connecting them as composite system.

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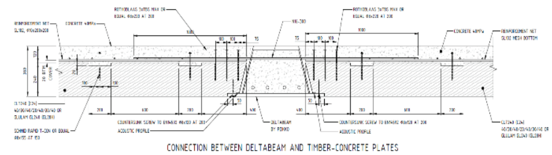

Figure 18. Typical detail between Deltabeam and floor plate.

As a result, the composite slab can match spans required for commercial floor. Improved performance is due to diaphragm forces being transferred via the concrete rebar and rather than through the CLT resulting in a stiffer and narrower slab.

The GLT columns and beams internally used a Service Class 1 Spruce. For the Verandah zone and ground floor a Service Class 3 Spotted Gum was specified. However, this design would be challenged during procurement.

4.6 PROCUREMENT AND VALUE MANAGEMENT

The primary challenge for the Workplace Hub was balancing feasibility and suitability. In the case of the external GLT, a Queensland Spotted Gum was originally investigated. The main supplier could not provide adequate volumes of timber. The 280m^3 of GLT required represented a significant amount of the annual production capacity. Without adequate local competition, other products and species introduced differences in characteristics and cost. Since alternatives for the external structure were cost-prohibitive, a timber clad steel structure was used for the external structure.

Similarly, as Deltabeam was considered as the preferred hybrid timber proprietary product, there were few comparable alternatives when it came to competitive tendering or value management. Due to the wide range of different hybrid systems and their respective ideal performance, experience and diligence is required of the project team to assess the most suitable alternatives.

Masslam [18] emerged during value management as a compelling alternative to the previous structural system. However, this required redesign and adjustment of the structural grid to yield optimal performance. Costs in design change, structural efficiency, and brief outcomes each factored into the project team's decision making.

In the case of the Workplace Hub, a range of alternatives were explored and presented back to the stakeholder group. Without persistent effort from the design team, environmental and structural consultants, MTC may have left the project at the first sign of resistance. As the design development continues, the team remains proactive in developing and communicating the best options in alignment with the project aims.

5 – RESULTS

The challenge hybrid timber faces is not in structural performance alone, though it can perform on-par in most metrics of a conventional systems, in the case of these case studies, spans, and services coordination. At times, it can outperform conventional systems in the case of weight. Where hybrid falls short is the differences in design and tender processes. As with pure timber, a hybrid system is most effective when fully documented and tendered with the manufacturer. Then, complexities in interaction between systems can be fully understood, coordinated, and costed.

Both case studies faced challenges due to procurement pathways. Primarily, with each hybrid system the 'right size' for structural efficiency changed. Each system is comprised of proprietary products that influence ideal spans, details of key junctions, fire protection, lead times, etc.

As Australia's MTC and hybrid products are few and varied, tendering multiple systems is not like-for-like, so in absence of 'locking in' a particular structural system requires a diligent and proactive project team. If the favoured structural system becomes infeasible, the project team must contextualise trade-offs with client values and project objectives to help select an appropriate alternative.

The challenges in procurement were, however, outweighed by the benefits. Oakhill Innovation Hub simplified servicing due to avoiding the majority of GLT penetrations due to the composite slab. The untested Viridi system now has precedence for future application.

For 2 Castle Street, a flat slab made division of floor plates into multiple tenancies is feasible from a servicing perspective, with improved flexibility in fire compartmentalisation and alignment — or misalignment — to structural grids. These factors enhance the building's long-term adaptability. 2 Castle Street also highlighted advantages in complex sites where weight considerations are critical. Timber's lightweight nature unlocks greater yield and improves overall development feasibility, making it economically advantageous despite potentially higher structural costs.

6 – CONCLUSION

Though Australia may lead in landmark timber projects, we have yet to see mass timber become commonplace. The market maturity is not yet sufficient for some large-scale projects due to manufacturing through-put and risks associated with availability of alternative systems within procurement.

Composite System, producer of Strongfloor, argued hybrid systems lower the barrier of entry for use of timber in buildings. Asking of the industry which would create greater impact, "one building with 5000m3 of timber in it, or encourage 500 buildings to use 500m3 in each of them?" [19]. Although a valid assertion it avoids the complex factors that influence adoption.

Where conventional construction provides a consistent approach through centuries of standardisation, MTC has rapid innovation and a wide range of choice. If one system is inappropriate for a particular brief, it is not representative of MTC holistically. To challenge 'conventional construction' requires a growth in local industry in terms of production capacity, competition in like-for-like systems, and the shift to early design and procurement. As with pure timber, the shift to front loaded design resolution unlocks compressed programmes, based careful planning and coordination by experts in the products at hand.

The Australian building industry must utilise new systems to provide precedent, gain experience, and grow resilience in our local supply chain so there is adequate choice and competition. Hybrid systems can be used as a transitional step to help legitimise mass timber as a primary structural material. Doing so supports growth in Australia's capacity in production and delivery.

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