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Case Study of a Base-Isolated 6-Storey Timber Frame Building in a High Seismic Region

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ABSTRACT: This paper will present a case study for a high profile 6-storey mass timber office building located in Wellington, New Zealand. The region has very high seismic loads and the brief for the project required Importance Level 4 (1.8 times higher loads than a standard office building), as well as very high sustainability goals (targeting Greenstar 6) and low damage seismic design. These combined goals necessitated an innovative design approach and resulted in a mass timber frame (braced frame and post-tensioned moment frame in the two orthogonal directions) supported on a supplementary damped base-isolated support structure. The paper focuses on key components of the mass timber construction journey from the structural engineer's perspective for this unique project. This paper addresses the WCTE theme of Timber Engineering & Structural Performance.

KEYWORDS: timber, seismic, base isolation, sustainability, resilience

1 – INTRODUCTION

This case study focuses on an office building located in Wellington, New Zealand, the client for which is currently confidential. The building is 6 storeys above a basement, with a total gross floor area approximately of 8,000 square metres. The building is currently under construction.

The brief for the project required Importance Level 4 (1.8 times higher loads than a standard office building), as well as very high sustainability goals (targeting 6-star Greenstar) and low damage seismic design. Furthermore, the proposed use of the building requires future flexibility in the floor plans, which precluded the use of shear walls or braced frames internally to the structure.

These combined goals necessitated an innovative performance-based design approach. Implementation of a supplementarily damped base isolated system is the principal strategy for delivering this brief. Unlike traditional base isolation, inclusion of supplemental damping provides further control of the isolated building's movements and seismic demands. Adoption of this system has had a significant influence on opportunities to maximise timber and satisfy Low Damage Seismic Design principle.

The primary lateral load resisting system is a timber braced frame in the longitudinal direction, along the façade lines, and post-tensioned (Pres-Lam) moment frames in the transverse direction, allowing for the required usage flexibility in the future while still using a primarily timber system. Cross-laminated timber (CLT) floor panels are used to resist both gravity and lateral diaphragm demands with an acoustically rated raised floor allowing for the removal of concrete topping to the CLT. The client expressed a strong desire to use New Zealand timber suppliers. This goal was achieved, and required careful consideration of compliance pathways and coordination of specifications to what could be supplied locally.

This paper focuses on key components of the mass timber construction journey from the structural engineer's perspective, covering design development, preconstruction refinements, and initial construction considerations for this innovative Wellington project.

2 – BACKGROUND

2.1 ENHANCED SEISMIC PERFORMANCE

The site for this project is located within 1000 metres of the Wellington Fault. Based on fault proximity and known shortcomings of the current codification of the New Zealand seismic hazard, a site-specific probabilistic seismic hazard analysis was conducted, and the resulting spectra were used to design the building. This analysis showed design loads of more than twice that of the code-mandated loads.

Beyond the elevated hazard, the structure is being designed as Importance Level 4, requiring explicit consideration of Low Damage Seismic Design principles (Serviceability Limit State 2). This introduced additional drift limit performance objectives not typically addressed in conventional mass timber designs. Implementation of a

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supplementarily damped base isolated system is the principal strategy for delivering this brief. With what we believe will be the first of its kind in New Zealand, this system is a response to the significant seismic hazard in New Zealand, particularly in Wellington. Unlike traditional base isolation, inclusion of supplemental damping provides further control of the isolated building's movements and seismic demands. Adoption of this system has had a significant influence on opportunities to maximise timber and satisfy Low Damage Seismic Design principles.

2.2 SUSTAINABILITY

The client's brief noted that the building should target Greenstar 6 certification, as well as Carbon Net Zero. The high sustainability goals of this project necessitated using timber as much as possible as a structural building material. This included glue-laminated columns, glue-laminated braces, laminated veneer lumber post-tensioned beams, and cross-laminated timber (CLT) floors used for both diaphragm and gravity support purposes. A Life Cycle Assessment was completed to quantify the reduction in global warming potential.

3 – DESIGN

3.1 PRES-LAM SYSTEM

The project employs Pres-Lam timber frames in the transverse direction to maintain open floor spaces without the need for obtrusive shear walls or braces. This system, first developed in the 2000s at the University of Canterbury [1] and evolved from the PRESSS systems [2], has been successfully implemented in several buildings across New Zealand [3][4] and internationally [5]. Pres-Lam utilises post-tensioning technology to connect structural timber elements, typically combined with dissipative reinforcing devices in a 'hybrid' configuration. The structural response of these connections is characterised by the combined moment capacity from both post-tensioning (M_{pt}) and supplementary reinforcing (M_s). During design, engineers adjust the parameter β, representing the ratio between M_{pt} and the total moment capacity ($M_t = M_{pt} + M_s$), to optimise the structural behaviour for specific performance objectives.

While traditional Pres-Lam frame design typically prioritises ultimate limit state response, this project presented unique design considerations due to its base isolation system and stringent post-earthquake performance requirements. The initial (pre-gap opening) stiffness of the frame became a critical design parameter. Although timber frames inherently exhibit flexibility, Pres-Lam offers the advantage of reduced joint rotations by eliminating fastener slip that occurs in more

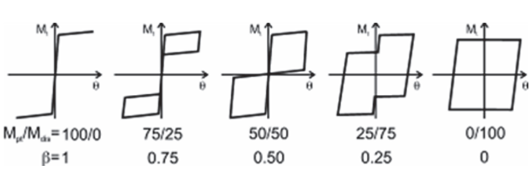

Figure 1. Moment response with varying levels of the parameter,

conventional gusset or knife plate connections. To further enhance beam-column joint stiffness, supplementary reinforcing devices were integrated into the bottom two floors of the frame.

These frames incorporated a concurrent column which interacted with the perpendicular braced frame. Care was taken to avoid disrupting the beam column joint load path with the brace connection.

To preserve post-tensioning forces and prevent perpendicular-to-grain compression in the columns, steel circular hollow section (CHS) tubes are embedded within the columns. This detail ensures that post-tensioning loads transfer directly to the beam face via steel plates positioned at the beam-column interfaces. This maintains the integrity of the post-tensioning system while protecting the timber elements from unfavourable stress conditions.

The Pres-Lam system thus provides an elegant solution that combines the sustainability benefits of mass timber with the robust seismic performance necessary for a high-importance structure.

3.2 TIMBER BRACED FRAME AND BRACED FRAME STABILITY

The longitudinal lateral load resisting system consists of Timber Concentrically Braced Frames (Timber-CBFs) on external longitudinal gridlines, extending from the ground floor to the roof. These frames comprise Glulam braces, columns (shared with the Pres-Lam frames), and LVL/steel collectors.

Recent research into the performance of yielding buckling restrained braced frames (BRBs) has highlighted significant detailing challenges when considering deformation compatibility, particularly as frames displace in the orthogonal direction. Contemporary design approaches recommend the introduction of two designated hinge zones or Specified Deformation Zones (SDZ) while maintaining sufficient stiffness in the remaining components [6].

For stability under axial compression, a Timber-CBF system—comprising beam-column joint, gusset, gusset-to-brace connection, and brace—must have no more than two hinges along its length. MacRae et. al provide design philosophies that can be adapted for such systems, including considerations for reduced buckling capacity resulting from decreased system restraint when rotational stiffness of connections decrease along the brace length, whether from axial actions or out-of-plane (OOP) movements.

MacRae et. al introduces a method for calculating the Euler's buckling capacity of the gusset by relating a cantilever of fixed length and flexural rigidity (EI) with a spring support to a fixed-based cantilever with the same length but an adjusted EI that reflects the reduction in stiffness due to the spring support. Several elements influence the cantilever support stiffness, including the column's flexural and torsional properties.

Figure 2 highlights the potential sources of additional rotation between a Timber-CBF node points. This includes any gusset, steel pins, timber pins and the brace

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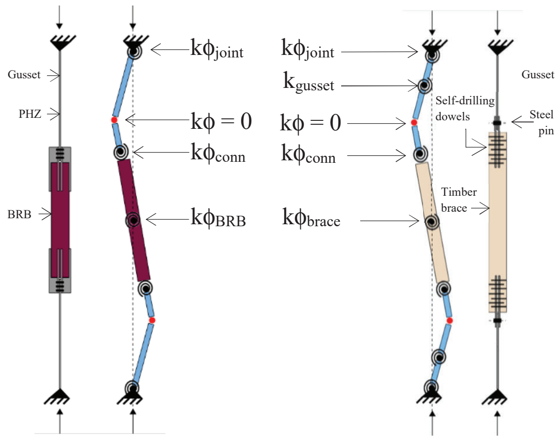

Figure 2. Stability of generalised MacRae Case for a BRB (left) and adapted generalised case for Timber-CBFs (right)

itself – and can have a large influence on brace stability if not detailed adequately for.

To address these challenges, the Timber-CBF system was designed elastically, ensuring no hinges form along its length at Ultimate Limit State (ULS). This design decision had two significant consequences: first, it eliminated the possibility of "yielding" in the self-drilling dowel CBF connections, necessitating the use of "yield" capacity as the design capacity to maintain elastic behaviour; and second, it required designing the self-drilling dowels to withstand the elastic out-of-plane moment generated by transverse displacements in the moment-resisting frame direction. This approach ensures robust performance of the braced frame system while acknowledging the unique characteristics of timber construction in lateral force-resisting applications.

The experience from this project highlights that stability considerations for timber braced frames must be integrated into the earliest design phases, as subsequent modifications to address these complex interactions become increasingly difficult and costly as the design progresses.

3.3 STRUCTURAL FIRE CONSIDERATIONS

While it is relatively straightforward to determine the dimensions of mass timber elements to meet minimum required fire ratings through sacrificial charring, special consideration was given to connections which often use steel components that provide conduits for heat and create additional char surfaces. The knowledge of the behaviour of mass timber construction in fire is rapidly evolving. This project integrated recommendations from the fire engineer into a comprehensive structural fire strategy.

The fire protection philosophy incorporated several key principles:

- Design char rate of 0.86mm/min for exposed timber surfaces as an conservative approach.
- Exclusion of all charred surfaces plus an allowance for thermal gradient (which further reduces capacity) when calculating structural capacity.
- Specific protection measures for post-tensioned bars and bearing plates.
- Positioning steel plates and connectors beyond the char layer, protected where appropriate by non-structural sacrificial timber plugs.
- Consideration of reduced bearing area between dowels and timber due to charring.
- Placement of epoxied fixings beyond the char layer and thermal impact zone.
- Finite element analysis of exposed steel elements (not providing primary gravity support) to evaluate thermal conductivity and associated charring effects on gravity-supporting members.

These strategies relied on architectural detailing to complement the structural approach. During design development, extensive collaboration between the structural engineer, fire engineer, and architect ensured the design intent was maintained while allowing adequate provision for these protective measures. This integrated approach balanced aesthetic considerations with robust fire performance, demonstrating how mass timber structures can satisfy stringent fire safety requirements without compromising design vision.

3.4 NEW ZEALAND SUPPLY OF ENGINEERED WOOD PRODUCTS

When working with timber, understanding manufacturers' capabilities is critical to creating buildable, cost-effective designs. For several engineered timber materials in New Zealand, there are no standardised sizes or parameters, with each manufacturer producing different products to suit their equipment and material supply. This non-standardisation can create extra complexity for the designer if all supplier options are to be allowed for, particularly when detailing connections. Therefore, from a design perspective, the ideal design process will allow the designer to nominate a manufacturer for each material and design to their suite of products and with awareness of that manufacturer's detailing preferences. However, there are numerous reasons why an owner might choose to keep the decision on manufacturer open through the design phases, including confidentiality, deference to future main contractor preferences, a desire for competitive pricing, or to follow their own procurement protocols.

For this project, the owner required an open procurement process for the main contractor and their subcontractors. Therefore, the design team needed to find an approach to progress the design in a way that wouldn't preclude or advantage any of the likely manufacturers. That included the following strategies:

- Obtaining permission from our client to speak to New Zealand manufacturers to understand their capabilities and limitations on specific products without revealing any details about the project
- Discussions with the manufacturers, including questions about likely fabrication strategy for certain elements (particularly the post-tensioned beam, which required internal ducts for the post-tensioning rod to be formed)

- Creation of an internal project database of size and grade availability from the various manufacturers
- Design to the lower bound of manufacturers' design strengths where no standard existed, or design to the reliable strength in published standards where they did. This ensured that regardless of what product was ultimately selected, it would be equal to or stronger than our assumed design strength. (Note that this building did not require capacity design of timber elements as the ductility was concentrated at the isolation plane; if it had, the upper bound strengths would have also required consideration.)
- Design to worst-case stiffnesses where required.
- Detailing to an assumed manufacturer when specific dimensional parameters were critical and designing for all possible products was no longer practical. The assumed manufacturer was communicated to the owner and design team in a memo that described this strategy; this was not communicated to outside parties to avoid influencing the procurement process. In this memo, the possible impact of a change from the assumed supplier was described for each member type (e.g., "Glulam Entry Lobby Collector Beams – Possible changes to width/depth availability/efficiency, no change to strength or stiffness properties" or "LVL Pres-Lam Frame Beams – Possible efficiencies could be investigated using less conservative properties."). This process allowed the owner to understand the risk they were carrying by keeping the procurement process open, while also taking reasonable steps to advance the design. They were also advised to allow non-conforming tenders to allow non-assumed manufacturers to tender with their equivalent product, and to budget for an evaluation process from the design team on any non-conforming tenders.

4 – PRECONSTRUCTION

The preconstruction phase provided a valuable opportunity for contractor input on key elements of the design, enabling the team to address risks, validate design assumptions, and optimise the structural approach. Alongside the main contractor, the design team was able to refine details while maintaining the core design intent, resulting in more constructable and cost-effective solutions. This collaborative approach proved particularly beneficial for the mass timber structure, where feedback from individual suppliers and their fabrication methods could be incorporated.

The strategies that avoided precluding or advantaging any manufacturer helped during this phase. Through meaningful dialogue and ideation with suppliers, we gathered valuable recommendations, even though not all could be implemented. Earlier engagement of suppliers in New Zealand would have likely allowed all recommendations to be accommodated.

Looking forward, the industry would benefit from greater standardisation of engineered wood product sizes, manufacturing processes, and strength grades, potentially reducing the need for early engagement on future projects (although there is still value in consulting with manufacturers on buildability). While standardisation might appear to limit competitive advantage for individual suppliers, a collaborative approach across the industry would likely expand the overall market for mass timber products by simplifying the design and specification process, benefiting all stakeholders.

The following sections highlight several key focus areas for the timber frame design during the preconstruction phase.

4.1 PRES-LAM DETAILING

The Pres-Lam timber frames incorporated 1200mm deep LVL beams and glulam columns with post-tensioned bars. These bars are positioned centrally near the top and bottom of the beam, extending through the supporting column and anchored on the outside face of the glulam column (refer Figure 3). This arrangement creates a robust connection that maintains structural integrity while allowing controlled rocking during seismic events.

The void to accept the post-tensioned bar was formed by block-gluing two standard sized LVL sections with portions routed on both elements to maintain concentric prestress. For future projects, it is recommended to rationalise the width of the timber beam to allow for routing to only one of the block-glued elements, which would simplify fabrication and potentially reduce costs. This minor modification would maintain structural performance while improving constructability – however requires an understanding of fabricator specific widths (which isn't always known during the design phase).

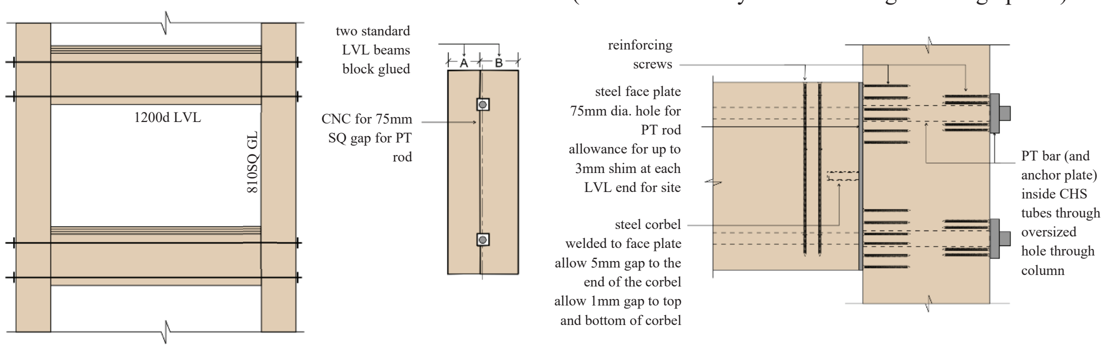

Figure 3. Pres-Lam moment frame (left), LVL build-up (middle), beam column joint (right)

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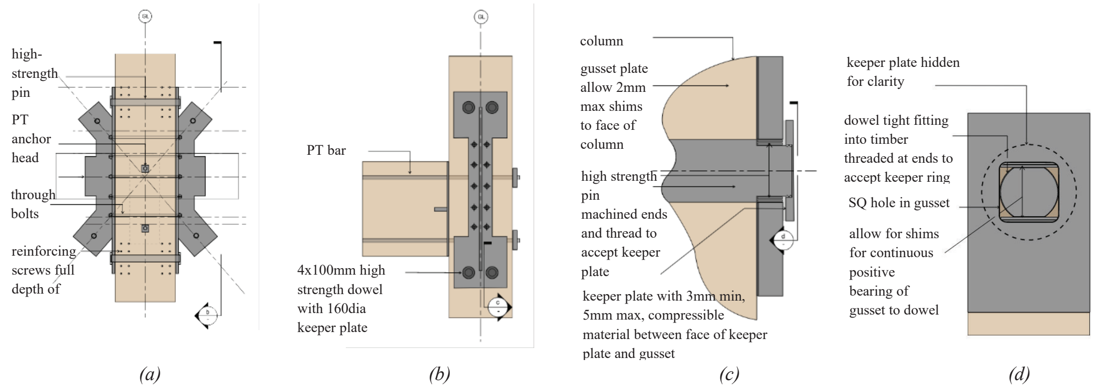

Figure 4. Glulam concentrically braced frames

Glulam columns were specified, as opposed to LVL, to satisfy architectural intent for a more natural timber aesthetic. However, this choice presented structural challenges, as glulam is generally weaker and softer than an equivalently sized LVL element, particularly when loaded perpendicular to grain. To address this, reinforcing screws were installed in critical areas, and an internal steel circular hollow section (CHS) through-tube was incorporated to minimise both short and long-term losses in post-tensioning force due to perpendicular-to-grain compression effects.

4.2 TIMBER BRACED FRAMES

Glulam concentrically braced timber frames feature on the two longitudinal external elevations of the building. The glulam columns must resolve concurrent actions from both the braced frame and the moment resisting frame. Figure 4 illustrates several key details of the connection between the braced frame and the glulam column.

The design team adopted a "bolted" gusset connection over a knife plate solution for multiple reasons: reduced weight of the combined timber/steel assemblage, better management of the congested joint zone, improved constructability by avoiding tight fit challenges, and more effective resolution of concurrent shears and beam-column joint stresses in the glulam column.

Although work points aligned concentrically for the braced frame, the eccentricity between shear at the column face and the column centreline introduced internal stresses. To create the stiff load path required, a detail incorporating tight-fitting high-strength pins rather than relying on a bolt-shear transfer mechanism was adopted. Bolts primarily resolved horizontal actions through the joint, while the high-strength dowels were positioned away from the Pres-Lam beam-column joint to minimise congestion and localised stresses.

Working with the contractor and suppliers, the team achieved the intent of a tight-fitting high-strength pin connection by providing tolerance between the pin and the shear plane of the gusset. This approach used intentionally oversized holes with allowances for shims to create a continuous positive connection throughout the structure. If concurrent columns cannot be eliminated, the adopted details proved to accommodate required strength and stiffness without increasing the buildability challenges of the joint.

4.3 COLUMN SPLICES

While several methods exist for achieving robust gravity timber-timber column splices, there appears to be an industry challenge for connections designed for high concurrent loads (simultaneously resisting high flexural, shear and tension demands).

A common approach implements both epoxied anchors and a shear key. However, in collaboration with the contractor and architect, the project team adopted a system that introduces a steel-to-steel site connection. This solution allowed the epoxied elements and shear keys to be installed in factory-controlled environments, significantly improving quality control and precision. Additionally, it provided a similar level of erection tolerance to traditional steel construction, streamlining the on-site assembly process.

At the floors where splices were introduced, an architectural timber cover plate served dual purposes: providing an aesthetically pleasing joint while simultaneously protecting the steel connection elements against fire. This integrated approach satisfied both structural and fire performance requirements without compromising the visual timber aesthetic of the building.

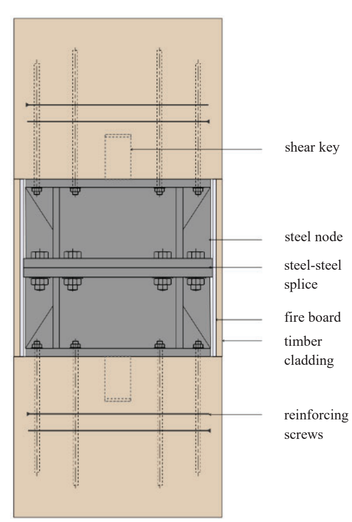

Figure 5. Glulam column splices

4.4 FAÇADE CONNECTIVITY

Connection of curtain wall systems to CLT panels presents added complexity compared to more typical suspended concrete systems.

For conventional curtain wall systems, a single façade bracket (supplied by façade manufacturers) typically supports two adjacent panels, aligned with the mullion/transom junction. These façade brackets commonly connect to concrete flooring systems through a cast-in weld plate detail. This weld plate then accepts a welded stud to suit the façade bracket with the required erection tolerances.

A similar philosophy was adopted for this project. Instead of a cast-in weld plate, a localised steel edge angle was provided, with through bolts into the CLT panel (refer Figure 7). These discrete angle brackets were positioned at mullion locations, with allowance for plan tolerance to accommodate welded studs and erection tolerances. The detail balanced industry norm façade brackets with mass timber construction.

The through-bolted steel angle bracket to the CLT needed to resolve lateral loads and fixed-end moments from the façade. Figure 6 highlights an idealised free-body diagram of a common façade connection support, showing the fixed-end moments requiring resolution. Lateral forces exist due to wind/seismic actions and cannot be ignored, with eccentricities adding to the complexity.

Supplier-designed façade brackets commonly demonstrate compliance through a combination of calculation and testing – typically adopting a fixed-end support boundary condition at the structural slab interface. This allows a pinned-end connection from the supplier-designed facade bracket to the curtain wall panel, which suits a range of on-site erection philosophies.

Whilst this is generally accommodated with minimal design/analysis effort in concrete flooring systems, care

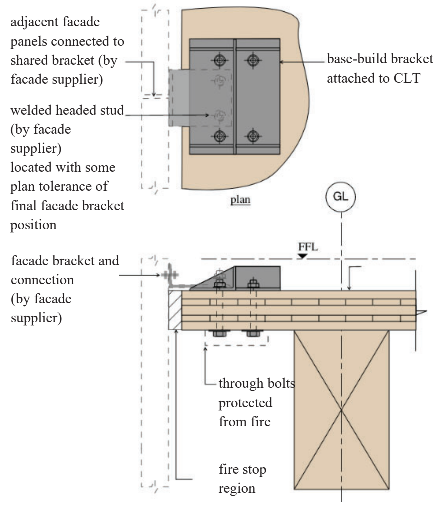

Figure 7. Façade connections

must be taken with CLT. This is for two reasons: local stresses in timber to resolve moments are challenging, and meeting the boundary condition assumptions for test specimens that the supplier relies upon to validate their design may not be achievable.

During preconstruction, we identified a potential modification – and whilst this could not be accommodated in this project, we believe it could help reduce connection complexity for future mass timber projects. If the façade supplier could resolve the fixed-end moments into the panel, the connection into the CLT panel could eliminate the need to design for moments. This potential opportunity is idealised as a free body diagram in the right of Figure 6.

Complexity is either required at the CLT edge or within the façade system itself. Current industry practice places the burden on the design engineer to resolve this complexity at the slab interface. Future mass timber

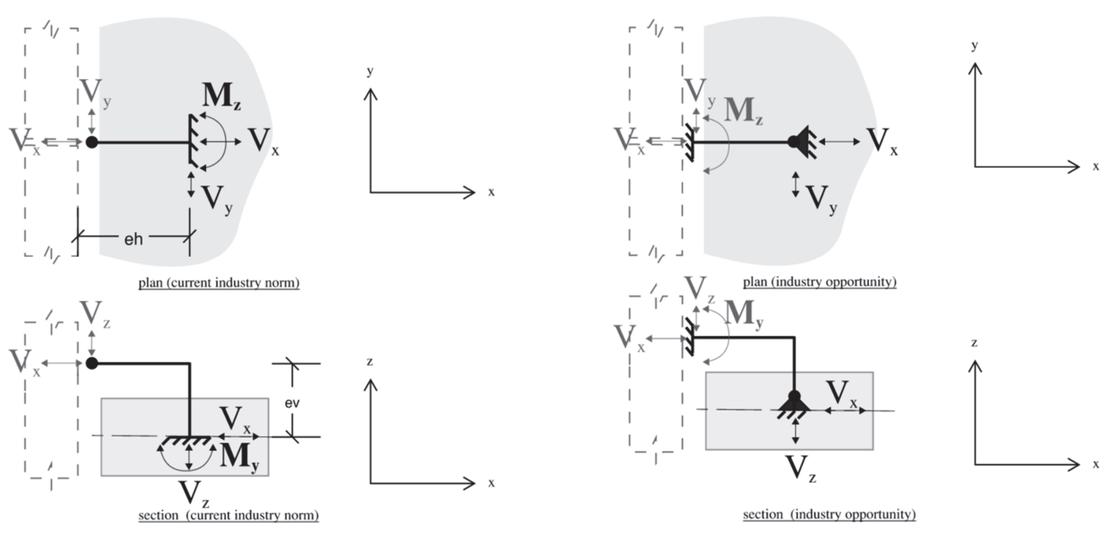

Figure 6. Idealised free body diagrams for façade, industry norm (left), potential opportunity (right)

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projects may benefit from shifting this responsibility to the supplier (if they are able). This approach would simplify interface details while maintaining all performance requirements.

4.5 CLT COMPLIANCE PATHWAYS IN NEW ZEALAND

New Zealand currently lacks a domestic manufacturing standard for Cross Laminated Timber (CLT), creating significant challenges for design and compliance verification. For this project, a standards-based compliance framework was established referencing ISO 16696-1, which provides guidelines for component performance, production requirements, and certification schemes. During preconstruction, it became apparent that the nominated supplier did not strictly conform to this specification nor to a recognised alternative international standard. This necessitated the development of a project-specific alternative compliance pathway through detailed comparison of manufacturing processes against international requirements, identifying areas of conformance and necessary modifications.

The alternative compliance pathway developed for this project addressed several critical aspects of CLT manufacturing. Key requirements included panel thickness and layer thickness tolerances in accordance with EN 16351-2021, minimum aspect ratio for boards in perpendicular layers, moisture content control at bonding, and glue line delamination testing to AS/NZS 1328.1:1998. Additionally, testing to determine characteristic rolling shear for the specified panel layups in accordance with Annex C of EN 16351:2021 was required. Third-party certification of factory production controls and detailed documentation of testing results were required to validate this compliance pathway throughout manufacturing and erection.

The development of this bespoke compliance pathway highlights a broader challenge in the use of similar types of engineered wood products in New Zealand. At the moment, without established domestic standards, designers and contractors must navigate complex international requirements and adapt them to local conditions and capabilities. This creates potential risks in quality assurance, structural performance verification, and regulatory approval. The compliance pathway must therefore be particularly robust, transparent, and defensible to territorial authorities who may be unfamiliar with the technology. Early engagement with suppliers, independent testing regimes, and third-party verification become essential risk mitigation strategies in this context.

The CLT compliance pathway developed for this project has provided a useful local precedent for local territorial authorities where we lack a comprehensive local standard. It demonstrated how international best practices can be adapted to local manufacturing capabilities while maintaining appropriate quality assurance. It also highlights the urgent need for local standards for these types of engineered timber products to reduce compliance uncertainty, streamline approval processes, and facilitate wider adoption of sustainable timber construction technologies.

Figure 8. Example of Pres-Lam tilt-up construction

Until such standards are developed, project-specific compliance pathways will remain a necessary but resource-intensive component of mass timber design in New Zealand.

5 – CONSTRUCTION

As of writing, this project is currently in construction. The erection strategy divides the building into multiple zones, with each zone comprising structure from foundation to roof. Most shop drawings have been reviewed, except for some ancillary structures. Timber is currently in manufacture. The first delivery of structural timber for erection scheduled for early-to-mid 2025 – with site preparation works and foundations well underway. The Pres-Lam frames will be assembled on the ground and erected using tilt-up construction, similar to Figure 8.

The following sections highlight key construction considerations that have been addressed during the early stages of construction.

Estimated completion date is end of 2026.

5.1 TIMBER SHOP DRAWING PROCESS

The design brings together multiple disciplines including structural steel, glulam, LVL and CLT trades. This requires significant coordination from the contractor to manage multiple manufacturing workstreams, particularly where mass timber connection components integrate with steel elements (plates, hot-rolled sections, screw reinforcing, etc.).

Over the past year, shop drawing reviews were undertaken for glulam, LVL and steel components, with the main contractor managing coordination through a federated 3D model. These have progressed well, capturing recommendations from subcontractors that couldn't have been easily identified during the preconstruction phase. This included manufacturing limitations as well as considerations for staged assembly.

An example of a typical beam-column joint is shown in Figure 9, which highlights the various components and subcontractor contributions. This illustrates the complexity of interfaces that must be carefully managed to ensure successful integration of the diverse structural elements.

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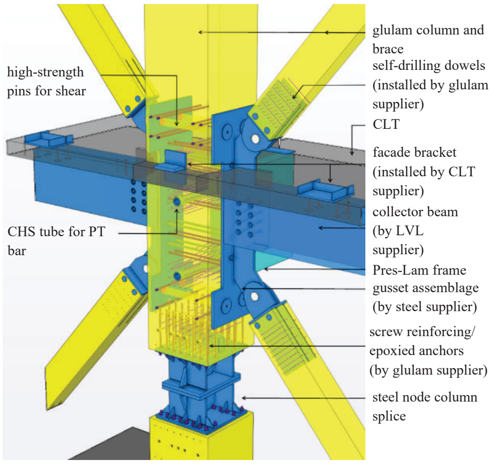

Figure 9. Typical beam-column joint at intersection of brace and Pres-Lam moment frame

5.2 TIMBER PROTECTION PLAN

The project specification required a comprehensive Moisture Management Plan addressing fabrication, delivery, storage, protection, and installation of all structural timber elements. This plan needed to include target moisture contents, measurement protocols, and protection strategies throughout the construction process. Mitigation measures against unintended water ingress included just-in-time delivery, taping CLT floor joints, promptly removing/sweeping off standing water, protecting end grain, using plinths for columns, and regular moisture content monitoring. Equally important were practices to avoid, such as using dissimilar materials, concrete to contact bare timber or poor storage conditions. Whilst a holistic review is required, vulnerable connection zones and exposed surfaces were highlighted, recognizing that prevention is far more effective than remediation for maintaining both structural integrity and aesthetic qualities in mass timber construction.

5.3 HYDROGEN EMBRITTLEMENT IN ENGINEERED TIMBER SCREWS

During construction, the project team began receiving reports about projects in North America with mass timber fixings failing due to presumed hydrogen embrittlement. Similar fixings were specified on this project. Luckily, the construction had not progressed to where the fixings had been installed, so the project team worked quickly to understand the risks to the project and ways to mitigate those risks.

Hydrogen embrittlement is a known failure mechanism of certain high strength steel when exposed to moisture under tension.

A table was developed detailing every instance of high strength fasteners on the project. This table included information on:

- location,
- size, length, and manufacturer specification,
- hardness value and coating type,
- whether it might be subjected to sustained tension (either by design or inadvertently through over-torquing during installation or from swelling/shrinkage of timber)
- susceptibility to moisture (especially pooling water during construction)

Relative risk scores were associated with the last three items, and these were summed to find an overall relative risk score for each fastener instance. This allowed us to identify the most critical fixings and, working with the contractor and client, the team were able to find alternative fixings or details to mitigate the risks for these fixings. This process also included close consultation with the manufacturers of various fixings to understand their materials, manufacturing processes and testing protocols, as well as cost and lead time.

For this project (and all future projects using high strength fasteners in mass timber applications), we recommended that manufacturers demonstrate compliance with the updated Canadian standard CSA O86:24.

Ultimately, agreement between all parties was reached that satisfactorily mitigated the risks of hydrogen embrittlement without jeopardising the budget or programme for the project. Fixings have been procured for installation during timber manufacture without delay to the programme.

6 – CONCLUSION

This project, although still under construction at the time of writing, provides a valuable case study of a significant mass timber project in a high seismic region. The innovative integration of supplementary damped base isolation with Pres-Lam timber frames effectively addresses Wellington's seismic challenges while delivering on design flexibility and sustainability objectives.

The building's pursuit of Greenstar 6 certification demonstrates how advanced timber applications can achieve substantial reductions in global warming potential.

Through proactive client, contractor and designer collaboration, mass timber has been able to be celebrated in design and vision, whilst also achieving compliance in a rapidly changing environment.

A persistent challenge exists in New Zealand's timber design and manufacturing landscape. Based on our experience, we recommend further development of local standards and standardisation of manufacturing processes to reduce compliance uncertainties and promote further implementation of mass timber in New Zealand.

https://doi.org/10.52202/080513-0055

7 – REFERENCES

[1] Palermo, A., Pampanin, S., Buchanan, A.H., Newcombe, M.P. 2005. Seismic design of multi-storey buildings using laminated veneer lumber (LVL). New Zealand Society of Earthquake Engineering, Annual Conference, Wairakei, New Zealand, University of Canterbury. Civil Engineering.

[2] Priestley, M.J.N. 1996. The PRESSS program - Current Status and Proposed Plans for Phase III. PCI Journal 41(2): 22-40.

[3] Brown, A., Lester, J., Pampanin, S. 2014. Re-building Trimble Navigation's Office Using a Damage-limiting Seismic System. 13th World Conference on Timber Engineering. Quebec City, Canada.

[4] Kirstein A, Siracusa J and Smith T (2018). "The new timber Von Haast replacement building in Christchurch". New Zealand Timber Design, 26(2): 25-32.

[5] Sarti, F., Smith, T., Danzig, I., Karsh, E. 2017. PresLam in the US: the seismic design of the Peavy Building at Oregon State University. New Zealand Society of Earthquake Engineering Annual Conference and AGM. Wellington, New Zealand.

[6] MacRae, G., Lee, C.-L., Vazquez-Colunga, S., Cui, J., Alizadeh, S., & Jia, L.-J. (2021). BRB system stability considering frame out-of-plane loading and deformation zone. Bulletin of the New Zealand Society for Earthquake Engineering, 54(1), 31–39.