Tall Wood Building Enclosures – A Race to the Top

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INTRODUCTION

Interest in taller wood buildings utilizing cross laminated timber (CLT), nail laminated timber (NLT), and structural glued laminated timber (glulam) is growing rapidly in Canada and the United States. On the west coast, recently completed projects including the 97 foot tall, 6-story Wood Innovation and Design Center (WIDC) in Prince George, BC, the 180 foot tall, 18-story UBC Brock Commons Tallwood House in Vancouver, BC, and the upcoming 12-story Framework project in Portland, OR, have captured the attention of the international construction industry. Several other taller wood buildings are on the horizon and feasibility studies are currently being performed for mass timber buildings over 30 stories in height. Tall wood buildings have been a reality in Europe longer than North America, and there is much to learn from the European experience. However, conditions unique to the North American construction industry create many challenges for the design team in demonstrating the safety, durability, and economics of these buildings, all while forming public perception of wood at taller heights.

WOOD STRUCTURE AND BUILDING ENCLOSURE – A RACE TO THE TOP

Structural systems for tall wood buildings are new to the industry and are unique in their design and construction. Heavy use of CLT or NLT panels and glulam beams/columns along with innovative connectors are features of taller wood buildings. Concrete and steel are also utilized with mass timber elements to create “hybrid tall wood structures.” Tall mass timber wood structures have the benefit of prefabrication and can be installed very quickly saving construction time and cost. To achieve this time savings, advanced computer models are often utilized to draw all components individually in 3D and combined to model the completed building. The 3D model for each component part is then linked directly to the wood and connector fabrication facilities to ensure the perfect fit of all components on site. Once complete, the model is then used to simulate construction of the building in 4D to optimize the on-site build schedule. An example for the UBC Tallwood House is shown in this video by CADMakers - https://www.youtube.com/watch?v=ATKpFtzCVFU.

Tall wood structures have many challenges that need to be overcome prior to construction. The greatest challenges include public perception and gaining acceptance with local code authorities. The most significant issues that need to be addressed to achieve this acceptance are fire safety, building movement, and durability. Wood is more sensitive to moisture than concrete or steel, especially during construction if not properly protected. This is where the integration of building enclosure and façade elements come into play. On Tall Wood Buildings in North America, the integrated design and erection of the building enclosure and façade components to protect mass wood structure during construction is critical to the economics, durability and overall success of these buildings. This is where the notion of a race to the top arises – build the structure fast, but build the enclosure just as fast to protect the wood structure and take full advantage of the time saving benefits of a prefabricated building.

Wet West Coast Challenges

The Pacific Northwest of Canada and the US is a temperate rainforest climate where persistent rain is expected for most of the fall, winter and spring months. In this climate, construction can proceed 12 months per year due to relatively mild temperatures. In this region, tall buildings are typically constructed of cast in place concrete that is poured year-round without the need for hoarding and heating. Building facades are installed in a vertical assembly line many floors below the concrete operations typically using moisture tolerant unitized curtain wall, window wall or steel stud assemblies. During construction, it is common for water to wet the structure and façade systems during and after installation from both the interior and exterior as rainwater flow is managed inside the building.

On tall wood buildings, mass timber elements including CLT, NLT, glulam, and other engineered components absolutely need to be protected from excessive wetting during construction. This requirement precludes the use of many conventional cladding systems unless the building is fully hoarded during construction. On buildings such as UBC Tallwood House, where scaffolding and hoarding is not practical or economical, the following risk mitigation strategies can be employed to help prevent heavy timber components from getting wet during construction:

1) Build and enclose very rapidly during the summer dry season;

2) Pre-protect heavy timber elements with appropriate membranes;

3) Prefabricate enclosures for quick installation;

4) Install factory finishes or coatings to reduce water absorption;

5) Employ an effective construction site water management plan.

NLT as a floor and roof panel is particularly challenging in rainy and damp coastal environments due to the tendency for the nailed framing to swell when wetted. The Nail Laminated Timber Design Guide recently published by the Binational Softwood Lumber Council (2017) provides practical guidance on avoiding these problems with considerations for climate and assembly design. CLT can handle wetting much better than NLT as it does not swell along the length or width, however, research and field experience over the past few years strongly suggests that panels should be coated with a factory applied water repellant, particularly at the edges and exposed end grain to reduce the amount of wetting during construction. If NLT or CLT gets too wet during construction, it will take significant time for the wood to dry out and this can result in costly construction delays.

Simple design strategies that allow wood that is wetted during construction (or could become wetted in-service due to leaks) the ability to dry out go a long way in making these buildings more durable. On WIDC, the roof system was installed over strapping over the CLT roof beams and open to the interior above the mass timber structure. When the plywood was wetted during construction as a result of snow melt, it was easily and quickly dried out from the interior by moving interior air between the plywood roof sheathing and the CLT beams.

Prefabrication and Detailing of the Façade

The two key differences that need to be considered early in design for tall wood buildings which are unique from other building types are summarized as follows:

1) **Need for Speed**

The building enclosure for larger and taller mass timber buildings should be erected and sealed water-tight as fast as possible following the erection of the wood structure. This necessitates the use of offsite prefabrication and minimal site work to prepare for installation of wall and roof panels. In addition, materials used within the enclosure panels, whether they be structurally fabricated of wood, steel, or concrete need to be accommodating of inclement weather and tolerant of moisture during construction. Pre-installation of windows and thoughtful design of panel joints and interfaces for ease of sealing is therefore crucial.

2) **Ensure Durability**

Materials used within the building enclosure need to be robust and essentially "high-rise appropriate." Given the potential short- and long-term vertical expansion/contraction and lateral drift of the wood structure, they also need to be more tolerant of movement. Thermal efficiency is necessary for code compliance as is the use of non-combustible materials. Wood structural components can be just as durable as steel or concrete when properly protected and have the added benefit of being more thermally efficient when bypassing installed insulation.

UBC BROCK COMMONS TALLWOOD HOUSE – WORLD'S TALLEST WOOD BUILDING

The building enclosure and façade of UBC Tallwood House consists of an innovative prefabricated steel stud rainscreen curtain-wall assembly that is pre-insulated, pre-clad, and has factory installed windows. Design of connections and air and water sealing of panel joints and interfaces was carefully considered given the tall wood structure they were designed to protect. While steel studs were utilized in the panelized structure, feasible curtain-wall designs were also developed and prototyped for wood-framing, CLT, and precast concrete as part of the project.

During the early schematic design phase for the UBC Tallwood House, the following criteria were outlined by the design and construction team for the façade system:

- A panelized façade that could be installed and sealed air and water tight at a pace of one floor per day.

- A durable moisture tolerant panel with windows pre-installed that could be installed and sealed without access to the exterior side.
- A wall assembly that met the current energy code target (R-16 effective) but could easily be scaled up if needed to meet more aggressive overall building energy performance targets.
- Be constructed of non-combustible materials or where wood is used, meet fire code requirements.
- Economical, and for this project, an installed cost of less than $50/square foot, which locally at the time was in line with pre-cast sandwich panel and aluminum window-wall systems.

With these criteria in mind, various prefabricated wall panel design options were explored for the project. These included both a bottom bearing small panel option which could be installed using small hoists installed like a window wall, and a larger top-hung curtain-wall panel option with preinstalled punched windows mounted using the site crane. A costing and scheduling assessment of both panel concepts by the construction team favored the larger panel option given the anticipated installation of the structural members and the significantly reduced level of slab edge preparation and membrane work required.

Given the preference for a larger hung prefabricated panel, the architectural design of the façade proceeded with this concept and aesthetic. The next step in the design process was to select a structural system for the panels and work with a local contractor to design a façade system to meet the project criteria. To spur design innovation and in the spirit of competition, three sub-contractors were tasked with the design and mock-up construction of a wood-frame/CLT, steel-stud, and pre-cast sandwich panel. Each team fully designed their panel, installed a set of panels on an offsite mock-up and submitted a tender for their system. Ultimately the exterior insulated steel stud backup wall was selected as it met the project criteria and budget.

Once the steel stud unitized curtain-wall approach was selected, the design was finalized and a full scale Performance Mock-up (PMU) was constructed and tested for assembly time, air, water, structural, seismic drift/deflection and condensation performance. The performance mock-up testing identified improvements to panel connections, windows, air and water seals, and corner panel connections. The panel cladding was also changed from light gauge steel to a high-pressure wood-fiber laminate for aesthetic reasons. The mock-up was installed in a record 60 minutes and is the fastest PMU installation that the authors have ever witnessed.

Upon the successful completion of the performance mock-up, full scale assembly of the panels was started in the manufacturer's facility.

During the summer of 2016, 24 prefabricated panels per floor were successfully installed at a speed of two floors per week (instead of the initially anticipated 1 floor per week), closely trailing the CLT floor and glulam column structural system. The strategically designed panel joints were sealed from the building interior following panel installation and tolerances were such that these panel joints are difficult to distinguish from other cladding joints. After the building was closed in and the roof installed, additional batt insulation within the stud cavities was installed followed by a vapor barrier membrane and drywall. Onsite commissioning was performed to confirm that the panel and window air and water tightness met project performance specifications. This fast and simple installation of the prefabricated panel system allowed the structure and façade of the world's current tallest modern wood building to be installed in a record breaking 9 weeks and contributed to the overall success of this project.

Onward and Upwards

Looking ahead, there will continue to be innovation in design and construction of fast and durable facades for taller wood buildings. New prefabricated panel designs incorporating CLT panels and connection technologies from unitized curtainwall systems are already being developed for the "next tallest" wood buildings in North America.

REFERENCES

Binational Softwood Lumber Council. 2017. Nail Laminated Timber – U.S. Design and Construction Guide v1.0.

Finch, Graham. 2016. "High-Rise Wood Building Enclosures" Proceedings from ASHRAE Buildings XIII Conference, Clearwater Beach, Florida, December 2016.

Cad Makers 4D construction sequence: https://www.youtube.com/watch?v=ATKpFtzCVFUPaper Title