Title: **New Heights for Renewables: The US Tall Wood Building Competition**

Authors: Thomas Robinson, Founder/Principal, LEVER Architecture
Anyeley Hallova, Partner, project^
Jeff Spiritos, Principal, Spiritos Properties LLC
Michelle Roelofs, Senior Engineer, Arup

Subject: Architectural/Design

Keyword: Timber

Publication Date: 2016

Original Publication: CTBUH Journal, 2016 Issue I

Paper Type:
1. Book chapter/Part chapter
2. **Journal paper**
3. Conference proceeding
4. Unpublished conference paper
5. Magazine article
6. Unpublished

New Heights for Renewables: The US Tall Wood Building Competition

Thomas Robinson

Anyeley Hallova

Jeff Spiritos

Michelle Roelofs

Authors

Thomas Robinson, Founder/Principal
LEVER Architecture
239 NW 13th Avenue Suite #303
Portland OR 97209
United States
t: +1 503 453 5939
f: +1 503 766 6990
e: thomas@leverarchitecture.com
www.leverarchitecture.com

Anyeley Hallova, Partner
project^
413 SW 13th Avenue, Suite #300
Portland OR 97205
United States
t: +1 503 922 0056
e: Anyeley@projectpdx.com
www.projectpdx.com

Jeff Spiritos, Principal
Spiritos Properties
276 Riverside Drive
New York NY 10025
United States
t: +1 917 453 2288
e: jspiritos@yahoo.com

Michelle Roelofs, Senior Engineer
Arup
77 Water Street
New York NY 10005
United Staes
t: +1 212 896 3000
e: newyork@arup.com
www.arup.com

In a continuing effort to support the Obama Administration's climate strategy, the United States Department of Agriculture (USDA), in partnership with the Softwood Lumber Board and the Binational Softwood Lumber Council, announced the US Tall Wood Building Prize Competition in October 2014. The competition aimed to promote the architectural and commercial viability of engineered mass timber products in tall buildings in order to support employment opportunities in rural communities, maintain the health and resiliency of the nation's forests, and advance sustainability in the built environment. Two projects, one in New York City and the other in Portland, Oregon, won the competition. This paper chronicles the early design stages of both projects.

Introduction

The competition's request for proposals called for entries by December 2014, and submissions needed to propose a project that would be eight or more stories tall and addressed the following criteria:

- Project specifics and details
- Business case for project
- Proposed wood solution
- Sustainability
- Rural economic ties

The winners of the competition, 475 West 18th in New York City and Framework in Portland, Oregon, are scheduled to receive US$1.5 million for the incremental costs of pioneering wood construction techniques, including manufacturer research, incremental design efforts, materials testing, and building code compliance. The competition requires that the winning project team attempt to source a share of the structural timber materials from rural manufacturers and sustainably managed forests in the United States, in order to promote environmental stewardship and economic development.

Project Genesis

475 West 18th

The owner of the project site, 130–134 Holdings, is working with development manager Spiritos Properties; SHoP Architects; Arup as the structural, fire, and acoustic engineer; and Atelier Ten as the sustainability consultant, to manifest a uniquely distinctive building on a prominent corner of West

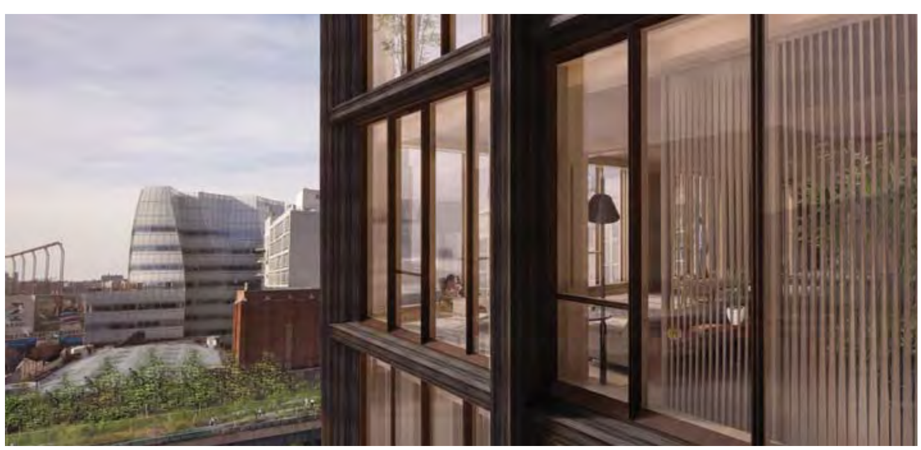

Figure 1. 475 West 18th exterior corner detail, with the High Line Park behind. © SHoP Architects

Chelsea, opposite the forthcoming main entry to the High Line Park (see Figure 1). As the neighborhood surrounding the High Line has come to be known for its high-end architecture, a plan was developed for an innovative condominium of luxurious homes, designed to minimize its carbon footprint through tasteful and environmentally responsible material and system selection. The decision to build tall in timber stems from the team's objective of environmental responsibility, and a belief that this new paradigm for urban construction might appeal to people who want to make their homes in a setting where climate consciousness is an evident priority. The team was intrigued that wood, a natural and renewable material, was increasingly being used as an alternative to steel and concrete in the form of structural Cross-Laminated Timber (CLT) and Glue-Laminated Timber (Glulam). As an emerging building material of the 21st century, mass timber represents the missing piece in the construction of a healthy building, in which energy-efficient systems are already commonplace.

Framework

Beneficial State Bancorp teamed with project^, a values-based real estate developer, and Home Forward, an affordable housing provider, to reenvision their existing Pearl District property in Portland, Oregon into Framework, one of the nation's first wood high-rise structures (see Figure 2). The building seeks to develop a model for a sustainable urban ecology by promoting social justice, environmental responsibility, and economic opportunity, thus yielding a broad advancement of these objectives at a national scale. This is achieved both during construction and through the programming of the building with affordable housing; office spaces for B-corporations (a type of for-profit corporation that has legally defined goals of societal and environmental benefit); a tall wood building exhibit; and retail uses that complement its residents and tenants.

The building is intended to promote a virtuous cycle from "forest to frame," in which tall wood buildings drive more wood products and wood product innovation from sustainably managed forests, thus boosting rural economic development, which in turn supports the health of cities.

This structure is complemented by the fact that the Pacific Northwest region has deep ties to wood products and their development. Projects using mass timber products are receiving both City of Portland and State of Oregon support.

Site and Climate

475 West 18th

475 West 18th is located directly in the center of Manhattan's West Chelsea neighborhood, rezoned in 2005 by the New York City Department of City Planning to be a mixed-use manufacturing (largely art gallery/commercial office space) and residential area. New construction was to be concentrated along the long-dormant High Line elevated rail line. Redeveloped and opened in 2009, the High Line is now established as a highly successful urban landscape lined with a number of prominent buildings. Most new buildings in the West Chelsea zoning district are limited to a 36.6-meter maximum height, usually accomplished in 10 or 11 stories.

New York's climate has four full seasons, is somewhat moist in spring (with rain) and winter (with snow) and temperatures range from upwards 32ºC in summer to below freezing in winter. It is not dissimilar to some routinely cold and wet climates in Europe, where tall timber buildings are more

Figure 2. Framework, Portland. © LEVER Architecture

common. As wood is a natural material that retains a degree of moisture, considerations must be made with respect to weatherproofing during delivery and erection in order to control its behavior and thus, its visual performance.

Framework

Framework is located in the heart of the Pearl District, an area formerly occupied by warehouses and light industry. Undergoing significant urban regeneration for the past 20 years, the district is now known internationally for its upscale businesses and residences, and is home to several Portland icons, such as Powell's City of Books, the Brewery Blocks, and notable public parks.

Portland has a strong reputation as a well-planned city where public transit plays an integral role in the lives of residents, visitors, and tourists. The construction of the streetcar system in the Pearl District has contributed to mixed-use and high-density development over the past decade. The site itself sits at a streetcar stop. The city's small

> "The decision to build tall in timber stems from the team's objective of environmental responsibility, and a belief that this new paradigm for urban construction might appeal to people who want to make their homes in a setting where climate consciousness is an evident priority."

Figure 3. 475 West 18th interior concept showing exposed columns, beams, and ceiling. © SHoP Architects

61-square-meter blocks allow for more corners, making for a pedestrian-oriented environment and creating opportunities to showcase prominent buildings. Complementing its position as a leader in urban planning, Portland is also a leader in sustainable architecture. A building with the proposed program is highly desired in the district and would be constructed on the site of the existing Albina Community Bank, which will be relocated back into the building when the project is complete.

Portland experiences all four seasons, but none of them are extreme. The city has very high rainfall activity; thus the design team will focus on the control of rainwater penetration in exterior walls. The Framework team also has to account within its structural design for potential seismic activity.

Design Concept

475 West 18th

475 West 18th will be a 10-story, 36.6-meter-tall luxury residential condominium building with commercial retail space on the ground floor. The lower six residential floors have two apartments per floor, consisting of two- and three-bedroom units, while the top three floors, after a required building setback, will have full-floor three-bedroom units. The apartments will feature exposed columns, beams, and ceilings in the living rooms and bedrooms (see Figure 3), and timber-structured balconies to connect homeowners to the natural beauty and warmth of wood. The team has committed to creating a healthy building through an airtight façade; energy-efficient electrical, mechanical, and plumbing systems; and non-toxic materials.

The structure consists of a post-and-beam gravity system with a shear wall lateral system, utilizing engineered timber for both the gravity and lateral systems beginning at ground level, above a concrete cellar (see Figure 4). The beams and columns consist of glue-laminated (glulam) timber with steel connectors concealed beneath the surface in order to provide resistance to structural loads and fire, and to support municipal structural integrity requirements, while maintaining a seamless design. The beams support an approximately 305-mm thick floor system comprised of a CLT floor slab topped with an isolated concrete topping, radiant heating, and hardwood floor finish. The CLT spans one-way across the beams and the concrete topping provides additional mass and sound deadening to enhance the acoustic performance of the floor buildup, as well as a pathway for electrical services. The lateral loads are carried by the CLT panels surrounding the central circulation core and forming the north and east perimeter walls. As CLT shear walls are not currently defined in the NYC Building Code as a lateral force-resisting system, the project team is using performance-based seismic engineering to validate the design.

Framework

Framework will be a 12-story, 39.6-meter-tall mixed-use office, retail, and affordable housing building with a roof deck on the top floor and a publicly accessible tall wood exhibit on the ground floor. Framework's design is intended to reveal the nature of the innovative tall timber structure at street scale and the larger city skyline. The building mass is split around a central vertical core and lifted to the south to create a double-height, daylit community space that showcases the core structure and brings the main entries of the retail, housing, and office spaces together.

Double-height glulam wood columns and an exposed CLT ceiling frame this space and also connect to a second-floor green terrace facing south. Daylit stairs bookend the east and west sides of the building core and provide glimpses of circulation and the nature of the innovative wood structure from a distance. The roof deck and amenity spaces are framed by the primary wood columns, which extend the expression of the tall wood structure into the skyline. The ceilings of the apartments are intended to show the exposed underside of the CLT floor panels above, with building services grouped around "cores" that stack through the building mass.

Special Challenges

There are a handful of special challenges to building tall timber in the United States. The following describes in greater detail some of the initial challenges faced by the two teams, including fire safety design, public

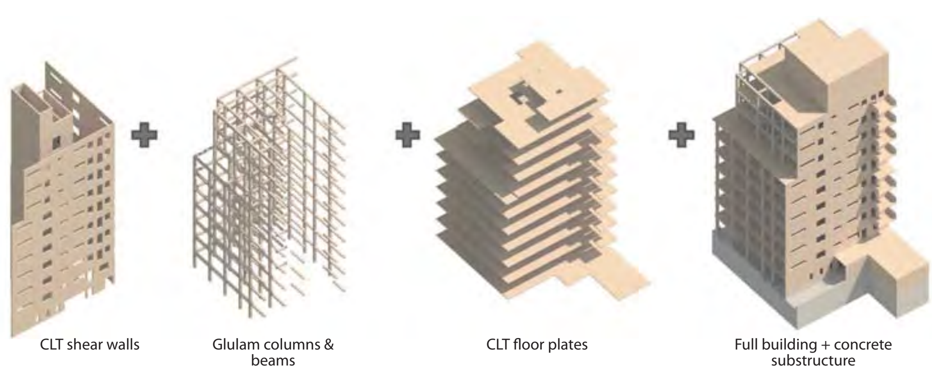

Figure 4. 475 West 18th structural concept. © Arup

perception, aesthetic, supply chain, and seismic challenges.

Fire safety design challenges

Mass wood buildings have been constructed in the United States for more than 100 years, with structural building elements providing fire resistance through wood's natural ability to slowly char and retain strength when exposed to fire. The inherent fire resistance of mass wood is particularly applicable to tall buildings and distinctly different from light wood-frame members. Wood buildings that utilize mass wood products such as glulam and CLT can be designed with fire-resistance ratings of two hours or more, without relying on additional passive protection. Engineered wood products have fire properties that have been very well researched and understood, with numerous fire tests undertaken in North America, so that they can be used as building materials.

Fire safety for a tall building is an important design consideration, and for a wood building of 10 stories or more, code compliance can be a barrier to construction in the United States. The challenge for both 475 West 18th and Framework is that wood construction is limited to only six stories, by both the Oregon state and New York City building codes, consistent with national codes in the United States.

Thus, to construct a high-rise building in which the primary structure is wood requires approval of an engineered approach, whereby construction materials can be considered for use and approved by the building authority based on the evidential documentation submitted.

As a high-rise building, defined in the code as a building with an occupied floor located more than 23 meters above the lowest level of fire department vehicle access, 475 West 18th falls under the category of Type 1-B construction and must meet the associated fire resistance ratings (FRR). For exposed timber elements, fire resistance is achieved by increasing the surface dimensions to include a sacrificial char layer (see Figure 5). The beams and floor slabs will have a two-hour FRR and the columns which are sized based on charring rates will have a three-hour rating. The CLT shear walls will meet a two-hour FRR through encapsulation with gypsum board.

The process for approval differed for the two buildings. 475 West 18th was reviewed by the New York City Department of Buildings, and Framework was reviewed by the Oregon State Building Codes Division. Local fire department representatives have also been involved in discussions and documentation review.

The review process for both buildings is currently underway, with the submission of detailed design reports and drawings, regular round-table discussions, and questions forming part of the review process. The documentation required for each building varies, but will be based on historical fire test information and specific evidential fire test reports. Each will include details related to fire risk during construction, fire spread from penetrations, fire resistance of connections, and exposed wood's influence on room fires. The buildings' fire safety is enhanced with compliant means of egress, fire protection systems including detection and suppression, protection for fire spread to neighboring buildings, and compliant firefighting access and facilities.

Public perception challenges of 475 West 18th

There are a handful of special challenges to building tall in timber in New York City. Perhaps the largest is the public perception that wood buildings are unsafe in fire and structurally unstable. This perception stems from the performance characteristics of light-frame timber construction, from which two-to-six-story buildings have been built in urban and suburban settings for the past half-century. This building type is constrained by its typically thin wood elements and the limited capacity to withstand gravity, shear, and seismic loads above six stories in height. Heavy timber is in many ways a material unto itself, as it has excellent tensile and compressive properties, and a self-protecting char layer resists progressive deterioration in fire.

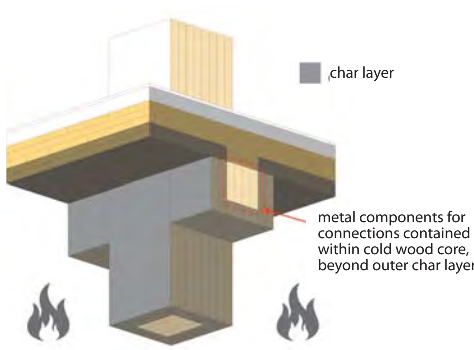

Figure 5. Structural assembly with char layer. © Arup/SHoP Architects

This public perception is starting to erode due to precedent-setting tall timber buildings constructed in the past 10 years outside the United States and the ongoing fire and structural testing that demonstrate the safety of a well-designed tall timber structure. Nonetheless, New York City and US building codes have yet to be updated to include mass timber as a structural material for high-rise construction, thus preventing timber construction above six stories.

The design team for 475 West 18th is in the process of applying for a variance for the building's structure, founded on a performance-based design. The team must demonstrate sound design and engineering of timber elements through fire and structural testing and expect to achieve a safety level that meets or exceeds code.

Aesthetic challenges of 475 West 18th

The decision to expose the wood presents a second challenge relating to the aesthetic of the timber structure. In the 475 West 18th project, the wood columns, beams, and undersides of floors, which constitute the ceilings, are to remain exposed in the apartments' living rooms and bedrooms, out of a desire to reveal the structure and connect owners with the warmth and serenity that emanates from this material. The challenge will be to select the highest-grade raw material to capture the desirable visual features of the wood and finish the exposed elements with meticulous detailing to suit the luxury design expectation. Based on meetings with CLT and glulam manufacturers, the design team is confident that the heavy-timber market is up to this challenge.

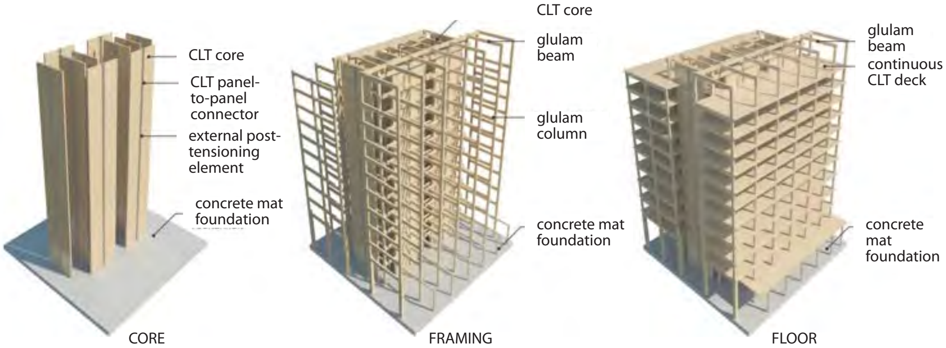

Figure 6. Framework 3D model. © LEVER Architecture

Seismic challenges for Framework

Most of the tall wood buildings constructed around the world to date have been residential buildings, located in non-seismically active regions.

Lateral resistance has typically been provided by a "honeycomb" of interior bearing CLT walls. The Framework project is unique; it is in an active seismic region and is a mixed-use building, requiring large open floor plates for the office spaces. Despite this, the team is aiming to maintain an all-wood solution.

The gravity framing is a relatively simple glulam post-and-beam structure surrounding a central core topped by CLT floor panels and gypsum concrete topping (see Figures 6 and 7). The beam-to-column and column-to-column splice connections are all custom-concealed. In addition to achieving the required fire rating, the connections must be capable of withstanding the larger inter-story drifts associated with tall buildings in seismically active regions.

The real ingenuity of the structural design is in the lateral force-resisting system. When exploring potential lateral systems for this project, the team evaluated a concrete core option, a mass timber core option, and a post-tension rocking CLT shear-wall option. The last option was chosen, as it best met the sustainability goals of the project. Not only is it an all-wood solution, but the system integrated "Low-Damage Design" concepts pioneered in New Zealand (Canterbury Earthquakes Royal Commission 2012). The goal of this concept is to exceed the basic code-level life-safety performance objective by achieving a resilient and easily repairable solution, thus avoiding the potential need to tear down the building following a design-basis earthquake.

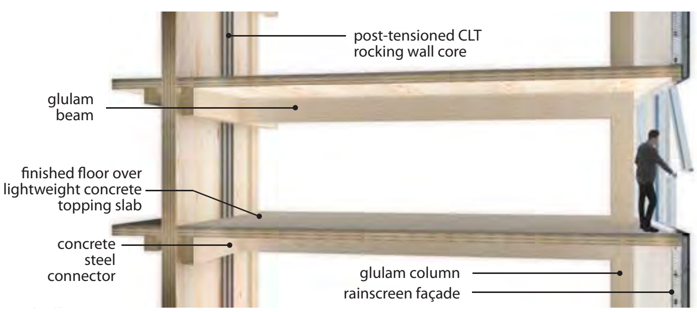

Figure 7. Framework glulam beam and rocking CLT wall connection. © LEVER Architecture

> "The goal of the 'Low-Damage Design' concept is to exceed the basic code-level life-safety performance objective by achieving a resilient and easily repairable solution, thus avoiding the potential need to tear down the building following a design-basis earthquake."

The post-tension rocking CLT shear-wall option builds on existing precast post-tensioned rocking-wall systems, which are some of the most-tested lateral systems available. This research has led to precast post-tensioned rocking-wall systems being codified through ACI ITG-5.1-07 (ACI 2008). The real benefit of this system is that the rocking occurs on a predetermined plane at the base of the wall, eliminating the cracking and strain hardening of reinforcing steel seen in traditional concrete shear wall systems. Damage is limited to ductile energy-dissipating devices, which occur either in the form of mild steel bars at the base of the wall, or through U-Shaped Flexural Plates (UFPs) between coupled walls or bounding columns (see Figure 8). These "fuses" can be detailed in such a way that they are easily replaceable following a major seismic event.

The lateral force-resisting system for the Framework project is specifically intended to emulate the Precast Wall with End Columns (PreWEC) rocking wall system (Sritharan et al. 2015), which includes post-tensioned thread bars located at the center of the wall and UFPs located between the CLT wall and bounding glulam columns. "Collar" beams connect the glulam columns, supporting the floor, and allowing the CLT walls to slide vertically past the floor system. This eliminates the potential for damage at the floor-to-wall connection, in keeping with the Low-Damage Design philosophy. There are unique challenges adapting this system for CLT wall systems, but the concept is the same.

As the building height and lateral system are not within the prescriptive bounds of the International Building Code, the Framework project is taking advantage of the "Alternate

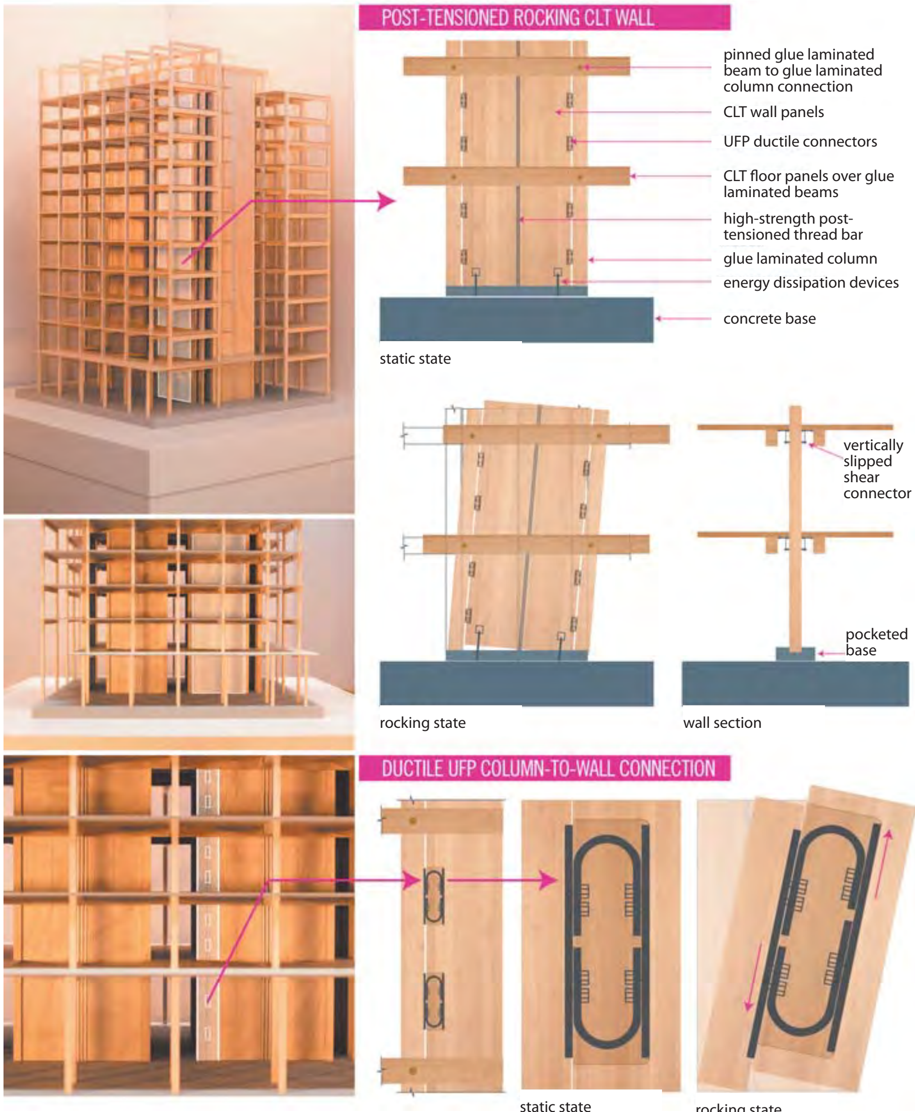

Figure 8. Framework post-tension rocking CLT shear-wall. © KPFF

Materials & Methods" path allowed within the code in order to realize this project (ASCE 2010). In this case, this path includes a performance-based design utilizing non-linear response history analysis. This process also includes an independent review, conducted by a team consisting of a qualified registered structural engineer, academic, and seismologist. Component-level testing will also be completed to validate the existing research and testing completed on precast post-tensioned rocking walls systems, along with recently completed test conducted by the National Science Foundation/Network for Earthquake Engineering Simulation and the Colorado School of Mines (Pei et al. 2014).

Next Steps

For 475 West 18th, completion is expected by September 2016, with required fire testing taking place over several months starting in early spring 2016. Concurrently, an official offering plan must be submitted and approval must be obtained from the New York State Attorney General to sell apartments, which is standard procedure for the formation and sale of condominiums.

In Portland, the Framework team intends to start construction in October 2016 and complete construction in November 2017. The project is currently running according to schedule. Potential challenges the team foresees include confirming the supply chain and testing wood materials in enough time to meet the schedule.

Conclusion

475 West18th and Framework provide great promise for paving the future pipeline of tall wood buildings in the United States.

Situated on both coasts, they demonstrate the variety of programming in a tall wood building, as well as the unique challenges inherent to their locations, from weather, to seismic activity, to different methods for addressing structural and fire/life safety issues. With two rigorous jurisdictions in New York and Oregon, the projects will indeed provide the demonstration and affirmation needed for other local projects to follow suit. ■

Acknowledgement

The team acknowledges the editorial contributions of: David Barber, Principal and Fire Engineer Consultant, Arup; Eric McDonnell, Structural Engineer, KPFF; and Amir Shahrokhi, Project Director, SHoP Architects PC.

References

AMERICAN CONCRETE INSTITUTE (ACI) INNOVATION TASK GROUP 5. 2008. ***ITG-5.1-07 Acceptance Criteria for Special Unbonded Post-Tensioned Precast Structural Walls Based on Validation Testing.*** Farmington Hills: ACI.

AMERICAN SOCIETY OF CIVIL ENGINEERS (ASCE). 2010. ***ASCE/SEI 7-10 Minimum Design Loads for Buildings and Other Structures.*** Reston: ASCE.

CANTERBURY EARTHQUAKES ROYAL COMMISSION. 2012. ***Final Report, Volume 3 Low-Damage Building Technologies.*** Christchurch: Canterbury Earthquakes Royal Comission.

PEI, S.; BERMAN, J.; DOLAN, D.; VAN DE LIND, J.; RICLES, J.; SAUSE, R.; BLOMGREN, H.; POPOVSKI, M. & RAMMER, R. 2014. "Progress on the Development of Seismic Resilient Tall CLT Buildings in the Pacific Northwest." In ***Proceedings of the 2014 World Conference on Timber Engineering***, Quebec City: 10–14.

SRITHARAN, S.; AALETI, S.; HENRY, R.; LIU, K. & TSAI, K. 2015. "Precast Concrete Wall with End Columns for Earthquake Resistant Design." ***Earthquake Engineering & Structural***