Building Blocks

updates and information on structural materials

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Height and Area Considerations for Commercial Wood Buildings

By Paul D. Coats, P.E., C.B.O. and Dennis Richardson, P.E., C.B.O.

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Wood buildings have economic, aesthetic, green, and structural attributes that make them a good choice for commercial buildings. However, perceived barriers have made designers reluctant to choose wood for large buildings, like building code limitations and the challenge to meet structural capacities. Fortunately, codes are shifting to accommodate new technology that, in turn, is permitting wood structures of sizes and heights heretofore unthinkable.

Fewer Size and Use Limits

Since the inception of the *International Building Code* (IBC), wood frame commercial structures have enjoyed larger building sizes inherited from the upper limits of each of the legacy building codes. Although certain uses and occupancies retain traditional size restrictions, limits for many low-rise buildings are nearly gone, given area increases permitted for sprinkler systems and open space around the building perimeter. In the IBC, one and two-story business and mercantile buildings can be unlimited in area when sprinklered and at least 60 feet of open space is provided on all sides of the building. Currently, even single-story assembly occupancies of Type IV (Heavy Timber) or Type III construction (typically wood frame with noncombustible or fire retardant treated wood exterior walls) are permitted to be unlimited in area under fairly standard conditions.

It has been suggested that building size limits are unnecessary if compartmentalization is provided to address fire resistance. An appendix in the *NFPA 5000 Building Construction and Safety Code* provides an alternate approach to construction types based on compartmentalization with fire resistance rated construction rather than the traditional building size limits.

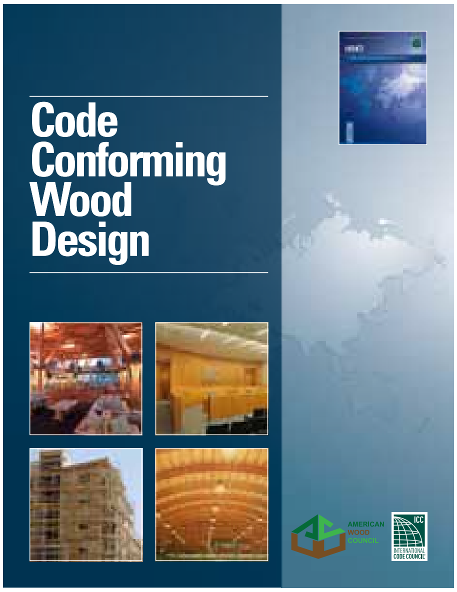
Case Study

Project: Union Square Condominiums
Location: San Diego, CA
Architect: Togawa Smith Martin, Inc.
Engineer: Edmond Babayan and Associates
Size: 263 condominium units
Completion Date: 2005

Architects for the Union Square condominium project in San Diego made use of code provisions to increase the height of the project by adding two levels for residential use. First, utilizing IBC Section 505, designers added a mezzanine, which increased the number of wood-frame levels to six. Second, since the project was not located in a retail neighborhood, the Type IA concrete level at grade was designed to incorporate residential "stoop units," each with access to the street. The building was thus able to achieve seven levels of residential use with a density of 143 units per acre.

Height Considerations

The IBC has for some time permitted wood buildings to be nearly as tall as structural design considerations will allow them to be. The use of fire retardant treated wood (FRTW) in exterior walls, permitted by the IBC in Type III and Type IV Heavy Timber construction, enables



buildings entirely of wood to expand beyond low-rise into the mid-rise market. Type IIIA buildings (two hour exterior walls, either noncombustible or FRTW, and one-hour light frame interior structure) can go 85 feet above grade in a sprinklered building. Business occupancies could be six stories; mercantile, apartments, and condominiums can be five stories of wood frame construction, with one or more additional stories if they take advantage of special occupancy provisions for pedestal buildings.

However, code height limits are often not the determining factor in choice of materials – there are engineering considerations for taller structures such as structural performance and detailing for wood shrinkage. In recent years, wood has taken a giant leap toward becoming a preferred structural choice for tall buildings with the introduction of Cross Laminated Timber (CLT). The IBC and NFPA 5000 have already changed to allow for the use of CLT.

Case Study

Project: Promega GMP Facility
Location: Fitchburg, WI
Building design: Uihlein-Wilson Architects; EwingCole; Archemy Consulting
CLT Engineer: Equilibrium Consulting Inc.
Size: 260,000 square feet
Completion Date: October 2012

Building codes are flexible enough to accommodate new materials, and it is common for building projects to require – and be granted – alternate methods approval for designs not in the code that can be justified on a case-by-case basis. Such was the case for the new Promega biotechnology production facility, which features an innovative mix of glulam and CLT.

Building department approval was achieved through use of the newly completed ANSI/APA PRG 320-2011 *Standard for Performance-Rated Cross-Laminated Timber*. "The design team discussed the standard with building officials early in the process," says Kris Spickler of StructurLam Products Ltd. "Engineering information was then submitted under the "alternate designs" section of the code. IBC Section 104.11 states that 'An alternative material, design or method of construction shall be approved where the building official finds that the proposed design is satisfactory and complies with the intent of the provisions of the code.' Local building officials accepted both the ANSI/APA standard and the design."

Most of the new Promega facility will be dedicated to manufacturing with committed (fixed) production lines and flexible manufacturing areas. It will also feature a customer experience center for employees and guests that will include spaces for training, laboratory demonstrations, conferences, an exercise and fitness center, and dining.

The 260,000-square-foot Promega biotechnology production facility, completed in October 2012, is dedicated to manufacturing with committed (fixed) production lines and flexible manufacturing areas.

The Promega biotechnology production facility features an innovative mix of glued laminated timber and cross laminated timber.

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Recent Code Changes Accommodating Greater Heights

Sometimes referred to as "plywood on steroids," CLT typically consists of three, five, or seven layers of solid wood, kiln-dried and layered as perpendicular laminations bonded with adhesives to create full-depth solid wood wall and floor panels up to 12 feet by 60 feet. In the most recent code change cycle, CLT was given a place in IBC Type IV construction provisions, and a new product standard, *ANSI/APA PRG 320-2011* Standard for Performance-Rated Cross-Laminated Timber was referenced. Leading wood organizations have collaborated to publish a new *CLT Handbook* which can be downloaded at **www.masstimber.com**.

A building constructed entirely of CLT is intriguing, but other changes in the 2015 IBC may also affect the choice of wood in tall hybrid buildings, including:

- The 2015 code will permit wood to "top" multi-story Type I concrete or pedestal "podiums." Currently, special podium building provisions limit Type I construction to a single story. The code currently allows multiple separate buildings over the top of a Type I podium.
- Occupancy restrictions for the lower levels of special Type I "podium" buildings are eliminated in the 2015 code so that any occupancy permitted by the code except Hazardous (H) can be located in the podium itself. This follows a change to the 2006 IBC (appeared in the 2009 IBC) which had expanded the possibilities for occupancies in the podium from S-2 parking only to include B, M, and R occupancies.
- Minimum sizes for Structural Composite Lumber (SCL) will be included in descriptions for Type IV

Structural "Brainstorming" with CLT

CLT is formed of laminated nominal 2x wood members with alternating layers in perpendicular directions. It forms a robust structural billet that can be well adapted for walls (similar to tilt-ups) or prefab floor and roof slabs.

One published concept for a thirty-story high rise using CLT and other building materials in a hybrid framing system involves the use of the strong column (or wall), weak beam approach. *The Case for Tall Wood Buildings* by Michael C Green and J. Eric Karsh can be downloaded here: **www.woodsolutions.com.au/Blog/the-case-for-tall-wood-buildings**. This system utilizes high aspect ratio CLT wall piers (or columns) connected to specially detailed steel link beams for energy absorption and ductility. A similar system using ductile connections to wood link beams may also be effective for energy absorption, and could be a very robust system. The weak link in such wood frame systems has been crushing of wood perpendicular-to-grain at the column/beam joints. However, CLT has the unique advantage of providing parallel-to-grain bearing in two directions, thus the ability to minimize this problem.

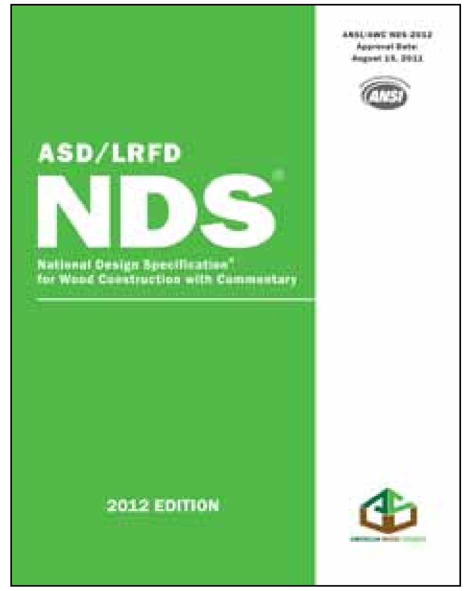
One of the many challenges facing the broad acceptance of CLT in the U.S. is the lack of codified seismic design provisions. The International Building Code references ASCE 7 *Minimum Design Loads for Buildings and Other Structures*, which provides comprehensive requirements for seismic design. For example, Section 12.2.1 of ASCE 7 provides guidance on the selection of Response Modification Coefficients, R, for various Seismic Force-Resisting Systems (SFRS). CLT is not a recognized system in ASCE 7 Table 12.2-1; therefore, designers must rely on other provisions of the standard. ASCE 7 Section 12.2.1 states "SFRS not contained in Table 12.2-1 are permitted provided analytical and test data are submitted to the authority having jurisdiction for approval that establish their dynamic characteristics and demonstrates their lateral force resistance." Until an R is recognized in ASCE 7, expected compliance pathways for CLT designs include performance-based design procedures described in ASCE 7, or demonstrating equivalence to an existing ASCE 7 system. Guidance for such evaluations can be derived directly from ASCE 7-10, FEMA P695, and FEMA P795 *Quantification of Building Seismic Performance Factors: Component Equivalency Methodology*.

Construction next to glulam, enabling the incorporation of large dimension SCL members in Type IV buildings without special approval.

- Fire resistance rating requirements for building elements and structural members bracing exterior walls will be simplified to preclude code interpretations that currently result in substantially increased requirements for fire resistance rating of interior elements.

Taken together, these code developments will make it easier for design teams to take advantage of current building height limits. Here are some potential design concepts that previously may have been more difficult from a code standpoint:

- Heavy timber or Type IIIA light frame apartment buildings over heavy timber open parking garages has been allowed by the IBC for years, but now SCL and CLT will be permitted in Type IV parking podiums. This would allow an 85 foot tall, six story structure with five stories of apartment over one story of open parking.
- CLT will be a possible solution for future fire wall construction; a CLT wall assembly with gypsum recently exceeded three-hours in a fire resistance test (see NGC Testing Services Test Report WP-1950 dated October 15, 2012). Currently, buildings can be subdivided by fire walls to create separate buildings for code purposes, but fire walls built out of combustible framing materials are limited to type V construction. The impressive three hour performance of a CLT test wall may now allow code officials to consider approval of CLT as a fire wall in Type III and Type IV Heavy Timber construction. This means one CLT open parking garage podium structure could potentially support multiple wood frame residential buildings, each remaining within required area limits.
- With removal of the one story limit and expansion of use and occupancy designations in buildings with a Type I podium, a variety of uses, including high occupancy assembly (with the



associated taller story configuration), could be located in one area of the podium with two or more lower-height stories of parking adjacent in the perimeter areas of the podium to fill in the remainder of the site.

What about Concerns for Fire?

Fire has always been a concern for combustible construction, and the use of wood in taller buildings will need adequate protection. A key concept for codes is fire resistance, which is not necessarily related to the combustibility of a material. Fire resistance is a performance metric and, for wood structures, it is typically achieved by protecting exposed wood with gypsum board or over-sizing the exposed wood structural elements to provide for sustained load-bearing capacity even while the member chars. The methodology is contained in the American Wood Council's referenced design standard for wood construction, the *National Design Specification® (NDS®) for Wood Construction*.

There is an acceptance by most fire professionals that heavy timbers and large-dimension engineered products provide a known level of performance in fire conditions. This explains the larger building sizes permitted for Type IV construction, even over the unprotected Type IIB (noncombustible, unprotected) construction type. CLT will undoubtedly prove to be an exceptional performer for fire resistance (as the above-mentioned test indicated).

As wood buildings become taller, there will be higher expectations that finished wood buildings perform under fire conditions like tall buildings of noncombustible construction types. Occupant life safety is first addressed through early fire detection and notification, followed by active fire suppression and adequate means of egress, which are well covered in the IBC. Interior wall and ceiling finish requirements are no different for CLT buildings and are based on the function of the particular space. Concealed spaces, while not permitted in a Type IV building, are permitted to be constructed with FRTW in certain locations within Type I and II construction. Concealed spaces in CLT construction, where otherwise not permitted, will need to be approved by the code official as an alternate method when adequately protected with noncombustible materials or fire sprinkler systems. Studies have already begun to determine if the current combination of fire resistance, flamespread protection, life safety systems, and fire suppression systems required for high rise buildings make the combustibility of the structural frame inconsequential in the big picture. Fire protection during construction is critical for combustible-frame structures and this is an area where codes may likely need to be improved.

Conclusion

New technology is dramatically increasing the potential for large commercial wood structures, and building codes are shifting to accommodate. In Europe, more so than the U.S., environmental concerns and incentives have resulted in a shift to wood for tall buildings that, until recently, would have been of other materials. There are notable high rise CLT buildings in other countries, and interest has been high in North America as a result. Although the 2015 IBC is not yet available for purchase or adoption, it is already influencing these trends.

The codes are paying less attention to combustibility of the frame and more attention to life safety and fire resistance, which is appropriate. The negatives of wood for large buildings are disappearing, as required levels of structural and fire performance in all environmental conditions are being emphasized.▪

Exterior Walls in Type III Construction

The historic definitions for Type III and IV in the IBC require noncombustible exterior walls of 2-hour fire resistive rating. Traditionally, Type III construction described industrial buildings of masonry exterior walls and interior of heavy timber or wood frame. Often located in crowded urban sites, the protection afforded by masonry walls was a valuable asset in mitigating conflagration.

Since Type III buildings are now permitted to have fire retardant treated wood (FRTW) exterior walls, there are some "disconnects" in the code in regard to the interface of exterior walls with interior structure, and code provisions which originally assumed masonry exterior walls may be the focus of varying interpretations in typical platform construction, since the floor assembly "interrupts" and supports the exterior wall at each floor level. Code officials handle this in a variety of ways, but usually a practical approach is to require solid wood blocking in all floor cavities that extend within the plane of the exterior wall. The char rate of solid wood substantiates such an approach, since solid wood of three inches in thickness would provide approximately two hours of fire resistance.

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The American Wood Council (AWC) is the voice of North American traditional and engineered wood products, representing over 75% of the industry. AWC's engineers, technologists, scientists, and building code experts develop state-of-the-art engineering data, technology, and standards (e.g. NDS) on structural wood products for use by design professionals, building officials, and wood products manufacturers to assure the safe and efficient design and use of wood structural components.

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