MID-RISE WOOD CONSTRUCTION

A COST-EFFECTIVE AND SUSTAINABLE CHOICE FOR ACHIEVING HIGH-PERFORMANCE GOALS

Presented by: THINK WOOD

Crescent TerminusAtlanta, Georgia. Architect: Lord Aeck Sargent

LEARNING OBJECTIVES

At the end of this program, participants will be able to:

1. Identify the sustainability and economic benefits of using wood construction for mid-rise buildings.
2. Summarize building code requirements and provisions for mid-rise multi-family wood-frame structures.
3. Discuss wood framing solutions that address issues such as shrinkage, fire protection, and seismic requirements while minimizing carbon footprint.
4. Explore innovations in wood framing design techniques and wood product technologies that enhance energy efficiency.

CONTINUING EDUCATION

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Cost-effective, code-compliant and sustainable, mid-rise wood construction is gaining the attention of developers and design professionals, who see it as a way to achieve higher density housing at lower cost—while reducing the carbon footprint of their projects. Yet, many familiar with wood construction for two- to four-story residential structures are not aware that the International Building Code (IBC) allows five stories of wood-frame construction in building occupancies that include multi-family, military, senior, student and affordable housing—and six stories for business.

"Once designers know that wood offers all the required safety and structural performance capabilities and meets code requirements for mid-rise, the most appealing feature of wood tends to be its price," says Michelle Kam-Biron, P.E., S.E., director of education for the American Wood Council. "Multi-family housing was one of the first market segments to rebound from the recession—because it's more affordable than single-family housing while offering advantages such as less upkeep and, in most cases, closer proximity to amenities. Wood construction is attractive for multi-family projects because it offers a high percentage of rentable square footage at a relatively low cost, but its benefits are equally applicable to other occupancy types."

Among their benefits, wood buildings typically offer faster construction and reduced installation costs. For example, after completing the first phase of a developer-funded five-story student housing project using steel construction, OKW Architects in Chicago switched to wood. "The 12-gauge steel panels were expensive, very heavy and difficult to install; and welding and screwing the shear strap bracing was very time consuming," says

LUXURY AND PERFORMANCE

Photo: Richard Lubrant

Project: Crescent Terminus

Location: Atlanta, Georgia

Architect: Lord Aeck Sargent

Engineer: SCA Consulting Engineers

Owner: An affiliate of Boston-based Berkshire Group

Developer: Crescent Communities

Size: 275,000 square feet, 355 units

Type of construction: IIIA wood-frame construction over Type IA concrete podium

Year of completion: 2014

Surrounded by high-rises, Crescent Terminus consists of three luxury apartment buildings, each with three levels of parking topped with five stories of wood-frame construction.

"This land was at a cost basis that is among the highest in our portfolio," says Jared Ford, senior vice president for Crescent Communities. "It's prime real estate, but that's where the market is. We're either building or hunting in 13 of the top 20 metropolitan markets, and we're almost entirely focused on wood-frame multi-family apartments."

As with any complex project, there were a number of design challenges. For example, to maintain the integrity of the fire rating of the exterior bearing walls, the team used top-chord bearing trusses for the floor framing. To minimize shrinkage, techniques included using engineered wood for the plates and blocking in the first two floors, and larger sealant joints around windows and doors to allow movement. The team also designed stairs with double stud walls to provide a 2-hour fire separation, specified concrete block construction at the elevator shaft and used a wood-frame wall to separate the elevator shaft from the rest of the construction.

project architect Eileen Schoeb. "Using wood was far more economical for the second phase."

For the three-building, five-story Crescent Terminus development in Atlanta's upscale Buckhead district, wood framing helped to achieve overall budget goals. "From a design standpoint, we were able to use wood to introduce a fresh, contemporary aesthetic to a mid-rise multi-level development," says architect Erik Brock of Lord Aeck Sargent. "By saving on the framing and speed of construction, Crescent Communities was able to deliver a higher-quality finished product for their tenants by putting more into the amenity package as well as landscaping, finishes and character of the residential units."

Wood construction also offers advantages for project teams seeking green building certification or simply to reduce the environmental impact of their buildings. Wood grows naturally and is renewable, and life cycle assessment studies consistently show that wood offers environmental advantages in terms of embodied energy, air and water pollution, and other impact indicators.[1]

From a carbon footprint perspective, wood continues to store carbon absorbed during the tree's growing cycle, keeping it out of the atmosphere for the lifetime of the building—or longer if the wood is reclaimed at the end of the building's service life and reused or manufactured into other products. The manufacturing of wood products also results in less greenhouse gas emissions than other materials.[2] For example, according to the online Wood Carbon Calculator for Buildings,[3] the new Crescent Terminus development, which includes three buildings, each with five stories of wood-frame construction over a concrete podium, has a carbon benefit equivalent to 13,523 metric tons of CO_2. This includes 4,327 metric tons of CO_2 stored in the wood products and 9,196 metric tons of avoided CO_2 emissions. According to the U.S. Environmental Protection Agency's Greenhouse Gas Equivalencies Calculator, this equates to emissions from 2,583 cars in a year, or from the energy to operate an average home for 1,149 years.[5]

"Wood is also versatile and adaptable," says Kam-Biron. "Modifications on the jobsite tend to be straightforward and are easily made."

When asked how building with wood fits into Crescent Communities' quality mission, Ford cites both sustainability and design flexibility. "With concrete, you can't easily design to have the building pop in and out to create the architectural reveals the way you can with a wood-frame building. We can do a lot more design-wise with wood that we couldn't do with other products. So both our environmental goals and our design goals provided the motivation for [Crescent Terminus] to be a wood-frame building."

A survey of 227 buildings demolished in Minneapolis/St. Paul found that buildings are often torn down within 50 years, regardless of material, because of changing needs and increasing land values as opposed to performance issues.[6] Overall, wood buildings

PODIUMS—AN ALL-WOOD SOLUTION

Although a podium structure typically refers to wood-frame construction over concrete, a handful of designers have lowered their costs even further by designing the podium in wood.

"When determining the cost of a structure, there are a lot variables, including most notably time, materials and labor," said Karyn Beebe, P.E., of APA. "Using wood instead of concrete lowers the mass of the building, which results in more economical podium shear walls and foundations. Using the same material for the entire structure may also mean lower design costs, and the construction team experiences savings in the form of fewer trades on site, which means less mobilization time, greater efficiency because framing is repeated on all of the levels, easier field modifications, and a faster schedule."

Architect Dan Withee, AIA, LEED AP, of Withee Malcolm Architects designed an 85-unit wood podium project in San Diego. He estimated that a concrete podium can cost $15,000 per parking space compared to $9,500 for an all-wood solution.[4]

RESIDENTIAL
Permanent stay multiple-family facilities (R-2) and Transient (R-1)(i.e., apartments, convents, dormitories, fraternities and sororities for R-2; hotels and motels for R-1) NFPA 13 Sprinklers. 100% Open Perimeter

	Type IIIA	Type IIIB	Type VA	Type VB
Maximum stories	5	5	4	3
Maximum building height (ft)	85	75	70	60
Total building area (at maximum permitted stories) (ft²)	270,000	180,000	135,000	78,750
Total building area (ft²), single-story building	114,000	76,000	57,000	33,250
Total building area (ft²), two-story building	180,000	120,000	90,000	52,500

in the study had the longest life spans, showing that wood structural systems are fully capable of meeting a building's longevity expectations. However, when you consider the embodied energy in demolished buildings and the implications of material disposal, the fact that wood is adaptable—either through renovation or deconstruction and reuse (with minimal additional processing)—is a significant advantage.

MASTERING WOOD CONSTRUCTION DESIGN

As with any type of construction, mastering the technical details of wood-frame construction is critical to creating cost-effective buildings that are safe and durable. Building codes require all building systems to perform to the same level of safety, regardless of material used, and wood-frame structures can be designed to meet or exceed standards for (among other things) fire protection, seismic performance and resistance to high winds.

The following pages will provide an overview of technical considerations related to the design, safety and structural performance of mid-rise wood buildings, as well as two trends that are expanding the opportunities for wood use in multi-story design.

Free project support related to the code-compliant design, construction and engineering of non-residential and multi-family wood buildings is also available through the Wood Products Council's WoodWorks program (woodworks.org; help@woodworks.org).

Building Code Requirements

The IBC is the predominant U.S. model building code, having been adopted by most states with or without amendments. Chapters 16, 17 and 23 cover structural wood design and construction. (Non-structural provisions such as heights and areas are covered elsewhere.) IBC Chapter 6 classifies buildings into five types of construction. Construction Types I and II are generally limited to non-combustible materials such as concrete and steel, although wood can be used in all types of construction to varying degrees. Type III allows a mix of non-combustible and combustible materials, while construction Types IV and V can have combustible building materials.

Multi-story wood construction generally falls under Types III and V. (However, Type IV multi-story construction, also known as Heavy Timber, is growing in interest.) Each building type is further subdivided into A and B, which have different fire-resistance rating requirements, with A being the more rigorous.

FIVE STORIES OF WOOD OVER A CONCRETE PODIUM

Photo: Lincoln Barbour

Project: University House Arena District

Location: Eugene, Oregon

Architect: Mahlum Architects

Structural engineer: Froelich Engineers

Owner: Inland American Communities

Developer: Gerding Edlen

Size: 109,600 square feet, 65 units

Type of construction: Type IIIB wood-frame construction over Type IA concrete podium

Year of completion: 2013

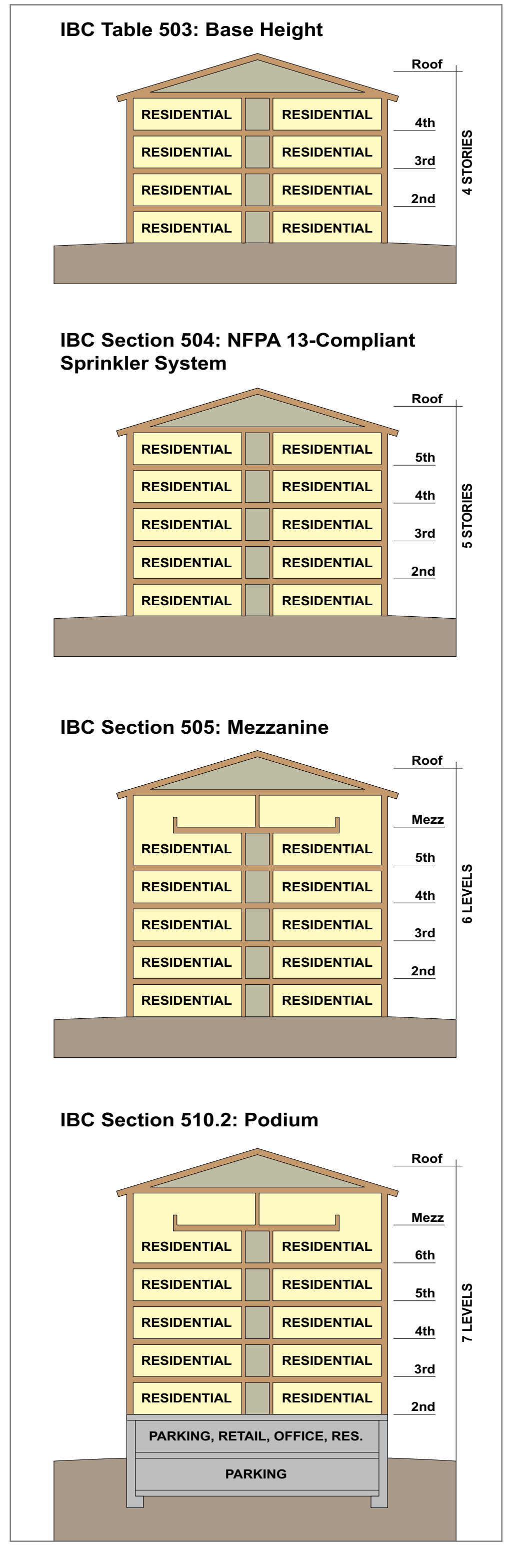
Built to accommodate recent growth at the University of Oregon, the University House Arena District student housing project includes five stories of wood-frame construction over a concrete podium. (Not shown in the photo, the podium is akin to a 'daylighted basement' at the rear of the building.)

The use of wood framing over concrete helped the design team achieve an aggressive budget of $128/square foot while ensuring a modern design aesthetic. The team also underwent an Alternate Materials and Methods Review with the City of Eugene to allow wood wrapped in fire-retardant gypsum board for exterior walls. Previously accepted as an alternate method by the City of Portland, this design approach was used instead of the fire retardant-treated wood required for exterior walls as an alternate to non-combustible construction in Type III buildings under the IBC.

"The project is a showcase of smart design that leverages tested assemblies for fire protection as well as innovative materials to express the culture of Eugene," says Kurt Haapala, principal in charge of the project at Mahlum Architects. Just a five-minute walk to the university, it contributes to the City's 'Envision Eugene' program, which encourages compact development in the city's core.

Among its sustainability features, the LEED Gold-certified project includes wood studs spaced at 24 inches on center to allow more insulation within the wall cavity, as well as a rooftop solar hot water system and energy-efficient LED lighting throughout. Based on actual utility data analyzed against the energy model, the building is operating approximately 50 percent more efficiently than originally anticipated.

PERMISSIBLE INCREASES IN HEIGHT AND AREA UNDER THE 2012 IBC



Source: Togawa Smith Martin

(See section: Fire Protection Requirements.) "From a cost perspective it makes no sense to use Type I for five stories," says Tim Smith, AIA, founding principal of Togawa Smith Martin, Inc., Los Angeles, and a pioneer of five-story wood framing in California. "Type I is more realistic for taller buildings. Type III for wood construction helps fill the gap between low-rise and taller buildings."

Permissible Increases in Area and Height

Table 503 of the IBC lists allowable building heights and floor areas for different construction types; however, there are provisions for increases. For Type IIIA, for instance, an allowable floor area of 24,000 square feet as stipulated in Table 503 for Group R-2 occupancies could be increased to 90,000 square feet per story. Such provisions include:

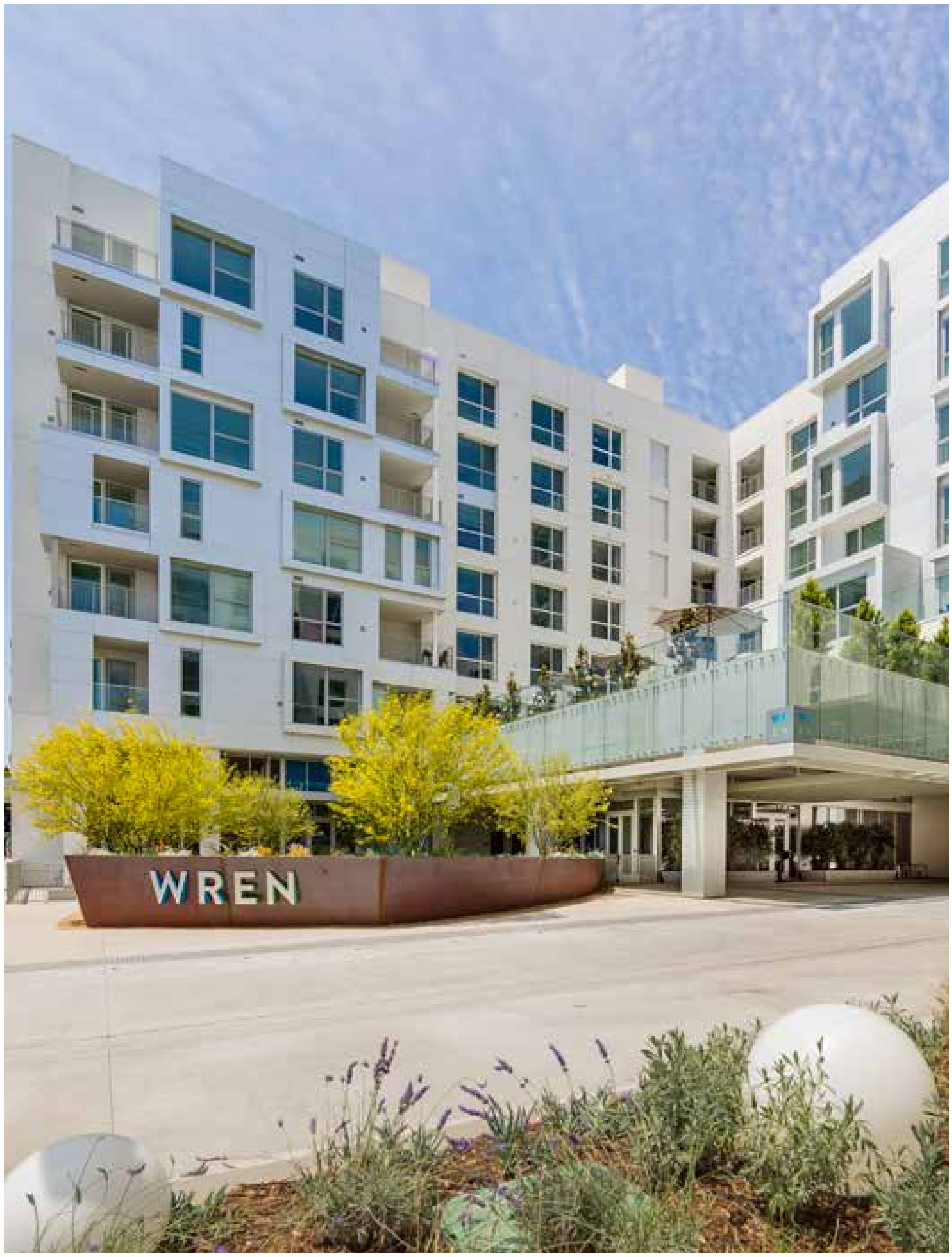
Open front areas. IBC Section 506.2 permits area increases up to 75 percent for buildings with open spaces around their perimeters such as yards, courts, parking areas and streets, which provide fire-fighting access.

Sprinkler systems. For most occupancy groups, increases to the allowable height (and number of stories) and floor area are permitted according to IBC Section 504.2 with the use of an approved automatic sprinkler system in accordance with the National Fire Protection Association (NFPA) 13 standard.

"Type IIIA construction for Residential Group R is allowed to be four stories and 65 feet high while a Type VA building is permitted to be three stories and 50 feet," explains Kevin Cheung, Ph.D., P.E., chief engineer for the Western Wood Products Association. "However, when protected by automatic sprinklers, Type IIIA and Type VA buildings are allowed to be five and four stories, respectively. Type IIIA is permitted an increase in height to 85 feet and Type VA an increase to 70 feet." (See Table of IBC Allowable Heights and Areas for Residential Construction.)

In the Pacific Northwest (Washington, Oregon and Idaho), the model code has been amended to allow Type V residential buildings to have up to five stories of wood-frame construction with additional limitations. In Canada, the British Columbia building code was revised in 2009 to permit residential wood construction up to six stories.

Use of fire walls to "separate" buildings. While the code does not explicitly require fire walls, they may be utilized in many cases to expand the prescribed size of a building. (See Parkside sidebar on page 7.)



The wood-frame, residential building, WREN, located in Los Angeles, CA, is one of the first of a new building type using multiple podiums. By providing a sprinkler system, a type III construction, and multiple building modifications, the wood portion of the building was able to increase from 4 stories to 5 stories. Architect: Togawa Smith Martin Inc. Photo: Kevin C. Korczyk

FIRE SAFETY DURING CONSTRUCTION

Although less than 2 percent of building fires occur during construction, this phase presents unique risk scenarios that make any building more vulnerable regardless of material.

IBC Chapter 33 provides minimum safety precautions for fire during construction and the protection of adjacent public and private properties. The section includes provisions for fire extinguishers, standpipes, means of egress and sprinkler system commissioning. The International Fire Code also contains detailed requirements.

The most common causes of fire in wood buildings under construction are arson and hot work, making site security, rigorous procedures for workers and access to fire hydrants a must. Education is also important, since fires that occur during this phase are also caused when required elements—such as fire doors, smoke alarms and sprinklers—have not been put in place.

THREE-HOUR FIRE WALL ASSEMBLY.

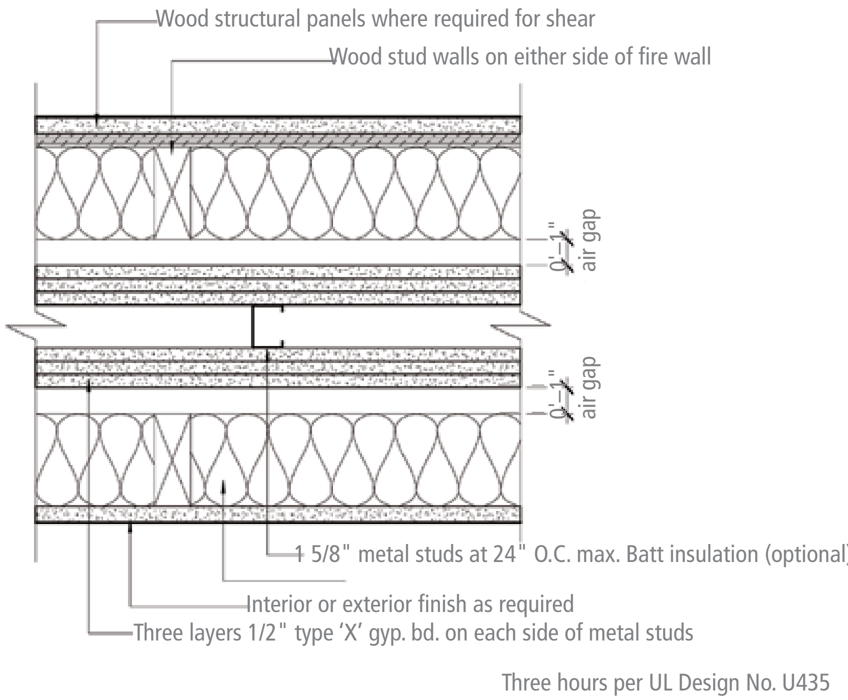


Image: Togawa Smith Martin

IBC Section 706 permits portions of a building separated by one or more fire walls to be considered as separate, side-by-side buildings. In this way, wood-frame buildings can be designed as separate but connected buildings for code-compliance purposes. This partitioning allows wood buildings to be unlimited in size.

Mezzanines. IBC Section 505 excludes mezzanines from the determination of number of stories or building area. Mezzanines may be one-third of the floor area of the room or space beneath. For example, a loft or penthouse plus a mezzanine on the first concrete podium floor could add two "stories" to the building.

Podium design. In multi-level wood-frame buildings, architects and engineers are increasingly turning to podium or pedestal design—which can add another floor level to the maximum permissible number of stories—instead of building directly on a concrete slab on grade. Section 510.2 of the 2012 IBC allows five- or six-story wood-frame structures over one level of typically concrete Type IA construction. These "five-over-one" and "six-over-one" buildings are treated in the code as two structures separated by a three-hour fire-resistance-rated horizontal assembly.

The podium is considered as a separate and distinct building for the purpose of determining height and area limitations and vertical continuity of fire walls. The overall height of the two buildings together is measured from grade plane, and the height limitations of Chapter 5 apply. The 2015 IBC will expand this opportunity by allowing two or more stories below the three-hour horizontal fire assembly with the caveat that the overall building height from grade still not exceed the limits set out in Chapter 5.

Fire-resistance requirements for Type IIIA and Type VA construction.

	Exterior Bearing Walls*	Interior Bearing Walls*	Floor Construction*	Roof Construction*	Fire Walls**
Type IIIA	2 hrs	1 hr	1 hr	1 hr	3 hrs (most occupancies)
Type VA	1 hr	1 hr	1 hr	1 hr	2 hrs

*Source: IBC Table 601, **IBC Table 706.4

FIRE PROTECTION REQUIREMENTS

Fire-resistance rating requirements for building elements, based on construction type and fire separation distance, are provided in IBC Table 601. Chapter 7 of the IBC covers materials and assemblies used for fire-resistance-rated construction and separation of adjacent spaces.

Wood-frame building elements that require fire resistance often have their fire-resistance rating determined in accordance with the test procedures set forth in ASTM E119, *Standard Test Methods for Fire Tests of Building Construction Material* or *UL 263 Fire Tests of Building Construction and Materials*. The code also provides alternative methods for determining fire resistance per IBC Section 703.3, which includes prescription tables in 720 or calculations for fire resistance in 721.

Fire-Resistance Assemblies

One-hour and two-hour fire-resistance requirements are generally provided by fire-rated assemblies that include gypsum sheathing.

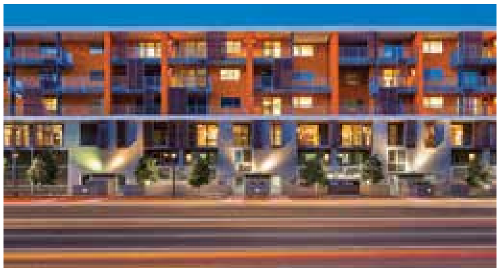
Lists of accepted rated wood floor and wall assemblies are available from the *American Wood Council (DCA 3: Fire-Rated Wood-Frame Wall and Floor/Ceiling Assemblies, awc.org)* and APA (Form W305, apawood.org).

Other sources are (UL) *Fire-resistance-rated Systems and Products, the UL Fire Resistance Directory*, and the *Gypsum Association's Fire Resistance Design Manual.*

Fire Retardant-Treated Wood (FRT)

The building code (IBC Section 2303.2) permits exterior two-hour rated bearing walls in Type III construction to be constructed of fire retardant-treated (FRT) wood, an acceptable substitute for a non-combustible material.

DENSITY, COST AND PERFORMANCE



Photos: Lawrence Anderson, lawrenceanderson.net

Project: Stella

Location: Marina del Rey, California

Architect: DesignARC

Structural Engineer: Taylor & Syfan Consulting Engineers

Owner: Merlone Geier Partners

Developer: GLJ Partners

Size: Two buildings, 650,466 square feet (total), 244 units

Type of construction: IIIA and VA

Year of completion: 2013

Until a few years ago, it was fairly uncommon for an architect to go beyond four stories with wood-frame construction. Today, many designers choose five stories of wood over concrete podiums as a way to cost-effectively increase the density of projects.

"It seems that all of the newer projects here in southern California are going taller, and they're all being built in wood," said Tony Ditteaux, partner and vice president for GLJ Partners, developer and general contractor of Stella. "As developers, we're trying to maximize our height and the number of units we can get on a site. Wood allows us to do that quickly and affordably."

GLJ did a quick analysis and found that wood framing was the most cost-effective option. Prefabricating part of the project off-site—another trend—brought the costs down further, saving 1–2 months of construction time and a few hundred thousand dollars.

Designing for Different Fire Ratings

One framing consideration for Type IIIA is that floors and walls may have different fire ratings. Since load bearing exterior walls are required to have a two-hour rating, the intersection of a one-hour floor requires detailing. This can be accomplished by allowing the wall studs with one layer of gypsum to extend to the underside of the floor sheathing, and supporting the floor framing off the top plates with the use of a hanger designed to span over a layer of gypsum sheathing. Another framing option is to hang the floor framing off a 2x ledger, which provides as much if not more fire resistance as the layer of gypsum. The one-hour wall rating plus the one-hour floor system yields the required two-hour rating. Designers should work with their local building official to determine an acceptable solution to fire-resistance detailing at the floor-to-wall intersection as the code is silent in this area.

Fire Walls

Fire walls are not required by the building code; however, they may be utilized to increase the square footage of a building. For R-1 (transient) and R-2 (permanent) occupancy, IBC Section 706.4 requires fire walls in Type IIIA buildings to be three-hour fire-resistance-rated constructed with non-combustible framing. In Type VA buildings, walls are permitted to have combustible framing and a two-hour fire-resistance rating. Under the *NFPA 221 Standard for High Challenge Fire Walls, Fire Walls and Fire Barrier Walls*, designers may build a two-hour rated fire wall using two contiguous one-hour fire-resistance-rated assemblies.

HOW TO FRAME WITH WOOD

In addition to selecting the appropriate framing technique, designers of wood buildings must consider factors such as shrinkage, differential movement, and seismic requirements.

Platform Framing and Balloon Framing

There are three common types of framing for wood construction. For Type VA buildings, where exterior walls require a one-hour fire-resistance rating, traditional platform framing is usually used, where the joists sit on top of the double top plates of the wall. Balloon framing is where the joists hang off the ledger that is attached to the structural studs that frame the building. In modified or semi-balloon framing, the floor framing hangs off the double top plates; it is often used as an alternative to platform-framed structures for both Type VA and Type IIIA construction.

Shrinkage

Regardless of the framing type, IBC Section 2304.3.3 requires that designs for buildings over three stories take into account the fact that wood shrinks as it dries. Shrinkage continues until wood reaches its Equilibrium Moisture Content (EMC), which averages 8–12 percent moisture content for most structures in the U.S. The Western Wood Products Association (wwpa.org) offers a technical guide that includes formulae for calculating shrinkage for different wood species across the country as well as a downloadable shrinkage estimator.

"Shrinkage calculations aren't complex," says Kam-Biron, "but it's an area designers aren't always familiar with, and it can be challenging to detail for differential movements between two different materials and overall shrinkage." The shrinkage effects must be considered for horizontal framing members (width or thickness) in the wall (top/sill plates) and floor (joists) design. Wood is anisotropic, meaning the dimensional change in wood is unequal in different directions. In most softwoods, radial shrinkage (across growth rings) is approximately 4 percent and tangential shrinkage (parallel to growth rings) is approximately 8 percent from green (unseasoned) to typical EMC for structures in the U.S. Longitudinal shrinkage (parallel-to-grain) for vertical framing members is generally negligible and does not affect building performance. Therefore, the majority of shrinkage will occur in the top plates, sill plate and sole plates, and possibly the floor joists—depending on how the floor framing members are framed to the wall. If the framing is balloon-framed or modified balloon-framed, then sawn lumber joists won't play a huge role in overall movement from shrinkage because balloon framing, unlike platform framing, does not accumulate shrinkage over all floors. "Unseasoned (green) sawn lumber will shrink more compared with seasoned (dried) lumber," says Cheung. "Shrinkage should be considered for wood-frame buildings over three stories. The good thing about wood is that it will dry naturally." Ways to minimize shrinkage include (among others) specifying kiln dried lumber, letting the wood dry during construction before closing in the walls, and using products and systems such as pre-engineered metal-plate connected wood trusses for floor and/or roof framing, and manufactured wood products (laminated veneer lumber, I-joists, etc.). I-joist floor systems are dimensionally stable and offer minimal inter-floor shrinkage.

Additionally, there can be some overall settlement of the building that may occur due to gaps in the building construction that can contribute to the overall vertical movement. Some contractors will distribute the dead load throughout the height of the building and allow the building to acclimate to the environment and/or air dry prior to installation of the drywall, thus allowing the building to naturally settle.

Differential Movement

Allowing for differential movement between wood and other structural elements and building finishes is critical. Steel, concrete and brick continue to expand and contract due to temperature changes, while wood generally maintains its dimensions having reached its EMC. Differential movement occurs when, for example, floor joists are supported by a wood-frame wall at one end and by the masonry block of an elevator shaft at the other end. Areas such as stairwells, shafts and vaulted ceilings require attention for differential movements as do plumbing, electrical and mechanical systems. Using flexible joints such as flexible pipe, conduit, couplings, elbows, and tees for electrical, mechanical and plumbing between floors can prevent potential problems. The design of the joints between building envelope components, such as windows and doors, must also allow for differential shrinkage.

Seismic Requirements

Earthquakes and rigorous seismic requirements are a well-known aspect of building on the west coast, but other parts of the country, especially in the east, are not immune to earthquake activity and the need to comply with seismic codes. Wood construction provides high strength with relatively low weight, and the high strength-to-weight ratio makes wood a good choice for earthquake-resistant construction.[7] In wood-frame buildings, the large number of walls and floors often used in a project transfer lateral loads induced by winds and seismic forces.

Wood-frame construction also provides numerous load paths through shear walls and diaphragms, which typically have hundreds of structural elements and thousands of nail connections, adding ductility and redundancy to the system. Redundant load paths give additional assurance that loads will be transferred should a connection fail. In contrast, structures supported by heavy non-wood frames have relatively few structural members and connections, meaning fewer load paths. Moreover, the large number of walls reduces the loads shared by each wall. Tests and

MIXED-USE PODIUM BUILDING

Photo: Benson & Bohl Architects

Project: Parkside mixed-use project, a combination of the Parkside affordable housing project (77 apartment units) and East Village Community Church (11,000-square-foot sanctuary and related facilities)

Location: San Diego, California

Architect: Benson & Bohl Architects, Inc.

Code consultant: CHURCHILL ENGINEERING, INC.

Residential (five levels of wood-frame construction): 67,109 square feet

Church (one level plus mezzanine): 12,209 square feet

Parking garage (three levels): 48,213 square feet

Total area of building: 127,531 square feet

Type of construction: Type IIIA platform wood construction over a Type 1A concrete podium

Year of completion: 2010

Parkside, a $20-million LEED Platinum-certified project, demonstrates the use of code provisions to increase height and area. Installing NFPA 13-compliant sprinklers in the wood-frame portion permitted a height increase of one story to a total height of 85 feet with five stories, explains building code and life-safety consultant James E. Churchill, P.E., president of CHURCHILL ENGINEERING, INC. An additional 11,040 square feet in the wood portion of the building was permitted through the frontage provision (IBC 506.2), which allows an increase in building area if the building fronts on a public way or open space. (Unlike the IBC, the California Building Code [CBC] permits an increase in building area based on frontage, but not on the use of sprinklers if that provision has already been employed to gain an additional story.)

The concrete podium provides a three-hour fire-resistant horizontal assembly which separates the wood stories above from the stories below, allowing the wood building and the podium to be treated as separate buildings for the purposes of determining area limitations, continuity of fire walls, number of stories and type of construction.

Two vertical three-hour fire walls extend from the first floor level above the podium to the roof level, separating the residential portion of the building into three separate buildings. Without the special provisions for horizontal assemblies in Section 509.2 (2009 IBC), which permit portions of structures to be treated as separate buildings, the fire walls would have had to run from the foundation level to the roof level, dividing the parking garages, thus making the building program impossible to deliver.

Built to achieve LEED Platinum certification, New Genesis Apartments in Los Angeles, California, designed by Killefer Flammang Architects, is a mixed-use and mixed-income wood-frame building with commercial retail space. Photo: KC Kim, GB Construction

observations from past earthquakes show that wood buildings have performed well. For example, a six-story light-frame wood building tested on the world's largest shake table in Japan resisted a major 2,500-year earthquake with minimal damage.

Current building code requirements for wood diaphragms, shear walls and holdown devices work effectively in creating earthquake-resistive structures. Horizontal diaphragms in roofs and floors transfer the horizontal forces to the shear walls. Shear walls with holdowns such as a continuous tie-down rod system resist the tension forces in an overturning scenario, while wood studs or columns absorb the compression forces.

Wood structural panel shear walls are typically used throughout the building to provide vertical lateral resistance.

ACOUSTICS

As with any issue of building performance, the acoustics of a mixed-use wood-frame structure can be designed to meet or exceed minimal requirements, depending on the expectations of the developer, buyers and tenants.

For wall systems, sound isolation can be accomplished in two ways. One is to use partitions with a high mass (75 pounds per square foot, psf, or greater) or to use low mass systems (2 to 5 psf) separated by air spaces of 3 to 6 inches.

The goal in party walls or exterior walls is to keep other people's noise out of, and tenant noise in, the unit. In lightweight wood structures, this is achieved by separating the materials with an air space (e.g., stud or joist construction). In terms of acoustical performance, the most effective wood-frame wall is a double stud wall, followed by staggered stud and then single stud.

In mid-rise wood-frame buildings, options for improving acoustic performance include:

Sheathing. The mass of the sheathing is just as important as the air space provided by the stud or joist cavity. In acoustical detailing, 5/8-inch-thick type "X" gypsum board is typically required.

Plumbing joints with pipes nested in joint to allow for vertical movement of structure

Plumbing sleeve connected to structure with foam wrap to allow vertical movement of structure

Insulation. The most cost-effective acoustical improvement to a sound isolation system is the addition of batt insulation or any open cell foam system to the stud or joist cavity. While closed cell spray foams have higher R-values and offer improved building envelope energy performance by sealing the partition and improving air tightness, the closed cells do not allow the vibrating air molecules to interact with the insulation product so the sound attenuation is less. It is this interaction that helps reduce the sound.

Resilient channels. When double or staggered stud construction is not possible, decoupling the sheathing from the framing provides a similar form of isolation.

Floor finishes. Impact noise can be reduced considerably with the use of soft finishes such as carpet. When carpeting is not practical or desired, floating wood or tile floor systems offer the next best solution.

FIVE STORIES OF WOOD OVER CONCRETE SLAB

Photo: Skyshots Photography

Project: Advanced Individual Training Barracks with Company Operations

Location: Fort Lee, Virginia

Architect/design-build: LS3P ASSOCIATES LTD. and Clark Builders Group

Structural engineer: Michael M. Simpson & Associates, Inc.

Size: 360,000 square feet

Type of construction: Type IIIA wood-frame construction on concrete mat slab

Year of completion: 2011

LS3P ASSOCIATES LTD. and Clark Builders Group designed and constructed the design-build Advanced Individual Training Barracks with Company Operations in Fort Lee, Virginia, as the seed project under a Multiple Award Task Order Contract (MATOC) for the U.S. Army Corps of Engineers. The $68,169,000 LEED Silver project consists of two five-story barracks situated on an 11-acre site. Each 180,000-square-foot building has 600 beds and meets IBC 2006, NFPA 101 egress and life safety provisions, plus Anti-Terrorism/Force Protection Criteria. Set on a reinforced concrete mat slab, the buildings are clad primarily in brick.

"The team provided three structural options: cast-in-place concrete, light-gauge steel framing and panelized wood stud framing," recalls Chris Ions, AIA, LEED AP, vice president/principal of LS3P ASSOCIATES LTD. "The steel came in $2 million cheaper than the cast-in-place concrete and the wood came in $2 million cheaper than the steel, a significant difference." The advantage of working as a design-build team was being able to explore a number of framing choices to determine which was the most cost efficient.

To minimize the impact of shrinkage, the walls are balloon-framed with flooring rim beams on the inside, rather than on top of the top plates (platform framing) at each floor of vertical framing. The first floor has the heaviest framing with triple studs of southern yellow pine, selected for its high compression strength.

The first three stories of brick veneer were supported on the foundation; steel relieving angles through-bolted to the wood framing were used to support brick at the fourth and fifth floor levels. "The greatest challenge of wood construction is looking at every assembly, transition and penetration to ensure that fire-rated assemblies are truly continuous," says Ions.

For a more detailed introduction to these concepts, a technical paper, Acoustical Considerations for Mixed-Use Wood-Frame Buildings, is available at woodworks.org/wp-content/uploads/Acoustics_Solutions_Paper.pdf.

Interior of Stella, a contemporary apartment building in Marina del Rey, California. Photo: Lawrence Anderson, lawrenceanderson.net

INNOVATIVE WOOD PRODUCTS AND BUILDING SYSTEMS

A number of innovative technologies and building systems are increasing the opportunities for mid-rise wood buildings. For example:

Prefabricated Systems

Specifying prefabricated or factory manufactured wall and roof panels can provide better quality wall construction since the panels are constructed off-site in moisture controlled environments. Wall panelizing is particularly useful for jobsites that don't have adequate space to construct the walls and can speed the erection time considerably. Wall panels can also optimize stud design and increase sound proofing and energy efficiency. Panels may range from 4 to 30 feet long, and are lifted into place by crane.

Mass Timber

While traditional wood-frame construction is a proven solution for mid-rise structures up to six stories, mass timber products such as cross laminated timber (CLT) are creating new possibilities. CLT is a multi-layer wood panel in which each layer is oriented crosswise to its adjacent layer for increased dimensional stability and structural performance. Widely used in Europe and now available in North America, it is considered viable for buildings up to 12 stories and even higher.

In Australia, CLT has been used to create a 10-story all-wood building, while eight-story examples exist in the U.K. and Austria. North American applications include (among others) a two-story elementary school in West Virginia, a six-story CLT structure in Quebec, a five-story heavy timber/CLT hybrid building at the University of British Columbia , and an eight-level heavy timber/CLT hybrid (six stories plus a penthouse and mezzanine), also in British Columbia.

Among CLT's attractive structural characteristics are high dimensional stability, high axial load capacity, high shear strength, rigidity around openings and negligible settlement effects. CLT assemblies also offer inherent fire resistance due to thick cross-sections that, when exposed to fire, char at a slow and predictable rate.

After being lifted to a shake table and subjected to four progressively intense earthquakes, this six-story light-frame building was found to have only minimal damage to the gypsum wallboard and nail connections. (View a video of the test on YouTube.[8])

The industry is also conducting research on the ability of CLT structures to resist lateral loads caused by earthquakes or high winds. Other benefits include speed of construction, thermal performance, and the environmental advantages offered by all wood products—including a low carbon footprint.[9]

The 2015 IBC identifies CLT as a structural product and recognizes it for use in Type IV exterior walls, floors and roofs. The *2015 National Design Specification® (NDS®) for Wood Construction*, referenced in the 2015 IBC, also includes new structural and fire design provisions for CLT. However, while the 2015 IBC won't go into effect in most jurisdictions until 2016, designers can pursue the use of CLT under the alternate means and methods approach in the current code. More information is available from the American Wood Council (awc.org) or APA (apawood.org), which developed the American National Standard, *ANSI/APA PRG 320 2011: Standard for Performance Rated Cross-Laminated Timber*.

CONCLUSION

The last few years have seen a trend toward taller wood buildings, driven by their acceptance in building codes and the value they provide. Design professionals are capitalizing on wood's ability to offer high density at a cost that is typically less than other materials. They also appreciate wood's versatility, adaptability and light carbon footprint. However, while today's building codes recognize wood's safety and performance capabilities in buildings that are five and six stories—and these are becoming increasingly common—innovative technologies and products can be expected to propel designers of mid-rise wood buildings to even greater heights. ■

Mercer Court at the University of Washington includes five buildings, each with five stories of wood-frame construction over two or three stories of concrete. Photo: W.G. Clark Construction, Ankrom Moisan Architects

ENDNOTES

1. *Life Cycle Environmental Performance of Renewable Building Materials in the Context of Building Construction, Consortium* for Research on Renewable Industrial Materials, Phase I 2005, Phase II 2010; *A Synthesis of Research on Wood Products and Greenhouse Gas Impacts*, Sarthre, R. and J. O'Connor, 2010, FPInnovations; Werner, F. and Richter, K. 2007, *Wooden building products in comparative LCA: A literature review*, International Journal of Life Cycle Assessment
2. See endnote 1.
3. The Wood Carbon Calculator for Buildings was developed by FPInnovations, WoodWorks and the Canadian Wood Council; available at woodworks.org
4. Case study: All-wood Podiums in Midrise Construction, APA, http://www.apawood.org/SearchResults.aspx?tid=1&q=n110
5. *Case study, http://woodworks.org/wp-content/uploads/Stella-CaseStudy-WEB.pdf*
6. O'Connor, J., 2004, *Survey on Actual Service Lives for North American Buildings*, FPInnovations
7. *The ShakeOut Scenario—Woodframe Buildings*, URS Corporation, prepared for the U.S. Geological Survey and California Geological Survey, 2008
8. youtube.com/watch?v=c25HuZeQsyo&context=C3f612acADOEgsToPDskLH3EQs-aodM9-NsZgF2lGi
9. U.S. CLT Handbook, https://www.thinkwood.com/products-and-systems/mass-timber

QUIZ

1. Compared to other materials, installation time for wood construction is typically:

a. greater.
b. slightly more.
c. equal.
d. less.

2. From a carbon footprint perspective, wood:

a.stores carbon for the lifetime of the building or longer if the wood is reclaimed and reused or manufactured into other products.
b. loses an average of 4,000 metric tons of CO_2e per five-story building.
c. stores carbon until it is cut into lumber.
d. loses carbon into the atmosphere once the building is enclosed.

3. Multi-story light frame wood construction generally falls under:

a. Type I and Type III construction.
b. Type IV and Type V construction.
c. Type III and Type V construction.
d. Type II and Type III construction.

4. IBC allows increases in building height and area for wood construction:

a. only if a sprinkler system is installed.
b.if there is a parking area but no yard in front of the building.
c. when a mezzanine half the size of the floor below is added.
d. if fire walls are installed.

5. The design of the joints between building envelope components, such as windows and doors, must allow for:

a. moisture retention.
b. differential shrinkage.
c. continuous load paths.
d. airflow.

6. When a multi-story wood-frame structure is built over a concrete podium, the building is treated by code as separate and distinct buildings:

a.for purposes of height, area and continuity. of fire walls
b.only if there are fire-resistant wall assemblies in the wood structure.
c. if the concrete podium has two levels of parking d. beneath it.
only if the wood structure has four stories.

7. Fire-retardant-treated (FRT) wood is an acceptable substitute for a non-combustible material for a:

a. Type IIIA exterior two-hour rated bearing wall.
b. Type VB exterior one-hour rated bearing wall.
c. Type VA exterior one-hour rated bearing wall.
d. None of the above

8.True or False: Shrinkage effects need not be considered for horizontal framing members in the wall and floor design.

9. During an earthquake wood frame structures offer a high strength-to-weight ratio, which results in:

a. low inertia force compared with concrete or steel.
b. higher inertia force compared with concrete or steel.
c. containment of transfer loads induced by seismic activity.
d. fewer redundant load paths.

10. Panelized systems:

a. are manufactured on site.
b. offer better quality wall construction.
c. optimize stud design.
d. b. and c.

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