structural SYSTEMS

Mid-Rise Wood-Frame Buildings Safe, Cost Effective, and Sustainable

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here is a reason more developers and building designers are using wood-frame construction for large mid-rise projects. Designed to code, wood-frame buildings are safe, cost-effective, and sustainable, and increasing the use of wood in these projects can enhance their value proposition.

Podium buildings with up to six stories of wood construction over another construction style (typically concrete) are one of the best ways to add density while keeping costs in check (Figure 1). Podiums allow developers to maximize height and number of stories, while the wood-frame portion above is efficient and economical.

Safety is paramount, and wood buildings designed to code are just as safe as code-compliant buildings made from other materials. Building codes require all building systems to perform to the same rigorous standards for safety based on the construction type used, and wood systems can be designed to meet or exceed code requirements. Wood framing offers the added benefits of construction speed, design versatility, and a light carbon footprint

Structural engineers are often called upon to help make early project decisions on material type selection, and many of the factors that go into these decisions go beyond what might be seen as the normal scope of an engineer. WoodWorks provides project support and education related to the design of wood buildings, and the purpose of this article is to help design and construction professionals make informed decisions about material use. It touches on key topics related to mid-rise wood design - such as fire, seismic and wind resistance, thermal impacts of structural materials, acoustics, and cost.

Sustainable and Durable Design

When specifying any building material, it is important to consider its life cycle environmental impacts. Wood is renewable, and wood products have less embodied energy, are responsible for less air and water pollution, and have a lighter carbon footprint than other commonly used materials. Wood can contribute to a building's energy efficiency and is thought to have a positive impact on the health and well-being of occupants. The fact that it is durable and adaptable also creates opportunities for renovation, re-use, and recycling.

Durability is also an essential principle of sustainable design. However, despite many examples of wood buildings that have stood for centuries, wood has a perception issue when it comes to longevity.

A study by the Athena Sustainable Materials Institute looked at the longevity of buildings in Minneapolis and found that wood buildings were typically the oldest, the majority older than 75 years. In contrast, 80% of the steel buildings demolished were less than 50 years old (FPInnovations 2005).



Figure 1. 5-over-2 podium building in San Diego, CA. Courtesy of Brett Drury.

Code Acceptance: Achieving the Same Scale as Type II Buildings

Of the five construction types in the International Building Code (IBC), mid-rise wood-frame buildings generally fall under Types III and V. Each is further subdivided into A and B, which have different fire-resistance rating requirements (A being more rigorous) and allowable sizes. For Type III buildings, the IBC allows up to five stories of wood construction for residential occupancies and six for business, while Type V buildings have a maximum of four stories.

There are several options for using wood to more affordably achieve the scale of Type II buildings, which are generally steel or concrete. For multi-family occupancies, the allowable height, stories, and per-story area of Type IIIA construction are identical to Type IIA. Likewise, Type IIIB can be used to achieve the same height, stories, and area as Type IIB (Table 1).

Across the U.S., podium buildings have typically been 4-over-1 or 5-over-1, meaning they have four or five stories of wood over a singlelevel podium. In the 2015 and 2018 IBC, there is no limit on the number of podium stories, giving rise to more 5-over-2 buildings.

Cost and Construction Type

International Code Council (ICC) Building Valuation Data is an effective way to compare the average cost of buildings, which, as shown in Tables 2 through 4, varies widely by construction type. Table 3 highlights the difference between Type IIA, which is typically steel or concrete, and IIIA, which is typically wood-frame. As noted, both have the same allowable heights and areas, but the average Type IIIA building costs \$20 per square foot less. In Table 4, Type IIB construction is compared to Type IIIB (again the same size) and shows an \$18/square-foot savings for the wood building.

Factors that make wood-frame construction economical typically include lower material costs, construction speed, and wood's relatively light weight (which can reduce the need for foundation capacity).

Table 1. Multi-story residential occupancy allowable building sizes.

	Constru	uction Type	Options: 5	Stories	Construction Type Options: 3-4 Stories		
	Wood Framing		Steel/Concrete		Wood Framing		
Construction Type	IIIA	IIIB	IIA	IIB	VA	VB	
Stories ^a	5	5	5	5	4	3	
Height (feet)	85	75	85	75	70	60	
Allowable Floor Area ^b (square feet)	72,000	48,000	72,000	48,000	36,000	21,000	
Total Building Area ^c (square feet)	216,000	144,000	216,000	144,000	108,000	63,000	

^aAssumes NFPA 13 sprinklers throughout (IBC Table 504.4)

^bAssumes NFPA 13 sprinklers throughout (IBC Table 506.2), multi-story building, no frontage increase ^cAssumes three or more stories (IBC 506.2.3), no frontage increase

Further savings can be realized with off-site construction, which ranges from prefabricated components and panelized assemblies to full modular units.

Fire and Life Safety

Wood buildings are designed to meet the same level of fire performance as buildings made from other materials. This is achieved by combining various levels of fire resistance, fire class, and fire protection systems.

- **Passive fire resistance** is related to the degree of passive protection provided to the structure itself. It is usually achieved with a gypsum product, but fire endurance for exposed wood can also be shown through calculations described in Chapter 16 of the American Wood Council's (AWC's) *National Design Specification*^{*} (*NDS*^{*}) for Wood Construction.
- Fire class is specific to the finishes of a building and addresses criteria such as flame spread and smoke development potential.
- Active fire protection references the active fire protection systems of a building, such as sprinklers and fire/smoke alarms.

Exterior walls must be fire-retardant-treated (FRT) wood or a noncombustible material and require a 2-hour rating when load bearing to achieve the larger size of a Type III building. Exterior walls in a Type VA building may be framed with standard untreated lumber and require a 1-hour fire-resistance rating when load bearing. In both types, wood can be used for interior structural elements. Opportunities to increase allowable size include firewalls, open perimeters, and automatic sprinkler systems.

R-2 Residential

Source: ICC Building Valuation Data, February 2018

Although less than 1% of building fires occur during construction, special care must be taken to protection elements – such as gypsum, fire doors, smoke alarms, and sprinklers – are in place. For best practices, visit **www.constructionfiresafety.org**.

Wind and Seismic Safety

Wood has several characteristics that contribute to effective seismic and wind-resistive design. In addition to meeting code requirements for lateral loading, wood-frame structures can be designed to achieve enhanced Tables 2-4. Average cost by construction types. Published \$/square-foot of building area

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Table 2	CONSTRUCTION TYPE											
Occupancy Group	IA	IB	IIA	IIB	IIIA	IIIB	VA	VB				
R-2 Residential (Multi-Family)	162	155	150	143	130	125	113	109				
	Structural Woo Framing Allowe											
Table 3	CONSTRUCTION TYPE											
Occupancy Group	IIA			IIIA			Difference					
R-2 Residential	150			130			\$20/sf					
Table 4	CONSTRUCTION TYPE											
								0.11				

levels of resiliency, resulting in lower damage and higher occupant safety during and following an earthquake or high wind event.

- When compared to normal load durations (e.g., live loading on a floor structure), wood structures can resist 60% higher wind and seismic loads as permitted by a 1.6 load duration factor in the NDS.
- Wood buildings tend to be comprised of repetitive framing attached with numerous fasteners and connectors. This creates more load paths and better redundancy, so there is less chance the structure will collapse should some connections fail.
- Wood-frame buildings are relatively lightweight. Since seismic forces are proportional to weight, this means lower seismic forces which could result in further cost savings.

Thermal Advantages

While many people know that wood building materials store carbon and typically require less energy to manufacture than other building materials, their advantages from an operational energy perspective can be overlooked.

Thermal bridging is an essential consideration for the design of building envelopes. It references the conduction of heat more readily through structural/support members relative to the adjacent cavity insulation. This, in turn, reduces the overall effective thermal performance of the assembly under consideration. For exterior walls and roofs, the choice of structural framing material has a significant impact on the relative amount of thermal bridging. For example, a 6-inch nominal wall with R-19 batt insulation has an effective R-value of 16 when framed with 2x6 wood studs at 16 inches on center (o.c.). In contrast, the same R-19 batt insulation would have an effective R-value of 7.1 when the wall is framed with 6-inch metal studs at 16 inches o.c.

While energy-efficiency requirements vary, many states adopt the ICC volume of codes that includes the *International Energy Conservation Code* (IECC). One of the code-compliance paths in the IECC is prescriptive, where walls, floors, and roofs have specific insulation requirements based on framing type and climate zone.

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\$18/sf



Figure 2. Wood-frame exterior walls in a 5-over-1 project in Virginia.

The IECC recognizes wood's advantages from a thermal bridging perspective by requiring continuous insulation in metal-frame walls but not wood-frame walls. For example, in IECC 2015 Table C402.1.3, above-grade metal-frame walls in all climate zones are required to have R-13 cavity insulation and some amount of continuous insulation applied to one face of the wall (R-5 or R-7.5 depending on climate zone). However, in climates zones 1-5 (other than zone 5 group R), no continuous insulation is required for wood-frame walls; cavity insulation alone is adequate. The R-20 wood-frame wall is the only option available in the IECC prescriptive wall path using prescribed R values that does not require continuous insulation for above-grade walls.

Occupant Comfort: Exceeding Acoustic Minimums

The acoustics of a multi-family/mixed-use wood structure can be designed to meet or exceed minimum requirements, depending on the expectations of the developer, buyer, and tenants.

The IBC specifies minimum Sound Transmission Class and Impact Isolation Class ratings of 50 for assemblies separating dwelling units, and there are many options for acoustically-tested assemblies that meet and surpass code minimums.

In multi-family buildings, unit separation walls must perform multiple objectives. In addition to acoustic performance, they must meet fire separation requirements and serve as part of the lateral-force-resisting system (shear walls). They are often called upon to support hung cabinets or other features and need to take up minimal space.

Because of these and other considerations, many designers use staggered wood unit separation walls. A common construction includes 2x6 wall bottom and top plates with 2x4 studs at 8 inches or 12 inches o.c., alternating from one side of the plates to the other. STC ratings of staggered wood walls in the range of 50-63 can be accomplished.

Maximizing Value with Podium Designs

Maximizing the size and area of a wood-frame building is a costeffective way to achieve five or six stories of saleable or rentable space. Adding a podium increases the value of a project further with retail and parking. Concrete podiums are the most common, and the upper slab typically acts as both a fire separation and structural transfer slab for the framing above.

Podium-style buildings are a product of the horizontal building separation provision (IBC Section 510.2). Separated by a 3-hour fireresistance-rated horizontal assembly, they are treated in the code as two separate structures, built one on top of the other, to determine area limitations, continuity of firewalls, the allowable number of stories, and type of construction.

For the podium to be considered a separate and distinct building, the podium and construction below must be of Type IA construction and equipped with an NFPA 13 sprinkler system. Occupancies above the podium are permitted to be A, B, M, R or S, while occupancies below are permitted to be any except H. The overall height of the two buildings is measured from grade plane and is limited by the provisions of IBC Chapter 5 (with increases) for the more restrictive of the two buildings. Wood-frame exterior walls can be used within the podium level(s) (Figure 2) to improve energy efficiency and further reduce costs. Although Type IA construction (which typically requires all noncombustible framing) is required, there are several opportunities for the use of FRT wood wall framing in Type I and II buildings per IBC Section 603.1. One example is non-rated, non-bearing exterior walls, where using wood offers two advantages:

- 1) The building enclosure details utilized for the wood-frame building above the podium can also be used below the podium, and
- 2) The requirements for continuous insulation versus cavity insulation are the same above and below the podium. In contrast, using steel studs below the podium would require continuous insulation, likely causing the need to shift the wall framing into the building to accommodate a thicker thermal barrier.

When a building has an NFPA 13 sprinkler system throughout, only a 1-hour rating is required when separating enclosed parking areas from occupancies such as B, M, and R per IBC Table 508.4. This indicates that a mixed-use building consisting of an enclosed parking area and other occupancies could be entirely framed with wood if allowable building size calculations permit the use of Types III, IV or V construction under a separated occupancies approach. Even if other materials are used in the building (perhaps as lower walls or columns), there is value from a cost perspective in classifying the entire building as the least restrictive construction type as permitted by IBC Section 602.1.1.

Conclusion

Wood-frame construction is an excellent option for developers and designers looking to maximize the value of their mid-rise projects. Building codes require wood structures to meet the same level of safety and performance as structures made from other materials, and wood offers added advantages such as cost savings, construction speed, and sustainability..



The online version of this article contains references and a list of resources. Please visit www.STRUCTUREmag.org.

Discussion about cold-formed steel framing on podiums will be included in an upcoming issue of STRUCTURE.

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Additional Reading

WoodWorks - www.woodworks.org

- Maximizing Value with Mid-Rise Construction
- 5-over-2 Podium Design Parts I and II (reprinted from STRUCTURE)
- The Analysis of Irregular-Shaped Diaphragms
- Acoustical Considerations for Mixed-Use Wood-Frame Buildings, WoodWorks
- Energy Code Compliance in Wood-Frame Buildings

American Wood Council – <u>www.awc.org</u>

- Code Conforming Wood Design
- National Design Specification (NDS[®]) for Wood Construction[®]

Think Wood (CEUs) – <u>www.thinkwood.com</u>

- Designing for Fire Protection
- Designing for Earthquakes
- Designing for Wind Resistance
- Energy-Efficient Wood Buildings
- Exceeding Thermal Performance Goals Using Wood
- Designing for Durability
- Calculating the Carbon Footprint of Wood Buildings
- Wood and Indoor Environment

References

Survey on Actual Service Lives for North American Buildings, FPInnovations, 2005 Comparing Continuous Insulation R-Values in Steel vs. Wood Framing, SBC Magazine, May 2017