Reducing Carbon Footprint

The use of wood lowers a building's carbon footprint in two ways. Wood continues to sequester carbon absorbed by the trees while they were growing, keeping it out of the atmosphere for the lifetime of the building—longer if the wood is reclaimed at the end of the building's service life and re-used. Meanwhile, the regenerating forest continues the cycle of carbon absorption. Wood products also require less energy to produce than other building materials, and most of that comes from renewable biomass (e.g., bark and sawdust) instead of fossil fuels. Substituting wood for fossil fuel-intensive materials is a way to avoid greenhouse gas emissions and reduce embodied carbon.

Volume of wood products used:
1,708 cubic meters (60,334 cubic feet)

U.S. and Canadian forests grow this much wood in:
5 minutes

Carbon stored in the wood:
1,426 metric tons of CO_2

Avoided greenhouse gas emissions:
3,031 metric tons of CO_2

TOTAL POTENTIAL CARBON BENEFIT:
4,457 metric tons of CO_2

EQUIVALENT TO:

942 cars off the road for a year

Energy to operate 471 homes for a year

Source: US EPA

Estimated by the Wood Carbon Calculator for Buildings, based on research by Sarthre, R. and J. O'Connor, 2010, A Synthesis of Research on Wood Products and Greenhouse Gas Impacts, FPInnovations. Note: CO_2 on this chart refers to CO_2 equivalent.

[1] www.woodworks.org/wp-content/uploads/Alternate-Means-Wood-Solution-Paper-by-WoodWorks-Final-for-web.pdf

[2] www.woodworks.org/wp-content/uploads/wood_solution_paper-Accomodating-Shrinkage.pdf

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Considering wood?
Ask us anything.

Whether you have questions about light wood-frame, mass timber or hybrid construction, our team of architects, engineers and construction experts is available to help. Contact us for free project support, or visit woodworks.org for upcoming education, design tools, and a wide range of technical resources.

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Forestry Innovation Investment

Sacramento Developer Builds First Six-Story Light Wood-Frame Residential Building in the U.S.

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PROJECT DETAILS

LOCATION:
Sacramento, California

STORIES:
Six stories of wood plus mezzanine over a two-level concrete podium

SIZE:
63,000 square feet

CONSTRUCTION TYPE:
Type III-A over Type I-A podium

COMPLETED:
2020

PROJECT TEAM

CLIENT/OWNER:
D&S Development, Inc.

ARCHITECT:
HRGA, The HR Group Architects

STRUCTURAL ENGINEER:
Buehler

CONTRACT MANAGER:
Tricorp Group, Inc.

CODE CONSULTANT:
Churchill Engineering, Inc.

When D&S Development decided to build a new multi-family, mixed-use project in Sacramento, the firm did something no one had done before. D&S and their design team worked with the City's Building Department and built the country's first residential structure with six stories of light wood-frame construction plus mezzanine over a two-level concrete podium. The eight-story building makes the most of its small but desirable site while maximizing its owners' financial return.

For years, the International Building Code (IBC) allowed light wood-frame buildings up to five stories for residential occupancies (six for office) over a single-level podium. The 2015 IBC evolved to recognize multi-level podiums, which had been permitted in the Seattle Building Code for some time. Across the country, designers began maximizing the value of their mid-rise projects with 5-over-2 configurations; however, 5-over-2 still wasn't sufficient to make the investment in 1430 Q pencil out.

Sacramento's competitive building market required that 1430 Q have at least six floors of residential units to make the project profitable. By using the City's Alternate Means and Materials Request (AMMR) process, the design team was able to successfully achieve the extra height and, in so doing, build the country's tallest light wood-frame building.

"This building site provided a great opportunity, but it would have been tough to get the numbers to work in our market if we did things the traditional way," said Steve Lebastchi, Principal of D&S Development. "We needed a sixth floor of residential units to make the project viable, but the costs of concrete and steel would have made it too expensive to build. So, we approached WoodWorks and they connected us with a code consultant who helped make it work using wood."

The result is good news for owners and developers, since the process opens doors for more 6-over-2 buildings in the future. Since the overall building height exceeds code limits for Type III construction, the team had to demonstrate how to achieve code compliance—including required fire ratings and other fire-protection measures—through the AMMR process. 1430 Q also demonstrated that wood framing can be competitive for infill development, providing cost-effective building options for housing and retail in busy urban neighborhoods.

Location, Location, Location

1430 Q's location is what initially sold D&S Development on the project. The site, which has direct freeway access, is adjacent to a light rail station and a popular city park.

The six wood-frame levels include one- and two-bedroom rental units, ranging from 580 to 2,200 square feet, surrounding a center courtyard. Units on the sixth-floor benefit from the mezzanine, with floor-to-ceiling windows providing expansive views. High-grade interior finishes and amenities, including a fitness room, bike storage, pet washing station, and outdoor lounge with BBQ, make 1430 Q a desirable place to live.

The two-story podium features a 9,000-square-foot ground-level retail space with outdoor dining area, which leased almost immediately. It also includes four accessible parking spaces on level one, and additional parking and storage on level two. The project also has one level of below-ground parking.

At approximately $150/square foot (without finishes), Lebastchi said construction cost about $15 per square foot more than a typical 5-over-2 project. However, the additional story with premium mezzanine space made the development an instant financial success.

Working through the AMMR Process

The AMMR process allows a building official to consider the intent of prescriptive code provisions when deliberating on new or existing technologies in materials, design and methods that are not explicitly addressed in the code. In this way, the building code can provide the flexibility to address new concepts, innovations, and developments that may not have been recognized or even existed during the code's formal development process. Learn more about AMMRs in the WoodWorks paper, *Getting to Yes: Making Effective Use of the Alternate Means Process.*[1]

1430 Q was designed under the 2013 California Building Code, which limits Type III-A buildings to a maximum of 85 feet above grade, five stories of wood-frame construction with sprinklers, 65 feet maximum height for wood shear walls, and a single-story podium.

To go beyond those limits, the design team turned to Churchill Engineering. "The building code is designed to allow alternates if the design team can show equivalency," explained the firm's President, James Churchill. "The 1430 Q project team wanted to build six stories of Type III-A construction instead of five, and they wanted to go up to 94 feet when the limit was 85. Most people consider those tough limits to overcome—but we looked at what we could do to enhance the building in terms of life safety, to make it equivalent or better than what the code intended."

Together, the team studied the City of Sacramento's Building Code, and determined that deviations were allowed with additional fire protection. "We proposed a mitigation that included 2-hour ratings for all corridor walls, unit separation walls, and bearing walls," said Churchill. "So basically, the entire structural system was 2-hour rated. We also provided additional access to the roof from two separate exit stairways." Because the code has limitations on floor area, the team also added a 3-hour firewall assembly to separate the structure into different "buildings" from a code perspective.

The design team submitted the AMMR report and received approval just three days later.

"We've submitted a number of AMMRs over the years, but this one was significant," said Roland Ketelsen, a Principal at HRGA Architecture. "The process went smoothly in large part due to our collaboration with the City of Sacramento Building Department."

In fact, the Building Department's response was that "Fire-resistive elements are being added that make the Type III-A portion of the building better than Type II-A (in terms of fire rating of building elements)—almost Type I-B."

The team also considered a structural AMMR but determined that a height increase could not meet the shear wall deflection limitation requirements. Since ASCE 7 Table 12.2-1 limits wood-frame walls sheathed with wood structural panels rated for shear resistance to a height of 65 feet, they instead decided to extend the concrete shear wall system up from the concrete podium to level four, leaving the wood shear wall above within code limitations.

"We considered using the AMMR process to increase the maximum height of the wood shear wall system and assumed we'd have to go through some testing to justify that," said Ryan Miller, Associate Principal at Buehler. "Testing may have provided the results we were looking for, but we brought the concrete shear wall up one level from the podium into the wood framing as a more cost-effective alternative to testing."

Efficient Design and Construction

Even though 1430 Q went taller than a standard light wood-frame construction project, the products used were typical. "Wood is the obvious choice for these types of buildings," said Miller. "It's lighter in weight than other materials and so reduces the overall weight of the building, which reduces impact on the lateral system and the foundation, resulting in a more efficient structure. Plus, it's easy to work with for the contractors, which made it the 'go-to' choice here."

Plated dimension lumber floor trusses were spaced at 16-inches and roof trusses at 24-inches on center; roof trusses had sloped top chords for drainage. The team used prefabricated wall panels to speed construction. Corridor floors contained 2x8 joists spaced at 16 inches on center. Non-structural partition walls used 2x4s, and structural walls were framed with 2x6 and 3x6 dimension lumber, with some 2x8 and 3x8 in certain exterior conditions where a thicker wall was needed. Stud spacing varied depending on the floor; 3x6 at 12-inches on center was common for the lower levels. Door and window headers were framed with glued-laminated timber (glulam) beams or solid-sawn members. Standard 3/4-inch plywood was used for the floor sheathing, and 1/2-inch plywood for the roof sheathing and wood diaphragm.

Structural Design Took Some Unique Turns

The design team used standard wood framing design to reduce costs, with a few twists.

Two-Stage Analysis

First, while the code has some limitations governing when a two-stage analysis can be used, engineers at Buehler took this approach, though modified to reflect the unusual lateral system. "There are period and stiffness limitations in the code; however, once those were justified, we could use a two-stage analysis, which helped to simplify design," said Miller.

Lateral System Design

The design team's unique approach to lateral system design was another key to the project's success. As noted, Buehler extended the concrete shear walls above the concrete podium, which allowed the wood shear wall system to comply with the code-prescribed height limitations.

"The podium transfers the gravity loads for the wood structure because all of the wood levels come down to level three," said Miller. "Seismically speaking, the horizontal shear is transferred out at level four because that's the top of our extended concrete system. So, the level three podium is still an overturning transfer level because the shear walls are discontinued at the podium slab; that's where the wood system overturning was resolved."

The approach was not without challenges, since the shear walls lined up above the podium slab, but not below.

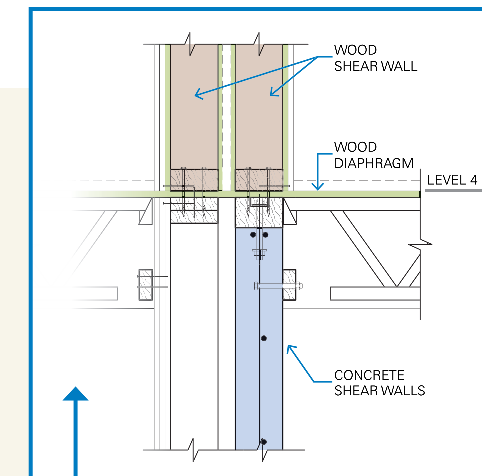
"The lateral force from the double wood shear walls on level four is transferred into the single concrete shear wall on level three, directly through the wall plates into a wood nailer on top of the concrete wall, which is bolted to the wall at 8-inches on center," said Miller. "The wood wall that does not stack on top of the concrete wall transfers its load through the small segment of wood diaphragm over to the nailer on the concrete wall. And as a measure of redundancy, the wood shear wall that does not stack on the concrete shear wall continues its shear nailing down to the podium. We were able to resolve the overturning forces at the podium level by using wide concrete transfer slab beams."

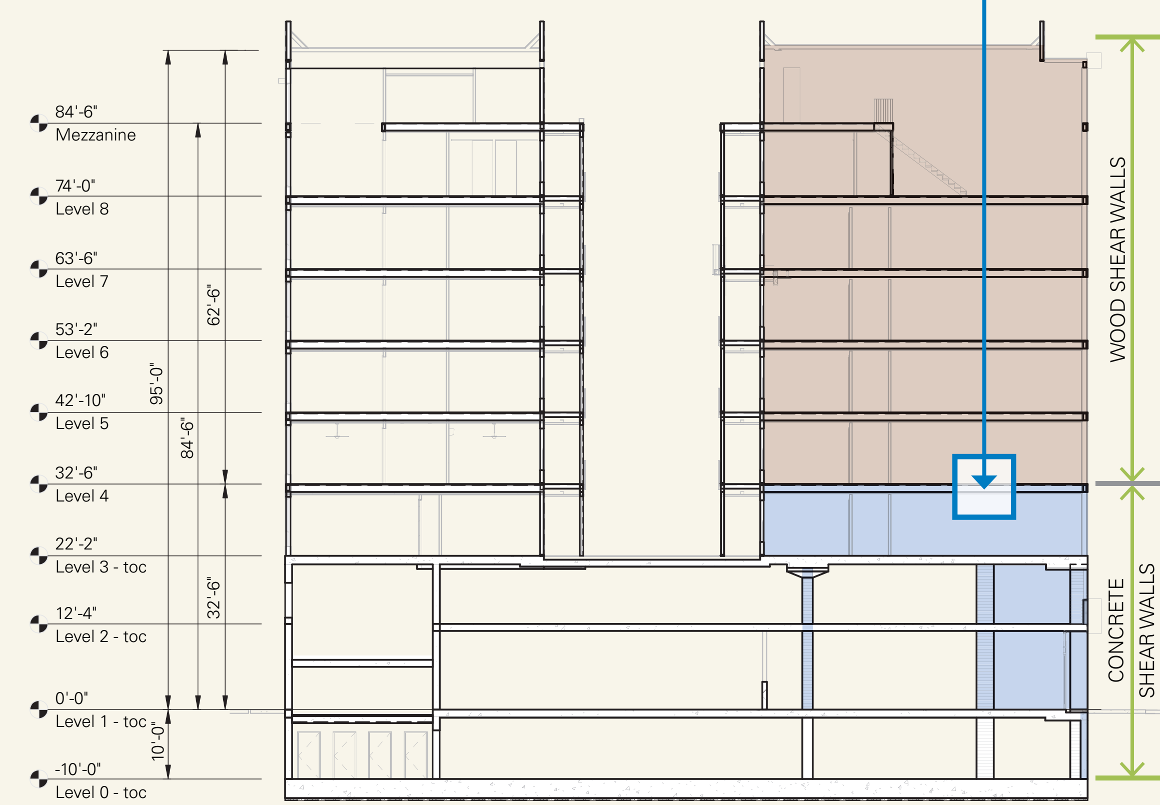
During installation, the lateral design also created some unique challenges in terms of construction sequencing. Wood-framed walls had been prefabricated; however, the contractor had to wait to install them until the concrete shear walls could be poured and cured.

Connecting a Wood Shear Wall to a Concrete Shear Wall

The unique concrete/wood shear wall configuration required a special detail to transfer load from the wood shear walls into the concrete shear walls. Buehler designed double-party walls—i.e., two wood-framed walls side by side—separated by a gap of about two inches. Both perform as shear walls and, once they hit level four, transfer their shear load into one concrete shear wall.

However, because the concrete shear wall is a single wall, it aligned with just one of the wood walls. Therefore, the wood shear wall on the left, which is not in alignment with the concrete shear wall below, transfers its load through a segment of the wood diaphragm sheathing, which then transfers the load a few inches until it reaches the wood nailers on the concrete wall.





Diaphragm Design

The team used an envelope solution for rigid and flexible wood diaphragm designs, which allowed a worst-case scenario for both the diaphragm and shear wall designs. "We needed to do that for 1430 Q because wood shear walls were only located at the party walls; the exterior walls of the building just didn't have enough length to be considered as shear walls," said Miller.

Since the design was limited to using interior walls, the wood diaphragm had to be cantilevered out to that exterior line. "We utilized some exceptions in the code that allowed us to increase that cantilever distance by maintaining a certain ratio of the length and width," Miller added. "This was required due to overall layout of the building and the fact that we had a lot of windows on the exterior, not because of the extra height of the building."

Seismic Design

Use of extra gypsum board allowed the team to achieve the 2-hour fire rating requirements, but this added more weight to the structure, creating extra challenges for shear wall and diaphragm designs, as well as shear transfer at the wood seismic base into the concrete shear wall system.

"We knew we could accommodate the extra weight, although it did make the seismic forces higher," said Miller. "In addition to those higher forces, we had offsets in the shear walls, in the transfers from shear walls at level four into the concrete walls, and then the overturning forces onto the podium slab, which did not have stacked walls below. This created discontinuities in the concrete system. We were able to transfer those forces into the concrete system, but it was certainly more complicated than a usual podium."

Acoustic Design

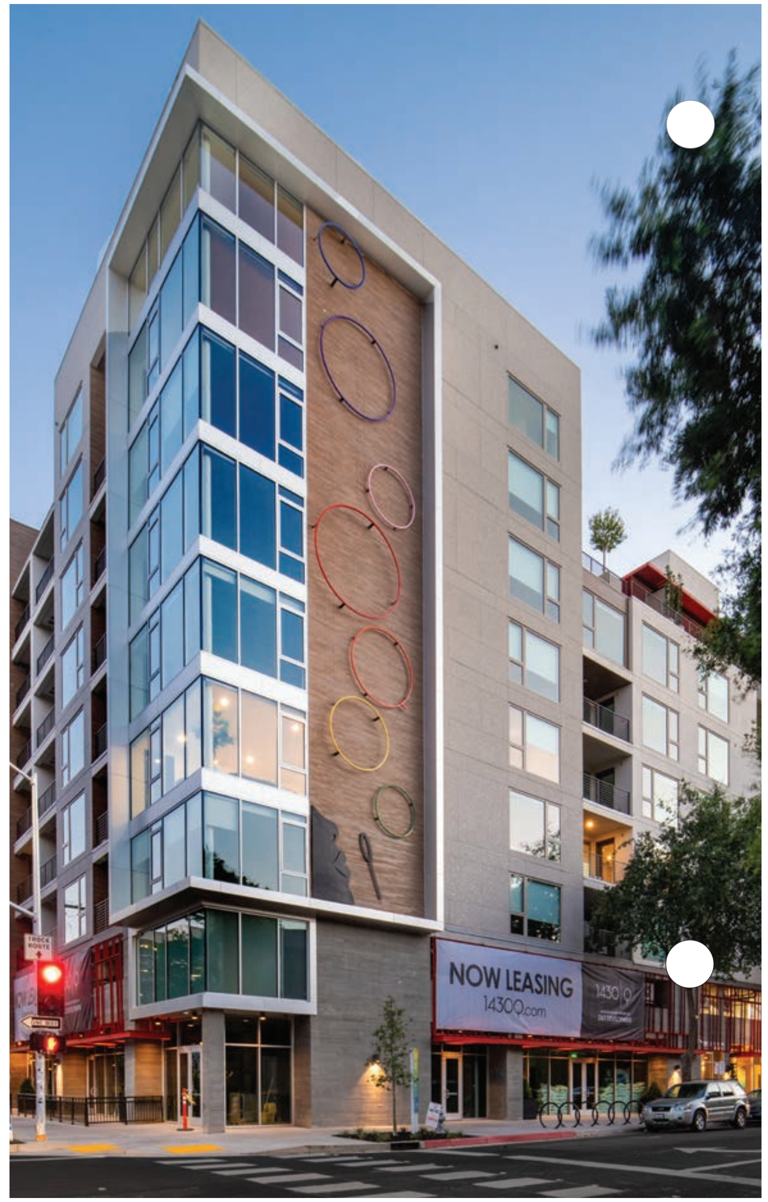
Acoustic and fire design solutions to some extent overlapped. For example, extra layers of gypsum board were required to meet the acoustic requirements for sound transmission through walls, which also made the 2-hour fire rating easier to achieve.

"We had already developed the partition assembly between apartments to include staggered studs and two layers of sheetrock on either side to achieve an STC rating in the mid-60s," said HRGA's Ketelsen. "So, all we needed for a 2-hour wall was to fire tape the sheetrock. The added cost to make the acoustic assembly work for the 2-hour fire assembly was minimal."

"In some cases, we added resilient channels, even on the ceiling, so we had two layers of sheetrock, then a resilient channel, and then another layer of sheetrock," added Michael Dobbin, a Senior Associate Architect at HRGA. "The code required an STC rating of 50 to 60, and we were around 63."

Fire Safety

Because fire safety was one of the City of Sacramento's main concerns with the increased height, the team designed 1430 Q to achieve the same level of protection as a Type II-B building. This was critical to the project's approval.



In addition to the 2-hour corridor, unit separation, and bearing walls, the building includes 2-hour floor assemblies with three layers of 5/8-inch gypsum for the ceiling and 1-1/4 inches of concrete topping on the floors, which is common in residential projects. It also includes 2-inch autoclaved aerated concrete (AAC) panels, sandwiched between party walls, to meet 3-hour separation requirements at fire walls.

Taller Buildings Require Additional Measures

Shrinkage is a concern in any multi-story wood building, but the extra story in 1430 Q warranted extra care. Since designers estimated 1-3/4 inches total cumulative shrinkage at the roof, HRGA took several mitigation steps.

Designers specified wood with moisture content less than 19 percent and added a slip joint in the exterior stucco at each floor to allow for movement. Buehler also used a continuous tie-down system, which is common in multi-story buildings. "While the hold-down system is not unique, the fact that it had to go up one floor higher than the usual maximum was significant," said Miller. "While it was an easy modification, the additional force is worth noting."

He added, "Overall, the accommodations we needed to make were no different than for a five-story building. You have the same consideration with shrinkage on five stories that you do with six. You just have one more floor to deal with, and the total shrinkage at that top level becomes a little more than you'd see on a shorter building." Detailed information on shrinkage can be found in the WoodWorks paper, *Accommodating Shrinkage in Multi-Story Wood-Frame Structures.*[2]

Taller buildings also have special safety requirements for building maintenance activities such as painting and window washing, so the design included tiebacks and davits on the roof. Loads imparted on the anchors needed to be considered in the roof truss design, but it was an easy modification to incorporate.

Constructability

While some local contractors were hesitant to be part of the country's first 6-over-2 building, Tricorp Group was eager to take on the challenge.

"There were a few things that differed from construction of a shorter wood-frame building, including addition of a few concrete shear walls on the first floor of the wood-framed structure, but overall, we found the process to be easier than expected," said Tony Moayed, Tricorp's CEO. "The Building Department was extra cautious, so inspections took a bit longer; they even had a special inspection for fire caulking. But it wasn't much more complicated than a five-story building. The key was to get the sequencing right." A tower crane was used to lift prefabricated wood wall panels directly into place from the delivery trucks.

Both quality and speed were important. Tricorp built mock-ups of the concrete wall, shear walls, exterior finishes, window assemblies, framing assemblies on the third floor, and other project elements for owner approvals and to show tradespeople what was expected. "It was a challenge to coordinate the trades on this because 1430 Q was a first, but we learned a lot," said D&S Development's Lebastchi. "And now that we understand what's involved, we expect future projects to go even faster."

Lessons Learned

Every first has a list of lessons learned, and 1430 Q is no exception.

HRGA's Ketelsen said, "Because it's a gravity-loaded building, the wood dimensions were bigger in the lower floors, so we sometimes struggled to find room for things like mechanical ductwork to wind its way through the building. We learned we had to plan for that." Miller agreed, adding that he'll also look for refinements for connections at the seismic base on future projects. "While the concept we used is certainly applicable to similar and even taller buildings, there may be seismic limitations of connections where bolts in the nailers on top of the shear wall may not work," he said. "Next time, we'll consider using embedded steel plates."

The team also learned from the AMMR process.

"We had gone through an AMMR before, but it was nothing like this; this was different," said Lebastchi. "Before starting construction plans, we made sure to meet and strategize with building officials. They were supportive, saying that, if we could prove both safety and structure, then the fire marshal would approve it. We were able to prove both."

"The AMMR process is about trying to make a building better than it would have been if it had been built prescriptively," added Ketelsen. "Because it is 2-hour fire-rated throughout, we think 1430 Q is a better building. We're grateful to the City of Sacramento Building Department for their support throughout this process."

The team agreed that 1430 Q is an indicator of good things to come for light wood-frame construction, as evidenced by all the questions coming in from other developers. "It is certainly significant that a precedent has been set," said Miller.

Moayed agreed, adding, "We learned that building six-story wood building is very doable, and we can count the lessons we learned on one hand. We showed that wood beats the price of steel and concrete for this type of construction, and, comparatively speaking, it was not difficult to add that one additional story."