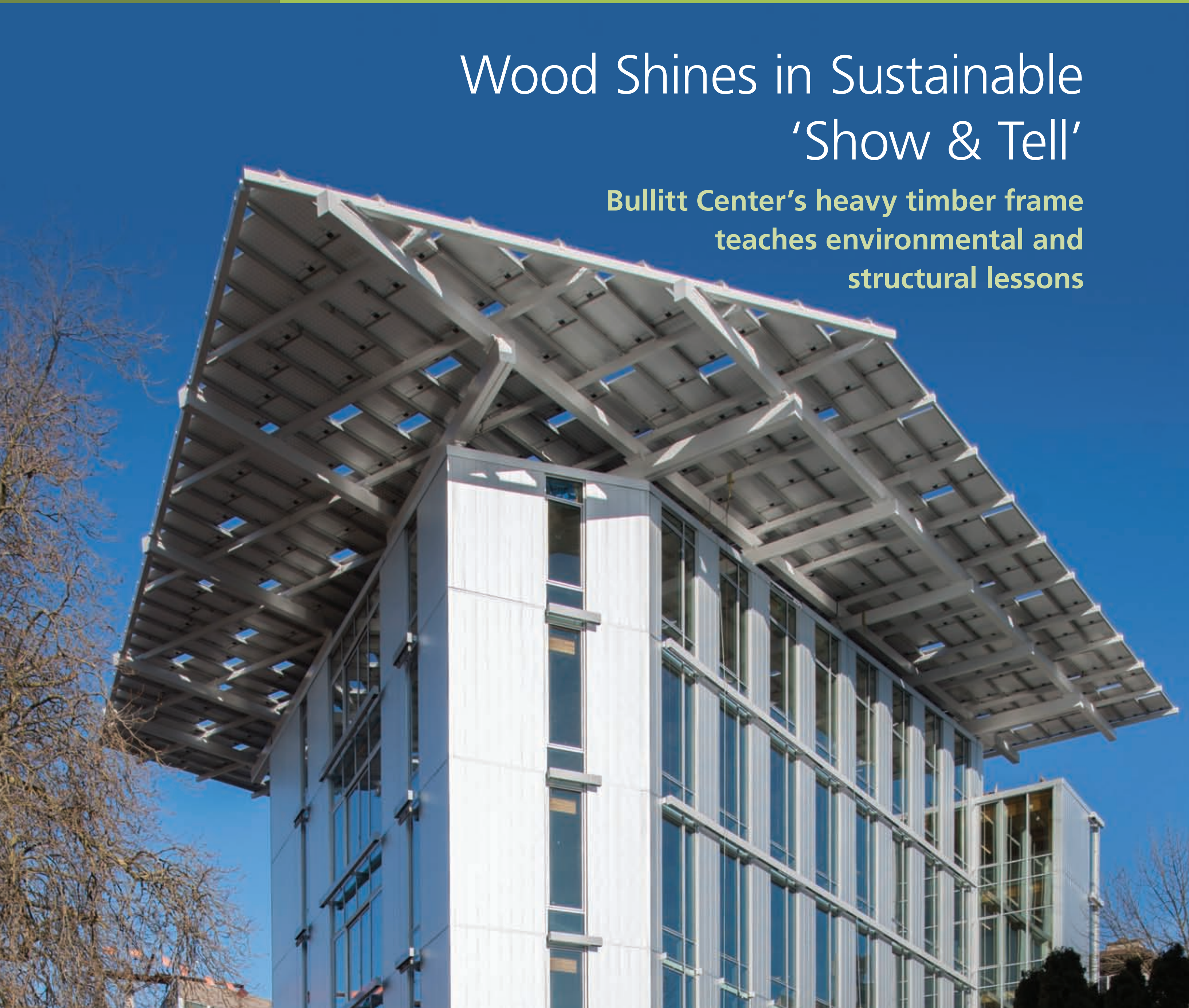
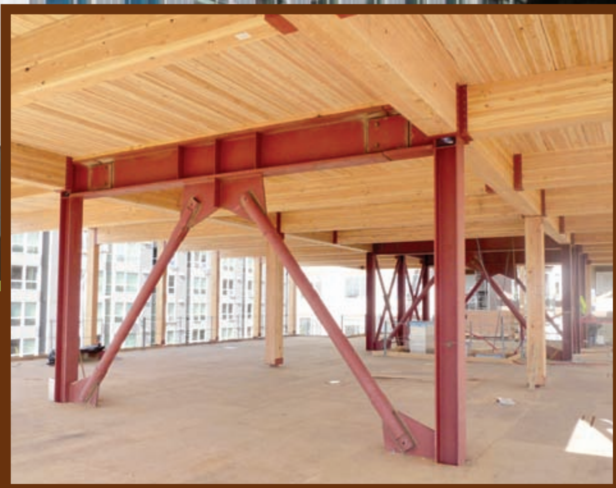
Wood Shines in Sustainable 'Show & Tell'

Bullitt Center's heavy timber frame teaches environmental and structural lessons





WoodWorks

Bullitt Center

DATE OF COMPLETION: 2013

OWNER: Bullitt Foundation

ARCHITECT: The Miller Hull Partnership • Seattle, WA

CONTRACTOR: Schuchart Construction • Seattle, WA

STRUCTURAL ENGINEER: DCI Engineers • Seattle, WA

DEVELOPER: Point32 • Seattle, WA

CERTIFICATION: Design, materials and construction practices met all criteria of the Living Building Challenge 2.0

Described as the greenest commercial building in the world, the Bullitt Center in Seattle, Washington pushes the envelope in urban sustainability. The six-story, 52,000-square-foot structure is designed to meet stringent requirements of the Living Building Challenge (LBC)—using photovoltaic cells to generate enough electricity to sustain the needs of its tenants, recycling its own water and waste, and reducing energy use by more than 80 percent compared to an average office building.

And yet, at the heart of this state-of-the-art structure lies a heavy timber frame—a traditional building system that is increasingly being used in new and innovative ways.

"The Bullitt Foundation wanted to do something that would have the biggest impact in terms of changing the building industry," said Brian Court, project architect with The Miller Hull Partnership. "So they shouldered the tremendous research costs to develop this prototype and see just how far we could take a building in an urban environment. We wanted a sustainable building that would last 250 years. That's just one of the reasons we chose wood."

Court added, "Energy efficiency gets a lot of attention on this project, but we have been equally excited to learn more about heavy timber as a structural system; discoveries we made while conducting life cycle assessments on various structural systems. Timber has so many great qualities from an aesthetic point of view that its environmental virtues are sometimes overlooked."

Sustainable Structure, Sustainable Community

It's hard to separate the goals of the project from those of its sponsor organization. The Bullitt Foundation's mission is 'to safeguard the natural environment by promoting responsible human activities and sustainable communities in the Pacific Northwest.' The Bullitt Center was designed to be the world's most energy-efficient commercial building and to meet the highest benchmark of building sustainability—LBC certification, which defines measures of sustainability through development and construction.

The goal of the Bullitt Center is 'to change the way buildings are designed, built and operated; to improve long-term environmental performance; and to promote broader implementation of energy efficiency, renewable energy and other green building technologies in the Northwest.'

"We also wanted to lower CO_2 emissions and reduce the environmental footprint of the building," said Court. "Our 250-year target life cycle is a key part of that goal."

Bullitt Center Basics

The first thing most people notice is the building's roof, oversized to support enough photovoltaic cells to power the entire building. But closer inspection finds that many of the building's most unique features lie inside.

The six-story podium structure (four floors of wood over two stories of reinforced concrete) is built with a Type IV heavy timber frame. The frame's Douglas-fir glulam beams and columns, finished to an industrial appearance grade, range in size from 5-1/8 x 15 to 12-1/4 x 21 inches.

A solid 2x6 dimension lumber wood deck forms the floors; the 2x6 #2 Douglas-fir members were set on edge and then nailed to one another to form a solid panel, 5-1/2 inches deep. Similarly, the roof deck is comprised of 2x4s nailed together. CDX plywood is used for roof and floor diaphragms and for some wall panels.

Challenging Material Requirements

LBC requirements stipulated that the Bullitt Center's design and construction team meet a number of criteria, including responsible site selection, 100 percent on-site renewable energy generation, 100 percent of water needs provided by harvested rainwater, and on-site waste management.

Materials acquisition was one of the toughest challenges because all building materials, including the lumber, plywood and glulam, had to meet LBC criteria. This meant that all of the wood, including the lumber that comprised the glulam beams and columns, had to be certified as Forest Stewardship Council (FSC) 100% (formerly known as FSC Pure).

In addition, achieving LBC certification required that all wood products come from mills within about 600 miles of the job site. "While the LBC has some flexibility, the goal is to reduce the carbon footprint of materials," said Court. "So, if you have to go outside the allowable radius to source some materials, or if you have to trade off some FSC Mix wood with 100%, the LBC is somewhat flexible." Materials such as steel and concrete had to be manufactured within 300 miles of the site.

Besides limiting the allowable distance for building material transport and requiring that all wood materials come from FSC-certified forests, LBC criteria also prohibited the use of 14 materials and 362 chemicals. The 'Red List' is comprised of toxic finishes including materials such as PVC, lead, mercury and other substances, many of which are commonly found in building components.

"While the LBC standards are constantly evolving, the overall goal remains constant," emphasized Court. "Reduce the amount of energy it takes to create building materials and get them to the job site, and reduce the use of toxic materials within the structure itself. Naturally, wood met those requirements on a number of levels."

Why Wood

Ironically, the Miller Hull design team originally expected to design the Bullitt Center using a reinforced concrete frame, because they thought they needed it for thermal mass. "In fact, we didn't go into this thinking we'd do it with heavy timber at all," Court said. "But when we considered the embodied energy and the carbon footprint of the concrete, timber was a much better environmental solution. When you consider the carbon sequestered in the timber itself, you have a carbon-positive building solution."

He added that, by using wood, they were also able to reduce the interior finishes. "That's where you find most of the toxic ingredients, such as paints and varnishes. By using a timber frame, the interior was essentially finished as it was assembled. There are great advantages to that—both in terms of cost savings and health benefits."

Wood also made more sense from an architectural point of view. "We think buildings should identify with the region; they should look like they belong in place," said Court. "We love timber here in the Northwest. We love it as architects; we love expressing the structure and connections of a building. Timber was not necessary to make this building happen, but we think wood gave it a unique regional place-based attribute."

For many reasons, Court and other architects at Miller Hull try to use wood as much as possible. "We've done quite a bit of heavy timber design, but mostly with two- or three-story structures," he said. "So we learned a lot about using wood in a taller structure like this."

Glulam—A Natural Framing Choice

Because wood is a sustainable, renewable resource, and because glulam makes efficient use of the material by bonding smaller pieces of dimension lumber together to form larger beams and columns, glulam was a logical choice over concrete for the Bullitt Center. According to Brian Oberg of Calvert Company in Vancouver, Washington, the project required approximately 119,000 board feet of Douglas-fir industrial appearance grade glulam beams and columns.

"To keep them all natural and avoid banned chemicals from the Red List, we did not fill knot holes with putty," said Oberg. "While lumber costs vary with the market, the decision to use FSC 100% lumber typically adds about 15 to 20 percent to the cost of the beams. We cut some of that expense by going to an industrial grade beam rather than a more expensive architectural appearance grade."

To protect the beams during Seattle's soggy construction season, they applied a wax-based finish, which also had to be vetted in relation to the Red List. They chose a sealer with low-VOC off-gassing and none of the chemicals or compounds that are prohibited in a Living Building.

Mike Warnek, with Matheus Lumber Company in Woodinville, Washington said his team provided detailed shop drawings showing the location of each beam on each floor, which allowed them to make sure that everything was accounted for. "Our big fear in all this was that we would forget something," said Warnek. "It's not easy to find FSC 100% material that meets Living Building Challenge criteria on short notice for a forgotten beam, so the cost of doing the shop drawings was money well spent."

The requirement to use FSC 100%-certified products, coupled with the fact that the wood had to be sourced within 600 miles, meant planning was critical. "My biggest takeaway from the project is to allow enough time," said Warnek. "Material acquisition was not difficult, but it could not be done at the last minute. My recommendation for future projects is to allow eight to ten weeks to source FSC 100% lumber."

Dimension Lumber Provides Energy Advantage

In order to minimize the building's energy footprint, the design required high ceilings and tall windows to let in as much natural daylight as possible. Miller Hull's unique use of 2x6 dimension lumber, set on edge and nailed in place to form the solid wood floor panels, provided an unusual design advantage in the quest to meet LBC criteria.

"Base zoning height for this site in Seattle is 65 feet, but the City directed a number of agencies to be flexible with existing codes," said Court. "The zoning office told us they would grant us an extra 10 feet of building height if we could show that doing so helped us achieve the goals of the LBC. In our case, we were able to show that by raising the standard 11-foot-6-inch floor-to-floor height to 14 feet, we could improve daylighting."

Court explained that the general rule of thumb is that, for every additional one foot of height on the perimeter of the building, daylight penetration increases by two feet. "So by getting an extra two feet in our floor-to-floor height, we got an extra four feet of daylight penetration," said Court. "And by having relatively shallow floors—achieved by using the solid 2x6 wood floor panels instead of deeper floor joists—it allowed us to increase the daylight penetration even further. Plus, the 2x6 deck easily spans the 10-foot-6 inch dimension, effectively eliminating the need for a perimeter beam. This allowed the windows to extend all the way to the bottom of the decking, improving daylighting even further."

Pushing Performance Boundaries

While the building pushed performance boundaries in a number of categories, traditional building products like plywood still played a key role. Lee Zulch, senior superintendent for Schuchart, the general contractor, said wood also helped them meet their criteria in a number of other applications. "While the plans only

"Every board, beam, pipe and fastener going into the Bullitt Center must meet a strict set of guidelines established by the LBC to ensure that the building is constructed of materials that cause minimal harm to the land, air, water and people during the extraction, harvesting, processing, manufacturing, and transportation of that material."

BullittCenter.org

called for ½-inch plywood on the roof for lateral shear, we used ¾-inch plywood, which made it easier to screw in the huge photovoltaic panels."

They also used plywood for backing panels on some walls, and installed ½-inch plywood to the floor assembly on top of the 2x6s for structural diaphragm. The floor panels were covered with an insulation mat to serve as a noise barrier, followed by three inches of concrete topping slabs on each floor to provide thermal mass and facilitate Miller Hull's natural ventilation and night flushing strategies. Night flushing is an energy-saving strategy used to flush hot air out of a building during the evening, to naturally cool elements with thermal mass within the building and blow out stale air. The concrete slab also contained embedded radiant heating and cooling coils.

Simply Functional Timber Frame Connectors

When it came to design and installation of the glulam beams and columns, the design team had a number of criteria for connectors. "We looked early on at a knife plate system which would have been more architectural, but it was expensive," explained Court. "We needed something that could be easily and quickly installed on site, so we value-engineered it back to a bucket connector. We also wanted to use screws instead of bolts. And it all needed to connect to the internal steel brace frame for lateral stability."

The resulting heavy timber frame and bucket connector system was simple and straightforward. "Each beam was cut to length on site and then lifted by crane and placed into the buckets without the need for temporary shoring or scaffolding," Court said. "Framers then fastened the beams to the bucket connectors using ¼-inch diameter SDS screws instead of the typical larger, bolted connections to save time and eliminate the need to pre-drill the beams. The screws could be installed closer to the end of the beam, which gave us a smaller, simpler connector with a more elegant, minimal expression."

The innovative design of the buckets, which Schuchart's crew called helmets, resulted in smooth erection. "The timber frame went up quickly and efficiently," said Zulch. "Our crane lowered each beam into the steel helmets for a snug fit. The buckets were pre-slotted, so our crew just screwed them into place with a hand-held drill. It was fast and simple."

Court added, "Typically, designers like a concealed connection but I like this better because you can see the connection, you can understand the building; it shows the integrated design process. When you have the architect, contractor and structural engineer all sitting around the same table like we did, you get a system that is as efficient as possible."

Easy Design Solution to Avoid Shrinkage

Another noteworthy aspect of the connection is the steel post standoff. "When designing a timber building, architects and engineers need to know that wood shrinks slowly over time and can be compressed if loaded perpendicular to the grain," explained Court. "If you're not careful, your building can shrink, up to half an inch per floor. This adds up quickly when you have multiple floors and makes it difficult to detail a high performance envelope."

To avoid this issue, Schuchart crews inserted a steel tube to connect the top of one timber column to the bottom of the next. Therefore, any radial shrinkage in the beams and girders will not impact the columns. "The result is a timber-frame building that should not shrink and settle over time," Court said.

Natural Fire Protection

One of the great virtues of a heavy timber structural system is the natural fire resistance inherent in the size of the wood members. "We know that wood burns, but it does so at a relatively slow and predictable rate," explained Court. "So, were there ever to be a fire in the Bullitt Center, the timber would char, allowing plenty of time for occupants to vacate and the fire department to arrive."

Additional fire protection is gained by the fact that the bucket connectors were installed so that main girders bear directly on the timber columns that support them from below. "In the event of a fire, even when the steel buckets are weakened by heat, we

still have timber bearing on timber and the beams will not fail," said Court. "Each of the four beams passing through the bucket connection has about three inches of material bearing directly on the column below."

Building Cost is an Investment in the Future

When the Bullitt Foundation challenged Court and his associates at Miller Hull to design a building with a life expectancy of 250 years, they did so knowing that comparative costs would be impacted, since commercial office buildings are typically designed with a 40- or 50-year lifespan.

Total project cost for the Bullitt Center was estimated at $30 million, or $577 per square foot—about double the cost of a comparable building. But this includes all of the soft costs (i.e., design fees; land; negotiations with local, state and federal regulatory agencies; research and other fees). Construction costs were about $360 per square foot of the total; about $50 per square foot more than a typical commercial building, but in line with many institutional projects.

"People have a strong reaction to the $577 figure, but we're trying to change laws about how rainwater can be used and how graywater can be treated and used in commercial structures," said Court. "We've spent time working with the local utility companies to change laws on how photovoltaics can be used and how renewable energy can be generated. So there are a lot of issues we've had to deal with on this project which won't factor into future projects. Plus, we're not just building to code minimums here; we're trying to do it right. And there is a difference."

Court expects hard construction costs to change over time because, with the Bullitt Center, they were forced to use products selected by transport radius and Red List guidelines rather than cost. "We couldn't always use the least expensive product because of toxicity. But as more of these types of buildings come on line, I am confident that costs will also come down.

"The Bullitt Center's initial construction costs are higher, but over its 250-year life, it's going to be a money maker. This is a structure that essentially has prepaid utility bills for the life of the building."

Wood is On Target for the Bullitt Center

While prepaid utilities certainly hold attraction for prospective tenants, most are attracted to the Bullitt Center for bigger reasons. Court is convinced that these global issues will continue to matter to more organizations. "As clients, regulatory agencies and certification programs like LBC or LEED (Leadership in Energy and Environmental Design) increase their influence on material and structural system selection, I think we will see more wood buildings. By increasing our understanding of the material growing in the forest—this renewable, natural resource which is sequestering carbon and has all these great environmental benefits—I am certain that timber will become much more in demand as a building system."

Life cycle assessment will certainly have an impact. "More people are paying attention to life cycle assessment, and wood is coming out as the winner when it fits within the structural criteria for the project," Court said. "In fact, I think one of the things we learned with the Bullitt Center is that wood has the structural capability to do way more than we're letting it do right now. People need to look at wood with fresh eyes, especially because it has so many environmental virtues over concrete or steel."

Court said he was told that Bullitt Center was the first six-story heavy timber project permitted in Seattle since the 1920s. "A lot of people were surprised to learn that a wood structural system was possible here, but this project helped them learn about wood's environmental advantages in terms of embodied energy and life cycle assessment. Wood really outperforms steel and concrete in the right applications. With this project, we think perceptions about wood are going to change."

Carbon Benefits

Wood lowers a building's carbon footprint in two ways. It continues to store carbon absorbed during the tree's growing cycle, keeping it out of the atmosphere for the lifetime of the building—longer if the wood is reclaimed and reused or manufactured into other products. When used in place of fossil fuel-intensive materials such as steel and concrete, it also results in 'avoided' greenhouse gas emissions.

Volume of wood used:
24,526 cubic feet

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

Carbon stored in the wood:
545 metric tons of CO_2

Avoided greenhouse gas emissions:
1,158 metric tons of CO_2

TOTAL POTENTIAL CARBON BENEFIT:
1,703 metric tons of CO_2

EQUIVALENT TO:

325 cars off the road for a year

Energy to operate a home for 145 years

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.

Use the carbon calculator to estimate the carbon benefits of wood buildings. Visit **woodworks.org**.

WoodWorks is an initiative of the Wood Products Council

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