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GOING AGAINST THE GRAIN

'Timber huggers' are taking action to change conventional wisdom that tall wood buildings are inferior

By Nadine M. Post

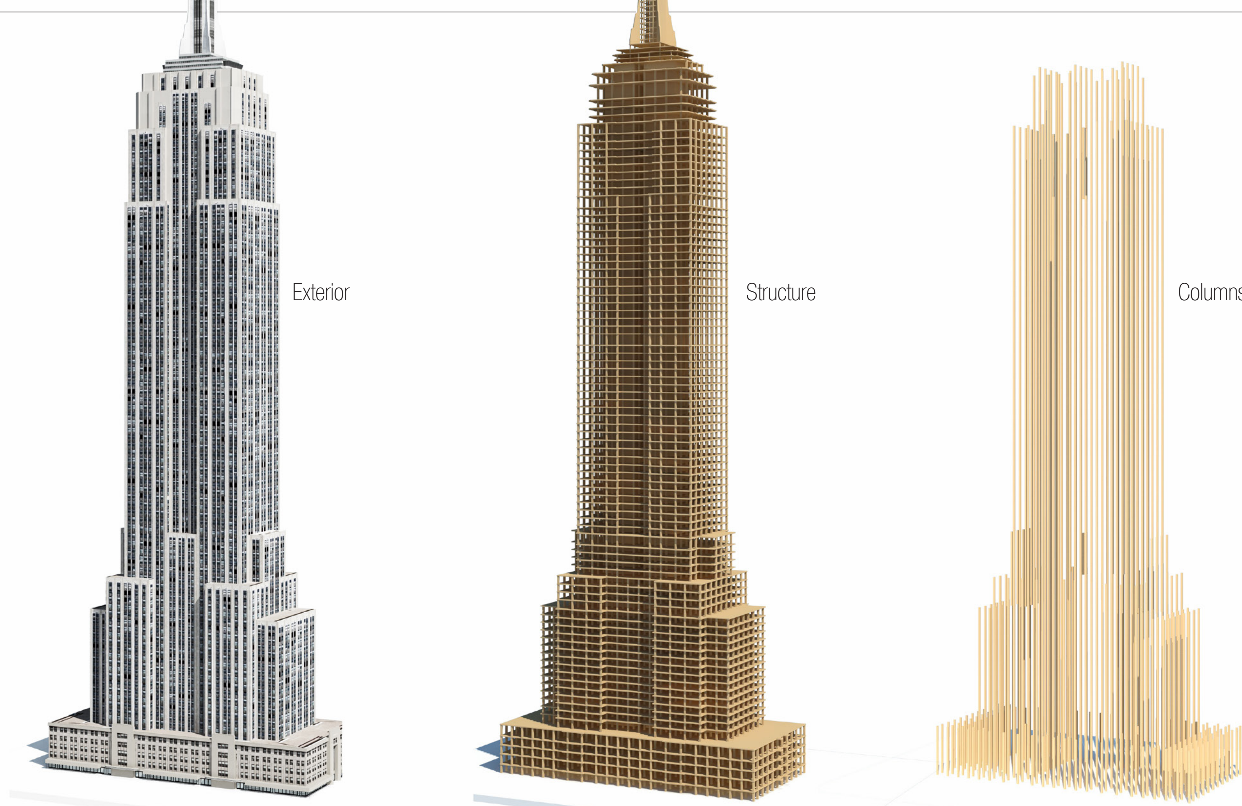
Architect Michael Green thinks most cities don't need high-rises taller than 30 stories. He says the sweet spot for wood buildings—and perhaps all high-rises—is 18 to 24 stories. But that didn't stop the "timber hugger" from accepting an invitation to do a conceptual redesign—in wood—of Manhattan's 102-story Empire State Building.

"The Empire State Building actually works in wood," says Green, founder, in 2012, of Michael Green Architecture (MGA). "But just because we can go that tall in wood doesn't mean we should," adds the architect, whose specialty is exposed timber.

Green says he took on the Empire State Building exercise to expand awareness. "It is important to say what can be done," he says. "So much of what we do is about changing public perception."

The Vancouver, B.C.-based architect is part of a global trend toward wood frames, because wood is considered the greenest of all building materials. There also have been, over two decades, advances in layered-wood products, referred to as "solid wood" or "massive timber."

"More and more, wood is recognized as the most technically advanced construction material and the only one grown by the sun," adds J. Eric Karsh, a principal of Equilibrium Consulting Inc., which has engineered many of MGA's timber jobs, including the 29.2-meter



EXERCISE IN WOOD A conceptual redesign of the Empire State Building shows that wood frames can go sky-high.

RENDERINGS COURTESY OF METSÄ WOOD

PHOTOGRAPHY BY MICHAEL GREEN ARCHITECTURE

WELL-BEING
Recent studies indicate that people are happier, more productive and less stressed when living and working surrounded by wood.

Wood Innovation Design Centre (WIDC) in Prince George, B.C., which opened last year.

Karsh also was Green's partner for the Empire State Building exercise as part of supplier Metsä Wood's "Plan B" promotion to re-envision iconic buildings in wood. For the project, they explored a prestressed moment-frame with hollow box beams, based on Presslam, a patented system developed at the University of Canterbury in Christchurch, New Zealand.

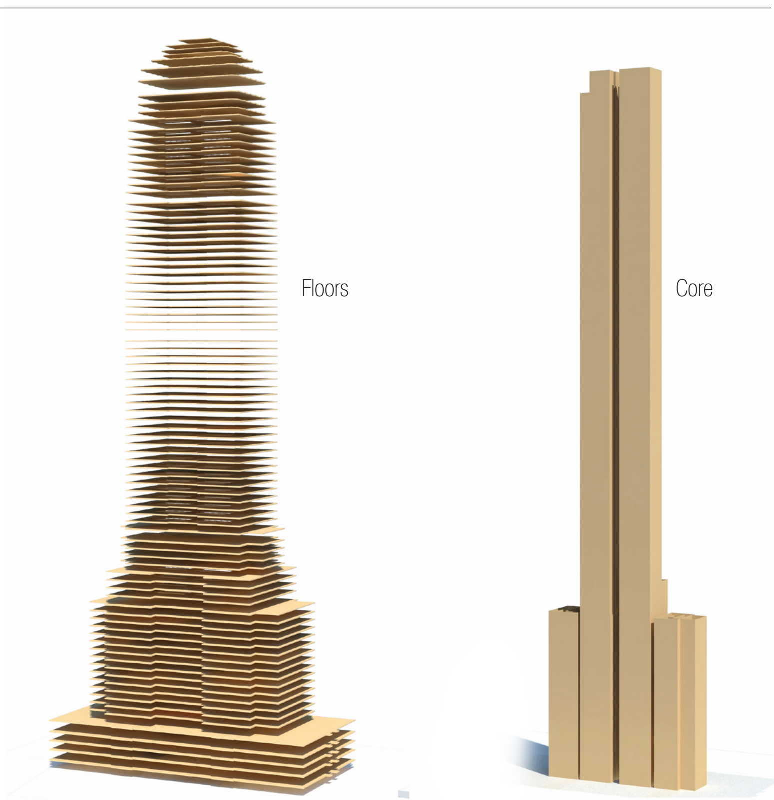
There are no tall wood buildings in the U.S., primarily because of regulatory resistance and a general reluctance to innovate. But since 2010, there have been more than 17 seven-story or taller wood buildings built outside the U.S., according to reThink Wood, formed in 2001 to promote wood buildings.

In Bergen, Norway, a 14-story, 45-m-tall residential timber building opened on Dec. 11. It is the tallest of them all. In London, a 33.3-m residential-commercial building is underway (see p. 17). The 32.17-m Forte, a residential building in Melbourne, Australia, opened in 2011.

reThink Wood and its partners spend time, energy and money countering concerns that wood is an inferior construction material because it can burn, rot and get undermined by termites. They say that, properly produced, designed and built, wood frames are durable and fire-resistant. "You can have exposed mass timber as a fire-resistant assembly," says Lori Koch, an engineer with the American Wood Council (AWC).

Two U.S. projects, hoping to prove the worth of wood, are on the horizon, thanks to a tall-timber building competition held by the U.S. Dept. of Agriculture, in partnership with the Softwood Lumber Board and the Binational Softwood Lumber Council. Teams for Portland, Ore.'s mixed-use Framework—designed to rise 130 ft—and New York City's residential condominium 475 W. 18 Street—planned at 120 ft—are splitting \$3 million to help them with the regulatory process, defray the cost of fire tests and set standards (ENR 9/26-10/5 p. 16).

"We are creating a catalyst to spur a forest-to-frame industry," says Anyeley Hallova, a partner of project^, Framework's developer.



ALL TIMBER Unlike many solid-wood buildings that have reinforced-concrete first levels, the 29.2-m Wood Innovation Design Centre has timber from the ground up.

In the U.S., regulations are the biggest impediment to tall wood. Codes allow heavy timber only for buildings up to four or five stories, depending on the occupancy, and 65 ft—85 ft with sprinklers. Anything taller has to seek local approval under the alternative-methods section.

Wood experts say there is no scientific basis for the height limits. "No one has been able to explain [the rationale], except to say it was the highest reach of a fire truck, which makes no sense today," says Green.

A recent proposal to allow nine-story heavy-timber buildings, in the 2018 version of the model International Building Code (IBC), was shot down. "It was a very conservative proposal, from a structural standpoint," and already in the National Design Specification for Wood Construction, says Kenneth E. Bland, AWC's vice president for codes and regulations.

For regulators, the issue is simple: Unlike concrete and steel, wood burns. Authorities fear that increased height increases the risk of collapse during a burn-out fire scenario, potentially harming firefighters. Concern is heightened when the structure is exposed.

Typically, on the fire side, designers must demonstrate, through performance-based design and computer-based fire modeling, that tall-wood buildings are equivalent to steel and concrete, says Jon Siu, principal engineer and building official for Seattle's Dept. of Planning and Development. Through fire tests, they also must demonstrate that the structure would "survive full burn-out without sprinkler intervention," adds Siu.

Timber experts call that unfair treatment. "Tall-wood buildings, as new technology, are requested to prove their performance under the full burn-out situation, which is a level of engineering rigor that steel and concrete buildings have not regularly been asked to prove," says David Barber, a fire-protection principal with engineer Arup.

Barber and others point to 50 years of fire testing to show performance, including that wood chars on the outside, which insulates the core and slows combustion. The unburned portion retains 85% to 90% of its strength, says reThink Wood.

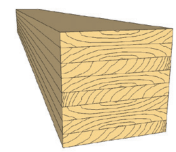
Members are sized to stay viable during a fire, based on known char rates. "The core remains structurally sound as long as you have enough material left to carry the structure," says Equilibrium's Karsh.

As far as code change, wood ad-

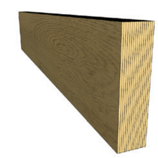
HARDY STOCK Timber chars on the outside, which naturally insulates the core. The core stays structurally sound, as long as there is enough material to carry the structure.

MASS TIMBER PRODUCTS

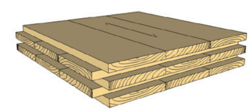
GLUED



Glue-laminated Timber

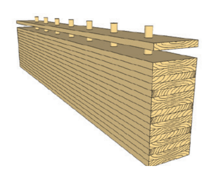


Structural Composite Lumber

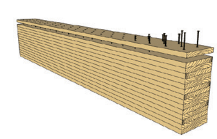


Cross-Laminated Timber

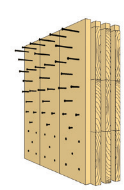
NOT GLUED



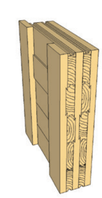
Dowel-Laminated Timber



Nail-Laminated Timber



Cross-Nail-Laminated Timber



Interlocking Cross-Laminated Timber

SOURCE: CENTRE FOR OFFSITE CONSTRUCTION + INNOVATIVE STRUCTURES, EDINBURGH NAPIER UNIVERSITY, AND INTEGRATED TECHNOLOGY IN ARCHITECTURE CENTER, UNIVERSITY OF UTAH

PHOTOGRAPHY BY EMA PETER

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vocates have a new strategy. "We hope to add an additional mass-timber type of construction to the heavy timber [section of the 2021 IBC code], which would allow up to 12 stories for certain occupancy classifications," says Bland.

Toward this end, at the request of AWC, the International Code Council, which publishes the IBC, just formed an ad hoc committee to explore the science of tall wood buildings, including studying the feasibility of developing code criteria.

Efforts are also underway to change the National Fire Protection Association's model code—NFPA 5000: Building Construction and Safety Code—to allow new hotels and residential buildings up to nine stories or 100 ft. The public comment closing date for NFPA 5000 is May 16. A vote on the proposal is scheduled for the summer.

Canada has set the precedent for code change. In 2009, British Columbia became the first province to allow six-story wood buildings; Quebec, Ontario and Alberta followed. And the 2015 Model National Building Code of Canada allows up to six stories. In August, Quebec began to allow 12 stories.

Changes in Canada were based on fire tests of assemblies, which met fire-resistance requirements of the National Fire Code of Canada 2015, says Canada's National Research Council. NRC is working to develop a test of a full-scale multi-component assembly, consisting of columns, beams, floors and walls.

Though model codes are similar, U.S. officials won't accept Canadian test results. Thanks to the tall-timber competition, U.S. testing is starting. And AWC, in partnership with the National Fire Protection Association's Fire Protection Research Foundation and the Property Insurance Research Group, has a $250,000 USDA grant to study fire performance.

The timber-building movement has been bolstered by advances in wood-product manufacturing, including engineered wood. Metal connection systems, embedded in the members to maintain integrity in fires, also have advanced, says Karsh. Building information modeling (BIM) and computer numerically controlled fabrication have supported the movement.

The 2015 IBC defines "heavy timber" as the type of construction in which the exterior walls are of noncombustible materials and the interior building elements are of solid or laminated wood.

"Solid-timber construction," not yet defined by the IBC, refers to different types of massive wood planar or frame elements used for load-bearing walls, floors, roofs, partitions and core elements, according to the 2015 Solid Timber Construction report, published by the University of Utah's Integrated Technology in Architecture Center.

The oldest solid-wood product is glue-laminated timber, which was introduced in the 1930s. GLT consists of a number of layers of dimensioned timber bonded with structural adhesive. It is used mostly for columns, beams and trusses.

Newer glued products include the family of structural composite lumber (SCL) and cross-laminated timber (CLT).

SCL is made by layering dried and graded wood veneers, strands or flakes, with moisture-resistant adhesive, into blocks of material known as billets, which subsequently are sawn into specified sizes. SCL varieties include laminated-veneer lumber, parallel-strand lumber and laminated-strand lumber. They are used for rafters, headers, beams, joists, studs, columns and I-joist flanges.

CONNECTORS Metal connectors typically are concealed to protect them in case of a fire. Consequently, fit-up tolerances for the prefabricated wood members are tighter than is the norm for other materials.

CLT was first introduced, in the early 1990s, in Austria and Germany but is relatively new to North America. There is only one certified CLT producer and another on the way in the U.S. and two in Canada, which limits price competition.

CLT, first included in the 2015 IBC, consists of at least three layers of solid-sawn lumber, with adjacent layers cross-oriented and bonded with structural adhesive. It typically

PROVING GROUND The Forte project in Melbourne was so successful that Lendlease plans to repeat the approach elsewhere.

PHOTOS TOP BY NATURALLY:WOOD®, BOTTOM COURTESY LENDLEASE

LEADING THE WAY Framework, a planned 12-story mixed-use building for Portland, Ore., designed by LEVER Architecture with KPFF Consulting Engineers, is one of two demonstration projects intended to pave a path for other tall-timber buildings in the U.S.

is used for load-bearing walls and floor diaphragms with spans of up to 20 ft; up to seven layers are available, and each is about 1.4-in. thick.

CLT has dimensional stability. As a bending or floor element, it can span in two directions, but it is "a little bit weaker" than the other laminated products because cross-lamination creates a failing mechanism, says Equilibrium's Karsh.

CLT slabs, due to increased thickness, lose cost-competitiveness with other materials when spans between columns or walls are greater than 20 ft, according to engineers.

The Empire State Building has 18-ft column spacing, which made it a good candidate for wood, says MGA's Green. "We didn't know" that going into the study, he adds.

Newer laminated products that do not use glue include nail-laminated timber, connected with steel or aluminum shank nails or screws fastening planks crosswise; and dowel-laminated timber, which locks together planks using dowels that expand over time to achieve moisture equilibrium, according to the solid-timber report.

Cross-nail-laminated timber has the lay-up of cross-rafting layers in CLT and uses nails to attach rafting layers to each other. Interlocking CLT uses no glues or fasteners; instead, dovetail notches interface with a nested key to create cross-laminated panels.

FRAMEWORK If approved, the 12-story building would have glue-laminated columns and beams, cross-laminated timber floors with a lightweight concrete topping, concealed steel connectors, a concrete mat and a post-tensioned CLT rocking-wall core, to handle seismic loads.

Excitement about tall-wood buildings is being fueled by the green-building movement. Wood is renewable, grows using the sun's energy and sequesters carbon dioxide. Consequently, designers see taller wood as a way to reduce, dramatically, a building's carbon footprint.

Using wood instead of steel and concrete could save 14% to 31% of global CO_2 emissions, according to a 2014 study by the Yale School of Forestry & Environmental Studies and the University of Washington's College of the Environment. And according to the Consortium for Research on Renewable Industrial Materials, greenhouse-gas emissions from the production of a wood floor, for example, are substantially less than emissions from the production of a comparable concrete floor, even without considering stored carbon.

In addition, wood is the only building material that has third-party certification programs to verify products are from a sustainably managed resource, says reThink Wood.

Pros and Cons

Some developers see exposed timber as a selling advantage, citing recent reports—including Planet Ark's "Wood: Housing, Health, Humanity"—which say wood makes people happier, more productive, lowers stress and promotes faster healing.

But there are risks for early adopters, says Jeff Spiritos, the co-developer of the New York City project. Approvals are not assured, market reception is unknown, product suppliers and fabricators are limited in number, crews are not experienced handling exposed wood and extra acoustics are required because of wood's light mass, he says.

IMAGES COURTESY OF LEVER ARCHITECTURE

Lendlease Australia, which developed, designed and built the fully occupied Forte using CLT walls and floors, went through timber's learning curve and came out committed. "Forte verified our due diligence and gave us the learnings to move forward on other developments," says Andrew Nieland, head of timber solutions for Lendlease.

Prefabricated components had significant safety, quality, sustainability, schedule and commercial benefits, Nieland adds. And there were no issues getting insurance, which was priced in line with the market for a conventional building.

Nieland says the key difference from conventional steel and concrete construction is the higher level of design detailing required early in the project. Because of prefabrication, large-scale elements are delivered to the site with all penetrations pre-machined. BIM helps with the need for early detailing, he adds.

Logistics, including scheduling and managing deliveries, are of critical importance, but construction, which is more like an assembly, is faster than site-built projects and requires fewer crews.

Wet weather is not a big concern, says Nieland. "Construction is quick, so any timber that gets wet will dry out and return to its previous moisture content," he adds.

For fire protection during construction, the local authority did require early installation and connection of hydrants and hoses.

Jackie Trach—British Columbia region senior project manager for PCL Constructors West Coast Inc., which built WDIC—says she was surprised at how similar solid-wood construction is to building with precast concrete or steel. "It uses the same methods of erection," but the wood members are not as heavy, so smaller cranes are needed, she says.

Tolerances are tighter, as a consequence of prefabricated, embedded connections, she adds. And for exposed wood, crews have to take care with the hoisting apparatus not to pinch it, which will leave marks.

BETTER GENE POTENTIAL Genetically engineered wood, in theory, would allow longer floor spans and fewer columns.

STRUCTURAL COMPARISON OF THREE WOOD TYPES

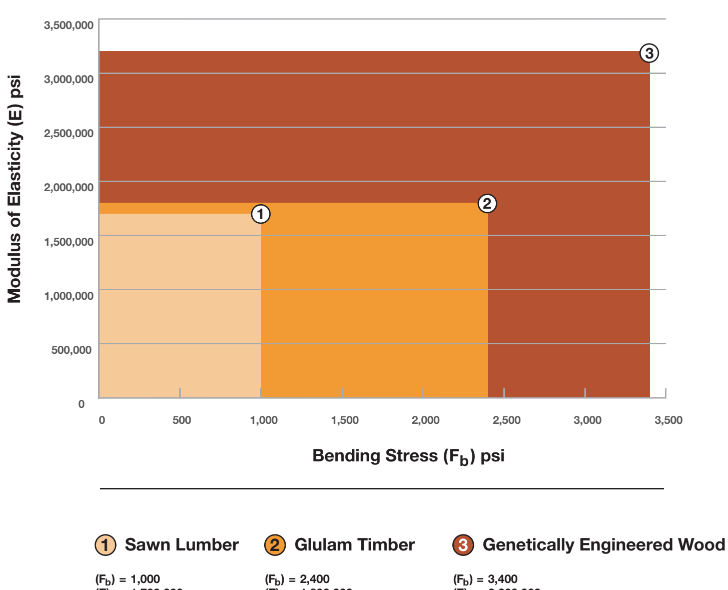

PHOTO BY NATURALLY:WOOD®; CHART COURTESY OF MKA

NEW GENERATION The six-story Wood Innovation Design Centre, completed last year in British Columbia, is the tallest wood building in North America.

For help designing in wood, there are handbooks and manuals, including the 2015 Code Conforming Wood Design, a joint publication of AWC and ICC that just became available for free download.

Two drawbacks of wood are its limited strength and stiffness, which keep floor spans to about 30 ft. For greater spans, wood is not economical, compared to other materials, experts say.

Ron Klemencic, chairman and CEO of Magnusson Klemencic Associates, hopes to change that. As a Charles Pankow Foundation board member, he is gathering experts in wood science, breeding and biotechnology to explore genetically engineered trees that are stronger and stiffer. The goal is to minimize floor thickness and maximize spans.

Laurence Schimleck, the department head of wood science and engineering at Oregon State University's College of Forestry, is organizing a meeting next month to discuss whether there is value in the "very complex" long-view approach.

MGA's Green does not embrace genetically engineered trees. But he has no qualms about 3D printing, using wood fibers and a natural wood adhesive, which he will soon begin exploring. The goal is to print more-efficient arced shapes that would minimize material and be even more sustainable.

Green predicts 3D-printed wood beams will be the norm in just 20 years. "It's the future," he says. ■