The use of engineered wood products in the structural systems of tall buildings is, to beg a pun, growing. Since 2008, more than 50 tall timber buildings across the globe have been proposed, been designed as experiments, broken ground, or been completed, according to a study, “Tall Timber: A Global Audit,” prepared by the Chicago-based Council on Tall Buildings and Urban Habitat (CTBUH), which appeared in the June 2017 issue of the CTBUH Journal. Roughly half of those timber projects have been completed, and one of the most recent—Brock Commons-Tallwood House, a residence hall that opened in July 2017 at Canada’s University of British Columbia—is currently the tallest timber building in the world.

Of course, the definition of a “tall” timber building does require clarification. The 100 tallest buildings designed in concrete, steel, or a combination of those materials reach heights of between 300 and 800-plus m, many of them featuring more than 100 stories, according to CTBUH data. By comparison, Brock Commons-Tallwood House rises just 53 m in 18 stories. But those 18 stories make Brock Commons-Tallwood House roughly three times taller than most timber-framed buildings, which are often restricted in height by local building codes to just five or six stories, notes Scott Breemen, Ph.D., P.E., S.E., M.ASCE, a senior technical director in the project resources and solutions division of WoodWorks Wood Products Council, a Washington, D.C.-based nonprofit organization that provides educational assistance to engineers, architects, and developers who are interested in designing wooden structures.

Many smaller timber buildings, those six stories and lower, are conventionally framed wooden structures called “stick-built” buildings. But Brock Commons-Tallwood House and other buildings in the CTBUH “Tall Timber” study, all of which measure at least seven stories in height, feature the use of so-called mass timber. That’s the umbrella term for panelized, engineered wood products, including cross-laminated timber (CLT), nail-laminated timber, glue-laminated timber (glulam), and other such building materials, explains Jennifer Cover, the president and chief executive officer of WoodWorks. Formed from layers of wooden material, mass timber products are used to create large structural el-

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By Robert L. Reid

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Oakwood Timber Tower is a conceptual design that is being used to help design other tall timber buildings. Framed with external mass-timber supports, the proposed tower would rise 80 m into the London skyline, opposite.
This year should see the completion of the tallest mass timber structure in the United States—a 12-story, mixed-use building in Portland, Oregon, known as Framework. Designed by Lever Architecture, of Portland, and engineered by the Portland office of KPF Consulting Engineers, the Framework building is also noteworthy for having been one of two winners of the U.S. Tall Wood Building Prize Competition, which was sponsored by the U.S. Department of Agriculture and two trade groups: the Softwood Lumber Board, based in Washington, D.C., and the National Softwood Lumber Council, based in Surrey, British Columbia. The other winner was a proposed 10-story residential building in New York City that has since been cancelled. Known as 475 West 18th, it was designed by New York City-based SHoP Architects, international engineering firm Arup, and Icor Consulting Engineers, of Iselin, New Jersey.

Around the globe, several mass timber structures even taller than Brock Commons—Tallwood House are also in the works, have been proposed, or are being researched. In Austria, for example, the 24-story mixed-use HoHo tower, is now under construction in Vienna. Designed by Vienna’s Rüdiger Lainer and Partner, this mass timber structure is expected to measure roughly 84 m in height. A 35-story tall mixed-use mass timber building known as Baobab has been proposed for Paris by Vancouver, British Columbia-based Michael Green Architecture. The international architecture and engineering firm Skidmore, Owings & Merrill LLP (SOM) has explored what it would take to design a 42-story building in Chicago that uses mass timber as its main structural system; the firm has also published four reports on mass timber research since 2013, the most recent released late last year. And in a pair of research projects, the Center for Natural Material Innovation at Cambridge University has worked with engineering and architecture firms in the United States and the United Kingdom to conceptualize 80-story mass timber towers for both Chicago and London.

The reasons for the uptick in interest for ever-taller mass timber buildings vary from aesthetics to economics to simply a desire to design something that has never been done before. But one critical point is cited repeatedly by engineers working with mass timber sustainability. For Benton Johnson, P.E., S.E., an associate director in SOM’s Chicago office, the issue centers on the fact that cities “outperform other ways of living in terms of their overall carbon footprint. If you look at the per-capita carbon footprint of people living in cities, it typically is much better” than for people living in the urban sprawl of suburbia or rural settings.

At the same time, the mostly steel and concrete buildings within cities tend to be large emitters of greenhouse gases—which presents a conundrum that mass timber can help resolve. “The design community recognizes the key to a lot of the sustainability goals that we have as a society are geared around living in cities, but if we want to make those cities more sustainable, we need to make the buildings in
those cities more sustainable,” Johnson explains. “That often means looking at mass timber.”

For mass timber structures to be relevant in an urban environment, those buildings need to be high-rise structures. “Maybe not forty-two stories tall,” Johnson says. “But they need to be in the realm of ten, fifteen, twenty, thirty stories to make a serious impact on the overall sustainability of these cities.”

The life cycle of the trees that are harvested to become mass timber products is a critical aspect of that sustainability, says Cover. “As trees grow, they absorb carbon dioxide from the atmosphere and they release oxygen, and they incorporate the carbon into their wood and their leaves and their needles and their roots,” she explains. “That carbon stays sequestered within the tree itself, so when that tree is harvested and turned into a wood product, it continues to sequester that carbon over the life of the project itself. And then a new tree is planted in that location which continues to pull carbon dioxide out of the environment.”

If the timber comes from a clear-cut site at which nothing was replanted, that lessens the sustainability of the resulting buildings. “But research shows that in communities with a strong market sector for wood products, they tend to protect their forests and manage their forests better than places in the world that do not have a strong forest industry,” adds Johnson, “because in those areas there’s no value for keeping the forest going.”

Mass timber structures often feature hybrid or composite systems that combine steel and/or concrete with the timber elements to provide the structures with the strength, stiffness, fire resistance, and other factors that are making taller timber buildings possible. An essential aspect of the 42-story building designed by SOM was a CLT floor system with a composite concrete topping slab, which underwent extensive testing at Oregon State University, Johnson notes. The floor system and its use in combination with structural steel columns were explored in the two most recent SOM reports on mass timber research.

Brock Commons-Tallwood House utilizes cast-in-place concrete foundations and cores, a concrete podium, and a steel-framed roof, together with steel connections between the CLT panel floor system and the glulam columns, according to the paper, “Structural Design, Approval, and Monitoring of a UBC Tall Wood Building,” by Thomas Tanner, Ph.D., PE, an associate professor of tall wood and hybrid structures engineering at the University of British Columbia, and Manu Moudgil, a research assistant at the University of British Columbia. The paper was presented at Structures Congress 2017, which was organized by ASCE and its Structural Engineering Institute and held in April in Denver.

Brock Commons-Tallwood House was designed by Acton Ostry Architects Inc., of Vancouver. The structural engineer was Past + Epp, also of Vancouver, and Architekten Hermann Kaufmann ZT GmbH, based in Schwarzenbach, Austria, served as the tall wood adviser.

Even tall buildings that are considered “all timber” generally have nontimber foundations. Timber piles were commonly used in Chicago a century ago and were initially considered for the Windy City’s conceptualized 80-story timber tower, which is known as the River Beech Tower and was designed to use primarily engineered wood products rather than any sort of hybrid or composite systems, notes David Weihing, P.E., S.E., LEED AP, a senior principal in the Chicago office of Thornton Tomasetti Inc. “But we found that [the 80-story structure] exceeded the potential capacity of wooden piles substantially—so we abandoned that idea,” Weihing says.

**Brock Commons-Tallwood House Structural Systems**
At 18 stories, the University of British Columbia’s Brock Commons-Tallwood House is currently the tallest mass timber structure in the world.

adding that the tower’s foundations were designed to use concrete caissons instead.

In addition to Cambridge University, Thornton Tomasetti also worked with the Chicago-based architecture firm Perkins+Will on the River Beech Tower, which actually features two side-by-side towers, one slightly taller than the other. The structures are linked by a multistory atrium and supported laterally via a diamond-shaped diagonal grid system on the facades that utilizes laminated veneer lumber elements, notes Weinig.

The other conceptual 80-story timber skyscraper, known as Oakwood Timber Tower, was designed by Cambridge University, London-based PLP Architecture, and Cambridge-based structural engineering firm Smith and Wallwork. The Oakwood Timber Tower also features exterior wooden supports, although in the London building’s case these would be extremely tall crisscrossing elements.

Although both 80-story structures were intended essentially as experiments, rather than as projects anyone was currently planning to build, the towers were designed under the assumption that everything would actually “work,” from the ways the buildings handled structural forces to the market forces that would drive rentals in each space, notes Michael Ramage, Ph.D., MStructE, CEng, the director of Cambridge University’s Center for Natural Material Innovation.

“We went with the premise of ‘Let’s try to design at scales we haven’t seen before, but let’s use materials already on the market, [and] work with practicing architects and engineers,’” says Ramage. The resulting designs would therefore demonstrate not only the exciting things that were theoretically possible with very tall timber buildings but also how those designs could apply to smaller timber buildings that might actually be under consideration. “If we can show that it works at three hundred meters, it is much more straightforward to do it at one hundred meters,” or even with the roughly 50 m tall timber buildings that are being built these days, Ramage notes.

Some of the ideas learned from the Oakwood Timber Tower project have already been applied via a proposed timber structure in the Netherlands that would have been roughly 120 m tall, notes Simon Smith, CEng, a founder and the director of Smith and Wallwork. A Dutch developer was very interested in a timber structure because of the potential environmental benefits as well as the
embedded energy and operational energy costs of wood, Smith says. Moreover, despite the building height restriction of 80 m in the local codes where this project was being considered, an “exemplary building” such as the timber tower might have been allowed to exceed that limit, Smith says. That would then have enabled the developer to provide more floor space than surrounding buildings and thus earn a greater return on investment.

In the end, the relatively low rents available in that regional market persuaded the developer to select concrete as a building material for a shorter tower, Smith says. The cost premium for timber was too great. But in larger markets—say, Rotterdam or Amsterdam—with higher potential rents, “our proposal might have stood a better chance,” he says. Ultimately, the exercise proved instructive. “We came away from that experience with some good information on what a tall timber building might look like,” Smith explains, “and structurally, in terms of its viability, we got very close, from a strength point of view, to making that one feasible.”

LOCAL BUILDING code limitations are one of the key obstacles to taller timber structures, but they are not insurmountable, says Breneman. Exceeding the heights prescribed in local codes involves the pursuit of an alternative means and methods process “that varies dramatically from jurisdiction to jurisdiction,” he explains. The design team essentially partners with the local authority to discuss the project and determine what it will allow, as well as what concessions it would like in return, notes Breneman. “To be successful, you have to demonstrate how your proposed design has equivalent or better safety than a code-allowed design and how what you’re proposing meets the ‘intent’ of the code in terms of life safety and other metrics,” he explains.

For the Framework building, which will exceed the heights al-

River Beech Tower, another conceptual 80-story mass timber structure, features two side-by-side towers, one slightly taller than the other, above. The facades, below, feature a diamond-shaped diagonal grid system that utilizes laminated veneer lumber elements.
it's up to the designers to satisfy those requirements. What I can say is that timber can meet all of the code requirements necessary for these large buildings in terms of fire.

The rate at which mass timber burns is also quite predictable, adds Carsten Hein, an associate director of structural engineering in the Berlin office of Arup. "If you have a fire in a timber building, you notice that your columns start burning, and you know you have ninety minutes to leave the building because you know the charring process behaves extremely predictably," explains Hein, who participated in the research design of a proposed 20-story timber building known as the LifeCycle Tower; an Austrian developer later constructed an eight-story prototype of the Lifecycle Tower using an Austrian engineering firm, Hein notes.

Mass timber has a charring rate of 0.7 mm per minute, Hein explains, which means that over a 90-minute period, the timber element will lose 6.3 cm of structure. But the remaining timber core is not weakened by the fire and has the same structural properties as before, Hein says, and therefore it has the same load capacity as before. "So after a fire in a timber building the remaining structure will stand up, allowing refurbishment or replacement of damaged elements," Hein explains.

Another way to protect a timber tower from fire is sim-
Timber Rising

(Continued from Page 51) At the same time, exposed timber and the threat of fire require more research, Hein says. Numerous tests have been conducted regarding the amount of exposed timber surfaces, especially in a building with extensive use of CLT, Hein notes. Such buildings might face an enhanced fire risk “because at a certain point the construction material turns into the fire load itself,” he says. “When it all starts burning, it can attract oxygen and burn even faster.”

For the timber buildings designed by Arup’s Berlin office—including the study for the LifeCycle Tower—timber columns and timber-concrete composite slabs with glulam beams were used, Hein notes. “This proved to be a huge advantage,” he adds, because the danger of a fire spreading was significantly reduced.

Thus, designers might have to limit the amount of exposed mass timber in buildings, encapsulating some elements as noted above or using fire-protected steel or concrete composite materials strategically to block the spread of a fire from one section of exposed mass timber to another, He...