Stronger timber

Engineering high-tech lumber for a sustainable future

IN 1885, the world's first "skyscraper" towered 10 stories — 138 feet — above the busy streets of Chicago. Residents marveled at its height, but were afraid to walk near it, and city officials, so worried the new and untested steel frame construction would collapse, temporarily halted progress to investigate the building's structural integrity.

Four short years later, in 1889, as the final pieces of steel were being riveted onto the frame of the 1,063-foot Eiffel Tower, city skylines across the globe were being transformed, and reaching ever higher, as engineers continued to push the boundaries of construction methods and materials.

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>
> Edwin Nagy

Today, tall buildings are a hallmark of urban landscapes around the world and, since the latter years of the 19th century, they have largely been constructed from steel and concrete. Now, engineers and wood scientists at the University of Maine are looking to Maine's forests to find new, more sustainable, alternatives for the large buildings of the future.

Mass timber is a quickly developing group of engineered wood products that can be used to construct a variety of mid- and high-rise buildings, says UMaine engineer Edwin Nagy, who is researching the structural properties and potential of Maine-made cross-laminated timber (CLT) at UMaine's Advanced Structures and Composites Center.

CLT, a type of mass timber, is touted to be as much of a revolution to tall buildings of the 21st century as steel and concrete were to those

Cross-laminated timber (CLT) made from solid-sawn and composite lumber under development at the Advanced Structures and Composites Center could translate into new markets and increased commercial value for Maine's forest products industry.

Advanced Materials for Infrastructure and Energy

The University of Maine's Signature Area in Advanced Materials for Infrastructure and Energy is focused on developing the use of advanced materials in civil infrastructure, energy, aerospace and defense applications. A cornerstone of the Signature Area is the Advanced Structures and Composites Center, an interdisciplinary research facility dedicated to the development of novel advanced composite materials and technologies that capitalize on Maine's manufacturing strengths and natural resources, while creating new industries and job opportunities, and educating students.

of the 20th, and it is changing the way engineers, architects, contractors and lumber producers are viewing the built environment of the future.

In Europe for more than two decades, CLT has been used as a construction alternative to concrete and steel. And an 18-story wood dormitory has been completed at the University of British Columbia.

In the United States, however, it is a relative newcomer to the construction scene, says Nagy, but it has quickly gained a lot of attention.

CLT IS made from three or more layers of dimensional lumber, stacked at right angles, and bonded with an adhesive to form robust structural panels. The panels exhibit strength, dimensional stability and rigidity while being architecturally flexible. They can be used in walls, roofs and floors.

It is a renewable, cost-effective building alternative that benefits from reduced waste, improved thermal performance, and aesthetic and design versatility. CLT has the added benefit of sequestering, rather than contributing, atmospheric carbon dioxide — an invaluable property, considering new buildings account for nearly half of the nation's total carbon emissions.

Large structures can be constructed rapidly and many pieces, including entire rooms, can be customized and prefabricated off-site prior to installation, drastically reducing the time, labor and, ultimately, cost of construction.

"There are still some hurdles to overcome before CLT is widely accepted in the United States," says Nagy. "Some are based in the public's perceptions of wood and others are based in our current building codes."

In 2015, CLT was incorporated into the international building code, allowing it to be an option in building construction in the U.S., provided it meets specific manufacturing standards. To date, only two plants in the country, both in the West, are approved for manufacturing the panels. Closer to home, a Canadian plant in Quebec currently serves the CLT needs of much of the northern half of the eastern U.S., says Nagy.

With 17 million acres of forestland, Maine is well positioned to become a leader in CLT production in the Northeast.

"A goal of this research is to help bring a CLT plant to Maine," says Nagy. "We have the forests and the infrastructure."

Spruce-Pine-Fir (SPF) South is the grouping of wood species found throughout the Northeast that are used for home construction and industrial applications. A recent project led by Russell Edgar, the center's wood composites manager, and the Northeastern Lumber Manufacturers Association (NELMA) has resulted in the inclusion of Norway spruce into the lumber grouping. Sawmills and forest landowners in Maine are already benefitting from what is being dubbed a new "timber age" for the region.

EDGAR AND professors of civil and environmental engineering Roberto Lopez-Anido and Bill Davids, along with School of Forest Resources professors Douglas Gardner, Mehdi Tajvidi, Robert Rice and Stephen Shaler recently completed a three-year project to evaluate the mechanical and thermal/moisture performance of CLT made from SPF South, as well as new CLT assembly configurations. Those include hybrid panels made with solid sawn SPF and laminated strand lumber (LSL), another type of engineered wood composite manufactured in Maine.

In addition, a new project to evaluate the role of finger-joints on the hybrid composite performance is now underway.

While the majority of the world is focused on building with CLT panels, the UMaine researchers spend much of their time breaking them in half at the Advanced Structures and Composites Center to test for flexure, shear, block shear, delamination and fatigue.

And most recently, Nagy has been blowing them up with explosives.

He is working in collaboration with WoodWorks, a trade group dedicated to promoting the use of wood in nonresidential constructions, as well as contractors, manufacturers and government agencies to investigate the blast-resistant properties of CLT buildings.

Static testing and modeling of the CLT was conducted at the UMaine Composites Center and in October, a series of live blast tests was performed on three two-story CLT structures at Tyndall Air Force Base, Florida.

Three explosions, in increasing strength, were detonated near each CLT structure. The first two smaller blasts were designed to stress the structures to within their respective limits, but the third was designed to push them beyond.

After the dust settled, the structures remained standing.

"The wood performed predictably when compared to our static testing models," says Nagy, "and each of the structures remained intact with relatively minimal levels of damage."

While the full analysis of the results aren't yet in, initial observations from the tests were positive, according to Nagy. The next step, he says, is to test how CLT structures handle explosive force under load.

"As we continue to come up with new and innovative ways to use CLT, it becomes very important to get an accurate handle on its properties," he says.

These results will be used to further expand on the use of wood solutions for Department of Defense applications and other blast-resistant constructions, such as the development of hotels on military bases.

Nagy hopes the research and development of CLT and other wood composite materials at UMaine helps to facilitate the growth of the mass timber industry in Maine. ■

CLT is sometimes referred to as plywood on steroids. The product consists of two-by laminated lumber or composite — two-by-fours, two-by-sixes, or two-by-eights — stacked at right angles — with as few as three and as many as nine laminated layers — and bonded with an adhesive. In the Advanced Structures and Composites Center, researchers are testing a hybrid CLT panel made from a combination of solid-sawn SPF South lumber, as well as an engineered wood composite — laminated strand lumber (LSL). The composites are tested for flexure, shear, block shear, delamination and fatigue, as well as blast resistance.