Council on Tall Buildings and Urban Habitat

TIMBER RISING

Global Perspectives on Mass Timber Advances for the Tall Building Industry

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Council on Tall Buildings and Urban Habitat

USDA

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ABOUT THIS PROJECT

This project was made possible by a grant from the USDA Forest Service. It represents a continuation of the Council on Tall Buildings and Urban Habitat's (CTBUH) focus on researching and furthering the dialogue regarding the use of mass timber in the tall building typology. In recent years, CTBUH has undertaken research activities aimed at better defining and classifying mass timber for the high-rise market, while an in-house team has conducted numerous data studies on the topic, such as 2017's "Tall Timber: A Global Audit." In addition, it has established a Tall Timber committee and continues to document burgeoning tall timber projects all over the world through its Global News platform. In 2019, the Council dedicated a "Building of Distinction" signboard for Mjøstårnet, located in Norway, declaring it the "tallest all-timber building in the world," in conjunction with updating the official CTBUH Height Criteria to include timber as a structural material in tall buildings.

This Timber Rising publication is one of several outputs in a CTBUH series produced in conjunction with the USDA Forest Service, all of which provide key information on mass timber innovations to stakeholders in the tall building industry. The collection of materials contained in this volume were written contributions to the CTBUH 10th World Congress, which took place in Chicago from 28 October–2 November, 2019, for which the Council convened peer-reviewed materials from global professionals on the latest mass timber technologies, advancements, and case studies. To learn more about this initiative, please visit ctbuh.org/timber-rising.

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Figure 1. From top to bottom:

A section of cross-laminated timber (CLT), a type of mass timber that can be used for high-rise construction due to its strength, rigidity, and stability. © Oregon Forest Resources Institute (cc by-sa)

Nail-laminated timber (NLT) consists of individual dimension lumber fastened together on-edge with nails. © Timmerman Timberworks

Ideal for beams and columns, glued-laminated timber (glulam) is constructed of multiple layers of solid wood bonded with an adhesive. Source: Mok9

Dowel-laminated timber (DLT) is an all-wood type of mass timber, using dowels as the means of fitting pre-milled boards together on-edge. © James Henderson (cc by-sa)

A type of structural composite lumber (SCL), laminated veneer lumber (LVL) consists of thin wood veneers bonded together so that the grain is parallel or cross-bonded. © KLski (cc by-sa)

With 1.5 million people moving into cities each week (United Nations 2018), the global imperative to plan and build urban environments that are resource-efficient and resilient to climate change has never been more urgent. Currently, the building and operation of cities accounts for nearly 40 percent of the global carbon emissions load, and studies indicate that 70 percent of the infrastructure needed by 2050 is yet to be built (World Green Building Council 2018). Thus, in order to address the question of how to provide housing, commercial, office, and other spaces in dense, vertical cities while minimizing the emission of greenhouse gases, the architecture, engineering, and construction industry must critically consider and evaluate choices behind designs, construction materials, and processes. The rise of the mass timber tall building, in which engineered timber products perform primary load-bearing functions for multi-story developments, may provide a significant opportunity to address many of the problems facing the building industry. Constructing more tall buildings with structural timber—a renewable, natural material that actively stores carbon in its dry weight, in a process known as carbon sequestration—could usher in a paradigmatic shift across the city-building industry, increasing its sustainability and reducing its contribution to greenhouse gas emissions.

Recent and emerging innovations in mass timber engineering and fabrication have allowed for the creation of a number of tall timber typologies, including all-timber and timber composite construction, which in some cases are able to meet the same safety standards that other materials and methods have provided, from resilience against storms and seismic activity, to advanced fire and life safety. Although timber has many benefits, it is not without its challenges, chief among them being fire safety. Due to its combustible nature, many still associate it with vulnerability to damaging and catastrophic fires, and indeed, fire safety testing and performance of mass timber projects and emerging engineered mass timber products still has a relatively short history, and will doubtlessly continue to be rigorously evaluated in a variety of contexts. However, innovations and improving construction techniques behind mass timber show promise of it becoming competitive and able to perform to the same standards as other tall building materials.

Changing the narrative on timber, particularly tall timber, requires a close examination of mass timber construction challenges, and highlighting the innovations that allow those challenges to be surmounted with engineered timber products, techniques, and best practices, while still allowing mass timber projects to thrive in an economically competitive marketplace.

WHAT IS MASS TIMBER?

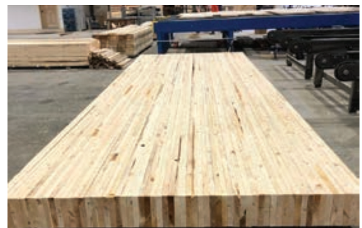
Mass timber buildings, which are distinguished from light timber buildings based upon larger cross-section size, use whole sawn timber pieces or engineered timber products to act as the primary load-bearing structure. Innovations in the timber industry have resulted in a number of "engineered timber products," in which smaller wood members are fused with a water-resistant adhesive, allowing for large enough cross-sections to achieve the structural parameters required to be defined as a mass timber building. These products, which can form a durable, load-bearing structural panel, column, or beam include cross-laminated timber (CLT), nail-laminated timber (NLT), glued-laminated timber (glulam), dowel-laminated timber (DLT), structural composite lumber (SCL), and wood-concrete composites (see Figure 1).

CLT is one example of an engineered timber product, consisting of layers of kiln-dried lumber boards stacked in alternating directions and secured with adhesive. The product was invented in Austria in the 1990s by Professor Gerhard Schickhofer, Graz University of Technology, and its high-strength, rigidity, and dimensional stability allows it to serve as a load-bearing element for high-rise structures, most often as floors, walls, and roofing.

Another common engineered mass timber product is glulam, which consists of multiple layers of solid wood lumber bonded with adhesive to form a single, structural unit. Available in both straight and curved members, glulam can have specific strength-to-weight ratios in the parallel-to-grain direction that is greater than structural steel (Foster and Ramage 2017), making it ideal for beams and columns. Other types

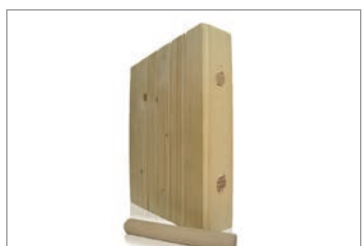
Figure 1

Cross-laminated timber (CLT)

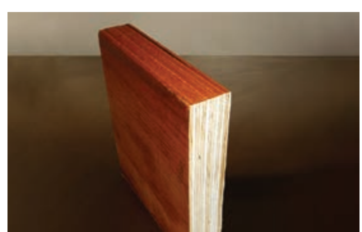


Nail-laminated timber (NLT)

Glued-laminated timber (glulam)



Dowel-laminated timber (DLT)



Structural composite lumber (SCL): Laminated veneer lumber (LVL)

Mjøstårnet: The World's Tallest All-Timber Building

RUNE ABRAHAMSEN

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Rune Abrahamsen is CEO of Moelven Limtre, Norway's largest glulam manufacturer. He received his MSc degree in Civil Engineering from NTNU in 1995. Abrahamsen has previously been Senior Vice President at the engineering company Sweco and has been chief engineer of numerous large building projects and timber bridges. He was chief engineer for the 14-story timber apartment building Treet in Bergen in 2014 and led the work for the 18-story Mjøstårnet building. Both projects set the world record for the world's tallest all-timber building. Abrahamsen is married, has two kids and loves watching Liverpool win football matches.

ABSTRACT

Building the world's current tallest all-timber building, Mjøstårnet, required testing the parameters of tall timber as never before. In addition to the building's structural and commercial successes, it was built using a hyperlocal supply chain as compared to the majority of tall buildings, relying on regional suppliers for materials, construction, and other services. The main load-bearing system consists of large-scale glue-laminated (glulam) trusses along the façades, as well as internal columns and beams. The trusses handle the global forces in the horizontal and vertical directions and give the building its necessary stiffness. Cross-laminated timber (CLT) walls are used for secondary load-bearing of three elevators and two staircases, but do not contribute to the building's horizontal stability.

When designing tall timber buildings, it is crucial to find smart ways to cope with horizontal accelerations induced by wind. Recommended comfort criteria are given in ISO 10137, and guidelines for calculations are given by EN 1991-1-4. Particularly important is the structural damping ratio, which bears significant influence on the end result. Damping can be derived from measurements and data collection taken on-site. During construction, Norwegian University of Science and Technology (NTNU) installed accelerometers to monitor the building's behavior, providing important information on how the structural skeleton behaves.

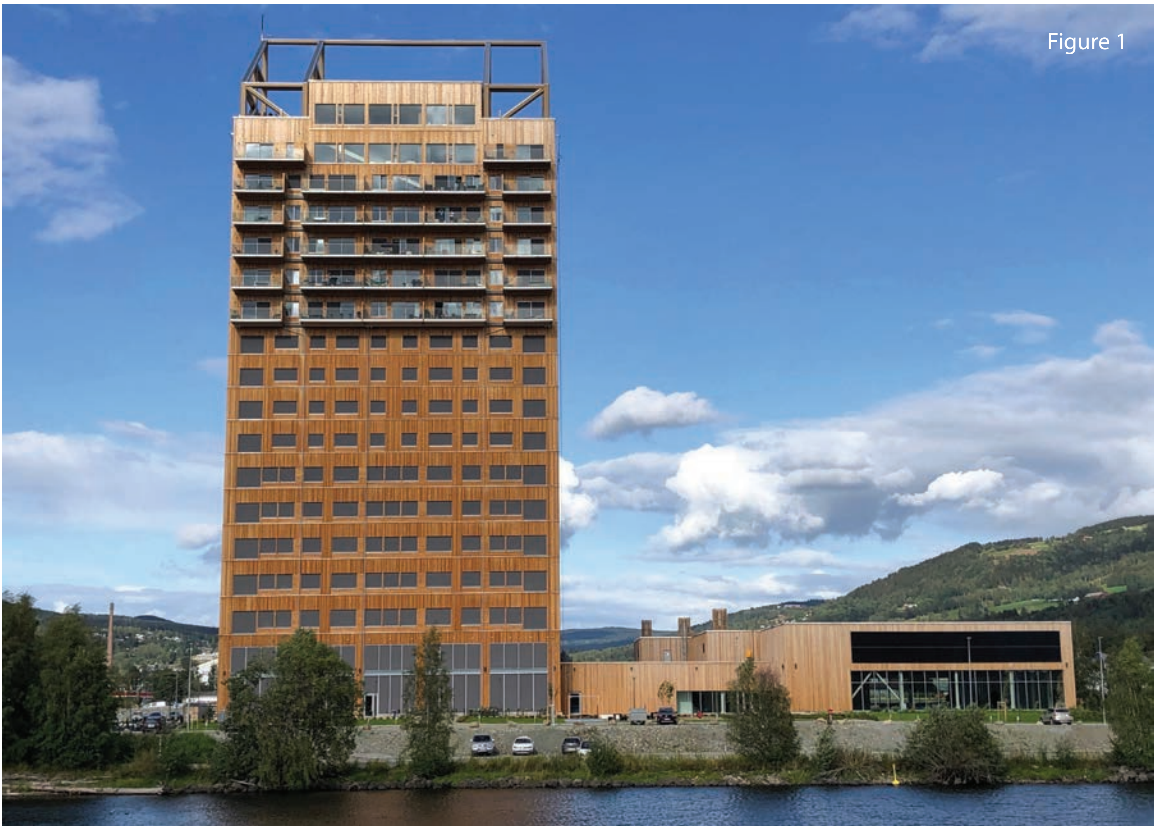

Figure 1. Mjøstårnet, with adjoining swimming arena seen from Lake Mjøsa.
© Moelven, Rune Abrahamsen

INTRODUCTION

Mjøstårnet is an 85-meter, 18-story mixed-use timber building in Brumunddal, Norway, that was ratified by CTBUH as the "Tallest All-Timber Building in the World" upon its completion in March 2019 (see Figure 1). The building's programming across its 11,300 square-meter area consists of offices, meeting rooms, 32 apartments, 72 hotel rooms, a restaurant, a conference room on level 17, and a rooftop terrace. The rooftop terrace is free to access for all residents, hotel guests, and building staff. Next to the tower there is a 4,700-square-meter indoor swimming area, which is also constructed out of wood. The residential component quickly sold out, and the office space is fully rented out. The Wood Hotel has already welcomed thousands of guests.

Brumunddal is approximately 140 kilometers north of Oslo and faces lake Mjøsa—Norway's largest lake. Translated from Norwegian, Mjøstårnet

ABOUT THIS BOOK

As the planet becomes more urbanized than ever before, tall buildings will continue to be essential to providing the level of housing, office, and retail space required to adequately serve dense populations. But if we are to simultaneously curtail the significant amounts of carbon released into the atmosphere by the building industry, these emerging buildings must incorporate materials that are equal parts renewable and resilient. The advent of mass timber products has provided such an opportunity, one with the promise of reinventing conventional approaches to not only tall building design and construction, but city-building as a whole. The papers within this book detail some of the cutting-edge mass timber innovations across energy-efficiency, structural improvements, technological advancements, and code and standard updates.

This and other CTBUH *Timber Rising* outputs are funded and made possible by a grant from the USDA Forest Service.

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