Research and Testing Lead to Historic Code Change

The History of Getting a Sustainable Tall Building Option—Mass Timber—Approved in the U.S. Building Codes

Heather Stegner

American Wood Council, Washington, DC;
hstegner@awc.org (corresponding author)

Nikki Fotheringham

Green Moxie; nikki@greenmoxie.com

Abstract

Simply substituting wood for conventional building materials could provide almost a tenth of the global carbon emission reductions needed to meet 2030 goals. However, while structural light-frame wood products are the go-to building material in the United States for low-rise residential construction, capturing over 90 percent of the market, any kind of wood-frame construction at the time under examination was limited to 5 stories and 85 feet in height. These story and height limitations dated back decades and prevented the design and construction of larger and taller buildings.

In 2014, the American Wood Council (AWC) began developing a plan to expand these limits, but recognized it would require the International Building Code, the predominant model code adopted in most local and state jurisdictions in the United States, to embrace a new type of construction: fire-resistance-rated tall mass timber.

By 2016, founding architect of atelierjones, Susan H. Jones, FAIA, had designed and built four mass timber buildings: a church, two schools, and her own house.

"As our knowledge of how sustainability is negatively impacted by our built environment and the role that designers, architects and contractors have to play in that, it became increasingly obvious that there were more and more drastic things that we needed to do. The profession was focusing on lowering operational carbon that it takes to run a building as a sustainable strategy. It was really clear to me that there was a lot of carbon being expended, whether it's building solar panels or extra petroleum-based insulation, to save this operational carbon," Jones said (Jones, 2022).

Up to 37 percent of our greenhouse gas emissions globally can be attributed to the construction industry (Programme, 2021). Emissions from producing cement alone, a key ingredient in concrete, is responsible for 7 percent of global carbon emissions (Borenstein 2022).

The wood products industry is a nearly zero-waste sector and wood products have very low embodied carbon emissions—the greenhouse gas emissions associated with the manufacturing and installation—as compared with competing materials (United Nations Environment Programme

Photo courtesy of atelierjones.

2021). Additionally, the United States is a global leader when it comes to managing our forests. Twice as much wood is grown in the United States each year than is harvested (Oswalt et al 2018).

Simply substituting wood for conventional building materials could provide almost a tenth of the global carbon emission reductions needed to meet 2030 goals (Himes and Busby 2020). However, while structural light-frame wood products are the go-to building materials in the United States for low-rise residential construction, capturing over 90 percent of the market (U.S. Census Bureau 2022), any kind of wood-frame construction at the time of the Jones quote was limited to 5 stories and 85 feet in height (Council I. C., 2015 International Building Code (IBC)). These story and height limitations dated back decades and prevented the design and construction of larger and taller buildings.

"This was nagging in the back of my brain. It doesn't really matter if I build my sweet, little house and I save carbon by 10 percent or even 90 percent," Jones said. "What we really need to do is scale. We need to substitute for concrete and steel and scale up." (Jones, 2022)

Around the time, in 2014, the American Wood Council (AWC) had begun developing a plan to expand these limits, but recognized it would require the *International Building Code*, the predominant model code adopted in most local and state jurisdictions in the United States, to embrace a new type of construction: fire-resistance rated tall mass timber.

Rendering of the first Type-IVC IBC Building Code building permitted in the City of Seattle. Photo courtesy of atelierjones.

"My early experiences with mass timber are ultimately what convinced me to say yes to the huge commitment to participate in the process of trying to change the building codes to allow for tall timber buildings," Jones said (Jones, 2022).

What are Tall Mass Timber Buildings?

Recent case studies of modern tall wood buildings in Europe and Canada highlight the fact that wood is a viable solution for attaining a safe, cost-effective, and high-performance tall building (Michael Green Architecture 2018).

According to the AWC, tall mass timber construction is defined as buildings over 85 feet in height (American Wood Council 2022). Large-dimension wood building elements are used as functional components of the structural support system. From the AWC:

"With advanced manufacturing technologies and modern mass timber products such as glued-laminated timber (glulam), cross-laminated timber (CLT), and structural composite lumber (SCL), building tall with wood is not only achievable but already underway—with completed contemporary buildings in Canada, U.S., Australia, Austria, Switzerland, Germany, Norway, Sweden, Italy, and the United Kingdom at seven-stories and taller." (Council A. W., 2022)

The Road to Tall Mass Timber in the 2021 IBC

In 2015, the AWC Board of Directors approved a 5-year plan outlining a strategy for the recognition of tall mass timber buildings in the 2021 edition of the *International Building Code* (IBC). Robert Glowinski, the retired President and CEO of the AWC, told the Board that such an undertak-

A panel is being lifted into place during construction of the 18-story Brock Commons Tallwood House student residence at The University of British Columbia.

ing should not be underestimated. The plan, developed by Kenneth Bland, AWC's retired Vice President of Codes and Regulations, called for unprecedented change to the IBC, unlike any change that had occurred to a legacy code since their introduction in the early 1900s. Two other wood organizations were aligned with the goals of the AWC Board and agreed to co-fund elements of the plan; the Softwood Lumber Board (https://softwoodlumberboard.org/) and U.S. Endowment for Forestry and Communities (https://www.usendowment.org/).

Cees de Jager is President/CEO of the Softwood Lumber Board and an advocate for the change that would see tall mass timber buildings as part of the North American skyline.

"Europe was really leading the way in terms of innovation. They take their logs and produce a building system where we had historically just produced building components," says de Jager. "Reducing the environmental footprint of buildings and using wood to do so was paramount. In 2014, I took a trip to Europe with Glowinski and Bland and learned about these innovative products called mass timber." (Jager, 2022)

Not only was the concept of using mass timber innovative, it also is sustainable. "Reducing the environmental footprint of buildings and using wood to do so was paramount," says de Jager. "We worked with architect Andrew Waugh to understand how to make wood a focus. We understood the code limitations that needed to be addressed, but we also needed to ensure that the market was ready for this." (Jager, 2022). Glowinski agrees: "We were tired of playing defense all the time. We wanted a code change that would put us on the offense. I talked to Ken and he prepared a plan. Our goal was a comprehensive code change for consideration by code and fire officials. The rest is history!" (Glowinski, 2022).

Led by the AWC, a multiyear initiative was undertaken to compile studies that would demonstrate the performance of tall mass timber structures, communicate those findings with code and fire officials, and introduce tall mass timber as an alternative building option.

International Code Council (ICC) Model Code Development History

Model codes published by the ICC are updated on a 3-year cycle. The consideration of key changes for mass timber began in 2012 during the code development cycle for the 2015 edition of the IBC. The AWC proposed adding CLT as a permitted building element in heavy timber (HT), also known at time as Type IV, construction. Historically, HT construction is commonly found in industrial mill buildings. HT building elements consist of large sawn timbers, glulam, and nail-laminated assemblies.

"The change to the 2015 IBC (G142-12) reorganized section 602.4 of the 2012 IBC to allow for the recognition of CLT as a HT building element," says Bland. "The proposal specified where CLT was permitted for use as an interior wall, roof, floor, and exterior wall building element in combustible construction. Additionally, a definition of CLT and a reference to the 2012 edition of the PRG 320 manufacturing standard was introduced. This addition not only allowed CLT in heavy timber buildings, but also created an opportunity for its use in other types of combustible construction. Most importantly, this began to lay the groundwork for expanding the allowable height, stories, and area of Type IV buildings." (Bland, 2022)

Over the years, AWC's experience in code development has shown that it could take multiple cycles to achieve a successful change to the code. Prior to the establishment of the ICC, which combined all regional model codes into one, the legacy code organizations held two or three annual code-change cycles for each triennial edition of the code. Therefore, it was possible to propose a revised version of a previously disapproved change a second or third time within the 3-year period leading to the triennial edition. This multicycle approach allowed code officials time to become familiar and more comfortable with a new technology, before approving

A group of building code officials and representatives from the forestry and wood products industries toured the construction site of the University of British Columbia's Brock Commons building in 2016.

it in the code. Conversely, the ICC has just one cycle for each triennial edition of the code, so starting the conversation in 2012 was seen as the precursor for greater opportunities in subsequent years.

In the spirit of continuous efforts to disseminate information on mass timber design, performance, and testing, AWC submitted proposed change G165-15 for consideration during the 2018 code development process. The proposal allowed for a nine-story special occupancy building of HT construction and was modeled after a similar existing provision for steel construction. The proposal received the support of many individuals, including both building code officials and fire officials, who testified in favor of the proposal. However, the opposing testimony of other material interests and some fire officials resulted in the disapproval of G165-15. Although unsuccessful, G165-15, played a major role in heightening the awareness of tall mass timber among building and fire officials. This awareness ultimately set the stage for the 2021 IBC.

Leveraging this experience, the next realistic opportunity to introduce tall mass timber in the IBC would occur in 2018, during the 2021 IBC code development process. The deadline established by ICC to propose changes to the 2021 IBC was January 2018, a full 3 years before the edition date of the code. At this point, AWC recognized the timeframe to execute a comprehensive plan and the code change proposal deadline was just over 2 years. The plan would involve a strategy that immediately brought stakeholder engagement into the discussion.

International Code Council Tall Wood Ad-Hoc Committee

On July 11, 2015, the AWC submitted a request to the ICC Board of Directors (BOD) to create an Ad Hoc Committee to study tall mass timber buildings. ICC policy CP#07-04 allows for the creation of committees for "…any issue of proper concern to ICC." (International Code Council 2019). The purpose of the Ad Hoc Committee was to determine the extent to which, if at all, the code should be expanded to contain prescriptive requirements for tall mass timber buildings. AWC delivered a compelling presentation, emphasizing the benefit of tall mass timber code provisions to building and fire officials. With emerging interest in the construction of taller mass timber buildings, adding well-vetted life safety and fire protection features for their construction in the code would ensure a consistent level of performance.

The ICC BOD conducted a survey of stakeholders in their process to gather information on the need for tall mass timber building code provisions. The response was overwhelmingly positive, and in December 2015, the Board established the Ad Hoc Committee on Tall Wood Buildings (TWAH). From the ICC: "The scope of the ad hoc committee is to investigate the feasibility of and take action on developing proposed changes to the International Codes or I-Codes for tall wood buildings. In making this decision, the Board notes that the scope is to review all aspects of the building science, and conclusions must be supported by technical justification when considering any proposed changes to the I-Codes." (Council I. C., ICC Accepting Applications for Ad Hoc Committee on Tall Wood Buildings, 2016)

In January 2016, ICC issued a call for membership on the TWAH committee and members were confirmed in March 2016. Steve DiGiovanni, Clark County, Nevada Fire Protection engineer, was appointed chair and Susan Jones represented the American Institute of Architects. The Committee met quarterly, quickly establishing four working groups, each responsible for developing code provisions over the next 2 years. Minutes for all of the meetings, as well as agendas, support documents, and presentations, were made publicly available on the TWAH website. The TWAH committee brought together a broad range of ICC key stakeholders to identify the research and testing necessary to recognize tall wood buildings in the 2021 code. This would also serve to educate stakeholders and increase their comfort with the proposals.

"TWAH committee Chairman DiGiovanni and its members that included experts in architecture, mass timber, and fire and life safety codes were highly motivated to develop a comprehensive set of provisions to allow larger and taller mass timber buildings. Their commitment was instrumental in completing a large task in such a short period of time," said Bland (Bland, 2022).

"Having that interdisciplinary group was essential for success," said Jones. "I can't imagine doing it any other way because it was necessary to have those representatives on the code committee to convince the code community as a broad, national body that all of the interests had been taken into account and wood was not dominating this. It was being dominated by issues of data, life safety and respect for the code." (Jones, 2022)

An important piece of the TWAH committee's work was the layout and planning of five fire tests of a full-scale, multistory mass timber apartment building with typical one-bedroom apartment layouts. AWC and the U.S. Forest Service's Forest Products Laboratory (FPL; https://www.fpl.fs.usda.gov/) collaborated with the TWAH committee to conduct the research, with the goal of validating the fire performance of a large compartment constructed from CLT and glued-laminated timber. Test scenarios included various arrangements of exposed CLT and others of CLT protected with gypsum wallboard. The effectiveness of automatic sprinkler systems was also evaluated. The results were a success and indicated that mass timber provides the level of fire-safety performance that warrants its use in larger buildings and potentially expands the option for exposed mass timber in certain projects.

The tests were conducted at the U.S. Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) Fire Research Laboratory (https://www.atf.gov/laboratories/fire-research-laboratory), the world's largest research laboratory dedicated to fire scene investigations. A General Technical Report FPL-GTR-247 with the full fire test data is now available from the FPL (Zelinka et al. 2018), detailing how the experiment was set up and conducted, instrumentation used to collect the data, and a summary of the results.

Ad Hoc Committee on Tall Wood Building members (International Code Council n. d.).

Stephen J. DiGiovanni, PE, Chair
Fire Department Protection Engineer
Clark County Department of Building and Fire Prevention
Las Vegas, Nevada

Jonathan C. Siu, PE, SE, Vice Chair
Principal Engineer/Building Official
City of Seattle; Seattle Department of Construction and Inspections
Seattle, Washington

Carl F. Baldassarra, PE
Principal
Wiss, Janney, Elstner Associates, Inc. Northbrook, Illinois

Kenneth E. Bush
Rep: National Association of State Fire Marshals Chief Fire Protection Engineer Maryland State Fire Marshal's Office
Easton, Maryland

Sean DeCrane
Lead Regulatory Engineer
Building & Life Safety Technologies
UL LLC
Cleveland, Ohio

Sam Francis
Rep: American Wood Council (AWC)
Retired from AWC
West Grove, Pennsylvania

Julie Frappier, PE
Director, Technical Services
Nordic Structures
Montreal, Quebec

Patrick Granson
Deputy Director Permitting and Plan Review Mecklenburg County Code Enforcement Charlotte, North Carolina

Board Liaison
David J. Spencer, CBO
Operations Manager City of Woodinville Covington, Washington

Jonathan Humble, AIA, NCARB, LEED-AP BD & C
Regional Director
American Iron and Steel Institute
West Hartford, Connecticut

Susan H. Jones, FAIA, LEED AP BD+C
Rep: The American Institute of Architects
Architect
atelierjones
Seattle, Washington

Paul Shipp, PE, PhD
Principal Research Associate
USG Corporation
Libertyville, Illinois

Stephen V. Skalko, PE
Rep: Masonry Alliance for Codes and Standards Principal and Consulting Engineer
Stephen V. Skalko, P.E. & Associates, LLC
Macon, Georgia

Matthew A. Timmers, SE
Rep: Structural Engineers Association of CA/So. California
John A. Martin & Associates
Los Angeles, California

Andrew Tsay Jacobs, LEED AP, EIT
Director of Building Technology Lab
Perkins+Will
Los Angeles, California

John L. Walser
Battalion Chief, Fire Prevention Services
Fairfax County Fire and Rescue Department
Fairfax, Virginia

Felix I. Zemel, CBO
Rep: Town of Dover, MA
Principal Pracademic Solutions
Needham, Massachusetts

Staff Secretariat
Michael J. Pfeiffer, PE
Senior Vice President, Technical Services Central Regional Office
Country Club Hills, Illinois
mpfeiffer@iccsafe.org

Update to PRG 320-18 Adhesives

In early 2017, prior to ATF tests, the Fire Protection Research Foundation (FPRF) initiated tests at the National Institute of Standards and Technology (NIST 2017). The findings indicated that adhesives used in the manufacturing of CLT complying with PRG 320-12 lacked adequate fire performance to achieve the life-safety and property-protection objectives established by the TWAH committee. Concurrent with the ATF fire tests, AWC worked with the Southwest Research Institute to develop a large-scale test that would expose the CLT to a severe fire exposure identical to what was used in the FPRF testing. The objective was to show that enhanced adhesives would prevent fire regrowth and result in a compartment fire that would decay and eventually not pose an unacceptable risk to the fire service.

Three tests were conducted. The first used identical material to that used in the FPRF tests, which produced the same results of inadequate fire protection. The second and third tested CLT manufactured using the updated adhesive protocol, and that ultimately proved to be fire resistant at higher temperatures. The new protocol was approved by the APA PRG 320 Committee and included in the 2018 edition

Five fire tests were conducted on this full-scale multistory mass timber apartment building as part of the Ad Hoc Committee on Tall Wood Buildings research into the feasibility of incorporating new construction types into the model building codes.

of the ANSI/APA PRG 320 CLT manufacturing standard (APA 2018).

The findings from the ATF fire test (Zelinka et al. 2018) and changes to CLT adhesive performance provided the justification for code changes proposed by the TWAH committee. The code change proposals provided a comprehensive set of code requirements to ensure an abundance of life safety and property protection in tall mass timber buildings. A thorough review of the entire IBC was undertaken to capture any provision that may affect taller mass timber buildings.

ICC 2018 Group A Code Development Process

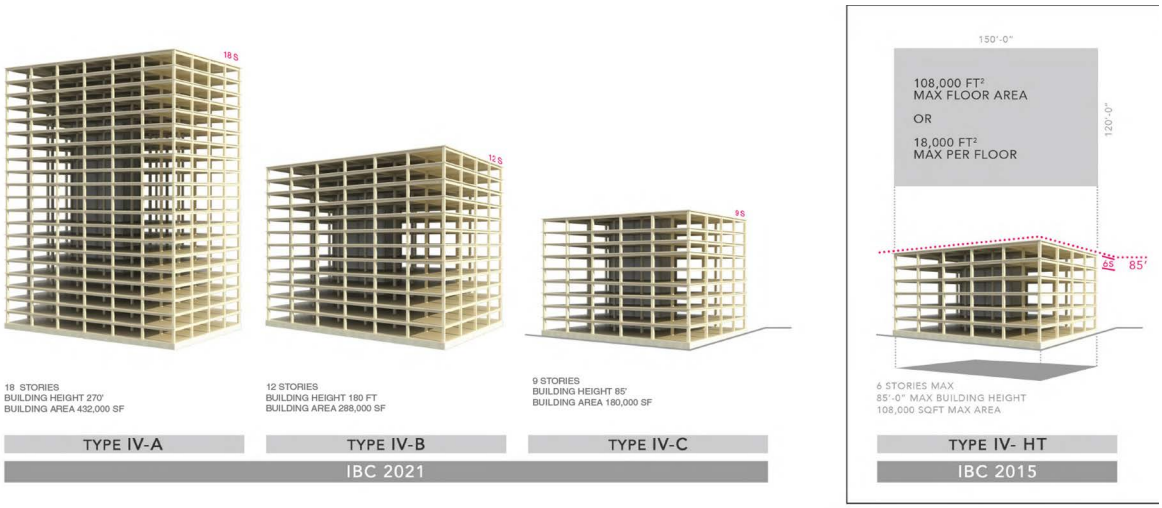
Based in large part on the results of the ATF fire tests, the TWAH committee deemed it appropriate to include expanded opportunities for mass timber in the IBC and developed 14 code changes that were submitted prior to the Group A deadline. In total, the proposals would allow for tall mass timber buildings up to 270 feet and 18 stories, if approved.

The ICC Committee Action Hearings on the proposals occurred in mid-April 2018, in Columbus, Ohio, where the work of the TWAH committee enjoyed unprecedented support. A few fire officials expressed concern that an allowable building height of 270 feet for fully protected mass timber was excessive. The fire officials cited the lack of aerial fire equipment that could be used to assist in the evacuation of building occupants from above the 12th floor. The opposition testimony was rebutted, emphasizing that buildings of mass timber have greater fire resistance than do equivalent height noncombustible structures and that occupant egress had been considered by the TWAH committee. Another concern raised was that a greater per-floor-area increase was allowed under the proposal than was permitted for structures made of steel and concrete. However, the rebuttal showed the concern was not accurate and was resolved by pointing out that the proposal did allow greater areas than those that were, at the time, permitted for wood frame construction.

All 14 code proposals were recommended for approval of the code development committees and moved forward to the next hearings. You can see both the concerns raised as

ATF mass timber fire test results (AWC summary of tests from Zelinka et al. 2018).

Test no.	Description	Sprinkler used	Results
1	The mass timber structure was fully protected with gypsum wall board and subjected to a large furnishings and contents fire.	No	The test was terminated after 3 h without significant charring on the protected wood surfaces of the structure.
2	Approximately 30% of the cross-laminated timber (CLT) ceiling area in the living room and bedroom were left exposed.	No	The test was terminated after 4 h, providing additional time to determine whether there would be any significant fire contribution from the exposed CLT. Notably, once the furnishings and contents had been consumed by the fire, the exposed CLT essentially self-extinguished as a result of the formation of char that protected the underlying wood.
3	Parallel CLT walls were left exposed, one in the living room and one in the bedroom.	No	Similar to Test 2, once the apartment furnishings and contents had been consumed by the fire, during which a protective surface of char formed on the CLT, the mass timber surfaces essentially self-extinguished.
4	All mass timber surfaces in the living room and bedroom were left exposed. Test examined the effects of sprinkler protection.	Yes	Test demonstrated that under normal operating conditions, a single sprinkler easily contained the fire.
5	All mass timber surfaces in the living room and bedroom were left exposed. Test examined the effects of sprinkler protection.	Yes	Test allowed fire to grow in the compartment for 23 min before water was supplied to the sprinklers, which quickly controlled the fire.



well as the committee's responses here: https://www.iccsafe.org/wp-content/uploads/TWB-Response-to-Concerns-Raised-at-Hearings_8_1_18-_Posted.pdf

As expected, there were several public comments that proposed limitations to changes recommended for approval by the code development committees. Most were of a theme consistent with what was presented in testimony in April. The Public Comment Hearings were set to take place October 24–31, 2018.

"October 2018 saw the final debate and vote on changes to the code," recalls Glowinski of the Public Comment Hearings. "That year, steel and concrete upped their opposition to the code changes. The final vote was going to take place in Richmond and in the lead up to the meeting, they took out billboard ads in opposition to tall mass timber from the airport to where the vote was set to take place. They gave out antiwood pamphlets and free giveaways. When the vote finally took place in Richmond, it was remarkable. It was historical and the code changes really enjoyed overwhelming support." (Glowinski, 2022)

ICC cdpACCESS

The recommendations of the code development committees were upheld by the governmental voting members (GVM) that were present in Richmond for public comment hearings, but there was one more critical voting opportunity remaining. The ICC online governmental voting process, known as cdpACCESS, provides an opportunity for GVM to cast votes following the public comment hearing. Reaching these qualified GVM to ensure they had a comprehensive understanding of the changes was critical to their final approval.

The ICC online governmental voting period occurred from November 19 to December 14, 2018. When the votes were tallied, all 14 tall mass timber code-change proposals were approved, ensuring their inclusion in the 2021 *International Building Code*. These 14 tall mass timber code-change proposals created three new types of construction allowing for tall mass timber buildings up to 18 stories tall:

- Type IV-A—Wood buildings up to 18 stories tall, with noncombustible protection on all mass timber.
- Type IV-B—Wood buildings up to 12 stories tall, limited-area of exposed mass timber walls and ceilings allowed.
- Type IV-C—Wood buildings up to 9 stories tall, all exposed mass timber designed for a 2-hour fire resistance.

"This vote is the culmination of years of research and testing that have proven unequivocally that mass timber meets and, in many cases, exceeds the performance and safety standards required by U.S. building codes," de Jager said of the final vote. "This is an exciting development for anyone interested in building design and construction around the world, especially for those committed to integrating high-performance, low-carbon materials into the built environment. We are particularly excited for the softwood lumber industry, as per our research, this change could represent an additional 1.5 billion board feet of new market opportunity every year, along with increased use of every product our industry sells." (Jager, 2022)

"To AWC's credit, they went out and secured an opportunity like this," says Michael Goergen of the U.S. Endowment for Forestry and Communities. "That's an incredible achievement, which changed the skyline to include tall mass timber buildings. It's a great example of what can be achieved when all these organizations work together." (Goergen, 2022)

After the 2018 success, the TWAH committee prepared 3 additional structural changes in support of mass timber for consideration during the Group B process, which occurred throughout 2019. The changes addressed inspection requirements and design criteria for protecting connections from fire. Similar to the success in 2018, the changes were approved and became part of the 2021 International codes.

2024 IBC Code Development Process

In 2019, AWC was awarded a Wood Innovation Grant for research by the U.S. Department of Agriculture that partially funded the study of fire behavior in CLT compartments with varying areas of exposed mass timber ceilings and walls. At this time, additional improvements had been made in the

A rendering of the 67,000-square-foot mass timber affordable housing project in Seattle that received support from a U.S. Forest Service Wood Innovation Grant for Community Roots Housing. The team is comprised of atelierjones, Skipstone Development, Swinerton Construction, Timberlab and DCI Engineering, and Dali Development. Photo courtesy of atelierjones.

fire performance of adhesives used to make CLT since the ATF tests were studied, and this additional research would test that performance. AWC contracted with the Research Institute of Sweden (RISE) to perform several fire compartment tests, each with progressively more exposed mass timber surfaces. The results were compelling and suggested that fires in compartments with fully exposed ceilings would self-extinguish. Based on the RISE report (Brandon et al. 2021), several members of the former ICC TWAH committee developed a proposed code change to the 2024 IBC with the support of AWC. The change was considered during the 2021 Group A code development hearings and approved by the ICC membership later that same year. Previously, mass timber buildings of Type IV-B, or up to 12 stories, construction were permitted to have a ceiling area exposed of no more than 20 percent of the floor area and the remainder protected with gypsum wallboard. Beginning with the 2024 IBC, ceilings areas in Type IV-B can have up to 100 percent of the floor area as exposed mass timber. This new provision will not only reduce construction costs but will also lower the carbon footprint of mass timber construction by not requiring the use of carbon intensive drywall.

Mass Timber and Climate Change

Increased adoption of wood-based construction products and technologies would displace embodied greenhouse gas emissions associated with other carbon-intensive construction materials, but equally as important, is prioritizing the use of renewable materials over finite materials that cannot be regenerated.

"The AEC community was ready for the change to allow tall mass timber construction," says Goergen. "The market is begging for a way to use the built environment to sequester carbon. The future will be giving construction professionals the confidence to work in wood. Not in terms of safety, but in terms of sustainability. This is our focus now, as we work on ways to track forest carbon through fiber sourcing. Every input will be understood, so that we can produce a science-based number for the amount of carbon that is stored in a wood product. This will produce better data and data that is regional specific." (Goergen, 2022)

"It was the natural immersive beauty [of mass timber] that [first] convinced me. Then understanding mass timber's lower carbon footprint and its relationship to sustainable forestry that pushed a giant tsunami wave throughout the architecture profession which was looking for solutions. Finally, the prefabrication aspects of mass timber, which is making a really big impact and disrupting our current construction industry in a powerfully good way," says Jones (Jones, 2022).

A decade-long process, with more work to be done, has advanced historic changes to the U.S. modern building codes to allow greater opportunities for mass timber structures. It is also contributing to the increased use of low-carbon alternatives in the built environment.

Today, Jones is now leading a team to design and build an 8-story, 126-unit mass timber affordable housing project in Seattle, Washington (atelierjones 2021), now under construction and scheduled for completion in mid-2023. "It's this incredibly happy story that I get to build, I believe, the first Type IV-C building in the U.S. based on the codes that I helped to write."

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