Tall Wood Buildings in the 2021 IBC
Up to 18 Stories of Mass Timber

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In January 2019, the International Code Council (ICC) approved a set of proposals to allow tall wood buildings as part of the 2021 International Building Code (IBC). Based on these proposals, the 2021 IBC will include three new construction types—Type IV-A, IV-B and IV-C—allowing the use of mass timber or noncombustible materials. These new types are based on the previous Heavy Timber construction type (renamed Type IV-HT) but with additional fire-resistance ratings and levels of required noncombustible protection. The code will include provisions for up to 18 stories of Type IV-A construction for Business and Residential Occupancies.

Based on information first published in the Structural Engineers Association of California (SEAOC) 2018 Conference Proceedings, this paper summarizes the background to these proposals, technical research that supported their adoption, and resulting changes to the IBC and product-specific standards.

Background: ICC Tall Wood Building Ad Hoc Committee

Over the past 10 years, there has been a growing interest in tall buildings constructed from mass timber materials (Breneman 2013, Timmers 2015). Around the world there are now dozens of timber buildings constructed above eight stories tall. Some international examples include:

Building Name	Location	Stories	Completion Date
Stadhaus at Murray Grove	London, UK	8-over-1	2008
Forté	Melbourne, Australia	8-over-1	2012
Via Cenni	Milan, Italy	9	2013
Treet	Bergen, Norway	14	2015
UBC Brock Commons	Vancouver, Canada	18	2016
Mjøstårnet	Norway	18	2019
HoHo Wien	Vienna, Austria	24	2019

Carbon12
Portland, Oregon I Eight stories of mass timber
Kaiser Group and Path Architecture
Munzing Structural Engineering

Photo: Andrew Pogue

In the United States, such buildings have been constrained by a strong reliance on prescriptive building code limits and less willingness to use performance-based fire protection engineering. That said, mass timber construction has grown significantly; by late 2018, more than a hundred projects had been constructed using mass timber and hundreds more were in design. Most of these projects were within the size limits of the current building code, such as T3 Minneapolis, a 6-over-1 office building developed by Hines. A few, such as the eight-story Carbon12 project in Portland, Oregon, successfully used an alternative means process to go beyond the prescriptive code limits.

In response to the growing interest in tall wood buildings, particularly constructed from new mass timber materials, in December 2015 the International Code Council (ICC) chartered the ICC Tall Wood Building (TWB) Ad Hoc Committee. The purpose of this committee is to "explore the building science of tall wood buildings and investigate the feasibility of and take action on developing code changes for tall wood buildings." To create a balanced committee, ICC solicited nominations from professional associations, including SEAOC. Voting members of the committee include building officials, fire officials, architects, fire protection experts and building construction material representatives including wood (American Wood Council, or AWC), steel, masonry, and gypsum. The committee is chaired by Stephen DiGiovanni, Fire Department Protection Engineer of the Clark County Nevada Department of Building and Fire Prevention. Initial activities included reviewing the technical state of mass timber knowledge and building performance and developing a series of compartment fire tests to test the proposed construction types. In January 2018, the Committee submitted a set of IBC code change proposals to the ICC 2018 Group A code development process, targeting changes to the 2021 IBC.

Photo courtesy Kaiser Group and Path Architecture

Completed in 2018, Carbon12 was engineered using an innovative steel brace frame core surrounded by a timber and CLT structure

Summary of the Group A Proposals

The Group A proposals included 14 individual proposals developed by consensus of the committee. All of the proposals were voted on and recommended for approval during the ICC Committee Action Hearings in April 2018, with a few receiving floor modifications. The scope of the proposals did not include any structural-specific changes (e.g., in IBC chapter 16 or 17) or material-specific changes (IBC Chapter 23 for wood), as proposals to these sections of the IBC are being considered as part of the Group B process in 2019.

The ICC TWB Ad Hoc Committee Group A proposals consisted of the following 14 parts.

Requirements for the new Types of Construction:

- IBC Section 602.4 – Type of Construction (G108-18)
- IBC Section 703.8 – Performance Method for Fire Resistance from Noncombustible Protection (FS5-18)
- IBC Section 722.7 – Prescriptive Fire Resistance from Noncombustible Protection (FS81-18)
- IBC Section 703.9 – Sealants at Edges (FS6-18)
- IBC Section 718.2.1 – Fire and Smoke Protection (FS73-18)
- IBC Section 403.3.2 – High-Rise Sprinkler Water Supply (G28-18)
- IBC Section 701.6 – Owners' Responsibility (F88-18)

  IFC Section 3308.4 – Fire Safety During Construction (F266-18)

Allowable building size limits:

- IBC Table 504.3 – Building Height (G75-18)
- IBC Table 504.4 –Number of Stories (G80-18)
- IBC Table 506.2 – Allowable Area (G84-18)

Housekeeping changes:

- IBC Section 3102 – Special Construction (G146-18)
- IBC Appendix D – Fire Districts (G152-18)
- IBC Section 508.4 and 509.4 – Fire Barriers (G89-18)

Seattle Mass Timber Tower
Seattle, Washington
12 stories of mass timber (proposed)
Architect: DLR Group
Structural Engineer:
Fast + Epp Structural Engineers

Rendering: DLR Group

Existing Construction Types

The current IBC (2018 and previous) contains five main construction types, four of which have sub-types. For noncombustible construction, the types and associated maximum allowable heights of any occupancy are:

Construction Type	Type I-A	Type I-B	Type II-A	Type II-B
Maximum Height	Unlimited	180'	85'	75'

The fire resistance and safety requirements for these construction type classifications range from the most resistive Type I-A to the least resistive Type II-B. For example, the base FRR for the primary structural framing is a 3-hour FRR for Type I-A incrementing down to no rating (0-hour) for Type II-B.

For light-frame wood construction, the construction types and associated maximum allowable heights for any occupancy are:

Construction Type	Type III-A	Type III-B	Type V-A	Type V-B
Maximum Height	85'	75'	70'	60'

Types III-A and V-A have a 1-hour FRR requirement for most structural elements. Types III-B and V-B have no FRR for many structural elements. Note: In Sections 420, 504.1 and 508.3.3, fire resistance-rated separations and supporting construction is required for residential occupancy groups even if the designer uses the "non-separated" option. Type III-A and III-B construction have additional requirements such as exterior walls that are either noncombustible or constructed with fire retardant-treated wood.

The current Type IV-HT construction requires wood construction to meet minimum prescriptive "heavy timber" sizes. Type IV-HT has a maximum allowed height of 85', equal to the maximum height of Type II-A and III-A. The base requirements of Type IV-HT construction do not include any fire-resistance rating requirements for heavy timber elements except for bearing walls or heavy timber structural elements providing vertical support of exterior bearing walls. Heavy timber relies on the cross-section size of the wood members to provide an intrinsic level of passive fire resistance. This passive protection is achieved through charring at the surface of the wood members which protects the remaining structurally sound wood. In the 2018 IBC, prescriptive minimum sizes as well as most detailing requirements from Section 602.4 were relocated and are now found in Section

2304.11. The ICC TWB Ad Hoc Committee determined a mass timber bearing wall is defined by the same 200 plf requirement for concrete and masonry bearing walls found in IBC Section 202.

New Construction Types

In looking at the existing tall wood buildings proposed and built around the country and world, the ICC TWB Ad Hoc Committee debated and settled on expanding the existing Type IV construction by adding three new sub-types—IV-A, IV-B and IV-C—and renaming Type IV as Type IV-HT. Similar to the noncombustible construction types, I and II, the four "mass timber" construction types are arranged from the highest fire resistance and safety requirements (IV-A) to the lowest (IV-HT). A scoping principle the committee followed when determining the changes was to change Type IV as little as possible.

Requirements for New Construction Types

This paper highlights some of the requirements for the new construction types, starting with the definition of mass timber. A relatively new category of wood products, mass timber can encompass well known and widely used products such as glue-laminated timber (glulam) framing as well as newer panelized products such as cross-laminated timber (CLT). The definition of mass timber adopted for the 2021 IBC is:

> *Structural elements of Type IV construction primarily of solid, built-up, panelized or engineered wood products that meet minimum cross section dimensions of Type IV construction.*

In practice, mass timber as defined in the IBC has been an umbrella term that includes heavy timber elements, with heavy timber materials and sizes serving as the prerequisite to be considered mass timber. A subtle difference is that most mass timber utilized in Types IV-A, B and C have a minimum required FRR in addition to the intrinsic fire-resistance rating due to the minimum prescriptive size requirements found in Type IV-HT.

Care should be taken to be clear when the minimum wood member size and detailing requirements of Type IV construction apply. When mass timber is used as one of the many current exceptions found in other construction types for "heavy timber" or "Type IV" construction, then the heavy timber size and detailing requirements found in Section 2304.11 are applicable. Large format panelized wood products made from solid sawn laminations include: CLT, nail-laminated timber (NLT), dowel-laminated timber (DLT), and glue-laminated timber (GLT). Panelized products made from structural composite lumber include: LVL panels and a proprietary mass plywood panel (MPP) made from laminated plywood. While such products are sometimes called "mass timber," they will only meet the 2021 IBC definition of mass timber when they meet the specific size and detailing requirements. When such products are used in Type III or Type V construction, as "any material permitted by this code" in Sections 602.4 and 602.5, the Type IV dimension and detailing requirements do not automatically apply.

Fire-Resistance Ratings: Table 1 below contains the minimum FRR requirements for the new construction types found in IBC Table 601. Included for comparison are the requirements for Type I-A and I-B. The new Type IV-A has the same base FRR requirements as Type I-A. Type IV-B and IV-C have the same base FRR as Type I-B.

Noncombustible Protection: A requirement unique to the new construction types is noncombustible protection (for mass timber). This noncombustible material applied to the mass timber helps determine fire behavior by delaying the contribution of the mass timber structure in a fire and has an added benefit of increasing the fire-resistance rating of the mass timber element. The minimum contribution of noncombustible protection was set by the ICC TWB Ad Hoc Committee to be no less than 2/3 of the Table 601 required FRR for mass timber elements. All mass timber in Type IV-A construction requires noncombustible protection. Most of the mass timber in Type IV-B requires noncombustible protection with limited exposed mass timber elements. Select mass timber elements in Type IV-C require noncombustible protection. A summary of the noncombustible protection required for building components in the different construction types is shown in Table 2.

TABLE 1:

Required Fire-Resistance Ratings by Construction Type (IBC Table 601)

Building Element	I-A	I-B	IV-A	IV-B	IV-C	IV-HT
Primary Structural Frame	3*	2*	3	2	2	HT
Ext. Bearing Walls	3*	2*	3	2	2	2
Int. Bearing Walls	3*	2*	3	2	2	1/HT
Floor Construction	2	2*	2	2	2	HT
Roof Construction	1½*	1*	1½	1	1	HT

**These values can be reduced based on certain conditions in IBC 403.2.1, which do not apply to Type IV buildings.*

Three new types: Conceptually, Type IV-A is similar to type I-A with equal or greater FRR requirements and no exposed mass timber. Type IV-C is similar to Type IV-HT with almost all of the interior mass timber permitted to be exposed; however, most structural building components have a 2-hour FRR in addition to minimum heavy timber sizes. In surveying the existing and desired applications of mass timber in the US and around the world, the committee determined that an intermediate construction type between IV-A and IV-C was needed, resulting in Type IV-B.

Photo: naturallywood.com

Brock Commons Tallwood House
Vancouver, Canada | 17 stories of mass timber over a concrete podium, with two concrete stair cores
Architect: Acton Ostry Architects
Structural Engineer: Fast + Epp Structural Engineers

Type IV-B has similar FRR requirements as IV-C; however, all the mass timber requires noncombustible protection except the following:

- Area of ceilings not greater than 20% of the floor area
- Area of walls not greater than 40% of the floor area

A "sum of the ratios" type equation allows for a combination of the exposed ceilings and walls within a dwelling unit or fire area: e.g., area of exposed ceilings equal to 10% of the floor area plus area of exposed walls equal to 20% of the floor area. Unprotected areas of ceilings and walls also need be located with at least 15 feet horizontal separation. This requirement is to avoid re-radiation of heat between adjacent exposed mass timber elements which could extend the duration or severity of an uncontrolled fire. As an aside, the most frequent application of exposed mass timber in buildings to date is a portion of the ceiling alone.

Common Requirements: Additional requirements applicable to Type IV-A, IV-B and IV-C were included in the G108-18 proposal and include:

- No exposed mass timber in concealed spaces; concealed space permitted only with noncombustible protection as required for the interior mass timber
- Exterior side of exterior walls protected by a non-combustible material—e.g., 5/8" Type X gypsum sheathing
- No combustible exterior wall coverings except for certain water-resistant barriers
- No exposed mass timber on the inside and outside surfaces of exit enclosures and elevator hoistways in high-rise buildings (occupied floor > 75 feet from lowest fire department access)
- Noncombustible construction only for exit enclosures and elevator hoistways greater than 12 stories or 180 feet

TABLE 2:

Required Noncombustible Protection on Mass Timber Elements by Construction Type

	IV-A	IV-B	IV-C	IV-HT
Interior Surface of Building Elements	Always required. 2/3 of FRR, 80 minutes minimum	Required with exceptions. 2/3 of FRR, 80 minutes minimum	Not required*	Not required*
Exterior Side of Exterior Walls	40 minutes	40 minutes	40 minutes	15/32" FRT sheathing or 1/2" gypsum board or noncombustible material
Top of Floor (above Mass Timber)	1" minimum	1" minimum	Not required*	Not required*
Shafts	2/3 of FRR, 80 minutes minimum, inside and outside	2/3 of FRR, 80 minutes minimum, inside and outside	40 minutes minimum, inside and outside	Not required*

**Not required by construction type. Other code requirements may apply.*
5/8" Type X gypsum = 40 minutes.

Additional Fire Protection Features

Parallel to the construction types, other fire protection features have been adopted for the 2021 IBC.

Noncombustible Protection: Proposal FS81-18 (new IBC 722.7) defined the level of noncombustible protection required and how to achieve this level, including a prescriptive method recognizing 1/2" Type X gypsum board providing 25 minutes of protection and 5/8" Type X gypsum board providing 40 minutes of protection. Proposal FS5-18 (new IBC 703.8) defined methods to determine the level of noncombustible protection provided by other applied materials through using the E119 test procedure. FS73-18 (IBC 718.2.1) added mass timber as a fire blocking material.

Sealants at Mass Timber Edges in Fire-Rated Assemblies: A new code section, IBC 703.9, was included in proposal FS6-18. It required that certain adhesives be applied at abutting edges and intersections of fire resistance-rated mass timber elements unless the assembly has been shown to provide the required fire-resistance rating without utilizing sealants.

Determination of Fire-Resistance Rating: Mass timber elements have inherent fire-resistance properties, providing structural integrity for fire with a structural fire-resistance rating that can be calculated in accordance with Chapter 16 of the NDS for exposed timber. Careful detailing and sometimes additional material is added to help prevent hot gases from being pushed through intersections around the edges of the mass timber elements when they serve as a fire resistance-rated wall or floor/ceiling designed to prevent the spread of fire from one side to the other. IBC Sections 703.2 and 703.3 state the fire-resistance rating can be determined through testing, calculations or engineering analysis based on comparison. New IBC language in Section 602.4 clarifies that the fire-resistance rating comes from the mass timber, added noncombustible protection or a combination of both. New Sections 703.7 and 722.7 give the specifics.

High-Rise Sprinkler Water Supply: In IBC Section 403.3.2 and the International Fire Code (IFC) Section 914.3.1.2, buildings over 420 feet tall are required to have redundant connections from the water mains to required fire pumps. Proposal G28-18 required similar redundant connections for Type IV-A and IV-B buildings over 120 feet tall.

Owners' Responsibility: In Section 701.6 of the IFC, owners are responsible for having and maintaining an inventory of fire-rated construction for the building, which is to be annually inspected and repaired when needed. Proposal F88-18 extended these requirements to explicitly include inventory of the noncombustible protection on mass timber elements of fire-rated assemblies.

Fire Safety During Construction: Because of the potential for increased fire risk during construction of high-rise buildings, proposal F266-18 added a new IFC Section, 3308.4, which requires certain active and passive fire-resistance features to be installed during construction, including standpipes and water supply. Unless otherwise approved by the Fire Code Official, when the building construction exceeds six stories, some minimum noncombustible protection and exterior wall coverings are to be installed on stories more than four floor levels below the active mass timber construction.

Miscellaneous: Proposal FS73-18 added mass timber as an acceptable fire blocking in IBC Section 718.2.1. Proposals G146-18 and G152-18 simply changed existing language referring to the old Type IV as the new Type IV-HT. Proposal G89-18 added language in IBC Section 508.4 and 509.4 requiring noncombustible coverings on fire-rated assemblies for occupancy separations.

Fire Testing at ATF

Numerous E119 assembly tests have been performed with CLT showing how wall and floor assemblies, both exposed and covered with noncombustible materials, can provide up to a 3-hour FRR [Osborne, 2012]. Limited testing has shown up to 5-hour FRR when multiple layers of noncombustible protection are added. Additional non-standard compartment tests have been performed to investigate different natural fire scenarios [Jannsens, 2015]. The committee determined early in the process that fire tests of the proposed construction types would be instrumental in validating the proposals. To this end, the committee designed, and AWC and the US Forest Products Laboratory managed, a series of five compartment fire tests on a structure at the US Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) Fire Research Laboratory [Zelinka et al, 2018; Hasburgh et al, 2018]. The two-story structure, schematically shown in Figure 1, was built (and repaired between tests) conforming to the new construction types. CLT was used for construction of the floors, perimeter walls of the dwelling units, and walls of the corridor and stair enclosure. Interior to the dwelling unit were glulam beams and columns supporting the levels above. The interior partition walls were built of non-rated light-gauge steel framing.

Five natural fires were performed, all with an identical fuel package representative of a high residential fuel load. Zelinka et al, 2018 is a nearly 500-page report on the testing; however, a very brief summary of the test scenarios is shown in Table 3.

TABLE 3:

ATF Compartment Test Scenarios

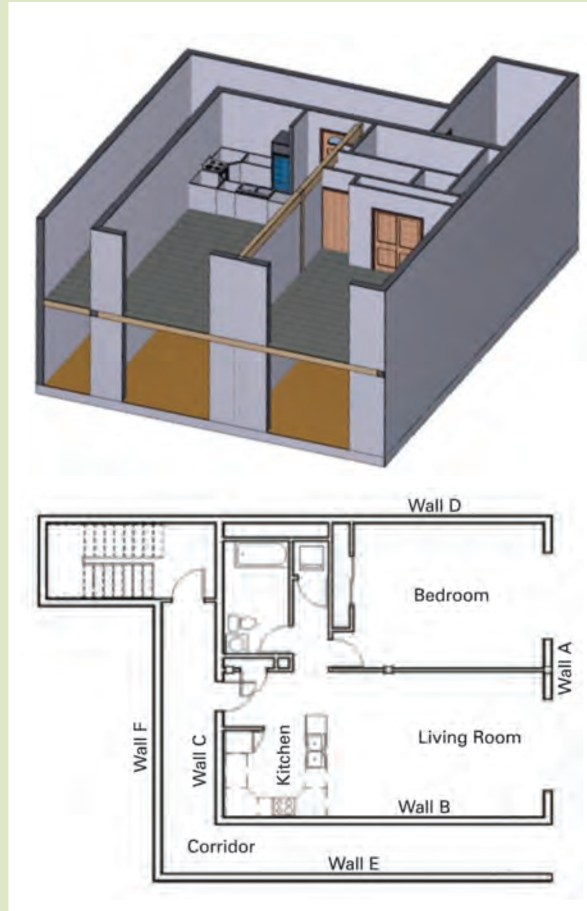
Test	Construction	Sprinklers	Result
1	IV-A	No	Fire contained; compartment burn-out
2	IV-B Partial Exposed Ceiling	No	Fire contained; compartment burn-out
3	IV-B Partial Exposed Walls	No	Fire contained; compartment burn-out
4	IV-C All Exposed Walls and Ceiling	Yes	Fire extinguished
5	IV-C All Exposed Walls and Ceiling	Yes, 20-minute delay	Fire extinguished

In each test, the fire was ignited in the kitchen area. Test 1 included a fully protected mass timber structure meeting the requirements of Type IV-A. Test 2 had 30% of the room ceiling area exposed (20% of the unit floor area) and Test 3 had two perimeter walls of the dwelling exposed with an exposed surface equal to 40% of the unit floor area. In tests 1 to 3, no sprinklers were activated after the fire was initiated and the fires were left to burn naturally for at least three hours. These test scenarios mimic an extreme combination of fire sprinklers not functioning and no fire service intervention. In each case, the fire was contained within the unit of origin, the contents were consumed, there were no structural failures, and where CLT was exposed, it self-extinguished. After flash-over within the unit, the fires decayed to hot-spots and embers less than two hours into the fire. These tests demonstrate how the proposed construction requirements can contain a fire within the compartment of origin with no structural failure or undue risk of the fire spreading to the rest of the building.

Tests 4 and 5 exposed almost all of the CLT in the ceilings and walls of the units. These tests were performed to demonstrate the impact of active fire sprinkler suppression. The sprinkler design density was 0.05 GPM/ft^2, which is half the minimum density required by the National Fire Protection Association's (NFPA's) NFPA 13. In Test 4, the sprinklers self-activated at around 2-1/2 minutes and quickly controlled the fire. In Test 5, the sprinklers were manually activated after approximately 22-1/2 minutes; after 2-1/2 minutes, the fire in the kitchen grew significantly, but was quickly extinguished when the sprinklers were activated. Figure 2 shows the total measured heat release rate of the five tests. Summary videos of the tests can be found at http://bit.ly/ATF-firetestvideos.

FIGURE 1

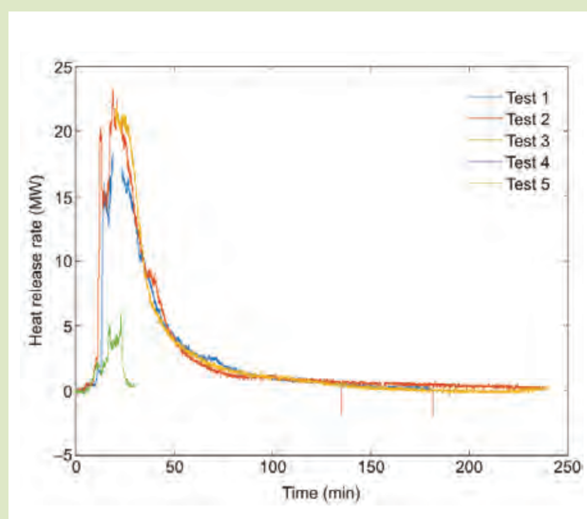
Two-Story Compartment Test Schematic



Courtesy USDA Forest Products Laboratory

FIGURE 2

Heat release Rate for ATF Tests



Courtesy USDA Forest Products Laboratory

TABLE 4:

Select Height and Area Limits by Construction Type

		I-A	I-B	IV-A	IV-B	IV-C	IV-HT
Occupancies	**Value**	**Allowable Building Height above Grade Plane, Feet (IBC Table 504.3)**					
A, B, R	S	Unlimited	180	270	180	85	85
		Allowable Number of Stories above Grade Plane (IBC Table 505.4)					
A-2, A-3, A-4	S	Unlimited	12	18	12	6	4
B	S	Unlimited	12	18	12	9	6
R-2	S	Unlimited	12	18	12	8	5
		Allowable Area Factor (At), Feet^2 (IBC Table 506.2)					
A-2, A-3, A-4	SM	Unlimited	Unlimited	135,000	90,000	56,250	45,000
B	SM	Unlimited	Unlimited	324,000	216,000	135,000	108,000
R-2	SM	Unlimited	Unlimited	184,500	123,000	76,875	61,500

S is sprinklered with NFPA 13 sprinklers. SM is the multi-story allowable area factor. Underlined entries are the new additions.

Allowable Building Sizes

As the ICC TWB Ad Hoc Committee developed and tested the requirements for the construction types, the allowable heights and areas were developed with the following performance objectives as the basis:

- No collapse under reasonable scenarios of complete burn-out of fuel without automatic sprinkler protection being considered
- No unusually high radiation exposure from the subject building to adjoining properties to present a risk of ignition under reasonably severe fire scenarios
- No unusual response from typical radiation exposure from adjacent properties to present a risk of ignition of the subject building under reasonably severe fire scenarios
- No unusual fire department access issues
- Egress systems designed to protect building occupants during the design escape time, plus a factor of safety
- Highly reliable fire suppression systems to reduce the risk of failure during reasonably expected fire scenarios; the degree of reliability should be proportional to evacuation time (building height) and risk of collapse

The comprehensive package of proposals from the ICC TWB Ad Hoc Committee met these objectives.

Proposal G75-18 defined allowable building heights in Table 504.3; proposal G80-18 defined the allowable number of stories in Table 504.4; and proposal G84-18 defined the allowable area in Table 506.2. The allowable heights and areas for select occupancies are shown in Table 4.

To help visualize the building size associated with these tabular limits, Figure 3 shows representative buildings of equal area per floor with the maximum building sizes for a Business occupancy. As Business occupancies have the largest allowable areas and share the tallest height limits with other occupancies, these are the largest building sizes permitted by the proposed construction types, excluding minor additional area increases allowed by the frontage increase of IBC 506.3.

Note that in the current IBC, the use of NFPA 13 sprinklers is mandatory for all high-rise buildings defined with an occupied floor more than 75 feet above the lowest level of fire department access. The use of NFPA 13 sprinklers typically provides for a one-story and 20-foot increase in the allowable building height but a substantial increase in allowable area. However, the new construction types are highly conservative when allowable area is compared with common A, B and R occupancy groups where unlimited area is allowed for existing Type I buildings.

Photo: Brudder, courtesy naturallywood.com

Completed in August 2017, Brock Commons has capacity for just over 400 students at the University of British Columbia

Other Testing

Concurrent with the work and testing directed by the ICC TWB Ad Hoc Committee, the NFPA Fire Protection Research Foundation (FPRF) has been working on a project titled "Fire Safety Challenges of Tall Wood Buildings." This project has primarily focused on aspects of mass timber construction. A recent series of compartment test of natural fires under this program looked at protected and unprotected CLT compartments independent of the ICC TWB Ad Hoc Committee code proposals (Su, 2018). In the FPRF series, compartment tests were performed with CLT fully encapsulated with noncombustible protection (i.e., Type IV-A). These tests resulted in compartment fires which essentially self-extinguished without contribution from the protected mass timber. Compartment tests were also performed with significant exposed CLT (i.e., Type IV-C) in which no sprinklers were used to control the fire. In certain configurations, the compartment fires did not decay and self-extinguish after burn-out of the contents. In these configurations, heat-induced delamination of CLT using certain adhesives not permitted in the proposal resulted in failure of the glue line as the char front approached. Thin pieces of the laminations fell to the floor exposing uncharred wood surface of a new lamination which contributed to regrowth of the fire.

As containment of the fire within the compartment or origin is an important performance goal for high-rise fire protection, further studies were led by the NFPA FPRF (Brandon, 2018) and AWC to define testing methods to discern when heat-induced char delamination can occur.

FIGURE 3
Representative Building Sizes, Business Occupancy

Courtesy atelierjones, LLC

18 STORIES
BUILDING HEIGHT 270 FT
ALLOWABLE BUILDING AREA 972,000 SF
AVERAGE AREA PER STORY 54,000 SF

TYPE IV-A

12 STORIES
BUILDING HEIGHT 180 FT
ALLOWABLE BUILDING AREA 648,000 SF
AVERAGE AREA PER STORY 54,000 SF

TYPE IV-B

9 STORIES
BUILDING HEIGHT 85 FT
ALLOWABLE BUILDING AREA 405,000 SF
AVERAGE AREA PER STORY 45,000 SF

TYPE IV-C

CLT Product Standard Update

The compartment tests 2 and 3 at ATF designed by the ICC TWB Ad Hoc Committee resulted in burn-out of the contents in the compartments with no delayed fire regrowth even though CLT used in the tests was made from adhesives that can exhibit heat-induced delamination. This demonstrated an acceptable behavior in the Type IV-B details without sprinkler suppression, even when using the less heat-resistant adhesives. Even so, the committee overseeing the code-referenced CLT product standard, ANSI/APA PRG-320 Standard for Performance-Rated Cross-Laminated Timber (PRG-320), responded to the desire by fire service representatives on the ICC TWB Ad Hoc Committee for higher assurances of CLT behavior in high-rise construction by incorporating a new required test for adhesives used in CLT production. Passing this test will be required for adhesives used in all CLT complying with the 2018 edition of PRG 320, referenced from IBC Section 602.4 in proposal G108-18. This test is based on a 4-hour compartment-like fire test designed "to identify and exclude use of adhesives that permit CLT char layer fall-off resulting in fire regrowth during the cooling phase of a fully developed fire" (PRG 320, 2018). This is a valuable change to the CLT product standard to help meet the performance desired in high-rise buildings.

Next Steps

Making changes to an ICC standard is a multi-step, multi-year process. The Group A proposals, including the set from the ICC TWB Ad Hoc Committee, were submitted to ICC in January of 2018. In April, the proposals were reviewed and recommended for approval by standing technical ICC committees (IBC General and IFC). In July, public comments were submitted on Group A proposals and a Public Comment Hearing was held in October, followed by an online Governmental Consensus Vote. The Group A proposals were adopted by the ICC in January 2019.

The ICC TWB Ad Hoc Committee anticipates submittal of Group B proposals for structural inspections (IBC Chapter 17) and material-specific modifications (IBC Chapter 23) in 2019.

Statewide Adoptions

With significant interest in tall mass timber construction occurring in Oregon and Washington, both states accepted or plan to accept the ICC TWB Ad Hoc Committee proposals for the basis of design prior to publication of IBC 2021.

On August 8, 2018, the State of Oregon Building Codes Division published Statewide Alternative Method 18-01 (www.oregon.gov/bcd/codes-stand/Documents/sam-18-01-tallwoodbldgs.pdf), which adopts the ICC TWB Ad Hoc Committee proposals as a pre-approved alternative method for use with the 2014 Oregon Structural Specialty Code. With approval of this Statewide Alternative Method, the new mass timber construction types and allowable building sizes described in this paper are now permitted in Oregon.

Further north, on November 30, 2018, the Washington State Building Code Council approved off-cycle amendments to the currently enforced IBC 2015-based Washington State Building Code to include the ICC TWB Ad Hoc Committee proposals. These approved amendments are anticipated to go into effect in Washington State in 2019.

Conclusions

The 14 individual Group A proposals from the ICC TWB Ad Hoc Committee led to a comprehensive set of code changes developed using a rational performance-based approach to establish new size allowances for mass timber buildings in the IBC. The three new construction types have been crafted to support a variety of exposed and protected mass timber design systems which have been validated through fire testing.

The 2018 NDS and AWC Technical Report 10 have been published and together include updated provisions for structural fire resistance calculations and protection of connections, as well as a summary of prior and recent fire testing providing substantiation for the design criteria.

Information on the proposals can be found on the ICC TWB Ad Hoc Committee website https://www.iccsafe.org/codes-tech-support/cs/icc-ad-hoc-committee-on-tall-wood-buildings/. Supporting documents are also available on the AWC website at https://www.awc.org/tallmasstimber.

References

ANSI/APA PRG 320-2018 Standard for Performance-Rated Cross-Laminated Timber; 2018. APA – The Engineered Wood Association. Tacoma, WA.

Breneman, S; and Podesto, L; *Timber Skyline: A Review of Structural Systems for High-Rise Wood Structures.* 2013 SEAOC Convention Proceedings. September 2013, San Diego, CA.

Brandon, D.; and Dagenais, C.; *Fire Safety Challenges of Tall Wood Buildings – Phase 2: Task 5 – Experimental Study of Delamination of Cross Laminated Timber (CLT) in Fire*. March 2018, NFPA Fire Protection Research Foundation, Quincy MA.

Hasburgh, L.E.; Zelinka, S. L; Bourne, K. J.; Tucholski, D. R.; and Ouellette, J. P.; *Full-Scale Fire Tests of a Two-Story Cross-Laminated Timber Structure.* 2018 World Conference of Timber Engineering. August 2018, Seoul Korea. http://bit.ly/ATF-firetestreport

Janssens, M; Albracht, N; and Carpenter, K; *Full-Scale Tests in a Furnished Living Room to Evaluate the Fire Performance of Protected Cross-Laminated and Nail Laminated Timber Construction.* September 2015. Southwest Research Institute, Fire Technology Department. San Antonio, TX.

Osborne, L; Dagenais, C. and Benichou, N.; *Preliminary CLT Fire Resistance Testing Report.* July 2012. FPInnovations/National Research Council of Canada.

Su, J.; Lafrance, P; Hoeler, M; and Bundy, M.; *Fire Safety Challenges of Tall Wood Buildings – Phase 2: Task 2 & 3 – Cross Laminated Timber Compartment Fire Tests.* February 2018. NFPA Fire Protection Research Foundation. Quincy, MA.

Timmers, M; Rogowksi, B; Jacobs, A. T; and Jones B.; *Mass Timber High-Rise Design Research: Museum Tower in Los Angeles Reimagined in Mass Timber.* 2015 SEAOC Convention Proceedings. September 2015, Bellevue, WA.

Zelinka Samuel L. Hasburgh, Laura E.; Bourne, Keith J.; Tucholski David R.; and Ouellette, Jason P.; *Compartment Fire Testing of a Two Story Mass Timber Building. 2018 Technical Report FPL-GTR-247.* USDA Forest Service, Forest Products Laboratory. Madison, WI. http://media.iccsafe.org/code-development/final-report-fpl.pdf