A Fire Safety, Environmental, and Economic Assessment of Modifying Building Codes for Tall Mass Timber Buildings

When Protected By Rigorous Systems and Controls

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MASS TIMBER CODE COALITION

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Executive Summary:

The International Code Council, developers of U.S. buildings codes, created an ad hoc committee of subject matter experts from the building design, building regulatory, and fire safety arenas to research and propose changes to the International Building Code (IBC) for the safe construction and use of mass timber buildings. These changes require highly redundant active and passive systems of fire protection to permit taller and larger buildings made from mass timber materials.

Peer review of the ad hoc committee's proposed changes identified a rigorous package of fire protective requirements intended to ensure that, under any reasonable fire scenarios, no structural collapse will occur despite complete burn-out of content fuels. Conservatively, this performance was dictated without consideration of the automatic sprinkler system required for mass timber buildings.

Intended fire performance of mass timber buildings was validated by a series of full scale, multiple-story fire tests at the U.S. Government's ATF Fire Research Laboratory. Testing evaluated the contribution of mass timber to a fire; integrity of structural members; performance of connections; performance of through-penetration protection; and conditions for responding fire personnel.

Test results supported the ad hoc committee's proposal for three new types of construction, Type IV-A, Type IV-B, and Type IV-C, to address options for tall mass timber buildings. Each new type of construction has hourly fire protection requirements more robust than those required for comparable noncombustible buildings. Fire testing has also demonstrated that the charring property of the material provides a reliable and predictable measure of fire-resistive performance even without added noncombustible protection.

Type IV-A requires noncombustible protection of all interior and exterior mass timber elements. Type IV-B permits limited exposure of interior mass timber elements where exposed elements are separated spatially to limit fire spread. Type IV-C buildings are permitted exposed mass timber elements similarly to what is currently allowed for Type IV-Heavy Timber buildings. While given some additional stories, Type IV-C buildings are also limited to the same height as current code requirements for Type IV-Heavy Timber buildings.

All new construction types proposed for the IBC prohibit combustible materials, other than water resistive membranes, on the exterior sides of exterior walls. All types also require noncombustible protection of all concealed spaces, shafts and exit enclosures. Dual water supplies for fire sprinklers are required for mass timber buildings exceeding 120 feet in elevation, i.e. about 8 to 12 stories.

Under-construction mass timber buildings have additional fire protection requirements compared to other building types, both combustible and noncombustible, requiring noncombustible protection of mass timber elements within 4 floor levels of any construction more than 6 stories above grade. Post-construction mass timber buildings are required to have their fire-resistance rated construction inspected annually by the owner, with any deficiencies repaired. Records of inspections and repairs are required to be maintained and are subject to review by the authority having jurisdiction.

Updating the International Building Code for modern mass timber buildings is projected to drive greater demand for mass timber, which will stimulate investment in its manufacturing and supply chain and put downward pressure on cost and pricing. Investment in mass timber production is projected to have significant economic benefit for rural communities in all areas of the country with timber resources. Because of repetitive building layouts in residential multifamily buildings, and the speed of assembling mass timber buildings versus other types of buildings, it is predicted that once the supply chain is developed, and material costs are lowered, mass timber will compete successfully with other materials used for multifamily buildings in the 4-6 story height range. In addition to construction efficiencies, expanded use of mass timber in these applications will likely reduce the occurrence of large construction site fires.

Mass timber construction sites are safer for workers. They are also quieter and are less disruptive than concrete or steel construction in the communities where projects occur. Mass timber projects are completed substantially faster than traditional methods of construction, minimizing waste and community impacts while maximizing both worker productivity and developers' returns on investment. In addition, building with pre-manufactured mass timber panels broadens the available labor pool and will likely alleviate a national shortfall in skilled construction labor.

Wildland fire safety on both the regional and global scale will benefit from increased use of mass timber. Low value wood, thinnings, and dead standing trees, can be used for mass timber, thereby creating a financial incentive for wildland fuels reduction, particularly of ladder fuels, improving regional fire safety and conserving federal and state resources. Globally, sequestering carbon in long-lived building materials from renewable, sustainably managed forests acts to mitigate drivers of climate change and worsening wildland fire seasons and intensities. Sequestering carbon in mass timber buildings also helps mitigate other issues associated with climate change. Sustainably managed and harvested forests capture more carbon than forests left unmanaged and provide habitat for a greater range of species.

Mass timber building are inherently energy efficient, with tight thermal envelopes, and exhibit superior performance in reducing operational energy compared to concrete and steel buildings, which typically rely upon nonrenewable and highly combustible foam plastic insulation for energy efficiency.

"To date, failure to accept wood products arises in part from conservatism in the construction industry. Outmoded attitudes need to be robustly challenged by drawing on the evidence and promoting the technical properties of wood."[1]

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WHEN PROTECTED BY RIGOROUS SYSTEMS AND CONTROLS

Abstract: This paper examines multiple benefits associated with expanding the use of mass timber by responsibly modifying building codes to accommodate taller mass timber buildings. The next edition of the International Codes may incorporate three new types of construction that recognize the use of mass timber and cross-laminated timber (a type of mass timber) materials for taller heights, more stories above grade and greater allowable area.

Aware of the many societal and environmental benefits of mass timber, but also cognizant of the fire safety implications of taller combustible buildings, the International Code Council (ICC) established a committee of designers, materials interests, code officials, and members of the fire service, including firefighters, fire chiefs and fire protection engineers, to research and design appropriate fire testing of mass timber materials and to draft code change proposals that ensure that tall wood buildings will have rigorous and redundant systems of fire protection suitable for the mission of protecting the public and fire responders.

In addition to providing economic opportunities to rural communities with timber resources, it is projected that reduced regulatory barriers to the use of mass timber will stimulate investment in the manufacturing and supply chain of the material, driving down the cost and making the material competitive with both noncombustible materials for 7+ story buildings and all materials in the 4-6 story range. Significant construction site fire safety advantages are provided by construction with mass timber. Significant wildland fire benefits are also attached to increased use of mass timber because of wildland fuels reduction made economically possible when smaller diameter ‘thinning’ trees and standing dead and unhealthy trees are harvested for use in mass timber panels.

Mass timber construction projects have less negative impact on communities during construction – reduced noise, dust, traffic – and fewer job site accidents than conventional construction methods. Mass timber projects take less time, need fewer human resources on site, have virtually zero waste.

Mass timber works to offset key drivers of climate change, which contribute to longer, more intense wildland fire seasons, by sequestering carbon absorbed while the trees grew and preventing the release of methane by decaying wood. The extremely tight building envelopes made possible by factory machined mass panels, and the excellent thermal performance of mass wood compared to noncombustible building materials, means mass timber buildings can also act against climate change through higher performance in the reduction of operational energy use.

Introduction

The next editions of the International Building and Fire Codes will feature important changes in material technologies and approved uses if the changes proposed by the International Code Council's (ICC) Ad Hoc Committee on Tall Wood Buildings (AHC-TWB) are adopted. Three new types of construction are proposed to allow the use of mass timber and cross-laminated timber materials (a type of mass timber) for buildings of taller heights, more stories above grade, and greater allowable area compared to current provisions for heavy timber buildings.

Expanding the use of mass timber will have environmental benefits; provide economic opportunities to disadvantaged rural communities with timber resources; make possible significant energy efficiency benefits, address construction labor shortfalls, shorten construction schedules, and have the potential to provide needed fire safety benefits, including wildland fire mitigation and more fire-safe construction sites.

In recognition of the array of benefits provided by large mass timber buildings, but also cognizant of the fire safety implications of taller combustible buildings, the ICC created the AHC-TWB in December 2015 to explore the building science of tall wood buildings and to investigate the feasibility of, and take action on, developing code changes for tall wood buildings that will assure the public and the fire service that code compliant tall wood buildings will have rigorous and redundant systems of fire protection, both passive and active, suitable for the mission of protecting the public and fire responders. The AHC-TWB was ideally suited to the task, consisting of subject matter experts, including members of fire and building departments, architects, structural engineers, representatives of testing laboratories, representatives of construction structural materials interests, and the fire service, including firefighters, fire chiefs and fire protection engineers.

Consistent with the professional expertise and stakeholder interest of the AHC-TWB, a rigorous set of performance objectives was created to provide requisite guidance in the development of its proposals. Those performance objectives were:

- 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 (height) and the risk of collapse.

To address these criteria, and in response to the very large body of technical subject matter to evaluate, four work groups were formed; anyone with an interest in tall wood buildings was allowed to participate. These work groups included: Standards/Definitions; Fire; Code; and Structural.

The heart of the proposed code changes involved assigning fire resistance requirements to proposed new construction types for mass timber buildings based upon their proposed heights and area. Table 1 identifies the proposed fire resistance requirements and compares them to existing requirements for other building types.

[a] https://cdn-web.iccsafe.org/wp-content/uploads/com_coun/roster_TWB.pdf

Table 1 Required Fire Resistance of Building Elements in Hours – New and Proposed

Current construction types	**TYPE I-A--Fire Resistive Protected Non-Combustible** (concrete; fire-protected steel)			
	Exterior Walls 3 Hrs.*	Structural Frame 3 Hrs.*	Floor Protection 2 Hrs.*	Roof Protection 1 ½ Hrs.*
	Note: Dual water supply for fire suppression systems required at 420 feet elevation and above. *Permitted to be reduced by 1 Hr. with certain fire sprinkler controls for buildings less than 420 feet high.			
	TYPE I-B--Fire Resistive Protected Non-Combustible (concrete; fire- protected steel)			
	Exterior Walls 2 Hrs.*	Structural Frame 2 Hrs.*	Floor Protection 2 Hrs.*	Roof Protection 1 Hrs.*
	Note: *Permitted to be reduced by 1 Hr. with certain fire sprinkler controls for less hazardous uses, smaller fuel loads			
	TYPE II-A--Protected Non-Combustible (fire-protected steel)			
	Exterior Walls 1 Hr.	Structural Frame 1 Hr.	Floor Protection 1 Hr.	Roof Protection 1 Hr.
	TYPE II-B--Unprotected Non-Combustible (bare steel)			
	Non-combustible materials, but no fire resistance required			
	TYPE III-A--Protected Combustible (protected light wood frame or masonry exterior walls)			
	Exterior Walls 2 Hrs.	Structural Frame 1 Hr.	Floor Protection 1 Hr.	Roof Protection 1 Hr.
	TYPE III-B--Unprotected Combustible (protected light wood frame or masonry exterior walls)			
	Exterior Walls 2 Hrs.	Structural Frame None	Floor Protection None	Roof Protection None
Proposed new construction types	**TYPE IV-A—Fully Protected, exterior and interior**			
	Exterior Walls **3 Hrs.**	Structural Frame **3 Hrs.**	Floor Protection **2 Hrs.**	Roof Protection **1 ½ Hrs.**
	Note: Dual water supply for fire suppression systems required at 120 feet elevation and above. No reductions in protection permitted.			
	TYPE IV-B- Mass timber protected exterior, limited exposed timber interior			
	Exterior Walls **2 Hrs.**	Structural Frame **2 Hrs.**	Floor Protection **2 Hrs.**	Roof Protection **1 Hr.**
	Note: Dual water supply for fire suppression systems required at 120 feet elevation and above. No reductions in protection permitted.			
	TYPE IV-C—Mass timber protected exterior, exposed timber interior			
	Exterior Walls **2 Hrs.**	Structural Frame **2 Hrs.**	Floor Protection **2 Hrs.**	Roof Protection **1 Hr.**
	Note: **No reductions in protection permitted.**			
Current construction	**TYPE IV--Heavy Timber**			
	Exterior Walls 2 Hr.	Structural Frame Heavy Timber or 1 Hr.	Floor Protection Heavy Timber	Roof Protection Heavy Timber
	TYPE V-A--Protected wood frame			
	Exterior Walls 1 Hr.	Structural Frame 1 Hr.	Floor Protection 1 Hr.	Roof Protection 1 Hr.
	TYPE V-B--Unprotected wood frame: No Fire Resistance			

Peer Review and Analysis of the Mass Timber Code Change Proposals

For this paper an independent review of the AHC-TWB's proposed code changes, technical substantiation and associated reason statements was performed to determine if the existing level of fire protection intended by the International Codes is retained. The proposed revisions appear to be at least as conservative, and in some cases more conservative, than the present level of protection required by code.

Fire Testing: The AHC-TWB determined fire testing was necessary to validate the performance objectives outlined above. Subsequently five, full-scale, multiple-story fire tests were developed to simulate the three new construction types proposed (Types IV-A, IV-B and IV-C). The following constraints were evaluated as part of these tests.

- Contribution of mass timber to a fire,
- Integrity of structural members,
- Performance of connections,
- Performance of through-penetration protection, and
- Conditions for responding fire personnel.

The tests consisted of one-bedroom apartments on two levels, with both apartments having a corridor leading to a stair. The results provided empirical support for the proposed amendments and were used to validate the fire performance for each of the proposed types of construction.

The results of those tests, as well as testing for structural performance in accordance with ASTM E119, *Standard Test Methods for Fire Tests of Building Construction and Materials,* and additional testing by others, helped establish the basis upon which the AHC-TWB developed the code change proposals.

Definitions: Three new or revised definitions were developed to clarify proposed amendments.

Load-bearing wall has been revised to recognize that "mass timber" can support structural loads similarly to masonry and concrete. Based on research conducted by wood industry associations, mass timber walls (e.g. sawn, glued laminated, cross-laminated timbers) have the ability to support a superimposed load of at least 200 pounds per linear foot in addition to their own weight.

Mass Timber represents the legacy Heavy Timber (Type IV) construction presently recognized by code and the three new construction types being proposed. This provides a single term to represent the various sawn and engineered timber products referenced in Chapter 23 (Wood) of the International Building Code (IBC) and in ANSI/APA PRG 320 *"Standard for Performance Rated Cross-laminated Timber."*

Noncombustible Protection addresses the passive fire protection required for mass timber. Depending on the building type, mass timber is permitted to have its own fire-resistance rating or have a fire-resistance rating through a combination of the inherent mass timber fire-resistance plus protection with non-combustible insulating materials meeting the requirements of Section 703.5 to delay ignition of the mass timber.

[b] A summary of the fire tests can be obtained from: http://bit.ly/ATF-firetestreport

[c] Summary videos, accelerated to run in 3 ½ minutes, can be viewed at: http://bit.ly/ATF-firetestvideos

Section 602.4 Type of Construction: Requirements in other regions of the world generally place tall mass timber buildings into three categories:

- The mass timber is fully protected with noncombustible insulating materials.
- A limited amount of exposed mass timber elements is allowed.
- The mass timber is permitted to be unprotected.

Type IV-A: Mass timber construction fully protected with noncombustible insulating materials has been designated Type IV-A. Protection is described in a new section (722.7). Testing has shown that mass timber construction protected with multiple layers of 5/8-inch Type X gypsum board, can survive a complete burnout of a residential fuel load without igniting the mass timber.

The fire protection specified applies to all building elements. As such, protection of all wall and ceiling surfaces, the underside of the roof surface, the top and bottom of all floor surfaces, as well as all shafts and exterior surfaces are required to be fully protected. In addition, Type IV-A construction is proposed to have the same fire-resistance rating as Type I-A construction (2-hour with 3-hour structural elements, (fire-protected steel/concrete)). The fire-resistance rating for Type IV-A construction is conservative since the structural elements are intended to resist the fuel loads associated with the various occupancies without the benefit of automatic sprinklers, and without involving the structural members, similar to the existing strategy for Type I construction.

Type IV-A also requires dual water supplies for buildings exceeding 120 feet in elevation. This provides redundancy to help ensure water is available for automatic and manual suppression systems. A noncombustible building would not have to meet this requirement until it reaches 420 feet.

Type IV-B: Some exposed wood surfaces of ceilings, walls, columns and beams are allowed in Type IV-B. The amount of exposed surfaces allowed, as well as the required separation between unprotected areas, is specified to limit contribution of the structure in an interior fire. Type IV-B has been subjected to the same fire tests, under the same conditions, as Type IV-A and the results demonstrate that a char layer develops on exposed mass timber in the same fashion as traditional sawn lumber (provided substantial delamination is avoided as required by the U.S. Department of Commerce *Voluntary Product Standards*, *PS 1, Structural Plywood (DOC PS 1)).*

As required for the other two new construction types, exterior faces of Type IV-B are required to be protected with noncombustible materials to restrict exterior ignition and fire spread. Concealed spaces, shafts and other specified areas are required to be fully protected with noncombustible protection limiting the ability of fire to ignite the mass timber and propagate through concealed spaces. Type IV-B must meet the same fire-resistance requirements as Type I-B construction (2-hour structural frame, (fire-protected steel/concrete)). However, the present allowance in IBC Section 403.2.1.1, to reduce I-B construction to 1-hour structural elements, has not been included for Type IV-B construction. As such, 2-hour structural elements are still required for Type IV-B construction.

[d] *A March 2018 panel failure at Oregon State University was determined to not be a case of delamination or material failure. Instead, a manufacturing process glitch was determined to be the cause and is in the process of being addressed by the involved parties. Changes have been made to enhance in-plant quality control procedures to prevent future occurrence. There is no field history of mass timber delamination failures.*

As with Type IV-A construction, Type IV-B also requires dual water supplies for buildings exceeding 120 feet in height. This redundant water supply, coupled with the 2 hour passively protected structural frame, provides a conservative approach to fire protection.

Type IV-C: Since noncombustible protection is not required for interior elements of Type IV-C, it has to rely on the inherent fire-resistance of the mass timber itself. Type IV-C construction is more conservative than traditional Heavy Timber construction in that Type IV-C is required to provide 2-hour fire-resistance.

Although IV-C construction permits interior mass timber elements to be fully exposed, concealed spaces, shafts, elevator hoistways, and interior exit stairway enclosures are required to be fully protected with noncombustible materials to limit fire spread within these spaces. As required for the other two new construction types, exterior faces of Type IV-C are required to be protected by noncombustible materials to restrict exterior ignition and fire spread.

Due to the increased fire-resistance of Type IV-C construction, additional stories for lower hazard occupancy groups have been proposed, but height (in feet) beyond that already recognized for Type IV- HT has not been proposed. This is reflected in reduced allowable height, in both feet and stories, compared to other AHC-TWB proposals to Table 504.3 and 504.4.

Revisions are proposed to Tables 601 and 602 to recognize the performance requirements of these new types of construction. In summary:

- Type IV-A has a 3-hour fire-resistance rating as presently required for Type I-A buildings.
- Type IV-B has a 2-hour fire-resistance rating as presently required for Type I-B buildings.
- Type IV-C has a 2-hour fire-resistance rating as presently required for Type I-B buildings and the newly proposed IV-B.

The additional active and passive protection features mandated for these structures provide the primary justification for the proposed height and area increases.

Tables 504.3 and 504.4: Allowable Height in Feet and Number of Stories: The following approach was used to determine reasonable, yet conservative height limits for the new construction types. The following methodology explains the majority of recommendations that were based on a review of fire safety and structural integrity performance for occupancy groups A, B, E, R, and U.

Type IV-B is equated to existing Type I-B for height (in feet and number of stories). Although Section

403.2.1.1 of the IBC allows Type I-B construction to be reduced to 1-hour fire-resistance rating, the same reductions were not proposed for Type IV-B. As a result, the comparison is between 2-hour mass timber construction, which allows a limited amount of exposed mass timber, versus 1-hour Type I-B construction. In general, the 2-hour mass timber construction, which is partially exposed per the limits of proposed Section 602.4, was determined to warrant the same heights as allowed for 1-hour Type I-B construction.

Even though Type IV-A construction is entirely protected (no exposed mass timber permitted) and the required rating of the structure is equivalent to Type I-A construction (3-hour rating for the structural frame), the AHC-TWB determined that it was not appropriate to allow Type IV-A to be of unlimited heights like Type I-A, but Type IV-A should be somewhat larger than proposed for IV-B. To establish reasonable height allowances for IV-A construction a multiplier of 1.5 was applied to the heights proposed for Type IV-B construction (rounded up or down based on the professional judgment of the committee).

While interior elements of both Type IV-C and Type IV-HT (no change from current code) are allowed to be entirely unprotected, Type IV-C provides a 2-hour rating of structural elements. It was the conservative judgment of the AHC-TWB to treat Type IV-C similarly to Type IV-HT, which uses traditional large dimensional lumber and is considered to provide approximately 1-hour fire-resistance based on the member sizes and charring. Even though additional stories for some lower hazard occupancies have been proposed for IV-C in recognition of its greater fire-resistance rating, the height in feet is proposed to be the same as already allowed for Type IV-HT. A multiplier of 1.5 was applied to the Type IV-HT to provide a reasonable increase to the allowable number of stories for lower hazard occupancies in Type IV-C buildings. More hazardous uses were limited to the number of stories permitted for Type IV-HT. Fully sprinklered mercantile was only recognized for a single additional story.

Tables 504.3 and 504.4 currently allow a height of 160 feet and 11 stories for non-sprinklered (NS) Type I-B construction for many occupancy classifications; the heights proposed for Types IV-A, IV-B, and IV-C are the same as those presently allowed for Type IV NS. Unprotected mass timber is required to provide at least a 2 hour fire-resistance rating or twice that of the 1 hour fire-resistance rating required for Type I-B. As such, the proposed new construction types are more conservative than presently required.

Reduced heights were proposed for specific occupancies, which in the professional judgement of the AHC-TWB were deemed to be more hazardous.

Table 506.2 Allowable Area: Allowable area should be considered a companion proposal to the height proposals. Each new construction type proposed was examined for its fire safety characteristics and compared with existing Type IV-HT for allowable area. A multiplier was developed for each to reflect the additional fire protection provided.

- Type IV-C is proposed to be 1.25 times the HT allowable area,
- Type IV-B is proposed to be 2.00 times the HT allowable area, and
- Type IV-A is proposed to be 3.00 times the HT allowable area.

These multipliers were then reexamined on a case-by-case basis based on relative hazard and occupancy classification. In the professional judgement of the AHC-TWB, some hazards were perceived to be greater and allowable areas were adjusted downward. Hazardous and Institutional occupancies were reduced from what the multiplier method would allow. In addition, allowable area and the associated height proposals were reconsidered by the AHC-TWB to ensure a conservative approach to the combined allowances.

722.7 Fire-Resistance Ratings: The AHC-TWB proposals include a prescriptive approach to achieve improved fire-resistance for mass timber structures. The designer is allowed to calculate the fire- resistance rating of a protected wood element by adding the fire-resistance rating of the unprotected wood member to the protection provided by noncombustible protection applied to the exposed wood. As a prescriptive solution, the conditions of use, such as attachment, finishing and edge treatment, when bordering exposed mass timber areas, are also detailed in this section. Fire testing of beams, columns, walls and ceiling panels was conducted to establish the values in Table 722.7.1(b).

To support the imposed structural loads, mass timber elements typically have large cross-sections. In addition, mass timber panels typically incorporate odd numbered laminations, which results in excess load carrying capacity. It also provides increased fire endurance due to charring of the sacrificial layer. Thus, mass timber elements are conservative in their fire-resistance rating. Additionally, at least two-thirds of the fire-resistance rating is required to be provided by the noncombustible protection, which also achieves conservative results.

The contribution of noncombustible materials to fire-resistance is determined by measuring the fire- resistance time to structural failure of a mass timber building element through a fire test and then conducting a second test with noncombustible protection applied. Each test is conducted with identical mass timber elements, identical loading, construction and conditions, but one of the tests includes the noncombustible protection (as defined in Section 703.5). The difference in the test results between the two samples is the contribution of the noncombustible protection. This testing procedure should not be confused with testing for "membrane protection" (addressed in Section 722.6), which is based on temperature rise on the unexposed side of a membrane attached to construction elements. Tests outlined in Section 703.8 can be used for future additions to this table.

Section 703.8 - Performance Method: This AHC-TWB proposal provides a performance path to determine the protection provided by protection mass timber elements with noncombustible insulating materials. The fire-resistance rating of mass timber structural members consists of the inherent fire-resistance rating of the mass timber and the additional fire-resistance provided by any noncombustible encapsulation as described in new definitions.

This proposal allows any material to be tested to determine the additional protection provided to the mass timber member. This procedure is neither new nor ambiguous. It is allowed by Section 722.6 to determine protection times for various membranes. Recent testing by the American Wood Council confirmed the values derived from historic testing.

IBC: 508/509 Fire Barriers: Where mass timber serves as a fire barrier or horizontal assembly, additional protection measures were determined appropriate by the AHC-TWB to meet the performance based objectives. Without modification to the provisions regulating separated occupancies and incidental uses, a fire barrier or horizontal assembly in Types IV-B and IV-C construction could be designed using mass timber that complies with the fire-resistance rating, but would allow exposed mass timber to contribute to the fuel load. The proposal forestalls this.

Section 508.4 provides a new option for separating mixed occupancies within a building. Section 509.4 discusses the fire-resistance rated separation required for incidental uses within a larger use group. Section 509 also permits, when stated, protection by an automatic sprinkler system without a fire barrier, however the construction enclosing the incidental use must resist the passage of smoke in accordance with Section 509.4.2.

The AHC-TWB applied professional judgment by incorporating the existing thermal barrier requirements into these two sections. The intent of the thermal barrier is to delay or prevent ignition of the mass timber, thus delaying or preventing the mass timber's contribution to the fuel load. Mass timber walls or floors serving as fire barriers for separated uses (Section 508.4) are required to have a thermal barrier on both faces of the assembly. The thermal barrier is only required to cover exposed wood surfaces and is not required in addition to noncombustible protection required by Section 602.4 (i.e. materials providing the fire-resistance rating can also serve as the thermal barrier). In addition, the thermal barrier is not recognized as adding a fire-resistance rating to the mass timber. This requirement will allow occupants additional time to evacuate as well as allow first responders additional time to perform their services.

Section 509.4 (separation of incidental uses) only requires the thermal barrier on the side where the hazard exists, that is, the side facing the incidental use. For example, a mass timber floor assembly with a noncombustible

[e] The test report can be obtained from: http://bit.ly/WFC-firetestofGWBonCLT

topping would not require a thermal barrier on the mass timber floor assembly when the incidental use area is located on that specific floor. In addition, the thermal barrier would not be required if the optional substitution of fire suppression for the thermal barrier is exercised.

It should be noted that this proposal only addresses the contribution of exposed mass timber to the fuel load of a fire, and does not relax any of the fire-resistance requirements of Sections 508 or 509 or other mass timber provisions.

IBC: 718.2.1 Fireblocking Materials (Fire and Smoke Protection): The code currently lists “nominal lumber” as an acceptable fireblocking material. Since mass timber (e.g. sawn, glued-laminated, and cross-laminated timbers) is of greater mass than nominal lumber, the correlation was determined to provide equal or greater resistance to fire, smoke and gases moving through combustible concealed spaces to different areas of the building. This code change proposal recognizes that mass timber is a suitable fireblocking material.

Section 703.9 & 1705.19 - Sealants at Edges: Mass timber has inherent fire-resistance properties, which provide both structural fire-resistance and limit the spread of fire and smoke through building components (walls and floors). Where a wall or horizontal assembly serves as the separation between fire compartments, a fire in one compartment can create sufficient pressure to force heated gases into uninvolved portions of the structure. As such, abutting edges and intersections are required to be sealed.

Where mass timber panels are connected, fire tests have demonstrated the importance of sealing abutting edges and intersections. The structures tested (as part of the fire tests providing empirical support for this submittal) were sealed as proposed in the code changes by the AHC-TWB.

The *US Edition of the CLT Handbook* recommends a bead of construction adhesive. Other sealants can also prevent air flow. A newly referenced standard, ASTM Standard D3498—03 (2011) *Standard Specification for Adhesives for Field-Gluing Plywood to Lumber Framing for Floor Systems* provides direction.

Where a sealant or adhesive is applied to mass timber building elements (as designated in the construction documents approved by the Authority Having Jurisdiction), special inspections are required during construction to ensure an appropriate sealant or adhesive is used and to provide quality control. An exception is provided for panels manufactured under a proprietary process and tested accordingly to ensure there are no voids at abutting edges. Even if the sealant is not required, but not specifically excluded, special inspections is still considered good practice.

This code change proposal does not apply to “joints” as defined in Section 202 of the IBC. Joints have an opening designed to accommodate construction tolerances or allow independent movement. Panels and members rigidly connected, as specified by this code change proposal, do not meet the definition of a joint. Joints have their own requirements for testing, installation and inspection in IBC Section 715.

IFC: 3308.4 Fire Safety during Construction: Additional active and passive fire protection features are required to justify the increased height and area for mass timber buildings (Types IV-A, IV-B & IV-C). The proposed changes to this section require this additional protection when these combustible buildings are under construction and, therefore, most vulnerable.

Over the past several years there have been a number of fires in buildings under construction. Many of these fires were in large structures of light-frame wood members prior to the installation of active and passive fire protection systems. Even though these loss statistics apply to light-frame construction, and mass timber has inherent fire-resistance and structural integrity due to the mass of the timber elements, the potential risk of fire in combustible construction was considered.

Mass timber construction is generally installed as it arrives at the job site. Therefore, smaller amounts of combustible building materials are expected to be stored on site than on a typical construction site using combustible building materials. This proposal requires protection of the installed material before the project extends above a specified number of levels, which is very different, and more stringent, than conventional construction processes.

The AHC-TWB had extensive debate regarding water supply to construction sites where substantial quantities of combustible building materials were being used or stored. It was agreed that developers should meet and confer with the local fire service to establish the fire department's needs, in terms of water flow and pressure, for the specific site. Sub-sections 1 and 2 of the proposal apply to the delivery of water to the job site and structure. Sub-sections 3 and 4 are specific to the passive protection aspects of the structure.

Due to the proposed increased heights and area of mass timber buildings, interior and exterior passive protection is required as construction progresses. This helps ensure lower portions of the combustible structure have redundant, active and passive protection as greater heights are reached. As such, the likelihood of catastrophic structural failure during a fire and adverse impact to surrounding structures are reduced, a benefit to responding firefighters.

The AHC-TWB included two figures with the proposed amendments to illustrate the requirements for passive protection of mass timber structures under construction. When buildings under construction exceed 6 stories, protection is required on building elements in accordance with the associated construction type, as well as exterior wall coverings, more than 4 floor levels below before additional levels can be erected. For example, prior to placing level 7 floor panels, meaning construction is being performed on level 6, passive protection must be provided for the elements under level 2. Similarly, when level 14 is the active level of construction, prior to placement of floor panels at level 15, protection is required at the underside of and below level 10.

IBC Section 3102 – Special Construction (Membrane Structures); Appendix D D102.2.5 – Fire Districts: These code changes were developed to retain the current Type IV-HT provisions and not modify existing requirements.

IFC 701.6 Owner's Responsibility: Mass timber construction is proposed to allow greater heights and area than previously permitted for wood frame construction. Construction materials currently required for buildings of similar heights and area will not contribute to the fuel load in the manner mass timber can. As such, tall mass timber buildings are required to include specific active and passive features to protect occupants and the structure from fire. The *International Fire Code* (IFC) currently requires active systems to be inspected periodically for performance and, for these unique structures, it is reasonable to require the same for the applicable passive aspects.

The proposed code amendments require a specified thickness of gypsum board or its equivalent for walls and ceilings in mass timber buildings of Type IV-A and IV-B construction (except for limited amounts as permitted in Type IV-B). The allowable heights and area are proposed based on this additional passive protection. As such, a methodology to ensure this passive protection remains in place is needed. Since Section 701.6 of the IFC allows annual inspections to be performed by building staff, this is not an excessive burden on the building owner or management. Local jurisdictions may or may not require the annual inspection to be reported. The building owner or management must simply keep a record of such inspections and take steps to correct any deficiencies identified. This requirement provides greater assurance that the passive encapsulation initially incorporated into the structure will be retained.

Cost Statements: Each of the cost statements for the proposed amendments indicated these new construction types will not increase or decrease the cost of construction. Although this may be true for a few of the proposed amendments, it seems reasonable that these construction types will decrease the cost of construction below today's costs. Otherwise these new construction types will be used sparingly.

Fire Protection Summary: The preceding fire protection summary provides an overview of the proposed code changes and is not intended to fully cover all nuances. For a complete understanding of the proposed amendments a thorough review is recommended. Overall the proposals recognize recent technological improvements and provide a level of protection more conservative than presently recognized by code. These code change proposals work together; all are needed to provide the holistic approach intended for tall wood buildings. Adopting a few of the proposed amendments without the complete package can potentially ignore details required to ensure mass timber structures are properly designed, constructed and maintained.

The following list provides an overview of the primary fire protection features required for mass timber buildings and substantiates the overall conservative approach.

All mass timber buildings are required to provide at least 2-hour fire-resistance for structural members, with 3-hour fire-resistance required for the structural frame of Type IV-A buildings.

- Noncombustible protection is required on the exterior of all mass timber buildings, which may be of less risk than a Type I-A or B building with combustible cladding as is currently permitted.
- All mass timber buildings require all concealed spaces to be protected with fire resistive materials.
- Type IV-A does not have any exposed mass timber (inside or outside).
- Type IV-B only allows limited exposed, but separated, interior mass timber members.
- Type IV-C is limited to the same height in feet as existing HT and only allows an increased number of stories in lower hazard occupancies.
- Dual water supplies are required for mass timber buildings exceeding 120 feet in height, which provides a more robust fire protection package than a comparable Type I-A building of less than 420 feet in height which only requires a single water supply.
- The inherent thickness of mass timber will limit smoke migration.
- Stringent protection is required for mass timber buildings under construction.
- Full scale fire testing has demonstrated the ability of mass timber buildings to survive a complete burnout of a typical residential fuel load without the aid of sprinklers.
- Annual inspections are required to ensure passive protection remains in place.
- Joints and penetrations are still required to be tested, installed and inspected as presently outlined in the IBC.

Peer Review Conclusion:

The question investigated is whether the proposed changes to the IBC will provide the level of fire protection presently required for all buildings of equivalent height and area. Based on the proposed amendments and preceding overview, it is clear the underlying logic is sound and all indications are that the fire protection aspects of the AHC-TWB Committee proposals are at least as conservative, and in most cases more conservative, than the fire protection requirements of the existing code.

Additional Considerations:

- Structural and fire design criteria are contained in the AWC *National Design Specification* for *Wood Construction*, which is referenced in the code.
- Mass timber is manufactured, with specified quality control, control per an ANSI consensus standard, ANSI/APA PRG 320: *Standard for Performance-Rated Cross-Laminated Timber*, which is referenced by the code.
- Compliant mass timber meets or exceeds the fire and structural performance standards required by the code.
- Mass timber has proven experience outside of the US, including in Canada, Europe, and Australia.
- Mass timber has undergone rigorous fire testing to demonstrate its behavior in real fire scenarios. Testing has included multiple ASTM E119 fire resistance rating tests conducted by Underwriters Laboratories, the Southwest Research Institute, and the National Research Council of Canada, among others.
- As proposed by the AHC-TWB, mass timber buildings will have code enhancements beyond what is required of other buildings of similar stories, height and area.

Benefits of Modifying Codes to Recognize Additional Uses for Mass Timber

Codifying increased opportunities for the use of mass timber – broadening the market by updating the *International Building Code* will create incentives for capital investment in the mass timber supply chain.[2] With more material providers in the market, competition will drive costs down. This in turn will create additional market opportunities in not just tall building construction, but in mid- and low-rise construction as well when mass timber becomes competitive with other structural system applications.

Environmental benefits: The environmental benefits of mass timber begin with the sustainable cultivation of renewable raw materials and extend beyond the building life cycle since mass timber panels are suitable for deconstruction and reuse in whole form in other building projects. Forests naturally capture and sequester atmospheric carbon dioxide (CO2) as trees grow.

According to an assessment of forest carbon fluxes between 1990 and 2007, intact forests and those re-growing after disturbance - like harvesting - sequestered around 4 billion ton's of carbon per year over the measurement period — equivalent to almost 60 percent of emissions from fossil fuel burning and cement production combined.[3]

Sustainable forestry ensures that the process of CO2 absorption is maximized. Trees are harvested at the peak of their cycle, and replaced with younger, more carbon efficient trees, before their ability to absorb declines. Actively growing forests sequester more carbon than older forests.[4] The rapid carbon capture of young forests slows relatively quickly compared to the potential lifetime of the stand.

Additionally, forests managed for the production of building products sequester more carbon than unmanaged forests. Assuming no fires or disease affect the growth, the amount of captured carbon in a period of 160 years can be nearly double in a sustainably grown and cultivated forest than in a forest left to grow naturally over the same timeframe.[5]

Carbon capture efficiency is achieved by the use of cut timber in products that keep the carbon out of the natural cycles of decay or combustion, meaning long-lived wood building products are an excellent vehicle for sequestration.[6] Wood building products incorporated into buildings continue to sequester the carbon captured by the trees that provided the resource for the building products. Many European timber buildings have sequestered carbon for more than 500 years and the Nanchan Temple in Shanxi Province, China has sequestered carbon for more than 1,200 years.[7]

According to the National Climate Change Assessment, *"The total amount of carbon stored in U.S. forest ecosystems and wood products (such as lumber and pulpwood) equals roughly 25 years of U.S. heat-trapping gas emissions at current rates of emission, providing an important national "sink" that could grow or shrink depending on the extent of climate change, forest management practices, policy decisions, and other factors.*[8,9] *For example, in 2011, U.S. forest ecosystems* ***and the associated wood products industry*** *captured and stored roughly 16% of all carbon dioxide emitted by fossil fuel burning in the United States."*[10] <emphasis added>

The carbon benefits of wood building products like mass timber are amplified by the extent to which they offset the use of much higher embodied carbon materials such as concrete, steel and plastics. The life- cycle benefits of such a substitution dramatically compound the favorability of mass timber over traditional concrete and steel methodologies.

Both concrete and steel construction methods average around 2,000 tonnes/m^3 of embodied CO_2. Mass timber methods average 727 tonnes/m^3 of embodied CO_2 before including sequestration benefits. Including the carbon sequestration value of the wood, mass timber building methods calculate to be carbon negative at around -2,314 tons/m^3 of embodied CO_2.[11] In a study that evaluated wall and floor assemblies, estimated CO_2 savings by wood products, relative to steel and concrete products, averaged 3.9 kg CO_2/kg.[12] These savings were calculated on the first use of materials; subsequent reuse of mass timber panels multiply the carbon benefits.

Given their poor thermal resistance, building envelope systems using concrete or steel frequently use foam plastic insulation to meet energy codes. In addition to being highly combustible, with no viable end-of-life strategy, such materials are made from nonrenewable resources and have high embodied carbon. At a global level, the carbon benefits of replacing high embedded carbon materials like steel, concrete, and plastic, with a carbon sequestering material like mass timber works to offset climate change, a proven factor in ever worsening wildland fires.

Accompanying the carbon benefits, avoiding the decay of wood in anaerobic conditions defeats the attendant release of methane and nitrous oxide,[13] greenhouse gases that are 25 times and 298 times, respectively, more potent than CO_2. The U. S. Environmental Protection Agency (EPA) calculates that methane is responsible for about 10 percent of manmade global warming and that nitrous oxide is responsible for 5 percent.[14]

Where forests are affected by disease or insect infestation much of the wood that would otherwise be lost for uses in other wood building materials is still viable for manufacturing mass timber. Similarly, smaller diameter trees too small for traditional wood products can be used for mass timber. The nature of laminating many layers of wood together means that material performance depends on the entire system and not the individual component.[15] Smaller boards can be cut from dead or dying standing trees and laminated into the center of a mass timber structural component due to decreased loading closer to the neutral plane. Harvesting these compromised forests is an effective way to control invasive species, reduce wildland fuels, and provide habitat for species that need edge versus deep forest conditions.

Some advocates argue against harvesting forests because of perceived impacts on biodiversity. Research however demonstrates that a biodiverse habitat is created by, and is specific to, each stage of forest's successional growth. Biodiversity is just as high in the early phases of growth where there are few trees, known as the savanna, and in other open periods with no trees, similarly to the later understory and complex forest stages.[16]

The ideology that suggests that biodiversity can be enhanced by protecting forests to let them grow old creates a situation where only natural forces, mainly wildfires, are the only vehicle for creating habitat suitable for the many species that do not thrive in dense old-growth forests. Burning forests was a method of actively restoring biodiversity used by Native Americans prior to the 19th and 20th centuries.[17] In the 21st century, managing a forest in a sustainable manner still means that many distinct phases of forest growth will occur and a symbiotic relationship between humans and the species that are at home in forests can be maintained while yielding wood building products, and in particular mass timber.

[f] The AHC-TWB proposals prohibit combustible materials on the exterior of mass timber buildings, precluding the use of foam plastic insulation

Operational Energy: Energy benefits are not limited to mass timber production but continue through the life of the building. The thermal properties of wood make it an exceptional natural insulator, especially compared to concrete and steel. A reasonable average thermal resistance (R-value) for concrete slab is 0.2 per inch.[18] The effective thermal resistance (effective R-value) of a 6-inch deep steel stud wall assembly with insulation assumed to have an R-value of 0.25, and studs spaced at 16 inches on center, calculates to be about 0.09. If no insulation is assumed steel calculates to have no thermal resistance.[19] The thermal resistance of wood ranges between 1.41 per inch for most softwoods and 0.71 for most hardwoods.[20] According to continuing education sponsored in part by the American Wood Council:

"Softwood in general has about one-third the thermal insulating ability of a comparable thickness of fiberglass batt insulation, but about 10 times that of concrete and masonry, and 400 times that of solid steel."[21]

Buildings using mass timber have a structural system that is more efficient at resisting heat transfer which requires less extra insulation than concrete and steel counterparts. Since mass timber panels are factory machined to their final configuration, and assembled on the construction site, versus site-built, it is possible to construct a very tight building envelope which greatly reduces air transfer, a prime cause of heat loss. The thermal mass of mass timber also provides a natural source or sink for heat that acts to reduce heating and cooling loads throughout the year.[22]

A nine-story residential mass timber building in Milan, Italy constructed in 2013 has reported *"temperatures within the comfort range on hot summer days without operation of the mechanical system, confirming a thermally efficient envelope." Also, "a cost analysis confirmed that while the project cost was 35 percent more expensive than a concrete building, the efficient envelope minimizes heating and cooling loads to result in an operational payback period of only eight years."*[23]

Economic Benefits of a Developed Mass Timber Market: The wood products and paper industries in the U.S. have suffered long term declines for multiple reasons; including long-term decline in paper manufacture that is connected to a diminished U.S. manufacturing sector and waning demand for paper used in media.[24] Environmental litigation and cyclical slumps in the construction sector also put downward pressure on the industry.

Oregon Best states: *"Economic analysis by Business Oregon determined that cross-laminated timber (CLT) and related mass timber manufacturing has the potential to create 2,000 to 6,100 direct jobs in Oregon, depending on Oregon's market share of demand for mass timber in the U.S. Including jobs created by indirect and induced impacts, approximately 5,800 to 17,300 jobs could be created in Oregon from mass timber manufacturing. For every job created in mass timber manufacturing in Oregon, an additional 1.8 jobs would be created."*

Similar mass timber economic opportunity has been identified for all lumber producing areas of the country. In February, a Montana-based company announced that it would open a new mass timber manufacturing facility in Maine. The project is projected to create 100 direct jobs and 200 indirect jobs.[25]
It is the second mass timber manufacturer to locate in Maine,[26] preceded by a manufacturer redeveloping a paper mill site shuttered in 2008 at the cost of more than 200 jobs.[27] The new mass timber facility will directly create up to 100 jobs and hundreds more in the supply and distribution chains.[28]

Dothan, Alabama is the site of a new mass timber manufacturing facility that, when completed in 2018, is estimated to create 60 jobs in the facility and another 140 jobs in local timber, sawmills, and trucking.[29]

Hardwood mass timber is being investigated in Indiana as a way to create a high value structural construction material from the low value portion – about 55 percent- of hardwood logs remaining after milling for higher grade material. Hardwood from local forests is Indiana's largest cash crop so value added in the material supply chain will provide significant economic benefits regionally.[30]

Hardwood mass timber is also being evaluated by the Michigan Technological University and the USDA Forest Service, Forest Products Laboratory: *"This project addresses the issues that are important to local sawmills and wood products manufacturers in reducing material waste and increasing profitability. It is also important to the economic growth and development in the* <Great Lakes> *region."*[31]

The USDA, referencing mass timber products, stated: " …. if next-generation wood products can penetrate just five to fifteen percent of the non-residential North American market, it would mean roughly 0.8 - 2.4 billion board feet of lumber consumed annually. To put that in real-world context, roughly 35 jobs are created for each million board feet of wood processed." Those figures calculate as up to roughly 84,000 jobs created by the mass timber industry.

A Portland State University study suggests that mass timber, *"presents a triple net solution to urban design, environmental, and housing affordability challenges. The planet benefits from the carbon sink of wood buildings while also promoting sustainable forest management. CLT <mass timber>also presents a social opportunity by promoting desperately needed rural timber production jobs. Finally, the pre-fabricated material addresses the needed profit margin in a capitalist real estate development industry by providing financial savings from reduced construction times. By merging the forest with the city, cross- laminated timber will play a key role in a sustainable, financially viable, and high-quality future built environment."*[32]

Constructability Advantages. Mass timber has a very high strength to weight ratio. Because of its light-weight structure (compared to concrete or steel), *"Foundations can be smaller, and buildings can be built taller for the similar costs as traditional methods of construction. This light-weight structure can also help in special site conditions such as near waterfronts and where soils may not be as favorable."*[33]

Contrasted with typical construction, where foundations precede above grade structural work, mass timber panels are factory made, which can be done concurrently with site and foundation work, reducing lag time between construction phases.[34] Additionally, mass timber panels can be delivered on a 'when needed' basis, a key advantage on small sites with little storage area for materials. On some sites this could mean not occupying for traffic lanes or the public way for construction purposes like storage or staging as would be necessary with traditional construction materials.

In a real-world application, a 62,688-square-foot mass timber hotel constructed as part of the Privatization of Army Lodging (PAL) program was constructed 37 percent faster and the structure built with 44 percent fewer person hours than similar hotels. Construction speed was optimized because of prefabrication of the mass timber panels, allowing the builder to control the sequence of construction.[35]

Table 2 Mass Timber versus Traditional Hotel Construction

PAL Portfolio	Typical New PAL Hotel (Actual*)	Redstone Arsenal (Actual)	Difference
Gross square feet (sf)	54,891	62,688	+14%
Average # of employees	18 (peak 26)	10 (peak 11)	-43%
Structural duration (days)	123	78	-37%
Structural person hours	14,735	8,203	-44%
Structural production rate/day	460 sf	803 sf	+75%
Overall schedule	15 months	12 months	-20%

Source: WoodWorks Case Study WW-020, 2016

The fast construction of the PAL hotel is particularly impressive considering the limited construction experience of the majority of the crew; three experienced carpenters and eight laborers. The laborers were unemployed veterans trained on the PAL jobsite.

According to the Tall Wood Design Institute, *"……taking advantage of prefabrication techniques will likely lead to more competitive pricing for mass timber construction in the near future. Building Information Modeling, which allows architecture and engineering design teams to create a 3D model with embedded information, is already the industry norm. These models allow direct translation to CNC fabrication, which can create highly precise mass timber panels, posts and beams that can be quickly and cleanly assembled in the field. This can provide considerable cost savings in labor on site and minimizes material waste. Prefabrication can also reduce noise and pollution on construction sites, minimizing truck traffic and providing a quieter construction process than those for concrete and steel."*[36]

Reduction of construction noise and pollution will in turn reduce some of the most common complaints received by local governments where building is happening. Shorter community exposure, in days, to construction impacts also mitigates negative community impacts.

The project developer of a 10-story residential building in Australia claimed a 30 percent improvement in construction speed compared to construction with steel or concrete.[37] Similarly, the timber portion of a 9-story building in London, England, was constructed about 30 percent faster than a comparable steel and concrete building with a small labor component; 27 days for 4 men, working 3 days a week.[38]

Smaller crew needs are a critical advantage for the use of mass timber given the current and future projected shortages of skilled construction workers.[39,40]

Faster construction means buildings are able to be occupied sooner, shortening the time that construction loans are outstanding, reducing financing costs and providing an incentive for banks to lend.[41]

An average of three case study comparisons, (a retail space, and office space, and a charter school), of mass timber buildings to conventional construction, showed an average of $5.81 per square foot in total cost reduction calculated on a 25 percent savings in construction schedule. Reduced costs included saved interest on construction loans and additional rental income generated by earlier opening dates.[42]

Site Worker Safety. Mass timber was not only faster for the previously referenced PAL hotel project, but it had worker safety advantages:

"Erection crews assembled safety devices and handrails to panels while they were still on the ground so, as each connecting floor panel was lifted into place, the area was immediately safe for workers. Once the floor deck was installed, crews enclosed the exterior of the building before coming back to install the interior walls. This allowed them to eliminate the potential for falls from elevated heights to the exterior as quickly as possible. The approach enabled the team to safely install almost 400 square feet of floor every 20 minutes with just three workers."[43]

The PAL project superintendent said, *"CLT* <mass timber> *panels allowed us to erect walls quickly and safely, with very few crew members working in the radius and swing fall of the crane."*

As noted in the following section, mass timber projects will have less scrap and clutter on site, minimizing tripping hazards and the potential of falling debris. Also, because little or no job site cutting of materials is needed on a mass timber site there are fewer opportunities for accidents with power tools.

Construction Site Fire Safety. Because they are manufactured in factory conditions to their final configuration, mass timber panels are usually lifted directly from the delivering truck and placed in position for a bolted connection. There is typically no welding or hot work on a mass timber project, reducing a common cause of structure fires.[44]

There is also very little wood waste material present on a mass timber site since cutting and milling of the material is done at the factory. Less combustible scrap and dust on a construction site are key factors in fire prevention. Insurer AIG states: "Good housekeeping is an important part of reducing the fire risk of a property. Accumulations of combustible scrap materials and trash can provide a fuel source and contribute to fire development."[45]

Well suited for use in repetitive dwelling unit layouts, mass timber aligns with the needs of the multifamily housing market both at mid- and high-rise heights, according to a joint study by Forterra, Heartland, Washington State University Institute for Sustainable Design, and the University of Washington Center for International Trade in Forest Products:[46]

"In analyzing the results of the adoption-diffusion models, specifically for multifamily construction, ***most of the future demand for mass timber is expected to be in mid-rise construction, i.e., 4-6 story buildings.*** *<emphasis added> However, in the short term (4 to 6 years) most of the demand for mass timber panels for multifamily construction is expected to be in higher storied buildings (7+) to compete with steel and concrete construction until mass timber reaches cost parity at mid-rise heights."*

It is widely acknowledged that construction in the 4 to 6 story multifamily residential market is vulnerable to fire before active and passive systems of protection are in place. While only a tiny percentage of the built area, construction site fires do occur and can pose threats to neighboring properties and responding fire departments. Because of the favorable fire resistance of mass timber, the occurrence of these construction site fires will be diminished because of the superior ignition resistance and charring performance of the larger mass sections of mass timber.

Expanding the use of mass timber for midrise construction will be easier to accomplish when the manufacturing capacity and supply chain for the material has been developed sufficiently to make the material competitive with other materials. This means that regulatory barriers – height and area limits – which reduce the market and have the effect of discouraging investment in production capacity, must be overcome if mass timber is to create fire safer construction sites.[47]

Climate Change Mitigation and Wildfire: Researchers estimate that climate change contributed to more than 10 million acres of U.S. forest fire area during 1984–2015, nearly doubling the forest fire area expected in its absence. They also determined that anthropogenic climate change as a driver of increased forest fire activity will continue where fuels are not limiting.[48] Climate models predict increased wildland fire frequency, intensity and longer fire seasons.[49]

Increased wildfire activity severely impacts Federal budgets, including diverting money from fire prevention to fire suppression.

"Forest Service spending on fire suppression in recent years has gone from 15 percent of the budget to 55 percent – or maybe even more – which means we have to keep borrowing from funds that are intended for forest management," said U.S. Secretary of Agriculture Sonny Perdue in September 2017. "We end up having to hoard all of the money that is intended for fire prevention, because we're afraid we're going to need it to actually fight fires. It means we can't do the prescribed burning, harvesting, or insect control to prevent leaving a fuel load in the forest for future fires to feed on."[50]

At the discretion of the U.S. President, the Federal Emergency Management Agency can reimburse state and local governments up to 75 percent of qualifying funds from the disaster relief fund (DRF) for wildfire disaster response. In 2018 the DRF is projected to be exhausted by June due to obligations from Hurricanes Harvey, Irma, and Maria; and the 2017 California wildfires.[51] Wildfire disasters compete for resources from other disaster relief efforts.

The EPA estimates that with reductions in greenhouse gas emissions over the course of the 21st century, the amount of U.S. forested land that can be prevented from burning by 2100 will be twice or more the size of California, saving $8.6 to $11 billion in wildfire response costs and $3.4 billion in fuel management costs. Approximately 5.3 million more acres of forested land in the US are projected to burn each year by the end of the century without reductions over the course of the century, compared to today.[52]

Wildfire Mitigation: Because of its carbon sequestration advantages, greater use of mass timber has the potential to mitigate wildland fires. Given the impacts predicted with increased global warming,[53] offsetting climate change with carbon storage in mass timber buildings, while better managing forests, will work to mitigate other health and life safety threats[54,55] in addition to wildfires.[56]

Mass timber allows the use of wood that would not otherwise have value for structural building applications, including insect and disease killed trees, smaller dimension trees and species not desirable for typical structural use.57,58 This mean that wood that may not have been utilized for economic reasons, including 'thinnings' and ladder fuels - will now have value as structural building materials when removed from the forest. In other words, a method to pay for wildland fuels reduction is created. This is a considerable fire safety benefit, particularly for communities located in the wildland-urban interface.

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