An analyzed, annotated and scientific rebuttal to

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

When Protected By ~~Rigorous~~ dubious Systems and Controls

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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.

Seriously?!

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.

Every fire service organization testified in opposition to this proposition during the ICC Committee Hearings...

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; pe[illegible] of through-penetration protection; and conditions for responding fire personnel.

Their testing didn't indicate real life conditions, like wind or moisture, which impacts fire-fighting and property damage.[2]

Hardly. It was a two-story mock up.[1]

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 option[illegible] mass timber buildings. Each new type of construction has hourly fire protection requirements more ~~robust~~ Inferior 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.

Charring occured much faster than expected.[4]

The sprinklers didn't stop the fire from spreading![3]

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.

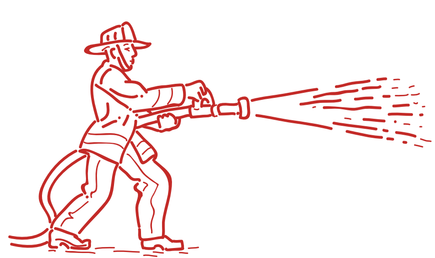
Note: CLT is wood and wood still burns. https://bbc.in/2mgd6ed

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 bu[illegible]s timber ele[illegible]mass tim[illegible]er, with any deficiencies repaired. Records of inspections and repairs are required to be maintained and are subject to review by the authority having jurisdiction.

Wood industry continues to hide the National Institute of Standards tests concerns that "flashover occurred earlier" with CLTs, and "a larger re-flash occurred on the exposed wall with delamination of the second ply of the CLT."[5]

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



Translation:
CLT BURNS DEEP DOWN INSIDE ITS LAYERS.

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.

FAKE NEWS #1
Combustible materials are less safe during construction.

FAKE NEWS #2
Unsubstantiated claim.

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.

FAKE NEWS #3
No reference given.

Not so much. CLT buildings emit more carbon than either steel or concrete.[8]

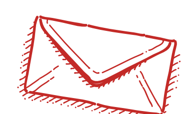
Wildland fire safety on both the regional and global scale will benefit from increased use of mass timber. Low value wood, thinnings, and dead standing trees, can be used for mass timber, thereby creating a financial incentive for wildland fuels reduction, particularly of ladder fuels, improving regional 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.

This would be great, except for those pesky studies showing that logging does NOT reduce the risk of future fires.[6,7]

Only if they're using magical manufacturing equipment and vehicles that don't emit any carbon.[9,10]

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.

That envelope is clearly not tight enough to hold a reference for this claim.[11]



"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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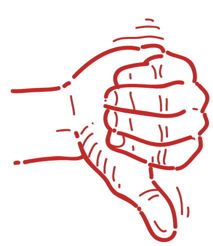
> Note: At the International Code Council's April 2018 committee action hearings some mass timber proposals were modified by the hearing committee. No proposed modifications were opposed and all but one of the proposed modifications passed unanimously.
>
> The proposed modification that did not pass was ruled out-of-order and not discussed. The chair of the Ad Hoc Committee for Tall Wood Buildings has indicated that the modification will be proposed again through a public comment for consideration at the ICC's public comment hearings.
>
> Comments regarding the modifications of specific proposals follow the applicable subject matter of the proposal in this paper, updated May 22, 2018.



FALSE!
Most passed with a 12-2 vote.

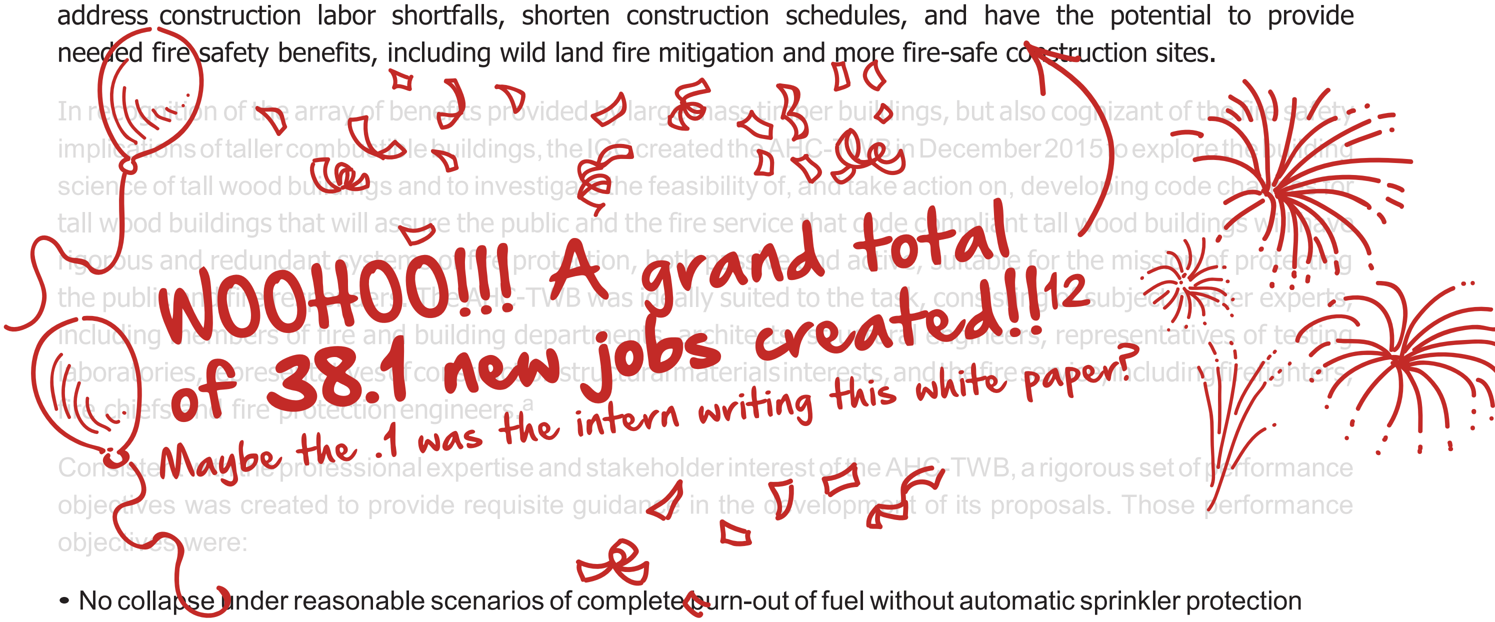
Introduction

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 wild land 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 service. 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 competing structural materials interests, and the fire service, including firefighters, fire chiefs and fire protection engineers.[a]

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

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.

Oh yeah, just like that building at Nottingham University.

THE ONE THAT BURNED DOWN.[13]

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.

The only similarity is that they're both construction. Let's say it together.

WOOD. BURNS.

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[d] 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.

You know what else you're avoiding?

Sharing the National Institute of Standards' test concerns of "earlier flashover," "heat delamination of exposed CLT," and "large re-flash."[14]

Nothing to worry about, right?

[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 [illegible] in-plant quality control procedures to prevent future occurrences. 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.

At the committee action hearings an editorial modification of the proposal which corrected an internal reference was accepted by ICC staff without opposition or discussion.

An additional modification was heard, without opposition, and approved unanimously by the committee. It changed the referenced standard used for determination of adhesive acceptability. The newly referenced standard, ANSI/APA PRG 320-2018: *Standard for Performance-Rated Cross-Laminated Timber,* has a mandatory appendix which specifies test procedures to be used to evaluate the elevated temperature performance of adhesives used in cross-laminated timber (a form of mass timber). It resolved expressed concerns regarding the performance of adhesives in fire conditions.

Sounds like they may have been sniffing some adhesives themselves.

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.

And remind us how the use of a residential fuel package validates other occupancies?

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).

Because you cheated, putting the test surfaces further away from each other than they would be in an actual building.

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.

A proposal to modify the originally proposed changes to Table 504.3 was passed unanimously by the hearing committee with no opposition. The modification made the proposal more conservative by reducing the allowable height of Type IV-A and Type IV-B buildings by 90, and 60 feet, respectively, for I-4 uses (day care facilities). Type IV-A I-4 uses would now be limited to 180 feet in height; Type IV-B to 120 feet.

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

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.

The hearing committee unanimously approved an unopposed modification which reduced the protection attributed to ½ inch Type X gypsum board from 30 minutes to 25 minutes. This made the proposal slightly more conservative, but more importantly correlated the new value with the existing code value for ½ inch Type X gypsum board in Table 722.2.1.4(2).

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.[e]

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 discusses the fire-resistance rated separation requirements for incidental uses within a larger use group. Section 509 also permits, where 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.

What does that even mean?
Show us your procedures.

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

TO THE TIMBER INDUSTRY

Benefits of Modifying Codes to Recognize Additional Uses for Mass Timber

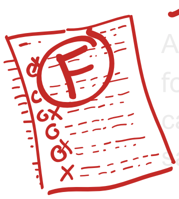
Codifying increased opportunities for the use of mass timber – broadening the market by updating the *International Building Code* will create incentives for capital investment in the mass timber supply chain.[2] With more material providers in the market, competition will drive costs down. This in turn 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.

So then you chop them down, causing 12% of the world's greenhouse emissions.[15] Nice.

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.



Someone flunked math...

Additionally, forests managed for the production of building products sequester more carbon than unmanaged forests. Assuming no fires or diseases affect the growth, the amount of captured carbon in a period of 100 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]

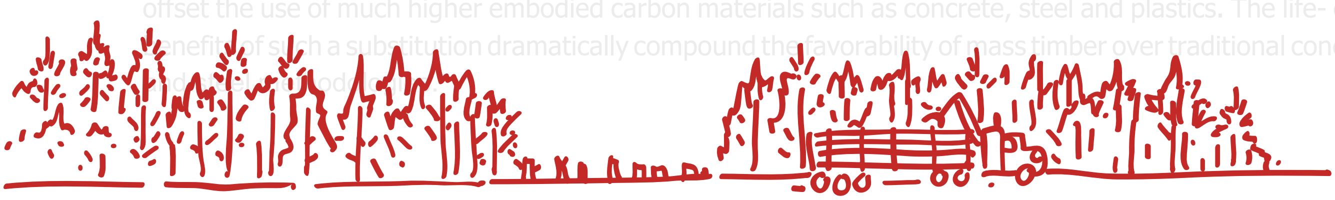
A live tree can absorb up to 48 lbs of CO_2/year, one ton by the time it's 40 years old,
ZERO AFTER YOU CUT IT DOWN.[16]

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]

The impact of forestry is **250-325%** higher than concrete and **110-140%** higher than steel.[17] This is not the efficiency you're looking for.

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.



THIS JUST IN: The same study also estimated that "CLT panels use 3x more wood than a wood-frame system solution."

[illegible] 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.[f] 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.

OK, champs.
Now what about the harm to forest ecosystems, biodiversity, and soil and water quality?!

Accompanying the carbon benefits, avoiding the decay of wood in anaerobic conditions defeats the at[illegible] release of methane and nitrous oxide,[illegible] greenhouse gases that are 25 times and 298 times, respectiv[illegible] potent than CO_2. T[illegible] Protection Agency (EPA) [illegible] that methane is [illegible] about 10 percent of manmade global warming and that nitrous oxide is responsible for 5 perce[illegible]

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~~ intelligent people argue against harvesting forests because of ~~perceived~~ actual[18] 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:

1 https://buildtallbuildsafe.com/sites/default/files/pdf/WCTE-2018_Fire-Tests.pdf

2 https://www.fireengineering.com/articles/2013/07construction-concerns-for-firefighters-cross-laminated-timber.html

3 https://sustainable-fire-engineering.sustainable-design.ie/wp-content/uploads/2015/08/NFPA-FPRF_Tall-Wood-Buildings-Fire-Safety-Challenges_2013.pdf

4 http://www.mypaper.se/html5/customer/355/11143/?page=21

5 https://www.nist.gov/el/fire-research-division-73300/national-fire-research-laboratory-73306/fire-safety-challenges-0

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10 U.S. Forest Carbon and Climate Change", A. Ingerson, The Wilderness Society, 2007.

11 http://www.treteknisk.no/resources/filer/publications/Air_leakages_in_cross_laminated_timber_constructions_28022011_docx_xy7tg.pdf

12 The Economic Impacts of Using More Wood Products in the Construction of State Buildings in the 2014-2015 Biennium in Oregon," M. Meyers, Economist, Oregon Business Development Department, and Brandon Kaetzel, Ph.D., Principal Economist, Oregon Department of Forestry.

13 http://www.dailymail.co.uk/news/article-2754270/New-15million-university-laboratory-goes-flames-Students-warned-stay-indoors-60-fire-fighters-battle-blaze.html Accessed May 2018.

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15 CO_2 Emissions from Forest Loss, G. R. van der Werf, et al. Nature Geoscience, VOL 2, November 2009

16 U.S. Forest Carbon and Climate Change", A. Ingerson, The Wilderness Society, 2007.

17 Assessing the Relative Ecological Carrying Capacity Impacts of Resource Extraction, Athena Sustainable Materials Institute, August 1994.

18 https://sustainable-economy.org/wp-content/uploads/2015/11/Clearcutting-our-Carbon-Accounts-Final-11-16.pdf and http://www.wweek.com/news/city/2018/02/02/environmental-groups-blast-new-city-funded-all-timber-building-for-shirking-environmental-standards/