

Tall Wood Buildings – The US Approach to Performance and Protection

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ICC AD HOC Committee on tall wood buildings Responds to concerns raised during the public comment period

The International Code Council (ICC) established an Ad Hoc Committee on Tall Wood Buildings (TWB) in December 2015. This committee studied building science for tall wood buildings and has proposed amendments to the 2021 edition of the International Building Code (IBC) to address building construction using mass timber.

The committee worked for two years to develop code proposals in a consensus process. It should be noted that all of the meetings and phone calls were posted on a website: <https://www.iccsafe.org/codes-tech-support/cs/icc-ad-hoc-committee-on-tall-wood-buildings/>

In addition to the committee members, who represented many interests, including the engineers, architects, building and fire code officials, fire service, materials representatives, and testing laboratory representatives, the committee also welcomed close to 100 others as interested parties to follow and comment on committee proceedings. In addition, the documentation provided to the committee was also posted on the website. Committee members have routinely spoken about the committee activities to interested parties at various conferences and meetings to further ensure open and inclusive discussion exploring the issues of tall wood buildings.

The TWB code proposals were assigned the following IDs.

G28-18: IBC 403.3.2, High Rise Sprinkler Water Supply
G75-18: IBC 504.3, Height, Feet
G80-18: IBC 504.4, Height, Stories
G84-18: IBC 506.2, Allowable Area
G89-18: IBC 508.4.4.1/509.4.1.1, Fire Separations, Occupancy and Incidental Uses
G108-18: IBC 602.4 (also definitions and IBC 601), Types of Construction
FS5-18: IBC 703.8, Performance method for noncombustible protection
FS6-18: IBC 703.9, Sealant/Adhesives at Edges
FS73-18: IBC 708.2.1, Fire and Smoke Protection
FS81-18: IBC 722.7, Prescriptive method for noncombustible protection
G146-18: IBC 3102, Membrane Buildings
G152-18: IBC Appendix D, Fire Districts
F88-18: IFC 701.6, Owner's responsibility
F266-18: IFC 3308.4, Fire Safety during construction

Interested parties are invited to visit [CDPAccess](#) to review the committee proposals and the supporting justifications.

The TWB code proposals were approved at the ICC Code Action Hearings in Columbus, OH in April 2018. Previously, the TWB responded to concerns raised during the Code Action Hearings, linked here: https://cdn-web.iccsafe.org/wp-content/uploads/TWB-Response-to-Concerns-Raised-at-Hearings_8_1_18-Posted.pdf

As many of the current issues are similar to the concerns already raised, the reader is invited to review this link in addition to reading this document.

During the current public comment period, concerns have again been raised regarding the approved code proposals. This document seeks to inventory the concerns raised during this public comment period, and to provide a summary response from the committee.

Concern #1

There is currently no complete testing or engineering justification for expanding the height limitation for mass timber from 6 stories to 18 stories.

Response

As discussed in the previous response to issues raised at the code hearings, the committee reviewed the building codes, data from numerous fire tests, and utilized a performance-based approach to justify the taller heights. Performance objectives adopted by the committee are as follows:

1. No collapse under reasonable scenarios of complete burn-out of fuel without automatic sprinkler protection being considered.
 - Note, the ATF test series included tests of Type IV-A and IV-B construction. No automatic sprinkler protection was provided, and the structure withstood complete burn-out of fuel without any collapse. The proposed construction types require passive fire resistance ratings of structural elements consistent with other construction types and in consideration of expected fuel loads.
2. No unusually high radiation exposure from the subject building to adjoining properties to present a risk of ignition under reasonably severe fire scenarios.
 - Note, the proposals require exterior wall protection with 40 minutes of noncombustible fire protection on any mass timber exterior walls, and does not permit the walls to contain other combustible materials other than a water barrier, which limits the impact from a building fire to adjoining properties
3. 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
 - Note, the proposals require exterior wall protection with 40 minutes of noncombustible fire protection on any mass timber exterior walls, and does not permit the walls to contain other combustible materials other than a water barrier, which reduces the risk of ignition of the exterior wall from adjacent properties
4. No unusual fire department access issues
 - Note, the ATF test series incorporated a corridor to determine conditions that a fire fighter would face in response, and no unusual conditions were observed. Vehicle access is governed by the Fire Code and would apply to these buildings the same as all others. The code proposals require that stair enclosures in taller wood buildings either be fully encapsulated, and non-combustible stairs are required when a building exceeds 12 stories. In addition, note that elevators for fire department access are also required for buildings heights over 120 feet.
5. Egress system design to protect building occupants during the design escape time, plus a factor of safety
 - Note, the egress factors provided in the code apply also to tall wood buildings. As previously noted, additional criteria are applied to stair enclosures to ensure that occupants are protected during egress
6. Highly reliable fire suppression system to reduce the risk of failure during reasonably expected fire scenarios. The degree of reliability should be proportional to evacuation time and the risk of collapse
 - Note, the proposals include a requirement to provide redundant water supply to the site, which adds reliability to the automatic fire protections systems, and also to the water supply available through fire hydrants for use by responding personnel. This criteria is triggered at a building height of 120 feet for tall wood buildings (note the trigger for other construction types is a building height of 420 feet).

The performance based approach considers all fire protection features contributing to the building's fire safety. The Ad Hoc Committee performed a rigorous review to evaluate the

risks and include building features to address those risks without relying on a single element to provide for the safety of occupants and the structure. An important thought to remember is that high-rise buildings of mass timber are still considered high-rise buildings with respect to all of the other code requirements. Tall Wood Buildings are required to comply with all of the same high-rise requirements that currently protect Type I high-rise buildings, and more. In fact, while Type I high-rise buildings are allowed to reduce their fire resistance ratings under the high-rise provisions, this reduction does not apply to Tall Wood Buildings. In other words, mass timber high-rise buildings will have a greater degree of fire resistance than current Type I highrise buildings are permitted to have, while also having all of the high-rise features that currently only apply to Type I buildings. By matching, and often exceeding, the hourly ratings already used for taller buildings, mass timber was determined to provide equal performance, and thus is being proposed to have the same tolerances for building height.

Concern #2

Allowing wood framed structures to be built above the level of fire department access is a serious mistake. The vast majority of municipal ladder trucks cannot reach above the 7th floor.

Response

This is not an issue related only to tall wood. Regardless of construction type, at a certain height, fire response is required to utilize the interior of the building for all high-rise buildings, through elevators and/or stairs to ascend to the fire event. For this reason, the committee bolstered requirements for exit enclosures and elevator shafts, which increases safety for 4 responding personnel. In addition, tall wood buildings are required to have exterior skin of non-combustible materials (i.e. plastics are not permitted), so the exterior surface fire concerns that relate to current steel/concrete high-rise buildings do not apply to tall wood buildings. These buildings will have higher fire resistance ratings requirements than currently required of current wood-frame construction, providing additional passive protection. The ATF tests incorporated features to address conditions expected to be encountered by responding personnel, and no abnormal issues were observed.

Concern #3

Wood does not offer the resilience and fire protection of non-combustible alternatives like concrete, masonry and steel.

Response

The ability of mass timber to endure through various fire scenarios is well understood. Through standard tests and compartment tests, often lasting over many hours, the committee was able to determine the strengths and weaknesses of the materials and provide code proposals that ensure mass timber provides suitable protection. Even as the resilience of mass timber against fire was proven, it is important to note that the mass timber prescribed in the code proposals have even greater fire resistance requirements than comparable concrete, masonry or steel high-rise buildings. With respect to structural resilience, the structural requirements that currently apply in the code will be applicable to tall wood buildings also. The tall wood buildings will be required to provide the same structural resilience as is required by the code for all other construction types currently.

Concern #4

Cross-Laminated Timber chars in a fire; however, charring is not equivalent to noncombustible. Charring wood will add fuel to the fire and increase the heat and smoke output relative to noncombustible materials. Note: if the char rate is 1" per hour in a fire, then after 2 hours in a fire, a 6" thick CLT wood load bearing wall will only have 2" of structural material left. This is not acceptable and is not addressed in the code change proposals.

Response

The committee is aware that mass timber is combustible, so it will burn and add fuel to the fire. The question is whether the burning characteristics can be quantified. Through numerous tests, the char rate of mass timber has been established and the amount of material expected to char can be calculated. The char rate calculation feeds into the structural design, so that all wood expected to char is determined to be sacrificial, and the

remaining cross section of wood is calculated to ensure that the structural design requirements have been met. From full scale comparative testing, the committee has found that the increase in burning rate from mass timber is negligible in the amounts prescribed in the code proposals for taller buildings.

Concern #5

To date, there has been no full scale CLT fire tests done to ASTM standards.

Response

The committee is not aware of what testing is being referred to. Full scale building fire tests are not required of any construction type. Full-scale testing in compartments has obviously occurred, however there are no ASTM standard tests for compartment testing, nor are there ASTM standards or code requirements to build a full-scale, complete buildings and subject them to fire tests for any other construction materials. Wall assembly and ceiling/floor assembly testing has occurred to ASTM E119, which is a full scale test.

Concern #6

There has been no wind component involved in the fire testing of Mass Timber assemblies. This is a serious mistake. This type of testing is essential.

Response

The issue of wind has been raised previously as well. There is no wind driven component in any of the tests required for construction using any material, such as ASTM E119 and NFPA 285. The wind driven component was rejected by the committee during design of the ATF tests, as wind can yield unpredictable results (both positive and negative results are possible), and there is a need to have reproducible data to assist with future areas of study. However, the ATF full scale tests were configured to allow an abundance of air to the fire by removing the glazing of both the living room and the bedroom prior to fire initiation, which resulted in a significant fire test that reinforced the performance characteristics of mass timber. Also, note that study of wind effects on exterior fires has shown that wind can actually move the flame away from the exterior surface and could yield a less intense fire test, so the effects of wind are not as predictable or as negative as may be assumed.

Concern #7

It is unknown what will happen to water that accumulates as a result of a fire sprinkler system discharge as a result of fire or accidental incident that opens a sprinkler head. The system has not been tested with the additional water load and what of the water damage and mold issues?

Response

Regarding the load concern, this is not an issue unique to mass timber. Certainly, the weight of water from sprinkler discharge is something all buildings, of all materials and all sizes, can sustain. There is no reason to expect that mass timber will not perform as well as all other buildings that have experienced water accumulation, from fire sprinklers or other means. Regarding mold issues, those issues can occur in steel, concrete and masonry buildings also. Again, these concerns are not specific to mass timber, and mass timber is expected to perform as well as existing construction methods. There is over 100 years of heavy timber buildings without issues or concerns.

Concern #8

Neither the Fire Code Action Committee nor the Building Code Action Committee voted to support this series of Tall Wood / Mass Timber Code Changes.

Response

There is no current process for any of the code action committees (CACs) to vote on code proposals from any groups or individuals outside of the CACs. The charge of the CACs is to develop code change proposals to "improve or enhance an International Code or a portion thereof" (ICC Council Policy 31), not review and take positions on code change proposals not originating within their CAC. Instead, the ICC process sets up the Code Development Committees as the groups that will review the work of all code action committees. The FCAC, BCAC, and Ad Hoc Committee for Tall Wood Buildings; all have to

submit code proposals, not to each other, but to these Code Development Committees. While the TWB kept the FCAC and BCAC informed during the process of preparing the code proposals, the charge of the committee was to create proposals for review by the Code Development Committees. It is worthy to note that the proposals were overwhelmingly approved by the IBC General Code Development Committee and the IFC Code Development Committee. ICC committees are governed by Council Policy 7 *Committees and Members* which was developed and updated by the ICC Board. Section 9.3 specifically addresses inter-committee coordination by assigning primary responsibility to a single committee – in this case, it was assigned to the TWB. As noted in the policy, this is intended to avoid conflicts and minimize duplication.

Concern #9

Adhesives used between the layers of CLT have not been standardized and are key to whether the CLT delaminates during fire and continues to advance till complete burnout. A test standard for the adhesives has been proposed, but not fully vetted by the cognizant committees.

Response

Structural adhesives are standardized. As discussed in the previous response to issues raised at the code hearings, the committee deliberated adhesive performance extensively. The performance of adhesives has been bolstered by updates to PRG 320-18, which standardize the minimum performance of adhesives. The performance of the adhesives per the new PRG 320-18 have been validated by the NRC re-testing of the NIST fire tests.

Concern #10

The behavior of CLT is completely dependent on the connections, and all connections used to date are proprietary. There is no publicly available information on their design or capacities, even for the Tall Wood Ad-Hoc. There is no information on the performance of the proprietary connections during fires?

Response

The connections utilized in the ATF tests were non-proprietary connections designed in accordance with the CLT Handbook AND NDS. Connections can be engineered using existing standards, so standard/prescriptive designs are not needed. Connections are not prescriptively set forth in the codes for any of the construction types.

Concern #11

Wood absorbs water, and the resulting rot and mold can seriously impair a wood structures' overall anticipated performance. Note: non-combustible materials such as concrete, masonry and structural steel do not rot.

Response

Heavy timber wood construction has endured for many years under many conditions. This issue is not specific to tall wood, but past history has shown that wood construction is resilient from the serious impairments alluded to in the comment. It is to be noted that noncombustible materials are not immune from water damage. Appropriate protection is required for all construction materials.

Concern #12

With respect to the proposed Type IV-B construction type, there is practical difficulty with defining areas of exposed wood and enforcement in the field.

Response

The percentage of exposed wood permitted in Type IV-B construction is derived from the ATF tests. It is normalized to the floor area as walls and ceilings can have detailing and surface elevation changes that could be improperly used to increase the amount of exposed wood. It is expected that exposed areas of walls and ceilings will be shown on construction documents with details sufficient to allow review by the AHJ. It is important that these details be shown on plans to ensure that the exposed wall percentage allowed is per code, and to ensure that exposed areas of walls and ceiling are separated from each

other by the minimum separation distance mandated by the proposals. As the plans are expected to contain this level of detail, it is expected that field inspections will be facilitated by these plan details.

Concern #13

With respect to Type IV-B construction, this construction type does not fit into a category that coincides with existing construction types. Existing construction types are generally categorized as protected or unprotected. Type IV-B is a designer construction type for aesthetic purposes that is a mix of IV-A and IV-C construction, and not clearly protected or unprotected.

Response

While the focus of this proposal is to add three new construction types, a nuance that needs to be remembered is that traditional Type IV construction has been maintained, and is identified as Type IV-HT. This existing construction type continues in the code and is the “unprotected” version of all of the Type IV construction types, in that the majority of the structural frame has no assigned minimum fire resistance rating. In contrast, the three new construction types all have minimum assigned fire resistance rating for the structural frame, so all three are considered to be different versions of “protected” construction. Type IV-B is validated by the ATF tests, and provides clear prescriptive requirements to ensure that protection is sufficiently provided to limit the contribution of mass timber walls to a fire, by exposing a limited quantity of mass timber, all while maintaining the minimum required fire resistance ratings. Note that the existing Type IB construction is a protected construction type, so the current code does not follow the framework described by the comment.

Concern #14

Concerns with vetting of NFPA 285 changes mean that additional clarification is needed to limit combustible products from the exterior wall construction. Additional protection is necessary for the exterior walls of high-rise buildings. In addition to adding to fire resistance rating, the additional protection is needed to ensure that ignition of exterior mass timber walls does not occur during the minimum fire resistance time rating.

Response

The original text within the code proposals clearly indicates that the entire exterior wall covering is required to be of noncombustible materials, except for the combustible water barrier, which must meet strict flammability limits. The concern stating that additional protection should be provided is overstated, as in typical high-rise construction, the load-bearing structural members in core areas carry larger loads than those that occur on the exterior perimeter of the building, meaning that there is less mass timber that will occur on the exterior perimeter. Adding a provision about combustion involvement of the wood does not follow any of the exterior wall flame spread standards and would be targeting only one type of construction if added here; these types of amendments to exterior wall testing criteria need to be added to the code sections in Chapter 14 that address these test requirements. Finally, please note that additional safeguards for exterior walls occur as the plastic/foam wall panels currently allowed in Type I and II buildings, which has exhibited the significant fire problems throughout the world, are not permitted to be installed on Tall Wood Buildings. 9

Concern #15

The prohibition of combustible materials in exterior walls and concealed spaces will create a conflict with the International Energy Conservation Code.

Response

The intent of the committee is to ensure the fire safety of these buildings. In doing so, the committee added these prohibitions of using combustible materials. The design will still be required to meet energy code provisions. Note that continuous insulation is only required if using the prescriptive path for compliance, but compliance can still be achieved using non-combustible materials such as mineral wool insulation. Also, performance approaches are available as a means of compliance, which can take advantage of the minimal leakage through mass timber elements.

Concern #16

There is no language in the code proposals that describe what should be provided or expected to protect the connections for the required fire resistance ratings.

Response

Please note that Section 704 of the IBC prescribes fire-resistance protection to be applied to structural members and requires that this protection must extend to connections to other structural members. As the base code already addresses this issue, no additional code proposals were necessary. Note also that the NDS requires protection for connections.

Concern #17

The proposed heights are not technically justified.

Response

Heights were based on a performance based approach and analysis of fire resistance rating. The performance based approach is validated by the results of fire testing, including the ATF fire tests. Numerous tests also validate the fire-resistance rating of mass timber elements. The TWB proposals address the issue of non-combustible construction versus the contribution of the mass timber to the fire load by requiring minimum levels of non-combustible protection for the mass timber elements in the taller buildings (Types IV-A and IV-B Construction). Following is a discussion for heights that speaks to each individual type of construction proposed.

Proposed Type IV-A: Currently, Type I-A is permitted unlimited heights, depending on occupancies. Please note that proposed Type IV-A construction is required to have exactly 10 identical fire resistance ratings as Type I-A construction. Although the proposed Type IV-A has the same fire resistance rating requirements as Type I-A, the committee decided to limit the height of Type IV-A, specifically to address firefighting concerns. The heights provided for Type IV-A construction are lower than what is permitted for Type I-A construction, even with identical fire resistance rating requirements.

Proposed Type IV-B: Currently, Type I-B is permitted heights up to 12 stories (180 feet), depending on occupancies. Please note that Type I-B has tabular values for fire-resistance ratings that equal those proposed for Type IV-B. However, a big difference occurs where, per Section 403 of the IBC, the ratings for Type I-B are permitted to be reduced in high-rise buildings. Please note that this reduction is not allowed for Type IV-B. The net effect is that the fire resistance ratings for Type IV-B are higher than those required for Type I-B when considering these buildings. As such, it is a conservative treatment to limit Type IV-B to the same heights allowed for Type I-B.

Proposed Type IV-C: The heights for IV-C construction are based on the existing requirements for Heavy Timber construction (now termed Type IV-HT). Please note that IV-C construction is fully exposed wood, but still requires a fire resistance rating of 2-hours for the structural frame; only dimensional criteria are provided for Type IV-HT. Type IV-HT is currently permitted to a height of 85 feet; conservatively, no additional height in feet is proposed for Type IV-C. However, due to the higher fire resistance rating of IV-C construction, the committee proposed additional stories for IV-C construction, as the fire resistance rating provides greater compartmentation within the building. Please note that CLT assemblies have achieved 2-hour and 3-hour fire-resistance ratings in standardized tests, as is required by the table setting forth rating requirements. Also, note that mass timber does not utilize the fire-resistance rating reductions set forth in the building code for high-rise buildings, so deeper analysis shows that mass timber will often yield higher fire resistance ratings than currently required of other construction types, which is a conservative approach taken by the committee, to justify the height proposed.

Concern #18

The proposed building areas are not technically justified.

Response

The allowable areas for both Type I-A and I-B construction are unlimited for many occupancy types. While the committee used a performance based approach that centered on

comparing Type IV-B to Type I-B construction, and while such an approach could be used to justify unlimited areas for some of these new construction types for certain specific occupancies, the committee instead decided to limit the size of these buildings, to provide a conservative approach to introducing these types of construction into the code. In other words, rather than 11 being an increase in the allowable areas, these proposals actually limit the size of these buildings, versus the construction Types I-A and I-B.

Concern #19

There has been no live fire testing at the limits being proposed

Response

To the committee's knowledge, there are no standard tests that involve full building mock-up fire testing. The committee reviewed testing of compartments to determine material response to fire and to quantify the compartment boundary conditions. From ATF Tests 1-3, each of which experienced a fire in the range of 20 MW, it is clear that the proposed high-rise Type IV construction types can contain a fire within the compartment, which provides sufficient information about the conditions expected anywhere in a building.

Concern #20

There is incomplete data regarding the fire loading of test burn buildings.

Response

Please note that the fire test report for the ATF tests is publicly available at:
https://www.fpl.fs.fed.us/documnts/fplgtr/fpl_gtr247.pdf

For loading of the structure, the report details construction of the two-story test structure, including a description of the loading applied via roof top water containers.

Also, fire loading is addressed in the report as heat potential per floor area. Note that the fire loading used in the ATF tests are in general agreement with the NIST tests series, which was important to allow comparative review of the tests.

Concern #21

No indication that any seismic testing has been performed or evaluated which goes to the issue of resiliency and sustainability.

Response

The committee has researched and tracked a variety of mass timber seismic research efforts, including the Japan mass timber shake table test and ongoing research into mass timber behavior under seismic conditions. Structural issues have been a constant focus of this committee, beginning from being one of the main issues identified by the committee, to having presentations regarding structural systems, including lateral structural design. The fact of the matter is that structural engineers, like with buildings of any other materials, will need to engineer their designs understanding the capabilities of mass timber. Note that seismic design 12 will be required in accordance with Chapter 16 of the IBC, which references ASCE 7 and the NDS.

Concern #22

The reason statements for these proposals places an over reliance on the presence of fire sprinklers.

Response

Fire sprinklers are effective and provide a strong measure of fire protection. It is true that the committee did not propose any increased heights for the Non-sprinklered rows in the heights tables. However, fire sprinklers were not a part of Tests 1-3 in the ATF fire tests, as the TWB needed to confirm that these new proposed types of construction could withstand a fire without a bevy of fire protection features, including the lack of fire sprinklers. It was these tests, not just the prescriptive requirements for fire sprinklers, that formed the basis for the committee proposals. There is a great deal of emphasis placed on passive protection in the code proposals. Unlike other construction types, taller wood buildings are not permitted to reduce fire resistance rating requirements of structural members when high-rise provisions are applied.

Concern #23

There is concern that if a fire occurs and damages a CLT panel, there is not a prescribed method for repair.

Response

There are currently no code-prescribed methods of repair for any construction materials, nor does the code detail methods of replacement of wood, steel, concrete, or masonry structural members that have been exposed to adverse conditions such as fire, seismic and weathering. In any building, engineering review and judgement will be required to assess proper repair methods. Manufacturers are currently validating a variety of repair concepts for basic damage scenarios, many of which are derived from procedures used for other products such as glu-lam. Current code does not have prescriptive methods for repair, but requires repair to meet original design, which would apply also to taller wood buildings.

Concern #24

There is concern about CLT panels and marking requirements of these for field identification

Response

Chapter 23 of the IBC and the NDS both reference PRG-320. PRG-320 sets forth criteria for the labelling of CLT panels.