

Demonstrating Fire-Resistance Ratings for Mass Timber Elements in Tall Wood Structures

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Changes to the 2021 International Building Code (IBC) have created opportunities for wood buildings that are much larger and taller than prescriptively allowed in past versions of the code. Occupant safety, and the need to ensure fire performance in particular, was a fundamental consideration as the changes were developed and approved. The result is three new construction types—Type IV-A, IV-B and IV-C—which are based on the previous Heavy Timber construction type (renamed Type IV-HT), but with additional fire protection requirements.

One of the main ways to demonstrate that a building will meet the required level of passive fire protection, regardless of structural materials, is through hourly fire-resistance ratings (FRRs) of its elements and assemblies. The IBC defines an FRR as *the period of time a building element, component or assembly maintains the ability to confine a fire, continues to perform a given structural function, or both, as determined by the tests, or the methods based on tests, prescribed in Section 703.*

FRRs for the new construction types are similar to those required for Type I construction, which is primarily steel and concrete.¹ (See Table 1.) They are found in IBC Table 601, which includes FRR requirements for all construction types and building elements; however, other code sections should be checked for overriding provisions (e.g., occupancy separation, shaft enclosures, etc.) that may alter the requirement.



Image: Korb + Associates Architects

Ascent | Milwaukee, WI
 Architect: Korb + Associates Architects
 Structural Engineer: Thornton Tomasetti

TABLE 1:
FRR Requirements (Hours) for Tall Mass Timber Construction Types and Existing Type I

| Building Element | I-A <i>Unlimited stories, heights and areas*</i> | IV-A <i>Max. 18 stories, 270 ft, 324,000 sf**</i> | I-B <i>Max. 12 stories, 180 ft, unlimited areas*</i> | IV-B <i>Max. 12 stories, 180 ft, 216,000 sf**</i> | IV-C <i>Max. 9 stories, 85 ft, 135,000 sf**</i> |
|------------------------|---|--|---|--|--|
| Primary Frame | 3 | 3 | 2 | 2 | 2 |
| Exterior Bearing Walls | 3 | 3 | 2 | 2 | 2 |
| Interior Bearing Walls | 3 | 3 | 2 | 2 | 2 |
| Roof Construction | 1.5 | 1.5 | 1 | 1 | 1 |
| Primary Frame at Roof | 2 | 2 | 1 | 1 | 1 |
| Floor Construction | 2 | 2 | 2 | 2 | 2 |

Assumes an NFPA 13 automatic sprinkler system throughout building
 *Unlimited building size permitted for most occupancies
 **Area limits indicated are per level, assuming no frontage increase; see IBC Tables 504.3, 504.4 and 506.2 for additional details

Source: 2021 IBC Tables 504.3, 504.4, 506.2 and 601

A provision commonly used in Type I construction for high-rise buildings that do not exceed 420 feet in height allows a reduced FRR if the building has sprinkler control valves equipped with supervisory initiating devices and water-flow initiating devices for each floor (per IBC Section 403.2.1.1). With this provision, the FRR requirements for elements in a Type I-A building may be reduced to the lesser requirements of Type I-B construction (with the exception of columns that support floors) and the requirements for a Type I-B building may be reduced to the lesser requirements of Type II-A construction. These reductions are not available for the new construction types, making them more conservative than Type I requirements.

In addition to meeting FRR requirements, all mass timber elements used in Types IV-A, IV-B and IV-C construction must meet minimum size criteria prescribed in IBC Section 2304.11. Examples of required minimum sizes are shown in Table 2.

Guidelines for Exposed vs. Protected Wood

Definitions of the new construction types, found in IBC Sections 602.4.1, 602.4.2 and 602.4.3, dictate that only mass timber or noncombustible materials can be used for the structural systems. Where mass timber elements are used, the definitions also include guidelines for whether the wood may be exposed on the building's interior, or must be covered with noncombustible protection. General allowances for exposed timber are:

- Type IV-A: No exposed timber permitted
- Type IV-B: Limited exposed timber permitted, as follows:
 - ▶ Ceilings (including integral exposed beams) up to 20% of floor area in dwelling unit or fire area,* or
 - ▶ Walls (including integral exposed columns) up to 40% of floor area in dwelling unit or fire area,* or
 - ▶ A combination of each using sum of ratios (actual exposed/allowable exposed wood) not to exceed 1.0
- Type IV-C: All exposed timber permitted*

*Exceptions: No exposed timber is allowed at shaft walls, within concealed spaces, or on the exterior side of exterior walls.

TABLE 2:
Minimum Dimensions of Heavy Timber Structural Members

| Supporting | Heavy Timber Structural Elements | Minimum Nominal Solid Sawn Size | | Minimum Glued-Laminated Net Size | | Minimum Structural Composite Lumber Net Size | |
|---|---|---------------------------------|-------------|----------------------------------|-------------|--|-------------|
| | | Width, inch | Depth, inch | Width, inch | Depth, inch | Width, inch | Depth, inch |
| Floor loads only or combined floor and roof loads | Columns | 8 | 8 | 6-3/4 | 8-1/4 | 7 | 7-1/2 |
| | Wood beams and girders | 6 | 10 | 5 | 10-1/2 | 5-1/4 | 9-1/2 |
| Roof loads only | Columns | 6 | 8 | 5 | 8-1/4 | 5-1/4 | 7-1/2 |
| | Framed timber trusses and other roof framing ^a | 4 ^b | 6 | 3 ^b | 6-7/8 | 3-1/2 ^b | 5-1/2 |

Source: IBC Table 2304.11 / See IBC for footnotes

Contribution of Noncombustible Protection to FRR

When noncombustible protection is required to cover timber elements, it must provide at least two thirds of the FRR. For example, a beam that requires a 2-hour FRR and requires noncombustible protection must achieve at least 80 minutes of protection from the noncombustible coverings. Section 722.7, which is new to the 2021 IBC, has been introduced to codify the demonstration of FRR using a combination of time assigned to the noncombustible coverings and inherent fire-resistance of the mass timber framing members. (See Table 3.)

722.7 Fire-resistance rating of mass timber.

The required fire resistance of mass timber elements in Section 602.4 shall be determined in accordance with Section 703.2 or Section 703.3. The fire-resistance rating of building elements shall be as required in Tables 601 and 602 and as specified elsewhere in this code. The fire-resistance rating of the mass timber elements shall consist of the fire resistance of the unprotected element added to the protection time of the noncombustible protection.

TABLE 3:
Required Noncombustible Contribution to FRR

| FRR of Building Element (hours) | Minimum from Noncombustible Protection (minutes) |
|---------------------------------|--|
| 1 | 40 |
| 2 | 80 |
| 3 or more | 120 |

Source: 2021 IBC Table 722.7.1(1)

Any noncombustible material used as protection of mass timber elements can be tested by following the procedure outlined in IBC Section 703.8 to determine its contribution to FRR. However, two prescriptive options are presented in IBC 2021 Section 722.7.1. Determined through testing, these options are shown in Table 4.

TABLE 4:
Prescriptive Noncombustible Contributions to FRR

| Type of Protection | Contribution per Layer (minutes) |
|--------------------------|----------------------------------|
| 1/2" Type X gypsum board | 25 |
| 5/8" Type X gypsum board | 40 |

Source: 2021 IBC Table 722.7.1(2)

As shown in Tables 3 and 4, each layer of 5/8" Type X gypsum board meets the required two-thirds contribution for each hour of required fire resistance. In other words, where mass timber is required to have noncombustible protection, two layers of 5/8" Type X gypsum board covering would meet the requirements for a 2-hour FRR, and three layers would meet the requirements for a 3-hour FRR.

Contribution of Mass Timber to FRR

As noted, for mass timber elements requiring noncombustible protection, a minimum of two thirds of the FRR must be met by those materials. The remaining one third must be achieved through inherent fire resistance of the mass timber element.

For example, a mass timber floor assembly requiring a 2-hour FRR would require 80 minutes of noncombustible protection, with the remaining 40 minutes achieved from the mass timber. In applications where the timber is exposed, the full FRR must be achieved through inherent fire resistance of the mass timber element.

There are several options for demonstrating the contribution of various elements to the FRR. One method is to provide the results of testing undertaken in accordance with ASTM E119 (or UL 263). However, if the exact assembly has not been tested, IBC Sections 703.2 and 703.3 provide a number of alternatives. Section 703.3 states:

The required fire resistance of a building element, component or assembly shall be permitted to be established by any of the following methods or procedures:

1. Fire-resistance designs documented in approved sources
2. Prescriptive designs of fire resistance-rated building elements, components or assemblies as prescribed in Section 721
3. Calculations in accordance with Section 722

4. Engineering analysis based on a comparison of building element, component or assemblies designs having fire-resistance ratings as determined by the test procedures set forth in ASTM E119 or UL 263
5. Alternative protection methods as allowed by Section 104.11
6. Fire-resistance designs certified by an approved agency

These alternatives are all founded on ASTM E119 testing. Item 3, which permits the use of calculations in accordance with Section 722, is frequently used to demonstrate the fire-resistance rating of exposed mass timber. IBC Section 722.1 states: *The calculated fire resistance of exposed wood members and wood decking shall be permitted in accordance with Chapter 16 of ANSI/AWC National Design Specification® for Wood Construction (NDS®).* Chapter 16 of the NDS can be used to calculate up to a 2-hour fire-resistance rating for a variety of exposed wood members including solid sawn, glued-laminated timber (glulam), cross-laminated timber (CLT), and structural composite lumber (SCL).

Successful fire tests completed on numerous mass timber elements and assemblies have substantiated fire-resistance ratings of 3 hours or more. Additional tests by manufacturers and others are ongoing. Most are conducted according to ASTM E119 or its Canadian equivalent, ULC S101. Both utilize the same time-temperature curve and performance criteria and, as such, ULC S101 fire tests are usually acceptable to U.S. building officials. However, each project's building official should be consulted if choosing this design route.

To help building designers compare options, WoodWorks has compiled a web-based inventory of completed mass timber fire tests. *The Inventory of Fire Resistance-Tested Mass Timber Assemblies & Penetrations* is updated as new tests become available, and can be found at <http://bit.ly/2FRwAPG>.

For additional information on both the calculation-based method and the ASTM E119 testing method of demonstrating FRR of mass timber elements, see the WoodWorks publication *Fire Design of Mass Timber Members*.²

Noncombustible Protection on Top of Mass Timber Floors

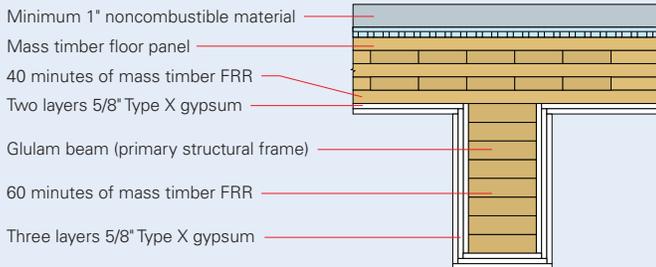
Although not necessarily required to achieve the floor assembly's FRR, floor assemblies in Types IV-A and IV-B construction require a minimum 1-inch-thick noncombustible covering. Examples include a poured concrete or gypsum layer, or sheets of noncombustible board products.

Example Assemblies

Based on the provisions and design options discussed in this paper, here are some example assemblies indicating total FRR and the contribution of each component.

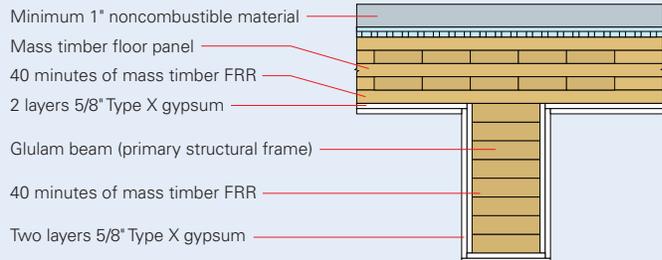
Type IV-A Fire-Resistance Ratings

Primary Frame (3-hr) + Floor Panel Example (2-hr)



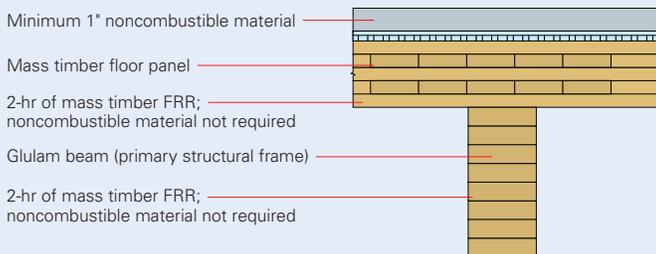
Type IV-B Protected Fire-Resistance Ratings

Primary Frame (2-hr) + Floor Panel Example (2-hr)



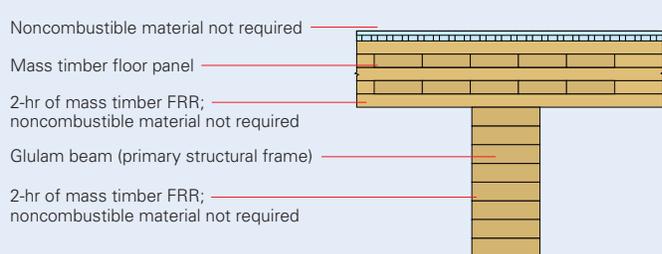
Type IV-B Exposed Fire-Resistance Ratings

Primary Frame (2-hr) + Floor Panel Example (2-hr)



Type IV-C Fire-Resistance Ratings

Primary Frame (2-hr) + Floor Panel Example (2-hr)



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¹Construction Types I and II are defined in IBC Section 602 as having all elements of noncombustible materials except where permitted in IBC Section 603.

²www.woodworks.org/wp-content/uploads/Wood_Solution_Paper-Fire-Design-of-Mass-Timber-Members-WoodWorks-Apr-2019.pdf