

Fire Design of Mass Timber Construction

This internal note, elaborated in collaboration with [CHM Fire Consultants Ltd.](#), specifies applicable Codes and Standards for fire design of mass timber construction along with recent significant changes and Nordic Structures position.

Applicable Codes and Standards

[International Building Code \(IBC\)](#)

The International Building Code (IBC) is a model building code developed by the International Code Council (ICC) and establishes minimum requirements for building systems using prescriptive and performance-related provisions. This code is intended to establish provisions that adequately protect public health, safety, and welfare.

Chapter 6 establishes five types of construction in which each building must be categorized. Depending on the type of construction and the specific building element, fire resistance of 1 to 3 hours is specified. The 2021 IBC includes three new construction types (i.e., Type IV-A, IV-B, and IV-C) based on the previous Heavy Timber construction type (renamed Type IV-HT) but with additional fire-resistance ratings and levels of required noncombustible protection. The 2024 IBC will allow fully exposed mass timber ceilings in Type IV-B construction.

Chapter 7 provides detailed requirements for fire-resistance-rated construction, including structural members, walls, partitions, and horizontal assemblies. This chapter specifies how these elements are constructed, how openings in walls and partitions are protected, and how penetrations of such elements are protected. Since the 2015 IBC, Section 722.1 allows the fire resistance of exposed wood members to be calculated in accordance with NDS Chapter 16, which is much broader in application and leaves less room for design error.

[National Design Specification \(NDS\) for Wood Construction](#)

The National Design Specification (NDS) for Wood Construction defines the methods to be followed in structural design with wood products such as structural glued-laminated timber and cross-laminated timber. It also defines the practice to be followed in the design and fabrication of single and multiple fastener connections.

Since 2001, the NDS has contained provisions in Chapter 16 for design of fire exposed wood members to meet code-required structural fire-resistance ratings based on a standardized ASTM E119 time-temperature exposure. A comprehensive discussion of this mechanics-based design procedure can be found in AWC's Technical Report No. 10.

[AWC's Technical Report No. 10 \(TR10\)](#)

The AWC's Technical Report No. 10 (TR10), *Calculating the Fire Resistance of Exposed Wood Members*, contains full details of the NDS Chapter 16 method as well as design examples. TR10 also defines additional calculation procedures to address the added fire resistance and thermal benefits of protection using additional wood, gypsum panel products, and some types of insulation. These additional calculation provisions have been developed to provide standardized methods of calculating thermal separation and burn-through requirements as required in ASTM E119.

[Fire Design Specification \(FDS\)](#)

The Fire Design Specification (FDS) incorporates the existing design provisions in NDS Chapter 16 and the new protection provisions contained within TR10. As of now, the FDS is referenced in neither the NDS nor the IBC. However, the 2024 NDS will most likely include changes to Chapter 16 that are necessary to bring the exposed wood member provisions into agreement with the 2022 FDS and provide both a general and specific references to the FDS, where thermal separation and burn-through resistance are required. AWC will be submitting FDS for reference in the 2027 IBC.

[NDS edition referenced in the IBC](#)

IBC	NDS
2015	2015 TR10-2015
2018	2018 TR10-2018
2021	2018 TR10-2018
2024	2024 FDS-20??

For more information about applicable Codes and Standards, refer to internal note *Codes and Standards* ([NS-NI203-US](#)).

Significant Changes

1. Sealing of Adjacent Mass Timber Elements for Buildings of Types IV-A, IV-B and IV-C Construction

Status	Effective since IBC 2021
Description	<u>703.7 Sealing of adjacent mass timber elements</u> In buildings of Types IV-A, IV-B and IV-C construction, sealant or adhesive shall be provided to resist the passage of air in the following locations: - At abutting edges and intersections of mass timber building elements required to be fire-resistance rated. - At abutting intersections of mass timber building elements and building elements of other materials where both are required to be fire-resistance rated. Sealants shall meet the requirements of ASTM C920. Adhesives shall meet the requirements of ASTM D3498. Exception: Sealants or adhesives need not be provided where they are not a required component of a tested fire-resistance-rated assembly. <u>1705.20 Sealing of mass timber.</u> Periodic special inspections of sealants or adhesives shall be conducted where sealant or adhesive required by Section 703.7 is applied to mass timber building elements as designated in the approved construction documents.
Rationale	This addresses new construction Types IV-A, IV-B and IV-C. The requirement to provide sealants or adhesive at intersections of fire-resistance-rated mass timber elements addresses the potential for air flow to carry hot gases and other products of combustion into gaps at the connections between mass timber elements. Construction adhesive or other sealants can be used to prevent air flow. Where a wall or horizontal assembly serves as the separation between two atmospheres, a fire creates differential pressure where heated gases raise the pressure and work to drive fire and hot gases through the structure. Voids that are not properly sealed can serve as a conduit for air movement during a fire, so abutting edges and intersections are recommended to be sealed. Periodic special inspections during construction are required to ensure that the appropriate sealant or adhesive is used and to establish inspections to verify for ongoing quality control. The exception is included so that any fire-resistance-rated mass timber assembly that has been tested to and passed ASTM E119 without such sealants or adhesive at mass timber element intersections will not be required to add any sealants or adhesive during design and construction.
Upcoming changes	No changes expected for IBC 2024.
Nordic Structures position	According to the IBC Commentary, Section 703.7 addresses the potential for air flow to carry hot gases and other products of combustion into gaps at the connections between mass timber elements. However, there are many cases where air flow through gaps does not occur and where Section 703.7 is thus deemed unnecessary: - A fire-resistant joint system in accordance with ASTM E1966 or UL 2079 is used to firestop the intersection. - The intersection is detailed to prevent burn-through. - Draftstopping material (e.g., 1/2-inch gypsum panel product, 3/8-inch wood structural panel, 3/8-inch particleboard, 1-inch (nominal) lumber, cement fiberboard) is installed on the unexposed side of the assembly. - The intersection occurs entirely within a single compartment (i.e. no pressure differential across the gap). Section 703.7 also requires sealants conforming to ASTM C920 (i.e. specifications for elastomeric joint sealants) or adhesives conforming to ASTM D3498 (i.e. specifications for adhesives for field-gluing plywood to lumber framing for floor systems). However, these standards cover a wide variety of sealant and adhesive chemistries and may not be appropriate if exposed to high temperatures where they are used for thermal separation and burn-through prevention. Products in conformance with ASTM E814, <i>Standard Test Method for Fire Tests of Penetration Firestop</i>, are deemed more appropriate where air flow through gaps occurs and sealing of adjacent mass timber elements is required. Many firestop sealants (e.g., Hilti FS-ONE MAX, Hilti CP 606, Hilti CFS-S SIL GG, and STI SSS100) and intumescent strips (e.g., Hilti CP 648-E) are certified under ASTM E814. Joint movement due to wood shrinkage, loading, creep, or lateral movement should be considered when specifying joint sealant details.

2. Char Penetration at Intersections and Abutting Edges

Status	Effective since NDS 2018 TR10-2018
Description	NDS 2018 C16.3 requires connections located at ends of members to be detailed to ensure that char contraction is addressed to prevent premature loss of protection. Where wood is used as protection, char contraction must be considered at ends and edges of protective elements. According to TR10-2018, for intersections and abutting edges of exposed wood members that are in contact, the char front shall be assumed to penetrate between wood members a distance equal to $2a_{char}$. This compares with $1.14a_{char}$ which is the thickness of wood protection usually required to provide thermal separation for steel components. It should be noted that bearing interfaces, however, don't need to be designed for char contraction.
Rationale	As wood chars, it contracts so the thickness of the char layer is less than the depth of the wood that has charred. Char contraction at unbonded wood member ends and edges results in ignition, albeit delayed, of wood surfaces in the gaps at these locations. As a result, ignition extends into these gaps a distance that is approximately twice the char depth, $2a_{char}$. As for bearing interfaces, AWC staff and others have looked at the available data and have concluded that there is no significant char penetration in this configuration.
Upcoming changes	The 2024 NDS will most likely reference the FDS for char penetration at intersection and abutting edges. The 2022 FDS considers different scenarios depending on the gap size in service and the occurrence or non-occurrence of air flow through the gap. Cases where air flow through the gap is permitted to be neglected are listed in Section 3.2.4.3 of the 2022 FDS. - Gap up to 1/8 inch (in service) a) Air flow through the gap can be neglected: Char front shall be assumed to penetrate between wood members a distance equal to $2.0a_{char}$. b) Air flow through the gap cannot be neglected: Wood surfaces within the gap shall be assumed to be fully exposed to fire for the full depth of the gap. - Gap over 1/8 inch (in service): Wood surfaces within the gap shall be assumed to be fully exposed to fire for the full depth of the gap.
Nordic Structures position	In July 2022, Nordic Structures conducted two ASTM E119 fire tests at Southwest Research Institute (SwRI). The two connections tested consisted of a glulam beam-to-column connection with a CLT floor slab. First test was a knife plate steel connector with a 5 mm (3/16 in.) gap between the end of the beam and the column (SwRI Project No. 01.26260.01.704). Second test was a bearing plate connector with a 3 mm (1/8 in.) gap between the end of the beam and the column (SwRI Project No. 01.27009.01.413). Connections were loaded by placing an axial load on the CLT floor slab a short distance from the column. Both tests achieved a 2-hour fire-resistance rating without firestop sealant at the gap between the end of the beam and the column. The presence of this gap did not seem to significantly affect the fire performance, and no evidence of char contraction on the end of the beam was observed (Mass Timber Connections Fire-Resistance Testing). The following recommendations have been established based on those test results: - Gap initially designed up to 1/8 inch a) Air flow through the gap can be neglected (see Section 3.2.4.3 of the 2022 FDS) i. End-grain-to-end-grain interfaces: Char contraction can be neglected. ii. End-grain-to-side-grain interfaces: Char contraction can be neglected. iii. Side-grain-to-side-grain interfaces: Char front shall be assumed to penetrate between wood members a distance equal to $2.0a_{char}$, except if a firestop is applied in which case char contraction can be neglected. b) Air flow through the gap cannot be neglected: Wood surfaces within the gap shall be assumed to be fully exposed to fire for the full depth of the gap, except if a firestop is applied in which case wood surfaces within the gap can be considered as fully protected. - Gap initially designed over 1/8 inch: Wood surfaces within the gap shall be assumed to be fully exposed to fire for the full depth of the gap, except if a firestop is applied in which case wood surfaces within the gap can be considered as fully protected. As mentioned, no evidence of char contraction on the end of the beam was observed for a gap of 3/16 inch. Initial gaps of 1/8 inch allows flexibility for potential dimensional changes in service. If a firestop is applied, it is recommended to apply intumescent firestop sealants (e.g., Hilti FS-ONE MAX and STI SSS100) or intumescent strips (e.g., Hilti CP 648-E) meeting the requirements of ASTM E814. Non-intumescent ASTM E814 products (e.g., Hilti CP 606 and Hilti CFS-S SIL GG) may be applied provided they fill the gap a distance equal to at least $1.0a_{char}$.

References

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