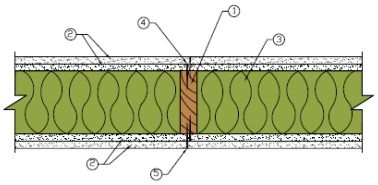

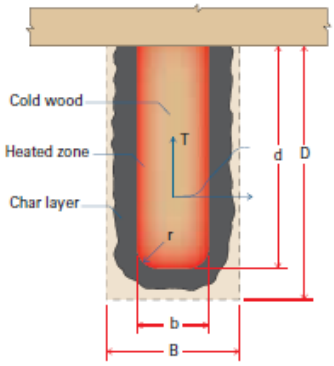

AMERICAN WOOD COUNCIL

Fire Resistance Design for Wood Construction – BCD220

John "Buddy" Showalter, P.E.
Vice President, Technology Transfer
American Wood Council

Michelle Kam-Biron, PE, SE, SECB
Senior Director, Education
American Wood Council

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- Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

3

Description

Determining proper code applications for designing for fire-resistance in wood-frame construction can be challenging. This presentation will include code requirements, compliance options, and nuances related to fire-resistance rated assemblies, fire design of exposed wood members, and flame-spread performance of wood products. Included will be design examples for calculating fire-resistance for exposed wood members and the component additive method for assemblies.

4

Learning Objectives

1. Apply approved methods and alternatives for establishing the fire-resistance of wood building elements.
2. Identify some distinguishing characteristics of fire-resistance rated exterior walls, fire walls, fire barriers, and fire partitions.
3. Understand the basic fire-resistance design procedures for wood frame assemblies and certain exposed wood members.
4. Understand code requirements for flame spread performance of wood products.

5

Polling Question

1. **What is your profession?**
   a) Architect
   b) Engineer
   c) Code Official
   d) Building Designer
   e) Other

6

Outline

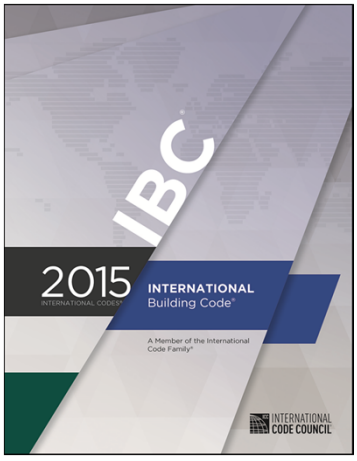
- **Code Overview**
  - **Background**
  - **Fire-resistance building elements**
- **Achieving Fire-Resistance**

7

International Building Code

The IBC

- **Controls building size**
- **Regulates types of materials**
- **Stipulates fire-resistance**

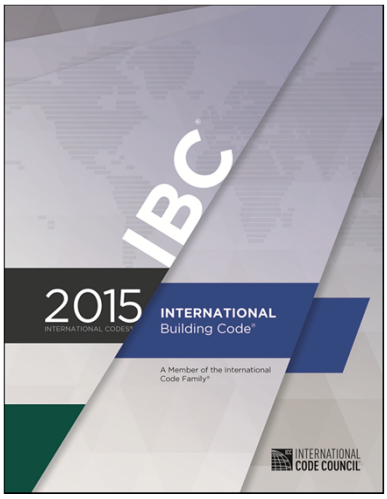


8

International Building Code

Allowable heights & areas determined by

- **Tabular values**
- **Factors allowing increases**
  - Frontage
  - Sprinkler Systems
- **Special Provisions IBC 510**



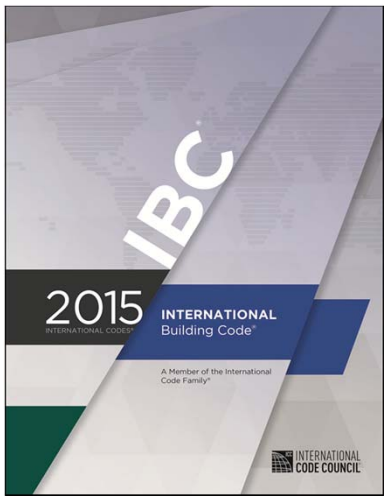
9

Allowable Heights & Areas

Allowable area is based upon

- **Use of building**
- **Type of construction**
- **Frontage**
- **Existence of sprinkler systems**

Tabular areas establish *minimum* allowable building areas that can be increased by added fire safety features - frontage and/or sprinkler.

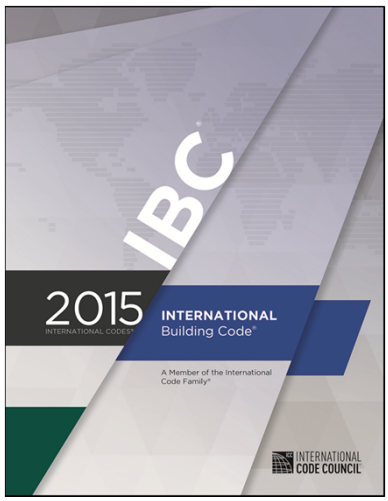


10

Allowable Heights & Areas

Each occupancy group presents a different level of fire and life safety risk

- Number of occupants
- Capability of occupants
- Fuel load



11

Allowable Heights & Areas

Allowable heights and areas are based on a concept of equivalent risk, involving three interdependent considerations

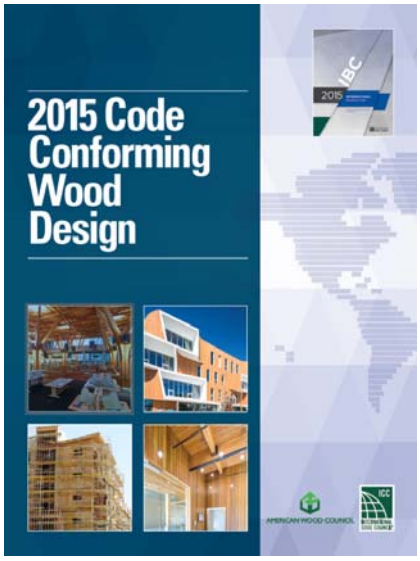
- level of fire hazard likely to be associated with the occupancy
- nature of contents associated with the use
- level of overall fire protection provided by the
  - Type of construction
  - Setbacks of the building from other structures (exposure)
  - Sprinklers and life safety systems
  - Other code trade-offs

12

2015 Code Conforming Wood Design

- Special occupancies
- Fire-resistance
- Building features
- Wood in noncombustible construction types
- Structural considerations
- Precautions during construction

- **Also available for 2009 and 2012 IBC**
  - **http://awc.org/codes-standards/buildingcodes/ccwd**



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2015 Code Conforming Wood Design

	Occupancy Classification		Type of Construction				
			Type III		Type IV	Type V	
			A	B	HT	A	B
TABLE 504.3: Allowable Building Height (Ft above Grade)	A, B, E, F, M, S, U	NS	65	55	65	50	40
		S	85	75	85	70	60
	I-1 Condition 1, I-3	NS	65	55	65	50	40
		S	85	75	85	70	60
	I-1 Condition 2, I-2	NS	65	55	65	50	40
		S					
	I-4	NS	65	55	65	50	40
		S	85	75	85	70	60
	R	NS	65	55	65	50	40
		S13R	60	60	60	60	60
		S	85	75	85	70	60

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2015 Code Conforming Wood Design

TABLE 504.4: Allowable Number of Stories above Grade							
	A-1, A-2, A-3, A-4	NS	3	2	3	2	1
		S	4	3	4	3	2
	B	NS	5	3	5	3	2
		S	6	4	6	4	3
	E	NS	3	2	3	1	1
		S	4	3	4	2	2
	M	NS	4	2	4	3	1
		S	5	3	5	4	2
	S-2	NS	4	3	4	4	2
		S	5	4	5	5	3
	R-1	NS	4	4	4	3	2
		S13R				4	3
		S	5	5	5	4	3
	R-2	NS	4	4	4	3	2
		S13R				4	3
		S	5	5	5	4	3

2015 Code Conforming Wood Design

TABLE 506.2: Allowable Area Factor							
	A-2, A-3	NS	14,000	9,500	15,000	11,500	6,000
		S1	56,000	38,000	60,000	46,000	24,000
		SM	42,000	28,500	45,000	34,500	18,000
	B	NS	28,500	19,000	36,000	18,000	9,000
		S1	114,000	76,000	144,000	72,000	36,000
		SM	85,500	57,000	108,000	54,000	27,000
	E	NS	23,500	14,500	25,500	18,500	9,500
		S1	94,000	58,000	102,000	74,000	38,000
		SM	70,500	43,500	76,500	55,500	28,500
	M	NS	18,500	12,500	20,500	14,000	9,000
		S1	74,000	50,000	82,000	56,000	36,000
		SM	55,500	37,500	61,500	42,000	27,000
	S-2	NS	39,000	26,000	38,500	21,000	13,500
		S1	156,000	104,000	154,000	84,000	54,000
		SM	117,000	78,000	115,500	63,000	40,500
	R-1, R-2	NS	24,000	16,000	20,500	12,000	7,000
		S13R					
		S1	96,000	64,000	82,000	48,000	28,000
		SM	72,000	48,000	61,500	36,000	21,000

NS - nonsprinklered
S - sprinklered (NFPA 13 System)
S13R - sprinklered NFPA 13R requirements (NFPA 13R System)
S1 - single-story sprinklered building (NFPA 13 System)
SM - multistory sprinklered building (NFPA 13 System)

Building Elements

Table 601 Fire-Resistance Rating Requirements For Building Elements (hours)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A[d]	B	A[d]	B	HT	A[d]	B
Primary structural frame[g] (see Section 202)	3[a]	2[a]	1	0	1	0	HT	1	0
Bearing walls, Exterior[f, g]	3	2	1	0	2	2	2	1	0
Interior	3[a]	2[a]	1	0	1	0	1/HT	1	0
Nonbearing walls and partitions, Exterior	See Table 602								
Nonbearing walls and partitions, Interior[e]	0	0	0	0	0	0	See Section 602.4.6	0	0
Floor construction and associated secondary members (see Section 202)	2	2	1	0	1	0	HT	1	0
Roof construction and associated secondary members (see Section 202)	1-1/2[b]	1[b,c]	1[b,c]	0[c]	1[b,c]	0	HT	1[b,c]	0

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Exterior Walls

TABLE 602
FIRE-RESISTANCE RATING REQUIREMENTS FOR EXTERIOR WALLS BASED ON FIRE SEPARATION DISTANCE[a, e, h]

FIRE SEPARATION DISTANCE = X (feet)	TYPE OF CONSTRUCTION	OCCUPANCY GROUP H[f]	OCCUPANCY GROUP F-1, M, S-1[g]	OCCUPANCY GROUP A, B, E, F-2, I, R, S-2[g], U[b]
X < 5[c]	All	3	2	1
5 ≤ X < 10	IA	3	2	1
	Others	2	1	1
10 ≤ X < 30	IA, IB	2	1	1[d]
	IIB, VB	1	0	0
	Others	1	1	1[d]
X ≥ 30	All	0	0	0

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Fire Partition (708)

- A vertical assembly of materials designed to restrict the spread of fire in which openings are protected
- Not a fire barrier and not a fire wall
  - **Wall assemblies for**
    - Separation walls for Group I-1, R-1, R-2 and R-3 per section 420.2
    - Walls separating tenant spaces in covered and open mall buildings per section 402.4.2.1
    - Corridor walls per section 1020.1
    - Elevator lobby separation per section 3006.2
    - Egress balconies per section 1019.2

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Fire Partition (708)

- A vertical assembly of materials designed to restrict the spread of fire in which openings are protected (cont.)
  - **Of materials permitted by the building type of construction**
  - **Fire-resistance rating 708.3** not less than 1 hour
    - See exceptions for corridor walls, dwelling unit separations, and sleeping unit separations

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Fire Barrier (707)

- A fire-resistance-rated wall assembly of materials designed to restrict the spread of fire in which continuity is maintained
- Not a fire wall
- **Of materials permitted by the building type of construction**
  - **Fire-resistance rating 707.3 - specific ratings as indicated for** shaft enclosures, interior exit stairways and ramp, enclosed exit access stairways, exit passageway, horizontal exit, atriums, incidental uses, control areas, separated occupancies, fire areas

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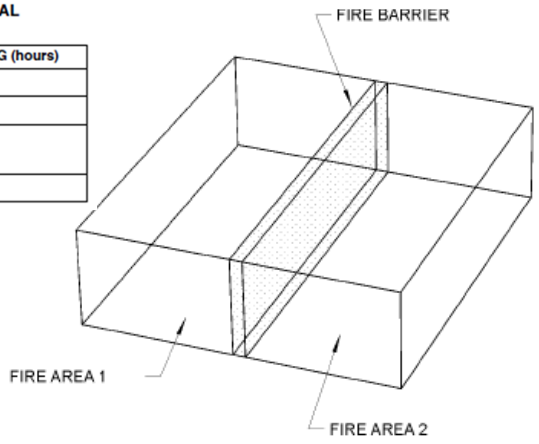
Fire Barrier (707)

Fire-resistance rating for separation of fire areas per table 707.3.10

TABLE 707.3.10
FIRE-RESISTANCE RATING REQUIREMENTS FOR FIRE BARRIER ASSEMBLIES OR HORIZONTAL ASSEMBLIES BETWEEN FIRE AREAS

OCCUPANCY GROUP	FIRE-RESISTANCE RATING (hours)
H-1, H-2	4
F-1, H-3, S-1	3
A, B, E, F-2, H-4, H-5, I, M, R, S-2	2
U	1



BUILDING AREA = FIRE AREA 1 + FIRE AREA 2

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Separation of Occupancies

TABLE 508.4
REQUIRED SEPARATION OF OCCUPANCIES (HOURS)

OCCUPANCY	A, E		I-1[a], I-3, I-4		I-2		R[a]		F-2, S-2[b], U		B[e], F-1, M, S-1		H-1		H-2		H-3, H-4		H-5	
	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS
A, E	N	N	1	2	2	NP	1	2	N	1	1	2	NP	NP	3	4	2	3	2	NP
I-1[a], I-3, I-4	—	—	N	N	2	NP	1	NP	1	2	1	2	NP	NP	3	NP	2	NP	2	NP
I-2	—	—	—	—	N	N	2	NP	2	NP	2	NP	NP	NP	3	NP	2	NP	2	NP
R[a]	—	—	—	—	—	—	N	N	1[c]	2[c]	1	2	NP	NP	3	NP	2	NP	2	NP
F-2, S-2[b], U	—	—	—	—	—	—	—	—	N	N	1	2	NP	NP	3	4	2	3	2	NP
B[e], F-1, M, S-1	—	—	—	—	—	—	—	—	—	—	N	N	NP	NP	2	3	1	2	1	NP
H-1	—	—	—	—	—	—	—	—	—	—	—	—	N	NP	NP	NP	NP	NP	NP	NP
H-2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	NP	1	NP	1	NP
H-3, H-4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1[d]	NP	1	NP
H-5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	NP

S = Buildings equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1.
NS = Buildings not equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1.
N = No separation requirement.
NP = Not permitted.
a See Section 420.
b. The required separation from areas used only for private or pleasure vehicles shall be reduced by 1 hour but not to less than 1 hour.
c. See Section 406.3.4.
d. Separation is not required between occupancies of the same classification.
e. See Section 422.2 for ambulatory care facilities.

Shaft Enclosures (713)

- **Constructed as fire barriers (713.2) and continuity provisions are the same (713.5)**
- **Of materials permitted by the building type of construction (713.3)**
- **Openings and penetrations are not permitted except those necessary to serve the shaft (713.7 and 713.8)**
- **713.11 and 713.12 for special provision for enclosure at the top and bottom of the shaft**
- **Fire resistance rating:** Shaft enclosures shall have a fire-resistance rating of not less than 2 hours where connecting four stories or more; not less than 1 hour where connecting less than four stories; and not less than the rating of the floor penetrated. (713.4)

Fire Walls (706)

- **Define separate buildings for allowable building size (706)**
  - **Requires continuity from foundation through the roof and constructed to allow collapse on either side under fire conditions without collapse of the wall**
  - **Not smoke barriers, smoke partitions or horizontal assemblies**
  - **Table 706.4 gives required ratings based on occupancy**

TABLE 706.4
FIRE WALL FIRE-RESISTANCE RATINGS

GROUP	FIRE-RESISTANCE RATING (hours)
A, B, E, H-4, I, R-1, R-2, U	3[a]
F-1, H-3[b], H-5, M, S-1	3
H-1, H-2	4[b]
F-2, S-2, R-3, R-4	2

a. In Type II or V construction, walls shall be permitted to have a 2-hour *fire-resistance rating*.
b. For Group H-1, H-2 or H-3 buildings, also see Sections 415.7 and 415.8.

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Fire Walls (706.3)

- **Type V construction**
  - **Fire walls may be wood frame**
- **Types I, II, III and IV construction**
  - **Fire walls must be of noncombustible materials in accordance with Section 706.3**

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Smoke Barriers (709)

- A continuous membrane, either vertical or horizontal, such as a wall, floor or ceiling assembly, that is designed and constructed to restrict the movement of smoke
- **Vertical and horizontal smoke barriers**
  - **Of materials permitted by the building type of construction**
  - **Mostly required in Hospital and Healthcare Facilities**
  - **1 hour fire-resistance rating** Exception: Smoke barriers constructed of minimum 0.10- inch-thick (2.5 mm) steel in Group I-3 buildings. (709.3)

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Horizontal Assemblies (711)

- A fire-resistance-rated floor or *roof assembly* of materials designed to restrict the spread of fire in which continuity is maintained
  - **Of materials permitted by the building type of construction**
  - **Fire-resistance rating - specific ratings as indicated 711.2.4 but not less than that for building type of construction:** separating mixed occupancies, fire areas, dwelling units and sleeping units, smoke compartments, incidental uses, other separations

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Polling Question

2. Which of the following can be built out of wood for Type V Construction?

a) Fire Wall
b) Fire Barrier
c) Fire Partition
d) b and c
e) All of the above

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Outline

- **Code Overview**
  - **Background**
  - **Fire-resistance building elements**
- **Achieving Fire-Resistance**

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Methods for Determining Fire-Resistance (703)

1. (703.2) Tested fire assembly (ASTM E 119 or UL 263) (703.3)
2. Fire-resistance designs documented in approved sources
3. Prescriptive assemblies using of fire-resistance-rated designs in Section 721
4. Calculation of fire-resistance per Section 722
5. Engineering analysis based on a comparison of building element, component or assembly designs that have been tested
6. Alternative protection methods per Section 104.11
7. Fire-resistance designs certified by an approved agency

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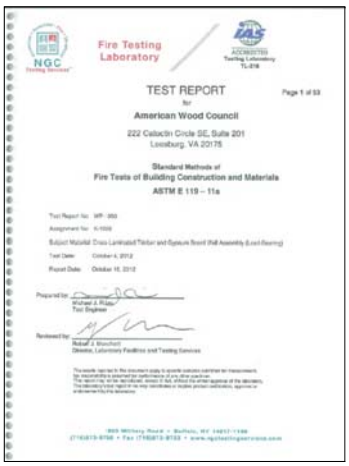
Fire Tests

Tested fire assembly (ASTM E 119)


Fire Testing Laboratory

TEST REPORT

for

American Wood Council

222 Catoctin Circle SE, Suite 201

Leesburg, VA 20175

Standard Methods of Fire Tests of Building Construction and Materials ASTM E 119 – 11a

http://www.awc.org/Code-Officials/2012-IBC-Challenges/#

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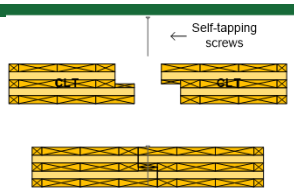
Fire Test

American Wood Council
ASTM E119 Fire Endurance Test
- 5-Ply CLT (approx. 7" thick)
- 5/8" Type X GWB each side
- Sought 2 hour rating
- RESULTS: 3 hours 6 minutes



Half-lapped – middle of panel

Fire Test

National Frame Building Association
ASTM E119 Fire Endurance Test
- 4-Ply 2x6 (approx. 6" thick)
- 2x4 girts at 16" o.c.
- 4 layers 5/8" Type X GWB each side
- RESULTS: 3 hours 47 minutes

See *Frame Building News* January 2014
"NFBA ATTAINS CERTIFICATION FOR 2- AND 1-HOUR FIRE-RATED WALLS"
http://www.nfba.org/uploads/T_and_R_January_Article.pdf

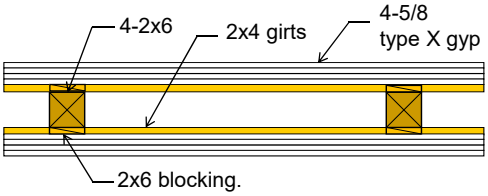
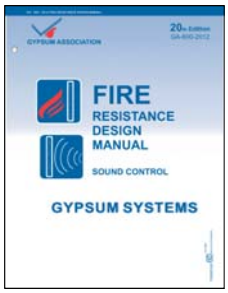


Figure 1. Full-scale testing of a post-frame fire-wall assembly

Documented in Approved Source

- **Based on testing to the ASTM E 119 or UL 263 standard**
- **Choose listed assemblies from fire-resistance publications or directories**



Documented in Approved Source

Fire-resistance design - AWC Design for Code Acceptance Pubs

Documented in Approved Source

DCA 3

Fire-Resistive Wood Wall and Floor/Ceiling Assemblies

- **ASTM E 119 or UL 263**
- **NFPA 251**


Design for Code Acceptance 3

Fire-Rated Wood-Frame Wall and Floor/Ceiling Assemblies

Building Code Requirements

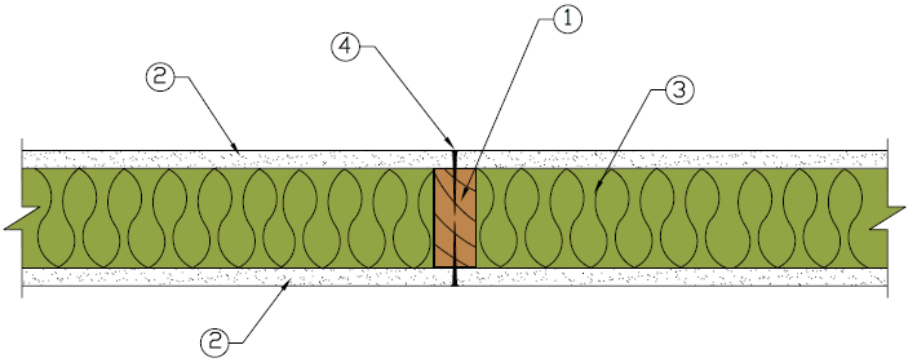
Fire Tested Assemblies

Conclusions

Documented in Approved Source

WS4-1.1 One Hour Fire-Resistive Wood-Frame Wall Assembly

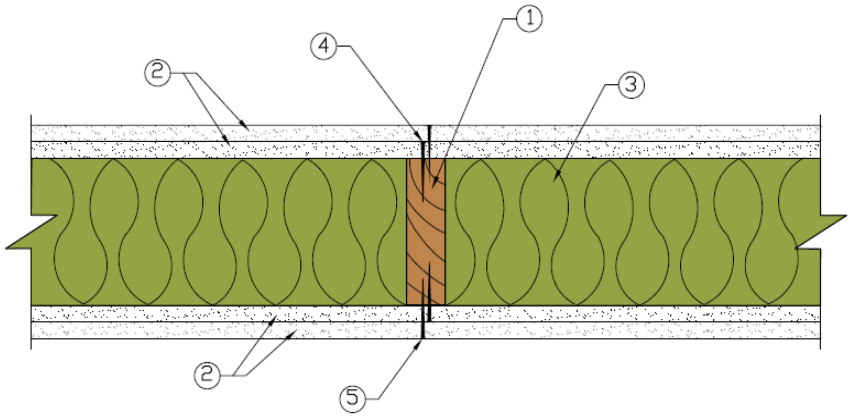
2x4 Wood Stud Wall – 100% Design Load – ASTM E 119/NFPA 251



Documented in Approved Source

WS6-2.1 Two-Hour Fire-Resistive Wood-Frame Wall Assembly

2x6 Wood Stud Wall – 100% Design Load – ASTM E 119/NFPA 251



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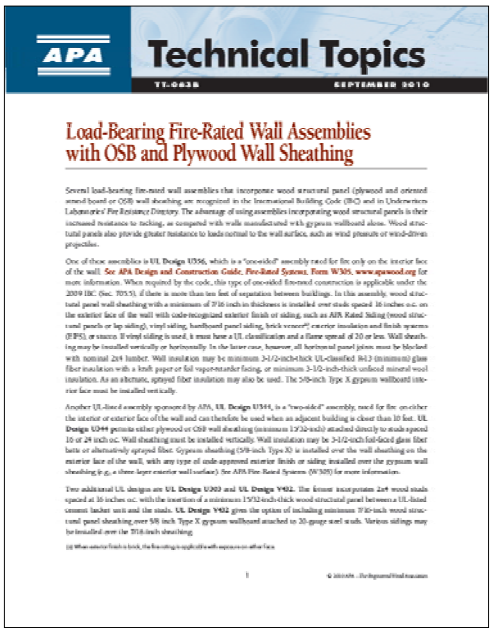

APA Technical Topics

TT-063B SEPTEMBER 2010

Load-Bearing Fire-Rated Wall Assemblies with OSB and Plywood Wall Sheathing

Several load-bearing fire-rated wall assemblies that incorporate wood structural panel (plywood and oriented strand board or OSB) wall sheathing are recognized in the International Building Code (IBC) and in Underwriters Laboratories's *Fire Resistance Directory*. The advantage of using assemblies incorporating wood structural panels is their increased resistance to racking, as compared with walls manufactured with gypsum wallboard alone. Wood structural panels also provide greater resistance to loads normal to the wall surface, such as wind pressure or wind-driven projectiles.

One of these assemblies is **UL Design U356**, which is a "one-sided" assembly rated for fire only on the interior face of the wall. **See APA Design and Construction Guide, Fire-Rated Systems, Form W305, www.apawood.org** for more information. When required by the code, this type of one-sided fire-rated construction is applicable under the 2009 IBC (Sec. 705.5), if there is more than ten feet of separation between buildings. In this assembly, wood structural panel wall sheathing with a minimum of 7/16 inch in thickness is installed over studs spaced 16 inches o.c. on the exterior face of the wall with code-recognized exterior finish or siding, such as APA Rated Siding (wood structural panels or lap siding), vinyl siding, hardboard panel siding, brick veneer[a], exterior insulation and finish systems (EIFS), or stucco. If vinyl siding is used, it must have a UL classification and a flame spread of 20 or less. Wall sheathing may be installed vertically or horizontally. In the latter case, however, all horizontal panel joints must be blocked with nominal 2x4 lumber. Wall insulation may be minimum 3-1/2-inch-thick UL-classified R-13 (minimum) glass fiber insulation with a kraft paper or foil vapor-retarder facing, or minimum 3-1/2-inch-thick unfaced mineral wool insulation. As an alternate, sprayed fiber insulation may also be used. The 5/8-inch Type X gypsum wallboard interior face must be installed vertically.

Another UL-listed assembly sponsored by APA, **UL Design U344**, is a "two-sided" assembly, rated for fire on either the interior or exterior face of the wall and can therefore be used when an adjacent building is closer than 10 feet. **UL Design U344** permits either plywood or OSB wall sheathing (minimum 15/32-inch) attached directly to studs spaced 16 or 24 inch o.c. Wall sheathing must be installed vertically. Wall insulation may be 3-1/2-inch foil-faced glass fiber batts or alternately sprayed fiber. Gypsum sheathing (5/8-inch Type X) is installed over the wall sheathing on the exterior face of the wall, with any type of code-approved exterior finish or siding installed over the gypsum wall sheathing (e.g., a three layer exterior wall surface). See APA Fire-Rated Systems (W305) for more information.

Two additional UL designs are **UL Design U303** and **UL Design V402**. The former incorporates 2x4 wood studs spaced at 16 inches o.c. with the insertion of a minimum 15/32-inch-thick wood structural panel between a UL-listed cement backer unit and the studs. **UL Design V402** gives the option of including minimum 7/16-inch wood structural panel sheathing over 5/8 inch Type X gypsum wallboard attached to 20-gauge steel studs. Various sidings may be installed over the 7/16-inch sheathing.

[a] When exterior finish is brick, the fire rating is applicable with exposure on either face.

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WSP over Gypsum

Special Design Provisions for Wind and Seismic 2015

Table 4.3B Nominal Unit Shear Capacities for Wood-Frame Shear Walls[1,2,5,6]

Wood Structural Panels Applied over 1/2" or 5/8" Gypsum Wallboard or Gypsum Sheathing Board

Sheathing Material	Minimum Nominal Panel Thickness (in.)	Minimum Fastener Penetration in Framing Member or Blocking (in.)	Fastener Type & Size	A SEISMIC Panel Edge Fastener Spacing (in.) 6 v_s (plf)	6 G_a (kips/in.) OSB	6 G_a (kips/in.) PLY	4 v_s (plf)	4 G_a (kips/in.) OSB	4 G_a (kips/in.) PLY	3 v_s (plf)	3 G_a (kips/in.) OSB	3 G_a (kips/in.) PLY	2 v_s (plf)	2 G_a (kips/in.) OSB	2 G_a (kips/in.) PLY	B WIND Panel Edge Fastener Spacing (in.) 6 v_w (plf)	4 v_w (plf)	3 v_w (plf)	2 v_w (plf)
Wood Structural Panels - Structural I[3,4]	5/16	1-1/4	Nail (common or galvanized box) 8d	400	13	10	600	18	13	780	23	16	1020	35	22	560	840	1090	1430
	3/8, 7/16, 15/32	1-3/8	10d	560	14	11	860	18	14	1100	24	17	1460	37	23	785	1205	1540	2045
Wood Structural Panels - Sheathing[3,4]	5/16	1-1/4	8d	360	13	9.5	540	18	12	700	24	14	900	37	18	505	755	980	1260
	3/8			400	11	8.5	600	15	11	780	20	13	1020	32	17	560	840	1090	1430
	3/8, 7/16, 15/32	1-3/8	10d	520	13	10	760	19	13	980	25	15	1280	39	20	730	1065	1370	1790
Plywood Siding	5/16	1-1/4	Nail (galvanized casing) 8d (2-1/2" x0.113")	280		13	420		16	550		17	720		21	390	590	770	1010
	3/8	1-3/8	10d (3"x0.128")	320		16	480		18	620		20	820		22	450	670	870	1150

1. Nominal unit shear capacities shall be adjusted in accordance with 4.3.3 to determine ASD allowable unit shear capacity and LRFD factored unit resistance. For general construction requirements see 4.3.6. For specific requirements, see 4.3.7.1 for wood structural panel shear walls. See Appendix A for common and box nail dimensions.
2. For species and grades of framing other than Douglas-Fir-Larch or Southern Pine, reduced nominal unit shear capacities shall be determined by multiplying the tabulated nominal unit shear capacity by the Specific Gravity Adjustment Factor = [1-(0.5-G)], where G = Specific Gravity of the framing lumber from the *NDS* (Table 12.3.3A). The Specific Gravity Adjustment Factor shall not be greater than 1.
3. Apparent shear stiffness values, G_a, are based on nail slip in framing with moisture content less than or equal to 19% at time of fabrication and panel stiffness values for shear walls constructed with either OSB or 3 ply plywood panels. When 4-ply or 5-ply plywood panels or composite panels are used, G_a values for plywood shall be permitted to be multiplied by 1.2.
4. Where moisture content of the framing is greater than 19% at time of fabrication, G_a values shall be multiplied by 0.5.
5. Where panels are applied on both faces of a shear wall and nail spacing is less than 6" on center on either side, panel joints shall be offset to fall on different framing members. Alternatively, the width of the nailed face of framing members shall be 3" nominal or greater at adjoining panel edges and nails at all panel edges shall be staggered.
6. Galvanized nails shall be hot-dipped or tumbled.

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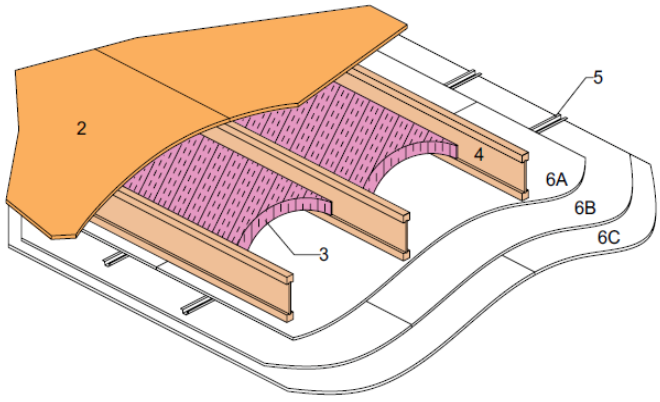
Documented in Approved Source

WIJ-2.1 Two-Hour Fire-Resistive Ceiling Assembly

Floor[a]/Ceiling - 100% Design Load - 2 Hour Rating - ASTM E 119 / NFPA 251



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Prescriptive Fire-Resistance Rated Assemblies

Fire-resistance of certain wood assemblies is prescribed in Section 721 based on testing using ASTM E 119 or UL 263

TABLE 721.1(3)—continued
MINIMUM PROTECTION FOR FLOOR AND ROOF SYSTEMS[a, q]

FLOOR OR ROOF CONSTRUCTION	ITEM NUMBER	CEILING CONSTRUCTION	THICKNESS OF FLOOR OR ROOF SLAB (inches)				MINIMUM THICKNESS OF CEILING (inches)			
			4 hours	3 hours	2 hours	1 hour	4 hours	3 hours	2 hours	1 hour
28. Wood I-joist (minimum I-joist depth $9^1/_4$" with a minimum flange depth of $1^1/_2$" and a minimum flange cross-sectional area of 2.25 square inches; minimum web thickness of $^3/_8$") @ 24" o.c. Unfaced fiberglass insulation or mineral wool insulation is installed between the I-joists supported on the upper surface of the flange by stay wires spaced 12" o.c.	28-1.1	Base layer of $^5/_8$" Type C gypsum wallboard attached directly to I-joists with $1^5/_8$" Type S drywall screws spaced 12" o.c. with ends staggered. Minimum 0.0179" thick hat-shaped $^7/_8$-inch furring channel 16" o.c. (channels doubled at wallboard end joints), placed perpendicular to the joist and attached to each joist by $1^5/_8$" Type S drywall screws after the base layer of gypsum wallboard has been applied. The middle and face layers of $^5/_8$" Type C gypsum wallboard applied perpendicular to the channel with end joints staggered. The middle layer is fastened with 1" Type S drywall screws spaced 12" o.c. The face layer is applied parallel to the middle layer but with the edge joints offset 24" from those of the middle layer and fastened with $1^5/_8$" Type S drywall screws 8" o.c. The joints shall be taped and covered with joint compound.	—	—	—	Varies	—	—	$2^3/_4$	—

Prescriptive Fire-Resistance-Rated Assemblies

Fire-resistance of certain wood assemblies is prescribed in Section 721 based on testing using ASTM E 119 or UL 263

TABLE 721.1(2)—continued
RATED FIRE-RESISTANCE PERIODS FOR VARIOUS WALLS AND PARTITIONS [a, o, p]

MATERIAL	ITEM NUMBER	CONSTRUCTION	MINIMUM FINISHED THICKNESS FACE-TO-FACE[b] (inches)			
			4 hours	3 hours	2 hours	1 hour
	14-1.1[h, m]	2" × 4" wood studs 16" on center with two layers of $^3/_8$" regular gypsum wallboard[e] each side, 4d cooler[n] or wallboard[n] nails at 8" on center first layer, 5d cooler[n] or wallboard[n] nails at 8" on center second layer with laminating compound	—	—	—	5
	14-1.2[h, m]	2" × 4" wood studs 16" on center with two layers $^1/_2$" regular gypsum wallboard[e] applied vertically or horizontally each side[k], joints staggered. Nail base layer with 5d cooler[n] or wallboard[n] nails at 8" on center face layer with 8d cooler[n] or wallboard[n] nails at 8" on center.	—	—	—	$5^1/_2$
14. Wood studs-interior partition with gypsum wallboard each side	14-1.3[k, m]	2" × 4" wood studs 24" on center with $^5/_8$" Type X gypsum wallboard[e] applied vertically or horizontally nailed with 6d cooler[n] or wallboard[n] nails at 7" on center with end joints on nailing members. Stagger joints each side.	—	—	—	$4^3/_4$
	14-1.4[i]	2" × 4" fire-retardant-treated wood studs spaced 24" on center with one layer of $^5/_8$" Type X gypsum wallboard[e] applied with face paper grain (long dimension) parallel to studs. Wallboard attached with 6d cooler[n] or wallboard[n] nails at 7" on center.	—	—	—	$4^3/_4$[d]

m. For studs with a slenderness ratio, l_e/d, greater than 33, the design stress shall be reduced to 78 percent of allowable F'_c. For studs with a slenderness ratio, l_e/d, not exceeding 33, the design stress shall be reduced to 78 percent of the adjusted stress F'_c calculated for studs having a slenderness ratio l_e/d of 33.

Polling Question

3. **The code always requires an assembly to be fire tested to establish fire-resistance rating, T/F?**

   True

   False

Calculated Resistance (703.3)

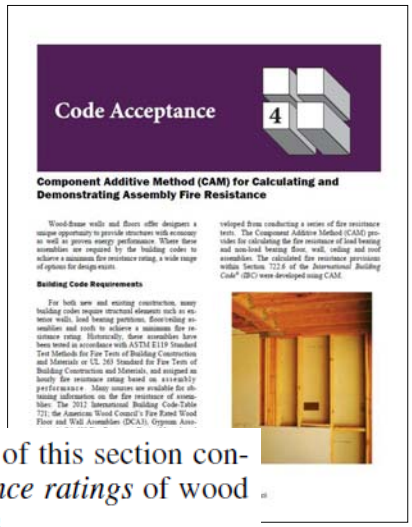
- **Fire-resistance of wood frame assemblies also may be calculated based on the known fire-resistance of the components, using the provisions of Section 722.6**
  - **1.0 hour maximum**

722.6 Wood assemblies. The provisions of this section contain procedures by which the *fire-resistance ratings* of wood assemblies are established by calculations.

Calculated Fire Resistance (722.6)

DCA 4

Component Additive Method (CAM) for Calculating and Demonstrating Assembly Fire Endurance



722.6 Wood assemblies. The provisions of this section contain procedures by which the *fire-resistance ratings* of wood assemblies are established by calculations.

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Calculated Fire Resistance (722.6)

CAM Membrane Table

Time Assigned to Protective Membranes

- IBC Table 722.6.2(1)

TABLE 722.6.2(1)
TIME ASSIGNED TO WALLBOARD MEMBRANES[a, b, c, d]

DESCRIPTION OF FINISH	TIME[e] (minutes)
3/8-inch wood structural panel bonded with exterior glue	5
15/32-inch wood structural panel bonded with exterior glue	10
19/32-inch wood structural panel bonded with exterior glue	15
3/8-inch gypsum wallboard	10
1/2-inch gypsum wallboard	15
5/8-inch gypsum wallboard	30
1/2-inch Type X gypsum wallboard	25
5/8-inch Type X gypsum wallboard	40
Double 3/8-inch gypsum wallboard	25
1/2-inch + 3/8-inch gypsum wallboard	35
Double 1/2-inch gypsum wallboard	40

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Calculated Fire Resistance (722.6)

CAM Wood Component Table

Assigned Times for Wood Components

IBC Table 722.6.2(2)

TABLE 722.6.2(2)
TIME ASSIGNED FOR CONTRIBUTION OF WOOD FRAME [a, b, c]

DESCRIPTION	TIME ASSIGNED TO FRAME (minutes)
Wood studs 16 inches o.c.	20
Wood floor and roof joists 16 inches o.c.	10

For SI: 1 inch = 25.4 mm.
a. This table does not apply to studs or joists spaced more than 16 inches o.c.
b. All studs shall be nominal 2 × 4 and all joists shall have a nominal thickness of not less than 2 inches.
c. Allowable spans for joists shall be determined in accordance with Sections 2308.4.2.1, 2308.7.1 and 2308.7.2.

Calculated Fire Resistance (722.6)

CAM Wall Membranes

Membranes on Exterior Face of Walls

IBC Table 722.6.2(3)

TABLE 722.6.2(3)
MEMBRANE[a] ON EXTERIOR FACE OF WOOD STUD WALLS

SHEATHING	PAPER	EXTERIOR FINISH
$^5/_8$-inch T & G lumber $^5/_{16}$-inch exterior glue wood structural panel $^1/_2$-inch gypsum wallboard $^5/_8$-inch gypsum wallboard $^1/_2$-inch fiberboard	Sheathing paper	Lumber siding Wood shingles and shakes $^1/_4$-inch fiber-cement lap, panel or shingle siding $^1/_4$-inch wood structural panels-exterior type $^1/_4$-inch hardboard Metal siding Stucco on metal lath Masonry veneer Vinyl siding
None	—	$^3/_8$-inch exterior-grade wood structural panels

For SI: 1 inch = 25.4 mm.
a. Any combination of sheathing, paper and exterior finish is permitted.

Calculated Fire Resistance (722.6)

CAM Cavity Insulation Table

Assigned Times for Insulation of Cavity

- IBC Table 722.6.2(5)

TABLE 722.6.2(5)
TIME ASSIGNED FOR ADDITIONAL PROTECTION

DESCRIPTION OF ADDITIONAL PROTECTION	FIRE RESISTANCE (minutes)
Add to the *fire-resistance rating* of wood stud walls if the spaces between the studs are completely filled with glass fiber mineral wool batts weighing not less than 2 pounds per cubic foot (0.6 pound per square foot of wall surface) or rockwool or slag material wool batts weighing not less than 3.3 pounds per cubic foot (1 pound per square foot of wall surface), or cellulose insulation having a nominal density not less than 2.6 pounds per cubic foot.	15

For SI: 1 pound/cubic foot = 16.0185 kg/m^3.

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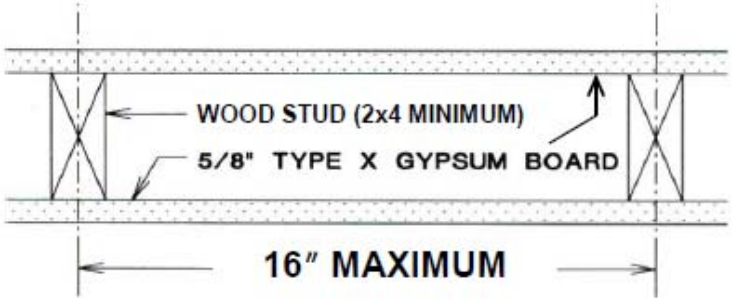
CAM Example 1

Interior Wall



5/8 inch Type X gypsum wallboard	=	40 minutes
Wood studs	=	20 minutes
Combined Assembly Fire Resistance Rating	=	60 minutes

Figure 1 Interior Wall

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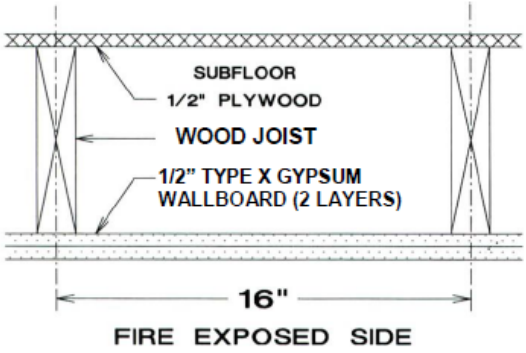
CAM Example 2

Floor/Ceiling with Wood Joists

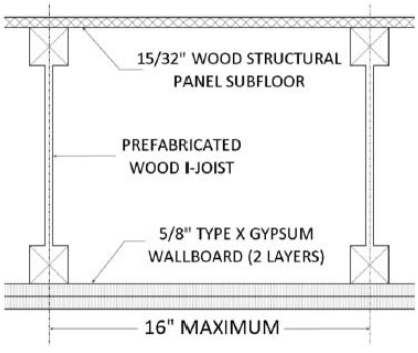


1/2 inch Type X Gypsum wallboard	=	25 minutes
1/2 inch Type X Gypsum wallboard	=	25 minutes
Wood joists	=	10 minutes
Combined Assembly Fire Resistance Rating	=	60 minutes

Figure 2 Floor/Ceiling Assembly

CAM Example 3

Floor/Ceiling with I-joists



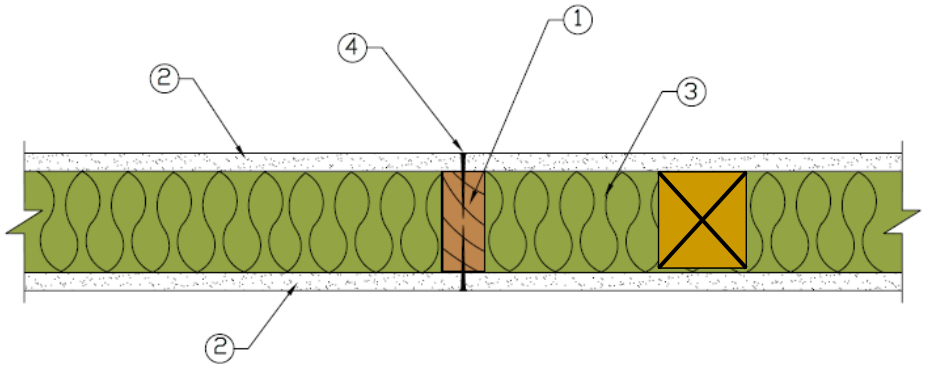
5/8 inch Type X Gypsum wallboard	=	40 minutes
5/8 inch Type X Gypsum wallboard	=	40 minutes
Sum of assigned component times	=	80 minutes
Combined Assembly Fire Resistance Rating (limited to 1 hour per IBC 722.6.1.1)	=	60 minutes

Figure 3 Floor/Ceiling Assembly with Prefabricated Wood I-joists

Columns within Wall Assembly

WS4-1.1 One Hour Fire-Resistive Wood-Frame Wall Assembly

2x4 Wood Stud Wall – 100% Design Load – ASTM E 119/NFPA 251



IBC 704.2 and 704.3 No additional fireproofing required for the column in the assembly

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Columns within Wall Assembly

- **704.2 Column protection (IBC 2018 text)**
  - **"Exception: Columns that meet the limitations of Section 704.4.1"**
- **704.4.1 Light-frame construction (IBC 2018 text)**
  - **"Studs, columns, and boundary elements that are integral elements in walls of light-frame construction, and are located entirely between the top and bottom plates or tracks shall be permitted to have required fire-resistance ratings provided by the membrane protection provided for the wall."**

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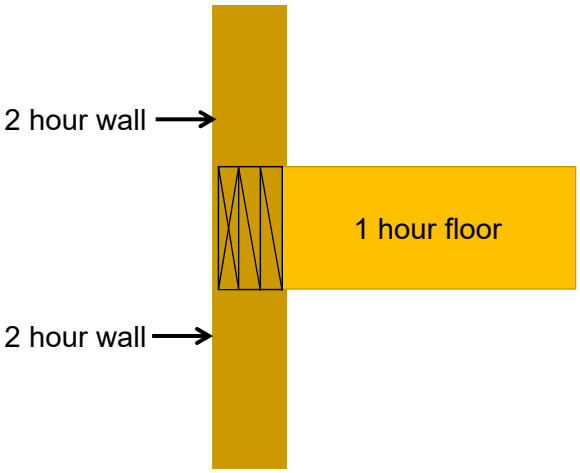
Structural Stability 705.6



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Polling Question

4. Per the Component Additive Method (CAM) described in IBC 722, fire resistance of up to _____ can be calculated.

a) 1 hour
b) 2 hours
c) 3 hours
d) All of the above
e) None of the above

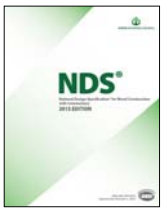
Calculated Fire-Resistance

Fire-resistance up to *two hours*

- Columns
- Beams
- Tension Members
- ASD only

Products

- Lumber
- Glulam
- SCL
- Decking
- CLT



SECTION 722
CALCULATED FIRE RESISTANCE

722.1 General. The provisions of this section contain procedures by which the *fire resistance* of specific materials or combinations of materials is established by calculations. These procedures apply only to the information contained in this section and shall not be otherwise used. The calculated *fire resistance* of concrete, concrete masonry and clay masonry assemblies shall be permitted in accordance with ACI 216.1/TMS 0216. The calculated *fire resistance* of steel assemblies shall be permitted in accordance with Chapter 5 of ASCE 29. The calculated *fire resistance* of exposed wood members and wood decking shall be permitted in accordance with Chapter 16 of ANSI/AF&PA *National Design Specification for Wood Construction (NDS)*.

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Fire Design of Exposed Wood Members

Beam Fire Test
ASTM E 119

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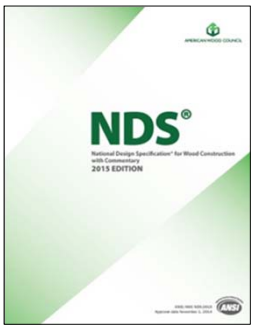
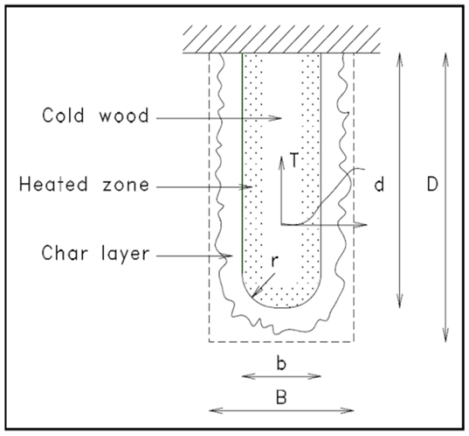
Calculated Fire-Resistance (722)

Chapter 16 of the National Design Specification® (NDS®)





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Fire Design of Exposed Wood Members

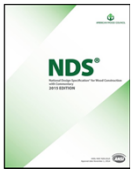
Effective char rate

solid sawn, structural glued laminated softwood, laminated veneer lumber, parallel strand lumber, and laminated strand lumber

$$\beta_{eff} = \frac{1.2\beta_n}{t^{0.187}} \qquad (16.2\text{-}1)$$

where:

β_{eff} = effective char rate (in./hr.), adjusted for exposure time, t



β_n = nominal char rate (in./hr.), linear char rate based on 1-hour exposure

t = exposure time (hr.)

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Fire Design of Exposed Wood Members

Effective char depth

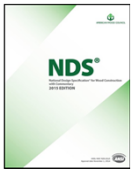
C16.2.1.2 Using Equation 16.2-1 and assuming nominal char rate, β_n or 1.5 inches/hr:

$$a_{char} = 1.8t^{0.813}$$

Fire Design of Exposed Wood Members

Table 16.2.1A Effective Char Rates and Char Depths (for β_n = 1.5 in./hr.)

Required Fire Endurance (hr.)	Effective Char Rate, β_{eff} (in./hr.)	Effective Char Depth, a_{char} (in.)
1-Hour	1.8	1.8
1½-Hour	1.67	2.5
2-Hour	1.58	3.2



Fire Design of Exposed Wood Members

Allowable Stress Design

Table 16.2.2 Adjustment Factors for Fire Design[1]

			ASD					
			Design Stress to Member Strength Factor	Size Factor [2]	Volume Factor [2]	Flat Use Factor [2]	Beam Stability Factor [3]	Column Stability Factor [3]
Bending Strength	F_b	x	2.85	C_F	C_V	C_{fu}	C_L	-
Beam Buckling Strength	F_{bE}	x	2.03	-	-	-	-	-
Tensile Strength	F_t	x	2.85	C_F	-	-	-	-
Compressive Strength	F_c	x	2.58	C_F	-	-	-	C_P
Column Buckling Strength	F_{cE}	x	2.03	-	-	-		

1. See 4.3, 5.3, 8.3, and 10.3 for applicability of adjustment factors for specific products.
2. Factor shall be based on initial cross-section dimensions.
3. Factor shall be based on reduced cross-section dimensions.

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Special Provisions NDS 16.2.4

Glued-laminated Timber
Tension Lam Provisions – unbalanced layup

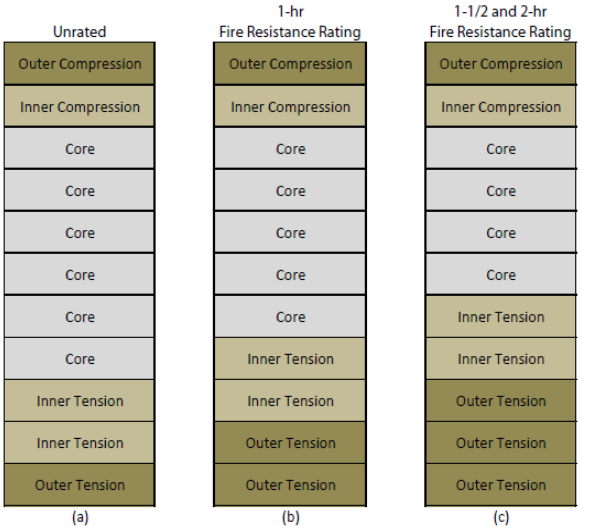

Figure 3-1 Typical glulam unbalanced beam layups

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Special Provisions NDS 16.2.4

Glued-laminated Timber
Tension Lam Provisions – balanced

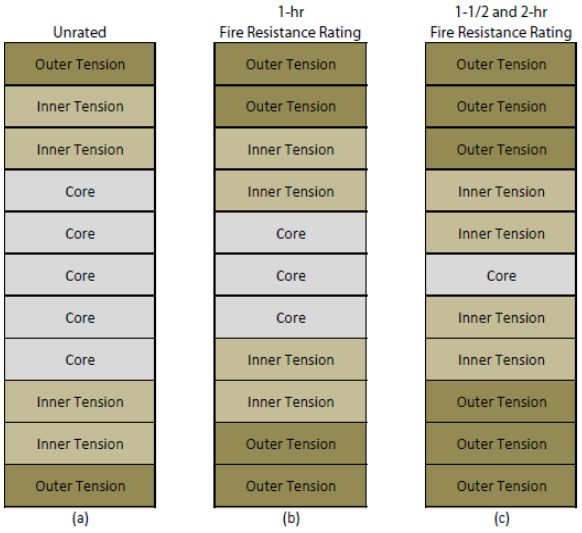

Figure 3-2 Typical glulam balanced beam layups

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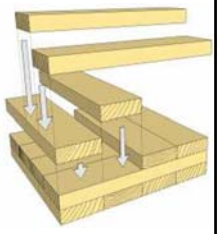
Fire Design of Exposed Wood Members

$$a_{char} = 1.2\left[n_{lam}\, h_{lam} + \beta_n \left(t - \left(n_{lam}\, t_{gi}\right)\right)^{0.813}\right]$$



Cross-laminated Timber-Effective Char Depth

$$t_{gi} = \left(\frac{h_{lam}}{\beta_n}\right)^{1.23}$$

t_{gi} = time for char front to reach glued interface (hr.)

h_{lam} = lamination thickness (in.)

$$n_{lam} = \frac{t}{t_{gi}}$$

n_{lam} = number of laminations charred (rounded to lowest integer)

t = exposure time (hr.)

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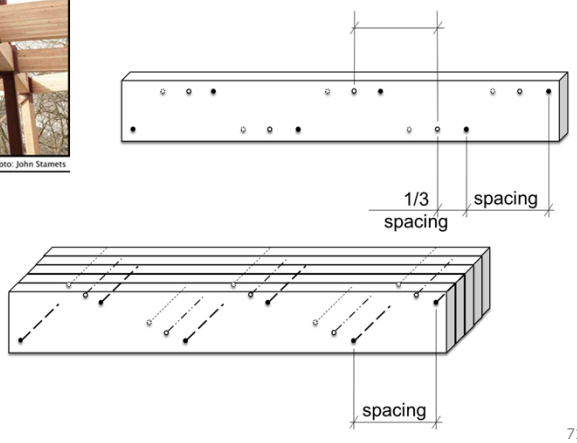
Fire Design of Exposed Wood Members

CLT manufactured with laminations of equal thickness

Table 16.2.1B Effective Char Depths (for CLT with β_n=1.5in./hr.)

Required Fire Endurance (hr.)	Effective Char Depths, a_{char} (in.) lamination thicknesses, h_{lam} (in.)								
	5/8	3/4	7/8	1	1-1/4	1-3/8	1-1/2	1-3/4	2
1-Hour	2.2	2.2	2.1	2.0	2.0	1.9	1.8	1.8	1.8
1½-Hour	3.4	3.2	3.1	3.0	2.9	2.8	2.8	2.8	2.6
2-Hour	4.4	4.3	4.1	4.0	3.9	3.8	3.6	3.6	3.6

Nail-Laminated Timber



Calculated fire-resistance of NLT

Method for calculated fire-resistance of Timber Decks may be used for Nail-laminated timber (NLT)

NDS 16.2.5. Provisions for Timber Decks

- **≥ 2" (actual) thick**
- **Planks span the distance between supporting beams**
- **Designed as an assembly of wood beams partially exposed on the sides and fully exposed on one face.**
  - Char rate on sides reduced to 33% of the effective char rate
  - Calculation do not address thermal separation
  - Typically would require one layer of Type X gypsur

72

Polling Question

5. Glued laminated timbers do not require substitution of additional, high-quality outer tension laminations to achieve fire-resistance ratings, T/F?

True

False

Calculated Resistance (722)

Technical Report No. 10 (TR10)

- contains background and examples

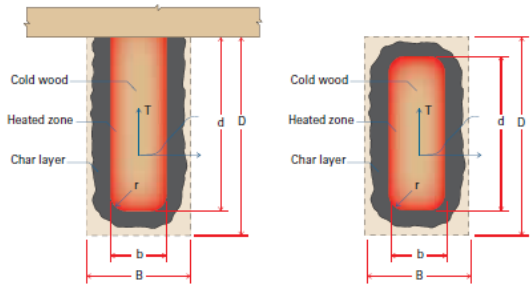
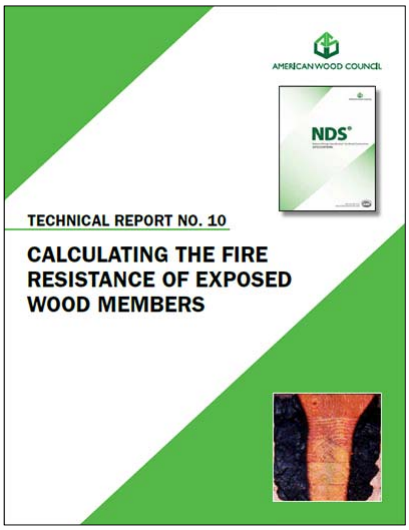


Figure 1-1 Reduction in member breadth and depth over time, t



74

TR-10 Design Example

TR10 contains

- decking
- beams
- columns
- CLT
- etc

75

TR-10 Design Example

4.1 Exposed Beam (*ASD*)

Simply-supported Douglas fir glued-laminated beam w/timber decking nailed for lateral bracing (C_L =1.0)

L = 18 feet q_{live} = 100 psf

S = 6 feet q_{dead} = 25 psf

Required section dimensions for a one-hour fire-resistance time?

76

TR-10 Design Example

4.1 Exposed Beam (*ASD*) (cont)

Calculate beam load:

$w_{load} = s(q_{dead} + q_{live}) = (6\text{ ft})(125\text{ psf}) = 750\text{ plf}$

$M_{max} = w_{load}\, L^2 / 8 = (750)(18^2)/8 = 30{,}375\text{ ft-lbs}$

Select a 6 ¾" x 13½" 24F visually-graded DF GLT

F_b=2400 psi

Calculate the section modulus:

$S_s = bd^2/6 = (6.75)(13.5)^2/6 = 205\text{ in}^3$

77

TR-10 Design Example

Table 5.3.1 Applicability of Adjustment Factors for Structural Glued Laminated Timber

	ASD only	ASD and LRFD										LRFD only		
	Load Duration Factor	Wet Service Factor	Temperature Factor	Beam Stability Factor [1]	Volume Factor [1]	Flat Use Factor	Curvature Factor	Stress Interaction Factor	Shear Reduction Factor	Column Stability Factor	Bearing Area Factor	Format Conversion Factor K_F	Resistance Factor ϕ	Time Effect Factor
$F_b' = F_b$ x	C_D	C_M	C_t	C_L	C_V	C_{fu}	C_c	C_I	-	-	-	2.54	0.85	λ
$F_t' = F_t$ x	C_D	C_M	C_t	-	-	-	-	-	-	-	-	2.70	0.80	λ
$F_v' = F_v$ x	C_D	C_M	C_t	-	-	-	-	-	C_{vr}	-	-	2.88	0.75	λ
$F_{rt}' = F_{rt}$ x	C_D	C_M	C_t	-	-	-	-	-	-	-	-	2.88	0.75	λ
$F_c' = F_c$ x	C_D	C_M	C_t	-	-	-	-	-	-	C_P	-	2.40	0.90	λ
$F_{c\perp}' = F_{c\perp}$ x	-	C_M	C_t	-	-	-	-	-	-	-	C_b	1.67	0.90	-
$E' = E$ x	-	C_M	C_t	-	-	-	-	-	-	-	-	-	-	-
$E_{min}' = E_{min}$ x	-	C_M	C_t	-	-	-	-	-	-	-	-	1.76	0.85	-

1. The beam stability factor, C_L, shall not apply simultaneously with the volume factor, C_V, for structural glued laminated timber bending members (see 5.3.6). Therefore, the lesser of these adjustment factors shall apply.

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TR-10 Design Example

4.1 Exposed Beam (*ASD*) (cont)

Assuming C_D = 1.0: C_M = 1.0: C_t = 1.0: C_L = 1.0: C_V = 0.98

$F'_b = F_b(C_D)(C_M)(C_t)$ (lesser of C_L or C_V)
$= 2400\ (1.0)(1.0)(1.0)(0.98) = 2342$ psi (NDS 5.3.1)

Calculate resisting moment:
$M'_s = F'_b\ S_s = (2342)(205.0)/12 = 40{,}032$ ft-lbs

79

TR-10 Design Example

4.1 Exposed Beam (*ASD*) (cont)

Assuming C_D = 1.0: C_M = 1.0: C_t = 1.0: C_L = 1.0: C_V = 0.98

$F'_b = F_b(C_D)(C_M)(C_t)$ (lesser of C_L or C_V)
$= 2400\ (1.0)(1.0)(1.0)(0.98) = 2342$ psi (NDS 5.3.1)

Calculate resisting moment:
$M'_s = F'_b\ S_s = (2342)(205.0)/12 = 40{,}032$ ft-lbs

Structural Check:
$M'_s \geq M_{max}$ 40,032 ft-lbs > 30,375 ft-lbs

80

TR-10 Design Example

4.1 Exposed Beam (cont.)

The fire-resistance must be calculated

Calculate the section modulus exposed on three sides:

a = 1.8 (NDS Table 16.2.1A)

$S_f = (b\text{-}2a)(d\text{-}a)^2/6$
$= (6.75\text{-}3.6)(13.5\text{-}1.8)^2/6 = 71.9\ in^3$ (NDS 16.2.1)

81

TR-10 Design Example

4.1 Exposed Beam (cont.)

Assuming C_D = N/A: C_M = N/A: C_t = N/A: C_L = 1.0:
C_V = 0.98

$F'_{b,f} = (2.85)\ F_{b,f}$ (lesser of C_L or C_V)
= 2.85(2400)(0.98) = 6703 psi (NDS 16.2.2)

Calculate resisting moment:
$M'_f = F'_{b,f}\ S_f = (6703)(71.9)/12$
= 40,145 ft-lbs (NDS 16.2.2)

Fire Check: $M'_f \geq M_{max}$ 40,145 ft-lbs > 30,375 ft-lbs

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TR-10 Design Example

4.4 Exposed Deck (*ASD*)

T&G or Butt Jointed Timber Decking

L = 6 feet
¾" sheathing

q_{live} = 40 psf
q_{dead} = 10 psf

Required decking depth for a one-hour fire-resistance time?

83

TR-10 Design Example

4.4.1 Tongue-and-Groove Decking

Calculate deck load on a one-foot-wide strip:

$$w_{load} = B(q_{dead} + q_{live}) = (1\ ft)(50\ psf) = 50\ plf$$

$$M_{max} = w_{load}\ L^2 / 8 = (50)(6^2)/8 = 225\ ft\text{-}lbs$$

Select nominal 3x6 (2½" x 5½") Hem-Fir tongue-and-groove Commercial decking $F_b(C_r)$ = 1350 psi

Calculate the section modulus of a one-foot-wide strip:

$$S_s = bd^2/6 = (12)(2.5)^2/6 = 12.5\ in^3$$

84

TR-10 Design Example

Table 4.3.1 Applicability of Adjustment Factors for Sawn Lumber

		ASD only	ASD and LRFD										LRFD only		
		Load Duration Factor	Wet Service Factor	Temperature Factor	Beam Stability Factor	Size Factor	Flat Use Factor	Incising Factor	Repetitive Member Factor	Column Stability Factor	Buckling Stiffness Factor	Bearing Area Factor	Format Conversion Factor K_F	Resistance Factor ϕ	Time Effect Factor
$F_b' = F_b$	x	C_D	C_M	C_t	C_L	C_F	C_{fu}	C_i	C_r	-	-	-	2.54	0.85	λ
$F_t' = F_t$	x	C_D	C_M	C_t	-	C_F	-	C_i	-	-	-	-	2.70	0.80	λ
$F_v' = F_v$	x	C_D	C_M	C_t	-	-	-	C_i	-	-	-	-	2.88	0.75	λ
$F_c' = F_c$	x	C_D	C_M	C_t	-	C_F	-	C_i	-	C_P	-	-	2.40	0.90	λ
$F_{c\perp}' = F_{c\perp}$	x	-	C_M	C_t	-	-	-	C_i	-	-	-	C_b	1.67	0.90	-
$E' = E$	x	-	C_M	C_t	-	-	-	C_i	-	-	-	-	-	-	-
$E_{min}' = E_{min}$	x	-	C_M	C_t	-	-	-	C_i	-	-	C_T	-	1.76	0.85	-

85

TR-10 Design Example

4.4.1 Tongue-and-Groove Decking (cont.)

Assuming C_D = 1.0: C_M = 1.0: C_t = 1.0: C_F = 1.04

$F'_{b,s} = F_b(C_r)\ (C_D)(C_M)(C_t\ )(C_F)$
= 1350 (1.0)(1.0)(1.0)(1.04) = 1404 psi (NDS 4.3.1)

Calculate resisting moment:
$M'_s = F'_b\ S_s$ = (1404)(12.5)/12 = 1463 ft-lbs

Structural Check:
$M'_s \geq M_{max}$ 1463 ft-lbs > 225 ft-lbs

86

TR-10 Design Example

4.4.1 Tongue-and-Groove Decking (cont.)

The fire-resistance must be calculated

Calculate the section modulus of a one-foot-wide strip exposed on the bottom surface:
a = 1.8 (NDS Table 16.2.1A)
$S_f = (b)(d\text{-}a)^2/6 = (12)(2.5\text{-}1.8)^2/6 = 0.98\ in^3$

Assuming C_D = N/A: C_M = N/A: C_t = N/A: C_F = 1.04

$F'_{b,f} = (2.85)\ F_b(C_r)(C_F)$
= 2.85(1350)(1.04) = 4001 psi

87

TR-10 Design Example

4.4.1 Tongue-and-Groove Decking (cont.)

Calculate resisting moment:
$M'_f = F'_{b,f} S_f = (4001)(0.98)/12 = 327$ ft-lbs (NDS 16.2.2)

Fire Check: $M'_f \geq M_{max}$ 327 ft-lbs > 225 ft-lbs

88

TR-10 Design Example

4.4.2 Butt-Jointed Decking

Assume a board width of 5.5 inches
Calculate deck load:
$w_{load} = B(q_{dead} + q_{live}) = (5.5 \text{ in} / 12 \text{ in/ft})(50 \text{ psf}) = 22.9$ plf

Calculate maximum induced moment on each member:
$M_{max} = w_{load} L^2 / 8 = (22.9)(6^2)/8 = 103$ ft-lbs

Select nominal 3x6 (2½" x 5½") Hem-Fir butt-jointed Commercial decking with a tabulated repetitive member bending stress, $F_b(C_r) = 1350$ psi

89

TR-10 Design Example

4.4.2 Butt-Jointed Decking (cont.)

Calculate the section modulus of each member:
$S_s = bd^2/6 = (5.5)(2.5)_2/6 = 5.73\ in^3$

Calculate the adjusted allowable bending stress assuming $C_D = 1.0$: $C_M = 1.0$: $C_t = 1.0$: $C_F = 1.04$
$F'_{b,s} = F_b(C_r)\ (C_D)(C_M)(C_t\ )(C_F) = 1350$
$(1.0)(1.0)(1.0)(1.04) = 1404$ psi (NDS 4.3.1)

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TR-10 Design Example

4.4.2 Butt-Jointed Decking (cont.)

Calculate resisting moment:
$M'_s = F'_b\ S_s = (1404)(5.73)/12 = 670$ ft-lbs

Structural Check: $M' \geq M_{max}$ 670 ft-lbs > 103 ft-lbs

91

TR-10 Design Example

4.4.2 Butt-Jointed Decking (cont.)

The fire-resistance must be calculated.

Calculate the section modulus of a member, exposed fully on the bottom surface, with 33% of the effective char rate on the butt-jointed sides:
a = 1.8 (NDS Table 16.2.1A)
$S_f = (b - 2(a/3))(d - a)^2/6$
$= (5.5 - 2(1.8/3))(2.5 - 1.8)^2/6 = 0.351$ in^3

92

TR-10 Design Example

4.4.2 Butt-Jointed Decking (cont.)

Calculate the adjusted allowable bending stress assuming C_D = N/A: C_M = N/A: C_t = N/A: C_F = 1.04
$F'_{b,f} = (2.85)\ F_b(C_r)(C_F) = 2.85(1350)(1.04) = 4001$ psi

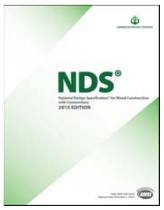
Calculate resisting moment:
$M'_f = F'_{b,f}\ S_f = (4001)(0.351)/12 = 117$ ft-lbs (NDS 16.2.2)

Fire Check: $M'_f \geq M_{max}$ 117 ft-lbs > 103 ft-lbs

93

Fire-Resistance of Exposed Wood

16.3 Wood Connections



- Where fire endurance is required, connectors and fasteners shall be protected from fire exposure
  - Wood
  - Fire-rated gypsum board

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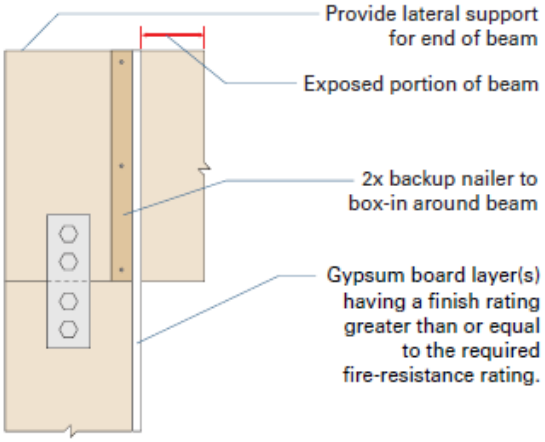
Connections



Beam-to-column (Protection provided by membrane)

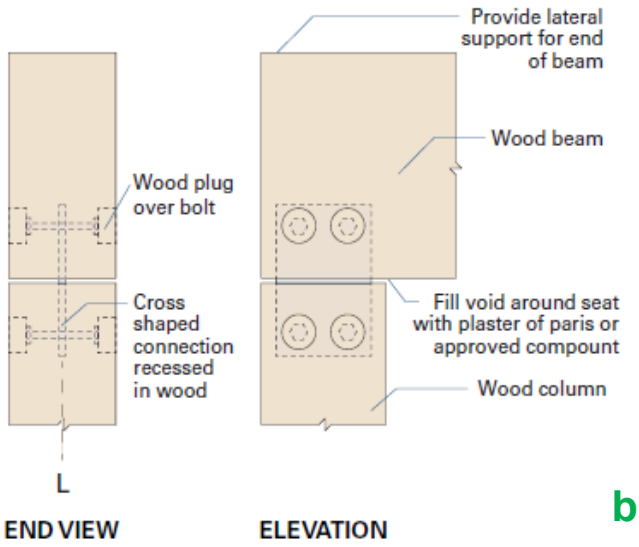
ELEVATION

Figure 3-3 Beam to column connection, connection not exposed to fire

Source: AWC TR-10

95

Connections



Concealed beam-to-column

Figure 3-4 Beam to column connection, connection exposed to fire where appearance is a factor

Source: AWC TR-10

Connections

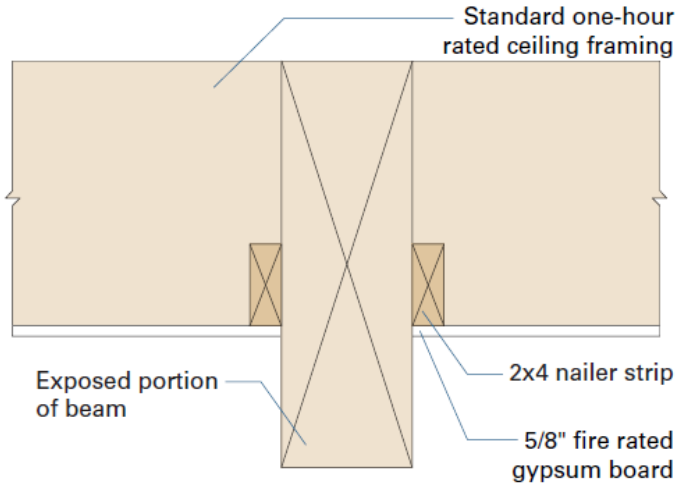


Figure 3-5 Ceiling construction

Beam supporting one hour rated ceiling

Source: AWC TR-10

Connections

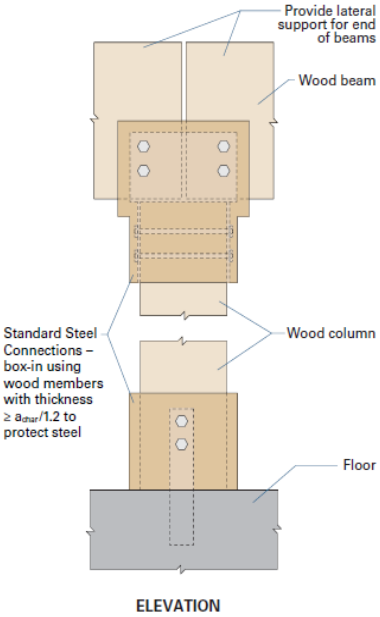


Figure 3-7 Column connections – covered

Covered column connection

Source: AWC TR-10

Connections

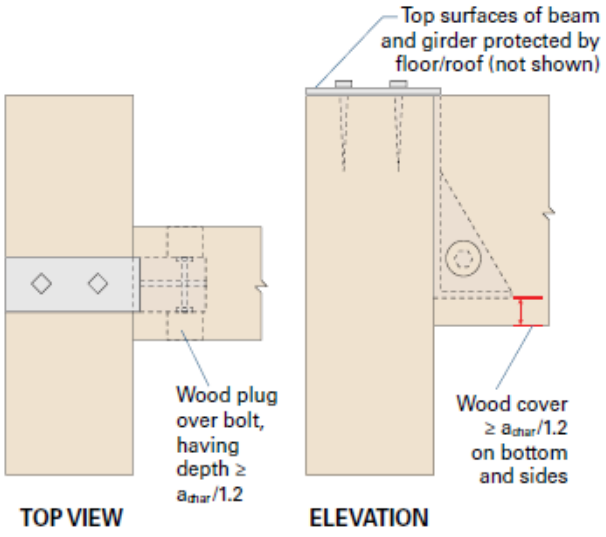


Figure 3-8 Beam to girder – concealed connection

Concealed beam-to-girder connection

Source: AWC TR-10

Fire Design of Exposed Wood Members

722.6.3 Design of fire-resistant exposed wood members. The *fire-resistance rating*, in minutes, of timber beams and columns with a minimum nominal dimension of 6 inches

722.6.3 deleted
NOT INCLUDED IN 2015 IBC

Limited to 1-Hour – IBC 722.6.1.1

Simplified approach

Only Beams/Columns

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Fire Design of Exposed Wood Members

DCA 2

Design of Fire-Resistive Exposed Wood Members

- **Glued-laminated timber, sawn lumber, & timber decking**
- **1, 1.5 & 2 hours**

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Fire Design of Exposed Wood Members

DCA 2

Design of Fire-Resistive Exposed Wood Members

$$M = F'_b S (R_s)$$

Table 3.1 **Design Load Ratios, R_s, for Butt-Jointed Timber Decks**
(Protected on Top Face; Partially Protected on Sides per NDS Section 16.2.5)
(Structural Calculations at Standard Reference Conditions: C_D=1.0, C_M=1.0, C_t=1.0, C_i=1.0, C_L=1.0)

	1-HOUR				1.5-HOUR			2-HOUR	
Width, b	1-1/2	2-1/2	3-1/2	5-1/2	2-1/2	3-1/2	5-1/2	3-1/2	5-1/2
Depth, d	Design Load Ratio, R_s								
2-1/2	0.05	0.12	0.15	0.18	-	-	-	-	-
3	0.10	0.24	0.30	0.36	0.03	0.04	0.05	-	-
3-1/2	0.14	0.35	0.44	0.53	0.08	0.12	0.16	-	-
4	0.18	0.45	0.57	0.68	0.14	0.21	0.28	0.05	0.08
4-1/2	0.21	0.54	0.68	0.80	0.19	0.30	0.39	0.10	0.16
5	0.24	0.61	0.77	0.92	0.24	0.38	0.50	0.16	0.24
5-1/2	0.27	0.68	0.85	1.00	0.29	0.45	0.59	0.21	0.32

1. Design load ratios (R_s) may be interpolated for widths (b) and depths (d) other than those shown.

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DCA 2 Decking Design Example

Butt-Jointed Decking using DCA 2

Nominal 3x6 (2½" x 5½") Hem-Fir
1-hour fire-resistance
(Identical to previous TR10 example)

	1-HOUR			
Width, b	1-1/2	2-1/2	3-1/2	5-1/2
Depth, d				Desig
2-1/2	0.05	0.12	0.15	0.18
3	0.10	0.24	0.30	0.36
3-1/2	0.14	0.35	0.44	0.53
4	0.18	0.45	0.57	0.68
4-1/2	0.21	0.54	0.68	0.80
5	0.24	0.61	0.77	0.92
5-1/2	0.27	0.68	0.85	1.00

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DCA 2 Decking Design Example

Butt-Jointed Decking using DCA 2

Nominal 3x6 (2½" x 5½") Hem-Fir
Calculate resisting moment:
$M = F'_b S (R_s)$
$= (1404)(5.73)/12(0.18) = 120$ ft-lbs

Fire Check: $M'_f \geq M_{max}$ 120 ft-lbs > 103 ft-lbs

Note: M'_f = 117 ft-lbs per TR10 example

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Polling Question

6. The nominal char rate for solid sawn lumber is:

a) Approximately 1.5”/hour
b) Is the same for glued-laminated timber
c) Is used to calculate the fire resistance
d) All of the above

Engineering Analysis

NFBA UL V304 2- and 1-Hour Walls

- UL engineering evaluation

Gypsum Layers and Fastener Length and Spacing			
	Length of screw @ horizontal spacing		
Hourly wall	3-hour	2-hour	1-hour
Layers per side	4	3	2
1st layer	2" @ 24"	2" @ 24"	2" @ 12"
2nd layer	2-1/2" @ 24"	2-1/2" @ 24"	2-1/2" @ 12"
3rd layer	3" @ 24"	3" @ 24"	N/R
4th layer	4" @ 12"	N/R	N/R

Table 1. UL V304: Gypsum Layers and Fastener Specifications

See *Frame Building News* January 2014
"NFBA ATTAINS CERTIFICATION FOR 2- AND 1-HOUR FIRE-RATED WALLS"
http://www.nfba.org/uploads/T_and_R_January_Article.pdf

106

Wood Interior Finish (Chapter 8)

May be used in almost all occupancies

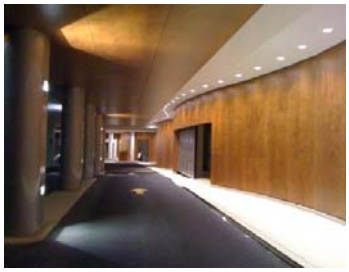
803.1.1 Interior wall and ceiling finish materials. Interior wall and ceiling finish materials shall be classified in accordance with ASTM E 84 or UL 723. Such *interior finish* materials shall be grouped in the following classes in accordance with their flame spread and *smoke-developed indexes.*

Class A: = Flame spread index 0-25; smoke-developed index 0-450.

Class B: = Flame spread index 26-75; smoke-developed index 0-450.

Class C: = Flame spread index 76-200; smoke-developed index 0-450.

Exception: Materials tested in accordance with Section 803.1.2.



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Wood Interior Finish Classification System

Nonsprinklered Buildings: Minimum Interior Finish Classification by Occupancy			
Location	**Minimum Interior Finish Classification**		
	A[b]	**B**	**C**
Exit enclosures and exit passageways[c]	**A, B, E, I, M, R-1, R-4**	**F, S, R-2**	**R-3**
Corridors	**A[d], I-2, I-3, I-4**	**B, E, M, S, I-1, R-1, R-2, R-4**	**F, R-3**
Enclosed spaces and rooms		**I, A-1[e], A-2[e], R-4**	**A-3, A-4, A-5, B, E, F, M, S, R-1, R-2, R-3**

(Table 803.11)

Wood Interior Finish Classification System

Sprinklered Buildings: Minimum Interior Finish Classification by Occupancy[a, b]			
Location	**Minimum Interior Finish Classification**		
	A	**Bc**	**C**
Exit enclosures and exit passageways[d]	**I-3**	**A, B, E, M, R-1, R-4, I-1, I-2, I-4**	**F, R-2, R-3, S**
Corridors	**I-3**	**A, I-2, I-4**	**B, E, F, M, R, S, I-1**
Enclosed spaces and rooms		**I-2, I-4**	**A, B, E, F, M, R, S, I-1, I-3**

(Table 803.11)

Wood Interior Finish (803)

- **Most wood species qualify as Class C or Class B**
- **Wood boards and panels may meet Class A criteria when pressure treated with a fire-retardant chemical**
- **AWC's DCA-1 documents the performance**


Design for Code Acceptance 1

Flame Spread Performance of Wood Products

Flame Spread Requirements

Test Method

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Flame Spread

Class I or A **0 - 25**

fire retardant treated wood

Class II or B **26 - 75**

redwood
cedar
douglas-fir
hem-fir
pine (other than lodge pole, ponderosa & red)
spruce

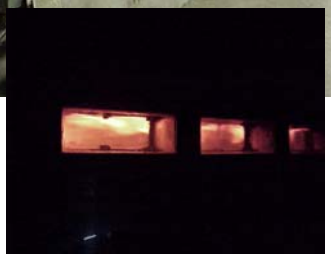
Class III or C **76 - 200**

most other wood species
softwood plywood
hardwood plywood
particleboard

111

Flame Spread

- **E84 Tunnel Apparatus**



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Smoke Developed Index

A smoke-developed index was also measured for some of the wood products listed in DCA 1. None of the products tested exceeded the limiting value of 450 commonly used in building code regulations

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Wood Interior Finish – Exceptions

- **Traditional wood floor covering is exempt from interior floor finish requirements (804.1)**
- **Exposed portions of Type IV structural members also exempt (803.3)**

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Design for Code Acceptance Pubs.

Free download
www.awc.org

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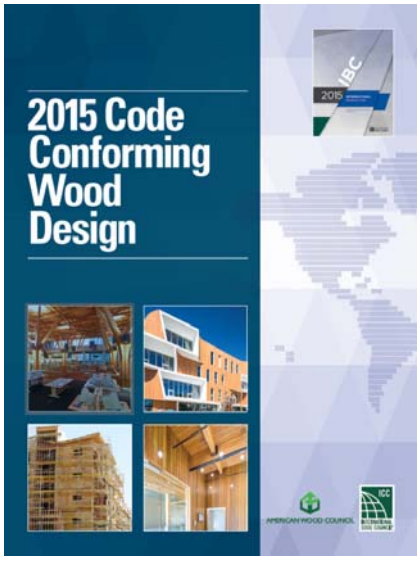
2015 Code Conforming Wood Design

- Special occupancies
- Fire-resistance
- Building features
- Wood in noncombustible construction types
- Structural considerations
- Precautions during construction

- Also available for 2009 and 2012 IBC
  - http://awc.org/codes-standards/buildingcodes/ccwd



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Questions?

- This concludes The American Institute of Architects Continuing Education Systems Course

American Wood Council
info@awc.org
www.awc.org

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