DES510/BCD420 Overview of Codes and Standards Affecting Mid-rise Construction

Based on Code Conforming Wood Design, 2015 Edition and the 2015 International Building Code® (IBC®)

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Course Description

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- Cost-effective, code-compliant and sustainable, mid-rise wood construction is popular with developers and design professionals, who see it as a way to achieve higher density housing at lower cost—while reducing the carbon footprint of their projects. Yet, many familiar with wood construction for two- to four-story residential structures are not aware that the International Building Code(IBC) allows five stories of wood-frame construction in building occupancies that include multi-family, military, senior, student and affordable housing—and six stories for business. This course will discuss techniques for designers to achieve code-compliant mid-rise wood structures. Participants may download a complimentary copy of the CCWD at: http://www.awc.org/codes/ccwdindex.html

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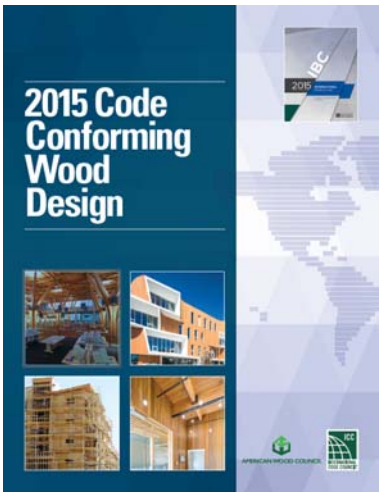
2015 Code Conforming Wood Design Document (CCWD)

- **The CCWD includes:**
  - **Allowable building size**
  - **Special occupancies**
  - **Fire resistance**
  - **Building features**
  - **Wood in noncombustible construction types**
  - **Structural considerations**
  - **Precautions during construction**



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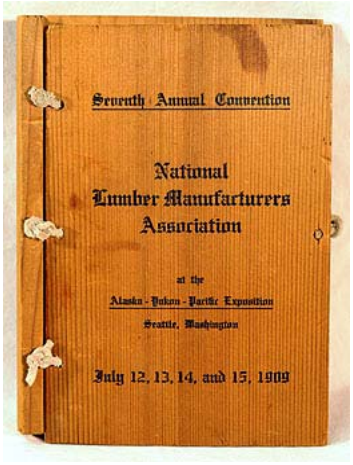
Who…

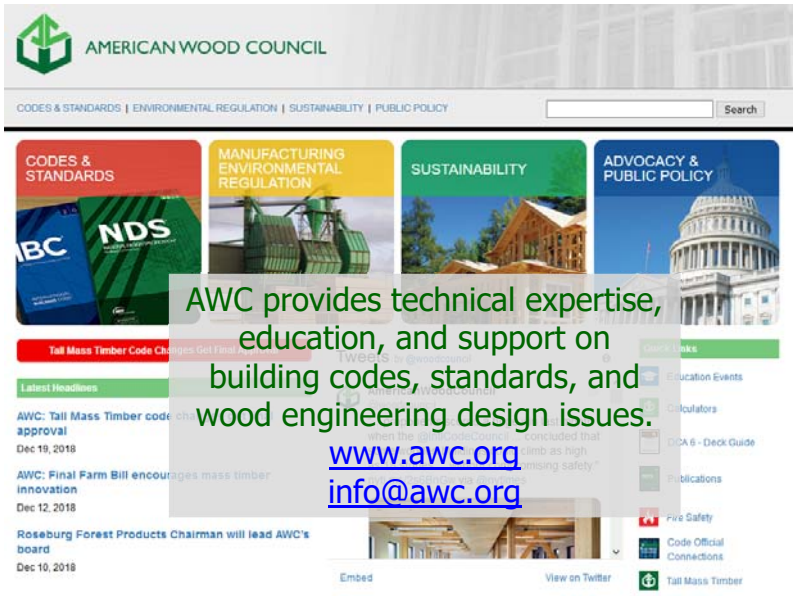
- **History of AWC**
  - **1902 – National Lumber Manufacturers Association**
  - **1965 – National Forest Products Association**
    - **1991 – American Wood Council – Codes & Engineering**
  - **1993 – American Forest & Paper Association**
  - **2010 – American Wood Council - rechartered**



What & How…

- **Codes and Standards**
- **Environmental Regulations**
- **Green Building**

American Wood Council



AWC provides technical expertise, education, and support on building codes, standards, and wood engineering design issues.

www.awc.org

info@awc.org

American Wood Council

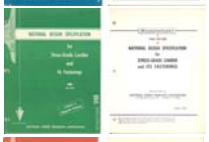
The American Wood Council (AWC) also provides wood design and construction information to assist building industry professionals, develops structural and fire performance data on a wide range of traditional and engineered wood products, and engages in long-term research.

NDS History

1944

1962

1968



1971

1973

1977

1982

1986

1991

1997

2001

2005

2012

2015

MID-RISE

MID-RISE

What is considered mid-rise?

Low-rise. NFPA 13R categorizes buildings having up to and including 4-stories as low rise.

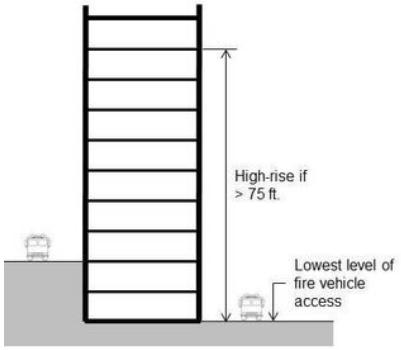
HIGH-RISE BUILDING. A building with an occupied floor located more than 75 feet (22 860 mm) above the lowest level of fire department vehicle access.

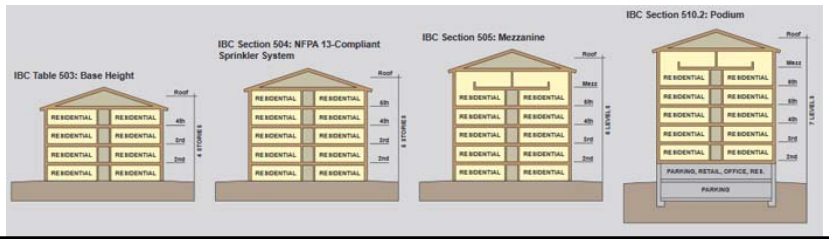
If considering a 7'-6" minimum ceiling height, one could get about 10 stories in with it's floor less than 75' above grade (fire apparatus access level).

MID-RISE

What is considered mid-rise?

Over 4-stories and under 11-stories?





5-Story Type III

Horyu-ji temple, Ikaruga, Nara Prefecture, Japan, (c. 711)
Urnes stave church , Sogn og Fjordane County, Norway (c. 1150)
Government Buildings Historic Reserve in Wellington, NZ (c. 1876)

Kelly, Douglas and Co. Warehouse; Vancouver , BC (c. 1905)
The Purse Building, Dallas, TX, (c. 1905)
Leckie Building, Vancouver, BC (c. 1908)

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Use and Occupancy Classification

Use and Occupancy Classification

- **Building code requirements**
  - **Appropriate building classification**
    - Design purpose
    - Current occupancy

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Use and Occupancy Classification CCWD

- **Eight occupancy classifications:**
  - **Group A, Assembly**
  - **Group B, Business**
  - **Group E, Educational**
  - **Group F, Factory/Industrial**
  - **Group I, Institutional**
  - **Group M, Mercantile**
  - **Group R, Residential**
  - **Group S, Storage**
  - **Group H, Hazardous occupancies is not covered within the CCWD**

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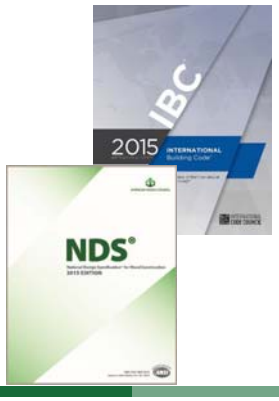
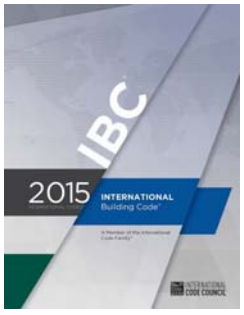


Referenced Codes and Standards

Referenced Codes and Standards

- **IBC Chapter 35**
  - **List of referenced standards**
    - Agency that writes the standard
    - Identification and title of the standard
    - Effective date



www.awc.org

AWC Standards

- **American Wood Council (AWC) Standards**
  - **2015 National Design Specification® (NDS®-2015) for Wood Construction with 2015 Supplement**
  - **2015 Special Design Provisions for Wind and Seismic (SDPWS-2015)**
  - **2015 Wood Frame Construction Manual (WFCM-2015) for One- and Two-Family Dwellings**
  - **2015 AWC Span Tables for Joists and Rafters (STJR-2015)**

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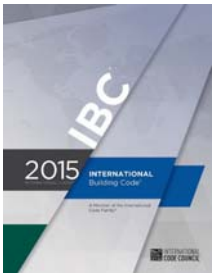
Types of Construction

Introduction

- **IBC Chapter 6**
  - **Defines types of construction**
  - **Wood framing is typical in Types V, IV and III**
  - **Specific applications permitting use of wood in Types I and II**
    - Addressed in Sections 5 and 6 of the CCWD



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Type V Construction

- **Permits the use of wood or other approved materials for loadbearing and nonloadbearing structural elements.**
- **Not a candidate for mid-rise construction unless one considers a one story podium with 4 stories on top!**

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Type IV Construction

- **Heavy Timber (HT)**
  - Exterior walls made of noncombustible materials, fire-retardant-treated wood (FRTW) or protected cross-laminated timber (CLT)
  - Interior building elements made of solid or laminated wood without concealed spaces
- **Columns**
  - Minimum of 6" × 8" when supporting roof and ceiling loads
  - Minimum of 8" × 8" when supporting floor loads
- **Beams and girders**
  - Minimum 6" × 10" for floors
  - Minimum 4" × 6" for roofs

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Type IV Construction

- **Flooring**
  - Minimum 3-inch thickness covered with 1-inch nominal dimension tongue and groove flooring or 4-inch thick CLT
- **Roof decking**
  - Minimum 2-inch thickness, 11/8-inch wood structural panels, or 3-inch thick CLT
- **Partitions**
  - 1-hour-fire-resistance-rated; or
  - Minimum two layers of 1-inch nominal board; or
  - Laminated construction 4-inches thick

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Type III Construction

- **Requires exterior walls to be noncombustible material or FRTW and have a minimum 2-hour fire-resistance rating (bearing walls).**
- **Type IIIA requires 1-hour fire-resistance rating for all building elements other than nonbearing walls.**
- **Type IIIB does not require any fire-resistance rating other than exterior loadbearing walls.**

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Type I and II Construction

- **Type I and II construction requires most structural loadbearing building elements to be of noncombustible materials.**

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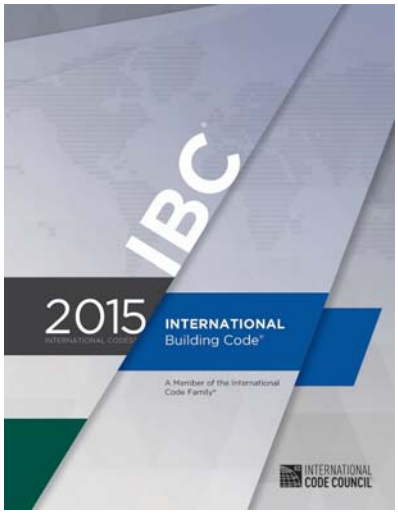
Allowable Heights and Areas

Introduction

- **IBC Chapter 5**
  - **Size thresholds for wood structures are often determined by structural considerations rather than code limitations.**



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SH66 PC194

Tables 504.3, 504.4 and 506.2, Allowable Building Heights and Areas CCWD

	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
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

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Tables 504.3, 504.4 and 506.2, Allowable Building Heights and Areas CCWD (cont)

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

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Slide 31

SH66 Update image to updated table from complete document.
SHyde, 9/14/2015

PC194 I replaced the figure from the one from the final PDF of document
Paul Coats, 9/24/2015

Allowable Building Area – Single Occupancy, One-Story Buildings (506.2.1)

$A_a = A_t + (NS \times I_f)$ (Equation 5-1)

Where:

A_a = Allowable building area (square feet).

A_t =Tabular building area factor (NS, S1, or S13R value, as applicable) in accordance with Table 506.2 (square feet).

NS =Tabular allowable area factor in accordance with Table 506.2 for a nonsprinklered building (regardless of whether the building is sprinklered).

I_f = Area factor increase due to frontage (percent) as calculated in accordance with Section 506.3.

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Allowable Building Area – Single Occupancy, Multi-story Buildings (506.2.3)

$A_a = [A_t + (NS \times I_f)] \times S_a$ (Equation 5-2)

Where:

A_a = Allowable building area (square feet).

A_t =Tabular building area factor (NS, S13R, or SM value, as applicable)in accordance with Table 506.2 (square feet).

NS =Tabular allowable area factor in accordance with Table 506.2 for a nonsprinklered building (regardless of whether the building is sprinklered).

I_f = Area factor increase due to frontage (percent) as calculated in accordance with Section 506.3.

S_a = Actual number of building stories above grade plane, not to exceed three. For buildings equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.2 (NFPA 13R system), use the actual number of building stories above grade plane, not to exceed four.

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Area Factor Increases for Frontage (506.3)

$I_f = [F / P - 0.25] W / 30$ (Equation 5-5)

Where:

I_f = Area factor increase due to frontage (percent) as calculated in accordance with Section 506.3.

F = Building perimeter that fronts on a public way or open space having 20 feet open minimum width (feet).

P = Perimeter of entire building (feet).

W = Width of public way or open space (feet) in accordance with Section 506.3.2.

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Weighted Average (506.3.2)

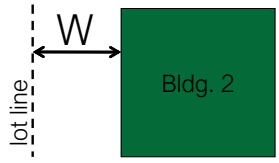
$W = (L_1 \times w_1 \times L_2 \times w_2 \times L_3 \times w_{3...}) / F$ (Equation 5-4)

Where:

L_n = Length of a portion of the exterior perimeter wall (feet).

w_n = Width of open space ($\geq$ 20 ft.) associated with that portion of the exterior perimeter wall (feet).

F = Building perimeter that fronts on a public way or open space having a width of 20 feet or more.



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Weighted Average (506.3.2)

- Length of Walls:

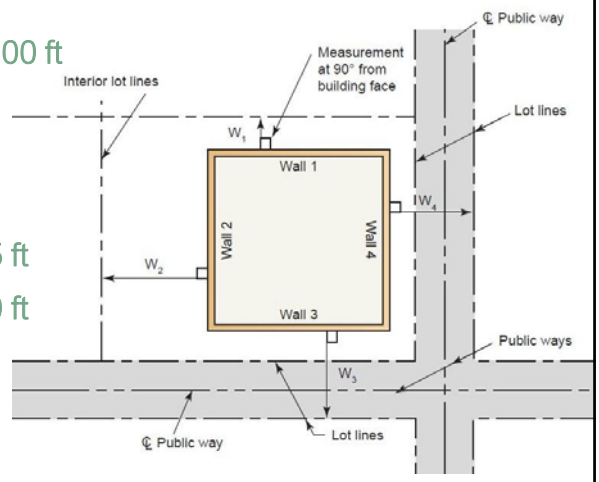
  L_1, L_2, L_3 and L4 = 200 ft

- Frontage Width:

  w_1 = 22 ft w_3 = 55 ft

  w_2 = 45 ft w_4 = 50 ft

  F = 200 x 4 = 800 ft



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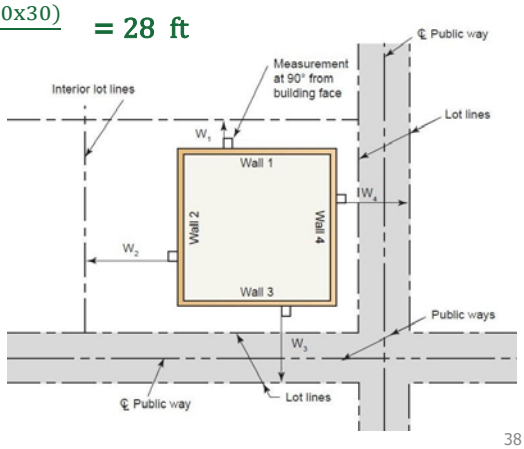
Weighted Average (506.3.2)

$$W = \frac{L_1 \times w_1 + L_2 \times w_2 + L_3 \times w_3 + L_4 \times w_4}{F}$$

$$W = \frac{(200x22+200x30+200x30+200x30)}{800} = 28 \text{ ft}$$



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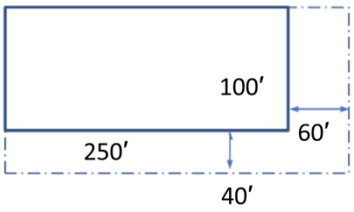
Allowable Building Area Calculation

- **Given:**
  - **100'x250' Six-story Type IIIA office building**
  - **Provided with an NFPA 13-compliant automatic sprinkler system and located on lot as shown.**
- **Determine:**
  - **Maximum allowable building area**



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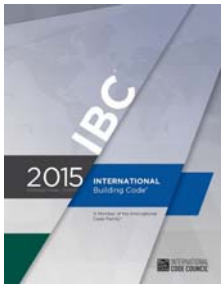
Midrise Single Occupancy (506.2.3)

- **Buildings five or more stories above grade have a total building area per story found in (A_a) calculated by Equation 5-2 with a value of 3 for the number of stories (S_a).**
- **This is built-in to new $A_a = A_t + (NS \times I_f)$ Equation 5-1 and $A_a = [A_t + (NS \times I_f)] \times S_a$ Equation 5-2 of the 2015 Code.**

S_a = Actual number of building stories above grade plane, not to exceed three. For buildings equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.2, use the actual number of building stories above grade plane, not to exceed four.



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Allowable Building Area Calculation

- **Formula for Solution:** $A_a = [A_t + (NS \times I_f)] \times S_a$

  NS = 28,500 (Table 506.2)

- **Frontage Increase (I_f): (Section 506.3)**

  $I_f = (F / P - 0.25) \times W / 30$
  $I_f = [(350 / 700) - 0.25] \times 30 / 30 = 0.25$
  (Setback was 40' & 60', but where W > 30, use 30)

- **Tabular Allowable Area Factor: (SM row - Table 506.2)**

  A_t = 85,500

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Allowable Building Area Calculation

Solution cont.:

Total Allowable Area (A_a) (Section 506.2.3)

NS = 28,500

A_t = 85,500

I_f = 0.25

Sa = 3

$A_a = A_t + (NS \times I_f) \times S_a$
$A_a = [85{,}500 + (28{,}500 \times 0.25)] \times 3 = 277{,}875$ square feet

Actual area = 250' × 100' x 6 stories = 150,000 square feet
✓ OK

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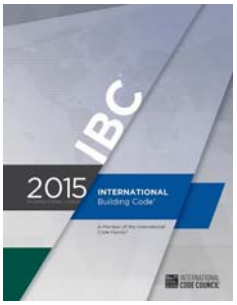
Mixed Occupancy (508)

- **Mixed occupancy buildings are permitted a total allowable building area calculated in accordance with Section 508.**
- **Single-story basement does not need to be included in the total allowable building area when the basement does not exceed the area permitted for a single-story per Section 506.1.3.**



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Mixed Occupancy (508)

- **Section 508.3 Nonseparated occupancies**
- **Section 508.4 Separated occupancies**
- **Sections 506.2.2 – 506.2.4 single- and multi-story mixed occupancy buildings**

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CCWD Building Area Tables

Table 5 – Group B Srinklered Buildings – Maximum Floor Area per Story [a, b, c]

Group B - NFPA 13 Compliant Sprinklered Buildings [a, b, c]						
# of stories	% frontage	Maximum floor area per story (sq. ft.)				
		IIIA	IIIB	IV	VA	VB
4	0-25	64,120	42,750	81,000	40,500	NP
	50	69,460	46,310	87,750	43,870	NP
	100	80,150	53,430	101,250	50,620	NP
5	0-25	51,300	NP	64,800	NP	NP
	50	55,750	NP	70,200	NP	NP
	100	64,120	NP	81,000	NP	NP
6	0-25	42,750	NP	54,000	NP	NP
	50	46,310	NP	58,500	NP	NP
	100	53,430	NP	67,500	NP	NP

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Footnotes – Group B, Sprinklered Buildings

Footnotes

a. The Maximum floor area for four or more stories above grade plane was determined by dividing the maximum total allowable area determined in accordance with Section 506.2.3 by the number of stories. The floor area of the stories is assumed to be equal.

b. Frontage based on open space widths of 30 feet or more.

c. Interpolation is permitted.

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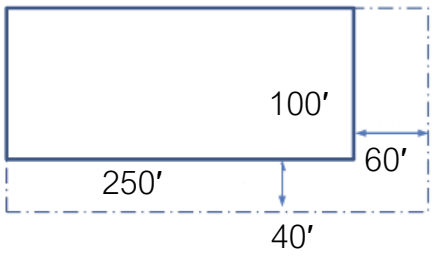
Example – Group B

Given: Six-story Type IIIA office building

- Provided with an NFPA 13-compliant automatic sprinkler system throughout and located on lot as shown.

Determine:
Maximum allowable building area



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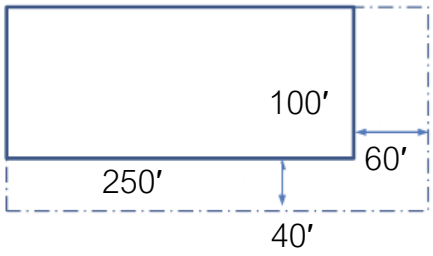
Example – Group B

Frontage Increase (Section 506.3)

- **50 percent of the perimeter open space qualifies for the frontage increase.**



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Example – Group B

Table 4–Group B NFPA 13-Compliant Sprinklered Buildings–Maximum floor area per story [a, b, c]

Group B - NFPA 13 Compliant Sprinklered Buildings [a, b, c]						
# of stories	% frontage	Maximum floor area per story (sq. ft.)				
		IIIA	IIIB	IV	VA	VB
4	0-25	64,120	42,750	81,000	40,500	NP
	50	69,460	46,310	87,750	43,870	NP
	100	80,150	53,430	101,250	50,620	NP
5	0-25	51,300	NP	64,800	NP	NP
	50	55,750	NP	70,200	NP	NP
	100	64,120	NP	81,000	NP	NP
6	0-25	42,750	NP	54,000	NP	NP
	50	46,310	NP	58,500	NP	NP
	100	53,430	NP	67,500	NP	NP

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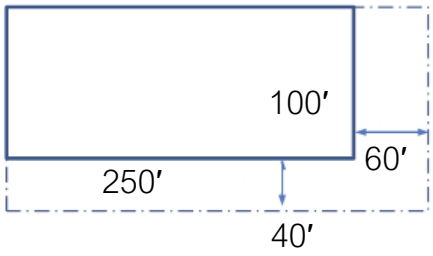
Example – Group R2

Given: Five-story Type IV apartment building

- **Provided with an NFPA 13-compliant automatic sprinkler system throughout and located on lot as shown.**

Determine:
Maximum allowable building area



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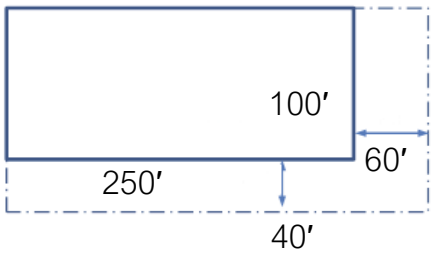
Example – Group R2

Frontage Increase (Section 506.3)

- **50 percent of the perimeter open space qualifies for the frontage increase.**



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Example – Group R2

Table 16 - Group R NFPA 13-Compliant Sprinklered Buildings– Maximum floor area per story [a, b, c, d]

Group R-1, R-2, R-4 - NFPA 13 Compliant Sprinklered Buildings [a, b, c, d]						
# of stories	% frontage	Maximum floor area per story (sq. ft.)				
		IIIA	IIIB	IV	VA	VB
2, 3	0-25	72,000	48,000	61,500	36,000	NP
	50	78,000	52,000	66,620	39,000	NP
	100	90,000	60,000	76,870	45,000	NP
4	0-25	54,000	36,000	46,120	27,000	NP
	50	58,500	39,000	49,960	29,250	NP
	100	67,500	45,000	57,650	33,750	NP
5	0-25	43,200	28,800	36,900	NP	NP
	50	46,800	31,200	39,970	NP	NP
	100	54,000	36,000	46,120	NP	NP

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AMERICAN WOOD COUNCIL

Stacked Buildings

Stacked Buildings (510)

- **Buildings of different types of construction and occupancy are allowed to be built on top of each other.**
- **They are commonly referred to as pedestal buildings.**

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Horizontal Building Separation Allowance (510.2)

- **3-hour rated Horizontal Assembly required between the lower and upper buildings**
  - **Limits in Section 510.2.**
  - **Group B, M and R occupancies and Group S-2 open and enclosed parking garages are permitted in the upper building.**
  - **Multiple Group A occupancies, each with an occupant load of less than 300, are also permitted in the upper building.**
  - **Lower building is permitted to be any occupancy except Group H.**

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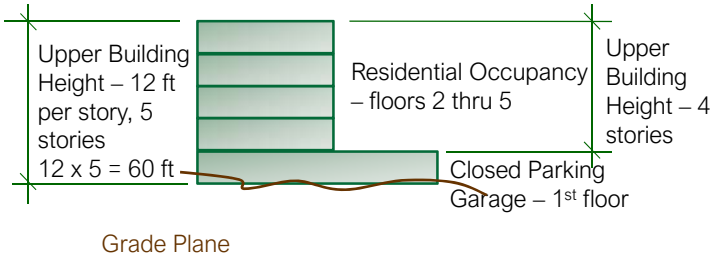
Building Height – Stacked Buildings

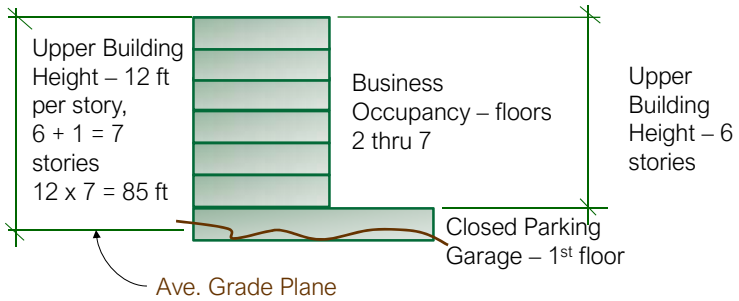
- **Building Height – in feet**
  - **Upper building height (feet) is measured from grade plane**
- **Building Height – in stories**
  - **Upper building height (stories) – measured from top of lower building**



57

Height – Group B Occy (Type IIIA or IV)

- **Building Height – 85 feet**
  - **Measured from average grade plane**
- **Building Height – 6 stories**
  - **Upper building height (stories) – measured from top of lower building**



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AMERICAN WOOD COUNCIL

Fire Resistance

Table 601

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

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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Methods for Determining Fire Resistance (703)

- **Seven methods to determine fire resistance:**
  - **Tested fire-resistance ass'y (ASTM E119 or UL 263)**
  - **Fire-resistance designs documented in approved sources**
  - **Prescriptive assemblies using fire-resistance designs in Section 721**
  - **Calculation of fire resistance per Section 722**
  - **Engineering analysis based on a comparison of building element, component or assembly designs that have been tested**
  - **Alternative protection methods per Section 104.11**
  - **Fire-resistance designs certified by an approved agency**

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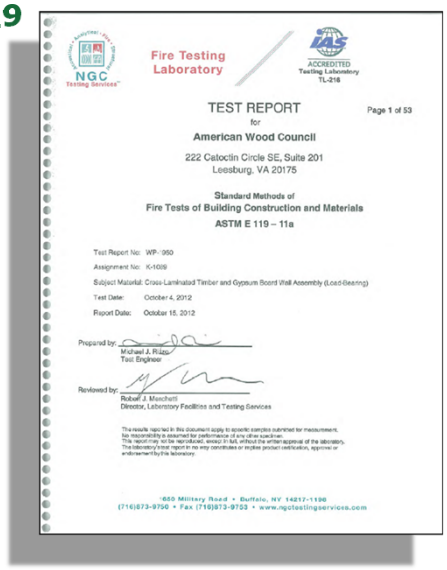
Tested Assembly (703.2)

- **Tested to the ASTM E 119 or UL 263 standard**



Fire Testing Laboratory

ACCREDITED Testing Laboratory TL-216

TEST REPORT

Page 1 of 53

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

Test Report No: WP-950
Assignment No: K-1009
Subject Material: Cross-Laminated Timber and Gypsum Board Wall Assembly (Load-Bearing)
Test Date: October 4, 2012
Report Date: October 15, 2012

Prepared by:
Michael J. Ritzo
Test Engineer

Reviewed by:
Robert J. Meschter
Director, Laboratory Facilities and Testing Services

The results reported in this document apply to specific samples submitted for measurement. No responsibility is assumed for performance of any other specimen. This report may not be reproduced, except in full, without the written approval of the laboratory. The laboratory's test report in no way constitutes or implies product certification, approval or endorsement by the laboratory.

1650 Military Road • Buffalo, NY 14217-1198
(716)873-9750 • Fax (716)873-9753 • www.ngctestingservices.com

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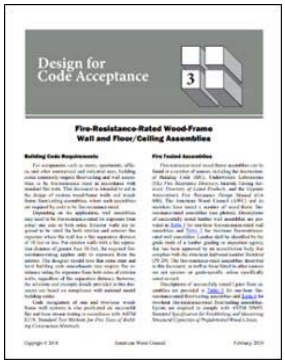
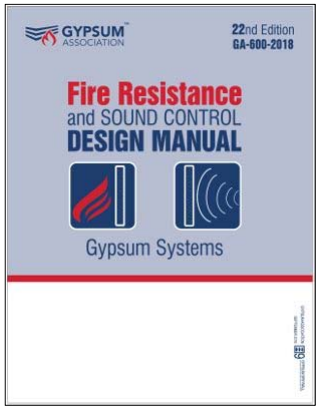
Designs Documented in Approved Sources (IBC 703.3 option 1)

- **Choose listed assemblies from fire-resistance publications or directories**





ONLINE CERTIFICATIONS DIRECTORY

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Prescriptive Assembly (703.3 option 2)

- **Fire resistance of wood assemblies as prescribed in Section 721**
- **All have been based on testing using ASTM E 119 or UL 263**

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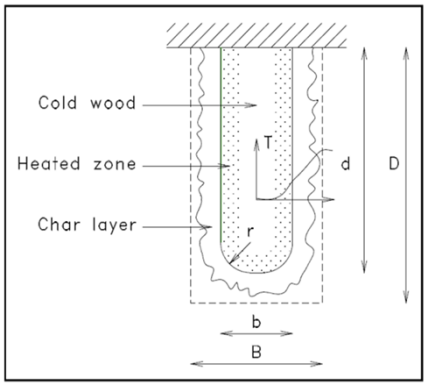
Calculated Fire Resistance (703.3 option 3)

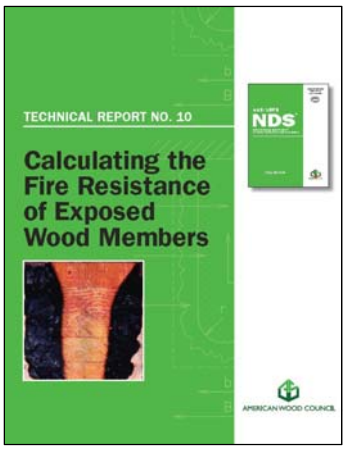
- **Fire resistance of exposed wood members may be calculated using the provisions of Chapter 16 of the National Design Specification® (NDS®).**
- **Up to 2 Hours**



65

Calculated Resistance (703.3)

- **AWC's Technical Report No. 10 (TR10), Calculating the Fire Resistance of Exposed Wood Members, contains explanations and examples of the method.**



66

Calculated Resistance (703.3)

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

Design for Code Acceptance 4

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

Wood-frame wall and floor office designers a unique opportunity to provide structure with economy as well as proven energy performance. Where these assemblies are required by the building codes to achieve a minimum fire endurance rating, a wide range of options for design exists.

Building Code Requirements

For both new and existing construction, many building codes require structural elements such as exterior walls, load bearing partitions, floor/ceiling assemblies and roofs to achieve a minimum fire endurance rating. Historically, these "protected" assemblies have been tested in accordance with the standard fire test and assigned an hourly fire endurance rating based on time to failure. The ASTM Standard E119 "Standard Method of Fire Tests of Building Construction and Materials" is normally used.

Many sources are available for obtaining information on the fire endurance of assemblies. Generally, publications from recognized testing laboratories are the source for fire endurance ratings of assemblies that have been tested. Building codes and regulators accept assemblies included in these publications as having the identified fire endurance rating. Until recently, building officials did not recognize methods for determining the fire endurance rating other than through testing. This has resulted in non-acceptance of many assemblies for which an experimental fire endurance rating was not available.

To permit use of "non-listed" assemblies, a methodology for calculating the fire endurance of load bearing and non-load bearing floor, wall, ceiling and roof assemblies has been adopted for use. A number of building codes now accept fire endurance ratings developed by this "Component Additive Method" (CAM) calculation methodology.

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Calculated Resistance (703.3 option 3)

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

DESCRIPTION OF FINISH	TIME[e](minutes)
7/16-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
1/2-inch gypsum wallboard	10
5/8-inch gypsum wallboard	15
1/4-inch gypsum wallboard	30
1/2-inch Type X gypsum wallboard	25
5/8-inch Type X gypsum wallboard	40
Double 1/4-inch gypsum wallboard	25
1/2-inch + 1/4-inch gypsum wallboard	35
Double 1/2-inch gypsum wallboard	40

For SI: 1 inch = 25.4 mm.

a. These values apply only when membranes are installed on framing members which are spaced 16 inches o.c. or less.

b. Gypsum wallboard installed over framing or furring shall be installed so that all edges are supported, except 5/8-inch Type X gypsum wallboard shall be permitted to be installed horizontally with the horizontal joints staggered 24 inches each side and unsupported but finished.

c. On wood frame floor/ceiling or roof/ceiling assemblies, gypsum board shall be installed with the long dimension perpendicular to framing members and shall have all joints finished.

d. The membrane on the unexposed side shall not be included in determining the fire resistance of the assembly. When dissimilar membranes are used on a wall assembly, the calculation shall be made from the least fire-resistant (weaker) side.

e. The time assigned is not a finished rating.

- **Sum of Assigned Times**
- **IBC Table 722.6.2 (1) Time Assigned to Wallboard Membranes**

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Engineering Analysis (703.3 option 4)

- **703.3 Alternative Methods for Determining Fire Resistance**
  - **Item 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 E 119 or UL 263.**

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SPECIAL DESIGN CONSIDERATIONS-SHRINKAGE

Shrinkage – 2015 IBC

- Section 2303 Minimum Standards and Quality

2303.7 Shrinkage. Consideration shall be given in design to the possible effect of cross-grain dimensional changes considered vertically which may occur in lumber fabricated in a green condition.

- Lumber in a "green condition" has a moisture content higher than that used to define a "dry condition" under the applicable grading rules, which is reflected on the grade mark (see Figure 2303.1.1). Because it will shrink more than dry lumber, use of lumber that is fabricated in a green condition requires consideration of the effects of cross-grain shrinkage. The extent of cross-grain shrinkage is a function of the lumber's moisture at the time of construction, the amount of drying that occurs after construction and the in-service moisture content.

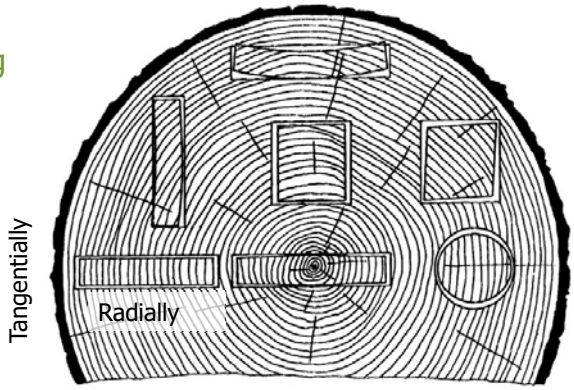
Shrinkage – 2015 IBC

2304.3.3 Shrinkage. Wood walls and bearing partitions shall not support more than two floors and a roof unless an analysis satisfactory to the building official shows that shrinkage of the wood framing will not have adverse effects on the structure or any plumbing, electrical or mechanical systems or other equipment installed therein due to excessive shrinkage or differential movements caused by shrinkage. The analysis shall also show that the roof drainage system and the foregoing systems or equipment will not be adversely affected or, as an alternate, such systems shall be designed to accommodate the differential shrinkage or movements.

Moisture Changes In Wood

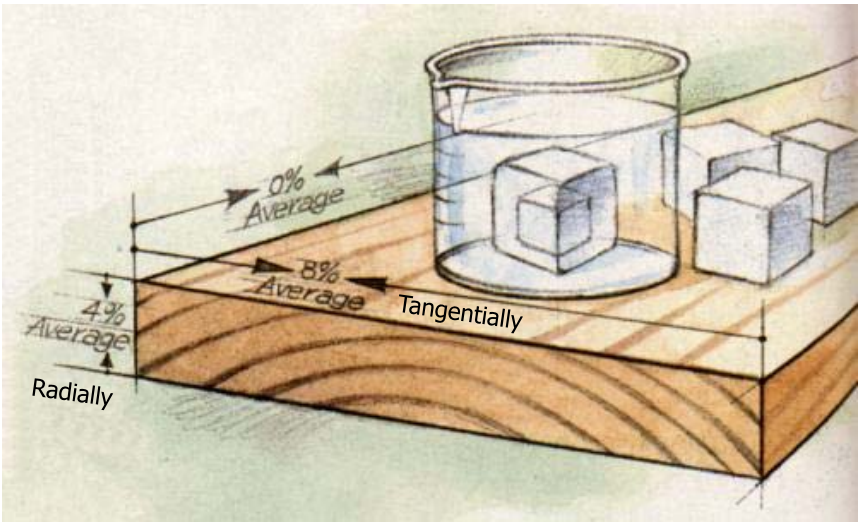
- **Causes dimensional changes perpendicular to grain**

Growing tree is filled with water



As wood dries, it shrinks perp. to grain

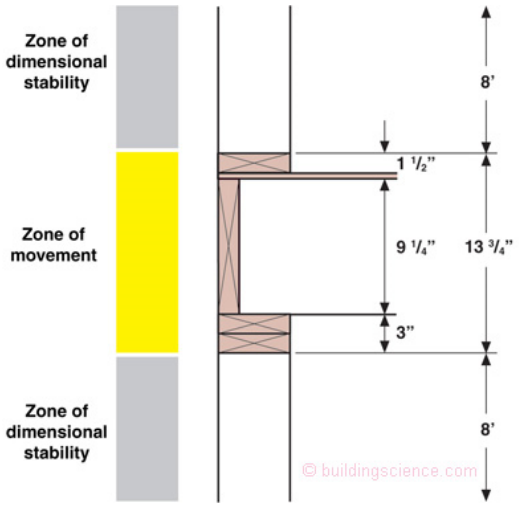
Wood Shrinks



Woodmagazine.com

Zone of Movement

- **Shrinkage occurs primarily in horizontal members such as wall plates and floor joists**



Grade Stamps

GRADE MARKS:

- Certification mark
- Mill Identification
- Grade designation
- Species identification

- Condition of seasoning
  - MC-15 or
  - KD-15 - 15% max. MC
  - S-DRY, KD or
  - KD HT- 19% max. MC
  - S-GRN, over 19% MC
  - HT S-GRN- (unseasoned)

BASIC INFORMATION FROM STAMP:
1. Who made it
2. How strong is it

Grade Stamps

- **Condition of seasoning at the time of surfacing:**
- **S-GRN (Surfaced Green) and HT S-GRN (Heat Treated Surface Green) – over 19% MC**
- **S-DRY (Surface Dry), KD (Kiln Dried) or KD HT (Kiln Dried and Heat Treated) – Maximum 19% MC**
- **MC 15 or KD 15 – Maximum 15% MC**

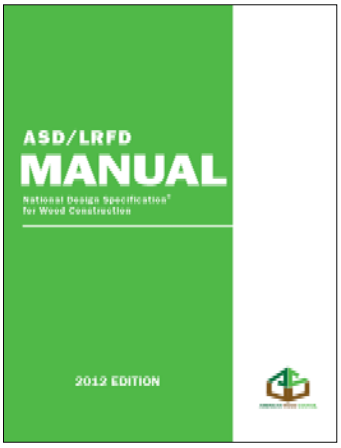
- **Varies on region and market conditions**
- **In Southwest region "green" (S-GRN) is common.**
- **Other parts of country "dry" (S-DRY) is common.**
- **Engineer should consider the availability of kiln dried lumber.**

Overview

- **Key factors influencing the magnitude of wood frame shrinkage**
- **Pre-construction moisture content (MC) will typically be higher than (in-service) equilibrium moisture content (EMC) For example: MC 19% or 15% kiln-dried for commercial construction vs. in-service 8-10%**
- **Wood species has relatively little impact since most species used in commercial construction have similar shrinkage properties**

M4.4 Special Design Considerations

•1% change in dimension per 4% change in MC



http://www.awc.org/pdf/2012ASD-LRFD_Manual_WEB.pdf

Calculating Shrinkage

•Shrinkage Calculator:
•https://wwpa.org/resources/shrinkage-estimator

http://autotighttiedowns.com/Website%202011%20Documents/WWPA%20Shrinkage%20TN10.pdf

Average Outdoor and Indoor EMC

http://autotighttiedowns.com/Website%202011%20Documents/WWPA%20Shrinkage%20TN10.pdf

For EMC of additional outdoor locations, refer to:

1) *Simpson, William T. 1998. Equilibrium Moisture Content of Wood in Outdoor Locations in the United States and Worldwide. Res. Note FPL-RN-0268. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory.* ***http://www.fpl.fs.fed.us/documnts/fplrn/fplrn268.pdf***
2) *Smith, Harvey H.; Ellwood, Eric L.; Erickson, Robert W. 1959. Survey of the Moisture Content of Wood in use in California. No. 16. Berkeley, CA: University of California, Forest Products Laboratory.*
3) *National Weather Service at* ***http://www.nws.noaa.gov***

Table 1. Average Outdoor and Indoor EMC

Location	Average Outdoor EMC (%)	Average Indoor EMC (%)
Los Angeles, CA	10	9
San Diego, CA	12	10
Twentynine Palms, CA	6	6
San Francisco Bay Area	13	9
Sacramento Valley (CA)	11	8
N. Coast Red. (CA)	14	9
Sierra Nevada (CA)	11	7
San Joaquin Valley (CA)	11	8
Phoenix/Tucson, AZ	7	6
Flagstaff, AZ	10	7
Denver/Co.Springs, CO	10	8
Missoula, MT	13	7
Salt Lake City, UT	11	7
Boise, ID	11	7
Reno, NV	10	7
Las Vegas, NV	7	6
Portland/Salem, OR	14	8
Eugene, OR	15	8
Seattle/Tacoma, WA	14	8
Spokane, WA	13	8
Chicago, IL	13	8
Kansas City/St. Louis, MO	13	8
Dallas-Ft. Worth, TX	13	8
Austin, TX	13	8
Houston, TX	14	11

Calculating Shrinkage

Shrinkage of a softwood lumber member can be estimated using the following equation:

$S = D \times M \times C$

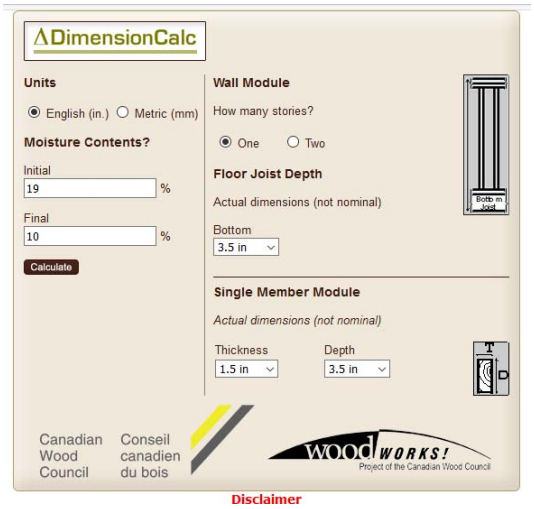
Where S = Shrinkage, inches
D = Dimension, inches
M = Change in moisture content, percent
C = Shrinkage coefficient, 0.0020 for Western softwood species (including Redwood) except 0.0017 for Western Red Cedar.

Table 2. Estimated Shrinkage of solid sawn Western softwood species except Western Cedars and Redwood, to 10% EMC
[shrinkage coefficient 0.0020]

	Nominal Size	S-GRN Size	Shrinkage (from FSP)	S-DRY Size	Shrinkage (from 19% MC)
Thickness	2"	1.563"	0.059"	1.500"	0.027"
	3"	2.563"	0.097"	2.500"	0.045"
	4"	3.563"	0.135"	3.500"	0.063"
	6"*	5.500"	0.209"	- - - -	- - - -
Width	6"	5.625"	0.214"	5.500"	0.099"
	8"	7.500"	0.285"	7.250"	0.131"
	10"	9.500"	0.361"	9.250"	0.167"
	12"	11.500"	0.437"	11.250"	0.203"

*6" thickness S-GRN size is for unseasoned 6x timbers.

Calculating Shrinkage Tool



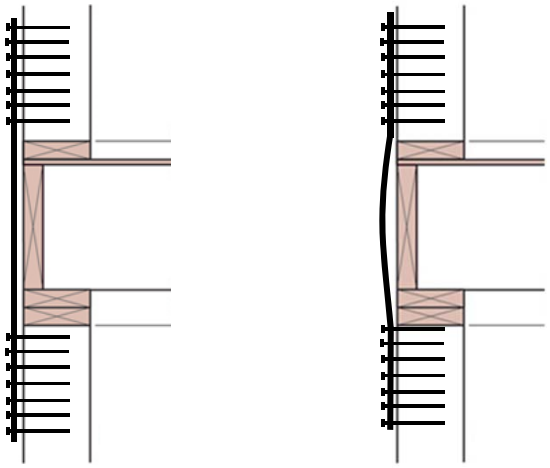
http://www.cwc.ca/dimensioncalc/

Overview

Key factors influencing the magnitude of wood frame shrinkage are:

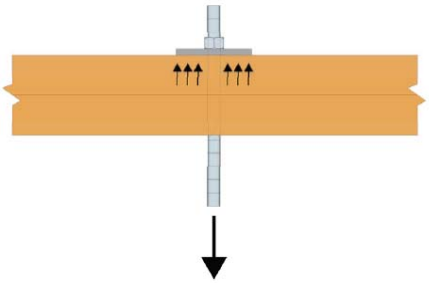
- **"settling" or "settlement of construction gaps" or "framing take-up"**
  - **1/8 inch per floor**
  - **½ to ¾ inch total at the top floor of a high-rise**
- **"creep" (long term movement under sustained loading)**
  - **1/8 to ¼ inch per story with magnitude progressively increasing from lower to upper stories).**

So What?



So What?

Tie-Down Rods



Deflection

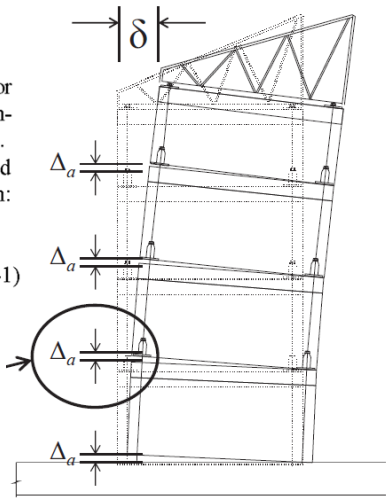
4.3.2 Deflection

Calculations of shear wall deflection shall account for bending and shear deflections, fastener deformation, anchorage slip, and other contributing sources of deflection.

The shear wall deflection, δ_{sw}, shall be permitted to be calculated by use of the following equation:

$$\delta_{sw} = \frac{8vh^3}{EAb} + \frac{vh}{1000G_a} + \frac{h\Delta_a}{b} \qquad (4.3\text{-}1)$$

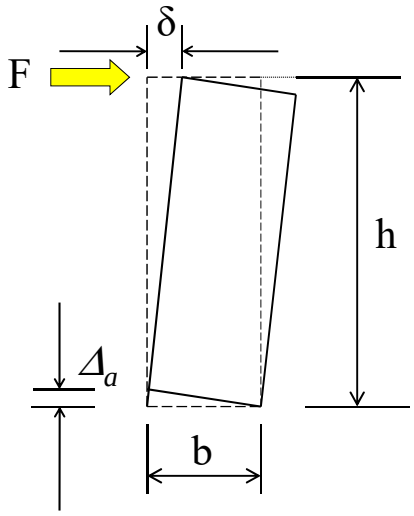
(bending, chord deformation excluding slip) *(shear, panel shear and nail slip)* *(bending, chord splice slip)*



Shear Wall Rotation

$$\delta = \Delta_a \left(\frac{h}{b} \right)$$

- Rod Elongation
- Bearing plate crushing
- Sill plate crushing
- Shrinkage & settlement
- Take-up device displacement



So What?

- Non-structural Challenges:
  - Mechanical/Electrical/Plumbing (MEP) Systems
  - Architectural Finishes
  - Drywall
  - Different Materials

So What?

Take-up Devices

Ratcheting Type Device

Spring Type Device

Mitigation

- Construction Considerations:
  - Sequencing
  - Framing
  - Finishes

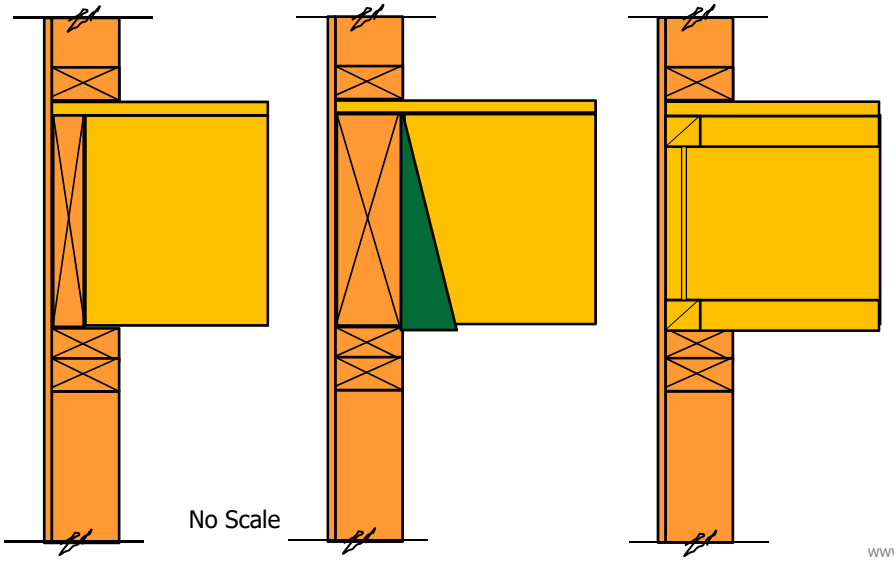
Site and Framing Timeline Guidelines

- **Minimize storage of material on site where rain and standing water can increase moisture content**
- **Keep unused framing material covered, especially at night when relative humidity increases**
- **Inspect pre-built wall panels prior to installation for proper material and quality of mechanical fasteners**
- **"Dry-in" the structure as quickly as possible**
- **Immediately remove any standing water from floor framing after rain showers**

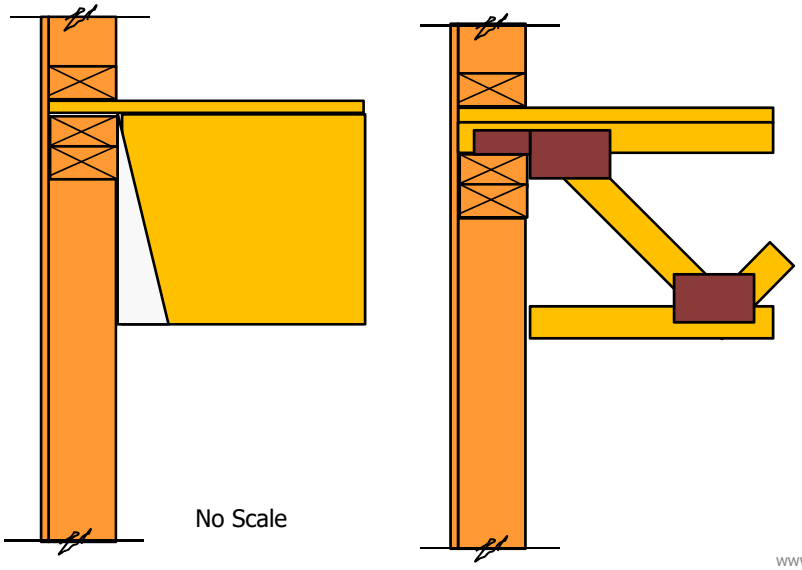
Framing Tips

- **Detail to reduce cumulative shrinkage**
  - **Minimize depth of framing members subject to (cross-grain) shrinkage**
  - **Specify material less subject to shrinkage**
    - Lumber with lower moisture content
      - Kiln dried
      - Treated wood

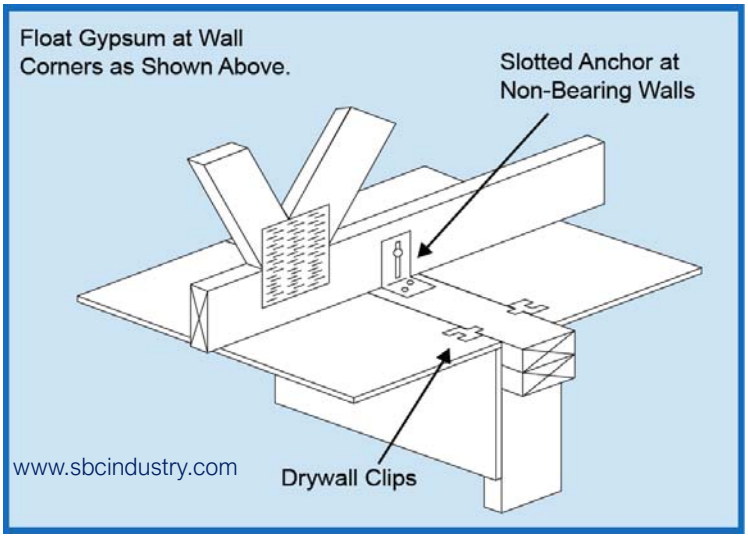
Platform Framing



Semi-balloon Framing



Differential Movement in Trusses



Mixed Materials

- **Cumulative shrinkage is the issue**
  - **Materials that do not shrink**
    - steel framing
    - steel/cast iron piping such as plumbing stacks
  - **Materials that shrink much less**
    - Concrete masonry - stair and elevator shafts
  - **Materials that expand**
    - Brick commonly used in veneers
    - Brick Institute of America's (BIA) Tek Note #18 covers the analysis and effects of movement

Site and Framing – Timing Guidelines

•Fully compress wall framing by completing all dead load potential.

•Complete all interior wall framing, roof framing, sheathing, floor toppings and roofing PRIOR to brick or stucco work.

Site and Framing – Plumbing

•Fully compress wall framing by completing all dead load potential PRIOR to mechanical installations.

•Avoid rigid vertical piping in mechanical and plumbing systems. Flexible members allow for shrinkage between floors.

Site and Framing – Timing Guidelines

•Vertical vent stacks should not be installed prior to full completion of framing.

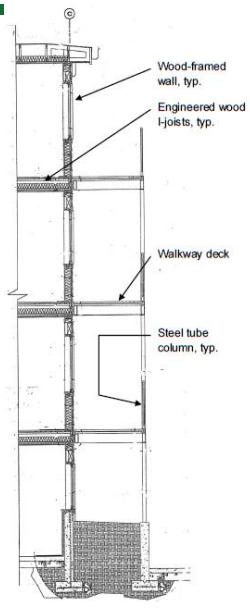
•Vent stacks require special attention and must be designed to allow for vertical movement due to shrinkage between floors.

Site and Framing – Plumbing

Design Considerations

- **Differential Movement at Balconies**
- **Multi-Story Wood-Frame Shrinkage Effects on Exterior Deck Drainage: A Case Study by Zeno Martn, Wood Design Focus Fall 2010 http://www.forestprod.com/wdfindex.html**

Figure 1. Section of wood-framed wall system showing deck framing with steel deck support columns.



AMERICAN WOOD COUNCIL

Precautions During Construction—Chapter 33

Fire Extinguisher (3309)

- **During construction, one portable fire extinguisher must be placed at:**
  - **Each stairway on all floor levels with combustible materials**
  - **Each storage or construction shed and where special hazards exist**

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Maintaining Means of Egress (3310)

- **During construction, when a building height reaches 50 feet or four stories, a minimum of one temporary lighted stairway must be provided unless a permanent stairway is available for use at all times.**

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Standpipes (3311)

- **When buildings are required to have standpipes, a minimum of one standpipe must be available during construction for fire department use.**
  - **The standpipe is installed before the construction is 40 feet above fire department access.**

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Sprinkler System Commissioning (3312)

- **Sprinkler system must be tested and approved before the certificate of occupancy is awarded.**

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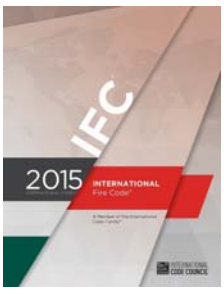
Requirements of the IFC

- **Additional requirements for fire safety during Construction are contained in the IFC (now directly referenced in Section 3302.3 of the IBC)**



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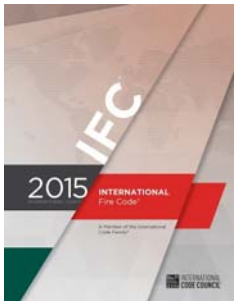
Requirements of the IFC Chapter 33

- **Additional requirements for fire safety during construction are contained in the IFC.**
  - **Temporary heating equipment must be listed and labeled (3303).**
  - **Smoking is prohibited except in approved areas with posted signage (3304.1).**
  - **A fire watch must be maintained with qualified personnel if required by the fire code official (3304.5).**



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Requirements of the IFC

- **Welding operations must follow the provisions of IFC Chapter 35. Electrical wiring must comply with NFPA 70 (IFC 3304).**
- **The owner must designate a fire prevention superintendent responsible for the fire prevention program during construction (3308).**
- **An accessible emergency phone must be provided in an approved location at the construction site (3309).**

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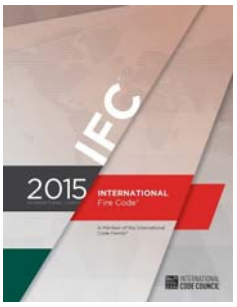
Requirements of the IFC

- **Fire-fighting vehicle access must be provided within 100 feet of temporary or permanent fire department connections (3310).**
- **An approved water supply for fire protection must be available when combustible material is at the construction site (3312).**
- **Requirements for safeguards during roofing operations 3317).**



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AMERICAN WOOD COUNCIL

Future Editions of the IBC

What's next? – Newer Editions of IBC

- **Massive Timber Products**
- **Incorporates New Technology**
- **Basic Code Requirements needs revisiting**
  - **Protect Public Health, Safety and Well-being**

Support Building Safety!

GLT and CLT in the 2018 IBC

- **510.12 (new) Special occupancy provision allowing up to 9 story CLT**
  Stand-alone provisions for a special occupancy R-1/R-2 with height increase similar to other existing special occupancies (G165-15)
- **602.3 CLT in exterior walls of Type III**
  Provides for CLT exterior walls in Type III construction (G172-15)
- **Structural Composite Lumber in Heavy Timber Construction**
  Reorganizes and clarifies the minimum dimensional requirements for sawn lumber, GLT, SCL, and CLT when used as an element of heavy timber construction (G178-15)
- **602.4 Concealed spaces in Type IV**
  Provides for protected concealed spaces in Type IV construction (G181-15)
- **602.4 SCL elements in CLT exterior walls**
  Provides for GLT and SCL elements in exterior walls of Type IV CLT construction (G182-15)

Heavy Timber "Reorganization"

- Clarifies reqs. Type IV Construction & HT elements
- Moves many HT details to Chapter 23
- 2018 Group A, G179 - G180 IBC 602.4

		MINIMUM NOMINAL SOLID SAWN SIZE		MINIMUM GLUED-LAMINATED NET SIZE		MINIMUM STRUCTURAL COMPOSITE LUMBER NET SIZE	
SUPPORTING:	HEAVY TIMBER CONSTRUCTION ELEMENT	Width, inch	Depth, inch	Width, inch	Depth, inch	Width, inch	Depth, inch
Floor loads only; combined floor and roof loads	Column; Framed sawn or glued-laminated timber arches, which spring from the floor line; Framed timber trusses	8	8	6 ¾	8 ¼	7	7 ½
	Wood beams and girders	6	10	5	10 ½	5 ¼	9 ½
Roof loads only	Lower half of: Wood-frame or glued-laminated arches, which spring from the floor line or from grade;	6	8	5	8 ¼	5 ¼	7 ½
	Column; Upper half of: Wood-frame or glued-laminated arches, which spring from the floor line or from grade;	6	6	5	6	5 ¼	5 ½
	Framed or glued-laminated arches that spring from the top of walls or wall abutments; Framed timber trusses and other roof framing	4 [a]	6	5	6 7/8	3 ½	5 ½

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TWB AD HOC COMMITTEE CHANGES 2021 IBC

- G108 Three New types of Heavy Timber construction
- G75 Height in feet
- G80 Height in stories
- G84 Allowable area per floor
- G89 Fire barriers
- G146 Membrane structures with mass timber
- G152 Appendix
- G28 Redundant water supply
- FS5 Performance based noncombustible protection
- FS6 Sealing of Splices and intersections
- FS73 mass timber as fire blocking
- FS81 Prescriptive noncombustible protection
- IFC F88 Owners responsibility
- IFC F266 Fire safety during construction

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2021 Ed. of the IBC – Construction Types

TABLE 601

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV				TYPE V	
	A	B	A	B	A	B	A	B	C	HT	A	B
Primary structural frame [f] (see Section 202)	3[a]	2[a]	1	0	1	0	3[a]	2[a]	2[a]	HT	1	0
Bearing walls Exterior [e, f] Interior	3 3[a]	2 2[a]	1 1	0 0	2 1	2 0	3 3	2 2	2 2	2 1/HT	1 1	0 0
Nonbearing walls and partitions Exterior	See Table 602											
Nonbearing walls and partitions Interior [d]	0	0	0	0	0	0	0	0	0	See Section 2304.11.2	0	0
Floor construction and associated secondary members (see Section 202)	2	2	1	0	1	0	2	2	2	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	1 1/2	1	1	HT	1[b, c]	0

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Type of Construction (2021 IBC)

TABLE 601

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV				TYPE V	
	A	B	A	B	A	B	A	B	C	HT	A	B
Primary structural frame [f] (see Section 202)	3[a]	2[a]	1	0	1	0	3[a]	2[a]	2[a]	HT	1	0
Bearing walls Exterior [e, f] Interior	3 3[a]	2 2[a]	1 1	0 0	2 1	2 0	3 3	2 2	2 2	2 1/HT	1 1	0 0
Nonbearing walls and partitions Exterior	See Table 602											
Nonbearing walls and partitions Interior [d]	0	0	0	0	0	0	0	0	0	See Section 2304.11.2	0	0
Floor construction and associated secondary members (see Section 202)	2	2	1	0	1	0	2	2	2	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	1 1/2	1	1	HT	1[b, c]	0

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Type of Construction IV-C (2021 IBC)

Building Element	
Maximum Height	85''
Number of Stories	4 - 9
Exposed Mass Timber	Fully Exposed
Sprinklers	Yes
Primary Frame FRR	2 hours
Floor FRR	2 hours
Stairs Tower	Protected Mass Timber
Concealed Spaces	Permitted if protected

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Type of Construction IV-B (2021 IBC)

Building Element	
Maximum Height	180'
Number of Stories	6 - 12
Exposed Mass Timber	Partially
Sprinklers	Yes
Primary Frame FRR	2 hours
Floor FRR	2 hours
Fire Resistance from Non-com	80 minutes
Stairs Tower	Protected Mass Timber
Concealed Spaces	Permitted if protected

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Type of Construction IV-A (2021 IBC)

Building Element	
Maximum Height	270’
Number of Stories	9 - 18
Exposed Mass Timber	Fully Protected
Sprinklers	Yes
Primary Frame FRR	3 hours
Floor FRR	3 hours
Fire Resistance from Non-com	120 minutes
Stairs Tower	Non-combustible
Concealed Spaces	Permitted if protected

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Table 504.4 Allowable Stories Group B

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AMERICAN WOOD COUNCIL

Resources

American Wood Council Standards

Code-Referenced American Wood Council Standards www.awc.org	
2015 NDS®	*2015 National Design Specification®* (NDS) *for Wood Construction with 2015 Supplement*
2015 SDPWS	*2015 Special Design Provisions for Wind and Seismic*
2015 WFCM	*2015 Wood Frame Construction Manual for One- and Two-Family Dwellings* PC199
2015 PWF	*2015 AWC Permanent Wood Foundation Design Specification*
2015 STJR	*2015 AWC Span Tables for Joists and Rafters*
WCD No. 4-2003	*2003 AWC Wood Construction Data—Plank and Beam Framing for Residential Buildings*

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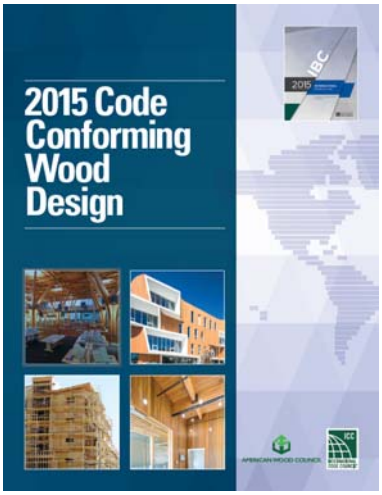
Slide 124

PC199 corrected table entry spacings
Paul Coats, 9/24/2015

2015 Code Conforming Wood Design Document (CCWD)

- 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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Design for Code Acceptance

The Design for Code Acceptance documents can be downloaded for free at: www.awc.org/codes-standards/publications.

American Wood Council Design Documents	
DCA 1	DCA 1 - *Flame Spread Performance of Wood Products*
DCA 2	DCA 2 - *Design of Fire-Resistive Exposed Wood Members*
DCA 3	DCA 3 - *Fire Rated Wood Floor and Wall Assemblies*
DCA 4	DCA 4 - *CAM for Calculating and Demonstrating Assembly Fire Endurance*
DCA 5	DCA 5 - *Post-Frame Buildings*
DCA 6	DCA 6 - *Prescriptive Residential Deck Construction Guide* – 2012 IRC Version
DCA 7	DCA 7 – *Meeting Residential Energy Requirements with Wood-Frame Construction* – 2012 IECC Version

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Other Associations Publishing Referenced Standards

Standards from additional organizations are referenced in this publication. The following table lists the standard, its title and the site from which the standard is available.

Standard-Edition	Title	Website
AAMA/WDMA/CSA 101/I.S.2/A440-11	*North American Fenestration Standard/ Specifications for Windows, Doors and Skylights*	aamanet.org wdma.com
APA *PDS—12*	*Panel Design Specification*	apawood.org
ASCE 7-10	*Minimum Design Loads for Buildings and Other Structures*	asce.org
ASTM D 2898-10	*Test Methods for Accelerated Weathering of Fire-retardant-treated Wood for Fire Testing*	astm.org
ASTM E 84-13a	*Test Methods for Surface Burning Characteristics of Building Materials*	
ASTM E 108-11	*Test Methods for Fire Tests of Roof Coverings*	
ASTM E 119-12a	*Test Methods for Fire Tests of Building Construction and Materials*	
AWPA C1-03	*All Timber Products-Preservative Treatment by Pressure Processes*	awpa.com
AWPA M4-11	*Standard for the Care of Preservative-treated Wood Products*	
AWPA U1-14	*USE CATEGORY SYSTEM: User Specification for Treated Wood Except Section 6, Commodity Specification H*	

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Other Associations Publishing Referenced Standards

Standard-Edition	Title	Website
2015 IBC	*2015 International Building Code*	iccsafe.org
2015 IRC	*2015 International Residential Code*	
ICC 400-12	*Standard on Design and Construction of Log Structures*	
ICC 600-14	*Standard for Residential Construction in High Wind Regions*	
NFPA 13-13	*Installation of Sprinkler Systems*	nfpa.org
NFPA 13D-13	*Installation of Sprinkler Systems in One- and Two-family Dwellings and Manufactured Homes*	
NFPA 13R-13	*Installation of Sprinkler Systems in Low Rise Residential Occupancies*	
NFPA 70-14	*National Electrical Code*	
UL 263-11	*Standard for Fire Tests of Building Construction and Materials*	ul.com
UL 723-08	*Standard for Test for Surface Burning Characteristics of Building Materials, with revisions through September 2010*	
UL 790-04	*Standard Test Methods for Fire Tests of Roof Coverings, with revisions through October 2008*	

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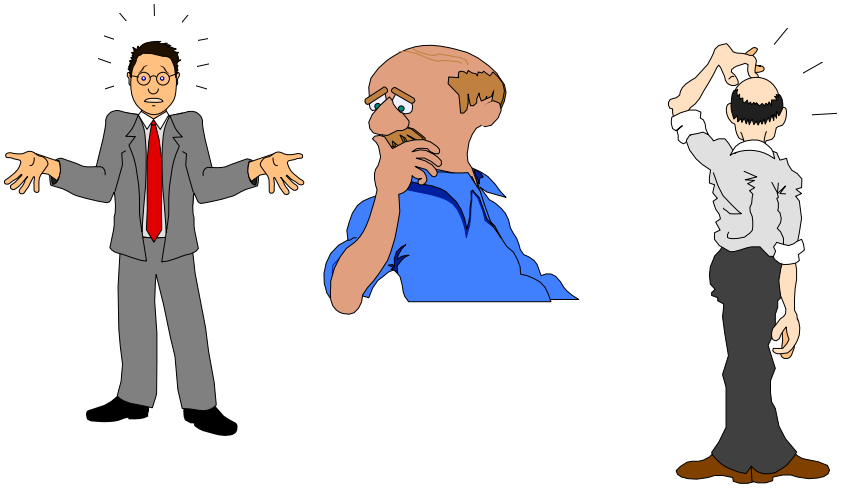
Questions ???



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Questions

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Questions?

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