AMERICAN WOOD COUNCIL

Cross-Laminated Timber in the 2015 IBC and NDS (MAT242)

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

Description

Cross Laminated Timber (CLT), one of the new mass timber products, is now included as a structural system in both the 2015 International Building Code and the 2015 National Design Specification® for Wood Construction. This presentation will give an overview of relevant building codes and standards provisions and describe how they can be used in the structural design of CLT elements and structures. Topics related to connections, structural, and fire protection will be discussed.

Learning Objectives

Upon completion of this course, participants will:

- Understand provisions for CLT under the 2015 IBC.
- Understand provisions for CLT under the 2015 NDS.
- Understand structural, fire, and connection design of CLT.
- Improve design knowledge on current applications of CLT throughout North America.

Outline

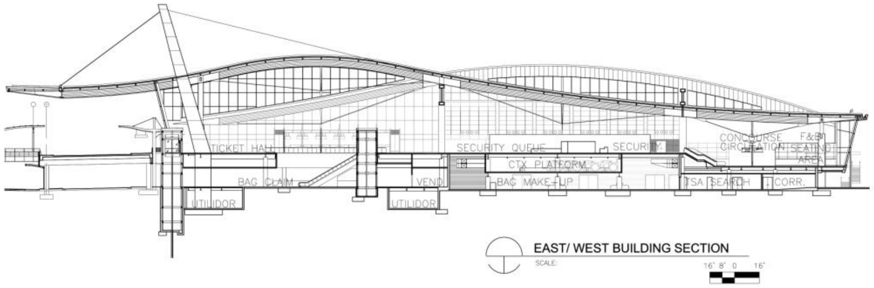
- **Overview**
- **Building Code Provisions**
- **Structural and Fire Provisions**
- **North American Projects**

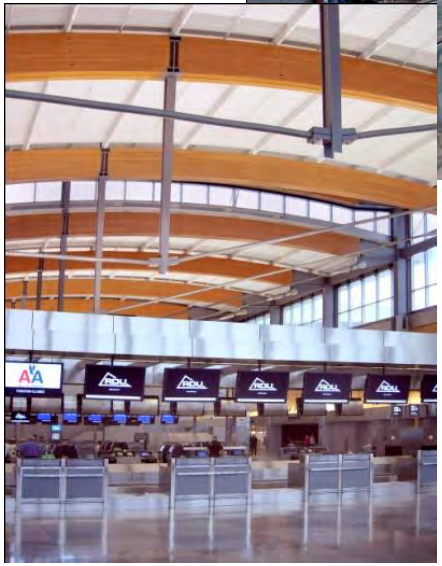
Traditional Stick Framed Construction

Heavy Timber Braced Frames

Simpson Strong Tie Demonstration Lab, Cal Poly San Luis Obispo Campus, CA

Glulam Roof System





Raleigh Durham Airport, North Carolina

Glulam Pedestrian Bridge - 105 ft. Span

Nail-Laminated Timber

- Type V Construction
- Assembly & Business Occupancy

http://www.structuremag.org/wp-content/uploads/D-Spotlight-Nov121.pdf

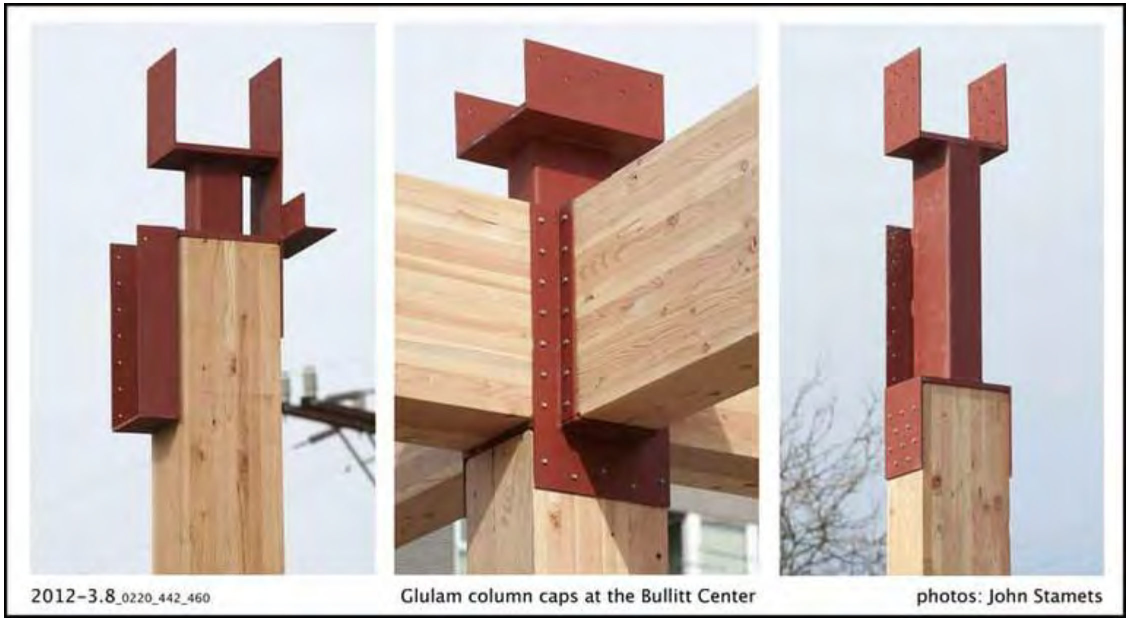
Warner Drive, Culver City, CA
Architect: Profeta Royalty Architecture
Structural Engineer: Structural Focus
Completed: 2011

Nail-Laminated Timber

- Nail Laminated Timber – 2x12 vertical mechanically connected w/ nails
- NDS principles of mechanics

Warner Drive, Culver City, CA
Architect: Profeta Royalty Architecture
Structural Engineer: Structural Focus
Completed: 2011

Glulam and Nail-Laminated Timber



Bullitt Center – Seattle, WA
Architect: Miller Hill Partnership
Structural Engineer: DCI Engineers
Photo Credit: Miller Hull Partnership

Glulam and Nail-Laminated Timber

- Glulam beams and columns
- Nail-laminated timber floors

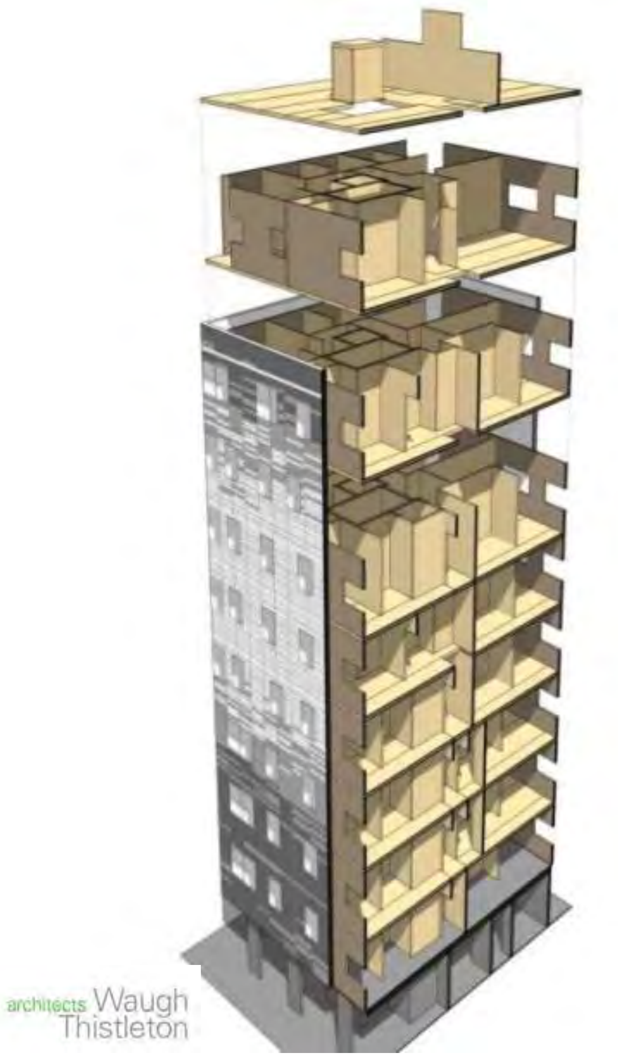
2012-3.19_0119 Bullitt Center – Ceiling of level 3 photo: John Stamets

2012-3.8_0117+119-124 Bullitt Center – Level 3 photo: John Stamets

Bullitt Center – Seattle, WA
Architect: Miller Hill Partnership
Structural Engineer: DCI Engineers
Photo Credit: Miller Hull Partnership

Cross-Laminated Timber

Cross-Laminated Timber



London infill project
29 flats (mixed affordable and private)
Ground floor office
4x less weight than precast concrete
~1/2 the construction time of precast concrete (saved 22 weeks vs. conc. 30%)
Saves 300 metric tons of CO_2
21 years of energy usage for the building

Cross-Laminated Timber

- **Scale:** 10 floors, 23 apartments
- **Build Period:**
  Start on site: February 2012
  Begin CLT installation: June 2012
  CLT structure complete: Aug 2012
  Practical completion: December 2012
- **Architect:** Lend Lease
- **CLT supplier:** KLH

Forté will have positively affected the environment by:

- Storing (sequestering) 761 tonnes CO2 eq an advantage of 1,451 tonnes CO2 eq over concrete and steel construction
- Equivalent to taking 345 cars off the road for a year
- Saving 7.7 GL of water
- Lowering eutrophication (the supply of excess nutrients to the water system) by 75%

In addition, the smart design and efficient systems of the building could save on average over $300 per year on energy and water bills.

Cross-Laminated Timber

10 stories, 23 apartments
https://youtu.be/pHpthNBiYqE

Cross-Laminated Timber

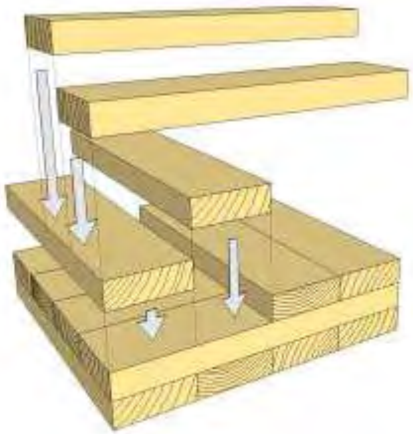
Cross-Laminated Timber

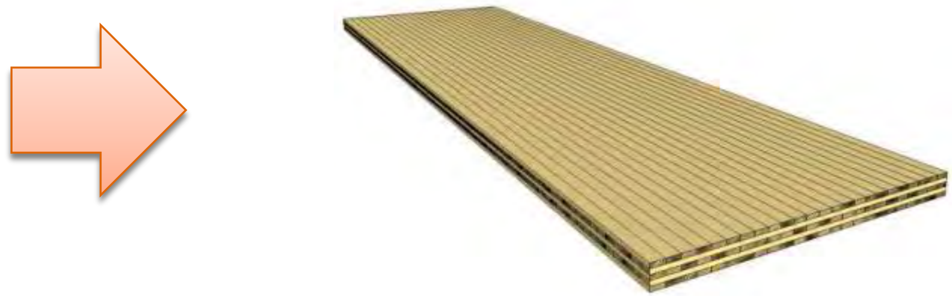
Under Construction
14 story
Architect: Artec
Structural Engineer: Sweco
Bergen, Norway

Cross-Laminated Timber

Under Construction
14 story
Architect: Artec
Structural Engineer: Sweco
Bergen, Norway

Concept of Cross Laminated Timber



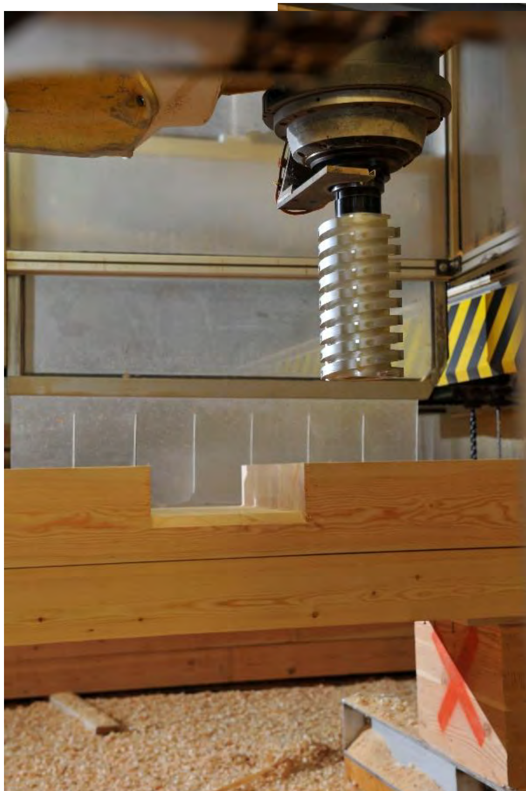


Photos provided by FPInnovations

CLT Layup, Press and Glue

Slide Courtesy of Structurlam

CNC Technology

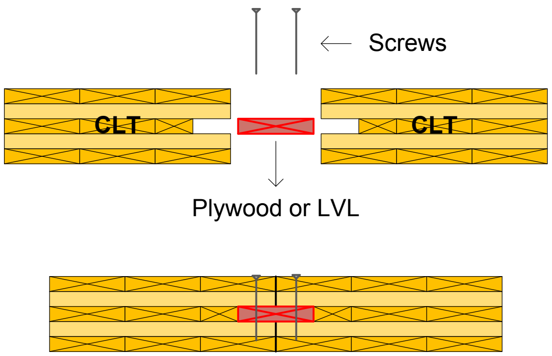


Slide Courtesy of Structurlam

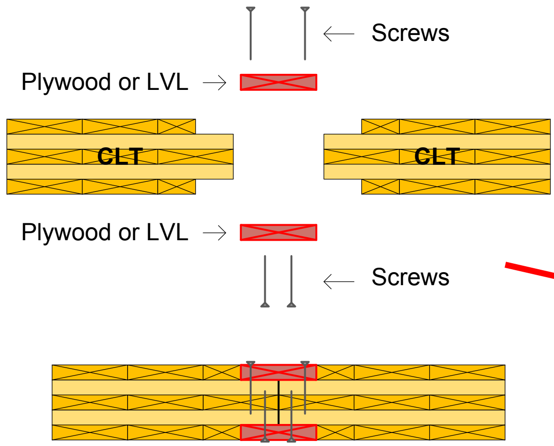
Ready to Ship

Slide Courtesy of Structurlam

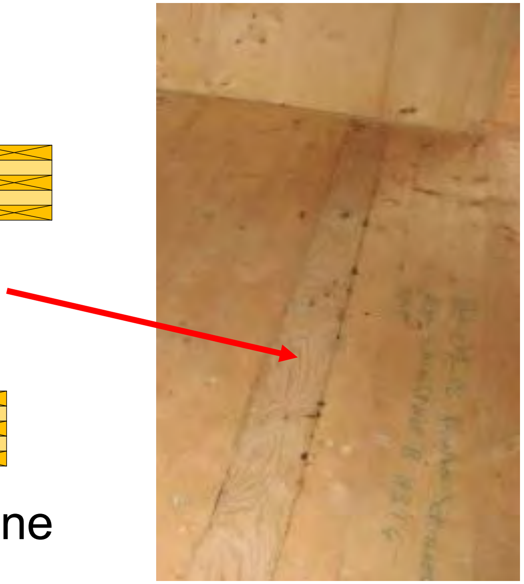
CLT - Typical Construction Details

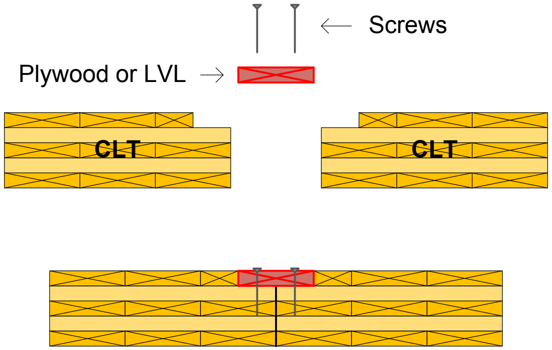


Internal spline



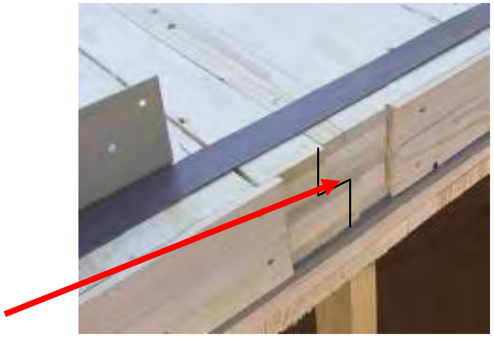
Double surface spline





Single surface spline

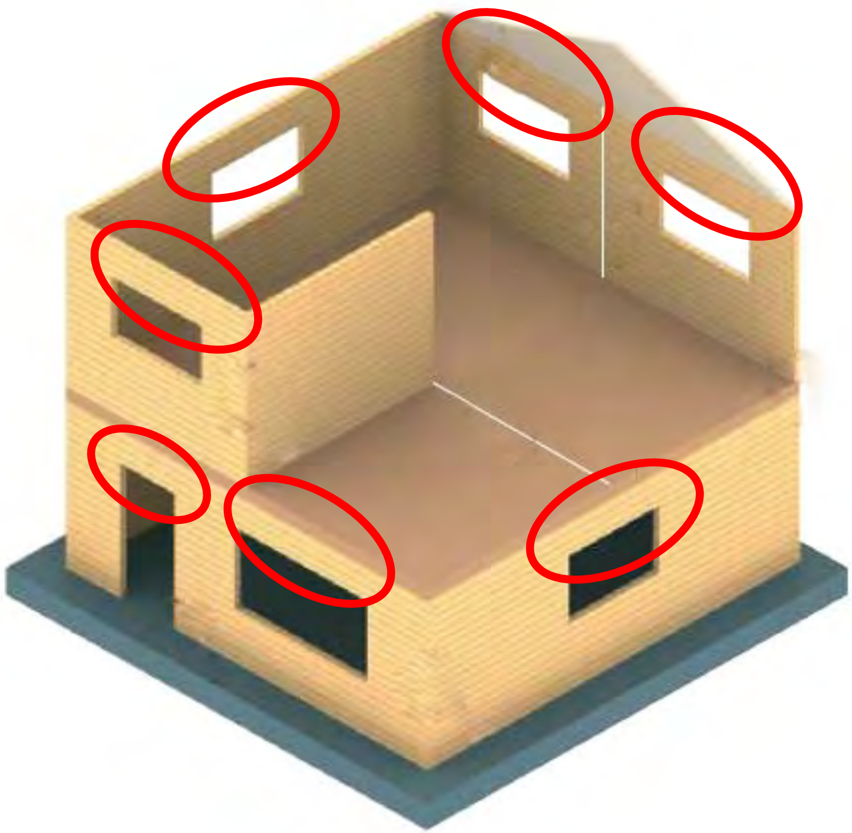
Half-lapped

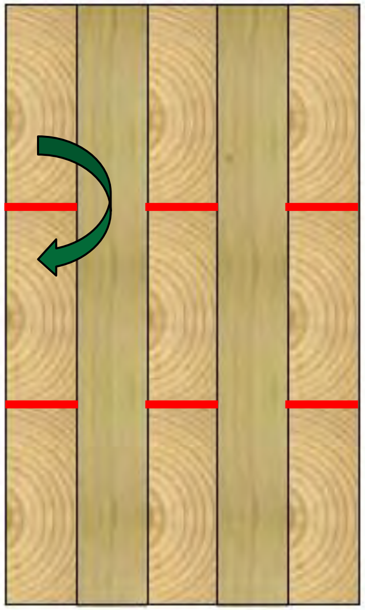


Bending Members

Design properties available for out-of-plane loading

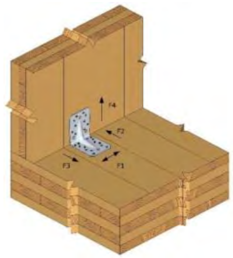
No design properties (not applicable) for in-plane loading



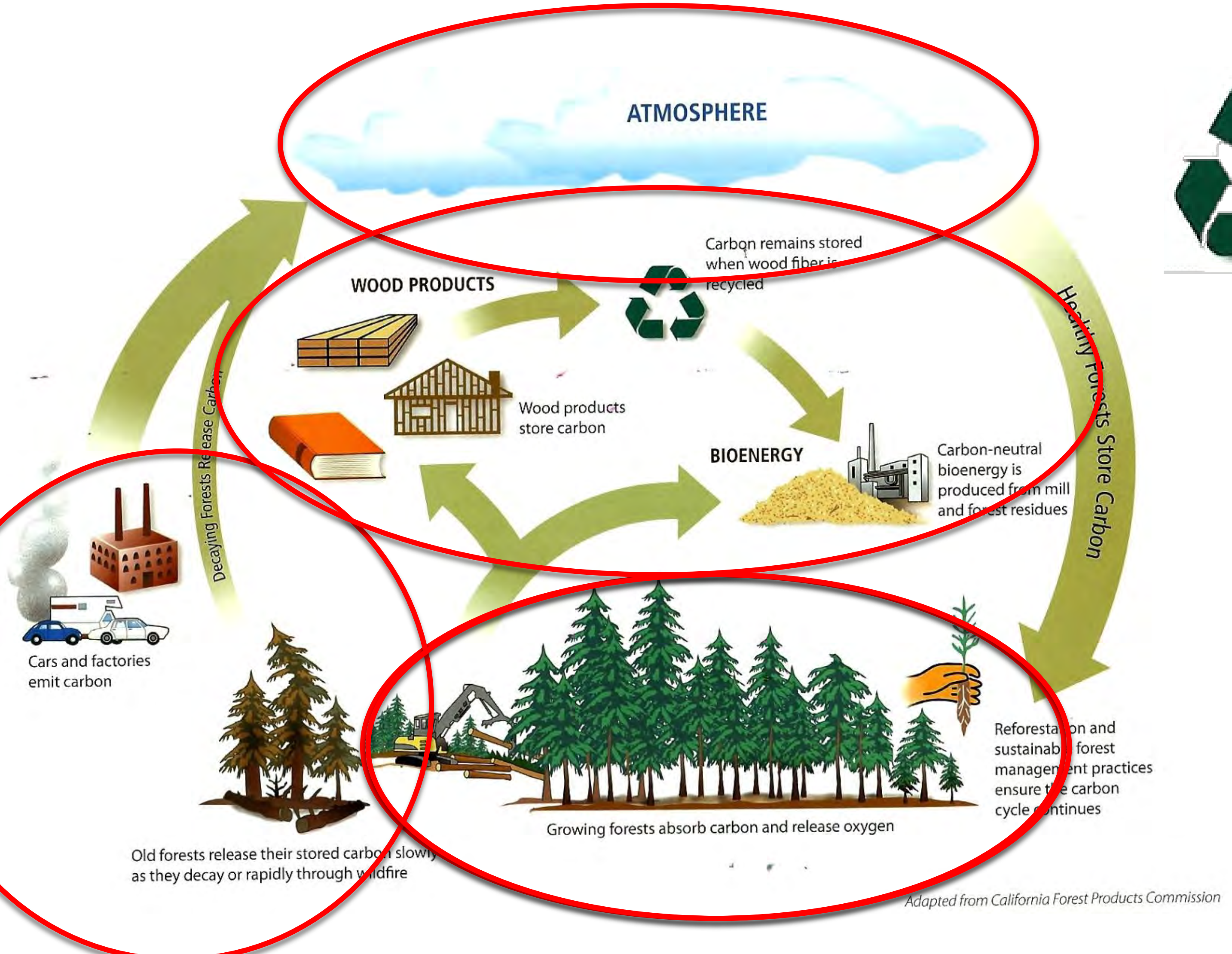


Typical Panel Connectors

Typical Panel Connectors



Carbon Cycle



Role of CO_2

=

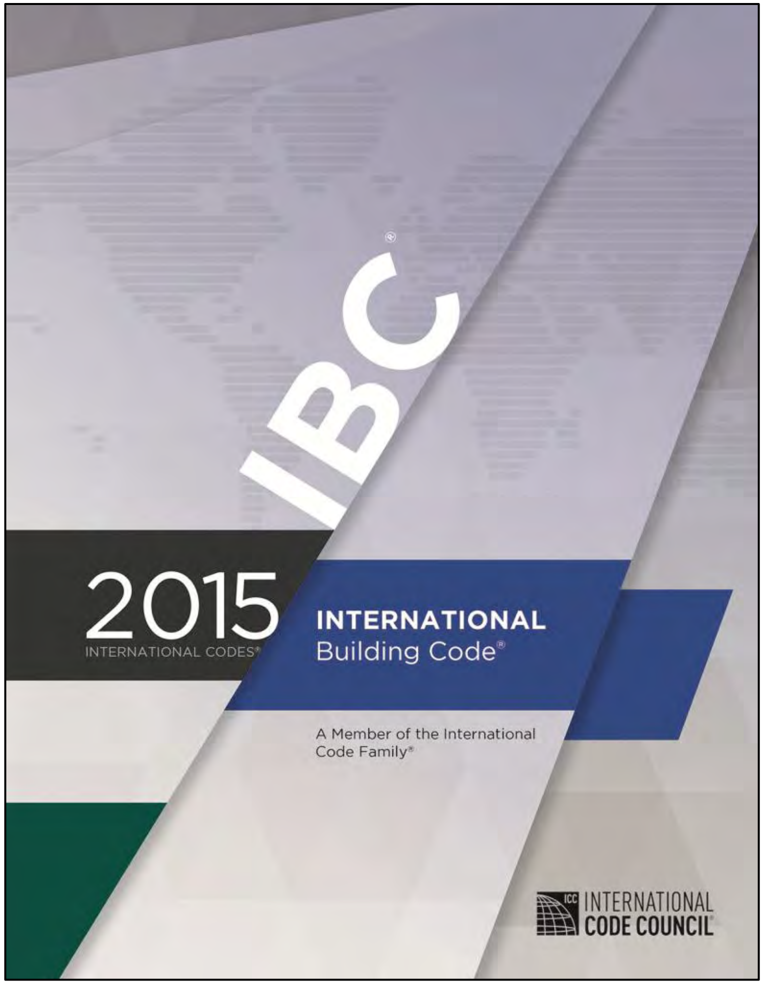
2,400 sf home = 32 m^3 structural wood = 29 metric tons CO_2 = 5.7 passenger annual emissions

Source: FP Innovations

Outline

- Overview
- **Building Code Provisions**
- Structural and Fire Provisions
- North American Projects

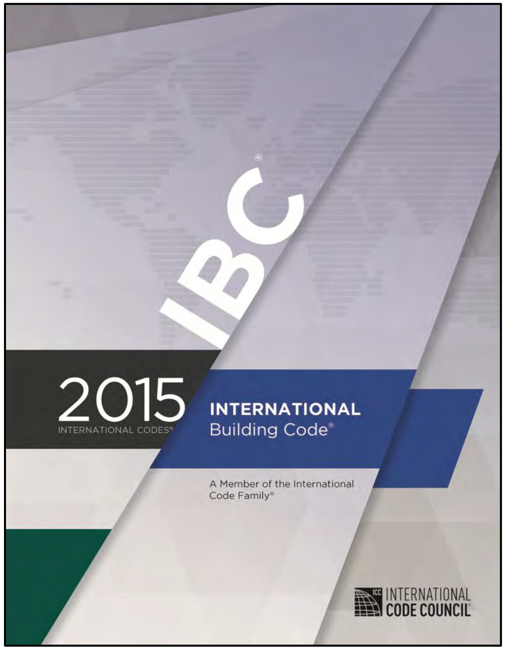
Building Code Provisions



CLT in 2015 IBC

Type IV Construction

602.4 Type IV. Type IV construction (Heavy Timber, HT) is that type of construction in which the exterior walls are of noncombustible materials and the interior building elements are of solid or laminated wood without concealed spaces...***Cross laminated timber*** **(CLT)** dimensions used in this section are actual dimensions.

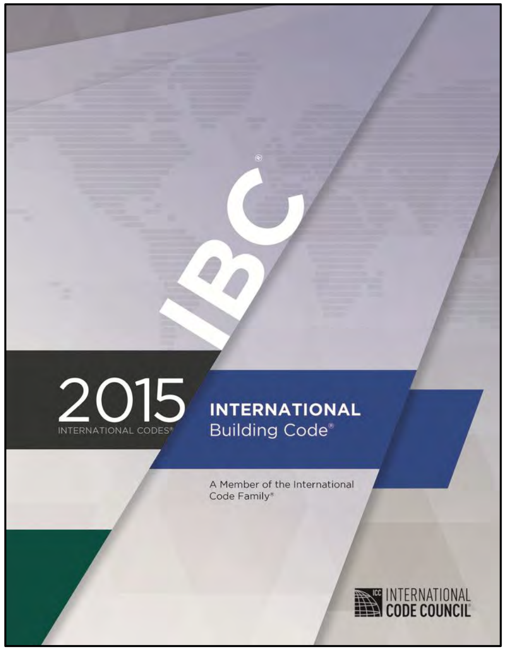


CLT in 2015 IBC

Chapter 23 Wood

2303.1.4 Structural glued **cross laminated timber**. Cross-laminated timbers shall be manufactured and identified as required in ANSI/APA PRG 320-2011.

CROSS-LAMINATED TIMBER. A prefabricated engineered wood product consisting of at least three layers of solid-sawn lumber or *structural composite lumber* where the adjacent layers are cross-oriented and bonded with structural adhesive to form a solid wood element.



Chapter 35 Reference Standards

ANSI/APA PRG 320-2011 Standard for Performance-Rated **Cross-Laminated Timber**

Type IV Construction – Exterior Walls

602.4.2 ***Cross-laminated timber*** complying with Section 2303.1.4 shall be permitted within exterior wall assemblies with a 2-hour rating or less provided:

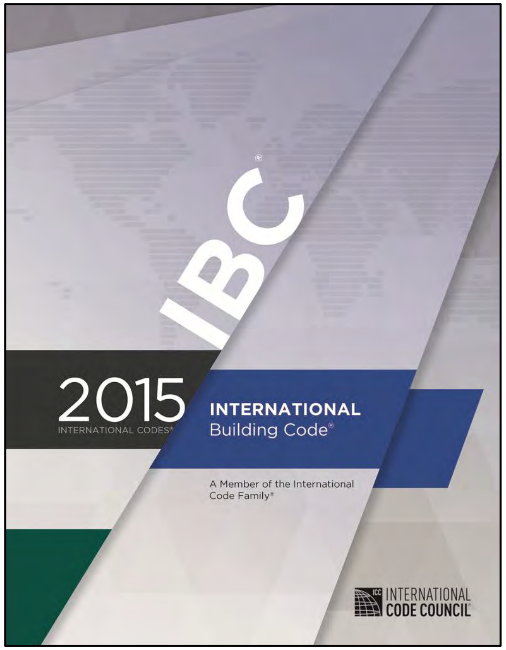
- Exterior surface of the **cross-laminated timber** is protected *fire retardant treated wood* sheathing complying with 2303.2 and not less than 15/32 inch thick;

OR

- *gypsum board* not less than ½ inch thick;

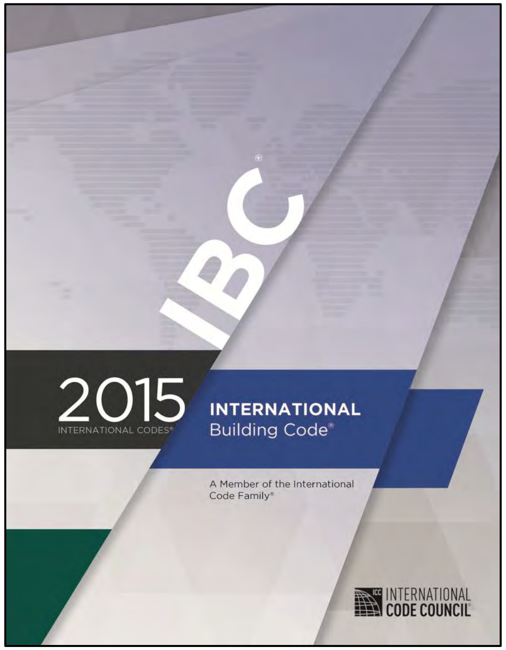
OR

- a noncombustible material.



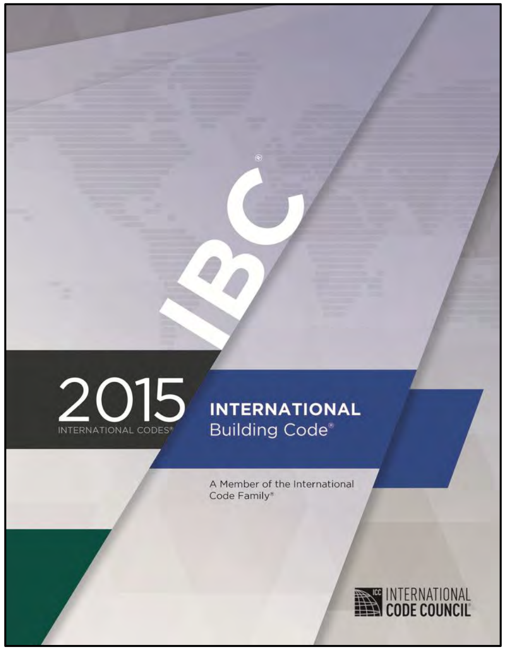
Type IV Construction – Floors

602.4.6.2 CLT. ***Cross laminated timber*** shall be not less than 4 inches (102 mm) in thickness. It shall be continuous from support to support and mechanically fastened to one another. ***Cross laminated timber*** shall be permitted to be connected to walls without a shrinkage gap providing swelling or shrinking is considered in the design…



Type IV Construction – Roofs

602.4.7 Roofs. Roofs shall be without concealed spaces and wood roof decks shall be sawn or glued laminated…or of **cross laminated timber**…**Cross laminated timber** roofs shall be not less than 3 inch nominal in thickness and shall be continuous from support to support and mechanically fastened to one another.



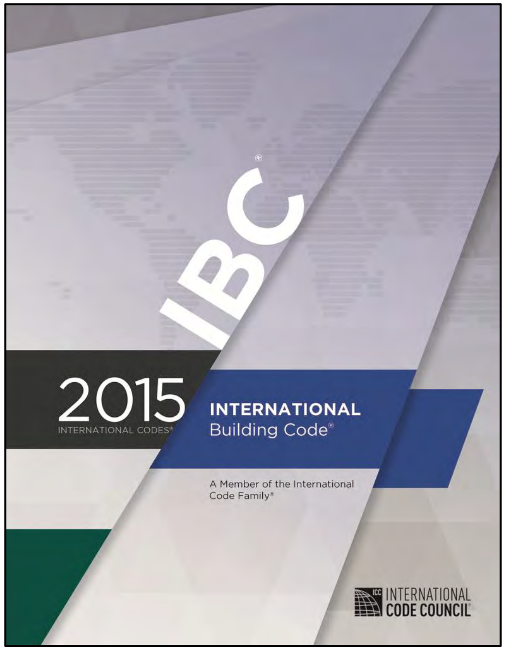
Type IV Construction – Walls & Partitions

602.4.8.2 Exterior walls. All exterior walls shall be of one of the following:

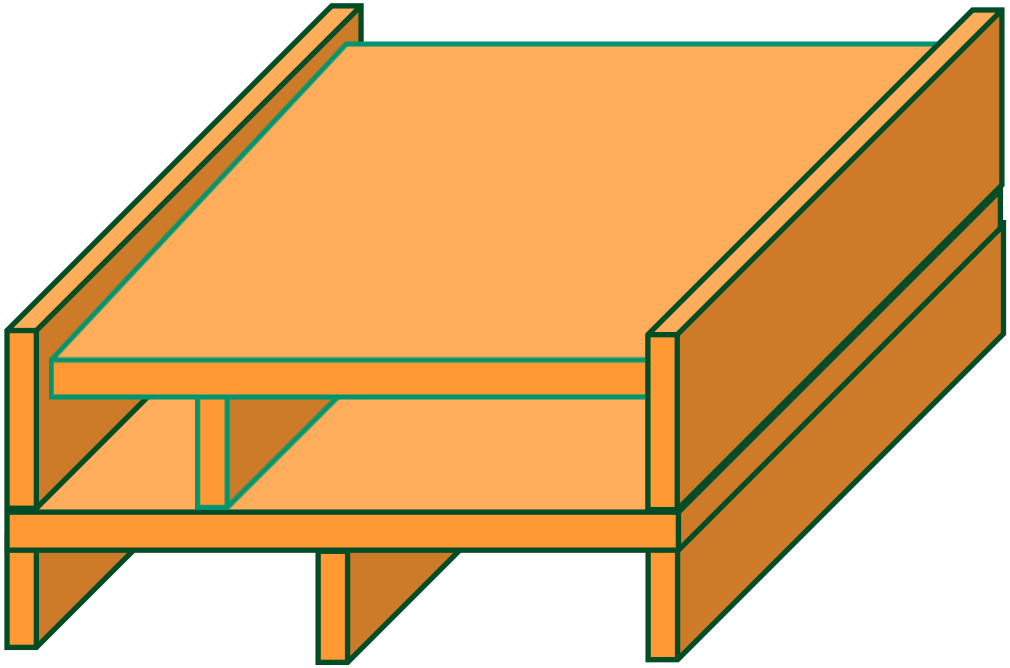
1. Noncombustible materials; or
2. Not less than 6 inches in thickness and constructed of one of the following:

2.1 *Fire retardant treated wood* in accordance with 2303.2 and complying with 602.4.1 or

2.2. ***Cross laminated timber*** complying with 602.4.2.

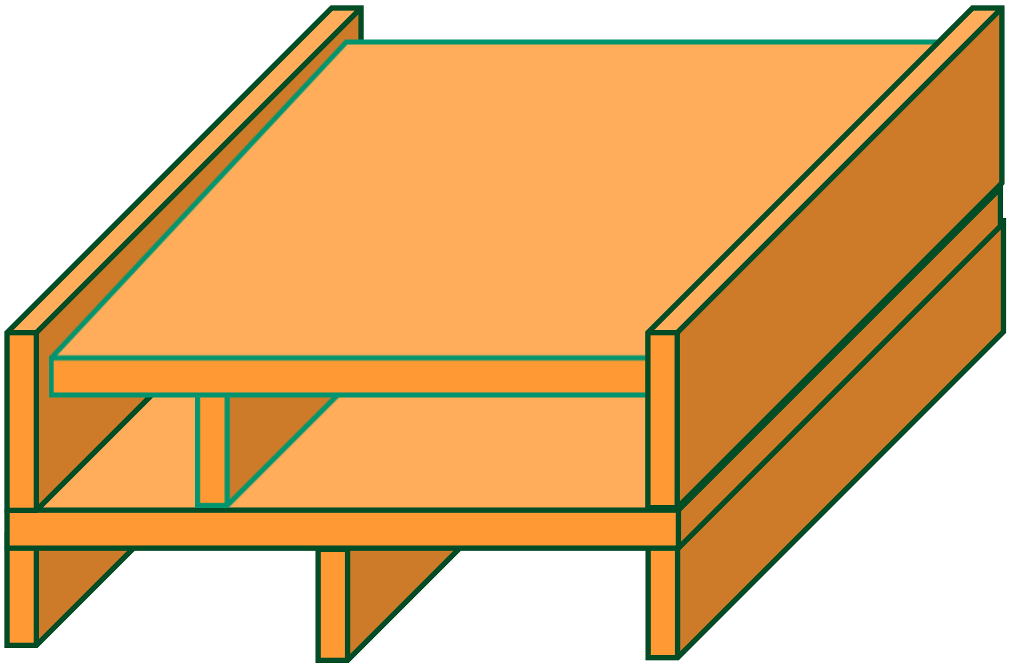


Type IV Construction



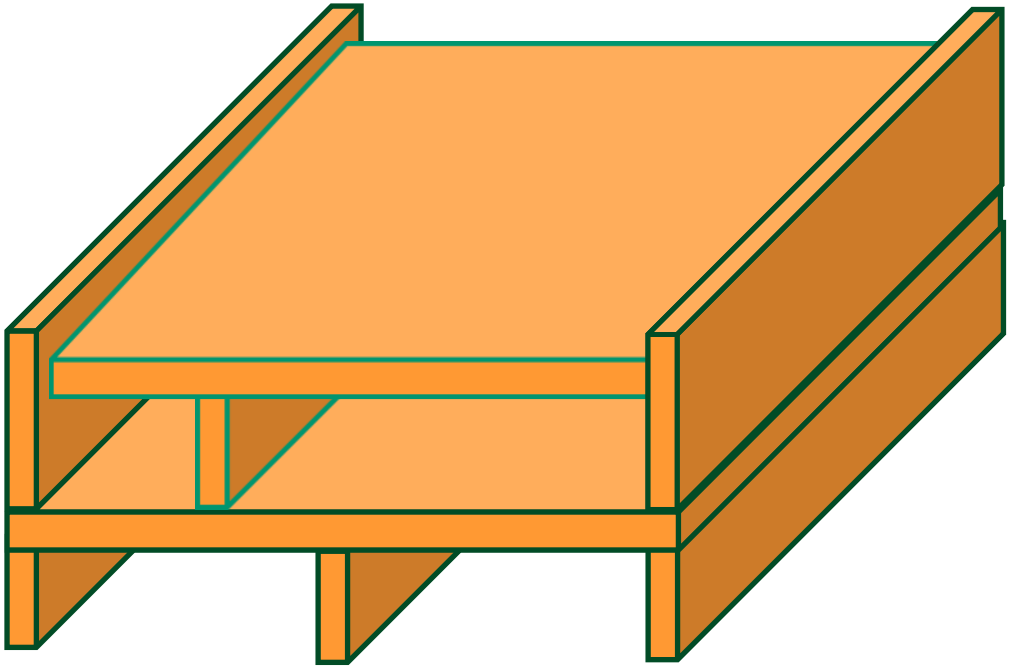
- ***All structural elements can be CLT***
  - *Exterior walls*
  - *Floor*
  - *Roof*
  - *Interior walls*

Type V Construction



- ***All structural elements can be combustible construction***
  - *Exterior walls*
  - *Floor*
  - *Roof*
  - *Interior walls*

Type III Construction



- *So where could CLT go?*
    - Almost anywhere!
- *Exterior Walls need to be non-combustible or FRT Wood (2 hour or less)*
- *Interior any material permitted by code*
- *Roof*

CLT in 2015 IBC

- **Summary**
  - 2015 IBC – most occupancies
    - Types VB and IV
    - Possibly Types VA, IIIA and IIIB

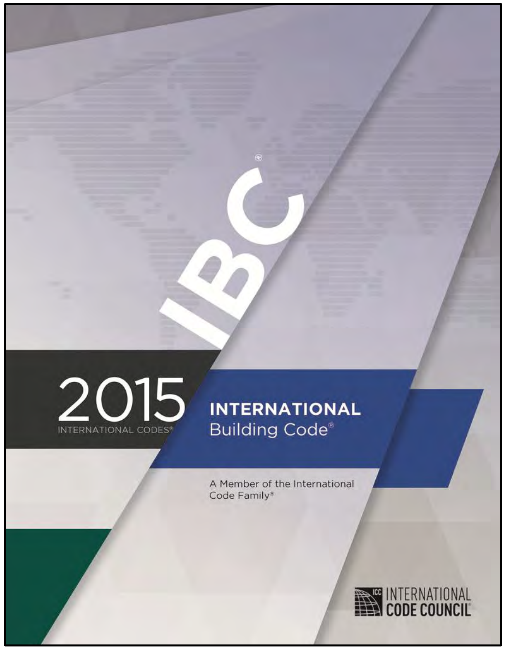


Table 504.4 Allowable Number of Stories Above Grade Plane

TABLE 504.4[a, b]
ALLOWABLE NUMBER OF STORIES ABOVE GRADE PLANE

OCCUPANCY CLASSIFICATION	SEE FOOTNOTES	TYPE OF CONSTRUCTION								
		TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
A-1	NS	UL	5	3	2	3	2	3	2	1
	S	UL	6	4	3	4	3	4	3	2
A-2	NS	UL	11	3	2	3	2	3	2	1
	S	UL	12	4	3	4	3	4	3	2
A-3	NS	UL	11	3	2	3	2	3	2	1
	S	UL	12	4	3	4	3	4	3	2
A-4	NS	UL	11	3	2	3	2	3	2	1
	S	UL	12	4	3	4	3	4	3	2
A-5	NS	UL	UL	UL	UL	UL	UL	UL	UL	UL
	S	UL	UL	UL	UL	UL	UL	UL	UL	UL
B	NS	UL	11	5	3	5	3	5	3	2
	S	UL	12	6	4	6	4	6	4	3
E	NS	UL	5	3	2	3	2	3	1	1
	S	UL	6	4	3	4	3	4	2	2
F-1	NS	UL	11	4	2	3	2	4	2	1
	S	UL	12	5	3	4	3	5	3	2
F-2	NS	UL	11	5	3	4	3	5	3	2
	S	UL	12	6	4	5	4	6	4	3

Table 506.2 Allowable Area Factor In Square Feet

TABLE 506.2[a, b]
ALLOWABLE AREA FACTOR (A_t = NS, S1, S13R, or SM, as applicable) IN SQUARE FEET

OCCUPANCY CLASSIFICATION	SEE FOOTNOTES	TYPE OF CONSTRUCTION								
		TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
A-1	NS	UL	UL	15,500	8,500	14,000	8,500	15,000	11,500	5,500
	S1	UL	UL	62,000	34,000	56,000	34,000	60,000	46,000	22,000
	SM	UL	UL	46,500	25,500	42,000	25,500	45,000	34,500	16,500
A-2	NS	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
	S1	UL	UL	62,000	38,000	56,000	38,000	60,000	46,000	24,000
	SM	UL	UL	46,500	28,500	42,000	28,500	45,000	34,500	18,000
A-3	NS	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
	S1	UL	UL	62,000	38,000	56,000	38,000	60,000	46,000	24,000
	SM	UL	UL	46,500	28,500	42,000	28,500	45,000	34,500	18,000
A-4	NS	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
	S1	UL	UL	62,000	38,000	56,000	38,000	60,000	46,000	24,000
	SM	UL	UL	46,500	28,500	42,000	28,500	45,000	34,500	18,000
A-5	NS	UL	UL	UL	UL	UL	UL	UL	UL	UL
	S1									
	SM									
B	NS	UL	UL	37,500	23,000	28,500	19,000	36,000	18,000	9,000
	S1	UL	UL	150,000	92,000	114,000	76,000	144,000	72,000	36,000
	SM	UL	UL	112,500	69,000	85,500	57,000	108,000	54,000	27,000
E	NS	UL	UL	26,500	14,500	23,500	14,500	25,500	18,500	9.500
	S1	UL	UL	106,000	58,000	94,000	58,000	102,000	74,000	38,000
	SM	UL	UL	79,500	43,500	70,500	43,500	76,500	55,500	28,500

Example

TABLE 506.2[a, b]—continued
ALLOWABLE AREA FACTOR (A_t = NS, S1, S13R, or SM, as applicable) IN SQUARE FEET

OCCUPANCY CLASSIFICATION	SEE FOOTNOTES	TYPE OF CONSTRUCTION								
		TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
R-2	NS[d, h] / S13R	UL	UL	24,000	16,000	24,000	16,000	20,500	12,000	7,000
	S1	UL	UL	96,000	64,000	96,000	64,000	82,000	48,000	28,000
	SM	UL	UL	72,000	48,000	72,000	48,000	61,500	36,000	21,000

TABLE 506.2[a,b]—continued
ALLOWABLE AREA FACTOR (A_t = NS, S1, S13R, or SM, as applicable) IN SQUARE FEET

Note: UL = Unlimited; NP = Not permitted;
For SI: 1 square foot = 0.0929 m^2.

903.3.1.1 NFPA 13 & 903.3.1.2 NFPA 13R

NS = Buildings not equipped throughout with an automatic sprinkler system; S1 = Buildings a maximum of one story above grade plane equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1; SM = Buildings two or more stories above grade plane equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1; S13R = Buildings equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.2.

a. See Chapters 4 and 5 for specific exceptions to the allowable height in this chapter.
b. See Section 903.2 for the minimum thresholds for protection by an automatic sprinkler system for specific occupancies.
c. New Group H occupancies are required to be protected by an automatic sprinkler system in accordance with Section 903.2.5.
d. The NS value is only for use in evaluation of existing building area in accordance with the *International Existing Building Code*.
e. New Group I-1 and I-3 occupancies are required to be protected by an automatic sprinkler system in accordance with Section 903.2.6. For new Group I-1 occupancies, Condition 1, see Exception 1 of Section 903.2.6.
f. New and existing Group I-2 occupancies are required to be protected by an automatic sprinkler system in accordance with Section 903.2.6 and Section 1103.5 of the *International Fire Code*.
g. New Group I-4 occupancies see Exceptions 2 and 3 of Section 903.2.6.
h. New Group R occupancies are required to be protected by an automatic sprinkler system in accordance with Section 903.2.8.

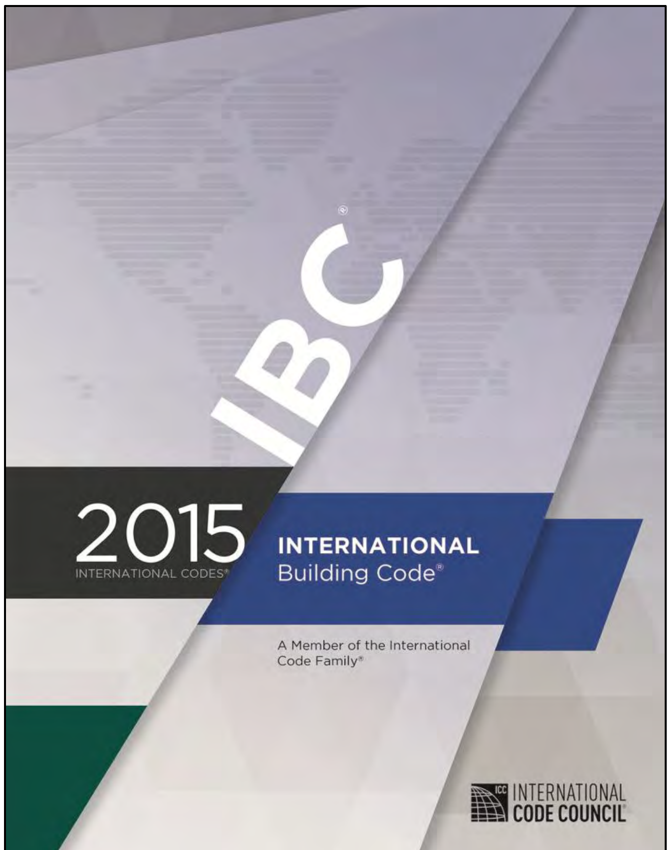
R-2 Occupancy Type IV Construction NFPA 13R Sprinklers
60 feet (85 feet w/NFPA 13 Sprinklers)
4 stories (5 stories w/ NFPA 13 Sprinklers)
Allowable area = 20,500 sf

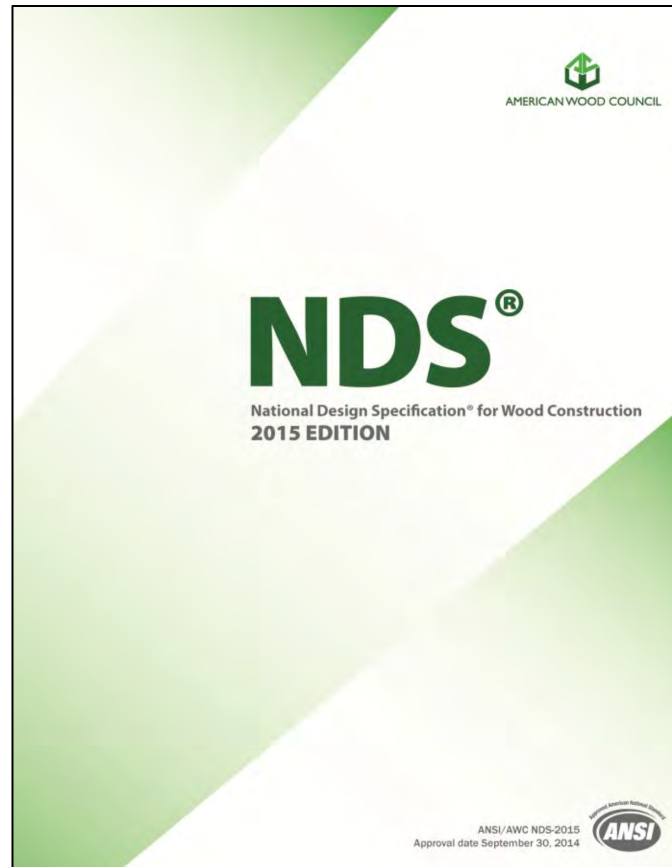
Outline

- Overview
- Building Code Provisions
- **Structural and Fire Provisions**
- North American Projects

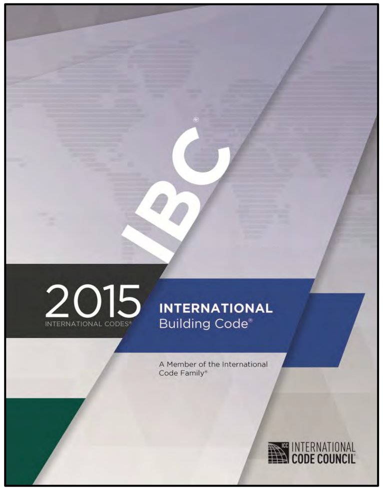
Governing Codes and Standards

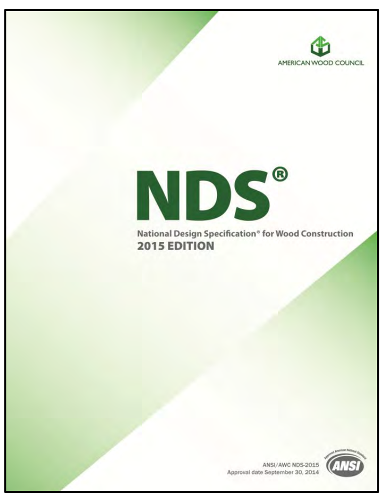
2015 IBC references the 2015 NDS

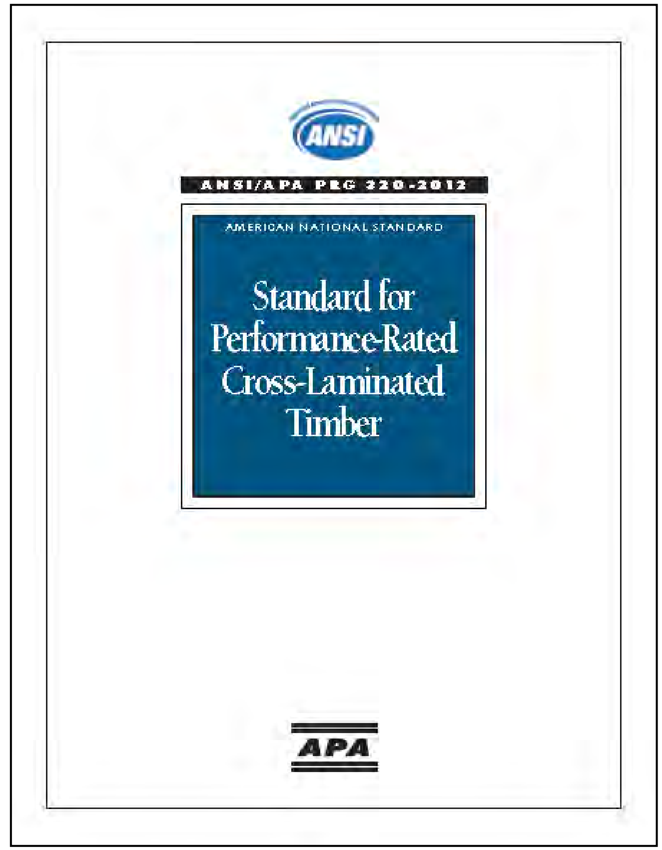




CLT Manufacturing Standard





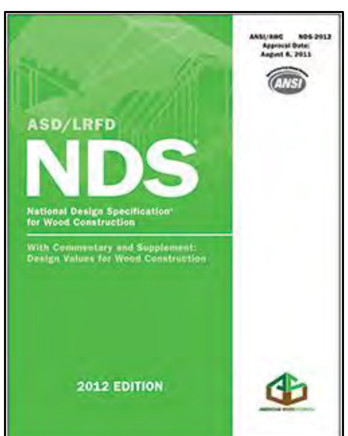


ANSI/APA PRG 320-2011
Manufacturing Standard

2015 NDS Chapter Reorganization

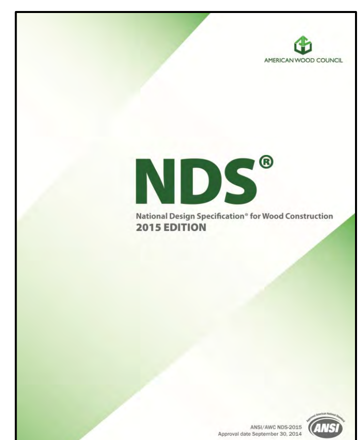
2012 NDS

- 1-3 General
- 4-9 Products
- 10-13 Connections
- 14 Shear Walls & Diaphragms
- 15 Special Loading
- 16 Fire



2015 NDS

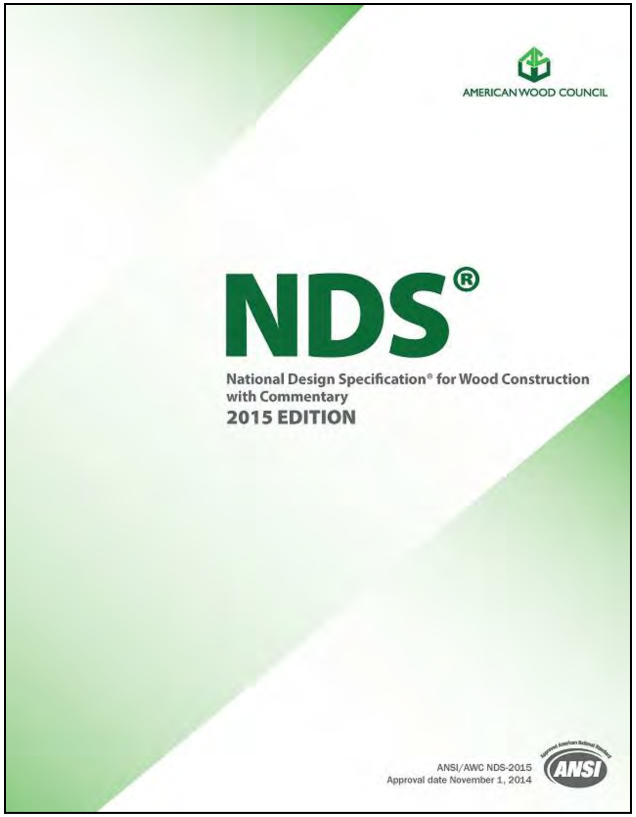
- 1-3 General
- 4-10 Products +CLT
- 11-14 Connections
- Shear Walls & Diaphragms
- 15 Special Loading
- 16 Fire



CLT Design: 2015 NDS

2015

1. General Requirements for Building Design
2. Design Values for Structural Members
3. Design Provisions and Equations
4. Sawn Lumber
5. Structural Glued Laminated Timber
6. Round Timber Poles and Piles
7. Prefabricated Wood I-Joists
8. Structural Composite Lumber
9. Wood Structural Panels
10. **Cross-laminated Timber**
11. Mechanical Connections
12. Dowel-Type Fasteners
13. Split Ring and Shear Plate Connectors
14. Timber Rivets
15. Special Loading Conditions
16. Fire Design of Wood Members



Chapter 2 – CLT Design Values

2.2 Reference Design Values

Reference design values and design value adjustments for wood products in 1.1.1.1 are based on methods specified in each of the wood product chapters. Chapters 4 through 10 contain design provisions for sawn lumber, glued laminated timber, poles and piles, prefabricated wood I-joists, structural composite lumber, wood structural panels, and cross-laminated timber, respectively. Chapters 11 through 14 contain design provisions for connections. Reference design values are for normal load duration under the moisture service conditions specified.

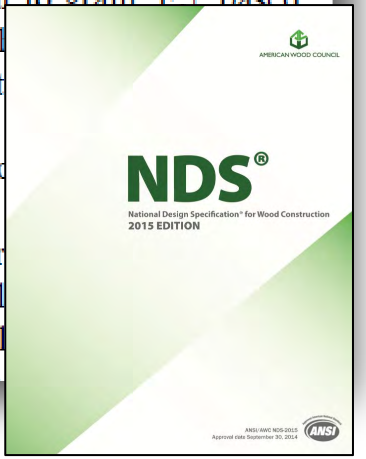
2.3 Adjustment of Reference Design Values

2.3.1 Applicability of Adjustment Factors

Reference design values shall be multiplied by all applicable adjustment factors to determine adjusted design values. The applicability of adjustment factors to sawn lumber, structural glued laminated timber, poles and piles, prefabricated wood I-joists, structural composite lumber, wood structural panels, cross-laminated timber, and connection design values is defined in 4.3, 5.3, 6.3, 7.3, 8.3, 9.3, 10.3, and 11.3, respectively.

modulus of elasticity for beam and column stability, E_{min}, and compression perpendicular to grain F, based on a deformation limit (see 4.2.6) sh
the appropriate load duration fact
2.3.2 or Figure B1 (see Appendix
count the change in strength of wo
load duration.

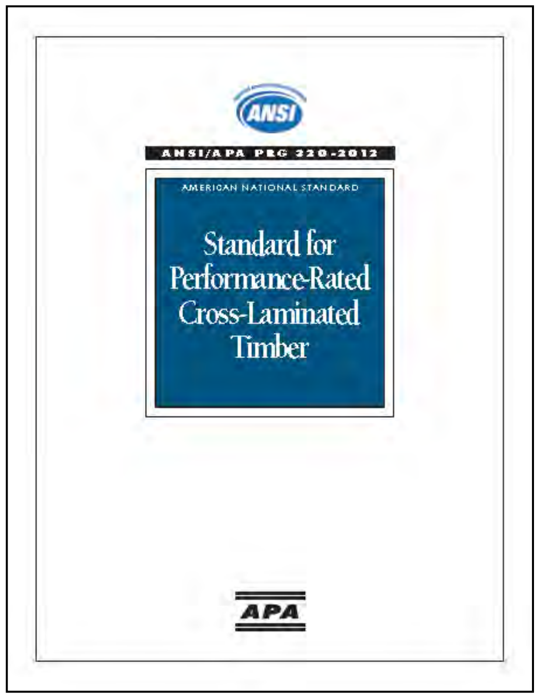
2.3.2.2 The load duration factor
duration load in a combination of l
that load combination. All applicabl
shall be evaluated to determine the



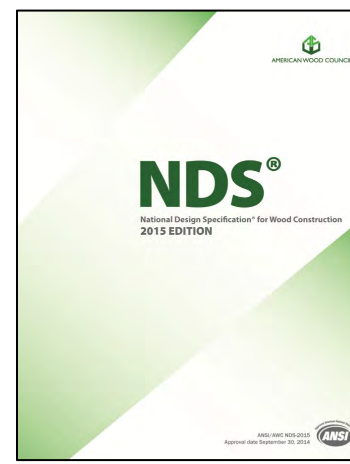
Chapter 2 – CLT Design Values

Design values

- APA Product reports
- APA PRG-320



ANSI/APA PRG 320-2011
Manufacturing Standard



Chapter 3 – CLT Design Equations

3.5 Bending Members – Deflection

3.5.1 Deflection Calculations

If deflection is a factor in design, it shall be calculated by standard methods of engineering mechanics considering bending deflections and, when applicable, shear deflections. Consideration for shear deflection is required when the reference modulus of elasticity has not been adjusted to include the effects of shear deflection (see Appendix F).

3.5.2 Long-Term Loading

Where total deflection under long-term loading ... creasing member size is one way to provide extra stiffness to allow for this time dependent deformation (see Appendix F). Total deflection, Δ_T, shall be calculated as follows:

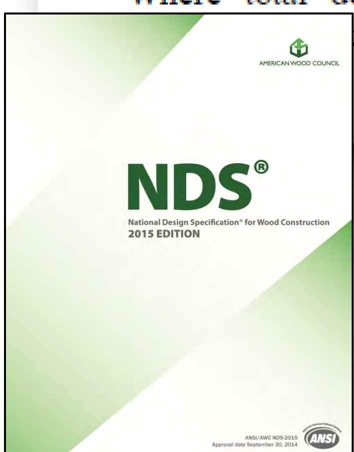
$$\Delta_T = K_{cr}\,\Delta_{LT} + \Delta_{ST} \qquad (3.5\text{-}1)$$

where:

K_{cr} = time dependent deformation (creep) factor

= 1.5 for seasoned lumber, structural glued laminated timber, prefabricated wood I-joists, or structural composite lumber used in dry service conditions as defined in 4.1.4, 5.1.4, 7.1.4, and 8.1.4, respectively.

= 2.0 for cross-laminated timber used in dry service conditions as defined in 10.1.5.



New

Chapter 3 – CLT Design Equations

3.7.1.5 The column stability factor shall be calculated as follows:

$$C_P = \frac{1+\left(F_{cE}/F_c^*\right)}{2c} - \sqrt{\left[\frac{1+\left(F_{cE}/F_c^*\right)}{2c}\right]^2 - \frac{F_{cE}/F_c^*}{c}} \quad (3.7\text{-}1)$$

where:

F_c^* = reference compression design value parallel to grain multiplied by all applicable adjustment factors except C_P (see 2.3), psi

$$F_{cE} = \frac{0.822\ E_{min}'}{(\ell_e/d)^2}$$

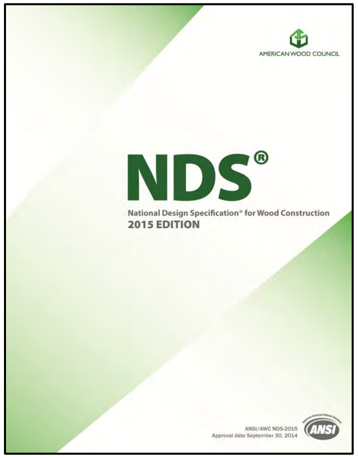
c = 0.8 for sawn lumber

c = 0.85 for round timber poles and piles

c = 0.9 for structural glued laminated timber, structural composite lumber, and cross-laminated timber

New

NDS Commentary – guidance on C_P



Chapter 10 – Cross-Laminated Timber

New

10.1 General

10.1.1 Application

10.1.1.1 Chapter 10 applies to engineering design with performance-rated cross-laminated timber.

10.1.1.2 Design procedures, reference design values and other information provided herein apply only to performance-rated cross-laminated timber produced in accordance with ANSI/APA PRG-320.

10.1.2 Definition

Cross-Laminated Timber (CLT) – a prefabricated engineered wood product consisting of at least three layers of solid-sawn lumber or structural composite lumber where the adjacent layers are cross-oriented and bonded with structural adhesive to form a solid wood element.

10.1.3 Standard Dimensions

10.1.3.1 The net thickness of a lamination for all layers at the time of gluing shall not be less than 5/8 inch or more than 2 inches.

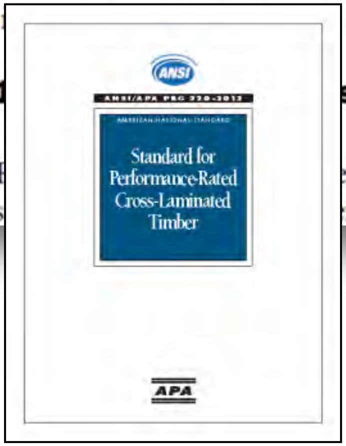
10.1.3.2 The thickness of cross-laminated timber shall not exceed 20 inches.

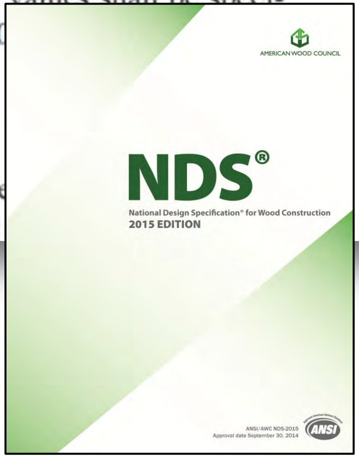
10.1.4 Specification

All required reference design values shall be specified ... 10

10.1 ... s

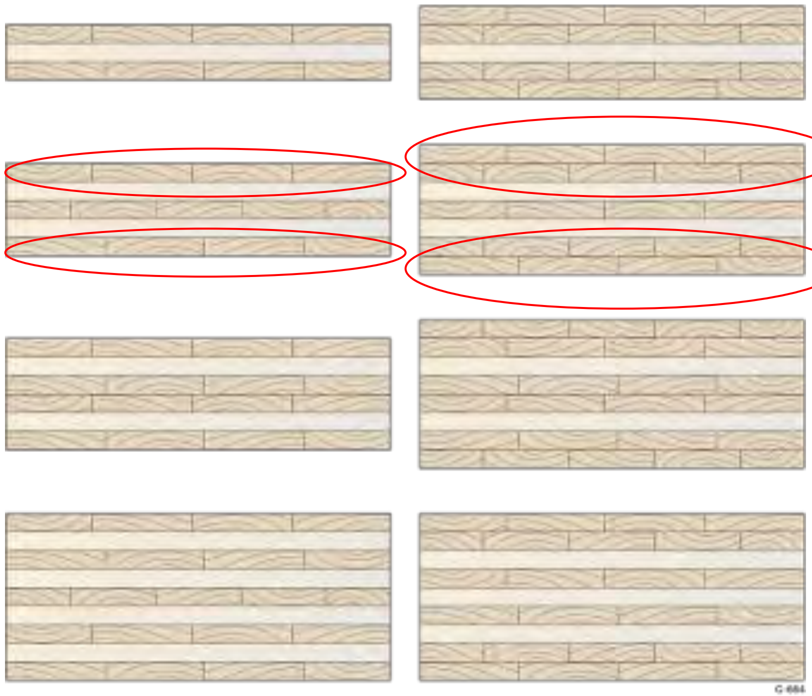
F ... efle ... tions ... nt

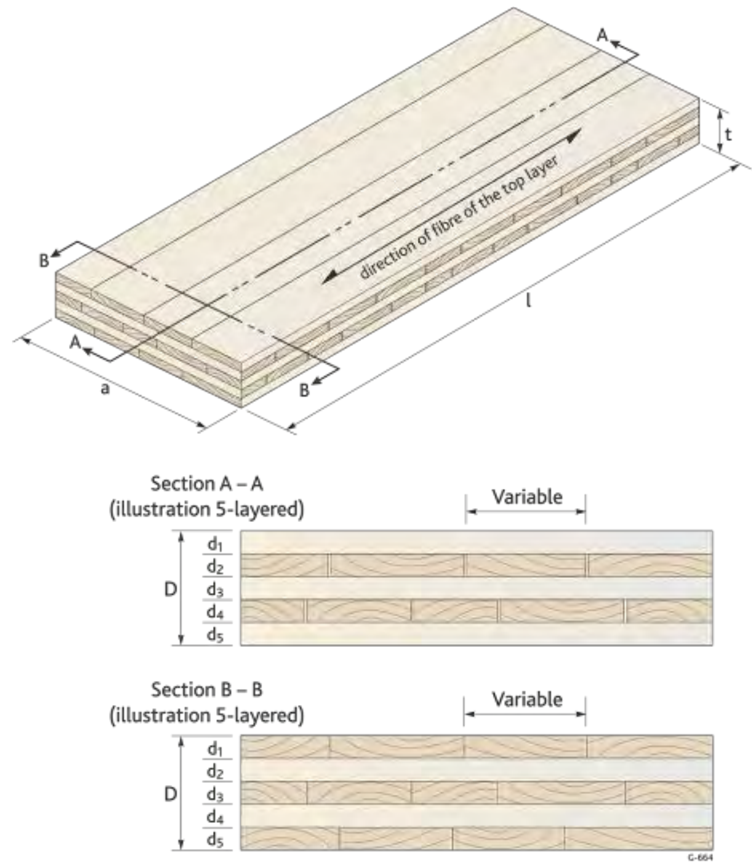




Chapter 10 – Cross-Laminated Timber

1, 2, 3, 4 transverse layers | **Single or multiple surface layers**





Laminations: 5/8”-2” sawn lumber or SCL
Panel thickness: 20” max
In-Service MC: 16%

Graphics provided by FPInnovations

Chapter 10 – Cross-Laminated Timber

10.2 Reference Design Values

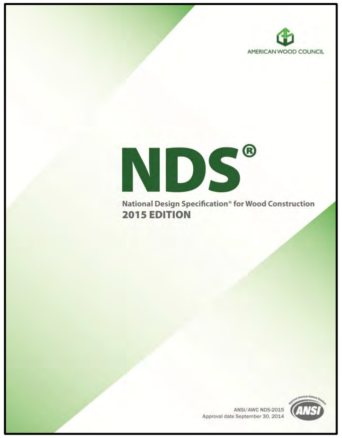
10.2.1 Reference Design Values

New

Reference design values for cross-laminated timber shall be obtained from the cross-laminated timber manufacturer's literature or code evaluation report.

10.2.2 Design Section Properties

Reference design values shall be used with design section properties provided by the cross-laminated timber manufacturer based on the actual layup used in the manufacturing process.



10.3 Adjustment of Reference Design Values

10.3.1 General

Reference design values: $F_b(S_{eff})$, $F_t(A_{parallel})$, $F_v(t_v)$, $F_s(Ib/Q)_{eff}$, $F_c(A_{parallel})$, $F_{c\perp}(A)$, $(EI)_{app}$, and $(EI)_{app-min}$ provided in 10.2 shall be multiplied by the adjustment factors specified in Table 10.3.1 to determine adjusted design values: $F_b(S_{eff})'$, $F_t(A_{parallel})'$, $F_v(t_v)'$, $F_s(Ib/Q)_{eff}'$, $F_c(A_{parallel})'$, $F_{c\perp}(A)'$, $(EI)_{app}'$, and $(EI)_{app-min}'$.

10.3.2 Load Duration Factor, C_D (ASD only)

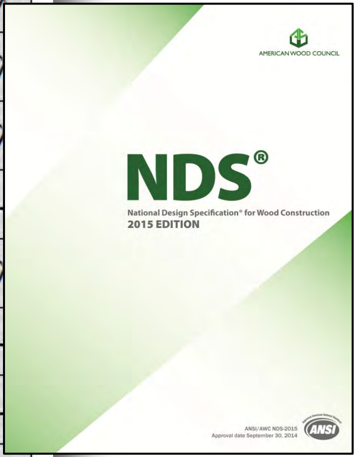
All reference design values except stiffness, $(EI)_{app}$, $(EI)_{app-min}$, rolling shear, $F_s(Ib/Q)_{eff}$, and compression perpendicular to grain, $F_{c\perp}(A)$, shall be multiplied by load duration factors, C_D, as specified in 2.3.2.

Chapter 10 – Cross-Laminated Timber

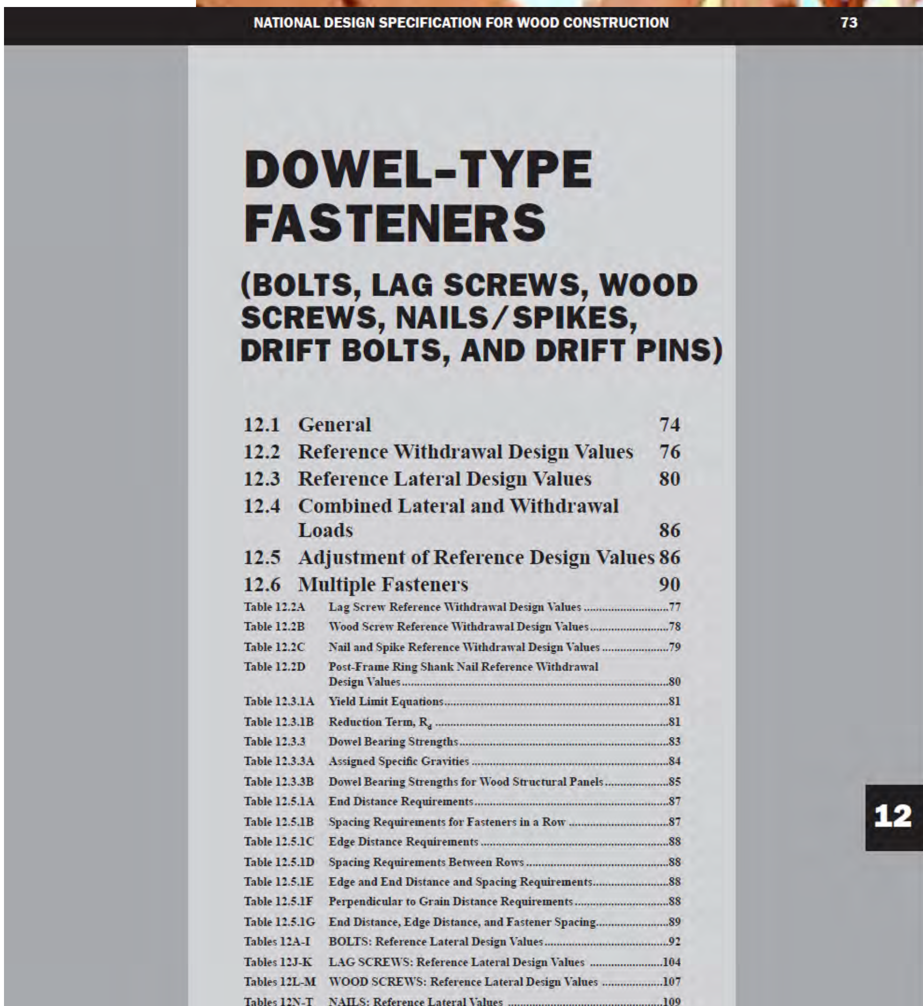
Table 10.3.1 Applicability of Adjustment Factors for Cross-Laminated Timber

New

		ASD only	ASD and LRFD					LRFD only		
		Load Duration Factor	Wet Service Factor	Temperature Factor	Beam Stability Factor	Column Stability Factor	Bearing Area Factor	Format Conversion Factor	Resistance Factor	Time Effect Factor
$F_b(S_{eff})' = F_b(S_{eff})$	x	C_D	C_M	C_t	C_L	-	-	2.54	0.85	λ
$F_t(A_{parallel})' = F_t(A_{parallel})$	x	C_D	C_M	C_t	-	-	-	2.70	0.80	λ
$F_v(t_v)' = F_v(t_v)$	x	C_D	C_M	C_t	-	-	-	2.88	0.75	λ
$F_s(Ib/Q)_{eff}' = F_s(Ib/Q)_{eff}$	x	-	C_M	C_t	-	-	-	2.88	0.75	-
$F_c(A_{parallel})' = F_c(A_{parallel})$	x	C_D	C_M	C_t	-	C_P	-	2.40	0.90	λ
$F_{c\perp}(A)' = F_{c\perp}(A)$	x	-	C_M	C_t	-	-	C_b	1.67	0.90	-
$(EI)_{app}' = (EI)_{app}$	x	-	C_M	C_t	-	-	-	-	-	-
$(EI)_{app\text{-}min}' = (EI)_{app\text{-}min}$	x	-	C_M	C_t	-	-	-	1.76	0.85	-



NDS – Chapter 12



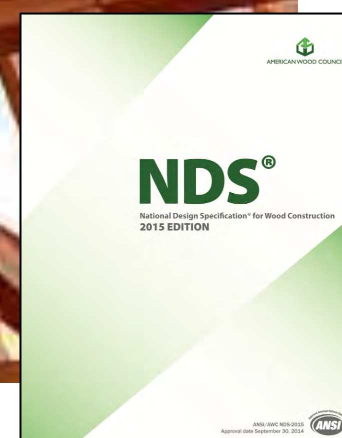
DOWEL-TYPE FASTENERS

(BOLTS, LAG SCREWS, WOOD SCREWS, NAILS/SPIKES, DRIFT BOLTS, AND DRIFT PINS)

12.1	General	74
12.2	Reference Withdrawal Design Values	76
12.3	Reference Lateral Design Values	80
12.4	Combined Lateral and Withdrawal Loads	86
12.5	Adjustment of Reference Design Values	86
12.6	Multiple Fasteners	90
Table 12.2A	Lag Screw Reference Withdrawal Design Values	77
Table 12.2B	Wood Screw Reference Withdrawal Design Values	78
Table 12.2C	Nail and Spike Reference Withdrawal Design Values	79
Table 12.2D	Post-Frame Ring Shank Nail Reference Withdrawal Design Values	80
Table 12.3.1A	Yield Limit Equations	81
Table 12.3.1B	Reduction Term, R_d	81
Table 12.3.3	Dowel Bearing Strengths	83
Table 12.3.3A	Assigned Specific Gravities	84
Table 12.3.3B	Dowel Bearing Strengths for Wood Structural Panels	85
Table 12.5.1A	End Distance Requirements	87
Table 12.5.1B	Spacing Requirements for Fasteners in a Row	87
Table 12.5.1C	Edge Distance Requirements	88
Table 12.5.1D	Spacing Requirements Between Rows	88
Table 12.5.1E	Edge and End Distance and Spacing Requirements	88
Table 12.5.1F	Perpendicular to Grain Distance Requirements	88
Table 12.5.1G	End Distance, Edge Distance, and Fastener Spacing	89
Tables 12A-I	BOLTS: Reference Lateral Design Values	92
Tables 12J-K	LAG SCREWS: Reference Lateral Design Values	104
Tables 12L-M	WOOD SCREWS: Reference Lateral Design Values	107
Tables 12N-T	NAILS: Reference Lateral Values	109

12

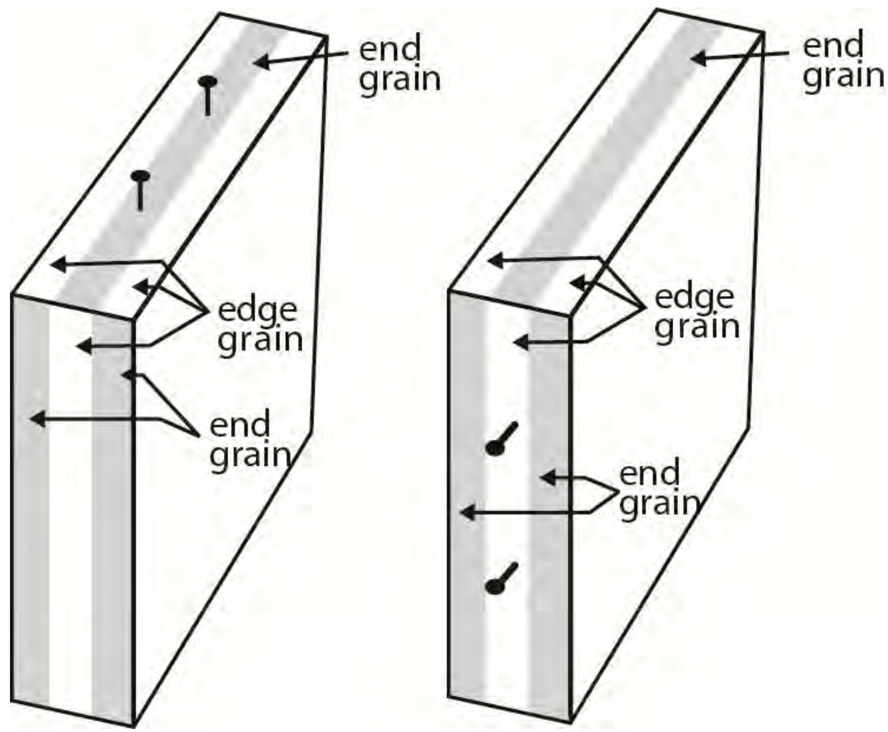
Updated to include CLT Connections

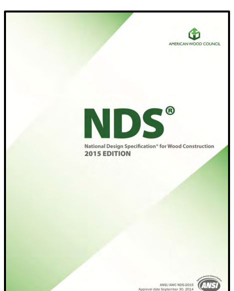


Chapter 12 – Dowel-type Fasteners

New

12.2.1.5 Where lag screws are loaded in withdrawal from the narrow edge of cross-laminated timber, the reference withdrawal value, W, shall be multiplied by the end grain factor, C_{eg}=0.75, regardless of grain orientation.



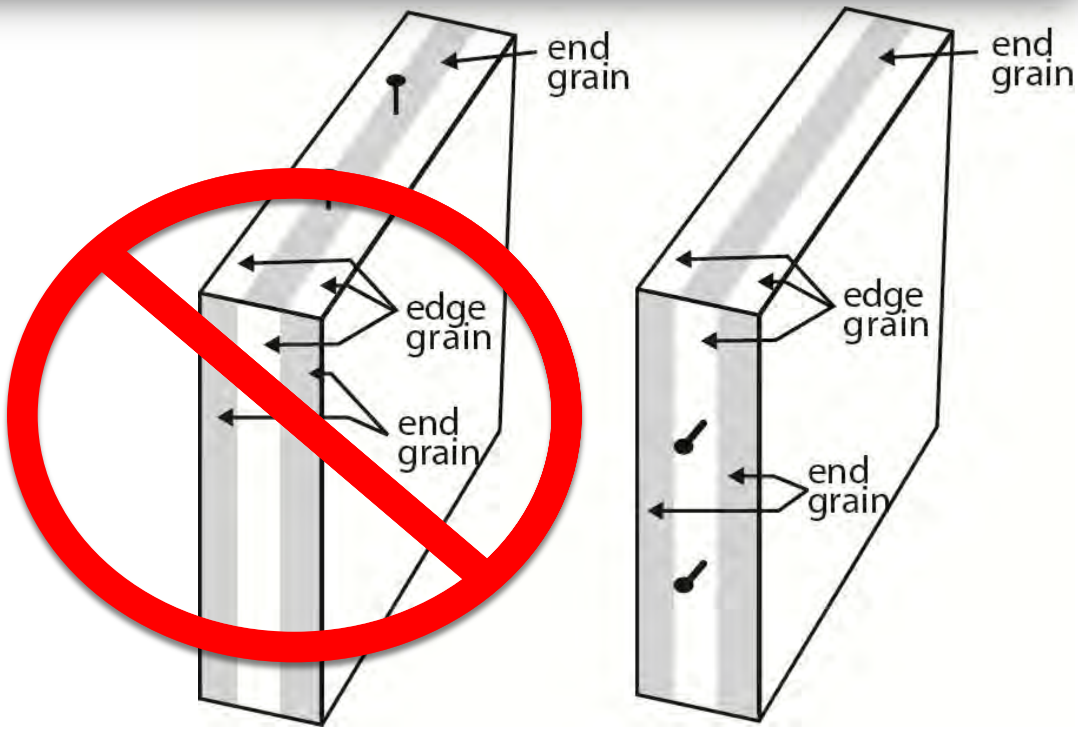


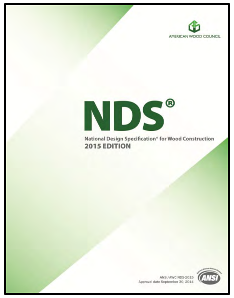
Chapter 12 – Dowel-type Fasteners

New

12.2.2.4 Wood screws shall not be loaded in withdrawal from end-grain of laminations in cross-laminated timber (C_{eg}=0.0).

12.2.3.6 Nails, and spikes shall not be loaded in withdrawal from end-grain of laminations in cross-laminated timber (C_{eg}=0.0).





Chapter 12 – Dowel-type Fasteners

12.3.3 Dowel Bearing Strength

New

12.3.3.5 Dowel bearing strengths, F_e, for dowel-type fasteners installed into the panel face of cross-laminated timber shall be based on the direction of loading with respect to the grain orientation of the cross-laminated timber ply at the shear plane.

12.3.3.6 Where dowel-type fasteners are installed in the narrow edge of cross-laminated timber panels, the dowel bearing strength shall be $F_{e\perp}$ for D≥1/4" and F_e for D<1/4".

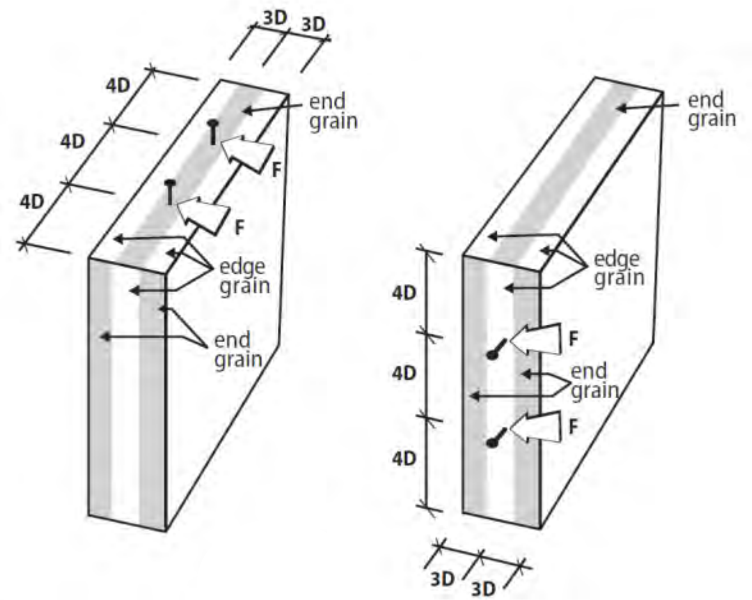
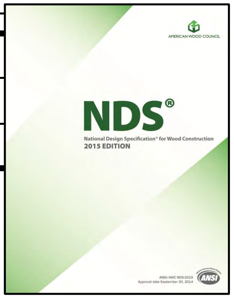


Table 12.3.3 Dowel Bearing Strengths, F_e, for Dowel-Type Fasteners in Wood Members

Specific[1] Gravity, G	Dowel bearing strength in pounds per square inch (psi)[2]									
	F_e	$F_{e\parallel}$	$F_{e\perp}$							
	D<1/4"	1/4" ≤ D ≤ 1"	D=1/4"	D=5/16"	D=3/8"	D=7/16"	D=1/2"	D=5/8"	D=3/4"	D=7/8"
0.55	5550	6150	5150	4600	4200	3900	3650	3250	2950	2750
0.54	5350	6050	5000	4450	4100	3750	3550	3150	2900	2650
0.53	5150	5950	4850	4350	3950	3650	3450	3050	2800	2600



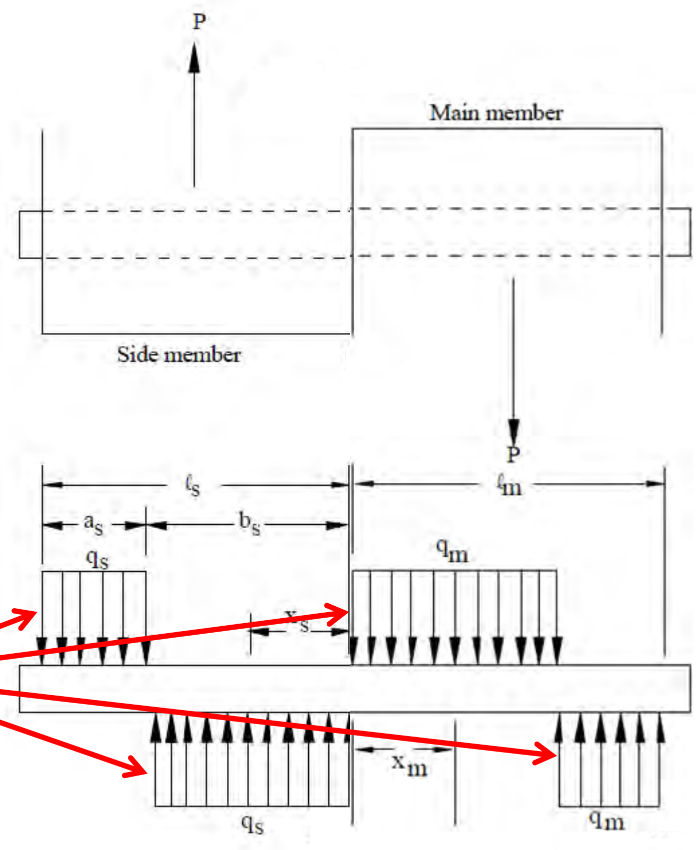
Chapter 12 – Dowel-type Fasteners

12.3.5 Dowel Bearing Length

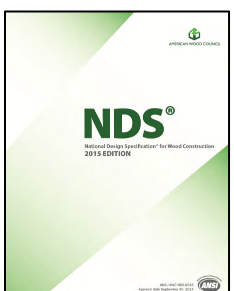
New

12.3.5.1 Dowel bearing length in the side member(s) and main member, ℓ_s and ℓ_m, shall be determined based on the length of dowel bearing perpendicular to the application of load.

12.3.5.2 For cross-laminated timber where the direction of loading relative to the grain orientation at the shear plane is parallel to grain, the dowel bearing length in the perpendicular plies shall be reduced by multiplying the bearing length of those plies by the ratio of dowel bearing strength perpendicular to grain to dowel bearing strength parallel to grain ($F_{e\perp}$ / $F_{e\parallel}$).



Non-uniform for CLT



Chapter 12 – Dowel-type Fasteners

- Adjust ℓ_m or ℓ_s to compensate for orthogonal grain orientations in adjacent layers
- Parallel to grain: $F_{e\perp}/F_{e\|}$

Example: ½″ bolt in southern pine 3-ply CLT with 1-½″ laminations

$$\ell_m = t_{1\|} + t_{2\perp} + t_{3\|} = 3(1.5) = 4.5''$$

$$\ell_{m\text{-}adj} = t_{1\|} + t_{2\perp}(F_{e\perp}/F_{e\|}) + t_{3\|}$$

$$= 1.5 + 1.5(3650/6150) + 1.5 = 3.9''$$

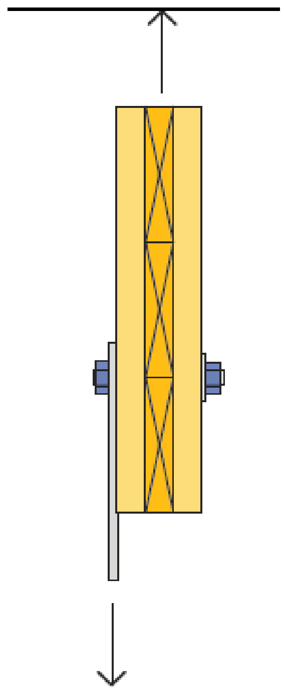
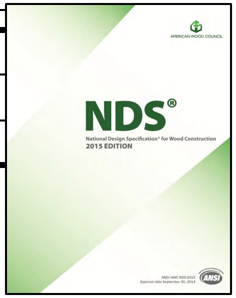


Table 12.3.3 Dowel Bearing Strengths, F_e, for Dowel-Type Fasteners in Wood Members

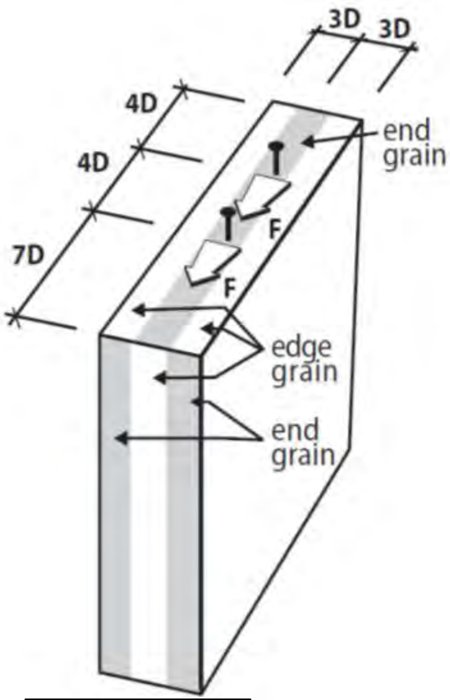
Specific Gravity, G[1]	Dowel bearing strength in pounds per square inch (psi)[2]									
	F_e	$F_{e\|}$	$F_{e\perp}$							
	D<1/4"	1/4" ≤ D ≤ 1"	D=1/4"	D=5/16"	D=3/8"	D=7/16"	D=1/2"	D=5/8"	D=3/4"	D=7/8"
0.55	5550	6150	5150	4600	4200	3900	3650	3250	2950	2750
0.54	5350	6050	5000	4450	4100	3750	3550	3150	2900	2650
0.53	5150	5950	4850	4350	3950	3650	3450	3050	2800	2600

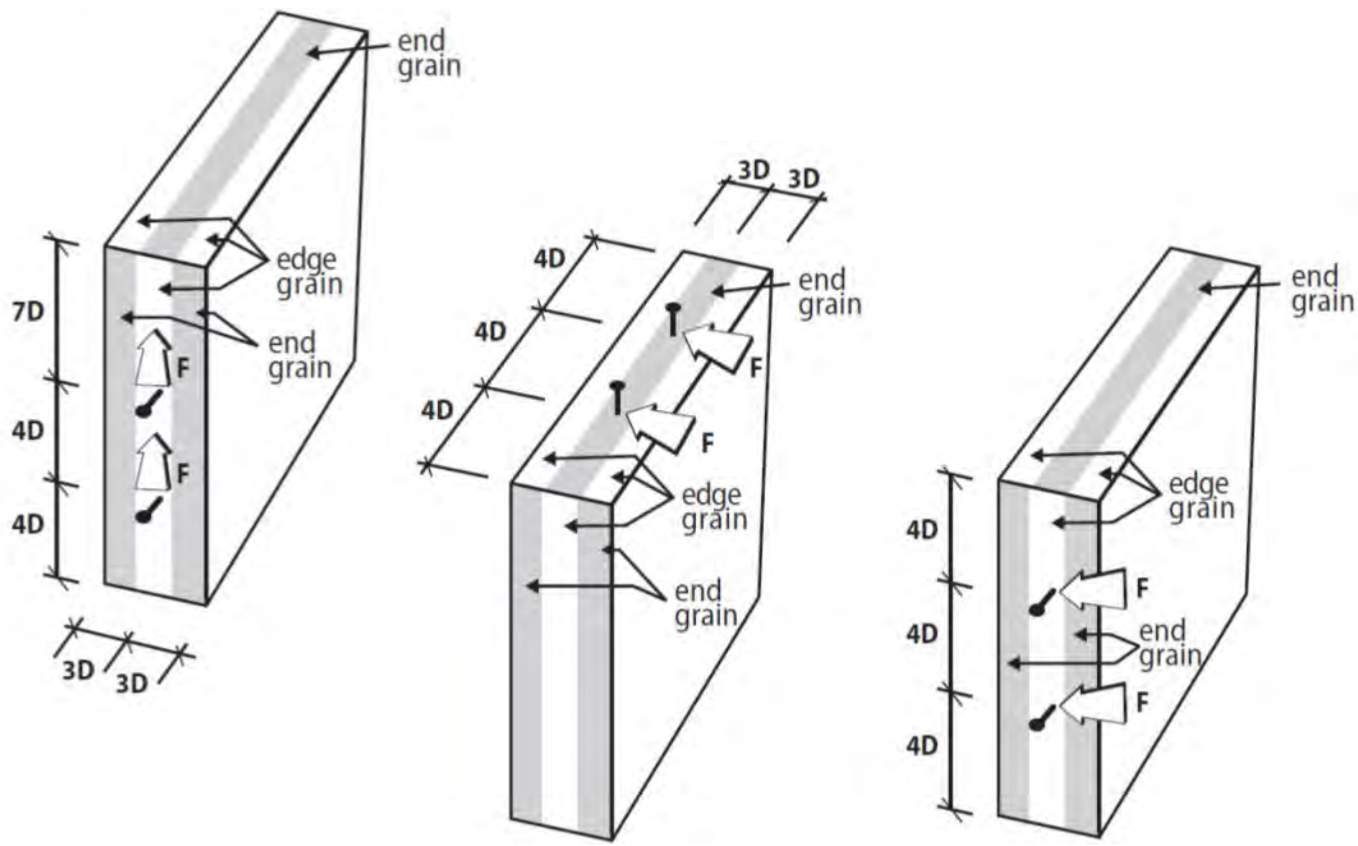


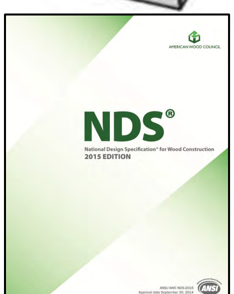
Chapter 12 – Dowel-type Fasteners

Figure 12I **End Distance, Edge Distance and Fastener Spacing Requirements in Narrow Edge of Cross-Laminated Timber**

New







Chapter 12 – Dowel-type Fasteners

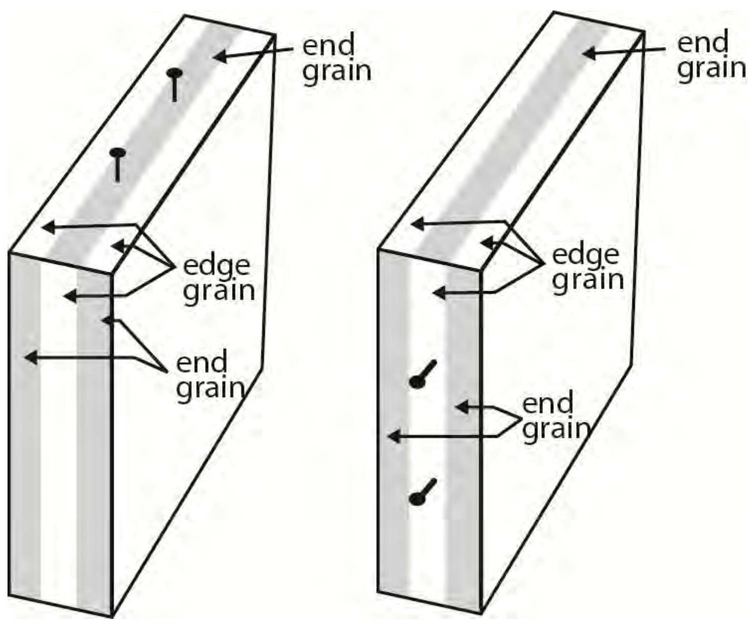
12.5.2 End Grain Factor, C_{eg}

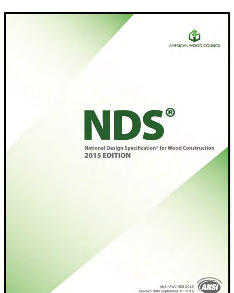
12.5.2.2 Where dowel-type fasteners are inserted in the end grain of the main member, with the fastener axis parallel to the wood fibers, reference lateral design values, Z, shall be multiplied by the end grain factor, $C_{eg} = 0.67$.

12.5.2.3 Where dowel-type fasteners with $D \geq 1/4"$ are loaded laterally in the narrow edge of cross-laminated timber, the reference lateral design value, Z, shall be multiplied by the end grain factor, $C_{eg}=0.67$, regardless of grain orientation.

New

- **Lateral – any end grain**
  - **$D<1/4" C_{eg}=0.67$**
- **Lateral – any CLT edge**
  - **$D \geq 1/4"$ $C_{eg}=0.67$**



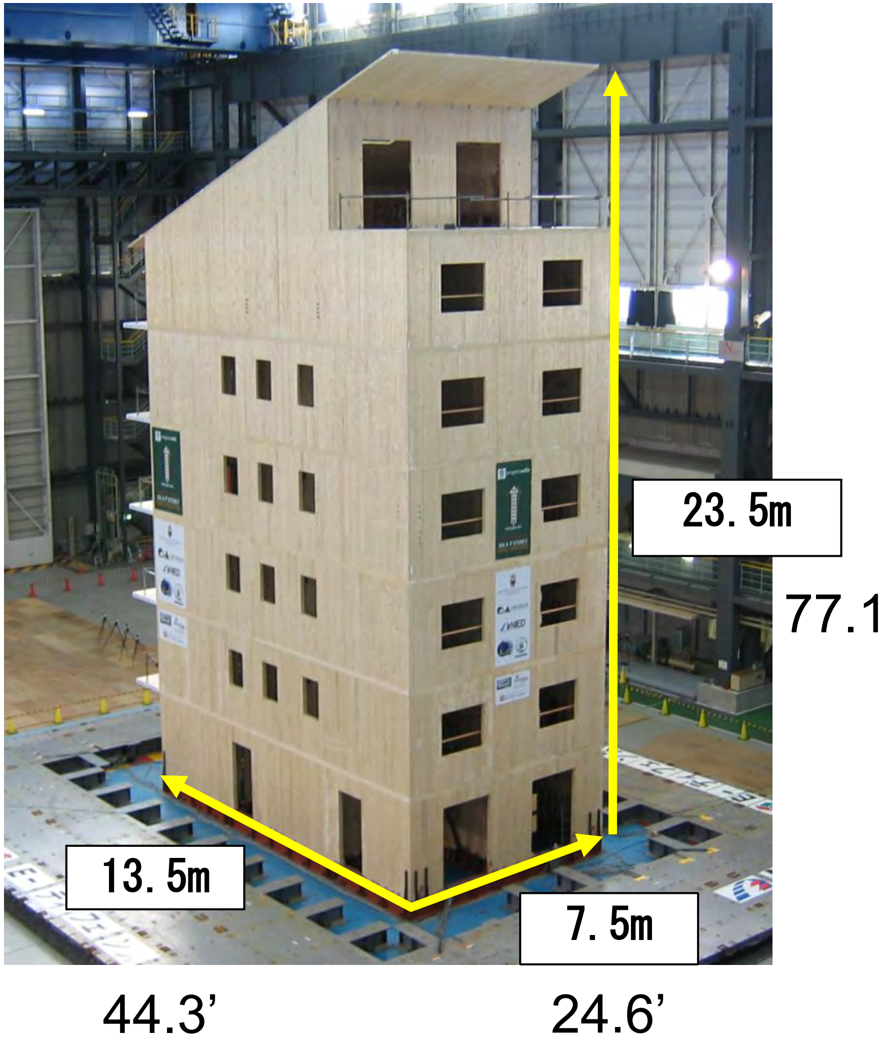


Seismic Design Options

- ***ASCE 7 Minimum Design Loads for Buildings and Other Structures***
- **Response Modification Coefficient, R**
  - CLT not recognized system in ASCE 7 Table 12.2-1
  - Options
    - Performance-based design procedure per ASCE 7
    - Demonstrating equivalence to an existing ASCE 7 system
    - ASCE 7-10, FEMA P695, and FEMA P795 Quantification of Building Seismic Performance Factors; Component Equivalency Methodology
- **Research**
  - NEES-CLT - John Van de Lindt
  - FPInnovations

Shake Table Tests on 7-story Building

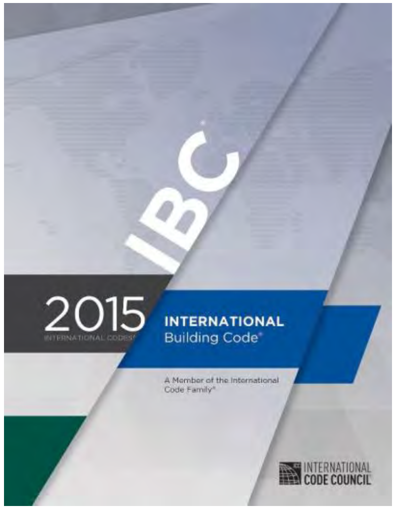
- Conducted at E-Defense
- Building weight 270t
  - Self weight 120t
  - Added weight 150t
- Panel thickness
  - 140 mm (5.5”) floors 1 and 2
  - 125 mm (4.9”) floors 3 and 4
  - 85 mm (3.3”) top 3 floors
- Wall panels length 2.3 m (7.5’)



Fire-Resistance

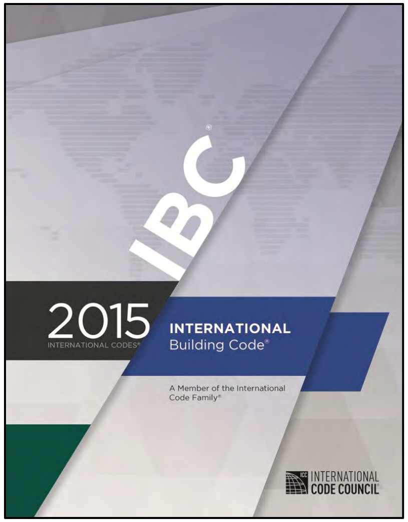
- **IBC 703 Fire-Resistance Ratings and Fire Tests**
  - IBC Section 703.2 Tested assemblies tested in accordance with ASTM E119 or UL 263
  - **IBC 703.3 Methods for determining fire resistance**
    - IBC Section 721 Deemed to comply tables (prescriptive)
    - IBC Section 722 Calculated Fire Resistance

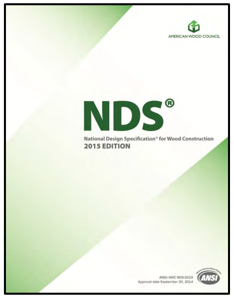
NOTE: Type IV Construction – for other than the walls, HT – required dimensions have performance presumed to be adequate



Chapter 16 – Fire

- **Fire resistance up to *two hours***
  - **Columns**
  - **Beams**
  - **Tension Members**
  - **ASD only**
- **Products**
  - **Lumber**
  - **Glulam**
  - **SCL**
  - **Decking**
  - **CLT - NEW**



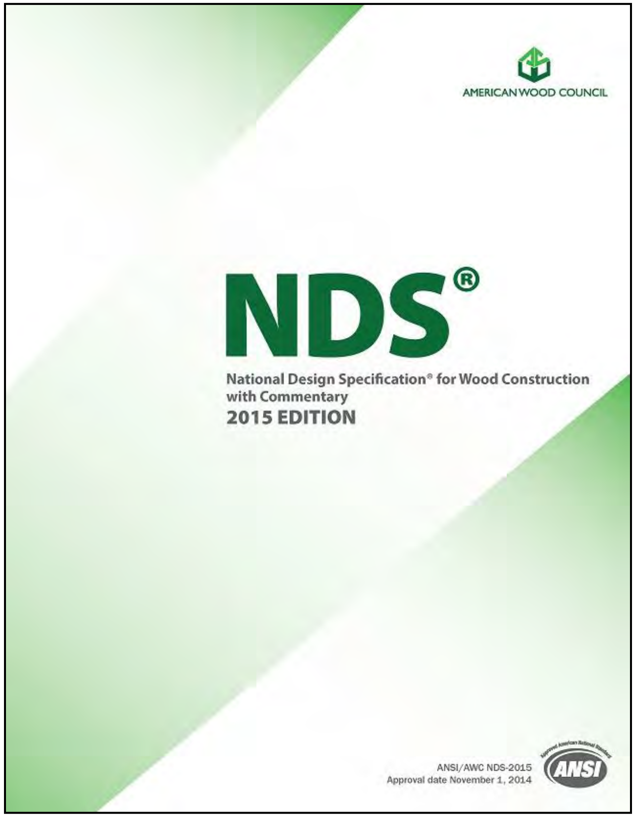


SECTION 722
CALCULATED FIRE RESISTANCE

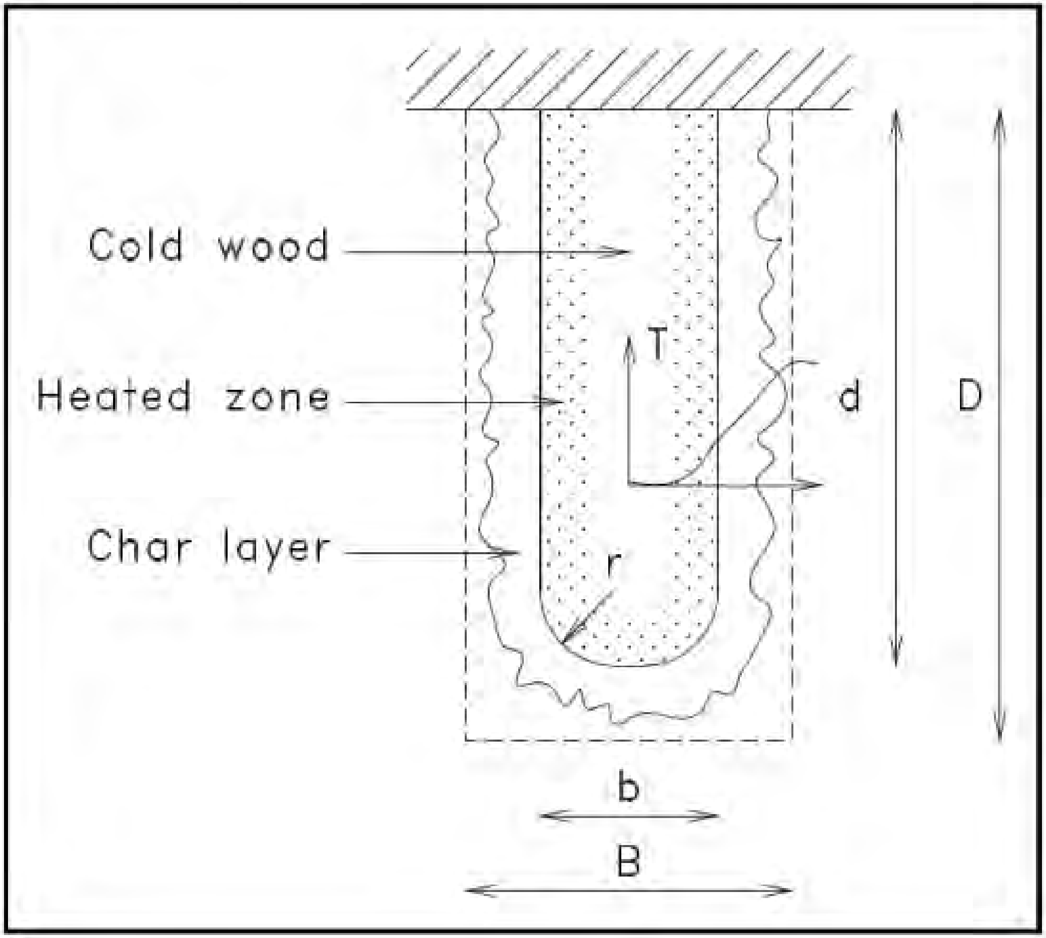
722.1 General. The provisions of this section contain procedures by which the *fire resistance* of specific materials or combinations of materials is established by calculations. These procedures apply only to the information contained in this section and shall not be otherwise used. The calculated *fire 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).*

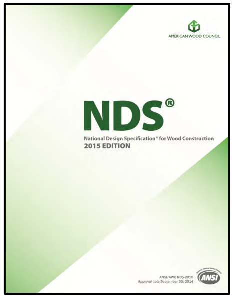
Chapter 16 – Fire

- **Mechanics Based Model**
- **Supported by empirical data**
- **ASD only**



Chapter 16 – Fire





Chapter 16 – Fire – CLT

New

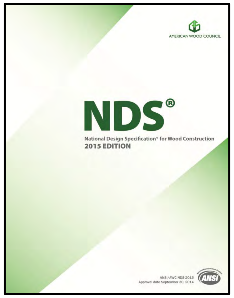
16.2.1.3 For cross-laminated timber, the effective char depth, a_{char}, shall be calculated as follows:

$$a_{char} = 1.2\left[n_{lam} \bullet h_{lam} + \beta_n\left(t - \left(n_{lam} \bullet t_{gi}\right)\right)^{0.813}\right] \quad (16.2\text{-}2)$$

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

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

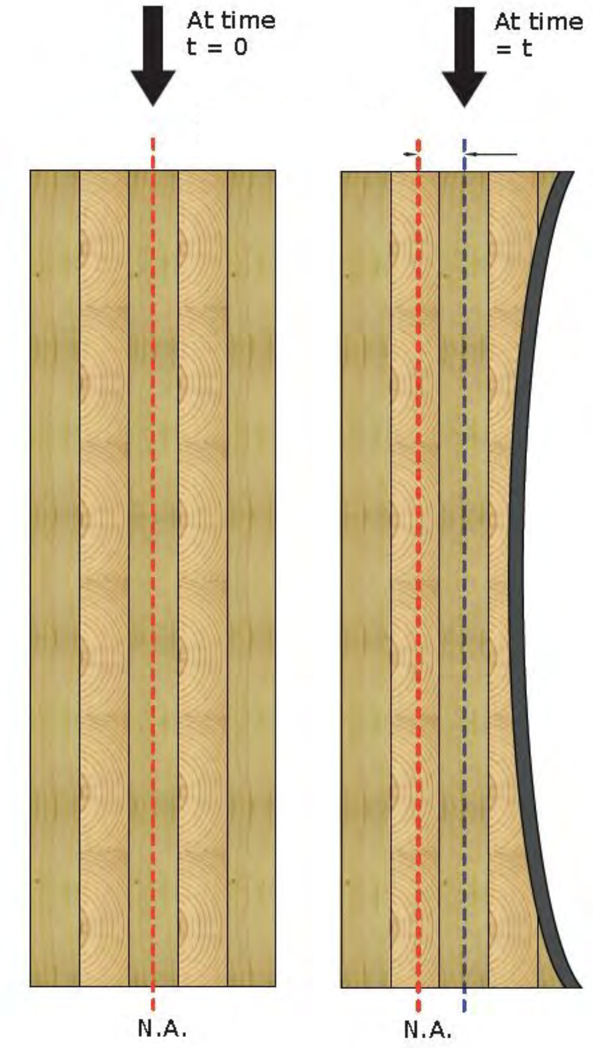
Required Fire Endurance (hr.)	Effective Char Depths, a_{char} (in.)								
	lamination thicknesses, h_{lam} (in.)								
	5/8	3/4	7/8	1	1-1/4	1-3/8	1-1/2	1-3/4	2
1-Hour	2.2	2.2	2.1	2.0	2.0	1.9	1.8	1.8	1.8
1½-Hour	3.4	3.2	3.1	3.0	2.9	2.8	2.8	2.8	2.6
2-Hour	4.4	4.3	4.1	4.0	3.9	3.8	3.6	3.6	3.6



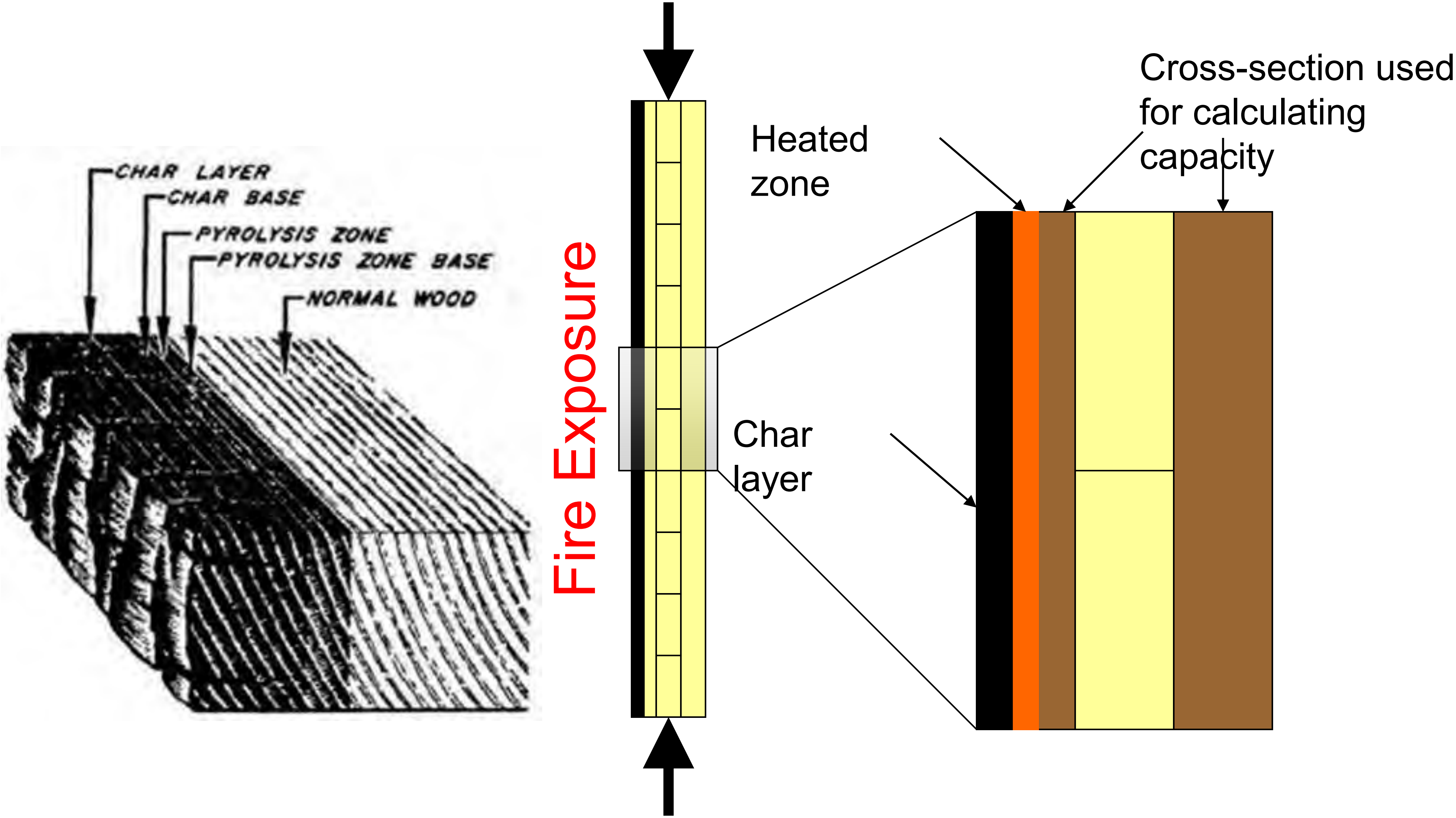
Commentary – laminations of unequal thickness

Chapter 16 – Fire – CLT

- Charring Rate and Char Depth
- Modified char depth model
  - Step-wise approach

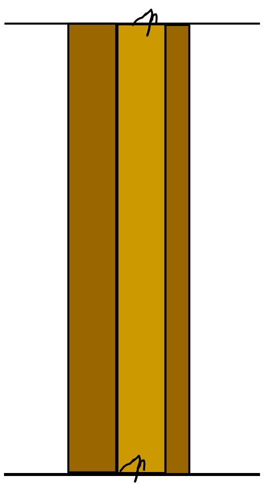


Chapter 16 – Fire – CLT



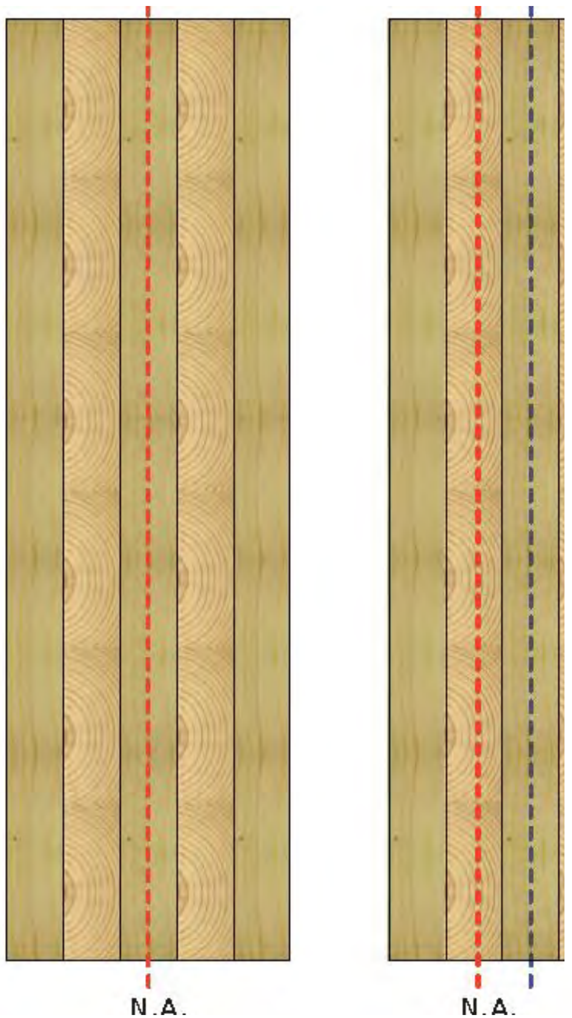
Chapter 16 – Fire – CLT

- **Net section properties**



Typical
one foot
section

Plan



Section

Chapter 16 – Fire

CODE UPDATES

code developments and announcements

Design of Fire-Resistive Exposed Wood Members

By Bradford Douglas, P.E. and Jason Smart, P.E.

The model building codes in the U.S. cover virtually every safety-related topic associated with construction of buildings. Fire-related issues comprise a surprisingly large portion of the model codes. Designing for fire safety is a complex and multifaceted issue. Discussion in this article is limited to design of exposed wood members. Additional information on building code requirements for wood can be found in the American Wood Council's (AWC) *Code Conforming Wood Design* documents available for free download at www.awc.org.

The calculation procedure for fire-resistance of exposed wood members is found in Chapter 16 of AWC's National Design Specification (NDS) for Wood Construction.

Fire Design of Exposed Wood Members

The fire resistance of exposed wood members, including lumber, glued laminated timber, and structural composite lumber (SCL), may be calculated using provisions of Chapter 16 of AWC's *National Design Specification®* (NDS®) *for Wood Construction*. This allowable stress design approach is referenced in 2012 *International Building Code* (IBC) Section 722.1. The design procedure allows calculation of the capacity of exposed wood members using basic wood engineering mechanics. Actual mechanical and physical properties of the wood are used, and member capacity is directly calculated for a given period of time – up to 2 hours. Section properties are computed assuming an effective char rate, β_{eff} at a given time, t. Reductions of strength and stiffness of wood directly adjacent to the char layer are addressed by accelerating the char rate by 20 percent. Average member strength properties are approximated from existing accepted procedures used to calculate design properties. Finally, wood members are designed using accepted engineering procedures found in NDS for allowable stress design. Note, the design procedures presented in NDS Chapter 16 are not intended to be used for design and retrofit of a structure after a fire event.

The fire resistance of exposed wood members, including lumber, glued laminated timber, and structural composite lumber (SCL), may be calculated per IBC Section 722.1.

The 2012 and earlier versions of the *International Building Code* (2012 IBC 722.6.3) have also contained an empirical calculation method for estimating the structural fire resistance of wood beams and columns exposed to a standard fire exposure for up to 1 hour. However, this empirical method has been deleted in the 2015 IBC in favor of the provisions contained within NDS Chapter 16, which are much broader in application and leave less room for design error.

Basis for NDS Chapter 16 Approach

AWC's Technical Report No. 10 (TR 10), *Calculating the Fire Resistance of Exposed Wood Members*, contains full details of the NDS method as well as design examples, and is available for free download at www.awc.org. TR 10 was recently revised to incorporate the following:

- A new section that supports the use of the design method with smaller dimension sizes associated with lumber joist floor assemblies;
- Revised design examples to match the 2012 NDS;
- Revised design tables in Appendix A, which allows more accurate calculation of fire resistance of columns with any slenderness ratio, eliminates tabulation of very special cases that can be misapplied (i.e., deleted beams that are exposed on 4-sides that are assumed to be fully-braced throughout the fire rating, columns that are only exposed on 3-sides but are assumed to be unbraced, and tension members that do not resist flexure due to member dead load), and more in-depth discussion of how the tables were developed; and
- A new Appendix B that calculates the fire resistance of single-span lumber joists for any design stress ratio when joists are exposed on 3-sides and braced on the top edge.

Brad Douglas, P.E. (bdouglas@awc.org), is Vice President of Engineering and Jason Smart, P.E. (jsmart@awc.org), is Manager of Engineering Technology with the American Wood Council.

Code Updates - Design of Fire-Resistive Exposed Wood Members

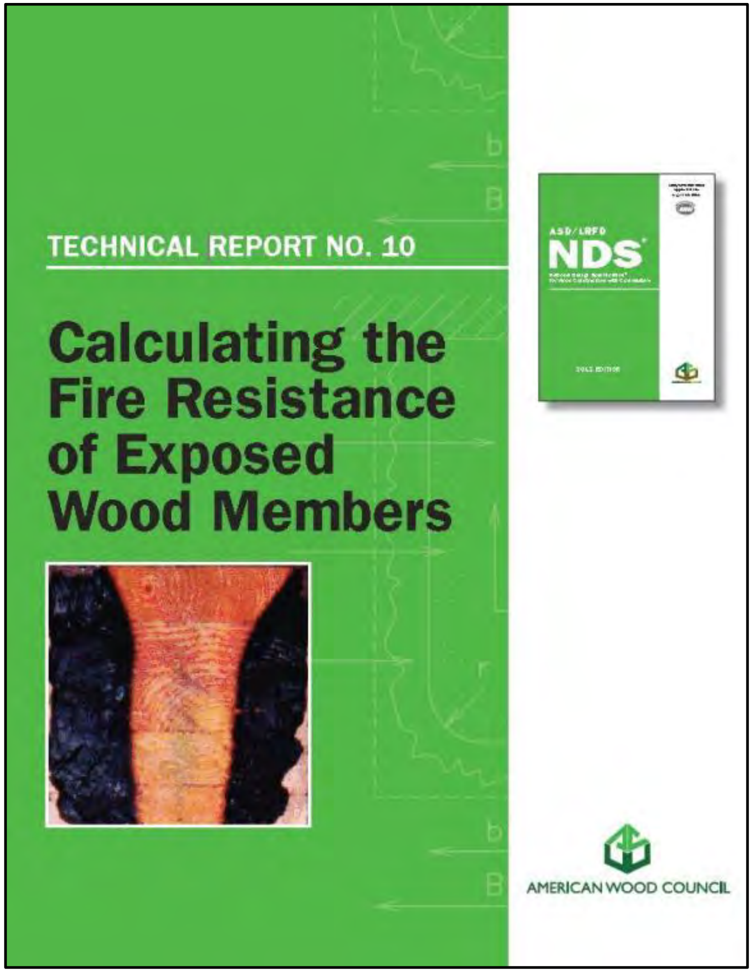
http://www.awc.org/publications/download.php

Chapter 16 – Fire

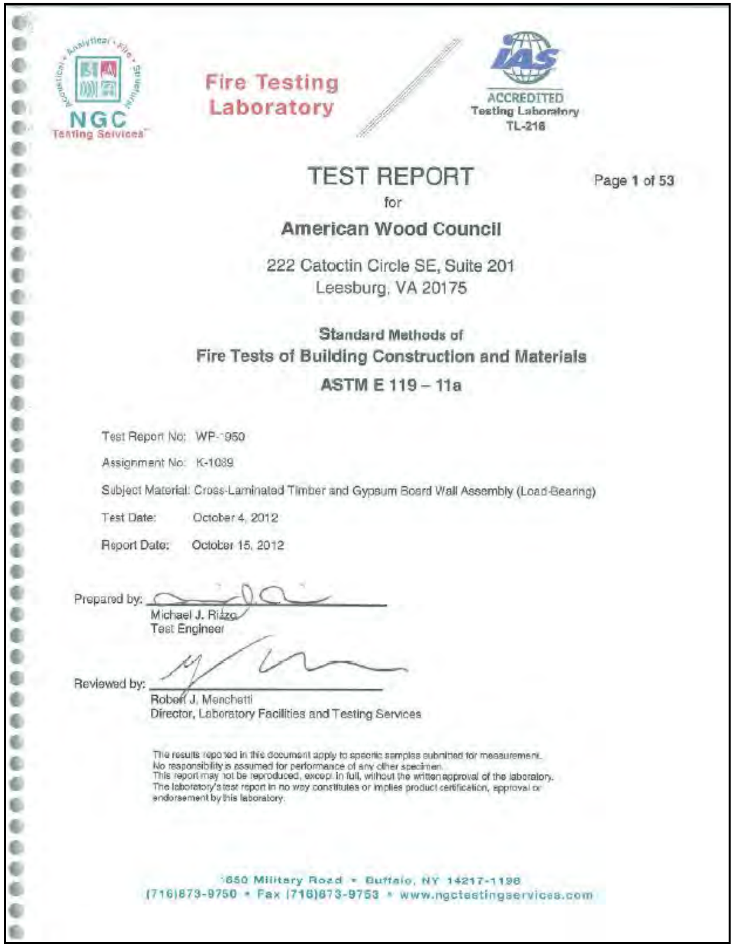
Technical Report No. 10

- Background on NDS provisions
- Design examples
- Floor assembly lumber joist provisions

TR-10 currently being up-dated which will include CLT
Free download www.awc.org



Fire Tests



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-1950

Assignment No: K-1089

Subject Material: Cross-Laminated Timber and Gypsum Board Wall Assembly (Load-Bearing)

Test Date: October 4, 2012

Report Date: October 15, 2012

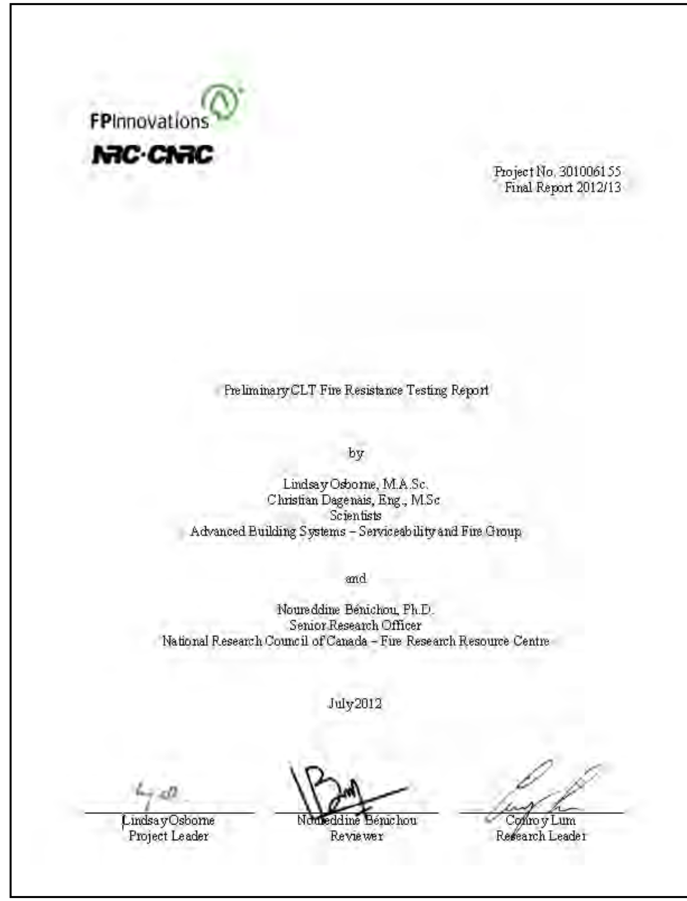
Prepared by: ______________________
Michael J. Rizzo
Test Engineer

Reviewed by: ______________________
Robert J. Menchetti
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 this laboratory.

1650 Military Road • Buffalo, NY 14217-1196
(716)873-9750 • Fax (716)873-9753 • www.ngctestingservices.com

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



FPInnovations
NRC·CNRC

Project No. 301006155
Final Report 2012/13

Preliminary CLT Fire Resistance Testing Report

by

Lindsay Osborne, M.A.Sc.
Christian Dagenais, Eng., M.Sc.
Scientists
Advanced Building Systems – Serviceability and Fire Group

and

Noureddine Bénichou, Ph.D.
Senior Research Officer
National Research Council of Canada – Fire Research Resource Centre

July 2012

Lindsay Osborne Project Leader	Noureddine Bénichou Reviewer	Conroy Lum Research Leader

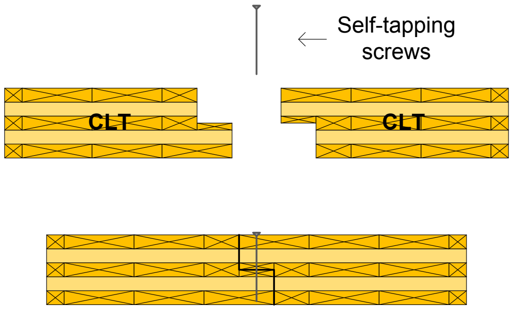
http://www.awc.org/Code-Officials/2012-IBC-Challenges/Preliminary-CLT-Fire-Test-Report-FINAL-July2012.pdf

Fire Test

American Wood Council

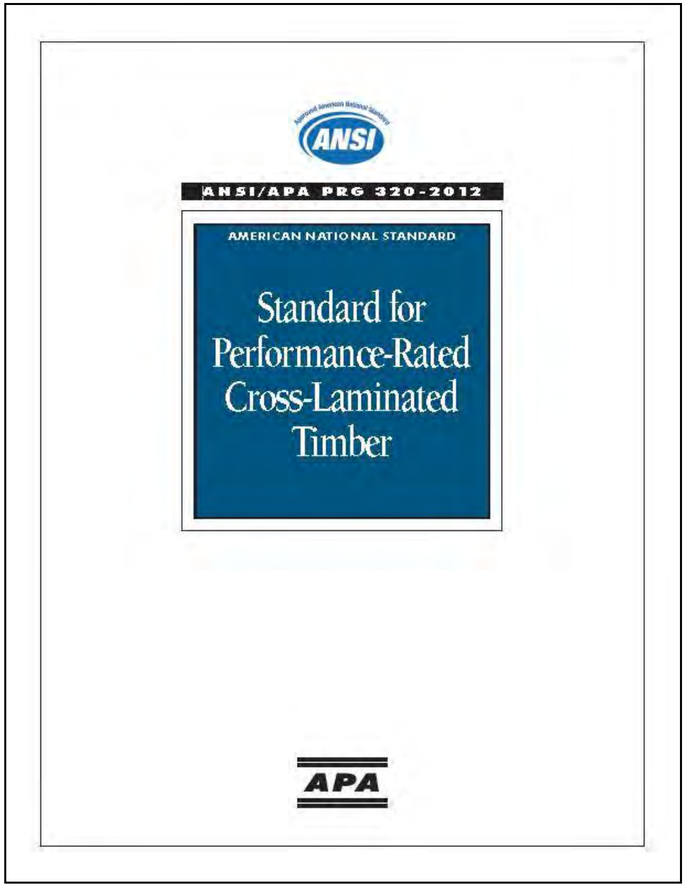
<u>ASTM E119 Fire Endurance Test</u>

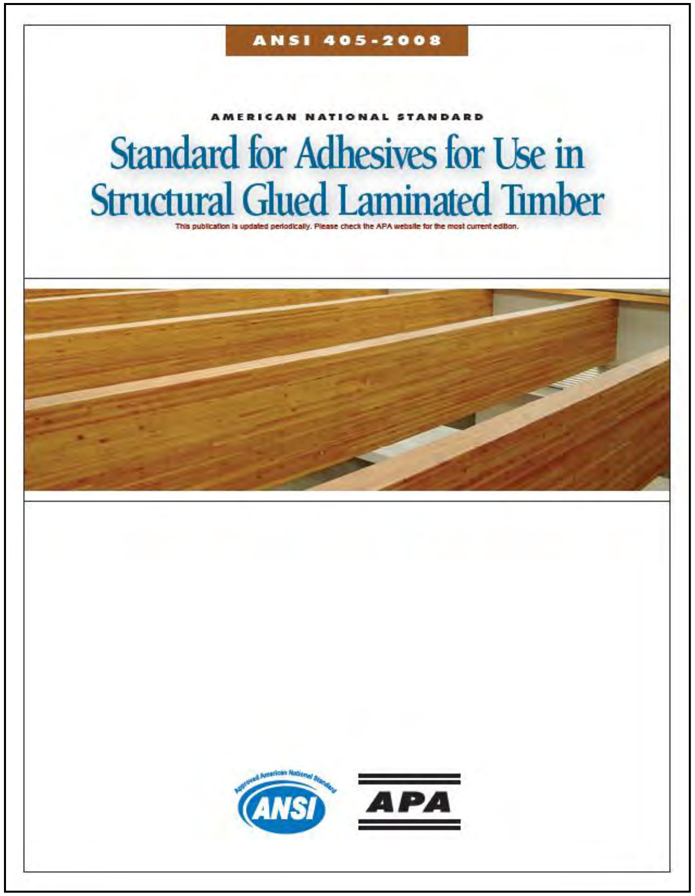
- 5-Ply CLT (approx. 7″ thick)
- 5/8″ Type X GWB each side
- Sought 2 hour rating
- RESULTS: 3 hours 6 minutes



Half-lapped – middle of panel

CLT Adhesives

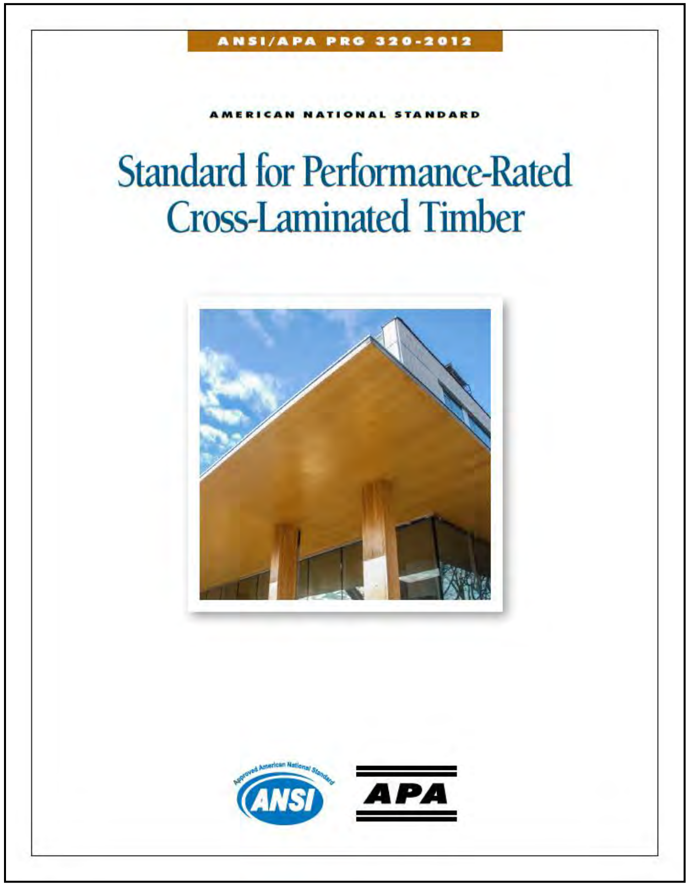


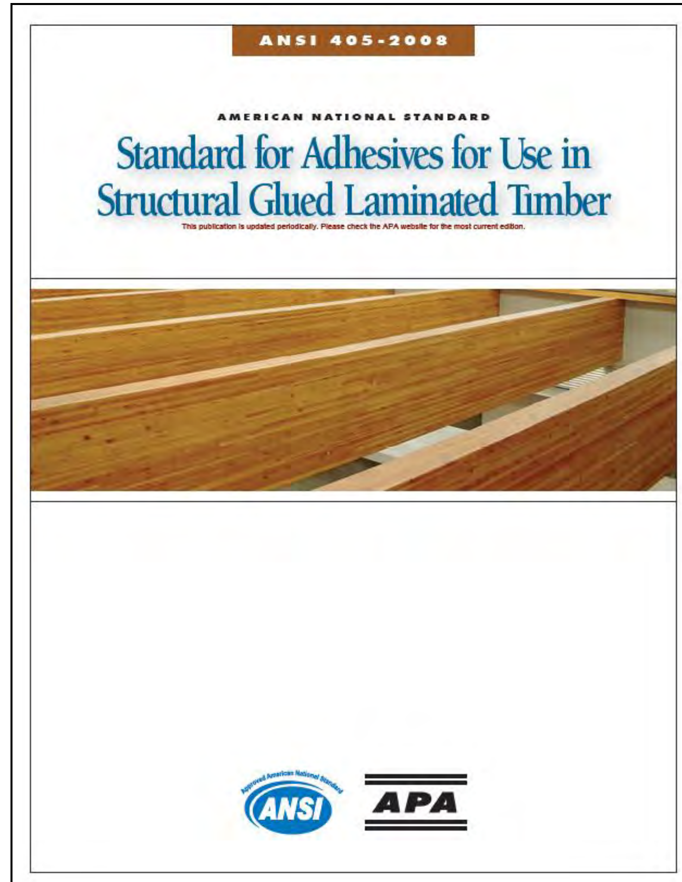


ANSI/APA PRG 320-2011 references

ANSI/APA 405-2008 – references ASTM D 7247

CLT Adhesives





CLT-ANSI/APA PRG 320-2012 references
ANSI/APA 405-2008 – references ASTM D 7247

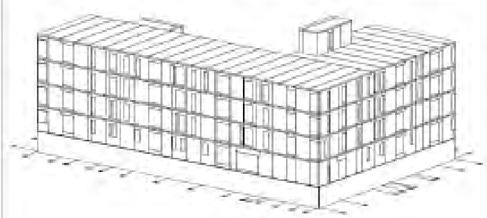
Outline

- Overview
- Building Code Provisions
- Structural and Fire Provisions
- **North American Projects**

Condominiums - Chibougamau, Quebec

Project Description

- Location: Chibougamau
- Date on Site: 2011-10-10
- Materials Volume:
  - CLT= 1150m^3
  - Glulam= 70m^3
  - Steel= 7000 Kg



- Fabrication Time (Estimated): 5 weeks
- Erection Time (Estimated): 7-8 weeks for the structure

Actual - 22 construction days (10 hours a day) - 5 men

Architect: ABCP Architecture

Exterior Wall Build-Up

Source: Nordic Engineered Wood

Franklin Elementary School - Franklin, WV

46,200 sq. ft.   8 week assembly
Architect: MSES Architects, Fairmont, WV

Source: LignaTerra

Franklin Elementary School - Franklin, WV

Scheduled completion date: Winter 2015

Redstone Arsenal Army Hotel - Huntsville, AL

Four stories 58,000 sq ft
Architect: Lend Lease

Redstone Arsenal Army Hotel - Huntsville, AL

Questions?

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

www.awc.org

info@awc.org

AMERICAN WOOD COUNCIL