

Code Applications for Nail-laminated Timber, Glued-laminated Timber and Cross-laminated Timber- MAT252-1

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2

Description

This presentation will focus on Nail-laminated Timber (NLT), Glued-laminated Timber (GLT) and Cross-laminated Timber (CLT) structural framing members. NLT and GLT has been adopted in the IBC and utilized throughout the world for several decades on a wide variety of buildings. Often selected for aesthetic reasons or its unparalleled design flexibility, both offer superior structural performance combined with long term durability. CLT has been recently incorporated in AWC's *National Design Specification® (NDS®) for Wood Construction 2015* as well as ICC's 2015 *International Building Code (IBC)*. It has been used for over a decade in other parts of the world such as Europe and Australia and has recently made its way into North America. Similar to NLT and GLT, in addition to its structural capabilities, CLT is specified for aesthetic appeal, structural simplicity and speed of construction. Additionally, all three products offer sustainable qualities as they are manufactured from a renewable resource and store carbon. Structural and fire protection characteristics of NLT, GLT and CLT will be discussed as well as IBC code provisions that allow their specification in both residential and commercial applications for a wide variety of occupancies.

3

Learning Objectives

1. **Be able to identify code acceptance of nail-laminated timber, glued-laminated timber and cross-laminated timber.**
2. **Become familiar with a number of technology advances and standards related to nail-laminated timber, glued-laminated timber and cross-laminated timber.**
3. **Improve design knowledge on building systems made with new types of mass timber products.**
4. **Become acquainted with the unique fire resistive characteristics of nail-laminated timber, glued-laminated timber and cross-laminated timber as it influences the use of wood in building construction.**
5. **Understand the application of NDS Chapter 16 which can be utilized to design up to 2-hours of fire-resistance for exposed wood members.**

4

Polling Question

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

5

Outline

- **Overview & Building Code Allowances**
- **Nail-laminated Timber**
- **Glued-laminated Timber**
- **Cross-laminated Timber**
- **Fire**

6

Traditional Stick Framed Construction



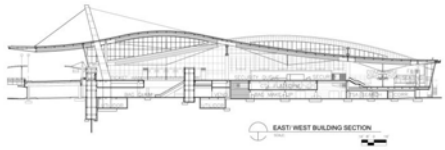

7

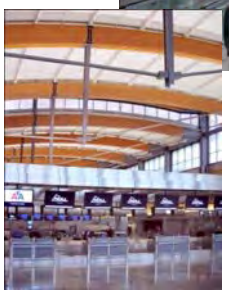
Simpson Strong-Tie Demo Lab
Cal Poly, San Luis Obispo, CA




8

Raleigh Durham Airport, North Carolina





9

Pedestrian Bridge - 105 ft. Span

10

Warner Drive – Culver City, CA

- Type V Construction
- Assembly & Business Occupancy

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

Architect: Profeta Royalty Architecture
Structural Engineer: Structural Focus
Completed: 2011

11

Warner Drive – Culver City, CA

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

Architect: Profeta Royalty Architecture
Structural Engineer: Structural Focus
Completed: 2011

12

Bullitt Center – Seattle, WA

Architect: Miller Hill Partnership
Structural Engineer: DCI Engineers
Photo Credit: Miller Hull Partnership

13

Bullitt Center – Seattle, WA

- Glulam beams and columns
- Nail-laminated timber floors

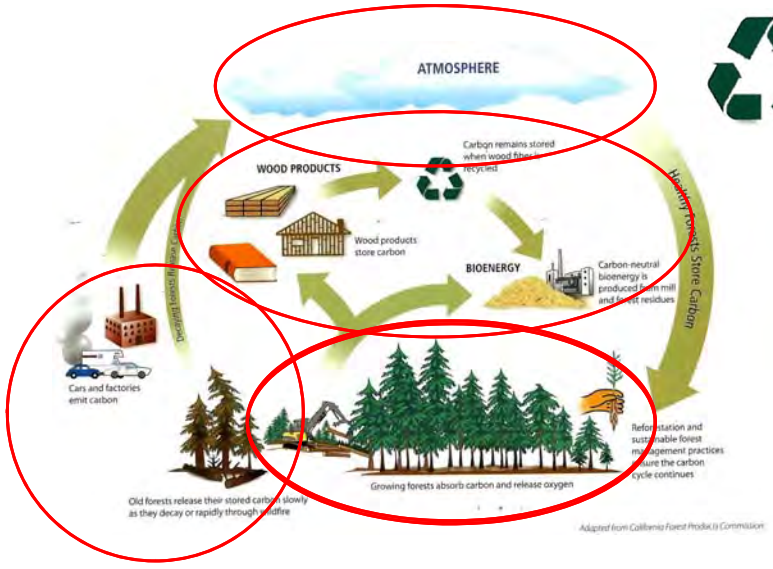
Architect: Miller Hill Partnership
Structural Engineer: DCI Engineers
Photo Credit: Miller Hull Partnership

14

Stadhaus, London, UK

15

The Story of Wood – Wood Carbon Cycle



16

Climate Change: The Role of CO_2

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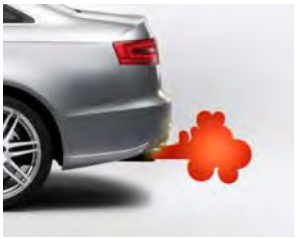
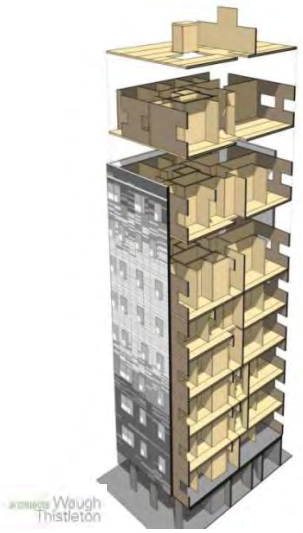


2,400 sf home = 32 m^3 structural wood = 29 metric tons CO_2 = 5.7 passenger annual emissions

Source: FP Innovations

17

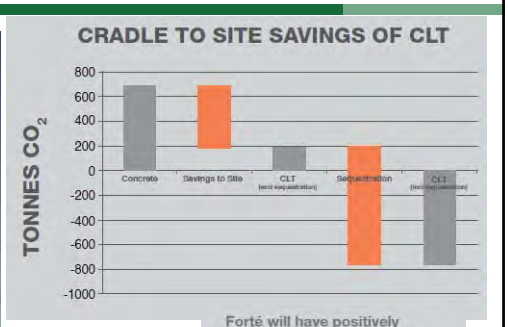
Stradthaus – 24 Murray Grove –Tallest Modern Mixed Use Timber Structure



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 CO2
21 years of energy usage for the building

18

Forte', Melbourne



- **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.

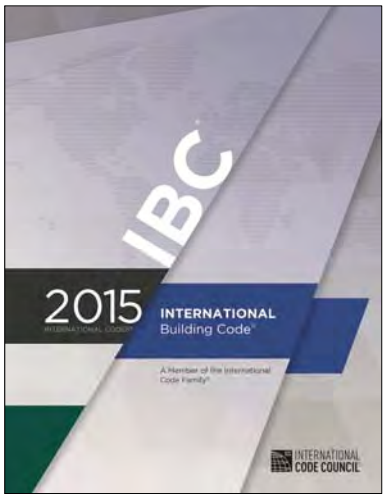
19

Forte', Melbourne

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

20

Building Code



23

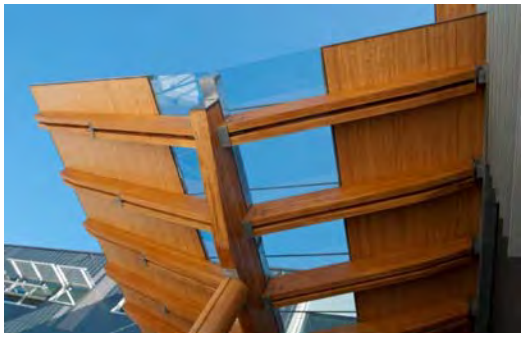
Where is GLT Allowed in IBC 2015?

LeMay – America's Auto Museum
Tacoma, WA

- **Types I and II are generally noncombustible inside and out – Roof applications**
- **Types III have noncombustible exteriors with interiors of any material.**
- **Type IV &V are generally combustible such as wood although V includes any material permitted.**

24

Where is NLT Allowed in IBC 2015?



Chilliwack Secondary School
Chilliwack, BC

Resource: StructureCraft

- **Types III have noncombustible exteriors with interiors of any material.**
- **Type IV &V are generally combustible such as wood although V includes any material permitted.**

25

Where is GLT Allowed in IBC 2015?

TABLE 601
FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (HOURS)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A	B	A	B	HT	A	B
Primary structural frame[f] (see Section 202)	3[a]	2[a]	1	0	1	0	HT	1	0
Bearing walls Exterior[e, f] Interior	3 3[a]	2 2[a]	1 1	0 0	2 1	2 0	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	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

For SI: 1 foot = 304.8 mm.

a. Roof supports: Fire-resistance ratings of primary structural frame and bearing walls are permitted to be reduced by 1 hour where supporting a roof only.

b. Except in Group F-1, H, M and S-1 occupancies, fire protection of structural members shall not be required, including protection of roof framing and decking where every part of the roof construction is 20 feet or more above any floor immediately below. Fire-retardant-treated wood members shall be allowed to be used for such unprotected members.

c. In all occupancies, heavy timber shall be allowed where a 1-hour or less fire-resistance rating is required.

d. Not less than the fire-resistance rating required by other sections of this code.

e. Not less than the fire-resistance rating based on fire separation distance (see Table 602).

f. Not less than the fire-resistance rating as referenced in Section 704.10.

26

Where is CLT Allowed in IBC 2015?

Code modifications to Ch. 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.

Code modifications to Ch. 35 Reference Standards

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

27

Fire Tests

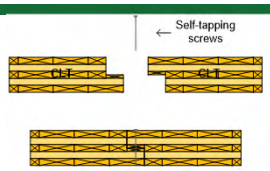
http://www.awc.org/Code-Officials/2012-IBC-Challenges/#

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

28

Fire Test

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



Half-lapped – middle of panel

29

Where is CLT Allowed in IBC 2015?

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.

30

Where is CLT allowed in IBC 2015?

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.

31

Where is CLT allowed in IBC 2015?

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…

32

Where is CLT allowed in IBC 2015?

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.

33

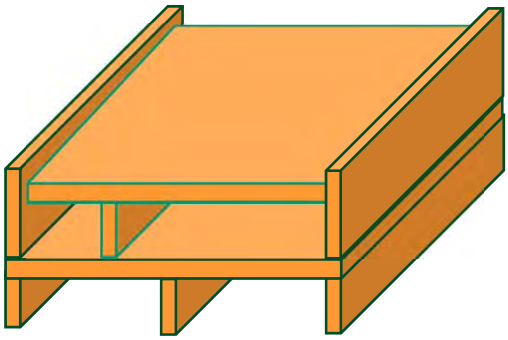
Where is CLT allowed in IBC 2015?

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.

34

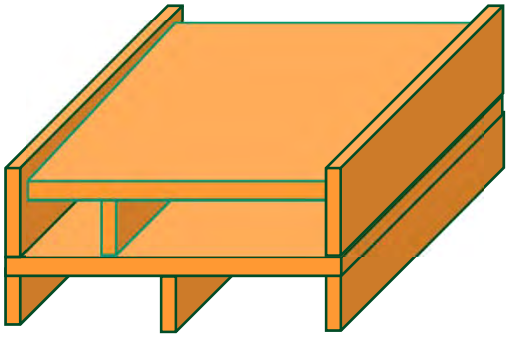
Type IV Construction



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

35

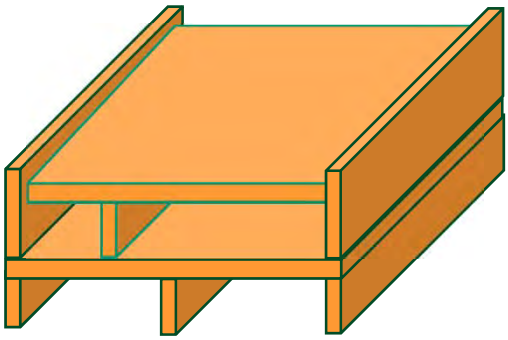
Type V Construction



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

36

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*

37

Possibilities for CLT?

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

38

Polling Question

2. The 2015 IBC allows cross-laminated timber to be used in the following applications?

a) Type III, IV, and V Construction
b) Roofs
c) Floors
d) All of the above

39

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

40

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

41

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]	UL	UL	24,000	16,000	24,000	16,000	20,500	12,000	7,000
	S13R									
	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 m².

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.

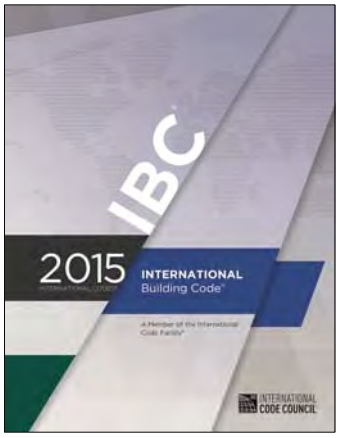
a. See Chapters 4 and 5 for specific exceptions to the allowable height in this chapter.
b. See Section 903.2 for the minimum thresholds for protection by an automatic sprinkler system for specific occupancies.
c. New Group H occupancies are required to be protected by an automatic sprinkler system in 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.

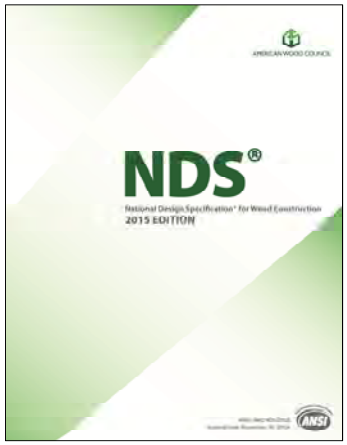
R-2 Occupancy Type IV Construction NFPA 13R Sprinklers
60 feet (85 feet w/NFPA 13 Sprinklers)
4 stories (5 stories w/ NFPA 13 Sprinklers)
Allowable area = 20,500 sf

42

Governing Codes for Wood Design

2015 IBC references in 2015 NDS



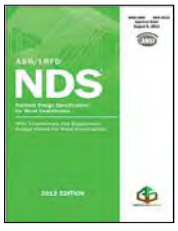


43

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

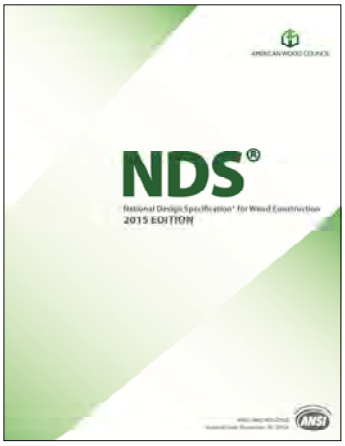
- 1-3 General
- 4-10 Products +CLT
- 11-14 Connections
- Shear Walls & Diaphragms
- 15 Special Loading
- 16 Fire

45

2015 NDS

Product Chapters

- Ch. 4 Sawn Lumber
- Ch. 5 Structural Glued Laminated Timber
- Ch. 10 Cross-Laminated Timber



46

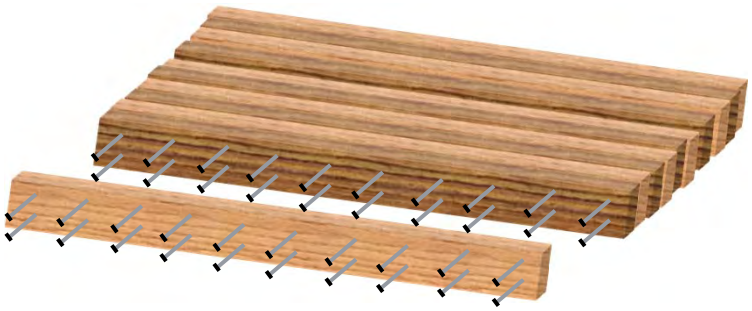
Outline

- Overview & Building Code Allowances
- **Nail-laminated Timber**
- Glued-laminated Timber
- Cross-laminated Timber
- Fire

Resource: StructureCraft

47

What is Nail-Laminated Timber?



48

Nail-Laminated Timber

- **2304.8.3 Mechanically laminated decking.** Mechanically laminated decking shall comply with Sections 2304.8.3.1 through 2304.8.3.3.
- **2304.8.3.1 General.** Mechanically laminated decking consists of square-edged dimension lumber laminations set on edge and nailed to the adjacent pieces and to the supports.
- **2304.8.3.2 Nailing.** The length of nails connecting laminations shall not be less than two and one-half times the net thickness of each lamination. Where decking supports are 48 inches (1219 mm) on center (o.c.) or less, side nails shall be installed not more than 30 inches (762 mm) o.c. alternating between top and bottom edges, and staggered one-third of the spacing in adjacent laminations. Where supports are spaced more than 48 inches (1219 mm) o.c., side nails shall be installed not more than 18 inches (457 mm) o.c. alternating between top and bottom edges and staggered one-third of the spacing in adjacent laminations. Two side nails shall be installed at each end of butt-jointed pieces.

  Laminations shall be toenailed to supports with 20d or larger common nails. Where the supports are 48 inches (1219 mm) o.c. or less, alternate laminations shall be toenailed to alternate supports; where supports are spaced more than 48 inches (1219 mm) o.c., alternate laminations shall be toenailed to every support.
- **2304.8.3.3 Controlled random pattern.** There shall be a minimum distance of 24 inches (610 mm) between end joints in adjacent courses. The pieces in the first and second courses shall bear on at least two supports with end joints in these two courses occurring on alternate supports. A maximum of seven intervening courses shall be permitted before this pattern is repeated.

49

Nail-Laminated Timber

Resource: StructureCraft

General Contractor: **EllisDon**
Location: **Richmond, British Columbia, Canada**
Design Assist, Fabrication and Installation: **StructureCraft**
Completion: **2010**

50

Nail-Laminated Timber

Resource: StructureCraft

51

Nail-Laminated Timber

Resource: StructureCraft

General Contractor: **Companion**
Location: **Surrey, British Columbia, Canada**
Design Assist, Fabrication and Installation: **StructureCraft**
Completion: **2013**

52

Nail-Laminated Timber

Resource: StructureCraft

53

Nail-Laminated Timber

Resource: StructureCraft

54

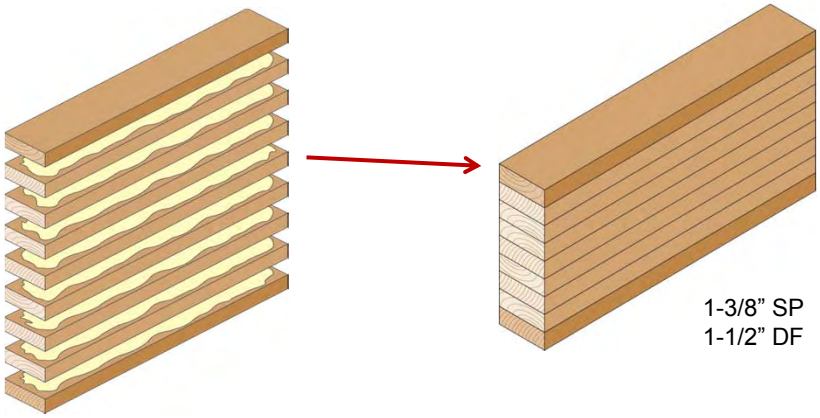
Outline

- Overview & Building Code Allowances
- Nail-laminated Timber
- Glued-laminated Timber
- Cross-laminated Timber
- Fire

55

What is Glulam?

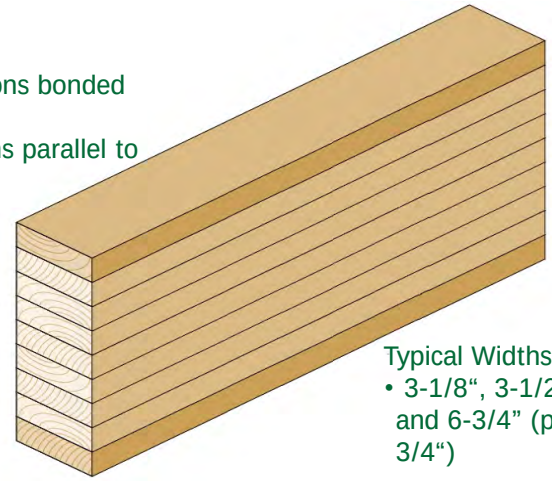
- Glued-laminated timber = Glulam = a structural composite of lumber and adhesives



56

Glulam – Characteristics

Glulam:
- Wood laminations bonded together
- Wood grain runs parallel to the length

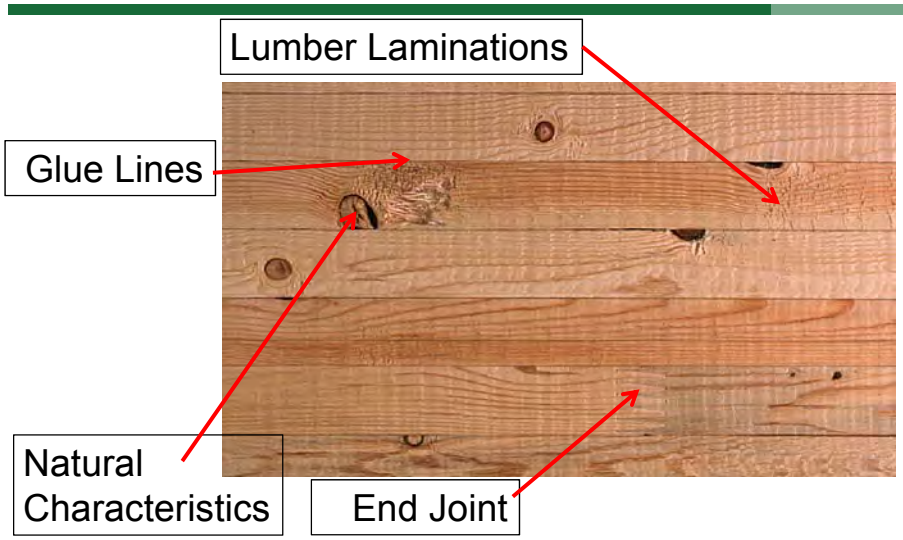


Typical Widths:
- 3-1/8“, 3-1/2, 5-1/8” and 6-3/4” (possibly 10-3/4“)

Laminations:
1-3/8" for Southern Pine
1-1/2" for Douglas Fir

57

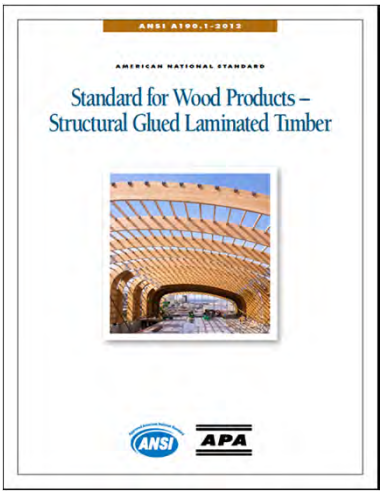
Glulam = One of the Original Engineered Wood Composites



58

Standards

- **Product qualification and quality assurance requirements are specified**
- **Third-party inspection is required on an on-going basis**
- **All glulam must bear a grademark meeting ANSI A190.1 -2012**



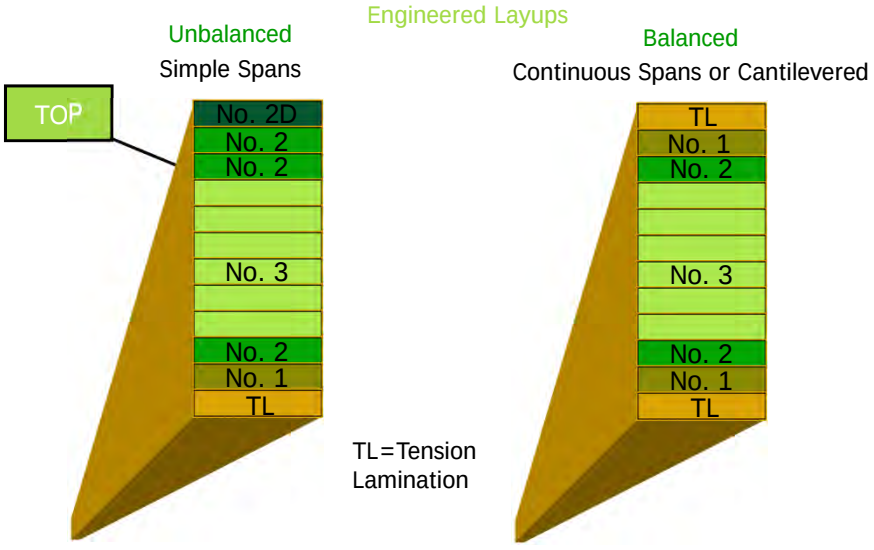
59

Lumber Species

- **Traditional softwoods**
  Douglas Fir & Southern Pine
- **Other softwoods**
  Spruce-Pine-Fir and Hem-Fir
- **Naturally durable softwoods**
  Alaska Yellow Cedar
  Port Orford Cedar
- **Hardwoods**
- **Mixed species layups**

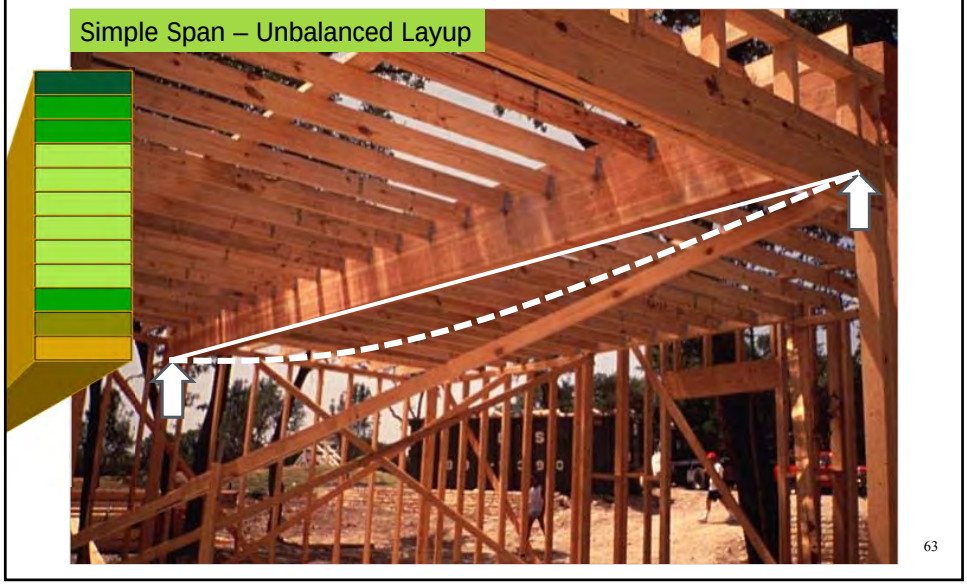
61

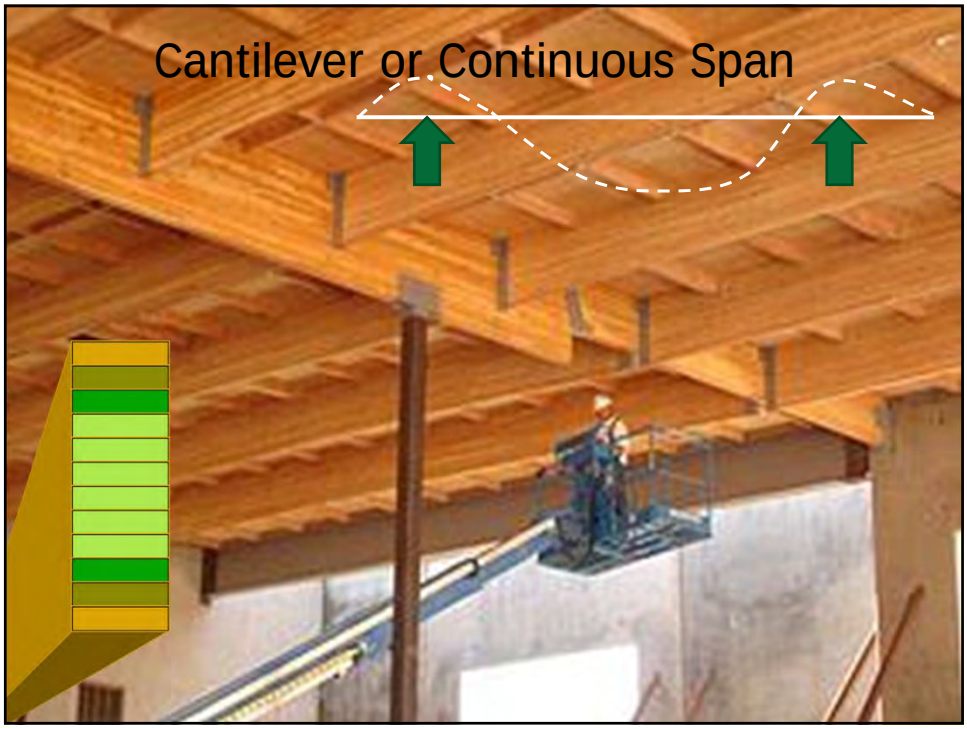
Glulam Manufacturing- Engineered Layups



62

Glulam Manufacturing- Engineered Layups



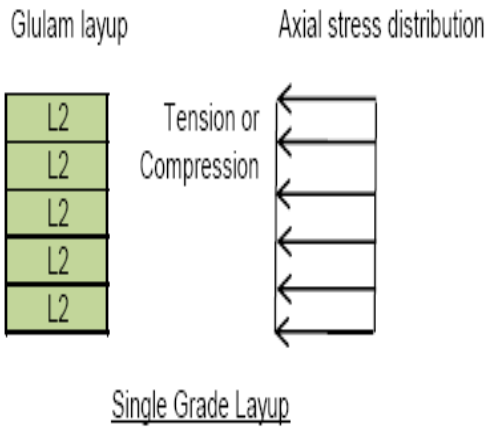


Note the "TOP" Stamp – for Unbalanced Layup

65

Single-Grade Layup

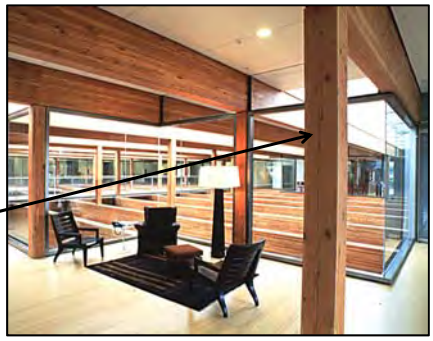
- Same lumber grade and species used throughout
- Primarily for use in axially loaded members, such as columns and truss chords



66

Single-Grade Layup

Glulam truss chords and webs



Glulam columns

67

Glulam Manufacturing- Appearance Classifications

Appearance Classifications:

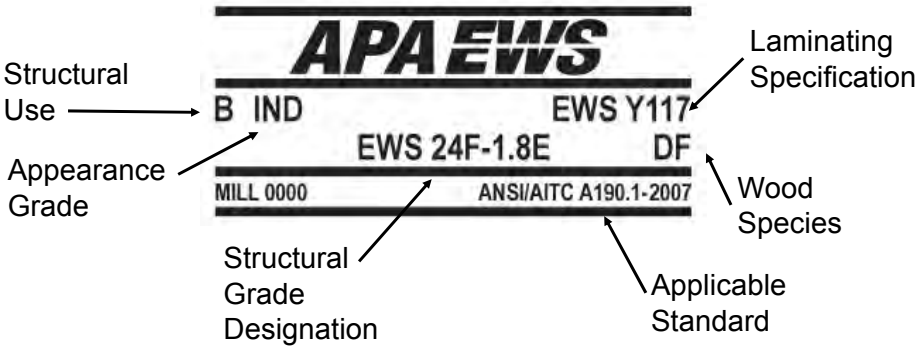
- **Framing (-L) (3-1/2", 5-1/2")**
- **Industrial (-L)**
- **Architectural**
- **Premium (verify local availability)**

Note: Appearance classifications do not affect design values.

APA Publication Y110

69

Marking



71

Polling Question

3. The Glued-laminated timber layups can be:

a) Balanced
b) Unbalanced
c) Single grade
d) All of the above

72

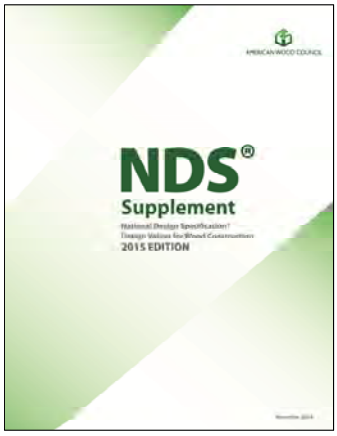
Glulam Design: 2015 NDS

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

73

NDS 2015 Supplement



1. **Sawn Lumber Grading Agencies**
2. **Species Combinations**
3. **Section Properties**
4. **Reference Design Values**
   - Sawn Lumber and Timber
   - MSR and MEL
   - Decking
   - Non-North American Sawn Lumber
   - Structural Glued Laminated Timber
   - Timber Poles and Piles

74

NDS Stress Classes

- **Stress Classes Combined for Simplicity**

Table 5A Reference Design Values for Structural Glued Laminated Softwood Timber

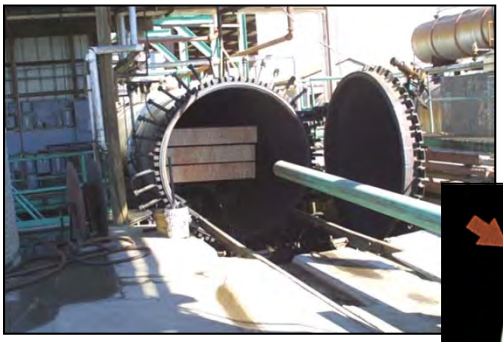
(Members stressed primarily in bending) (Tabulated design values are for normal load duration and dry service conditions. See NDS 5.3 for a comprehensive description of design value adjustment factors.)

Use with Table 5A Adjustment Factors

	Bending About X-X Axis (Loaded Perpendicular to Wide Faces of Laminations)						Bending About Y-Y Axis (Loaded Parallel to Wide Faces of Laminations)					Axially Loaded		Fasteners
	Bending		Compression Perpendicular to Grain	Shear Parallel to Grain	Modulus of Elasticity		Bending	Compression Perpendicular to Grain	Shear Parallel to Grain	Modulus of Elasticity		Tension Parallel to Grain	Compression Parallel to Grain	Specific Gravity for Fastener Design
	Bottom of Beam Stressed in Tension (Positive Bending)	Top of Beam Stressed in Tension (Negative Bending)			For Deflection Calculations	For Stability Calculations				For Deflection Calculations	For Stability Calculations			
Stress Class	F_{bx}^{+} (psi)	F_{bx}^{-} [1] (psi)	$F_{c\perp x}$ (psi)	F_{vx} [4] (psi)	E_x (10^6 psi)	$E_{x\,min}$ (10^6 psi)	F_{by} (psi)	$F_{c\perp y}$ (psi)	F_{vy} [4][5] (psi)	E_y (10^6 psi)	$E_{y\,min}$ (10^6 psi)	F_t (psi)	F_c (psi)	G
16F-1.3E	1600	925	315	195	1.3	0.69	800	315	170	1.1	0.58	675	925	0.41
20F-1.5E	2000	1100	425	195 [6]	1.5	0.79	800	315	170	1.2	0.63	725	925	0.41
24F-1.7E	2400	1450	500	210 [6]	1.7	0.90	1050	315	185	1.3	0.69	775	1000	0.42
24F-1.8E	2400	1450 [2]	650	265 [3]	1.8	0.95	1450	560	230 [3]	1.6	0.85	1100	1600	0.50 [10]
26F-1.9E [7]	2600	1950	650	265 [3]	1.9	1.00	1600	560	230 [3]	1.6	0.85	1150	1600	0.50 [10]
28F-2.1E SP [7]	2800	2300	805	300	2.1 [9]	1.11 [9]	1600	650	260	1.7	0.90	1250	1750	0.55
30F-2.1E SP [7][8]	3000	2400	805	300	2.1 [9]	1.11 [9]	1750	650	260	1.7	0.90	1250	1750	0.55

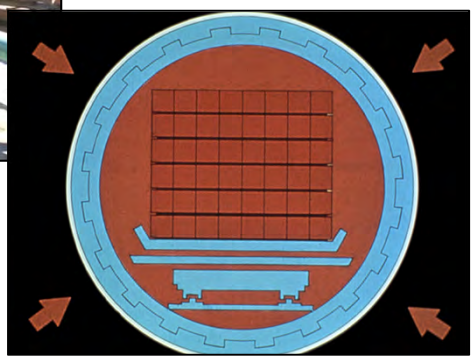
75

Preservative Treatment of Glulam



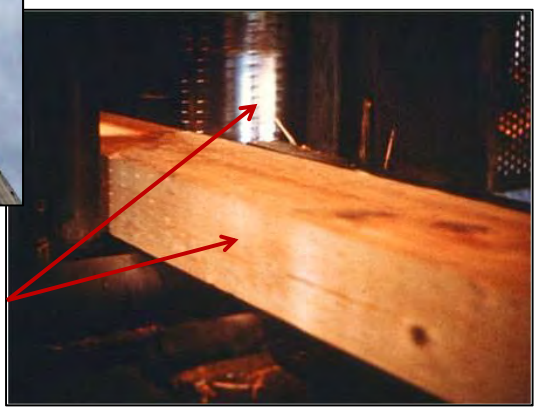
Untreated glulam in pressure cylinder ready for treatment

Preservative forced into wood cells under pressure



76

Preservative Treatment of Glulam



Incising used for difficult to treat species
No effect on glulam strength

77

Preservative Treatments

- **Considerations for preservative treatments**
  - **Incising may be required for some hard to treat species**
  - **Fastener corrosion may occur with some waterborne arsenical treatments – use hot dipped galvanized or stainless steel connectors**
  - **Field cuts require field applied treatments**
  - **Structural properties not affected by approved treatments and processes**

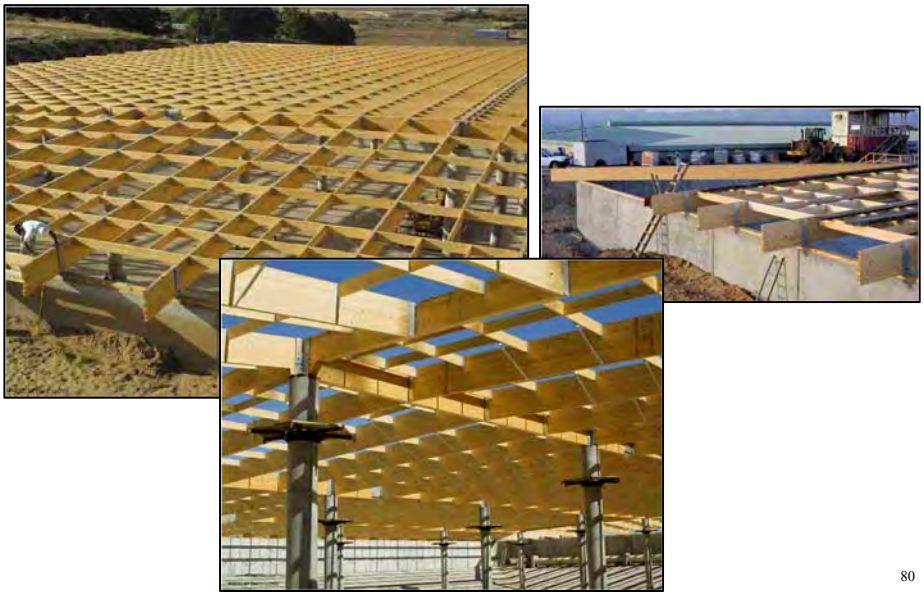
78

Naturally Durable Species

- **Port Orford Cedar** **22F-1.8E**
- **Alaska Yellow Cedar** **20F-1.5E**
- **Western Red Cedar** **16F-1.3E**
- **California Redwood** **16F-1.1E**

79

Alaska Yellow Cedar
Santa Monica, CA Reservoir Cover



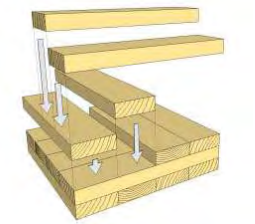
80

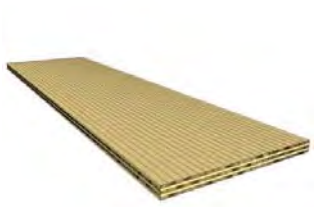
Outline

- Overview & Building Code Allowances
- Nail-Laminated Timber
- Glued-laminated Timber
- **Cross-laminated Timber**
- Fire

81

Concept of Cross-Laminated Timber





Photos provided by FPInnovations

82

CLT Layup, Press and Glue

Slide Courtesy of Structurlam

83

CNC Technology

Slide Courtesy of Structurlam

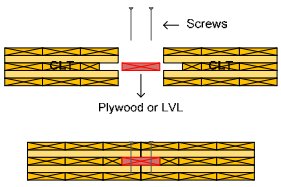
84

Ready to Ship

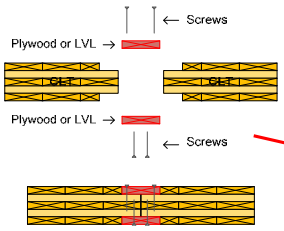
Slide Courtesy of Structurlam

85

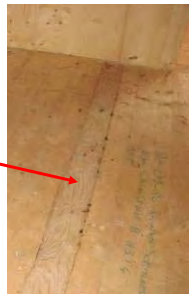
CLT - Typical Construction Details

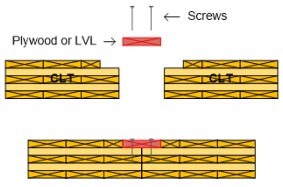


Internal spline

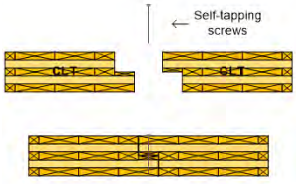


Double surface spline





Single surface spline



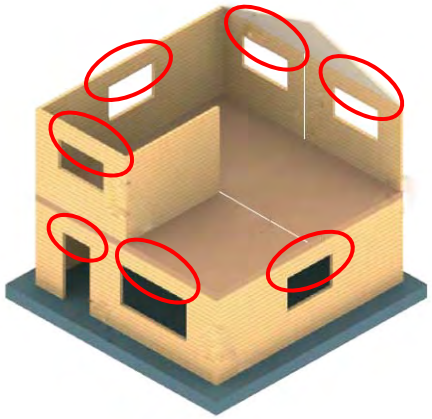
Half-lapped

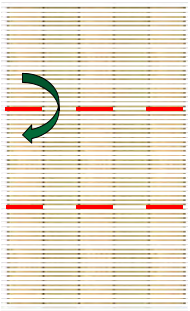
86

Bending Members

Design properties available for out-of-plane loading

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





87

Typical Panel Connectors

88

Typical Panel Connectors

89

CLT Design: 2015 NDS

2015

1. General Requirements for Building Design
2. Design Values for Structural Members
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4. Sawn Lumber
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90

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.

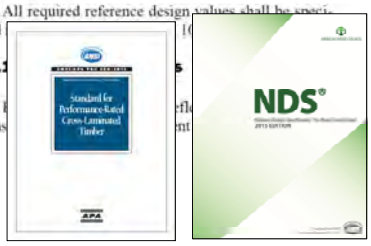
10.1.4 Specification

All required reference design values shall be speci-

fied

10.1

tions

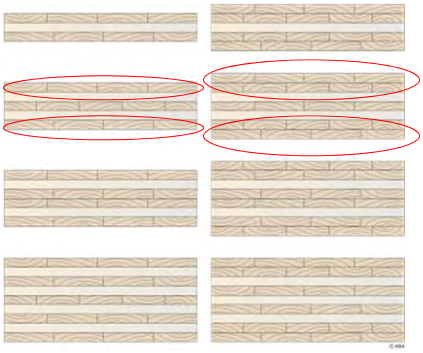


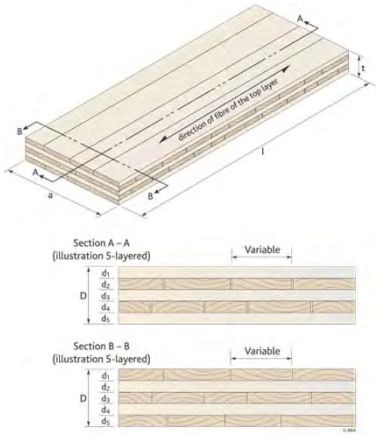
91

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

92

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

10.3.2 Load Duration Factor, C_D (ASD only)

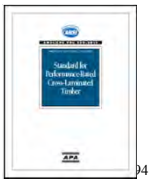
All reference design values except stiffness, $(EI)_{app}$, $(EI)_{app\text{-}min}$, rolling shear, $F_s(Ib/Q)_{eff}$, and compression perpendicular to grain, $F_{c\perp}(A)$, shall be multiplied by load duration factors, C_D, as specified in 2.3.2.

93

CLT Manufacturing Standard

TABLE 1
REQUIRED CHARACTERISTIC TEST VALUES[a,b,c,d] FOR PRG 320 CLT

	Major Strength Direction						Minor Strength Direction			
CLT Grades	$f_{b,0}$ (psi)	E_0 (10^6 psi)	$f_{t,0}$ (psi)	$f_{c,0}$ (psi)	$f_{v,0}$ (psi)	$f_{s,0}$ (psi)	$f_{b,90}$ (psi)	E_{90} (10^6 psi)	$f_{v,90}$ (psi)	$f_{s,90}$ (psi)
E1	4,095	1.7	2,885	3,420	425	140	1,050	1.2	425	140
E2	3,465	1.5	2,140	3,230	565	190	1,100	1.4	565	190
E3	2,520	1.2	1,260	2,660	345	115	735	0.9	345	115
E4	4,095	1.7	2,885	3,420	550	180	1,205	1.4	550	180
V1	1,890	1.6	1,205	2,565	565	190	1,100	1.4	565	190
V2	1,835	1.4	945	2,185	425	140	1,050	1.2	425	140
V3	2,045	1.6	1,155	2,755	550	180	1,205	1.4	550	180



94

CLT Manufacturing Standard

TABLE A1.
ALLOWABLE DESIGN PROPERTIES[a,b,c] FOR PRG 320 CLT (FOR USE IN THE U.S.)

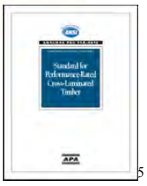
	Major Strength Direction						Minor Strength Direction			
CLT Grades	$F_{b,0}$ (psi)	E_0 (10^6 psi)	$F_{t,0}$ (psi)	$F_{c,0}$ (psi)	$F_{v,0}$ (psi)	$F_{r,0}$ (psi)	$F_{b,90}$ (psi)	E_{90} (10^6 psi)	$F_{v,90}$ (psi)	$F_{r,90}$ (psi)
E1	1,950	1.7	1,375	1,800	135	45	500	1.2	135	45
E2	1,650	1.5	1,020	1,700	180	60	525	1.4	180	60
E3	1,200	1.2	600	1,400	110	35	350	0.9	110	35
E4	1,950	1.7	1,375	1,800	175	55	575	1.4	175	55
V1	900	1.6	575	1,350	180	60	525	1.4	180	60
V2	875	1.4	450	1,150	135	45	500	1.2	135	45
V3	975	1.6	550	1,450	175	55	575	1.4	175	55

For SI: 1 psi = 0.006895 MPa

(a) See Section 4 for symbols.

(b) Tabulated values are allowable design values and not permitted to be increased for the lumber size adjustment factor in accordance with the NDS. The design values shall be used in conjunction with the section properties provided by the CLT manufacturer based on the actual layup used in manufacturing the CLT panel (see Table A2).

(c) Custom CLT grades that are not listed in this table shall be permitted in accordance with Section 7.2.1



5

CLT Manufacturing Standard

CLT layups:

- E1: *1950f-1.7E Spruce-pine-fir MSR lumber in all parallel layers and No. 3 Spruce-pine-fir lumber in all perpendicular layers*
- E2: *1650f-1.5E Douglas fir-Larch MSR lumber in all parallel layers and No. 3 Douglas fir-Larch lumber in all perpendicular layers*
- E3: *1200f-1.2E Eastern Softwoods, Northern Species, or Western Woods MSR lumber in all parallel layers and No. 3 Eastern Softwoods, Northern Species, or Western Woods lumber in all perpendicular layers*
- E4: *1950f-1.7E Southern pine MSR lumber in all parallel layers and No. 3 Southern pine lumber in all perpendicular layers*
- V1: *No. 2 Douglas fir-Larch lumber in all parallel layers and No. 3 Douglas fir-Larch lumber in all perpendicular layers*
- V2: *No. 1/No. 2 Spruce-pine-fir lumber in all parallel layers and No. 3 Spruce-pine-fir lumber in all perpendicular layers*
- V3: *No. 2 Southern pine lumber in all parallel layers and No. 3 Southern pine lumber in all perpendicular layers*

96

CLT Manufacturing Standard

TABLE A2.
THE ALLOWABLE BENDING CAPACITIES[a,b,c] FOR CLT LISTED IN TABLE A1 (FOR USE IN THE U.S.)

CLT Grade	CLT t (in.)	Lamination Thickness (in.) in CLT Layup								Major Strength Direction			Minor Strength Direction		
		∥	⊥	∥	⊥	∥	⊥	∥	⊥	∥	$EI_{eff,0}$ (10^6 lbf-in.²/ft)	$GA_{eff,0}$ (10^6 lbf/ft)	$F_cS_{eff,90}$ (lbf-ft/ft)	$EI_{eff,90}$ (10^6 lbf-in.²/ft)	$GA_{eff,90}$ (10^6 lbf/ft)
E1	4 1/8	1 3/8	1 3/8	1 3/8						4,525	115	0.46	160	3.1	0.82
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8				10,400	440	0.92	1,370	81	1.4
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8		18,375	1,089	1.4	3,150	313	1.9
E2	4 1/8	1 3/8	1 3/8	1 3/8						3,825	102	0.53	165	3.6	0.96
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8				8,825	389	1.1	1,440	95	1.3
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8		15,600	963	1.6	3,300	364	1.7
E3	4 1/8	1 3/8	1 3/8	1 3/8						2,800	81	0.35	110	2.3	0.62
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8				6,400	311	0.69	955	61	0.98
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8		11,325	769	1.0	2,210	234	1.4
E4	4 1/8	1 3/8	1 3/8	1 3/8						4,525	115	0.53	180	3.6	0.96
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8				10,425	441	1.1	1,570	95	1.4
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8		18,400	1,090	1.6	3,625	364	2.0
V1	4 1/8	1 3/8	1 3/8	1 3/8						2,090	108	0.53	165	3.6	0.96
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8				4,800	415	1.1	1,440	95	1.3
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8		8,500	1,027	1.6	3,300	364	1.9
V2	4 1/8	1 3/8	1 3/8	1 3/8						2,030	95	0.46	160	3.1	0.82
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8				4,675	363	0.91	1,370	81	1.2
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8		8,275	898	1.4	3,150	312	1.6
V3	4 1/8	1 3/8	1 3/8	1 3/8						2,270	108	0.53	180	3.6	0.96
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8				5,200	415	1.1	1,570	95	1.3
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8		9,200	1,027	1.6	3,625	364	1.9

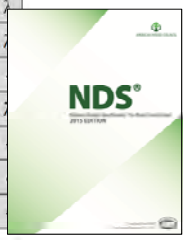
For SI: 1 in. = 25.4 mm; 1 ft = 304.8 mm
(a) See Section 4 for symbols.
(b) This table represents one of many possibilities that the CLT could be manufactured by varying lamination grades, thicknesses, orientations, and layer arrangements in the layup.
(c) Custom CLT grades that are not listed in this table shall be permitted in accordance with Section 7.2.1.

97

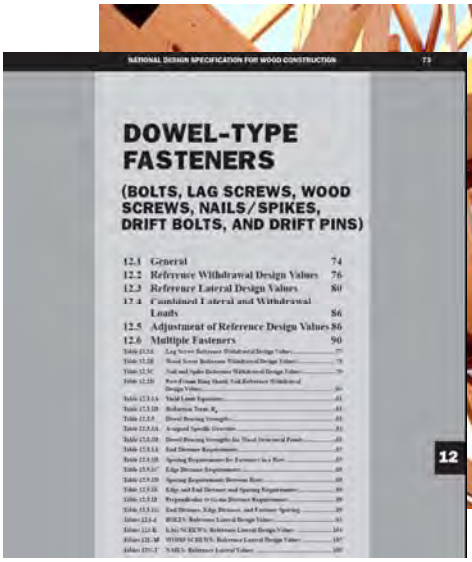
Chapter 10 – Cross-Laminated Timber

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



99

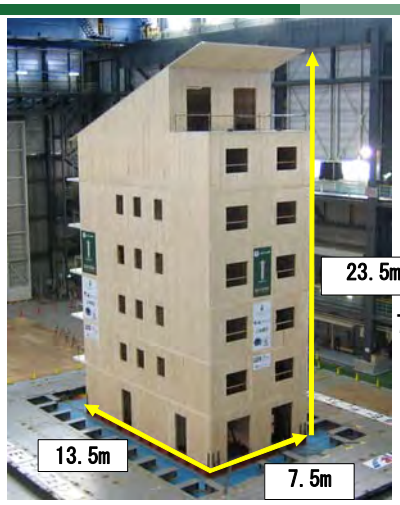
Seismic Design Options

- ***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

100

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’)



101

Polling Question

4. Cross-laminated timber panels used in bearing wall applications require additional framing above the openings in the panel

a) True

b) False

102

Outline

- Overview & Building Code Allowances
- Nail-Laminated Timber
- Glued-laminated Timber
- Cross-laminated Timber
- Fire

103

How is Fire-Resistance Provided?

- **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

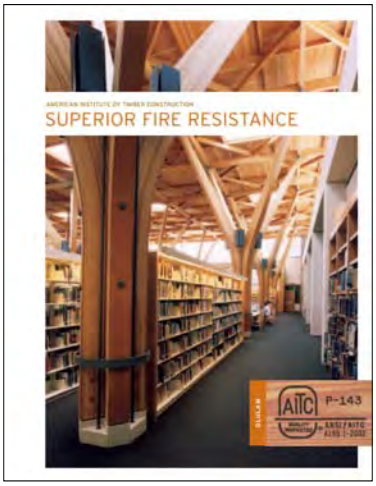
NOTE: Type IV Construction – for other than the walls, HT – required dimensions have performance presumed to be adequate

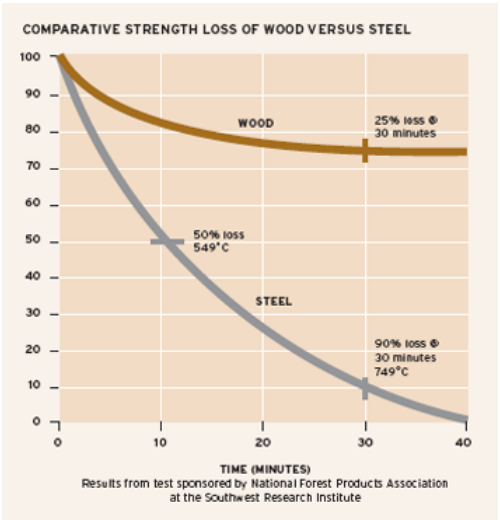
104

Fire Performance Glulam vs. Steel

105

Fire Performance of Wood vs. Steel





http://www.aitc-glulam.org/shopcart/Pdf/superior%20fire%20resistance.pdf

106

Chapter 16 – Fire (ASD)

- **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).*

107

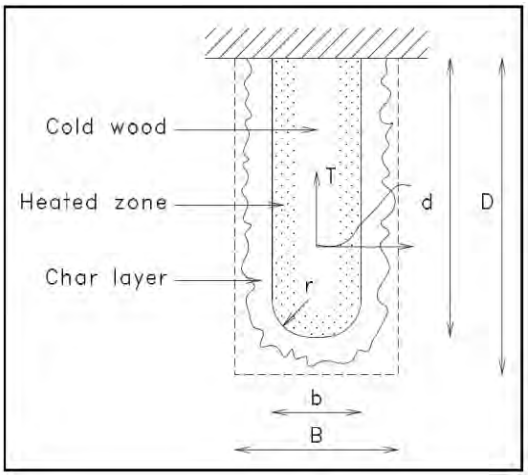
2015 NDS Methodology

- **Chapter 16 – Fire Design of Wood Members**
- **Mechanics Based Model**
- **Supported by empirical data**
- **NLT, GLT & CLT**

108

Chapter 16 – Calculated Resistance

- **Fire resistance of exposed wood members may be calculated using the provisions of NDS Chapter 16**



109

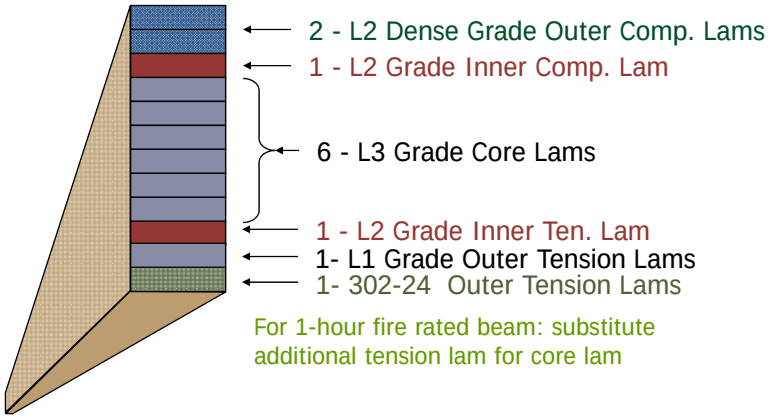
Fire-resistant NLT

- **16.2.5. Provisions for Timber Decks**
  - **≥ 2" (actual) thick**
  - **Planks span the distance between supporting beams**
  - **Designed as an assembly of wood beams partially exposed on the sides and fully exposed on one face.**
    - Char rate on sides reduced to 33% of the effective char rate
    - Calculation do not address thermal separation

110

Typical Glulam Beam Layup

- **24F-V4 Doug Fir (12 Lamination Example)**

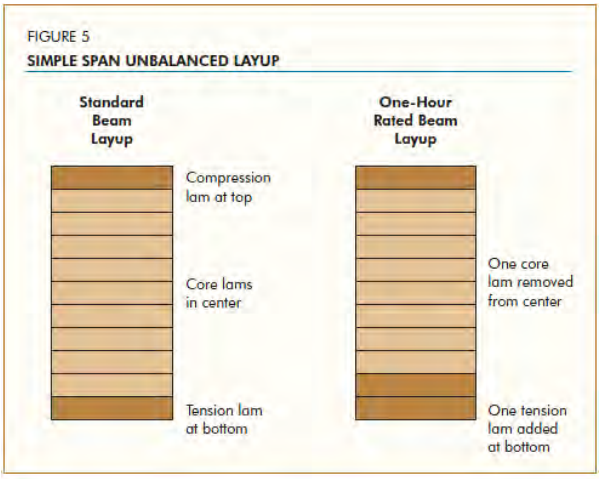


For 1-hour fire rated beam: substitute additional tension lam for core lam

112

Tension Lam Provisions

Fire Protection



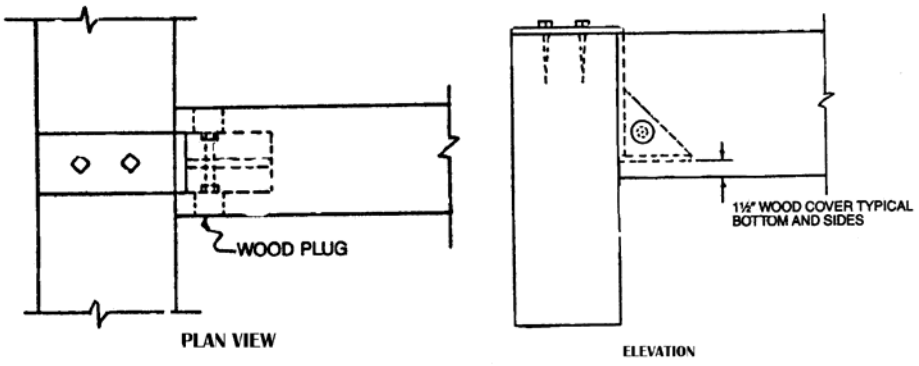
113

Fire Rated Glulam

- **16.3 Wood Connections-**
  - Where fire endurance is required, connectors and fasteners shall be protected from fire exposure
    - Wood
    - Fire-rated gypsum board
    - Coating (approved for required endurance time)

114

Connections

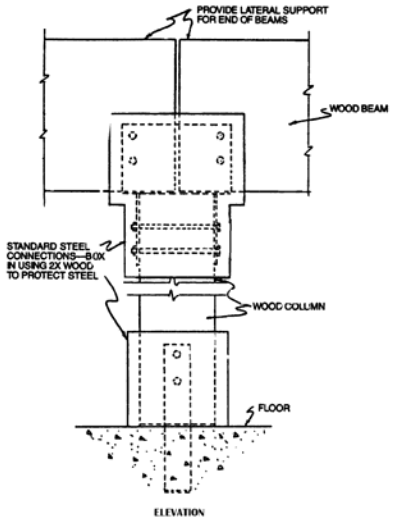


Concealed beam-to-girder connection

Source: AITC Technical Note 7

115

Connections

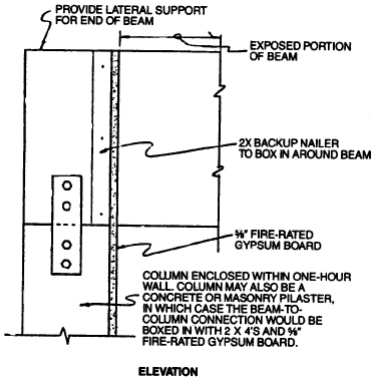


Covered column connection

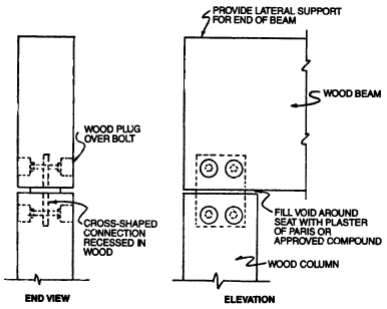
Source: AITC Technical Note 7

116

Connections



Beam-to-column (Protection provided by membrane)

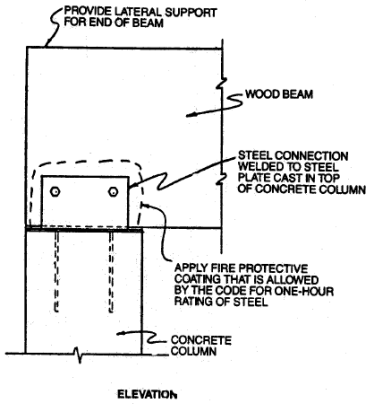


Concealed beam-to-column

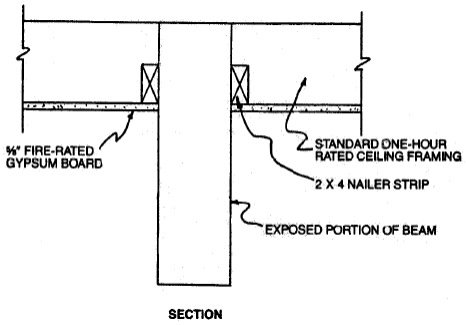
Source: AITC Technical Note 7

117

Connections



Beam-to-column (Steel has protective coating)

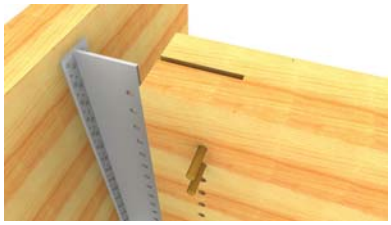


Glulam supporting one hour rated ceiling

Source: AITC Technical Note 7

118

Connections



Hidden kerf plates

119

Chapter 16 – Fire Design - CLT

New

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

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

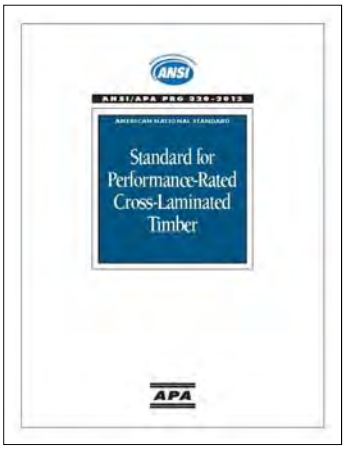
$$t_{gi} = \left(\frac{h_{lam}}{\beta_n}\right)^{1.23}$$

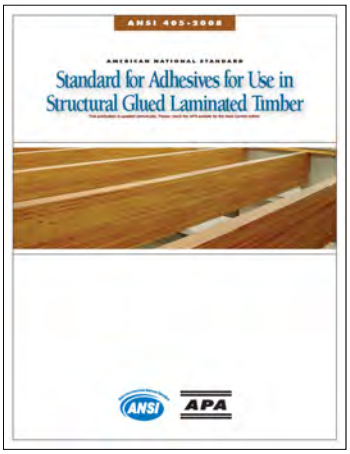
Table 16.2.1B Effective Char Depths (for CLT with β_n=1.5in./hr.)

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

120

GLT and CLT Adhesives

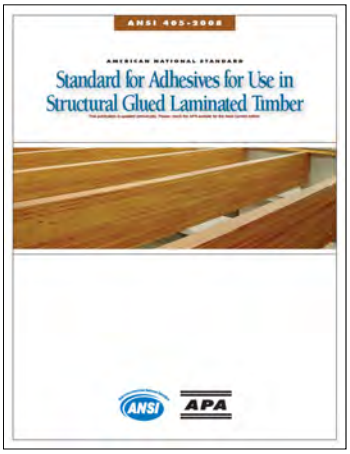




CLT- ANSI/APA PRG 320-2011 references ANSI/AITC 405-2008
GLT- ANSI/AITC 405-2008 – references D7247

121

GLT and CLT Adhesives



CLT-ANSI/APA PRG 320-2012 references ANSI/APA 405-2008
GLT - ANSI/APA 405-2008 – references D7247

122

TREET - Bergen, Norway

Under Construction
14 story
Architect: Artec
Structural Engineer: Sweco

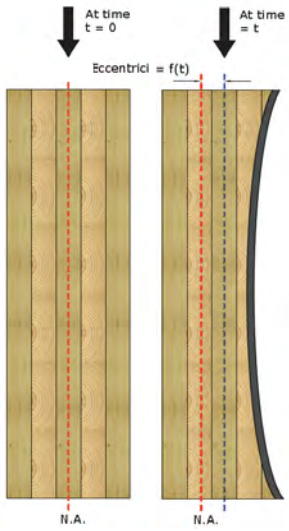
123

TREET - Bergen, Norway

124

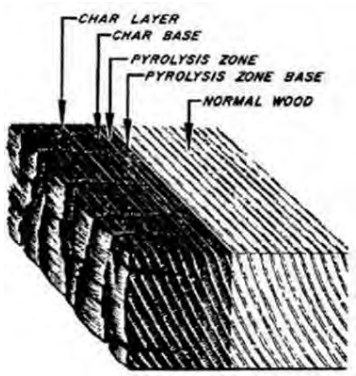
Calculated Fire Resistance?

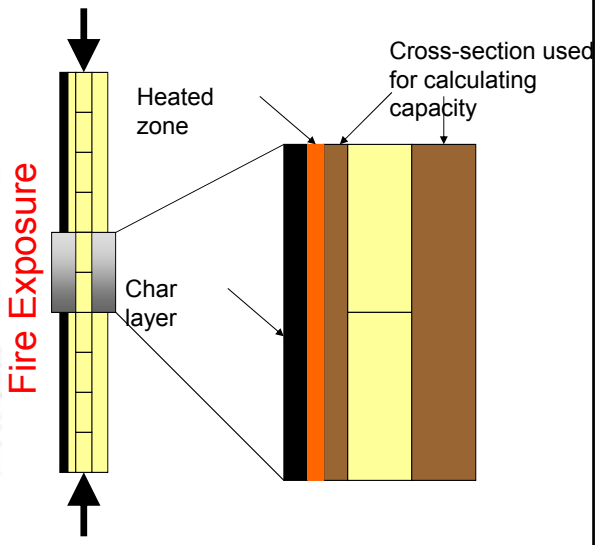
- Chapter 16 NDS
  - Charring Rate and Char Depth
- Modified char depth model
  - Step-wise approach



125

Fire Performance

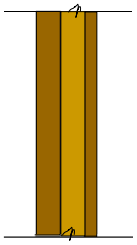




126

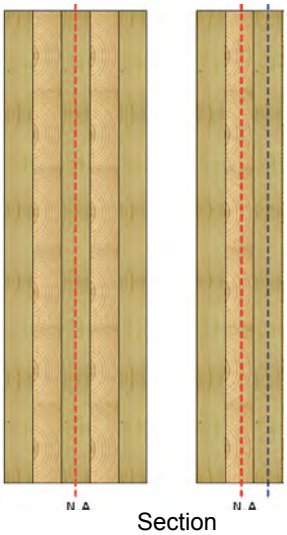
Calculated Fire Resistance?

- **Net section properties**



Typical one foot section

Plan



Section

127

Polling Question

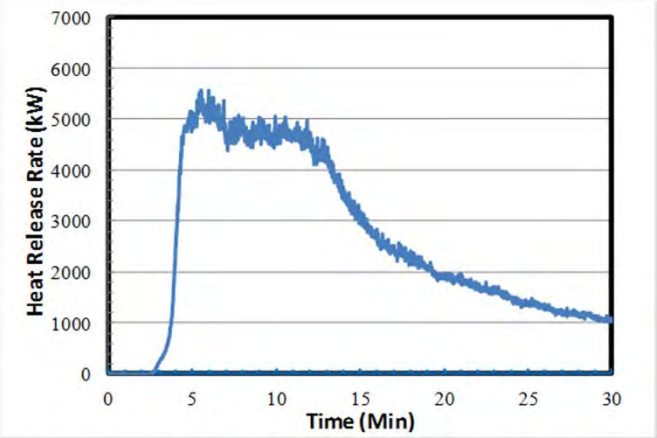
5. **The calculated fire resistance in NDS Chapter 16 may be used to determine the fire resistance of exposed nail-laminated timber**
   a) True
   b) False

128

Recent Demonstration Fire Tests

129

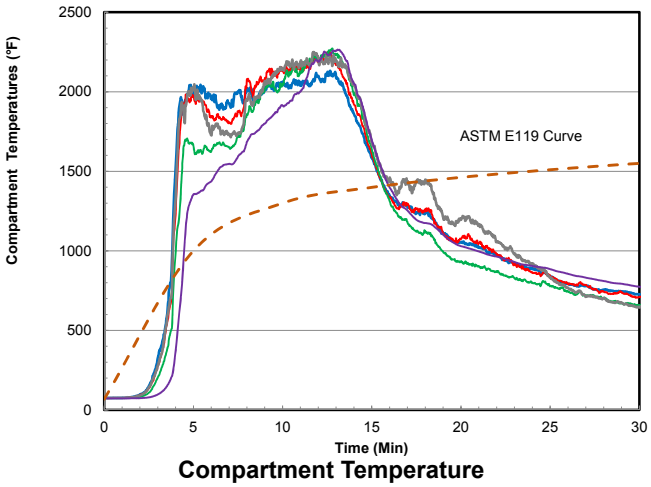
Recent Demonstration Fire Tests



Heat Release Rate

130

Recent Demonstration Fire Tests



Compartment Temperature

A complete report and video presentation are available at: http://awc.org/Code-Officials/2015-IBC-Code-Changes

131

Recent Demonstration Fire Tests

Room after 60 minutes

Room after drywall removed following the three-hour test

132

CLT Test

133

Chapter 16 – Fire (ASD)

Code Updates - Design of Fire-Resistive Exposed Wood Members

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

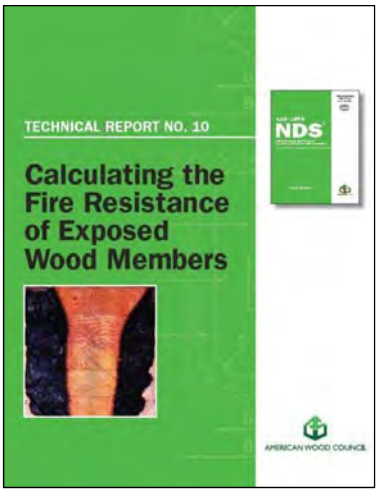
134

Chapter 16 – Fire (ASD)

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



135

Pedestrian Bridge, Burnaby, B.C.

Pedestrian Bridge, Burnaby, BC, Canada
Architect: Perkins+Will
Engineer: Fast+Epp
Photo Credit: Stephan Pasche

Pedestrian Bridge, Burnaby, B.C.

137

The Cathedral of Christ the Light Oakland, CA

Design Team: Skidmore Owings & Merrill, Craig W. Harman
Webcore Builders
GLT Manf: Western Wood Structures
Photo Credit: Timothy Hursley, Cesar Rubio, and John Blaustein,

138

The Cathedral of Christ the Light Oakland, CA

139

The Cathedral of Christ the Light
Oakland, CA

140

Tsingtao Pearl Visitor Centre
Qingdao, China

Resource: StructureCraft

General Contractor: **StructureCraft, SKF**
Location: **Qingdao, China**
Design Build: **StructureCraft**
Completion: **2012**

141

Tsingtao Pearl Visitor Centre
Qingdao, China




Resource: StructureCraft

142

Tsingtao Pearl Visitor Centre
Qingdao, China

Resource: StructureCraft

143

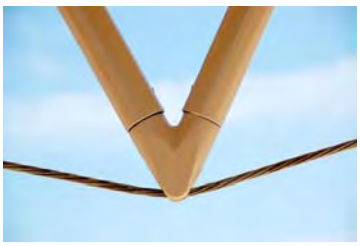
Samuel Bridghouse Elementary School

Resource: StructureCraft

General Contractor: **EllisDon**
Location: **Richmond, British Columbia, Canada**
Design Assist, Fabrication and Installation: **StructureCraft**
Completion: **2010**

144

Samuel Bridghouse Elementary School



Resource: StructureCraft

Design Team: Perkins + Will Canada, Fast + Epp
Photo Credit: Stephan Pasche

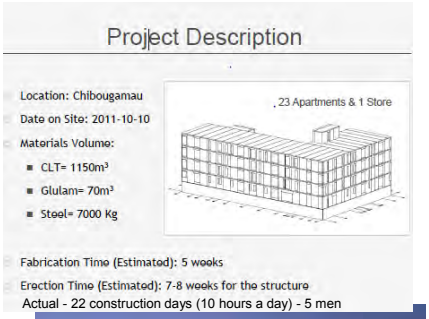
145

Samuel Bridghouse Elementary School

Design Team: Perkins + Will Canada, Fast + Epp
Photo Credit: Stephan Pasche
Resource: StructureCraft

146

Condominiums, Chibougamau, Quebec



Architect: ABCP Architecture

Source: Nordic Engineered Wood

147

Franklin Elementary School




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

Source: LignaTerra

148

Franklin Elementary School


Source: LignaTerra

Scheduled completion date: Winter 2015

149

Questions?

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info@awc.org

155