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

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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.

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.
Polling Question

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

Outline

- Overview & Building Code Allowances
- Nail-laminated Timber
- Glued-laminated Timber
- Cross-laminated Timber
- Fire
Traditional Stick Framed Construction

Simpson Strong-Tie Demo Lab
Cal Poly, San Luis Obispo, CA
Raleigh Durham Airport, North Carolina

Pedestrian Bridge - 105 ft. Span
Warner Drive – Culver City, CA

- Type V Construction
- Assembly & Business Occupancy

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

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
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
The Story of Wood – Wood Carbon Cycle
Climate Change: The Role of CO₂

2,400 sf home = 32 m³ structural wood = 29 metric tons CO₂ = 5.7 passenger annual emissions

Source: FP Innovations

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
Forte’, Melbourne

10 stories

CRADLE TO SITE SAVINGS OF CLT

TONNES CO₂

Concrete
Steel
Cladding
Site

Forte will have positively affected the environment by:
- Storing (equivalent) 761 tonnes CO₂ eq or an advantage of 1,463 tonnes CO₂ eq over concrete and steel construction
- Equivalent to planting 345 trees off the road for a year
- Saving 7,7 GJ of water
- Lowering water consumption (the supply of access (nutrients to the water system)) by 75%
- In addition, the wetted design and efficient systems of the building could save on average over $300 per year on energy and water bills.

Scale: 10 floors, 23 apartments
Build Period:
Start on site: February 2012
Sign CLT installation: June 2012
CLT structure complete: Aug 2012
Practical completion: December 2012
Architect: Land Use
CLT supplier: K2H

Forte’, Melbourne

10 stories, 23 apartments

https://youtu.be/pHpthNBiYqE
Building Code

Where is GLT Allowed in IBC 2015?

- 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.

LeMay – America’s Auto Museum
Tacoma, WA
Where is NLT Allowed in IBC 2015?

- 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.

Where is GLT Allowed in IBC 2015?

TABLE 601

FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (HOURS)

<table>
<thead>
<tr>
<th>BUILDING ELEMENT</th>
<th>TYPE I</th>
<th>TYPE II</th>
<th>TYPE III</th>
<th>TYPE IV</th>
<th>TYPE V</th>
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<td>B</td>
<td>A</td>
<td>B</td>
<td>H</td>
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<tr>
<td>Interior</td>
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<td>1 1/2</td>
<td>1 1/2</td>
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<td>1</td>
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</tbody>
</table>

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

b. Except in Group F-1, H-1, 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-resistant-rated wood members shall be allowed to be cut with saws or with other cutting tools if the cut member remains in position and is not supported by any other member which is required to be fire-resistant rated.

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 in other Sections of this Code.

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

f. For SI: 1 foot = 304.8 mm.
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**

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Fire Tests

[Fire Test Report Images]

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

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.
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.

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…
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.

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.
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

Possibilities for CLT?

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

Table 504.4
Allowable Number of Stories Above Grade Plane
### Table 506.2
Allowable Area Factor In Square Feet

<table>
<thead>
<tr>
<th>Occupancy Classification</th>
<th>SEE Footnote</th>
<th>TYPE I</th>
<th>TYPE II</th>
<th>TYPE III</th>
<th>TYPE IV</th>
<th>TYPE V</th>
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<td>70,000</td>
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</tbody>
</table>

Example

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
Governing Codes for Wood Design

2015 IBC references in 2015 NDS

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
2015 NDS

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

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

Resource: StructureCraft
What is Nail-Laminated Timber?

**Mechanically laminated decking.** Mechanically laminated decking shall comply with Sections 2304.8.3.1 through 2304.8.3.3.

**General.** Mechanically laminated decking consists of square-edged dimension lumber laminations set on edge and nailed to the adjacent pieces and to the supports.

**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.

**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.
Nail-Laminated Timber

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

Resource: StructureCraft

Nail-Laminated Timber

Resource: StructureCraft
Nail-Laminated Timber

Surrey Christian School
20,000 sqft
KMBR Architects

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

Resource: StructureCraft

Nail-Laminated Timber

Resource: StructureCraft
Nail-Laminated Timber

Outline

- Overview & Building Code Allowances
- Nail-laminated Timber
- Glued-laminated Timber
- Cross-laminated Timber
- Fire
What is Glulam?

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

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
Glulam = One of the Original Engineered Wood Composites

- Lumber Laminations
- Glue Lines
- Natural Characteristics
- End Joint

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
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

Glulam Manufacturing - Engineered Layups

Unbalanced Simple Spans

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<tr>
<th>TOP</th>
<th>No. 2D</th>
<th>No. 2</th>
<th>No. 3</th>
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<tr>
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Engineered Layups

<table>
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<th>Balanced Continuous Spans or Cantilevered</th>
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<tr>
<td>TL</td>
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<tr>
<td>No. 1</td>
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<tr>
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</tr>
<tr>
<td>No. 2</td>
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<tr>
<td>No. 1</td>
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</tbody>
</table>

TL = Tension Lamination
Glulam Manufacturing - Engineered Layups

Simple Span - Unbalanced Layup

Cantilever or Continuous Span
Note the “TOP” Stamp – for Unbalanced Layup

Single-Grade Layup

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

<table>
<thead>
<tr>
<th>Glulam layup</th>
<th>Axial stress distribution</th>
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<tbody>
<tr>
<td>L2</td>
<td>Tension or Compression</td>
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Single Grade Layup
Single-Grade Layup

Glulam truss chords and webs

Glulam columns

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.
Polling Question

3. The Glued-laminated timber layups can be:
   a) Balanced
   b) Unbalanced
   c) Single grade
   d) All of the above
Glulam Design: 2015 NDS

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

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
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 G.3 for a comprehensive description of design value adjustment factors.)

Use with Table 5A Adjustment Factors

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</tbody>
</table>

Preservative Treatment of Glulam

Preservative forced into wood cells under pressure

Untreated glulam in pressure cylinder ready for treatment
Preservative Treatment of Glulam

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

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
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

Alaska Yellow Cedar
Santa Monica, CA Reservoir Cover
Outline

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

---

Concept of Cross-Laminated Timber

Photos provided by FPInnovations
CLT Layup, Press and Glue

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

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 10 – Cross-Laminated Timber

New

10.1 General
10.1.1 Application
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
10.1.4 Specification

Panel thickness: 20” max
In-Service MC: 16%

Laminations: 5/8”-2” sawn lumber or SCL

Graphics provided by FPInnovations
Chapter 10 – Cross-Laminated Timber

10.2 Reference Design Values

10.2.1 Reference Design Values

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 lumber used in the manufacturing process.

10.3 Adjustment of Reference Design Values

10.3.1 General

Reference design values: $f_u(G_{ld})$, $f_y(A_{pmd})$, $f_y(\theta)$, $f_{v\phi}(A)$, $f_{v\phi}(\theta)$, $f_{v\phi}(A_{pmd})$, and $f_{v\phi}(\theta)$ provided in 10.2 shall be multiplied by the adjustment factors specified in Table 10.3.1 to determine adjusted design values: $f_u(G_{ld})$, $f_y(A_{pmd})$, $f_y(\theta)$, $f_{v\phi}(A)$, $f_{v\phi}(\theta)$, $f_{v\phi}(A_{pmd})$, and $f_{v\phi}(\theta)$.

10.3.2 Load Duration Factor, $C_D$ (ASD only)

All reference design values except stiffness, $E_{A_{pmd}}$, $E_{A_{pmd}}$, rolling shear, $f_{v\phi}(A)$, and compression perpendicular to grain, $f_u(A)$, shall be multiplied by load duration factors, $C_D$, as specified in 2.3.2.

CLT Manufacturing Standard

TABLE 1
REQUATH CHARACTERISTIC TEST VALUES FOR PRG 320 CLT

<table>
<thead>
<tr>
<th>CLT Grades</th>
<th>$f_u$ (ksi)</th>
<th>$E_a$ (10^3 ksi)</th>
<th>$f_c$ (ksi)</th>
<th>$f_y$ (ksi)</th>
<th>$f_v$ (ksi)</th>
<th>$f_o$ (ksi)</th>
<th>$f_{v\phi}$ (ksi)</th>
<th>$f_{v\phi}$ (ksi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1</td>
<td>4,095</td>
<td>1.7</td>
<td>2,885</td>
<td>3,420</td>
<td>425</td>
<td>140</td>
<td>1,050</td>
<td>1,250</td>
</tr>
<tr>
<td>E2</td>
<td>3,465</td>
<td>1.5</td>
<td>2,140</td>
<td>3,230</td>
<td>565</td>
<td>190</td>
<td>1,100</td>
<td>1,650</td>
</tr>
<tr>
<td>E3</td>
<td>2,520</td>
<td>1.2</td>
<td>1,260</td>
<td>2,660</td>
<td>345</td>
<td>115</td>
<td>735</td>
<td>345</td>
</tr>
<tr>
<td>E4</td>
<td>4,095</td>
<td>1.7</td>
<td>2,885</td>
<td>3,420</td>
<td>550</td>
<td>180</td>
<td>1,205</td>
<td>1,550</td>
</tr>
<tr>
<td>V1</td>
<td>1,890</td>
<td>1.6</td>
<td>1,205</td>
<td>2,565</td>
<td>565</td>
<td>190</td>
<td>1,100</td>
<td>1,650</td>
</tr>
<tr>
<td>V2</td>
<td>1,835</td>
<td>1.6</td>
<td>945</td>
<td>2,185</td>
<td>425</td>
<td>140</td>
<td>1,050</td>
<td>1,250</td>
</tr>
<tr>
<td>V3</td>
<td>2,015</td>
<td>1.6</td>
<td>1,155</td>
<td>2,755</td>
<td>550</td>
<td>180</td>
<td>1,205</td>
<td>1,550</td>
</tr>
</tbody>
</table>

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CLT Manufacturing Standard

**Table A1: Allowable Design Properties**

<table>
<thead>
<tr>
<th>CLT Grades</th>
<th>$F_{u0}$ (psi)</th>
<th>$F_{c0}$ (ksi)</th>
<th>$F_{c2}$ (ksi)</th>
<th>$F_{u2}$ (ksi)</th>
<th>$F_{w0}$ (ksi)</th>
<th>$F_{w2}$ (ksi)</th>
<th>$F_{w2}$ (ksi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1</td>
<td>1,950</td>
<td>1.7</td>
<td>1.375</td>
<td>1.800</td>
<td>135</td>
<td>45</td>
<td>500</td>
</tr>
<tr>
<td>E2</td>
<td>1,850</td>
<td>1.5</td>
<td>1.020</td>
<td>1.700</td>
<td>180</td>
<td>60</td>
<td>525</td>
</tr>
<tr>
<td>E3</td>
<td>1,200</td>
<td>1.2</td>
<td>0.600</td>
<td>1.400</td>
<td>110</td>
<td>35</td>
<td>330</td>
</tr>
<tr>
<td>E4</td>
<td>1,050</td>
<td>1.7</td>
<td>1.375</td>
<td>1.800</td>
<td>175</td>
<td>55</td>
<td>575</td>
</tr>
<tr>
<td>V1</td>
<td>900</td>
<td>1.6</td>
<td>0.750</td>
<td>1.350</td>
<td>180</td>
<td>60</td>
<td>525</td>
</tr>
<tr>
<td>V2</td>
<td>875</td>
<td>1.4</td>
<td>0.450</td>
<td>1.150</td>
<td>135</td>
<td>45</td>
<td>500</td>
</tr>
<tr>
<td>V3</td>
<td>975</td>
<td>1.6</td>
<td>0.550</td>
<td>1.450</td>
<td>175</td>
<td>55</td>
<td>575</td>
</tr>
</tbody>
</table>

Note: $\psi = 3,000$ ksi

(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

---

CLT Manufacturing Standard

**CLT Layups:**

- **E1:** 1950-1.7E Spruce-pine-fir MSR lumber in all parallel layers and No. 3 Spruce-pine-fir lumber in all perpendicular layers
- **E2:** 1650-1.5E Douglas fir-Larch MSR lumber in all parallel layers and No. 3 Douglas fir-Larch lumber in all perpendicular layers
- **E3:** 1200-1.2E 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:** 1950-4.7E 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. 2 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
Chapter 10 - Cross-Laminated Timber
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’)

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
Outline

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

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
Fire Performance Glulam vs. Steel

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

Fire Performance of Wood vs. Steel

http://www.aitc-glulam.org/shopcart/Pdf/superior%20fire%20resistance.pdf
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 calculation. 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 6216. The calculated fire resistance of steel assemblies shall be permitted in accordance with Chapter 5 of ASCE 3. The calculated fire resistance of exposed wood members and wood decking shall be permitted in accordance with Chapter 10 of ANSI/ABAA National Design Specification for Wood Construction (NDS).

2015 NDS Methodology

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

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

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
Typical Glulam Beam Layup

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

  - 2 - L2 Dense Grade Outer Comp. Lams
  - 1 - L2 Grade Inner Comp. Lam
  - 6 - L3 Grade Core Lams
  - 1 - L2 Grade Inner Ten. Lam
  - 1 - L1 Grade Outer Tension Lams
  - 1 - 302-24 Outer Tension Lams

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

Tension Lam Provisions

Fire Protection
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)

Connections

Concealed beam-to-girder connection

Source: AITC Technical Note 7
Connections

Covered column connection

Beam-to-column
(Protection provided by membrane)

Concealed beam-to-column

Source: AITC Technical Note 7
Connections

Beam-to-column (Steel has protective coating)

Glulam supporting one hour rated ceiling

Hidden kerf plates

Source: AITC Technical Note 7
Chapter 16 – Fire Design - CLT

16.2.1.3 For cross-laminated timber, the effective char depth, \( d_{\text{char}} \), shall be calculated as follows:

\[
d_{\text{char}} = 1.2 \left[ \frac{n_{\text{min}} \cdot t_{\text{char}} + \beta_i \left( t - (n_{\text{min}} \cdot t_{\text{char}}) \right)^{0.813}}{\beta_i} \right]^{0.29}
\]

Table 16.2.1B Effective Char Depths (for CLT with \( t_{\text{char}}=1.5\text{in.}/\text{hr.} \))

<table>
<thead>
<tr>
<th>Required Fire Endurance (hr.)</th>
<th>Effective Char Depths, ( d_{\text{char}} ) (in.):</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum Thickness, ( t_{\text{char}} ) (in.)</td>
</tr>
<tr>
<td>2-Hour</td>
<td>1.8, 1.8</td>
</tr>
<tr>
<td>1-Hour</td>
<td>2.2, 2.2</td>
</tr>
<tr>
<td>1/2-Hour</td>
<td>2.8, 2.8</td>
</tr>
</tbody>
</table>

GLT and CLT Adhesives

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

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

TREET - Bergen, Norway

Under Construction
14 story
Architect: Artec
Structural Engineer: Sweco
Calculated Fire Resistance?

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

- Char layer
- Heated zone
- Cross-section used for calculating capacity

Calculated Fire Resistance?

- Net section properties

Typical one foot section

Plan

Section
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
Recent Demonstration Fire Tests

Heat Release Rate

Compartment Temperature

ASTM E119 Curve

Recent Demonstration Fire Tests

Room after 60 minutes

Room after drywall removed following the three-hour test

CLT Test

Furnished Living Room Fire Tests in Compartments Of CLT and NLT Construction

Marc L. Janssens, Ph.D., FSFPE
Senior Engineer
Southwest Research Institute
6220 Culebra Road, San Antonio, TX
Chapter 16 – Fire (ASD)

Code Updates - Design of Fire-Resistive Exposed Wood Members

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

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
Pedestrian Bridge, Burnaby, B.C.

Pedestrian Bridge, Burnaby, BC, Canada
Architect: Perkins+Will
Engineer: Fast+Ferm
Photo Credit: Stephan Pasche
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,
The Cathedral of Christ the Light
Oakland, CA

Tsingtao Pearl Visitor Centre
Qingdao, China

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

Resource: StructureCraft
Tsingtao Pearl Visitor Centre
Qingdao, China

Resource: StructureCraft
Samuel Bridghouse Elementary School

Resource: StructureCraft

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

Design Team: Perkins + Will Canada, Fast + Epp
Photo Credit: Stephan Pasche
Samuel Bridghouse Elementary School

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

Condominiums, Chibougamau, Quebec

Architect: ABCP Architecture

Project Description

Location: Chibougamau
Date on Site: 2014-10-10
Materials Used:
- CLT - 1150 m²
- Glulam - 70 m²
- Steel - 700 kg

Fabrication Time (Estimated): 3 weeks
Erection Time (Estimated): 7-8 weeks for the structure
Actual - 22 construction days (10 hours a day) - 5 men

Source: Nordic Engineered Wood
Franklin Elementary School

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

Scheduled completion date: Winter 2015

Source: LignaTerra
Questions?

www.awc.org

info@awc.org