Course Description

AWC's National Design Specification (NDS) for Wood Construction 2015 is the dual format Allowable Stress Design (ASD) and Load and Resistance Factor Design (LRFD) document referenced in US building codes and used to design wood structures worldwide. Participants will learn about changes in the 2015 NDS and Supplement relative to previous editions and gain an overview of the standard.

Objectives

Upon completion, participants will be:
1. Able to understand the load and material resistance design process and how it applies to wood structural design.
2. Familiar with the significant changes between the 2012 and 2015 NDS and supplement.
3. Able to identify the similarities and differences with respect to ASD, design values, and behavioral equations.
4. Able to analyze format and content within the 2015 NDS.
Outline

- Overview
- Design Process Overview
- NDS
  - Chapter-by-chapter discussion
  - Changes from previous editions
  - Summary
  - More Info

NDS History

<table>
<thead>
<tr>
<th>Year</th>
<th>Cover Image</th>
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<th>Year</th>
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<td>1997</td>
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<tr>
<td>1973</td>
<td></td>
<td>1997</td>
<td></td>
<td>2015</td>
<td></td>
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</tbody>
</table>
Governing Codes for Wood Design

2015 NDS referenced in 2015 IBC

ANSI Accreditation

• AWC – ANSI-accredited standards developer
• Consensus Body
  • Wood Design Standards Committee
2015 NDS – Primary Change

New Provisions to Address CLT

• Charging Language
• Design Values
• Design Equations
• Product Chapter
• Connection Design
• Fire Design

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
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Design Process

Demand ≤ Capacity
Design Process

- Load
- Support Conditions
- Geometry
- Materials Performance
- Demand
- Capacity
- Fire
- Economics
- Aesthetics

Design Concepts

**Two Limit State concerns**

- Serviceability (performance in-service)
- Safety against failure or collapse
Serviceability

- ASD and LRFD
  - Unfactored loads
  - Mean (avg) material strength values

Safety

- ASD
  - Unfactored loads
  - Material strength values - modified

- LRFD
  - Factored loads
  - Material strength values – modified less
Structural Property Variability

Normal Distribution Curves

- $\mu = \text{mean}$
- $\sigma = \text{standard deviation}$
- $\text{COV} = \frac{\sigma}{\mu}$
- Coefficient of variation

Material Property Values

Engineered Wood Design

- $S > R$
- Failure

Figure 2: Sample distributions of load (S) and resistance (R)
LRFD vs ASD

ASD
• applied stress ≤ allowable stress

Theoretical safety margin applied to material stresses

Tested material strength

Design values

LRFD vs ASD

LRFD
• factored load ≤ factored resistance

Member performance factor

Tested member resistance

Design values
2015 NDS

LRFD Basic Load Combinations *ASCE 7-10*

1.4D
1.2D + 1.6L + 0.5(L_r or S or R)

1.2D + 1.6(L_r or S or R) + (L or 0.8W)
1.2D + 1.0W + L + 0.5(L_r or S or R)
1.2D + 1.0E + L + 0.2S
0.9D + 1.0W
0.9D + 1.0E

---

2015 NDS

ASD Basic Load Combinations *ASCE 7-10*

1. \( D \)
2. \( D + L \)
3. \( D + (L_r \text{ or } S \text{ or } R) \)
4. \( D + 0.75L + 0.75(L_r \text{ or } S \text{ or } R) \)
5. \( D + (0.6W \text{ or } 0.7E) \)
6a. \( D + 0.75L + 0.75(0.6W) + 0.75(L_r \text{ or } S \text{ or } R) \)
6b. \( D + 0.75L + 0.75(0.7E) + 0.75S \)
7. \( 0.6D + 0.6W \)
8. \( 0.6D + 0.7E \)
2005 NDS & ASCE 7-02

LRFD vs. ASD Load Combinations

LRFD versus ASD for Wood Design
Load Combinations Lead to Efficiencies

John "Sal" Shimer, P.E. and Robert L. Taylor, Ph.D., P.E.

Introduction

Load and resistance factor design (LRFD) for wood was recently incorporated into the new 2005 National Design Specification (NDS) for Wood Construction. As a comparison to the 2001 version of the NDS, the American Wood Council (AWC) revised the Wood Design Loads for the 2005 Wood Design Load Data for the 2005 Wood Design Load Data and the 2005 Wood Design Load Data for the 2005 Wood Design Load Data. The ASCE 7-02 Commentary (ACI 7-02) and LRFD Load Combinations (ACI 7-02) are consistent load combinations. The consistent load combinations are consistent with the 2005 NDS. The consistent load combinations are consistent with the 2005 NDS. The consistent load combinations are consistent with the 2005 NDS.

Load Combinations

LRFD

\[ R_N = \phi \lambda K_F R_{ASD} \]

ASD

\[ R_N = C_D R_{ASD} \]

Format Conversion Factor \( K_F \)

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2015 NDS

Table 2.3.6 Resistance Factor, \( \phi \) (LRFD Only)

<table>
<thead>
<tr>
<th>Application</th>
<th>Property</th>
<th>Symbol</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Member</td>
<td>( F_b )</td>
<td>( \phi_b )</td>
<td>0.85</td>
</tr>
<tr>
<td></td>
<td>( F_t )</td>
<td>( \phi_t )</td>
<td>0.80</td>
</tr>
<tr>
<td></td>
<td>( F_v, F_{in}, F_s )</td>
<td>( \phi_v )</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td>( F_c, F_{ed} )</td>
<td>( \phi_c )</td>
<td>0.90</td>
</tr>
<tr>
<td></td>
<td>( F_{mm} )</td>
<td>( \phi_{mm} )</td>
<td>0.85</td>
</tr>
<tr>
<td>All Connections</td>
<td>(all design values)</td>
<td>( \phi_d )</td>
<td>0.65</td>
</tr>
</tbody>
</table>

Reliability indices or data confidence factors

2015 NDS

\( \lambda \) tied to ASCE 7 Factored Loads
- Baseline 10 min (ASD uses 10 yrs)

Table N3 Time Effect Factor, \( \lambda \) (LRFD Only)

<table>
<thead>
<tr>
<th>Load Combination(^{1})</th>
<th>( \lambda )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.4D</td>
<td>Permanente ( \rightarrow 0.6 )</td>
</tr>
<tr>
<td>1.2D + 1.6L + 0.5(L or S or R)</td>
<td>0.7 when L is from storage</td>
</tr>
<tr>
<td></td>
<td>0.8 when L is from occupancy</td>
</tr>
<tr>
<td></td>
<td>1.25 when L is from impact(^{2})</td>
</tr>
<tr>
<td>1.2D + 1.0W + L + 0.5(L or S or R)</td>
<td>Long term ( \rightarrow 1.0 )</td>
</tr>
<tr>
<td>1.2D + 1.0E + L + 0.2S</td>
<td>Short term ( \rightarrow 1.0 )</td>
</tr>
<tr>
<td>0.9D + 1.0W</td>
<td></td>
</tr>
<tr>
<td>0.9D + 1.0E</td>
<td></td>
</tr>
</tbody>
</table>

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Table 2.3.5 Format Conversion Factor, $K_F$ (LRFD Only)

<table>
<thead>
<tr>
<th>Application</th>
<th>Property</th>
<th>$K_F$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Member</td>
<td>$F_b$</td>
<td>2.54</td>
</tr>
<tr>
<td></td>
<td>$F_t$</td>
<td>2.70</td>
</tr>
<tr>
<td></td>
<td>$F_{s}$</td>
<td>2.88</td>
</tr>
<tr>
<td></td>
<td>$F_{s1}$</td>
<td>2.40</td>
</tr>
<tr>
<td></td>
<td>$F_{cl}$</td>
<td>1.67</td>
</tr>
<tr>
<td></td>
<td>$E_{min}$</td>
<td>1.76</td>
</tr>
<tr>
<td>All Connections</td>
<td>(all design values)</td>
<td>3.32</td>
</tr>
</tbody>
</table>

$$R_N = \phi \lambda K_F R_{ASD}$$

$K_F$ converts reference design values (ASD normal load duration) to LRFD reference resistance

Outline

- Overview
- Design Process Overview
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NDS 2015 Chapters

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 2015 Appendices

A. Construction and Design Practices
B. Load Duration (ASD Only)
C. Temperature Effects
D. Lateral Stability of Beams
E. Local Stresses in Fastener Groups
F. Design for Creep and Critical Deflection
   Applications
G. Effective Column Length
H. Lateral Stability of Columns
I. Yield Limit Equations for Connections
J. Solution of Hankinson Equation
K. Typical Dimensions for Split Ring and Shear
   Plate Connectors
L. Typical Dimensions for Standard Hex Bolts,
   Hex Lag Screws, Wood Screws, Common,
   Box, and Sinker Nails
M. Manufacturing Tolerances for Rivets and Steel
   Side Plates for Timber Rivet Connections
N. Appendix for Load and Resistance Factor
   Design (LRFD) – Mandatory

NDS – Chapter 1

GENERAL REQUIREMENTS FOR STRUCTURAL DESIGN

1. Scope
2. General Requirements
4. Design Procedure
5. Specific Stress and Plate
6. Resistance
Chapter 1 - Terminology

\[ f_b \leq F_b' \]

*Reference* design values \((F_b, F_t, F_v, F_c, F_{cL}, E, E_{min})\)

*Adjusted* design values \((F_b', F_t', F_v', F_c', F_{cL}', E', E_{min}')\)

Chapter 1 - Design Loads

- Reference loads
- Minimum load standards
- ASCE 7 - 10
Chapter 1 – CLT Charging Language

1.1 Scope

1.1.1 Practice Defined

1.1.1.1 This Specification defines the methods to be followed in structural design with the following wood products:
- visually graded lumber
- mechanically graded lumber
- structural glued laminated timber
- timber poles
- timber poles
- prefabricated wood I-joists
- structural composite lumber
- wood structural panels
- cross-laminated timber

It also defines the practice to be followed in the design and fabrication of single and multiple fastener connections using the fasteners described herein.

1.1.1.2 Structural assemblies utilizing panel products shall be designed in accordance with provisions of 11.1.3 Structural assemblies utilizing metal connector plates shall be designed in accordance with accepted engineering practice (see Reference 9).

1.1.4 Shear walls and diaphragms shall be designed in accordance with the Special Design Provisions for Wood and Composite Structures (see Reference 50).

1.1.5 This Specification is not intended to preclude the use of materials, assemblies, structures, or designs not meeting the criteria herein, where it is demonstrated by analysis based on recognized theory, full-scale or prototype loading tests, exhaustive testing, or extensive experience in use that the assembly, structure, or design will perform in its intended end use.

1.1.2 Competent Supervision

The design values, design factors, and strength values must be determined by a qualified design professional.
Chapter 2 – Adjustment Factors

Table 2.3.6 Resistance Factor, $\phi$ (LRFD Only)

<table>
<thead>
<tr>
<th>Application</th>
<th>Property</th>
<th>Symbol</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Member</td>
<td>$F_b$</td>
<td>$\phi_b$</td>
<td>0.85</td>
</tr>
<tr>
<td></td>
<td>$F_t$</td>
<td>$\phi_t$</td>
<td>0.80</td>
</tr>
<tr>
<td></td>
<td>$F_v, F_m, F_s$</td>
<td>$\phi_v$</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td>$F_c, F_{cl}$</td>
<td>$\phi_c$</td>
<td>0.90</td>
</tr>
<tr>
<td></td>
<td>$E_{mm}$</td>
<td>$\phi_{E_{mm}}$</td>
<td>0.85</td>
</tr>
<tr>
<td>All Connections</td>
<td>(all design values)</td>
<td>$\phi_2$</td>
<td>0.65</td>
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</table>

Reliability indices or data confidence factors

Chapter 2 – Adjustment Factors

Table 2.3.5 Format Conversion Factor, $K_F$ (LRFD Only)

<table>
<thead>
<tr>
<th>Application</th>
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</tr>
<tr>
<td></td>
<td>$F_t$</td>
<td>2.70</td>
</tr>
<tr>
<td></td>
<td>$F_v, F_m, F_s$</td>
<td>2.88</td>
</tr>
<tr>
<td></td>
<td>$F_c$</td>
<td>2.40</td>
</tr>
<tr>
<td></td>
<td>$F_{cl}$</td>
<td>1.67</td>
</tr>
<tr>
<td></td>
<td>$E_{min}$</td>
<td>1.76</td>
</tr>
<tr>
<td>All Connections</td>
<td>(all design values)</td>
<td>3.32</td>
</tr>
</tbody>
</table>

$$R_N = \phi \lambda K_F R_{ASD}$$

$K_F$ converts reference design values (ASD normal load duration) to LRFD reference resistance
Appendix N – Adjustment Factors

λ tied to ASCE 7 Factored Loads: Baseline 10 minutes (ASD uses 10 years)

<table>
<thead>
<tr>
<th>Load Combination</th>
<th>λ</th>
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<tbody>
<tr>
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<td>1.2D + 1.6L + 0.5(L, or S or R)</td>
<td></td>
</tr>
<tr>
<td>1.2D + 1.6(L, or S or R) + (L or 0.8W)</td>
<td></td>
</tr>
<tr>
<td>1.2D + 1.0W + L + 0.5(L, or S or R)</td>
<td></td>
</tr>
<tr>
<td>1.2D + 1.0E + L + 0.2S</td>
<td></td>
</tr>
<tr>
<td>0.9D + 1.0W</td>
<td></td>
</tr>
<tr>
<td>0.9D + 1.0E</td>
<td></td>
</tr>
</tbody>
</table>

Permanent → 0.6
0.7 when L is from storage
0.8 when L is from occupancy
1.25 when L is from impact

Long term → 0.8

Short term →

1.0
1.0
1.0
1.0

Chapter 2 – Adjustment Factors

Adjusts from reference to site conditions

• C_D time-dependent

<table>
<thead>
<tr>
<th>Load Duration</th>
<th>C_D</th>
<th>Typical Design Loads</th>
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<tbody>
<tr>
<td>Permanent</td>
<td>0.9</td>
<td>Dead Load</td>
</tr>
<tr>
<td>Ten years</td>
<td>1.0</td>
<td>Occupancy Live Load</td>
</tr>
<tr>
<td>Two months</td>
<td>1.15</td>
<td>Snow Load</td>
</tr>
<tr>
<td>Seven days</td>
<td>1.25</td>
<td>Construction Load</td>
</tr>
<tr>
<td>Ten minutes</td>
<td>1.6</td>
<td>Wind/Earthquake Load</td>
</tr>
<tr>
<td>Impact^</td>
<td>2.0</td>
<td>Impact Load</td>
</tr>
</tbody>
</table>
Chapter 2 – Adjustment Factors

Adjusts from reference to site conditions

- \( C_t \) temperature

<table>
<thead>
<tr>
<th>Reference Design Values</th>
<th>In-Service Moisture Conditions</th>
<th>( C_t )</th>
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</thead>
<tbody>
<tr>
<td>( F_h, F_s, F_{min} )</td>
<td>Wet or Dry</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Dry</td>
<td>1.0</td>
</tr>
<tr>
<td>( F_h, F_s, F_c, \text{ and } F_{ci} )</td>
<td>Wet</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Exposed for “sustained” period

Chapter 2 – Adjustment Factors

Adjusts from reference to site conditions

- \( C_M \) wet service factor
Wet Service Conditions

Wet Service Conditions

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**Wet Service Factor, $C_M$**

- Sawn lumber MC $\leq 19\%$ considered dry
- Otherwise, NDS Supplement for lumber

**Wet Service Factors, $C_M$**

<table>
<thead>
<tr>
<th></th>
<th>$F_b$</th>
<th>$F_t$</th>
<th>$F_v$</th>
<th>$F_{c,\perp}$</th>
<th>$F_c$</th>
<th>$E$ and $E_{\min}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.85*</td>
<td>1.0</td>
<td>0.97</td>
<td>0.67</td>
<td>0.8**</td>
<td>0.9</td>
</tr>
</tbody>
</table>

* when $(F_b)(C_p) \leq 1.150$ psi, $C_M = 1.0$
** when $(F_t)(C_p) \leq 750$ psi, $C_M = 1.0$

---

**Chapter 2 – CLT Design Values**

### 2.2 Reference Design Values

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

### 2.3 Adjustment of Reference Design Values

#### 2.3.1 Applicability of Adjustment Factors

Reference design values shall be multiplied by all applicable adjustment factors to determine adjusted design values. The applicability of adjustment factors to sawn lumber, structural glued laminated timber, poles and piles, prefabricated wood I-joists, structural composite lumber, wood structural panels, cross-laminated timber, and connection design values is defined in 1.1.1.1.

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Chapter 3 – Behavioral Equations

ASD vs LRFD – adjusted stresses from reference

- **ASD** \( F'_{n} = F_{n} C_{D} \times \text{adjustment factors} \)
- **LRFD** \( F'_{n} = F_{n} K_{F} \phi_{n} \lambda \times \text{adjustment factors} \)
Chapter 3 – Behavioral Equations

Beams

- $C_L$ beam stability

$$C_L = \frac{1 + (F_{be}/F_b^*)}{1.9} - \sqrt{\left[1 + \frac{1 + (F_{be}/F_b^*)}{1.9}\right]^2 - \frac{F_{be}/F_b^*}{0.95}} \quad (3.3-6)$$

$F_b^*$ = reference bending design value multiplied by all applicable adjustment factors except $C_L$, $C_p$, and $C_u$ (see 2.3)

$F_{be} = \frac{1.20F_{min}'}{R_g}$ Critical Buckling Design Value for bending members

Columns

- $C_p$ column stability

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

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

$F_{ce} = \frac{0.822F_{min}'}{(\epsilon_e/d)^2}$ Critical Buckling Design Value for compression members
Chapter 3 – Behavioral Equations

\[ E_{\text{min}} = 1.03E(1 - 1.645(COV_E)) / 1.66 \]

- **E** = reference MOE
- **1.03** = adjustment factor to convert E to a pure bending basis (shear-free) (use 1.05 for glulam)
- **1.66** = factor of safety
- **COV_E** = coefficient of variation in MOE (NDS Appendix F)

**OR**

*E_{\text{min}}* values published in NDS Supplement

---

**Chapter 3 – Behavioral Equations**

**Tension members** (tension parallel to grain)

- **ASD** \[ F'_t = F_t \ C_D \ x \ \text{adjustment factors} \]
- **LRFD** \[ F'_t = F_t \ K_F \ \phi_t \ \lambda \ x \ \text{adjustment factors} \]
Chapter 3 – Behavioral Equations

Tension perpendicular to grain

- Not recommended per NDS 3.8.2

Initiators:
- notches
- moment connections
- hanging loads

Chapter 3 – Behavioral Equations

Combined bi-axial bending and axial compression

\[
\frac{f_c}{F_c'} + \frac{f_{b1}}{F_{b1}' \left[ 1 - \left( f_c / F_{cE1} \right) \right]} + \frac{f_{b2}}{F_{b2}' \left[ 1 - \left( f_c / F_{cE2} \right) - \left( f_{b1} / F_{bE} \right)^2 \right]} \leq 1.0 \quad (3.9-3)
\]
Combined bi-axial bending and axial compression

\[
\frac{f_c}{F_{ce2}} + \left( \frac{f_{bt}}{F_{de}} \right)^2 < 1.0
\]  

(3.9-4)

Chapter 3 – Behavioral Equations

Bearing perpendicular to grain

- \( F'_{\text{cL}} = F_{\text{cL}} C_M C_t C_i C_b \) (ASD)
- \( F'_{\text{cL}} = F_{\text{cL}} C_M C_t C_i C_b K_f \phi_c \lambda \) (LRFD)

<table>
<thead>
<tr>
<th>( \ell_b )</th>
<th>0.5&quot;</th>
<th>1&quot;</th>
<th>1.5&quot;</th>
<th>2&quot;</th>
<th>3&quot;</th>
<th>4&quot;</th>
<th>6&quot; or more</th>
</tr>
</thead>
<tbody>
<tr>
<td>( C_b )</td>
<td>1.75</td>
<td>1.38</td>
<td>1.25</td>
<td>1.19</td>
<td>1.13</td>
<td>1.10</td>
<td>1.00</td>
</tr>
</tbody>
</table>
Chapter 3 – CLT Design Equations

3.5 Bending Members – Deflection

3.5.1 Deflection Calculations

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

\[
\Delta = \Delta_e + \Delta_t
\]

(3.5.1)

where:

- \( \Delta_e \) = time dependent deformation (creep) factor
- \( \Delta_t \) = 1.5 for seasoned lumber, structural glued laminated timber, prefabricated wood posts, or structural composite lumber used in dry service conditions as defined in 4.1.4, 5.1.4, 7.1.4, and 8.1.4, respectively.
- \( \Delta_t \) = 2.0 for cross-laminated timber used in dry service conditions as defined in 10.1.5.

New

Chapter 3 – CLT Design Equations

3.1. The column stability factor shall be calculated as follows:

\[
C_p = \frac{1 + (\alpha / R_p)}{7c} - \left[ 1 + \left( \frac{\alpha / R_p}{7c} \right) \right]^\frac{1}{2} - \frac{F_{ed}}{F_p} \quad (3.7-1)
\]

where:

- \( \alpha / R_p \) = reference compression design value parallel to grain multiplied by all applicable adjustment factors except \( C_p \) (see 2.3), psi
- \( F_{ed} = 0.822 \ F_{cp} \quad \left( \frac{\sigma_p}{E_p} \right)^2 \)
- \( c = 0.8 \) for sawn lumber
- \( c = 0.9 \) for structural glued laminated timber, structural composite lumber, and cross-laminated timber

NDS Commentary – guidance on \( C_p \)
Chapter 4 – Lumber

**Design values**

- Visually graded lumber
- MSR / MEL
- Timber
- Decking
Chapter 4 – Lumber

Lumber adjustment factors

- CF - size factor

### Table 4.3.1 Applicability of Adjustment Factors for Sawn Lumber

<table>
<thead>
<tr>
<th>CSF, CF, C1, C2, C3, C4, C5</th>
<th>Load Duration Factor</th>
<th>Wet Service Factor</th>
<th>Basic Service Factor</th>
<th>Snow Load Factor</th>
<th>Basic Wind Factor</th>
<th>Basic Shear Factor</th>
<th>Basic Fire Resistance</th>
<th>Bending Stress Factor</th>
<th>Ultimate Strength Factor</th>
<th>Fatigue Limit Stress</th>
<th>LRFD only</th>
</tr>
</thead>
<tbody>
<tr>
<td>FI = FI</td>
<td>x</td>
<td>C0</td>
<td>C4</td>
<td>C5</td>
<td>C6</td>
<td>C7</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2.54</td>
<td>0.85</td>
</tr>
<tr>
<td>FI = FI</td>
<td>x</td>
<td>C0</td>
<td>C4</td>
<td>C5</td>
<td>C6</td>
<td>C7</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2.70</td>
<td>0.80</td>
</tr>
<tr>
<td>FI = FI</td>
<td>x</td>
<td>C0</td>
<td>C4</td>
<td>C5</td>
<td>C6</td>
<td>C7</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2.88</td>
<td>0.75</td>
</tr>
<tr>
<td>FI = FI</td>
<td>x</td>
<td>C0</td>
<td>C4</td>
<td>C5</td>
<td>C6</td>
<td>C7</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2.40</td>
<td>0.90</td>
</tr>
<tr>
<td>FI = FI</td>
<td>x</td>
<td>C0</td>
<td>C4</td>
<td>C5</td>
<td>C6</td>
<td>C7</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.67</td>
<td>0.90</td>
</tr>
<tr>
<td>FI = FI</td>
<td>x</td>
<td>C0</td>
<td>C4</td>
<td>C5</td>
<td>C6</td>
<td>C7</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>FI = FI</td>
<td>x</td>
<td>C0</td>
<td>C4</td>
<td>C5</td>
<td>C6</td>
<td>C7</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.76</td>
<td>0.85</td>
</tr>
</tbody>
</table>

### Table 4.4.1 Size Factors, CF

<table>
<thead>
<tr>
<th>Grades</th>
<th>Width (depth)</th>
<th>Thickness (breath)</th>
<th>F2</th>
<th>F1</th>
<th>F2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Select</td>
<td>2&quot;, 3&quot;, &amp; 4&quot;</td>
<td>2&quot; &amp; 3&quot;</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>5&quot;</td>
<td>4&quot;</td>
<td>1.4</td>
<td>1.4</td>
<td>1.4</td>
</tr>
<tr>
<td>Structural</td>
<td>6&quot;</td>
<td></td>
<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
</tr>
<tr>
<td>No.1 &amp; Btr,</td>
<td>8&quot;</td>
<td></td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>No.1, No.2,</td>
<td>10&quot;</td>
<td></td>
<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td>No.3</td>
<td>12&quot;</td>
<td></td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>14&quot; &amp; wider</td>
<td></td>
<td>0.9</td>
<td>1.0</td>
<td>0.9</td>
</tr>
</tbody>
</table>
Chapter 4 – Lumber

Lumber adjustment factors

Table 4.3.8 Incising Factors, $C_i$

<table>
<thead>
<tr>
<th>Design Value</th>
<th>$C_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E, E_{\text{min}}$</td>
<td>0.95</td>
</tr>
<tr>
<td>$F_h, F_b, F_c, F_v$</td>
<td>0.80</td>
</tr>
<tr>
<td>$F_p$</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Chapter 4 – Lumber

Lumber adjustment factors

- Repetitive member
- $C_r = 1.15$
- 2” – 4” lumber
- $\leq 24$ o.c.
- 3 or more members
- Load distributing element
Chapter 5 – Glulam

Adjustment factors

<table>
<thead>
<tr>
<th>Table 5.3.1</th>
<th>Applicability of Adjustment Factors for Structural Glued Laminated Timber</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASD only</td>
<td>ASD and LRFD</td>
</tr>
<tr>
<td>Load-resistant factor</td>
<td>Importance of loads</td>
</tr>
<tr>
<td>F_k</td>
<td>C_D</td>
</tr>
<tr>
<td>F_k</td>
<td>C_D</td>
</tr>
<tr>
<td>F_k</td>
<td>C_D</td>
</tr>
<tr>
<td>F_k</td>
<td>C_D</td>
</tr>
<tr>
<td>F_k</td>
<td>C_D</td>
</tr>
<tr>
<td>F_k</td>
<td>C_D</td>
</tr>
<tr>
<td>F_k</td>
<td>C_D</td>
</tr>
<tr>
<td>F_k</td>
<td>C_D</td>
</tr>
<tr>
<td>F_k</td>
<td>C_D</td>
</tr>
<tr>
<td>F_k</td>
<td>C_D</td>
</tr>
<tr>
<td>F_k</td>
<td>C_D</td>
</tr>
<tr>
<td>F_k</td>
<td>C_D</td>
</tr>
</tbody>
</table>

The force exhibited above C_2, shall be applied concurrently with the reduced forces. C_3, for structural load (assessed under review 3.4.2). Therefore, all three of these adjustment factors shall apply.
Chapter 5 – Glulam

- Adjustment factors
  - CV Volume Factor
  - CL Beam Stability Factor
  - Not cumulative with CL
  - Min (CV, CL)

\[ CV = \left( \frac{21}{L} \right)^{1/k} \left( \frac{12}{d} \right)^{1/k} \left( \frac{5.125}{b} \right)^{1/k} \leq 1.0 \]

Table 5.3.1: Applicability of Adjustment Factors for Structural Glued Laminated Timber

<table>
<thead>
<tr>
<th>ASD only</th>
<th>ASD and LRFD</th>
<th>LRFD only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Live Load Pass</td>
<td>Wind Load Pass</td>
<td>Snow Load Pass</td>
</tr>
<tr>
<td>F_L = F_D</td>
<td>C_L</td>
<td>C_M</td>
</tr>
</tbody>
</table>

NDS – Chapter 6

ROUND TIMBER POLES AND PILES

- General
- Reference Design Values
- Adjustment of Reference Design Values

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Chapter 6 – Poles & Piles

- Poles - post-frame
- Piles - foundations

Chapter 6 – Timber Piles

Design values

- NDS Supplement
Chapter 6 – Poles & Piles

Adjustment factors

Table 6.3.1 Applicability of Adjustment Factors for Round Timber Poles and Piles

<table>
<thead>
<tr>
<th></th>
<th>ASD only</th>
<th>ASD and LRFD only</th>
<th>LRFD only</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Load-Related Factor</td>
<td>Temporal Factor</td>
<td>Resistant Factor</td>
</tr>
<tr>
<td></td>
<td>$F_t$ = $F_L$</td>
<td>$C_D$</td>
<td>$C_t$</td>
</tr>
<tr>
<td>$F_L$ = $F_T$</td>
<td>$F_V = F_T$</td>
<td>$C_D$</td>
<td>$C_t$</td>
</tr>
<tr>
<td>$F_V$ = $F_T$</td>
<td>$F_L = F_T$</td>
<td>$C_D$</td>
<td>$C_t$</td>
</tr>
<tr>
<td>$F_T = F_T$</td>
<td>$E = E$</td>
<td>$C_D$</td>
<td>$C_t$</td>
</tr>
<tr>
<td>$E = E$</td>
<td>$E_{total} = E_{total}$</td>
<td>$C_D$</td>
<td>$C_t$</td>
</tr>
</tbody>
</table>

NDS – Chapter 7

Prefabricated Wood I-Joists

General

Reference Design Values

Adjustment of Reference Design Values

Special Design Considerations

Note 1: App. C.4.1.2: Adjustment of Factors for Field Nails (Welded I-Joists)
Chapter 7 – I-joists

- **Design values**
  - M, V, Ei, K - no changes

- **Evaluation Reports**
  - Contain proprietary design

### Adjustment factors

<table>
<thead>
<tr>
<th>Element</th>
<th>ASD only</th>
<th>ASD and LRFD</th>
<th>LRFD only</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M_i = M_k$</td>
<td>$c_D$</td>
<td>$c_M$</td>
<td>$c_L$</td>
</tr>
<tr>
<td>$V_i = V_k$</td>
<td>$c_D$</td>
<td>$c_M$</td>
<td>$c_L$</td>
</tr>
<tr>
<td>$R_i = R_k$</td>
<td>$c_D$</td>
<td>$c_M$</td>
<td>$c_L$</td>
</tr>
<tr>
<td>$EI = EI$</td>
<td>-</td>
<td>$c_M$</td>
<td>$c_L$</td>
</tr>
<tr>
<td>$(EI)<em>{max} = (EI)</em>{max}$</td>
<td>-</td>
<td>$c_M$</td>
<td>$c_L$</td>
</tr>
<tr>
<td>$K = K$</td>
<td>-</td>
<td>$c_M$</td>
<td>$c_L$</td>
</tr>
</tbody>
</table>
Chapter 8 – Structural Composite Lumber

- Design Values
- Evaluation Reports
  - Contain proprietary design
Chapter 8 – Structural Composite Lumber

- New products
  - Laminated Strand Lumber (LSL)
  - Oriented Strand Lumber (OSL)
  - ASTM D5456

- Adjustment factors
  - $C_v$ - volume
    - $C_v \leq 1.0$ Not cumulative with lateral stability factor, $C_L$, then min. ($C_v, C_L$)
    - $C_v > 1.0$ Cumulative with lateral stability factor, $C_L$

<table>
<thead>
<tr>
<th>Table 8.3.1</th>
<th>Applicability of Adjustment Factors for Structural Composite Lumber</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ASD only</td>
</tr>
<tr>
<td></td>
<td>ASD and LRFD</td>
</tr>
<tr>
<td></td>
<td>LRFD only</td>
</tr>
<tr>
<td>$F_{u} - F_{w}$</td>
<td>$x, C_D, C_M, C_L, C_V, C_T, -$</td>
</tr>
</tbody>
</table>
Chapter 8 – Structural Composite Lumber

**Adjustment factors**

- $C_r$ Repetitive Member Factor = 1.04
- $C_r$ is *different* than lumber ($C_r_{\text{lumber}} = 1.15$)
- Applies to $F_b$ only

---

NDS – Chapter 9

---
Chapter 9 – Wood Structural Panels

Design values - obtain from an approved source

- \( F_bS \)
- \( F_{tA} \)
- \( F_vt_v \)
- \( F_s \)
- \( F_{cA} \)
- \( E_{I} \)
- \( EA \)
- \( G_vt_v \)
- \( F_{cL} \)

Chapter 9 – Wood Structural Panels

Adjustment factors

Table 9.3.1  Applicability of Adjustment Factors for Wood Structural Panels

<table>
<thead>
<tr>
<th></th>
<th>ASD only</th>
<th>ASD and LRFD</th>
<th>LRFD only</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial Design Factor</td>
<td>Minimum Factor</td>
<td>Load Factor</td>
</tr>
<tr>
<td>( F_bS = F_{bS} )</td>
<td>( x )</td>
<td>( C_D )</td>
<td>( C_I )</td>
</tr>
<tr>
<td>( F_{tA} = F_{tA} )</td>
<td>( x )</td>
<td>( C_D )</td>
<td>( C_I )</td>
</tr>
<tr>
<td>( F_{cA} = F_{cA} )</td>
<td>( x )</td>
<td>( C_D )</td>
<td>( C_I )</td>
</tr>
<tr>
<td>( F_{tBQ} (F_{tBQ}) = F_{tBQ} (F_{tBQ}) )</td>
<td>( x )</td>
<td>( C_D )</td>
<td>( C_I )</td>
</tr>
<tr>
<td>( F_{cA} = F_{cA} )</td>
<td>( x )</td>
<td>( C_D )</td>
<td>( C_I )</td>
</tr>
<tr>
<td>( F_{cL} = F_{cL} )</td>
<td>( x )</td>
<td>( - )</td>
<td>( C_M )</td>
</tr>
<tr>
<td>( E_{I} = E_{I} )</td>
<td>( x )</td>
<td>( - )</td>
<td>( C_M )</td>
</tr>
<tr>
<td>( E_{A} = E_{A} )</td>
<td>( x )</td>
<td>( - )</td>
<td>( C_M )</td>
</tr>
</tbody>
</table>
| \( G_{tv} = G_{tv} \) | \( x \) | \( - \) | \( C_M \) | \( C_I \) | - | - | - | 90
Chapter 9 – Wood Structural Panels

Adjustment factors

• \( C_M \) - wet service

• \( C_T \) - temperature

Table C9.3.3 Wet Service Factor, \( C_M \)

<table>
<thead>
<tr>
<th>Reference Design Capacity</th>
<th>( C_M )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength ((F_S, F_A, F_T, F_{Th/Q}))</td>
<td>0.75</td>
</tr>
<tr>
<td>Stiffness ((E_I, E_A, G_{LT}))</td>
<td>0.85</td>
</tr>
</tbody>
</table>

\[ C_T = 1.0 - 0.005 \left(T - 100\right) \] (C9.3-1)

where:

\( T \) = temperature (°F)

NDS – Chapter 10

CROSS-LAMINATED TIMBER

New

10.1 General 60
10.2 Reference Design Values 60
10.3 Adjustment of Reference Design Values 60
10.4 Special Design Considerations 62

Table 10.4.1 Applicability of Adjustment Factors for Cross Laminated Timber 62
Table 10.4.2 Shear Deformation Adjustment Factors 62
Chapter 10 – Cross-Laminated Timber

10.1 General

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

10.1.2 Definition

Cross-Laminated Timber (CLT) is a prefabricated engineered wood product consisting of at least three layers of solid-sawn timber 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 obtained from the specification, where specified.

Table 10.3.1 Applicability of Adjustment Factors for Cross-Laminated Timber

<table>
<thead>
<tr>
<th>Adjustment Factor</th>
<th>ASD only</th>
<th>ASD and LRFD</th>
<th>LRFD only</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_d(S_{ct}) = F_d(S_{ct})$</td>
<td>$C_D$</td>
<td>$C_M$</td>
<td>$C_L$</td>
</tr>
<tr>
<td>$F_d(A_{cl,ct}) = F_d(A_{cl,ct})$</td>
<td>$C_D$</td>
<td>$C_M$</td>
<td>$C_L$</td>
</tr>
<tr>
<td>$F_d(I_{ct}) = F_d(I_{ct})$</td>
<td>$C_D$</td>
<td>$C_M$</td>
<td>$C_L$</td>
</tr>
<tr>
<td>$F_d(B_{Q,ct}) = F_d(B_{Q,ct})$</td>
<td>$C_D$</td>
<td>$C_M$</td>
<td>$C_L$</td>
</tr>
<tr>
<td>$F_d(A_{cl,ct}) = F_d(A_{cl,ct})$</td>
<td>$C_D$</td>
<td>$C_M$</td>
<td>$C_L$</td>
</tr>
<tr>
<td>$F_d(A_{ct}) = F_d(A_{ct})$</td>
<td>$C_D$</td>
<td>$C_M$</td>
<td>$C_L$</td>
</tr>
<tr>
<td>(EI)$<em>{app}$ = (EI)$</em>{app}$</td>
<td>$C_D$</td>
<td>$C_M$</td>
<td>$C_L$</td>
</tr>
<tr>
<td>(EI)$<em>{app}$ = (EI)$</em>{app}$</td>
<td>$C_D$</td>
<td>$C_M$</td>
<td>$C_L$</td>
</tr>
</tbody>
</table>

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Chapter 11 – Mechanical Connections

• Design issues
• Reference design values
  • Chapter 12 – dowel-type connectors (nails, bolts, lag/wood screws)
  • Chapter 13 – split rings and shear plates
  • Chapter 14 – timber rivets
• Adjustment factors
• No significant changes
• Connections session
Yield Limit Equations

Table 12.3.1A  Yield Limit Equations

<table>
<thead>
<tr>
<th>Yield Mode</th>
<th>Single Shear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ia</td>
<td>$Z = \frac{D \ell_m F_{nm}}{R_g}$ (12.3-1)</td>
</tr>
<tr>
<td>I</td>
<td>$Z = \frac{D \ell_s F_{ns}}{R_g}$ (12.3-2)</td>
</tr>
<tr>
<td>II</td>
<td>$Z = \frac{k_1 D \ell_s F_{ns}}{R_g}$ (12.3-3)</td>
</tr>
<tr>
<td>IIIa</td>
<td>$Z = \frac{k_2 D \ell_m F_{nm}}{(1 + 2R_g) R_g}$ (12.3-4)</td>
</tr>
<tr>
<td>IIIb</td>
<td>$Z = \frac{k_3 D \ell_s F_{ns}}{(2 + R_g) R_g}$ (12.3-5)</td>
</tr>
<tr>
<td>IV</td>
<td>$Z = \frac{D^2}{R_g} \sqrt{\frac{2 F_{nm} F_{ns}}{S (1 + R_g)}}$ (12.3-6)</td>
</tr>
</tbody>
</table>

- 4 Yield Modes
- 6 Yield Equations
- Single & Double Shear
- Wood-to-Wood
- Wood-to-Steel
- Wood-to-Concrete
Yield Modes

Connection Yield Modes

MODE I
- bearing-dominated yield of wood fibers

MODE II
- pivoting of fastener with localized crushing of wood fibers

MODE III
- fastener yield in bending at one plastic hinge and bearing - dominated yield of wood fibers

MODE IV
- fastener yield in bending at two plastic hinges and bearing - dominated yield of wood fibers
Dowel Bearing Strength

Table 12.3.3 Dowel Bearing Strengths, $F_c$, for Dowel-Type Fastener

<table>
<thead>
<tr>
<th>Specific Gravity, $G$</th>
<th>$F_c$</th>
<th>$F_{cd}$</th>
<th>Dowel bearing strength in pounds per square inch</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D&lt;1/4&quot;</td>
<td>1/4&quot; ≤ D ≤ 1&quot;</td>
<td>D=1-1/4&quot;</td>
</tr>
<tr>
<td>0.73</td>
<td>9300</td>
<td>8200</td>
<td>7750</td>
</tr>
<tr>
<td>0.72</td>
<td>9050</td>
<td>8050</td>
<td>7600</td>
</tr>
<tr>
<td>0.71</td>
<td>8850</td>
<td>7950</td>
<td>7400</td>
</tr>
<tr>
<td>0.70</td>
<td>8600</td>
<td>7860</td>
<td>7250</td>
</tr>
<tr>
<td>0.69</td>
<td>8400</td>
<td>7750</td>
<td>7100</td>
</tr>
<tr>
<td>0.68</td>
<td>8150</td>
<td>7600</td>
<td>6950</td>
</tr>
</tbody>
</table>

$F_{cd} = 11200G$

$F_c = 6100G^{1/4}/\sqrt{D}$

$F_c$ for D < 1/4" = 16600 $G^{3/4}$

Fastener Bending Yield Strength

Load
**Fastener Bending Yield Strength**

### Table I1  Fastener Bending Yield Strengths, $F_{yb}$

<table>
<thead>
<tr>
<th>Fastener Type</th>
<th>$F_{yb}$ (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bolt, lag screw (with $D \geq 3/8''$), drill pin (SAE J429 Grade 1 - $F_y \approx 36,000$ psi and $F_{u} = 50,000$ psi)</td>
<td>45,000</td>
</tr>
<tr>
<td>Common, box, orinker nail, spike, lag screw, wood screw (low to medium carbon steel)</td>
<td></td>
</tr>
<tr>
<td>$0.099'' \leq D \leq 0.142''$</td>
<td>100,000</td>
</tr>
<tr>
<td>$0.142'' &lt; D \leq 0.177''$</td>
<td>90,000</td>
</tr>
<tr>
<td>$0.177'' &lt; D \leq 0.236''$</td>
<td>80,000</td>
</tr>
<tr>
<td>$0.236'' &lt; D \leq 0.273''$</td>
<td>70,000</td>
</tr>
<tr>
<td>$0.273'' &lt; D \leq 0.314''$</td>
<td>60,000</td>
</tr>
<tr>
<td>$0.344'' &lt; D \leq 0.375''$</td>
<td>45,000</td>
</tr>
<tr>
<td>Hardened steel nail (medium carbon steel) including post-frame ring Shank nails</td>
<td></td>
</tr>
<tr>
<td>$0.120'' \leq D \leq 0.142''$</td>
<td>130,000</td>
</tr>
<tr>
<td>$0.142'' &lt; D \leq 0.192''$</td>
<td>115,000</td>
</tr>
<tr>
<td>$0.192'' &lt; D \leq 0.267''$</td>
<td>100,000</td>
</tr>
</tbody>
</table>

**Chapter 12 – Dowel-type Fasteners**

12.2.1.5 Where lag screws are loaded in withdrawal from the narrow edge of cross-laminated timber, the reference withdrawal value, $W$, shall be multiplied by the end grain factor, $C_{eg} = 0.75$, regardless of grain orientation.
Chapter 12 – Dowel-type Fasteners

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

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

Chapter 12 – Dowel-type Fasteners

12.3.3 Dowel Bearing Strength

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

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

<table>
<thead>
<tr>
<th>Specific Gravity</th>
<th>$D = 1/8&quot;$</th>
<th>$D = 1/4&quot;$</th>
<th>$D = 1/2&quot;$</th>
<th>$D = 5/32&quot;$</th>
<th>$D = 3/32&quot;$</th>
<th>$D = 1/32&quot;$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.55</td>
<td>5550</td>
<td>6150</td>
<td>5150</td>
<td>4650</td>
<td>4200</td>
<td>3900</td>
</tr>
<tr>
<td>0.54</td>
<td>5350</td>
<td>6050</td>
<td>5000</td>
<td>4450</td>
<td>4100</td>
<td>3750</td>
</tr>
<tr>
<td>0.53</td>
<td>5150</td>
<td>5950</td>
<td>4650</td>
<td>4300</td>
<td>3950</td>
<td>3650</td>
</tr>
</tbody>
</table>
Chapter 12 – Dowel-type Fasteners

12.3.5 Dowel Bearing Length

New

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

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

Non-uniform for CLT

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

\[ m = t_{1\parallel} + t_{2\perp} + t_{3\parallel} = 3(1.5) = 4.5” \]

\[ m_{\text{adj}} = t_{1\parallel} + t_{2\perp}(F_{d\perp}/F_{d\parallel}) + t_{3\parallel} \]

\[ = 1.5 + 1.5(3650/6150) + 1.5 = 3.9” \]

Chapter 12 – Dowel-type Fasteners

- Adjust \( m \) or \( s \) to compensate for orthogonal grain orientations in adjacent layers
- Parallel to grain: \( F_{d\perp}/F_{d\parallel} \)

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

\( m = t_{1\parallel} + t_{2\perp} + t_{3\parallel} = 3(1.5) = 4.5” \)

\( m_{\text{adj}} = t_{1\parallel} + t_{2\perp}(F_{d\perp}/F_{d\parallel}) + t_{3\parallel} \)

\[ = 1.5 + 1.5(3650/6150) + 1.5 = 3.9” \]

Table 12.3.3 Dowel Bearing Strengths, \( F_{d} \), for Dowel-Type Fasteners in Wood Members

<table>
<thead>
<tr>
<th>Specific Gravity</th>
<th>( G )</th>
<th>Dowel Bearing Strength (psf)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>( F_{d} )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( 6\text{½”} )</td>
</tr>
<tr>
<td>0.55</td>
<td>6050</td>
<td>6150</td>
</tr>
<tr>
<td>0.54</td>
<td>6550</td>
<td>6650</td>
</tr>
<tr>
<td>0.53</td>
<td>7150</td>
<td>7250</td>
</tr>
</tbody>
</table>
Chapter 12 – Dowel-type Fasteners

12.5.2 End Grain Factor, $C_{eg}$

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

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

- Lateral – any end grain
  - $D < 1/4''$ $C_{eg} = 0.67$
- Lateral – any CLT edge
  - $D \geq 1/4''$ $C_{eg} = 0.67$
Chapter 12-Dowels

12.3.7 Dowel Diameter

12.3.7.1 Where used in Tables 12.3.1A or 12.3.1B, the fastener diameter shall be taken as D for unthreaded full-body diameter fasteners and D_r for reduced body diameter fasteners or threaded fasteners except as provided in 12.3.7.2.

12.3.7.2 For threaded full-body fasteners (see Appendix L), D shall be permitted to be used in lieu of D_r where the bearing length of the threads does not exceed 1/4 of the full bearing length in the member holding the threads. Alternatively, a more detailed analysis accounting for the moment and bearing resistance of the threaded portion of the fastener shall be permitted (see Appendix L).

Chapter 12-Dowels

Appendix L (Non-mandatory) Typical Dimensions for Dowel-Type Fasteners and Washers

Table L1 Standard Hex Bolts

<table>
<thead>
<tr>
<th>D = diameter</th>
<th>D_r = root diameter</th>
<th>T = thread length</th>
<th>L = bolt length</th>
<th>F = width of head across flats</th>
<th>H = height of head</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full-Body Fastener</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table L2 Standard Hex Lag Screws

<table>
<thead>
<tr>
<th>D = diameter</th>
<th>D_b = reduced body diameter</th>
<th>S = unthreaded body length</th>
<th>T = minimum thread length^{2}</th>
<th>F = length of tapered tip</th>
<th>L = lag screw length</th>
<th>N = number of threads/inch</th>
<th>F = width of head across flats</th>
<th>H = height of head</th>
</tr>
</thead>
</table>
Chapter 12-Dowels

Dia. Fastener = D

Threaded length ≤ \( \frac{1}{4} \ell_m \)

\[ \ell_m \]

Chapter 12-Dowels

Dia. Fastener = \( D_r \)

\[ \ell_m \]
Chapter 12 - Dowels

Provide tools for the analysis of
• gaps between members
• various fastener bending moment configurations
• fasteners through hollow members
• fasteners with tapered tips


NDS – Chapter 13
Chapter 13 – Split Rings and Shear Plates

### Table 13.3A Split Ring Connector Unit Reference Design Values

<table>
<thead>
<tr>
<th>Split ring diameter</th>
<th>Bolt diameter</th>
<th>Number of holes in header with corresponding unit in same row</th>
<th>Net distance of header</th>
<th>Design values, P, per connection unit and bolt, kips</th>
<th>Loaded perpendicular to grain (90°)</th>
<th>Design values, Q, per connection unit and bolt, kips</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4</td>
<td>9/16</td>
<td>1 (1/4&quot;) or thicker</td>
<td>22.50</td>
<td>1500</td>
<td>1800</td>
<td>1900</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 (1/2&quot;) or (1&quot;)</td>
<td>2050</td>
<td>1600</td>
<td>1800</td>
<td>1900</td>
</tr>
<tr>
<td>1</td>
<td>5/8</td>
<td>2 (2&quot;) or thicker</td>
<td>2700</td>
<td>2300</td>
<td>2500</td>
<td>2600</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3/4 (1&quot;) or (1/2&quot;)</td>
<td>3500</td>
<td>3100</td>
<td>3300</td>
<td>3400</td>
</tr>
<tr>
<td>1 1/2</td>
<td>1 1/2&quot; or (1&quot;)</td>
<td>1 (3&quot;) or (2&quot;)</td>
<td>4400</td>
<td>4000</td>
<td>4200</td>
<td>4300</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 (4&quot;) or (2&quot;)</td>
<td>5200</td>
<td>4800</td>
<td>5000</td>
<td>5200</td>
</tr>
<tr>
<td>2</td>
<td>1 1/4&quot; or (1&quot;)</td>
<td>1 (5&quot;) or (3&quot;)</td>
<td>6200</td>
<td>5800</td>
<td>6000</td>
<td>6200</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 (6&quot;) or (4&quot;)</td>
<td>7200</td>
<td>6800</td>
<td>7000</td>
<td>7200</td>
</tr>
<tr>
<td>2 1/2</td>
<td>1 1/2&quot; or (1&quot;)</td>
<td>1 (6&quot;) or (3&quot;)</td>
<td>8000</td>
<td>7600</td>
<td>7800</td>
<td>8000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 (8&quot;) or (4&quot;)</td>
<td>9000</td>
<td>8600</td>
<td>8800</td>
<td>9000</td>
</tr>
</tbody>
</table>

1. Shear and tensile design values (kips) for split ring connectors shall be multiplied by applicable load factors (see Table 13.1A).

---

NDS – Chapter 14

### TIMBER RIVETS

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.1</td>
<td>General</td>
</tr>
<tr>
<td>14.2</td>
<td>Reference Design Values</td>
</tr>
<tr>
<td>14.3</td>
<td>Placement of Timber Rivets</td>
</tr>
</tbody>
</table>

---

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Chapter 14 – Timber Rivets

Many applications

Chapter 14 – Timber Rivets

Design Values

<table>
<thead>
<tr>
<th>Member Thickness in.</th>
<th>Rivets per row</th>
<th>P_{n} (kips)</th>
<th>No. of rows per side</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2770 6740 10490 14660 19100 23630 27690 31160 35050 39610</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>4080 8960 13310 18410 23640 28890 33440 37160 41650 47010</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>5470 11020 16160 22200 28280 34330 39170 43240 48710 55090</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>6830 13140 19170 25640 32410 39130 45620 51180 57700 64190</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>8000 15640 21780 29110 36510 44390 51270 58150 65190 72510</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>9040 16649 24370 32630 40630 48520 56740 64180 71920 79640</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>9650 18630 26630 35960 44380 53520 62390 71650 79620 88320</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>10300 20900 29880 39340 48580 58170 67870 77900 88090 98470</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>11550 22350 31960 41420 51510 61680 71130 80300 90790 101690</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>12230 24490 34230 46960 59430 70290 79720 89340 100540 112190</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Capacities > 100 kips
Chapter 15 – Special Loading

Figure 15B  Mechanically Laminated Built-Up Columns

Figure 15E  Eccentrically Loaded Column
Chapter 16 – Fire (ASD)

- Fire resistance up to **two hours**
  - Columns
  - Beams
  - Tension Members
  - ASD only
- Products
  - Lumber
  - Glulam
  - SCL
  - Decking
  - CLT - NEW
• Fire resistance of exposed wood members may be calculated using the provisions of NDS Chapter 16.
Performance of Wood vs. Steel

Chapter 16 – Fire Design - CLT

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

\[
\begin{align*}
\frac{d_{\text{eff}}}{\beta_n} &= \left( \frac{n_{\text{max}} + \beta_n \left( t - n_{\text{max}} t_{w} \right)}{1.25} \right) \left( \frac{t_{w}}{1.25} \right) \\
&= \left( \frac{n_{\text{max}} + \beta_n \left( t - n_{\text{max}} t_{w} \right)}{1.25} \right) \left( \frac{t_{w}}{1.25} \right)
\end{align*}
\]  

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

<table>
<thead>
<tr>
<th>Required Fire Endurance (hr)</th>
<th>Effective Char Depths, (d_{\text{eff}}) (in.)</th>
<th>Insulation thickness, (t_{w}) (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2-Hour</td>
<td>1.25</td>
<td>1/2</td>
</tr>
<tr>
<td>1-Hour</td>
<td>2.25</td>
<td>2</td>
</tr>
<tr>
<td>2-Hour</td>
<td>3.5</td>
<td>3</td>
</tr>
</tbody>
</table>

New
Chapter 16 – Fire (ASD)

Technical Report No. 10
• Background on NDS provisions
• Design examples
• Floor assembly lumber joist provisions

Code Updates - Design of Fire-Resistive Exposed Wood Members

http://www.awc.org/publications/download.php
2015 NDS – Summary

New Provisions to Address CLT

• Charging Language
• Design Values
• Design Equations
• Product Chapter
• Connection Design
• Fire Design

What’s Missing for CLT?

Seismic Design!

• *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
Outline

• Overview
• Design Process Overview
• NDS
  • Chapter-by-chapter discussion
  • Changes from previous editions
• Summary
  • More Info

2015 NDS Supplement

• New Southern Pine Design Values
  • ALSC approves design values
    • June 1, 2013
  • AWC compiles them
    • NDS Supplement
  • More information
    • www.spib.org
    • www.southernpine.com
Availability

- [www.awc.org](http://www.awc.org)
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    - Buy a printable PDF
  - Spring 2015
    - Commentary
    - Printed version

Technical Articles

- *Structure Magazine*
  - 2015 NDS
    - January 2015
  - 2015 SDPWS
    - July 2015

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info@awc.org
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