2015 NDS® Provisions for CLT

Michelle Kam-Biron, P.E., S.E., SECB
Director of Education
American Wood Council
• 2015 NDS referenced in 2015 IBC
ANSI Accreditation

- AWC – ANSI-accredited standards developer
- Consensus Body
  - Wood Design Standards Committee
New Provisions to Address CLT

- Charging Language
- Design Values
- Design Equations
- Product Chapter
- Connection Design
- Fire Design
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
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 piles
- 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 principles of...
2.2 Reference Design Values

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

2.3 Adjustment of Reference Design Values

2.3.1 Applicability of Adjustment Factors

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

The load duration factor, \( F_d \), based on a deformation limit (see 4.2.6) shall be multiplied by the appropriate load duration factor, \( C_d \), from Table 2.3.2 or Figure B1 (see Appendix I). The load duration factor accounts for the change in strength of wood in the initial load duration.

2.3.2.2 The load duration factor, \( C_d \), based on a deformation limit (see 4.2.6) shall be multiplied by the appropriate load duration factor, \( C_d \), from Table 2.3.2 or Figure B1 (see Appendix I). The load duration factor accounts for the change in strength of wood in the initial load duration.

All applicable load duration factors shall be evaluated to determine the final adjusted design value.
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, \( \Delta_T \), shall be calculated as follows:

\[
\Delta_T = K_{\alpha} \Delta_{lt} + \Delta_{st}
\]

(3.5-1)

where:

\( K_{\alpha} \) = time dependent deformation (creep) factor

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

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

3.5.2 Long-Term Loading

Where total deflection under long-term loading must be limited, increasing member size is one way to provide extra stiffness to allow for this time dependent deformation (see Appendix F).
3.7.1.5 The column stability factor shall be calculated as follows:

\[
C_p = \frac{1 + \left( \frac{F_{ct}}{F_c^*} \right)}{2c} - \sqrt{\left[ 1 + \left( \frac{F_{ct}}{F_c^*} \right) \right] ^2 - \frac{F_{ct}}{F_c^*} \frac{1}{c}}
\]

(3.7-1)

where:

- \(F_c^*\) = reference compression design value parallel to grain multiplied by all applicable adjustment factors except \(C_p\) (see 2.3), psi
- \(F_{ct}\) = \(\frac{0.822 \ E_{\text{min}}^{'}}{\left( \ell_s / d \right)^2}\)
- \(c\) = 0.8 for sawn lumber
- \(c\) = 0.85 for round timber poles and piles
- \(c\) = 0.9 for structural glued laminated timber, structural composite lumber, and cross-laminated timber

NDS Commentary – guidance on \(C_p\)
10.1 General

10.1.1 Application

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

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

10.1.2 Definition

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

10.1.3 Standard Dimensions

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

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

10.1.4 Specification

All required reference design values shall be specified in accordance with the NDS.
### Table 10.3.1  Applicability of Adjustment Factors for Cross-Laminated Timber

<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></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Load Duration Factor</strong></td>
<td>LD</td>
<td>LD</td>
<td>LD</td>
</tr>
<tr>
<td><strong>Wet Service Factor</strong></td>
<td>Fb(S)</td>
<td>Fb(S)</td>
<td>Fb(S)</td>
</tr>
<tr>
<td><strong>Temperature Factor</strong></td>
<td>F_t(A_p)</td>
<td>F_t(A_p)</td>
<td>F_t(A_p)</td>
</tr>
<tr>
<td><strong>Beam Stability Factor</strong></td>
<td>F_v(t_v)</td>
<td>F_v(t_v)</td>
<td>F_v(t_v)</td>
</tr>
<tr>
<td><strong>Column Stability Factor</strong></td>
<td>F_c(A_p)</td>
<td>F_c(A_p)</td>
<td>F_c(A_p)</td>
</tr>
<tr>
<td><strong>Bearing Area Factor</strong></td>
<td>F_c(A_p)</td>
<td>F_c(A_p)</td>
<td>F_c(A_p)</td>
</tr>
<tr>
<td><strong>Format Conversion Factor</strong></td>
<td>F_c(A_p)</td>
<td>F_c(A_p)</td>
<td>F_c(A_p)</td>
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<tr>
<td><strong>Resistance Factor</strong></td>
<td>F_c(A_p)</td>
<td>F_c(A_p)</td>
<td>F_c(A_p)</td>
</tr>
<tr>
<td><strong>Time Effect Factor</strong></td>
<td>F_c(A_p)</td>
<td>F_c(A_p)</td>
<td>F_c(A_p)</td>
</tr>
</tbody>
</table>

- **F_b(S_eff)’ = F_b(S_eff)**
- **F_t(A_{parallel})’ = F_t(A_{parallel})**
- **F_v(t_v)’ = F_v(t_v)**
- **F_c(Ib/Q)_{eff}’ = F_c(Ib/Q)_{eff}**
- **F_c(A_{parallel})’ = F_c(A_{parallel})**
- **F_c(A)’ = F_c(A)**
- **(EI)_{app}’ = (EI)_{app}**
- **(EI)_{app-min}’ = (EI)_{app-min}**
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.
12.2.2.4 Wood screws shall not be loaded in withdrawal from end-grain of laminations in cross-laminated timber ($C_{eg}=0.0$).

12.2.3.6 Nails, and spikes shall not be loaded in withdrawal from end-grain of laminations in cross-laminated timber ($C_{eg}=0.0$).
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 $F_{ul}$ for $D \geq 1/4''$ and $F_u$ for $D < 1/4''$.

<table>
<thead>
<tr>
<th>Specific Gravity, $G$</th>
<th>$F_u$</th>
<th>$F_{el}$</th>
<th>$D = 1/4''$</th>
<th>$D = 5/16''$</th>
<th>$D = 3/8''$</th>
<th>$D = 7/16''$</th>
<th>$D = 1/2''$</th>
<th>$D = 5/8''$</th>
<th>$D = 3/4''$</th>
<th>$D = 7/8''$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.55</td>
<td>5550</td>
<td>6150</td>
<td>5150</td>
<td>4600</td>
<td>4200</td>
<td>3900</td>
<td>3650</td>
<td>3250</td>
<td>2950</td>
<td>275</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>
<td>3550</td>
<td>3150</td>
<td>2900</td>
<td>265</td>
</tr>
<tr>
<td>0.53</td>
<td>5150</td>
<td>5950</td>
<td>4850</td>
<td>4350</td>
<td>3950</td>
<td>3650</td>
<td>3450</td>
<td>3050</td>
<td>2800</td>
<td>260</td>
</tr>
</tbody>
</table>
12.3.5 Dowel Bearing Length

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

12.3.5.2 For cross-laminated timber where the direction of loading relative to the grain orientation at the shear plane is parallel to grain, the dowel bearing length in the perpendicular plies shall be reduced by multiplying the bearing length of those plies by the ratio of dowel bearing strength perpendicular to grain to dowel bearing strength parallel to grain (\( F_{el} / F_{eq} \)).
• Adjust \( l_m \) or \( l_s \) to compensate for orthogonal grain orientations in adjacent layers
• Parallel to grain: \( F_{e\perp}/F_{e\parallel} \)

Example: \( \frac{1}{2}'' \) bolt in southern pine 3-ply CLT with 1-\( \frac{1}{2}'' \) laminations

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

\[
l_{m-adj} = t_{1\parallel} + t_{2\perp}(F_{e\perp}/F_{e\parallel}) + t_{3\parallel}
= 1.5 + 1.5(3650/5550) + 1.5 = 4.0''
\]
Figure 12I  End Distance, Edge Distance and Fastener Spacing Requirements in Narrow Edge of Cross-Laminated Timber
2015 NDS CLT Connection Design

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
  - $D \geq 1/4'' C_{eg} = 0.67$
16.2.1.3 For cross-laminated timber, the effective char depth, \( a_{\text{char}} \), shall be calculated as follows:

\[
\begin{align*}
\text{for } & \beta > 0, \\
a_{\text{char}} &= 1.2 \left[ n_\text{lam} \cdot h_\text{lam} + \beta \left( t - (n_\text{lam} \cdot t_\varphi) \right) \right]^{0.833} \\
t_\varphi &= \left( \frac{h_\text{lam}}{\beta} \right)^{1.23}
\end{align*}
\] (16.2-2)

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

<table>
<thead>
<tr>
<th>Required Fire Endurance (hr.)</th>
<th>Effective Char Depths, ( a_{\text{char}} ) (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>lamination thickness, ( h_\text{lam} ) (in.)</td>
</tr>
<tr>
<td>1-Hour</td>
<td>2.2   2.2   2.1   2.0   2.0   1.9   1.8   1.8   1.8</td>
</tr>
<tr>
<td>1½-Hour</td>
<td>2.4   2.2   2.1   2.0   2.0   1.9   1.8   1.8   1.8</td>
</tr>
<tr>
<td>2-Hour</td>
<td>4.4   4.3   4.1   4.0   3.9   3.8   3.6   3.6   3.6</td>
</tr>
</tbody>
</table>
What Are We Missing?

- 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
Availability

• Before December 1, 2014
  • PDF version
  • www.awc.org