CLT Floor Design: Strength, Deflection and Vibrations

Toward Taller Wood Buildings
November 2014

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Architectural and Engineering Solutions
WoodWorks – Wood Products Council
Product Standardization
CLT Composition

Planks in alternating directions
CLT Composition

Perpendicular Layer

Parallel Layer

Strength Axis of CLT
CLT Product Standard

ANSI/APA PRG 320

- CLT Stress classes
- Quality Assurance testing
- Identification marking

<table>
<thead>
<tr>
<th>CLT Grade</th>
<th>Lamination Thickness (in.) in CLT Lay-up</th>
<th>Major Strength Direction</th>
<th>Minor Strength Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLT Grade</td>
<td>CLT Thickness (in.)</td>
<td>F_{s,eff.0} (lb./ft.)</td>
<td>E_{s,eff.0} (10^6 lb./in.^2/ft.)</td>
</tr>
<tr>
<td>E1</td>
<td>4 1/8</td>
<td>4,525</td>
<td>115</td>
</tr>
<tr>
<td></td>
<td>6 7/8</td>
<td>10,400</td>
<td>440</td>
</tr>
<tr>
<td></td>
<td>9 5/8</td>
<td>18,375</td>
<td>1,089</td>
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<tr>
<td>E2</td>
<td>4 1/8</td>
<td>3,625</td>
<td>102</td>
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<td></td>
<td>6 7/8</td>
<td>8,625</td>
<td>389</td>
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<td>9 5/8</td>
<td>15,600</td>
<td>963</td>
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<tr>
<td>E3</td>
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<td>2,800</td>
<td>81</td>
</tr>
<tr>
<td></td>
<td>6 7/8</td>
<td>6,400</td>
<td>311</td>
</tr>
</tbody>
</table>
Product Reports

Structurlam CrossLam
Structurlam Products LP

Products: Structurlam CrossLam
Structurlam Products LP
2176 Government Street
Penticton, British Columbia, Ca
(250) 492-8912
www.structurlam.com

Nordic X-Lam
Nordic Engineered Wood

Products: Nordic X-Lam
Nordic Engineered Wood
1100 Avenue des Canadiens-de-Montréal, Suite 504
Montreal, Québec, Canada H3B 2S2
(514) 871-8526
www.nordicwp.com
**Laminations**: (Per PRG 320-2012)
5/8” to 2” thick.
Machine Stress Rated or Visually Graded Dimensional Lumber or SCL
Dried to 12% Moisture Content before layup.
A common NA thickness is 1 3/8” (planed 2x stock)
PRG 320 provides thickness to width requirements of laminations
Structural Composition of CLT

Layers: (Per PRG 320-2012)
- Oriented in orthogonal arrangement
- Odd number of symmetric layers most common
- Double parallel exterior layers permitted
- Unbalanced layup permitted
- Reference glu-lam adhesive standard (AITC 405)
Structural Composition of CLT

Panels, also known as Billets.
- 20 inch max thickness in PRG 320
- Up to 8 ft or more wide per manufacturer and shipping
- Up to 40 ft or more long per manufacturer and shipping
- Major axis: stronger, stiffer, usually long direction
- Minor axis: less strong and stiff, usually short direction
# CLT Stress Grades

<table>
<thead>
<tr>
<th>Stress Grade</th>
<th>Major Strength Direction</th>
<th>Minor Strength Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1</td>
<td>1950f-1.7E MSR SPF</td>
<td>#3 Spruce Pine Fir</td>
</tr>
<tr>
<td>E2</td>
<td>1650f-1.5E MSR DFL</td>
<td>#3 Doug Fir Larch</td>
</tr>
<tr>
<td>E3</td>
<td>1200f-1.2E MSR Misc</td>
<td>#3 Misc</td>
</tr>
<tr>
<td>E4</td>
<td>1950f-1.7E MSR SP</td>
<td>#3 Southern Pine</td>
</tr>
<tr>
<td>V1</td>
<td>#2 Doug Fir Larch</td>
<td>#3 Doug Fir Larch</td>
</tr>
<tr>
<td>V2</td>
<td>#1/#2 Spruce Pine Fir</td>
<td>#3 Spruce Pine Fir</td>
</tr>
<tr>
<td>V3</td>
<td>#2 Southern Pine</td>
<td>#3 Southern Pine</td>
</tr>
</tbody>
</table>

Non-mandatory in PRG 320. Other stress grades including SCL permitted.
### TABLE A2.
THE ALLOWABLE BENDING CAPACITIES\(^{(a,b,c)}\) FOR CLT LISTED IN TABLE A1 [FOR USE IN THE U.S.]

<table>
<thead>
<tr>
<th>CLT Grade</th>
<th>CLT t (in.)</th>
<th>Lamination Thickness (in.) in CLT Layup</th>
<th>Major Strength Direction</th>
<th>Minor Strength Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4 1/8</td>
<td>13/8 13/8 13/8 13/8</td>
<td>F_{s}S_{u,0} (lbf-ft/lbf-in.)</td>
<td>GA_{u,0} (10^6 lbf-in./in.^2)</td>
</tr>
<tr>
<td>E1</td>
<td>6 7/8</td>
<td>13/8 13/8 13/8 13/8 13/8 13/8</td>
<td>4,525 115 0.46 160 3.1 0.61</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9 5/8</td>
<td>13/8 13/8 13/8 13/8 13/8 13/8 13/8</td>
<td>10,400 440 0.92 1,370 81 1.2</td>
<td></td>
</tr>
<tr>
<td>E2</td>
<td>6 7/8</td>
<td>13/8 13/8 13/8 13/8 13/8 13/8</td>
<td>3,825 102 0.53 165 3.6 0.56</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9 5/8</td>
<td>13/8 13/8 13/8 13/8 13/8 13/8 13/8</td>
<td>8,825 389 1.1 1,430 95 1.1</td>
<td></td>
</tr>
<tr>
<td>E3</td>
<td>4 1/8</td>
<td>13/8 13/8 13/8 13/8</td>
<td>15,600 963 1.6 3,275 360 1.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6 7/8</td>
<td>13/8 13/8 13/8 13/8 13/8 13/8</td>
<td>2,800 81 0.35 110 2.3 0.44</td>
<td></td>
</tr>
<tr>
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<td>9 5/8</td>
<td>13/8 13/8 13/8 13/8 13/8 13/8 13/8</td>
<td>6,400 311 0.69 955 61 0.87</td>
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</tr>
<tr>
<td>E4</td>
<td>4 1/8</td>
<td>13/8 13/8 13/8 13/8</td>
<td>11,325 769 1.0 2,180 232 1.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6 7/8</td>
<td>13/8 13/8 13/8 13/8 13/8 13/8</td>
<td>4,525 115 0.53 180 3.6 0.63</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9 5/8</td>
<td>13/8 13/8 13/8 13/8 13/8 13/8 13/8</td>
<td>10,425 441 1.1 1,570 95 1.3</td>
<td></td>
</tr>
<tr>
<td>V1</td>
<td>4 1/8</td>
<td>13/8 13/8 13/8 13/8</td>
<td>18,400 1,090 1.6 3,575 360 1.9</td>
<td></td>
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<tr>
<td></td>
<td>6 7/8</td>
<td>13/8 13/8 13/8 13/8 13/8 13/8</td>
<td>2,090 108 0.53 165 3.6 0.59</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9 5/8</td>
<td>13/8 13/8 13/8 13/8 13/8 13/8 13/8</td>
<td>4,800 415 1.1 1,430 95 1.2</td>
<td></td>
</tr>
<tr>
<td>V2</td>
<td>4 1/8</td>
<td>13/8 13/8 13/8 13/8</td>
<td>8,500 1,027 1.6 3,275 360 1.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6 7/8</td>
<td>13/8 13/8 13/8 13/8 13/8 13/8</td>
<td>2,030 95 0.46 160 3.1 0.52</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9 5/8</td>
<td>13/8 13/8 13/8 13/8 13/8 13/8 13/8</td>
<td>4,675 363 0.91 1,370 81 1.0</td>
<td></td>
</tr>
<tr>
<td>V3</td>
<td>4 1/8</td>
<td>13/8 13/8 13/8 13/8</td>
<td>8,275 898 1.4 3,125 309 1.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6 7/8</td>
<td>13/8 13/8 13/8 13/8 13/8 13/8</td>
<td>2,270 108 0.53 180 3.6 0.59</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9 5/8</td>
<td>13/8 13/8 13/8 13/8 13/8 13/8 13/8</td>
<td>5,200 415 1.1 1,570 95 1.2</td>
<td></td>
</tr>
</tbody>
</table>

For St: 1 in. = 25.4 mm; 1 ft = 304.8 mm; 1 lbf = 4.448 N
(a) See Section 4 for symbols.
(b) This table represents one of many possibilities that the CLT could be manufactured by varying lamination grades, thicknesses, orientations, and layer arrangements in the layup.
(c) Custom CLT grades that are not listed in this table shall be permitted in accordance with Section 7.2.1.
Examples of CLT Configurations

3-ply 3-layer

5-ply 3-layer

5-ply 5-layer

7-ply 5-layer

6-ply 5-layer

8-ply 5-layer

9-ply 9-layer

9-ply 7-layer
Strength

Photos Courtesy Structurlam
Floors
Non-homogenous, anisotropic material
Flexural Strength

Design Properties based on Extreme Fiber Model:

Flexural Capacity Check:

\[ M_b \leq (F_b S_{eff})' \]

- \( M_b \) = applied bending moment
- \( (F_b S_{eff})' \) = adjusted bending capacity
- \( S_{eff} \) = effective section modulus
- \( F_b \) = reference bending design value of outer lamination

Flexural Strength

Design Properties based on Extreme Fiber Model:

Flexural Capacity Check (ASD)

\[ (F_b S_{eff})' = C_D C_M C_t C_L (F_b S_{eff}) \]

per NDS

Commonly 1.0

From Manufacturer*

\[ M_b \leq C_D (1.0) (F_b S_{eff}) \]

*From Manufacturer

Design Properties based on Extreme Fiber Model:

Flexural Capacity Check (LRFD)

\[(F_b S_{eff})' = C_M C_t C_L (F_b S_{eff}) K_f \phi \lambda\]

Commonly 1.0

From Manufacturer

\[M_b \leq (1.0) (F_b S_{eff}) (2.54)(0.85) \lambda\]

Select acceptable CLT section

Given:

- 16 foot span floor
- 40 psf live load, 40 psf total dead load.

Assume:

- one-way spanning action in major axis of CLT

ASD Dead + Live Flexural Demands:

\[ M_b = \frac{w L^2}{8} = \frac{(40+40 \text{psf}) (16 \text{ft})^2}{8} = 2560 \text{ lb-ft/ft} \]
**Design Example: Flexure**

Try 5 ply, (6 7/8 in thick) CLT Grade V2 Section

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**TABLE A2.**  
THE ALLOWABLE BENDING CAPACITIES\(^{\text{a,b,c}}\) FOR CLT LISTED IN TABLE A1 (FOR USE IN THE U.S.)

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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>4 1/8 1 3/8 1 3/8 1 3/8</td>
<td>F_{b,eff,0} (lbf-ft/ft)</td>
<td>2,090</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9 5/8 1 3/8 1 3/8 1 3/8 1 3/8 1 3/8</td>
<td>1,100</td>
<td>0.53</td>
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<tr>
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<td>4 1/8</td>
<td>1 3/8 1 3/8 1 3/8 1 3/8</td>
<td>165</td>
<td></td>
</tr>
<tr>
<td>V2</td>
<td>6 7/8</td>
<td>1 3/8 1 3/8 1 3/8 1 3/8 1 3/8 1 3/8</td>
<td>1,430</td>
<td></td>
</tr>
</tbody>
</table>

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**Reference:** ANSI/APA PRG 320-2012
Design Example: Flexure

ASD Flexural Capacity:
Dead + Live load, $C_D = 1.0$

$$(F_b S_{eff})' = C_D (1.0) (F_b S_{eff})$$

$$= 1.0 (1.0) (4675 \text{ lb-ft/ft})$$

$$= 4675 \text{ lb-ft/ft}$$

$$M_b = 2560 \text{ lb-ft/ft} \leq F'_b S_{eff} = 4675 \text{ lb-ft/ft}$$

Flexural Strength OK
Shear Strength

Design Properties based on Extreme Fiber Model:

Shear Capacity Check:

\[ V_{\text{planar}} \leq F_s (\text{lb/Q})_{\text{eff}}' \]

- \( V_{\text{planar}} \) = applied shear
- \( F_s (\text{lb/Q}_{\text{eff}})' \) = adjusted shear strength

Shear Strength

Design Properties based on Extreme Fiber Model:

Shear Capacity Check (ASD):

\[ F_s (IbQ)_{eff}' = C_M C_t \quad (F_s (IbQ)_{eff}) = C_M C_t \quad V_s \]

Commonly 1.0

From Manufacturer for Standard Sections

\[ V_{planar} \leq (1.0) \quad V_s \]

Stiffness & Deflection

Major Axis Stiffness

\[ EI_{\text{eff},0} \]

\[ GA_{\text{eff},0} \]

Minor Axis Stiffness

\[ EI_{\text{eff},90} \]

\[ GA_{\text{eff},90} \]
Structural Material Assumptions


Given lumber for a lamination with modulus of elasticity for bending in major strength direction, $E_0$, assume:

- $E_{90} = E_0 / 30$
- $G_0 = E_0 / 16$
- $G_{90} = G_0 / 10 = E_0 / 160$

Reference: US CLT Handbook & PRG 320
Flexural Stiffness

Shear Analogy Method

\[ EI_{\text{eff}} = \sum_{i=1}^{n} E_i \cdot b_i \cdot \frac{h_i^3}{12} + \sum_{i=1}^{n} E_i \cdot A_i \cdot z_i^2 \]

\[ S_{\text{eff}} = \frac{2EI_{\text{eff}}}{E_1h} \]

\[ (Ib / Q)_{\text{eff}} = \frac{EI_{\text{eff}}}{\sum_{i=1}^{n/2} E_i h_i z_i} \]

Reference: US CLT Handbook Chapter 3
Shear Stiffness

Shear Analogy Method

\[ G A_{eff} = \left[ \frac{h_1}{2 \cdot G_1 \cdot b} + \left( \sum_{i=2}^{n-1} \frac{h_i}{G_i \cdot b_i} \right) + \left( \frac{h_n}{2 \cdot G_n \cdot b} \right) \right] \]

Reference: US CLT Handbook Chapter 3
Flexural Stiffness

\[ EI_{\text{eff}} = \sum_{i=1}^{n} E_i \cdot b_i \cdot \frac{h_i^3}{12} + \sum_{i=1}^{n} E_i \cdot A_i \cdot z_i^2 \]

Important to develop properties of new CLT Sections.
Not to use standard CLT Sections

\[ GA_{\text{eff}} = \left[ \frac{h_1}{2 \cdot G_1 \cdot b} \right] + \left( \sum_{i=2}^{n} \frac{h_i}{G_i \cdot b_i} \right) + \left( \frac{h_n}{2 \cdot G_n \cdot b} \right) \]
Structural Section Properties

Flexural Strength: $F_{bS_{eff,0}}$
Flexural Stiffness: $EI_{eff,0}$
Shear Strength: $V_{s,0}$
Shear Stiffness: $GA_{eff,0}$

Values in RED provided by CLT manufacturer

Reference: PRG 320 and CLT Product Reports
General Purpose, 2 Way, Plate Action

Flexural Stiffness

\[ E_{I_{\text{eff},0}} \quad E_{I_{\text{eff},90}} \]

Shear Stiffness:

\[ \frac{5}{6} G A_{\text{eff},0} \quad \frac{5}{6} G A_{\text{eff},90} \]

5/6 from \( A' = 5/6 A \) for rectangular sections
Deflection Calculations

General Purpose: 1 Way, Beam Action

Stiffness: $E I_{\text{eff},0}$, $5/6 G A_{\text{eff},0}$

Can model multiple spans, cantilevers, etc.
Example Deflection Calculations

Example Calculation:

Uniform loading on one way slab:

Beam Analysis using

Flexural Stiffness: $E I_{\text{eff},0}$

Shear Stiffness: $\frac{5}{6} G A_{\text{eff},0}$

Maximum Deflection @ Mid-Span

$$\Delta_{\text{max}} = \frac{5}{384} \cdot \frac{wL^4}{E I_{\text{eff}}} + \frac{1}{8} \cdot \frac{wL^2}{5/6 G A_{\text{eff}}}$$

Design Example:

= $0.161 \text{ in} + 0.02 \text{ in} = 0.183 \text{ in}$

= $L / 1050$
Deflection Calculations

Simplified Beam Deflections:

Given load pattern and support conditions:

\[ \Delta_{\text{max}} = \frac{5}{384} \cdot \frac{wL^4}{EI_{\text{eff}}} + \frac{1}{8} \cdot \frac{wL^2}{5/6 \cdot GA_{\text{eff}}} \]

Find *Apparent* Flexural Stiffness, \( EI_{\text{app}} \), such that

\[ \Delta_{\text{max}} = \frac{5}{384} \cdot \frac{wL^4}{EI_{\text{app}}} \]

\[ EI_{\text{app}} = \frac{EI_{\text{eff}}}{1 + \frac{11.5EI_{\text{eff}}}{GA_{\text{eff}}L^2}} \]

Reference: US CLT Handbook
Deflection Calculations

Simplified Beam Deflections

For single span, simple loading patterns, Apparent Flexural Stiffness, $EI_{app}$, to determine maximum (mid-span) deflection:

\[
EI_{app} = \frac{EI_{eff}}{1 + \frac{K_s EI_{eff}}{GA_{eff}L^2}}
\]

US CLT Handbook

\[
EI_{app} = \frac{EI_{eff}}{1 + \frac{16K_s I_{eff}}{A_{eff}L^2}}
\]

NDS 2015

For Major Axis Spans:

\[
I_{eff} = \frac{EI_{eff}}{E_o}
\]

\[
A_{eff} = \frac{GA_{eff}}{G_o}
\]

\[
G_o = \frac{E_o}{16}
\]

Deflection Calculations

Simplified Beam Deflections

For single span, simple loading patterns, Apparent Flexural Stiffness, $EI_{app}$, to determine maximum (mid-span) deflection:

\[ EI_{app} = \frac{EI_{eff}}{1 + \frac{K_s EI_{eff}}{GA_{eff}L^2}} \]

\[ EI_{app} = \frac{EI_{eff}}{1 + \frac{16K_s EI_{eff}}{A_{eff}L^2}} \]

Apparent Flexural Stiffness depends on Load Pattern and Support Conditions

<table>
<thead>
<tr>
<th>Loading</th>
<th>End Supports</th>
<th>Ks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uniform</td>
<td>Pinned</td>
<td>11.5</td>
</tr>
<tr>
<td></td>
<td>Fixed</td>
<td>57.6</td>
</tr>
<tr>
<td>Midspan Line</td>
<td>Pinned</td>
<td>14.4</td>
</tr>
<tr>
<td></td>
<td>Fixed</td>
<td>57.6</td>
</tr>
</tbody>
</table>
Deflection Calculations

Simplified Beam Deflections

For single span, simple loading patterns, Apparent Flexural Stiffness, $EI_{app}$, to determine maximum (mid-span) deflection:

$$EI_{app} = \frac{EI_{eff}}{1 + \frac{K_s EI_{eff}}{GA_{eff}L^2}}$$

$$EI_{app} = \frac{EI_{eff}}{1 + \frac{16K_s EI_{eff}}{A_{eff}L^2}}$$

Apparent Flexural Stiffness depends on Span Length

$L_1 = 20$ foot

$EI_{app1} \neq EI_{app2}$

$L_2 = 16$ foot
Creep Factor

Deformation to Long Term Loads

\[ \Delta_T = K_{cr} \Delta_{LT} + \Delta_{ST} \]

NDS Eq 3.5-1

- \( \Delta_{ST} \): Deflection due to short-term loading
- \( \Delta_{LT} \): Immediate deflection due to long term loading
- \( K_{cr} \): 2.0 for CLT in dry service conditions

Occupant perception of vibration is a highly recommended design consideration.

**One approach: CLT Handbook, Chapter 7**

Calculated natural frequency of simple span:

\[ f = \frac{2.188}{2L^2} \sqrt{\frac{EI_{app}}{\rho A}} \]

Where:

- \( EI_{app} \) = apparent stiffness for 1 foot strip, pinned supported, uniformly loaded, simple span (\( K_s = 11.5 \)) (lb-in\(^2\))
- \( \rho \) = specific gravity of the CLT
- \( A \) = the cross section area (thickness x 12 inches) (in\(^2\))

*Reference: US CLT Handbook, Chapter 7*
Floor Vibration

CLT Handbook, Chapter 7 recommends,

\[ f = \frac{2.188}{2L^2} \sqrt{\frac{EI_{app}}{\rho A}} \geq 9.0 \text{ Hz} \]

and

Max span \( L \leq \frac{1}{12.05} \left( \frac{EI_{app}}{\rho A} \right)^{0.293} \left( \rho A \right)^{0.122} \)

Reference: US CLT Handbook, Chapter 7
Floor Vibration

CLT Handbook, Chapter 7 Recommendations

Experimental Verification – Results

Research by Lin Hu, et al.
Floor Vibration

CLT Handbook, Chapter 7 method:

Natural frequencies above 9 Hz and:

\[ \text{Max span} \quad L \leq \frac{1}{12.05} \left( \frac{E I_{\text{app}}}{\rho A} \right)^{0.293} \]

\( E I_{\text{app}} \) depends on \( L \), so an iterative calculation required.

Only depends on CLT section properties, so…

Values calculated and provided by CLT Manufactures

16ft span example: V2 Grade 5 ply (6 7/8 in) \( L \) max = 16.7 feet.

Reference: US CLT Handbook, Chapter 7
Continuous multi-span floor

- $L_2$ is the longest span
- Use the design method to determine $L_2$ assuming it is a single span floor
Floor Vibration

CLT Handbook, Chapter 7 Recommendations

With Suspended Ceiling

Use the design method *without* including the mass and stiffness of the drywall.
Floor Vibration

CLT Handbook, Chapter 7 Recommendations

With lightweight topping (<20 lb./ft.2) and drywall

- Lightweight topping examples:
  - Wood panel
  - Gypsum board
  - Cement fibreboard

- Use proposed design method without including the mass and stiffness of the drywall and the topping
With heavy topping ( >20 lb./ft.2)

Preliminary Recommendations

- Use the design method without including the mass and stiffness of the heavy topping to determine the span
- Reduce the bare floor stiffness and mass by 10%
Occupant perception of vibration a recommended design consideration

*CLT Handbook, Chapter 7* recommends natural frequencies above 9 Hz and:

$$\text{Max span} \quad L \leq \frac{1}{12.05} \left( \frac{EI_{\text{app}}}{\rho A} \right)^{0.293}$$

Limitations:

- Potential advantages of topping slab stiffness not taken into account
- Potential advantages of multiple spans or other restraining details
- Long spans can be uneconomical to keep natural frequency above 9 Hz.
SOM Timber Tower

Prototype Building

Source: SOM Timber Tower Research Project, May 2013
SOM Timber Tower

24 to 25 ft CLT Floor Spans.
6.5 to 8.5 Hz Range
Long spans can be designed using **CLT Handbook Criteria**:

- Keep Fundamental Frequency > 9 hz
- Idealized as Single Span, Simply Supported Panels

24 foot spans result in ~12 inch thick or greater CLT floors.
SOM Timber Tower

CLT Floor Panel

CIP R.C. Beam

Precast R.C. Beam

Steel dowels

Exterior Spandrel Beam

Rigid Panel to Spandrel Connection
Alternative Vibration Criteria

Alternative: Use acceptance criteria which address low frequency floors and alternative support configurations.

*Calibration of dynamic modeling with physical testing valuable*
Alternative Vibration Criteria

SOM Timber Tower used:

AISC Design Guide 11, Velocity Criteria (Chapter 6)

Acceptance Criteria selected:

\[ \leq 16,000 \, \mu\text{in/sec} \text{ w/ moderate walking in living areas} \]
\[ \leq 8,000 \, \mu\text{in/sec} \text{ w/ slow walking pace in sleeping areas.} \]

AISC DG 11 suggests approximate velocity limit of human perception

\[ 8,000 \, \mu\text{in/sec at 8 Hz and above.} \]

AISC Design Guide 11 not for dynamic modeling of CLT floors

SOM Timber Tower Resulted in 8” Thick Floor
Connection Styles

Floor Panel to Floor Panel

- **Single Surface Spline**
- **Double Surface Spline**
- **Half Lap**

**Interior Spline**

CLT Floor → Screws → CLT Floor

Plywood or LVL
Connection Styles

Floor Panel to Wall

Platform Frame With Only Screws

Platform Frame with Double Brackets

Platform Frame with Single Brackets
Connection Styles

Floor Panel to Wall

- Self-tapping screws

- Platform Frame with Hidden Bracket

- Balloon Frame With Supporting Ledger

- Platform Frame with Bracket
US CLT Handbook

1. Introduction  9. Sound
2. Manufacturing  10. Enclosure
3. Structural  11. Environmental
4. Lateral  12. Lifting
5. Connections
6. DOL and Creep
7. Vibration
8. Fire

www.masstimber.com
CLT Floor Design: Strength, Deflection and Vibrations

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