CLT Shear Wall and Diaphragm Design in California

February 16, 2023

Presented by
Mike Romanowski, SE, WoodWorks

Apex Plaza / Courtesy William McDonough + Partner
The use of cross-laminated timber (CLT) panels for structural floor and roof assemblies has seen incredible growth in the U.S. over the past decade. However, CLT’s use as part of a seismic or wind force-resisting system—either as a shear wall or a diaphragm—has only recently been codified. Up until now, this has required the use of the Alternate Materials and Methods Request (AMMR) process for CLT lateral force-resisting system design. This presentation will introduce the new provisions for CLT shear wall and diaphragm design contained in the American Wood Council’s 2021 Special Design Provisions for Wind and Seismic (SDPWS), including detailing and design requirements, and the range of seismic response modification coefficients (e.g., “R” values) recognized for CLT shear wall design in ASCE 7-22.
Learning Objectives

1. Develop an understanding of the design challenges related to using CLT for wind and seismic resistance while meeting the intent if 2022 California Building Code (CBC).
2. Discuss the new provisions in the 2021 Special Design Provisions for Wind and Seismic (SDPWS) applicable to all lateral systems.
3. Understand the new detailing options and path to code acceptance of several CLT shear wall systems.
4. Review the engineering design requirements for using CLT floor and roof assemblies as horizontal diaphragms for wind and seismic resistance.
Glued-Laminated Timber
Beam & column orientation

Cross-Laminated Timber (CLT)
Solid sawn laminations

Cross-Laminated Timber (CLT)
SCL laminations

Photo: Freres Lumber

Photo: StructureCraft

Photo: LendLease

Photo: LEVER Architecture
What is CLT?

**Solid-sawn or Structural Composite Lumber (SCL) laminations**

- 3 layers minimum
- Each layer rotated 90° (sim. to plywood sheathing)
- Glued with structural adhesives

*All dimensions are approximate.
Check with specific manufacturers
CLT Gravity Systems
CLT was recognized in the 2019 CBC for gravity systems only
FLATWISE Panel Loading

Span in **MAJOR** Strength Direction
“Parallel” Direction
*Use subscript ‘0’ in Notation*

Span in **MINOR** Strength Direction
“Perpendicular” Direction
*Use subscript ‘90’ in Notation*

*Source: PRG 320-2018*
### Table A2

**ASD Reference Design Values for Basic CLT Grades and Layups (For Use in the U.S.)**

<table>
<thead>
<tr>
<th>CLT Grade</th>
<th>$t_p$ (in.)</th>
<th>Major Strength Direction</th>
<th>Minor Strength Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1</td>
<td>4 1/8 13/8 13/8 13/8 13/8</td>
<td>($F_{S}^\text{eff,0}$ (lbf/ft of width), $E$, $G$, $V_{p,0}$)</td>
<td>($F_{S}^\text{eff,90}$ (lbf/ft of width), $E$, $G$, $V_{p,90}$)</td>
</tr>
<tr>
<td>E2</td>
<td>6 7/8 13/8 13/8 13/8 13/8 13/8</td>
<td>10,400 440 0.92 2,480</td>
<td>1,370 81 1.2 1,490</td>
</tr>
<tr>
<td>E3</td>
<td>9 5/8 13/8 13/8 13/8 13/8 13/8 13/8</td>
<td>18,375 1,089 1.4 3,475</td>
<td>3,150 313 1.8 2,480</td>
</tr>
<tr>
<td>E4</td>
<td>4 1/8 13/8 13/8 13/8 13/8</td>
<td>4,525 115 0.46 1,490</td>
<td>160 3.1 0.61 495</td>
</tr>
<tr>
<td>E2</td>
<td>6 7/8 13/8 13/8 13/8 13/8 13/8</td>
<td>8,825 389 1.1 3,300</td>
<td>1,440 95 1.1 1,980</td>
</tr>
<tr>
<td>E3</td>
<td>9 5/8 13/8 13/8 13/8 13/8 13/8 13/8</td>
<td>15,600 963 1.6 4,625</td>
<td>3,300 364 1.7 3,300</td>
</tr>
<tr>
<td>E4</td>
<td>4 1/8 13/8 13/8 13/8 13/8</td>
<td>2,800 81 0.35 1,160</td>
<td>110 2.3 0.44 385</td>
</tr>
<tr>
<td>E3</td>
<td>6 7/8 13/8 13/8 13/8 13/8 13/8</td>
<td>6,400 311 0.69 1,930</td>
<td>955 61 0.87 1,160</td>
</tr>
<tr>
<td>E4</td>
<td>9 5/8 13/8 13/8 13/8 13/8 13/8 13/8</td>
<td>11,325 769 1.0 2,700</td>
<td>2,210 234 1.3 1,930</td>
</tr>
<tr>
<td>E2</td>
<td>4 1/8 13/8 13/8 13/8 13/8</td>
<td>4,525 115 0.50 1,820</td>
<td>140 3.4 0.62 605</td>
</tr>
<tr>
<td>E3</td>
<td>6 7/8 13/8 13/8 13/8 13/8 13/8</td>
<td>10,400 440 1.0 3,025</td>
<td>1,230 88 1.2 1,820</td>
</tr>
<tr>
<td>E4</td>
<td>9 5/8 13/8 13/8 13/8 13/8 13/8 13/8</td>
<td>18,400 1,089 1.5 4,225</td>
<td>2,850 338 1.9 3,025</td>
</tr>
</tbody>
</table>

**CLT Basic Grades**

- E1
- E2
- E3
- E4

**Panel Properties**

- Major Strength Direction
- Minor Strength Direction

**Layup**

- $F_{S}^\text{eff,0}$ (lbf/ft of width)
- $E$ (10^4 lbf/ft of width)
- $G$ (10^4 lbf/ft of width)
- $V_{p,0}$ (lbf/ft of width)
- $F_{S}^\text{eff,90}$ (lbf/ft of width)
- $E$ (10^4 lbf/ft of width)
- $G$ (10^4 lbf/ft of width)
- $V_{p,90}$ (lbf/ft of width)
3rd Party Product Qualification of CLT
**CLT Product Reports**

### Table 1. Allowable Design Properties for Lumber Laminations Used in SmartLam CLT (for Use in the U.S.)

<table>
<thead>
<tr>
<th>CLT Grade</th>
<th>$F_{L,0}$ (psi)</th>
<th>$E_0$ ($10^6$ psi)</th>
<th>$F_{L,0}$ (psi)</th>
<th>$F_{L,0}$ (psi)</th>
<th>$F_{L,0}$ (psi)</th>
<th>$F_{L,0}$ (psi)</th>
<th>$E_{50}$ ($10^6$ psi)</th>
<th>$F_{L,0}$ (psi)</th>
<th>$F_{L,0}$ (psi)</th>
<th>$F_{L,0}$ (psi)</th>
<th>$F_{L,0}$ (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SL-V4</td>
<td>775</td>
<td>1.1</td>
<td>350</td>
<td>1,000</td>
<td>135</td>
<td>45</td>
<td>775</td>
<td>1.1</td>
<td>350</td>
<td>1,000</td>
<td>135</td>
</tr>
</tbody>
</table>

For SI: 1 psi = 0.006895 MPa

(a) Tabulated values are allowable design values and not permitted to be increased for the lumber flat use or size 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 Tables 2 and 3).

### Table 2. Allowable Design Capacities for SmartLam Balanced CLT (for Use in the U.S.)

<table>
<thead>
<tr>
<th>CLT Grade</th>
<th>Layup #</th>
<th>Thickness (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></td>
<td></td>
<td></td>
<td>$F_{S,M,0}$ (bf/ft)</td>
<td>$E_{M,0}$ ($10^6$ lb/ft$^2$)</td>
</tr>
<tr>
<td>3-alt</td>
<td>4 1/8</td>
<td>13/8</td>
<td>13/8</td>
<td>1,800</td>
<td>74</td>
</tr>
<tr>
<td>4-maxx</td>
<td>5 1/2</td>
<td>13/8</td>
<td>13/8</td>
<td>2,925</td>
<td>161</td>
</tr>
<tr>
<td>5-alt</td>
<td>6 7/8</td>
<td>13/8</td>
<td>13/8</td>
<td>4,150</td>
<td>266</td>
</tr>
<tr>
<td>5-maxx</td>
<td>6 7/8</td>
<td>13/8</td>
<td>13/8</td>
<td>5,150</td>
<td>355</td>
</tr>
<tr>
<td>6-maxx</td>
<td>8 1/4</td>
<td>13/8</td>
<td>13/8</td>
<td>7,200</td>
<td>596</td>
</tr>
<tr>
<td>7-alt</td>
<td>9 5/8</td>
<td>13/8</td>
<td>13/8</td>
<td>7,325</td>
<td>707</td>
</tr>
</tbody>
</table>
EDGEWISE Panel Loading

Span in **MAJOR** Strength Direction

Span in **MINOR** Strength Direction

*Source: PRG 320-2018*
EDGEWISE Panel Loading

Span in **MAJOR** Strength Direction  
Span in **MINOR** Strength Direction

*Source: PRG 320-2018*
Shear Force Terminology

Through-the-Thickness Shear
In-plane Shear Forces

EDGEWISE Shear in PRG 320-2018

Source: PRG 320-2018

2018 NDS: $F_v(t_v)$
PRG 320-2018: $F_{v,e,0} t_p$ & $F_{v,e,90} t_p$

Source: 2018 NDS Commentary
CLT In-Plane (Edgewise) Strength

145 to 290 PSI Edgewise Shear Capacity

= 1.7 to 3.5 kips/ft (ASD)

*per inch of thickness*

Consult with manufacturers for values

Multiply by \( Cd = 1.6 \)

for short term ASD strength

**CLT Panels** can have > 9 kips / ft in-plane shear capacity
Where wood lateral system requirements are referenced – No CLT

Where seismic (“R” values) and wind systems are referenced – No CLT

CLT lateral systems (including “R” values for shear wall design) were not referenced in the 2019 CBC
CLT lateral systems from the 2021 SDPWS (not “R” values for shear wall design) are referenced in the 2022 CBC.
2021 Special Design Provisions for Wind and Seismic

Top Changes Relevant to CLT Lateral Systems:
- New unified nominal shear capacity
- New CLT Shear Wall requirements
- New CLT Diaphragm requirements

View for free at awc.org
Top Changes Relevant to CLT Lateral Systems:
- New unified nominal shear capacity
- New CLT Shear Wall requirements
- New CLT Diaphragm requirements

View for free at awc.org
For Wood Structural Panel (WSP) shear walls and diaphragms, the 2015 SDPWS has two nominal shear capacities:

- $\nu_s$ Nominal shear capacity for seismic loads
- $\nu_w$ Nominal shear capacity for wind loads

The 2021 SDPWS has one nominal shear capacity for both wind and seismic loads (for all systems such as WSP and CLT):

- $\nu_n$ Nominal shear capacity
To calculate the ASD or LRFD shear capacity, the 2021 SDPWS has different reduction factors for wind and seismic.

<table>
<thead>
<tr>
<th>Loading</th>
<th>ASD Design Capacity $v_n/\Omega_D$</th>
<th>LRFD Design Capacity $\phi_Dv_n$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seismic</td>
<td>$v_n/2.8$</td>
<td>$0.50v_n$</td>
</tr>
<tr>
<td>Wind</td>
<td>$v_n/2.0$</td>
<td>$0.80v_n$</td>
</tr>
</tbody>
</table>

Source: 2021 SDPWS Section 4.1.4
CLT Shear Wall Design
CLT Shear Wall Design

Denver University Burwell Center for Career Achievement Photo Credit: WoodWorks
Top Changes Relevant to CLT Lateral Systems:
- New unified nominal shear capacity
- New CLT Shear Wall requirements
- New CLT Diaphragm requirements

View for free at awc.org
2021 SDPWS – CLT Shear Wall requirements

Section View
- CLT Wall
- CLT Floor
- Floor or Foundation
- Floor or Roof

Floor or Roof
- Above Wall
- Below Wall

Elevation View
-applied load $v_u$
2021 SDPWS – CLT Shear Wall requirements

Applied load $v_u$
2021 SDPWS – CLT Shear Wall requirements

- CLT Floor
- CLT Wall
- Floor or Roof
  - Above Wall
- Floor or Foundation
  - Below Wall

Section View

applied load $v_u$

Elevation View
2021 SDPWS – CLT Shear Wall requirements

Section View

Elevation View

applied load $v_u$
2021 SDPWS – CLT Shear Wall requirements

Panel to Panel Connection

0.105” ASTM A653 Grade 33 Steel
(8) 16d box nails to each wall panel
3.5” long x 0.135”Ø shank with 0.344” Ø head

Panel to Platform Connection

Same steel plate material and nails plus
(2) 5/8” Ø bolts or lag screws to roof, floor or foundation
**Panel to Platform Connection**

**Nominal shear capacity of connector**

\[ \nu_n = 2605 \ C_G \ [\text{lbs}] \text{ per angle connector} \]

- \( C_G \) adjusts for specific gravity, \( G \) of CLT
- \( C_G = 1.0 \) for \( G \geq 0.42 \)
- \( = 0.86 \) for \( G = 0.35 \)
- \( = 1.0 - 2 \ (0.42-G) \) for \( 0.42 > G > 0.35 \)

Nominal unit shear capacity:

\[ \nu_n = n \ (2605 / b_s) \ C_G \ [\text{lbs/ft}] \]
2021 SDPWS – CLT Shear Wall requirements

CLT Shear Walls

- Platform or balloon-framed
  - Not meeting 2021 SDPWS Appendix B
  - Seismic Design Category A or B only
    (2021 SDPWS 4.6.3)

- Platform-framed only
  - Meeting 2021 SDPWS Appendix B
    - Panel aspect ratios
      \[ 2 \leq h/b_s \leq 4 \]
    - Shear resistance provided by high aspect ratio panels only
      (2021 SDPWS B.3.7)
    - Panel aspect ratios
      \[ h/b_s = 4 \]
What “R” value can I use?
2021 SDPWS – “R” Values for CLT Shear Walls

(platform or balloon framed)

CLT Shear Walls
not meeting 2021 SDPWS Appendix B

“R” = 1.5

C_d=1.5, Ω_o=2.5, max. ht.=65’
(2021 SDPWS 4.6.3)

(platform-framed only)

CLT Shear Walls
meeting 2021 SDPWS Appendix B

Panel aspect ratios
2 ≤ h/b_s ≤ 4

“R” = 3.0

C_d=3.0, Ω_o=3.0, max. ht.=65’
(ASCE 7-22)

Panel aspect ratios
h/b_s = 4

“R” = 4.0

C_d=4.0, Ω_o=3.0, max. ht.=65’
(ASCE 7-22)

Cd=1.5, Ω_o=2.5, max. ht.=65’
(2021 SDPWS 4.6.3)
CLT in the 2025 CBC (Lateral)

Now with CLT shear wall and diaphragm requirements

Will have “R” values for CLT shear walls

CLT lateral systems will be fully recognized in the 2025 CBC
CLT Post-Tensioned Rocking Shear Wall System Tests

Source: S. PEI et al. http://nheritallwood.mines.edu/
CLT Diaphragm Design
Option 1: Separate diaphragm element over CLT
(1A) Structural concrete topping

Careful detailing required to provide adequate load path, minimum rebar cover, etc.
CLT Horizontal Diaphragm Strategies (pre-2022 CBC)

Option 1: Separate diaphragm element over CLT (1B) Wood Structural Panel (WSP) topping

Classify as a blocked WSP diaphragm per 2015 SDPWS 4.2.7.1.1
Option 2: CLT as the diaphragm via the AMMR process (principals of engineering)

Cementitious topping as needed

CLT deck as the diaphragm

CLT diaphragms were not recognized in the 2019 CBC and Referenced Standards
Top Changes Relevant to CLT Lateral Systems:
- New unified nominal shear capacity
- New CLT Shear Wall requirements
- New CLT Diaphragm requirements

View for free at awc.org
CLT Diaphragms

Strength of connections (covered by NDS and proprietary fastener Evaluation Reports) governs design.

Strength of CLT should never govern.
2021 Special Design Provisions for Wind and Seismic

4.5 Cross-Laminated Timber (CLT) Diaphragms

4.5.1 Application Requirements

CLT diaphragms shall be permitted to be used to resist lateral forces provided the deflection in the plane of the diaphragm, as determined by calculations, tests, or analogies drawn therefrom, does not exceed the maximum permissible deflection limit of attached load distributing or resisting elements. Permissible deflection shall be that deflection that will permit the diaphragms and any attached elements to maintain their structural integrity and continue to support their prescribed loads as determined by the applicable building code or standard.

4.5.2 Deflection

CLT diaphragm deflection shall be determined using principles of engineering mechanics.

4.5.3 Unit Shear Capacity

CLT diaphragms shall be designed in accordance with principles of engineering mechanics using design values for wood members and connections in accordance with NDS provisions.

The nominal unit shear capacity, $\tau_{0}$, of CLT diaphragms shall be based on the nominal shear capacity for dowel-type fastener connections used to transfer diaphragm shear forces, as calculated per 4.5.4, Item 1. ASD allowable shear capacity or LRFD factored shear resistance for the CLT diaphragm and diaphragm shear connections shall be determined in accordance with 4.1.1.

4.5.4 Additional CLT Diaphragm Design Requirements

CLT diaphragms shall meet the following additional requirements:

1. The nominal shear capacity for dowel-type fastener connections used to transfer diaphragm shear forces between CLT panels and between CLT panels and diaphragm boundary elements (chords and collectors) shall be taken as $4.52\sigma_{d}$, where $2\sigma_{d} = Z$ multiplied by all applicable NDS adjustment factors except $C_{d}$, $R_{d}$, $G$, and $I$, and $Z$ shall be controlled by Mode III or Mode IV fasteners yielding in accordance with NDS 12.3.1.

2. Connections used to transfer diaphragm shear forces shall not be used to resist diaphragm tension forces.

3. Wood elements, steel parts, and wood or steel chord splice connections shall be designed for 2.0 times the diaphragm forces associated with the shear forces induced from the design loads.

Exceptions:

1. Wood elements and wood splice connections shall be permitted to be designed for 1.5 times the diaphragm forces associated with the shear forces induced by the wind design loads.

2. Where dowel-type fasteners are used in chord splice connections and the connection is controlled by Mode III or Mode IV fastener yielding in accordance with NDS 12.3.1, fasteners in the connection shall be permitted to be designed for 1.5 and 1.0 times the diaphragm forces associated with the shear forces induced by the prescribed seismic and wind design loads, respectively.

Diaphragm chord elements and chord splice connections using materials other than wood or steel shall be designed using provisions in NDS 1.4.
24’ x 24’ CLT Diaphragm Test with Plywood Spline Joints by AWC

Strong and Stiff Panels

Diaphragm behavior controlled by connections
2021 Special Design Provisions for Wind and Seismic

4.5 Cross-Laminated Timber (CLT) Diaphragms

4.5.1 Application Requirements

CLT diaphragms shall be permitted to be used to resist lateral forces provided the deflection in the plane of the diaphragm, as determined by calculations, tests, or analogies drawn therefrom, does not exceed the maximum permissible deflection limit of attached load carrying or resisting elements. Permissible deflections shall be that deflection that will permit the diaphragm and any attached elements to maintain their structural integrity and continue to support their prescribed loads as determined by the applicable building code or standard.

4.5.2 Deflection

CLT diaphragm deflection shall be determined using principles of engineering mechanics.

4.5.3 Unit Shear Capacity

CLT diaphragms shall be designed in accordance with design procedures using design values for wind and seismic loads and connections in accordance with NDS provisions.

The nominal unit shear capacity, $u$, of CLT diaphragms shall be based on the nominal shear capacity for dowel-type fastener connections used to transfer diaphragm shear forces, as calculated per 4.5.4, Item 1. ASD allowable shear capacity or LRFD factored shear resistance for the CLT diaphragms and diaphragm shear connections shall be determined in accordance with 4.1.1.

4.5.4 Additional CLT Diaphragm Design Requirements

CLT diaphragms shall meet the following additional requirements:

1. The nominal shear capacity for dowel-type fastener connections used to transfer diaphragm shear forces between CLT panels and between CLT panels and diaphragm boundary elements (chords and collectors) shall be taken as $4.5Z^*$, where $Z^*$ is $Z$ multiplied by all applicable NDS adjustment factors except $C_D$, $K_F$, $\phi$, and $\lambda$; and $Z$ shall be controlled by Mode III or Mode IV fastener yielding in accordance with NDS 12.3.1.
Generic CLT Floor/Roof Diaphragm

- Typical CLT Panel
- Joists not at panel edges

- Columns
- Girders
- Joists
- CLT Panels
- Shear Walls
Generic CLT Floor/Roof Diaphragm

Collector

Chord

Collector

Shear Zone

Chord

Lateral Load
Generic CLT Floor/Roof Diaphragm

Shear Transfer Details:
- a – panel to panel
- b – panel to panel over beam
- c – panel to wall/collector
- d – panel to wall/chord
- e – shear in panel

Other:
- z – chord (and splice)
- y – collector (and splice)
CLT Diaphragm Shear Transfer Connections

Lateral Load

Chord

Diaphragm Shear, \( v \)

Collector

Shear Transfer Details:
- a – panel to panel
- b – panel to panel over beam
- c – panel to wall/collector
- d – panel to wall/chord
- e – shear in panel

Other:
- z – chord (and splice)
- y – collector (and splice)
Diaphragm shear transfer connections at CLT panel edges:

- Use dowel-type fasteners in shear (nails, screws, bolts)
- Yield Mode III or IV per NDS 12.3.1 must control capacity
Connection Yield Modes Per the NDS

Single Shear Connections

- Mode $I_m$
- Mode $I_s$
- Mode II
- Mode $III_m$

Double Shear Connections

- Mode $III_s$
- Mode IV

“m” denotes main member, “s” denotes side member
Panel to Panel Connection Styles

Top Surface Spline

Source: Simpson Strong-Tie
New version of slide
Scott Breneman, 3/7/2017
Panel to Panel Connection Styles

Half-Lap

Source: Simpson Strong-Tie
Nominal capacity of CLT diaphragm shear transfer connection fastener:

\[ Z_n = 4.5 \ Z^* \]

Where \( Z^* \) is reference lateral capacity \( Z \) from NDS multiplied by all applicable factors except \( C_D, K_F, \phi, \lambda = 1.0 \)

Source: 2021 SDPWS 4.5.4(1) and 2018 NDS Table 11.3.1
### Table 11.3.1  Applicability of Adjustment Factors for Connections

<table>
<thead>
<tr>
<th>Dowel-type Fasteners (e.g. bolts, lag screws, wood screws, nails, spikes, drift bolts, &amp; drift pins)</th>
<th>ASD Only</th>
<th>ASD and LRFD</th>
<th>LRFD Only</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Load Duration Factor</td>
<td>Wet Service Factor</td>
<td>Temperature Factor</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ Z^* = Z \times \begin{bmatrix} C_M \ C_t \ C_g \ C_\Delta \ - \ C_{eg} \ - \ 1.0 \ C_{tn} \end{bmatrix} \]

Also 1.0 for CLT Diaphragm Shear Transfer Connections

Source 2021 SDPWS 4.5.4(1) and 2018 NDS Table 11.3.1
Other CLT Diaphragm Components

Shear Transfer Details:
- a – panel to panel
- b – panel to panel over beam
- c – panel to wall/collector
- d – panel to wall/chord
- e – shear in panel

Other:
- z – chord (and splice)
- y – collector (and splice)

Diaphragm Shear, v

Lateral Load

Chord

Collector
4.5 Cross-Laminated Timber (CLT) Diaphragms

4.5.1 Application Requirements

CLT diaphragms shall be permitted to be used to resist lateral forces provided the deflection in the plane of the diaphragm, as determined by calculations, tests, or analogies drawn therefrom, does not exceed the maximum permissible deflection limit of attached load distributing or resisting elements. Permissible deflection shall be that deflection that will permit the diaphragm and any attached elements to maintain their structural integrity and continue to support their prescribed loads as determined by the applicable building code or standard.

4.5.2 Deflection

CLT diaphragm deflection shall be determined using principles of engineering mechanics.

4.5.3 Unit Shear Capacity

CLT diaphragms shall be designed in accordance with principles of engineering mechanics using design values for wood members and connections in accordance with NDS provisions.

The nominal unit shear capacity, \( v \), of CLT diaphragms shall be based on the nominal shear capacity for doweled fastener connections used to transfer diaphragm shear forces, as calculated per 4.5.4, Item 1. ASD allowable shear capacity or LRFD factored shear resistance for the CLT diaphragms and diaphragm connections shall be determined in accordance with 4.1.1.

Diaphragm chord elements and chord splice connections using materials other than wood or steel shall be designed using provisions at NDS 1.4.

4.5.4 Additional CLT Diaphragm Design Requirements

CLT diaphragms shall meet the following additional requirements:

1. The nominal shear capacity for doweled fastener connections used to transfer diaphragm shear forces between CLT panels and between CLT panels and diaphragm boundary elements (chords and collectors) shall be taken as \( 4.52v \), where \( v = Z^* \) multiplied by all applicable NDS adjustment factors except \( Z, K, \) and \( Z \). and \( Z \) shall be controlled by Mode III or Mode IV fastener yielding in accordance with NDS 12.3.1, fasteners in the connection shall be permitted to be designed for 1.5 and 1.0 times the diaphragm forces associated with the shear forces induced by the prescribed seismic and wind design loads, respectively.

3. Wood elements, steel parts, and wood or steel chord splice connections shall be designed for 2.0 times the diaphragm forces associated with the shear forces induced from the design loads.

Exceptions:

1. Wood elements and wood splice connections shall be permitted to be designed for 1.5 times the diaphragm forces associated with the shear forces induced by the wind design loads.

2. Where doweled fasteners are used in chord splice connections and the connection is controlled by Mode III or Mode IV fastener yielding in accordance with NDS 12.3.1, fasteners in the connection shall be permitted to be designed for 1.5 and 1.0 times the diaphragm forces associated with the shear forces induced by the prescribed seismic and wind design loads, respectively.
Other CLT Diaphragm Components

Amplified Diaphragm Design Forces ≤ Design Capacity

\[ \gamma \cdot \nu \leq \nu' \]

\( \nu = \) wind or seismic force demand \hspace{1cm} \( \nu' = \) Adjusted capacity calculated per the NDS \textit{not} 4.5 Z*

\( \gamma = \)

- 2.0 for wood and steel components, except:
- 1.5 for wood members resisting wind loads
- 1.5 for chord splice connections controlled by Mode III or IV (seismic)
- 1.0 for chord splice connections controlled by Mode III or IV (wind)

\*See 2021 SPDWS 4.5.4 for the full information
Additional Resources
Additional Resources

Available from woodworks.org

https://www.woodworks.org/resources/clt-diaphragm-design-for-wind-and-seismic-resistance/
Additional Resources

Under Development By:

Funded By:
Questions? Ask us anything.

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