Structural Design: Member Sizing, Optimized Grids, Connections and Lateral Load Resistance

March 27, 2023

Presented by Anthony Harvey and Mike Romanowski
Early Design Decisions: Priming Mass Timber Projects for Success

Presented by:
Anthony Harvey, PE
Regional Director
OH, IN, KY, MI
Structural Grid

Grids & Spans

- Consider Efficient Layouts
- Repetition & Scale
- Manufacturer Panel Sizing
- Transportation

24'-0"
24'-2"
30'-0"
30'-0"
Structural Grid

Grids & Spans

- Consider Efficient Layouts
- Repetition & Scale
- Manufacturer Panel Sizing
- Transportation

24'-6" 26'-2" 24'-6" 40'-0"

14'-0"
26'-0"
26'-0"
26'-0"
Structural Grid

Member Sizes
• Impact of FRR on Sizing
• Impact of Sizing on Efficient Spans
• Consider connections – can drive member sizing

0 HR FRR: Consider 3-ply Panel
• Efficient Spans of 10-12 ft
• Grids of 20x20 (1 purlin) to 30x30 (2 purlins) may be efficient

Albina Yard, Portland, OR
20x20 Grid, 1 purlin per bay
3-ply CLT
Image: Lever Architecture
Structural Grid

Member Sizes
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0 HR FRR: Consider 3-ply Panel
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• Grids of 20x20 (1 purlin) to 30x30 (2 purlins) may be efficient

Platte Fifteen, Denver, CO
30x30 Grid, 2 purlins per bay
3-ply CLT
Image: JC Buck
Structural Grid

Member Sizes
• Impact of FRR on Sizing
• Impact of Sizing on Efficient Spans
• Consider connections – can drive member sizing

1 or 2 HR FRR: Likely 5-ply Panel
• Efficient spans of 14-17 ft
• Grids of 15x30 (no purlins) to 30x30 (1 purlin) may be efficient

First Tech Credit Union, Hillsboro, OR
12x32 Grid, One-Way Beams
5-ply (5.5”) CLT
Image: Swinerton
Structural Grid

Member Sizes
- Impact of FRR on Sizing
- Impact of Sizing on Efficient Spans
- Consider connections – can drive member sizing

1 or 2 HR FRR: Likely 5-ply Panel
- Efficient spans of 14-17 ft
- Grids of 15x30 (no purlins) to 30x30 (1 purlin) may be efficient

Clay Creative, Portland, OR
30x30 Grid, 1 purlin per bay
2x6 NLT
Image: Mackenzie
Key Early Design Decisions

Construction Type Early Decision Example

7-story building on health campus
• Group B occupancy, NFPA 13 sprinklers throughout
• Floor plate = 22,300 SF
• Total Building Area = 156,100 SF

MT Construction Type Options:
• If Building is < 85 ft
  • 7 stories of IV-C
  • 6 stories of IIIA or IV-HT over 1 story IA podium
• If Building is > 85 ft
  • 7 stories of IV-B
Key Early Design Decisions

Construction Type Early Decision Example

MT Construction Type Options:
• If Building is < 85 ft
  • 7 stories of IV-C
  • 6 stories of IIIA or IV-HT over 1 story IA
• If Building is > 85 ft
  • 7 stories of IV-B

Implications of construction type choice in this example:
• FRR (2 hr vs 1 hr vs min sizes)
• Efficient spans & grid
• Exposed timber limitations
• Concealed spaces
• Cost
• And more…
Key Early Design Decisions

Construction Type Early Decision Example

MT Construction Type Options:

- If Building is < 85 ft
  - 7 stories of IV-C
  - 6 stories of IIIA or IV-HT over 1 story IA
- If Building is > 85 ft
  - 7 stories of IV-B

Implications of Type IV-C:

- 2 hr FRR, all exposed floor panels, beams, columns
- Likely will need at least 5-ply CLT / 2x6 NLT/DLT
- Efficient spans in the 14-17 ft range
- Efficient grids of that or multiples of that (i.e. 30x25, etc)
- No podium required
Key Early Design Decisions

Construction Type Early Decision Example

MT Construction Type Options:
• If Building is < 85 ft
  • 7 stories of IV-C
  • **6 stories of IIIA or IV-HT over 1 story IA**
• If Building is > 85 ft
  • 7 stories of IV-B

Implications of Type IIIA or IV-HT:
• 1 hr FRR or min. sizes
• Potential to use 3-ply or thin 5-ply CLT
• Efficient spans in the 10-12 ft range
• Efficient grids of that or multiples of that (i.e. 20x25, etc)
• 1 story Type IA podium required
Key Early Design Decisions

Construction Type Early Decision Example

MT Construction Type Options:
• If Building is < 85 ft
  • 7 stories of IV-C
  • 6 stories of IIIA or IV-HT over 1 story IA
• If Building is > 85 ft
  • **7 stories of IV-B**

Implications of Type IV-B:
• 2 hr FRR, mostly protected floor panels, beams, columns
• Exposed areas: likely 5-ply / 2x6 NLT/DLT
• Protected areas: potential for thinner panels
• Choose 1 system throughout or multiple systems?
• Does grid vary or consistent throughout?
• No podium required
Key Early Design Decisions

Why so much focus on panel thickness?
Key Early Design Decisions

Typical MT Package Costs

- Project Overhead: 7%
- Labor: 14%
- Material: 15%
- Equipment: 64%

Source: Swinerton
Key Early Design Decisions

Panels are the biggest part of the biggest piece of the cost pie

- Material: 64%
- Project Overhead: 7%
- Labor: 15%
- Equipment: 14%

Source: Swinerton
Key Early Design Decisions

Panel volume usually 65-80% of MT package volume

Type IIIA option 1
1-hr FRR
Purlin: 5.5”x28.5”
Girder: 8.75”x33”
Column: 10.5”x10.75”
Floor panel: 5-ply

Glulam volume = 118 CF (22% of MT)
CLT volume = 430 CF (78% of MT)
Total volume = 0.73 CF / SF
Key Early Design Decisions

Panel volume usually 65-80% of MT package volume

Type IIIA option 2
1-hr FRR
Purlin: 5.5”x24”
Girder: 8.75”x33”
Column: 10.5”x10.75”
Floor panel: 5-ply

Glulam volume = 123 CF (22% of MT)
CLT volume = 430 CF (78% of MT)
Total volume = 0.74 CF / SF

Cost considerations: One additional beam (one additional erection pick), 2 more connections
Key Early Design Decisions

Panel volume usually 65-80% of MT package volume

**Type IV-HT**

0-hr FRR (min sizes per IBC)
- Purlin: 5.5”x24” (IBC min = 5”x10.5”)
- Girder: 8.75”x33” (IBC min = 5”x10.5”)
- Column: 10.5”x10.75” (IBC min = 6.75”x8.25”)
- Floor panel: 3-ply (IBC min = 4” CLT)

Glulam volume = 120 CF (32% of MT)
CLT volume = 258 CF (68% of MT)
Total volume = 0.51 CF / SF

Source: Fast + Epp, Timber Bay Design Tool
Key Early Design Decisions

Panel volume usually 65-80% of MT package volume

Type IV-HT
0-hr FRR (min sizes per IBC)
Purlin: 5.5”x24” (IBC min = 5”x10.5”)
Girder: 8.75”x33” (IBC min = 5”x10.5”)
Column: 10.5”x10.75” (IBC min = 6.75”x8.25”)
Floor panel: 3-ply (IBC min = 4” CLT)
Glulam volume = 120 CF (32% of MT)
CLT volume = 258 CF (68% of MT)
Total volume = 0.51 CF / SF

Note that if size of building had permitted Type IIIIB, member sizing would essentially be the same as IV-HT. But there are other nuances between III and IV, we’ll cover that later…

Source: Fast + Epp, Timber Bay Design Tool
Key Early Design Decisions

Panel volume usually 65-80% of MT package volume

Type IV-C
2-hr FRR
Purlin: 8.75”x28.5”
Girder: 10.75”x33”
Column: 13.5”x21.5”
Floor panel: 5-ply

Glulam volume = 183 CF (30% of MT)
CLT volume = 430 CF (70% of MT)
Total volume = 0.82 CF / SF

Source: Fast + Epp, Timber Bay Design Tool
Key Early Design Decisions

Which is the most efficient option?

<table>
<thead>
<tr>
<th></th>
<th>Timber Volume Ratio</th>
<th>Podium on 1st Floor?</th>
</tr>
</thead>
<tbody>
<tr>
<td>IIIA – Option 1</td>
<td>0.73 CF / SF</td>
<td>Yes</td>
</tr>
<tr>
<td>IIIA – Option 2</td>
<td>0.74 CF / SF</td>
<td>Yes</td>
</tr>
<tr>
<td>IV-HT</td>
<td>0.51 CF / SF</td>
<td>Yes</td>
</tr>
<tr>
<td>IV-C</td>
<td>0.82 CF / SF</td>
<td>No</td>
</tr>
</tbody>
</table>

A general rule of thumb for efficient mass timber fiber volume is no higher than 0.75 CF per SF. Ratios in the 0.85 to 1.0 CF / SF range tend to become cost prohibitive.
Key Early Design Decisions

Which is the most efficient option?

There are other impacts of constriction type selection (exterior walls, concealed spaces) that should be considered.

<table>
<thead>
<tr>
<th>Constriction Type</th>
<th>Timber Volume Ratio</th>
<th>Podium on 1st Floor?</th>
</tr>
</thead>
<tbody>
<tr>
<td>IIA – Option 1</td>
<td>0.73 CF / SF</td>
<td>Yes</td>
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<tr>
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<td>No</td>
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A general rule of thumb for efficient mass timber fiber volume is no higher than 0.75 CF per SF. Ratios in the 0.85 to 1.0 CF / SF range tend to become cost prohibitive.

Source: Fast + Epp, Timber Bay Design Tool
Key Early Design Decisions

NEW MASS TIMBER FLOOR VIBRATION DESIGN GUIDE

Worked office, lab and residential Examples

Covers simple and complex methods for bearing wall and frame supported floor systems
Key Early Design Decisions

Many ways to demonstrate connection fire protection: calculations, prescriptive NC, test results, others as approved by AHJ
Key Early Design Decisions

Steel hangers/hardware fully concealed within a timber-to-timber connection is a common method of fire protection.
Key Early Design Decisions

Connection FRR and beam reactions could impact required beam/column sizes

Photos: Simpson Strong-Tie
Key Early Design Decisions

2017 Glulam Beam to Column Connection Fire Tests under standard ASTM E119 time-temperature exposure
## Key Early Design Decisions

### Fire Test Results

<table>
<thead>
<tr>
<th>Test</th>
<th>Beam</th>
<th>Connector</th>
<th>Applied Load</th>
<th>FRR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8.75” x 18”</td>
<td>1 x Ricon S VS 290x80</td>
<td>3,905lbs (17.4kN)</td>
<td>1hr</td>
</tr>
<tr>
<td></td>
<td>(222mm x 457mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>10.75” x 24”</td>
<td>Staggered double Ricon S VS 200x80</td>
<td>16,620lbs (73.9kN)</td>
<td>1.5hrs</td>
</tr>
<tr>
<td></td>
<td>(273mm x 610mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>10.75” x 24”</td>
<td>1 x Megant 430</td>
<td>16,620lbs (73.9kN)</td>
<td>1.5hrs</td>
</tr>
<tr>
<td></td>
<td>(273mm x 610mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Key Early Design Decisions

Softwood Lumber Board

Glulam Connection Fire Test
Summary Report

Issue | June 5, 2017

Full Report Available at:
Key Early Design Decisions

Member to member bearing also commonly used, can avoid some/all steel hardware at connection
Key Early Design Decisions

Member to member bearing also commonly used, can avoid some/all steel hardware at connection

Style of connection also impacts and is impacted by grid layout and MEP integration
Key Early Design Decisions

MASS TIMBER CONNECTIONS INDEX
A library of commonly used mass timber connections with designer notes and information on fire resistance, relative cost and load-acity.

WoodWorks Index of Mass Timber Connections
Connections

Other connection design considerations:
- Structural capacity
- Shrinkage
- Constructability
- Aesthetics
- Cost
CLT Shear Wall and Diaphragm Design Under the 2021 SDPWS
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
EDGEWISE Panel Loading

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

*Source: PRG 320-2018*
CLT is recognized in the 2015 & 2018 International Building Code for gravity systems only
CLT Lateral Systems
EDGEWISE Panel Loading

Span in **MAJOR** Strength Direction

Span in **MINOR** Strength Direction

*Source: PRG 320-2018*
CLT in 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

\textbf{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) are not recognized in the 2015 & 2018 International Building Code
CLT lateral systems from the 2021 SDPWS (not “R” values for shear wall design) are referenced in the 2021 International Building Code
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 $\frac{v_n}{\Omega_D}$</th>
<th>LRFD Design Capacity $\phi_Dv_n$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seismic</td>
<td>$v_n/2.8$</td>
<td>$0.50 \ v_n$</td>
</tr>
<tr>
<td>Wind</td>
<td>$v_n/2.0$</td>
<td>$0.80 \ v_n$</td>
</tr>
</tbody>
</table>

Source: 2021 SDPWS Section 4.1.4
CLT Shear Wall Design
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

Elevation View

applied load $\nu_u$
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

\[ \mathcal{V}_n = 2605 \ C_G \ [\text{lbs}] \text{ per angle connector} \]

\( C_G \) adjusts for specific gravity, \( G \) of CLT

\[ C_G = 1.0 \quad \text{for } G \geq 0.42 \]
\[ = 0.86 \quad \text{for } G = 0.35 \]
\[ = 1.0 - 2(0.42 - G) \quad \text{for } 0.42 > G > 0.35 \]

Nominal unit shear capacity:

\[ \mathcal{V}_n = n \left( \frac{2605}{b_s} \right) C_G \ [\text{lbs/ft}] \]
**2021 SDPWS – CLT Shear Wall requirements**

(platform and balloon-framed)

**CLT Shear Walls**

not meeting Appendix B

Seismic Design Category A or B only
(SDPWS Section 4.6.3)

(panel-framed only)

**CLT Shear Walls**

meeting Appendix B

Shear resistance provided by high aspect ratio panels only (SDPWS Appendix B.3.7)

Panel aspect ratios

\[ 2 \leq \frac{h}{b_s} \leq 4 \]

Panel aspect ratios

\[ \frac{h}{b_s} = 4 \]
What “R” value can I use?
2021 SDPWS – “R” Values for CLT Shear Walls

(platform and balloon framed)

CLT Shear Walls
not meeting Appendix B

“R” = 1.5

\[ C_d = 1.5 \quad \Omega_o = 2.5 \]

(SDPWS Section 4.6.3)

(platform-framed only)

CLT Shear Walls
meeting Appendix B

Panel aspect ratios

\[ 2 \leq \frac{h}{b_s} \leq 4 \]

“R” = 3.0*

\[ C_d = 3.0 \quad \Omega_o = 3.0 \]

“R” = 4.0*

\[ C_d = 4.0 \quad \Omega_o = 3.0 \]

* ASCE 7-22
CLT lateral systems will be fully recognized in the 2024 International Building Code

2021 SDPWS

Now with CLT shear wall and diaphragm requirements

ASCE/SEI 7-22

Will have “R” values for CLT shear walls

2024 IBC
CLT Post-Tensioned Rocking Shear Wall System Tests

Source: S. PEI et al. http://nheritallwood.mines.edu/
CLT Diaphragm Design
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
Strength of connections (covered by NDS and proprietary fastener Evaluation Reports) governs design.

Strength of CLT should never govern.
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 shown therefore, does not exceed the maximum permissible deflection limit of attached load distributed 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 as accordance with NDS provisions.

The nominal unit shear capacity, \( \tau_s \), 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 4.5.4.1, 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 \( \tau_s \ast \), where \( \tau_s \ast \) is \( \tau_s \) multiplied by all applicable NDS adjustment factors except \( C_{H}, K_{p}, \gamma, \), and \( \lambda \), and \( \tau_s \ast \) shall be controlled by Mode IIs or Mode IV fastener yielding in accordance with NDS 12.3.1.
2. Connections used to transfer diaphragm shear forces shall not be used to resist diaphragm tensile 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 fasteners, 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.
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 allowable deflection limit of attached load bearing 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, \( v_u \), of CLT diaphragms shall be based on the nominal shear capacity for dowel-type fasteners 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 \( 4.5Z^* \), 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.
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
Diaphragm **shear transfer connections** at CLT panel edges:

- Use dowel-type fasteners in shear (nails, screws, bolts)
- Yield **Mode III**s or **IV** per NDS 12.3.1 must control capacity
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 reacting 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, \( v_n \), 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 connections) shall be taken as 4.52* where \( Z \) is \( Z \) multiplied by all applicable NDS adjustment factors except \( \xi, \eta, \gamma, \) and \( \lambda \), and \( Z \) shall be controlled by Mode III or Mode IV fastener yielding in accordance with NDS 12.3.1.

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

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.
Other CLT Diaphragm Components

Amplified Diaphragm Design Forces ≤ Design Capacity

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

\[ \nu = \text{wind or seismic force demand} \quad \nu' = \text{Adjusted capacity calculated per the NDS not 4.5 Z*} \]

\[ \gamma = \]

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

See 2021 SPDWS 4.5.4 for the full information
Available from woodworks.org

https://www.woodworks.org/resources/clt-diaphragm-design-for-wind-and-seismic-resistance/
Questions? Ask us anything.

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