Design of Mass Timber Diaphragms and the New CLT Diaphragm Design Guide

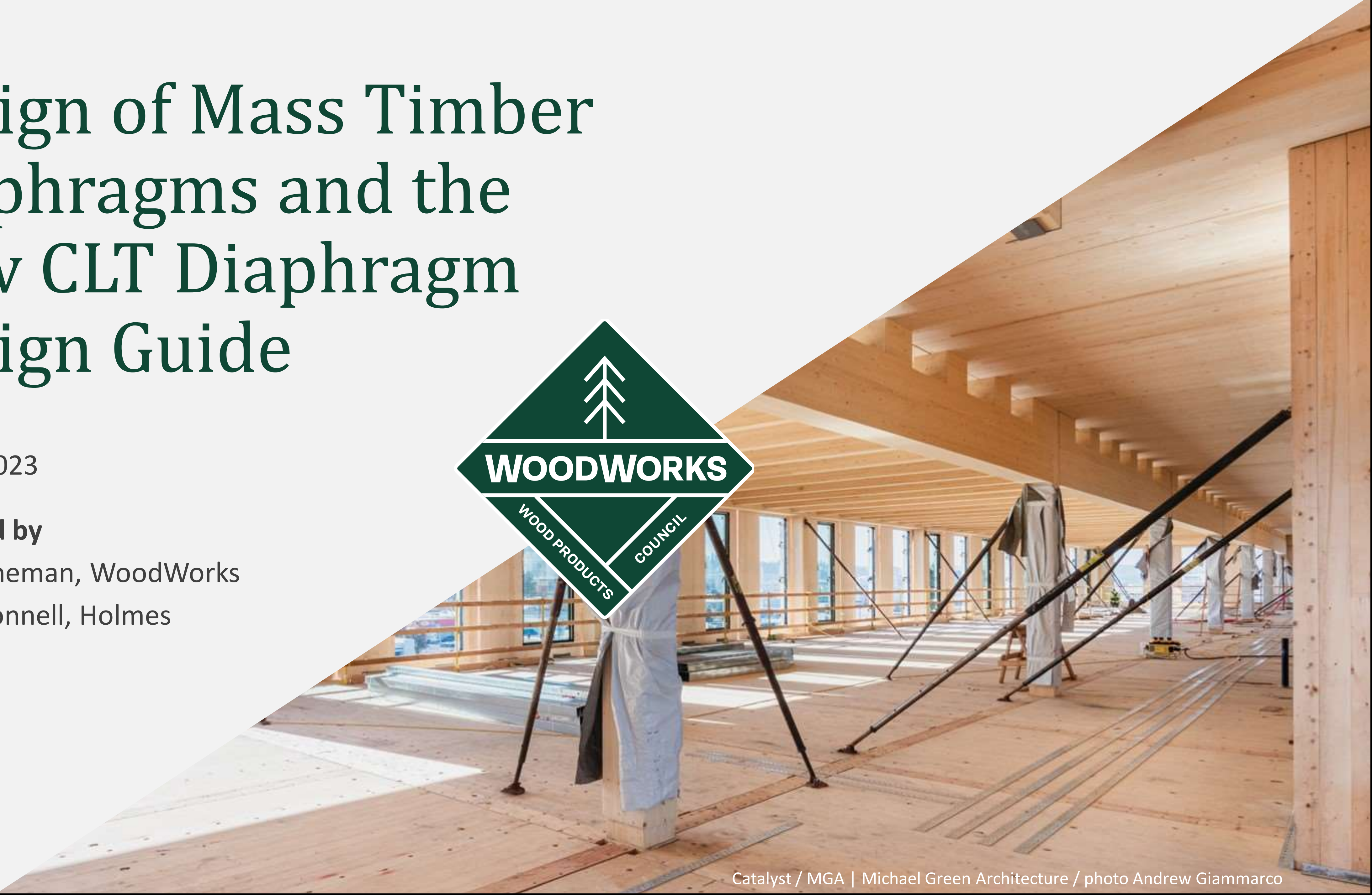
July 12, 2023

Presented by

Scott Breneman, WoodWorks

Eric McDonnell, Holmes

WOODWORKS
WOOD PRODUCTS COUNCIL



Catalyst / MGA | Michael Green Architecture / photo Andrew Giammarco

Background

Glue Laminated Timber (Glulam)
Beams & columns

Photo: StructureCraft

Cross-Laminated Timber (CLT)
Solid sawn laminations

Photo: LendLease

Cross-Laminated Timber (CLT)
SCL laminations

Photo: Freres Lumber

Photo: LEVER Architecture

Dowel-Laminated Timber (DLT)

Photo: StructureCraft

Nail-Laminated Timber (NLT)

Photo: Think Wood

Glue-Laminated Timber (GLT)

Plank orientation

Photo: StructureCraft

Photo: StructureCraft

Photo: Ema Peter

Photo: Manasc Isaac Architects/Fast + Epp

UMass Design Building

Amherst, MA

Photo Credit: Alex Schreyer

Virtuoso

Vancouver, BC

Image: Adera

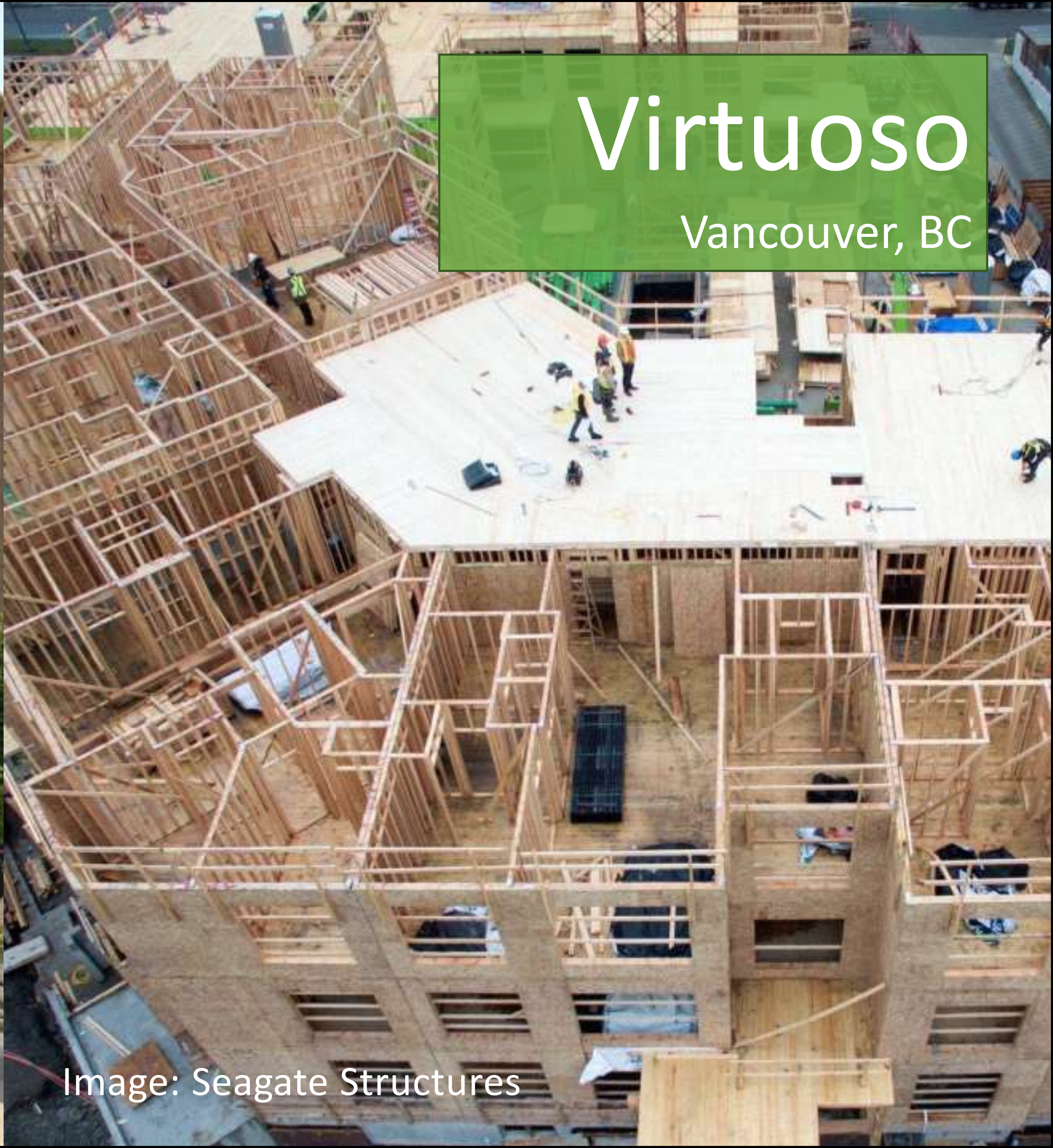
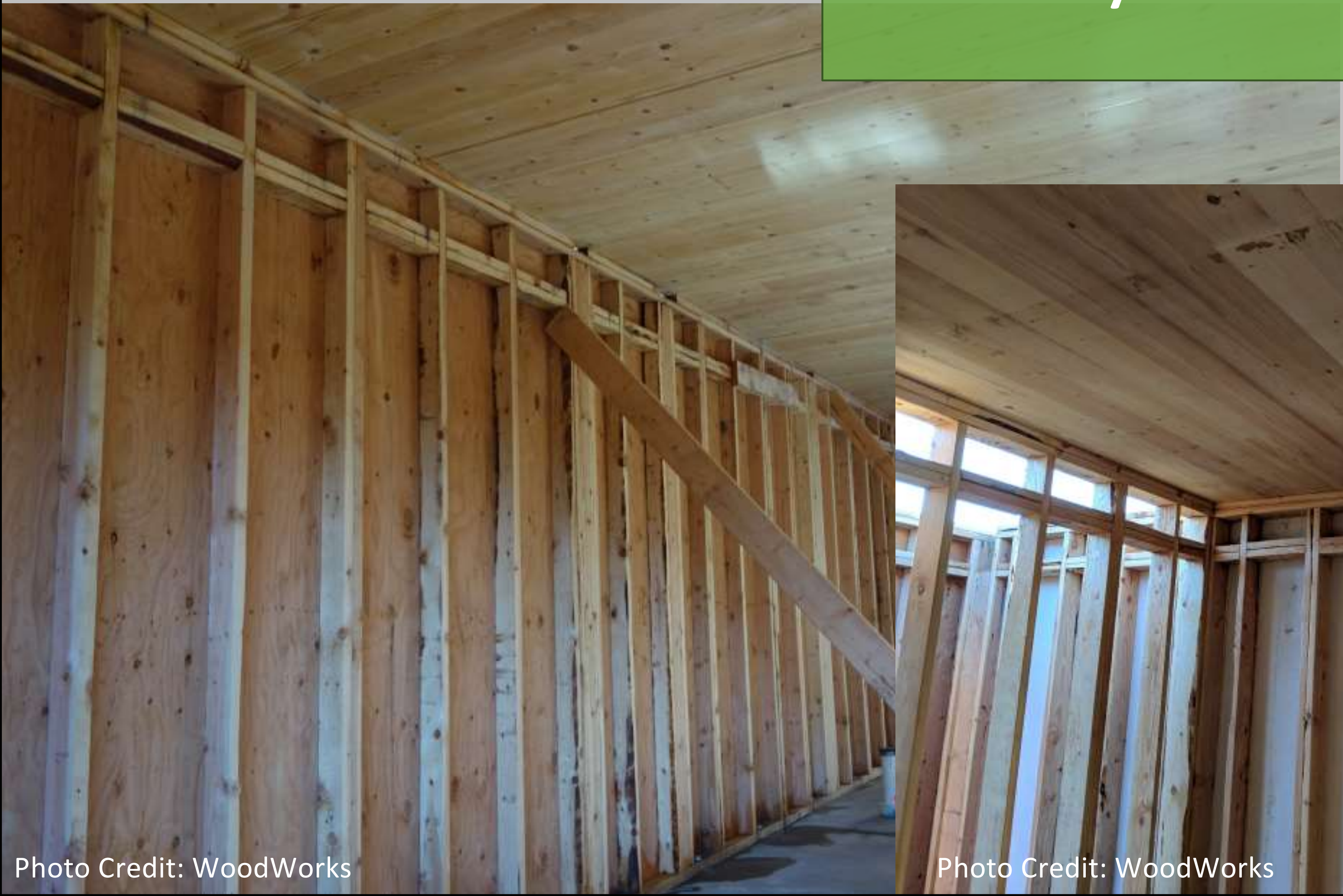


Image: Seagate Structures

Cheney Park Apartments

Cheney, WA

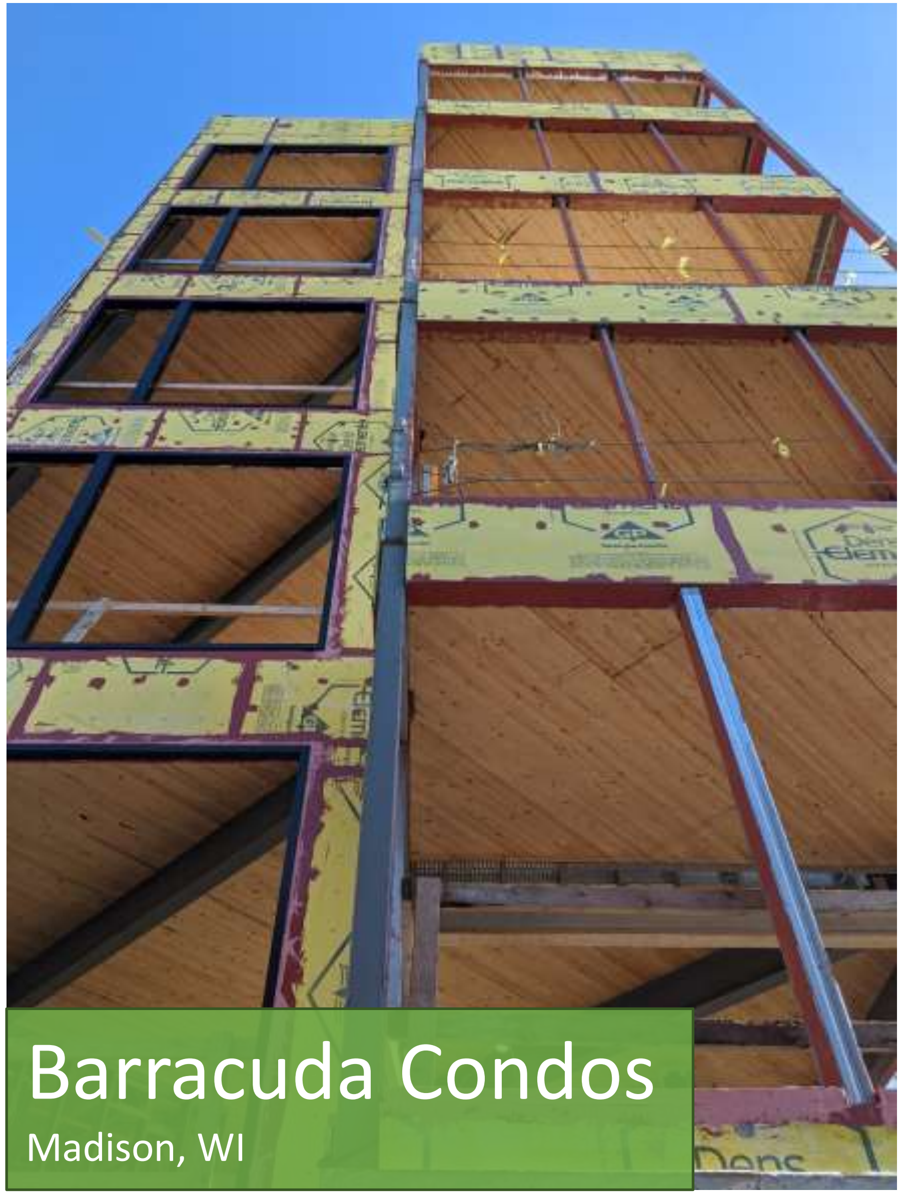


Cooley Landing Education Center

East Palo Alto, CA

Photo Credit: Michael O’Calahan

Hybrid Mass Timber and Steel Framing?



Barracuda Condos
Madison, WI

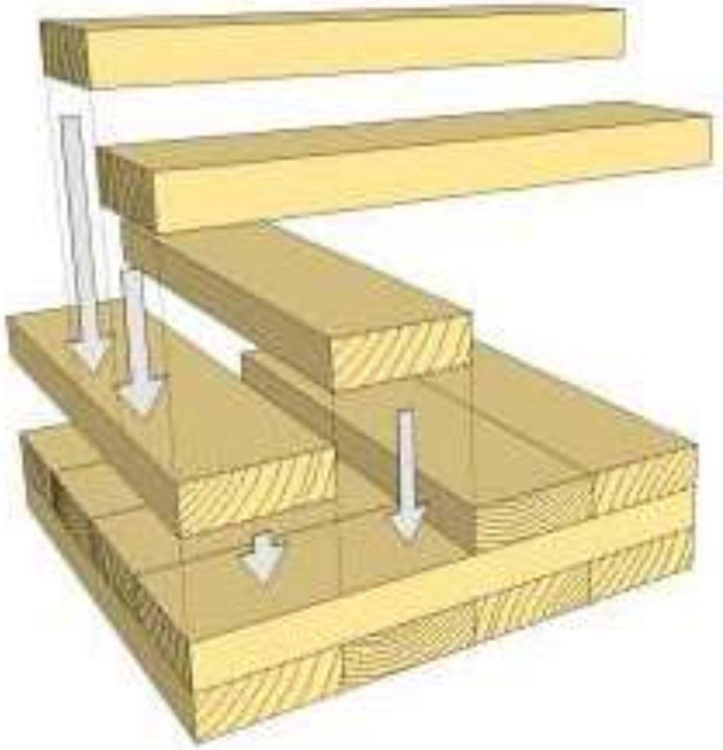
Photo Credit: WoodWorks

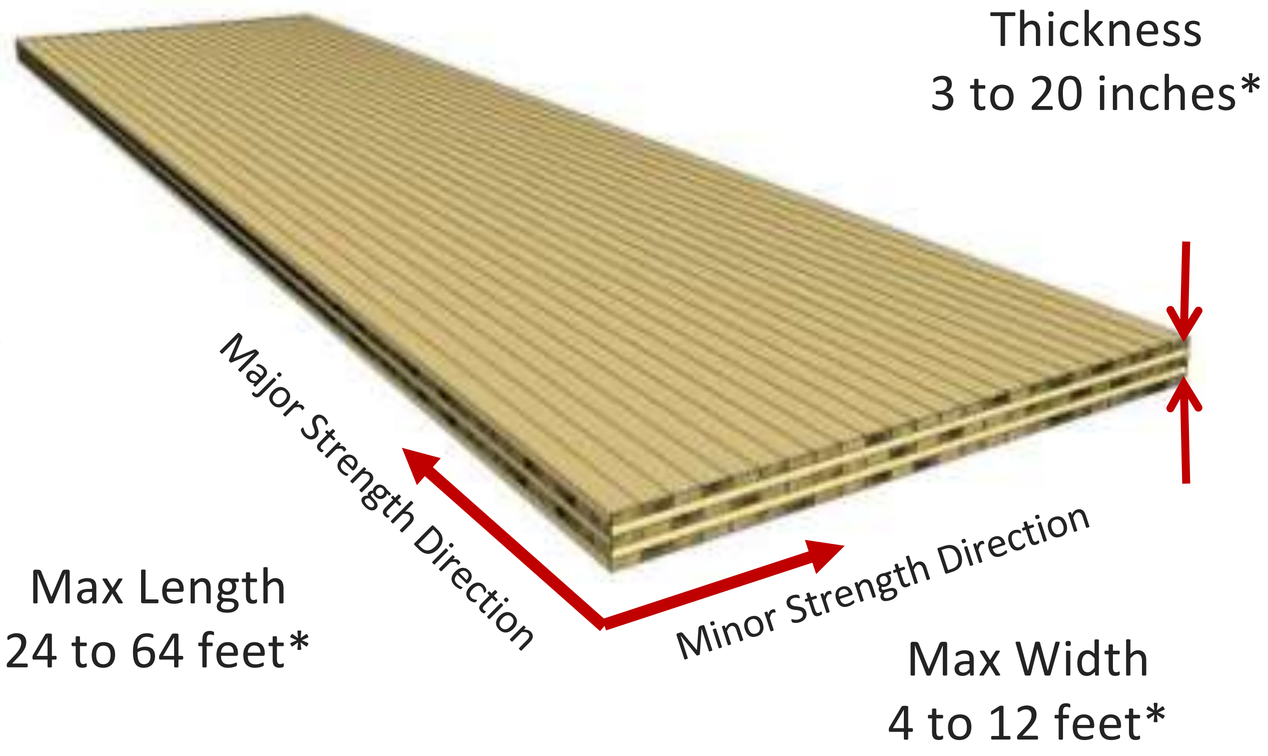
Brentwood Library

Brentwood, CA

What is CLT?

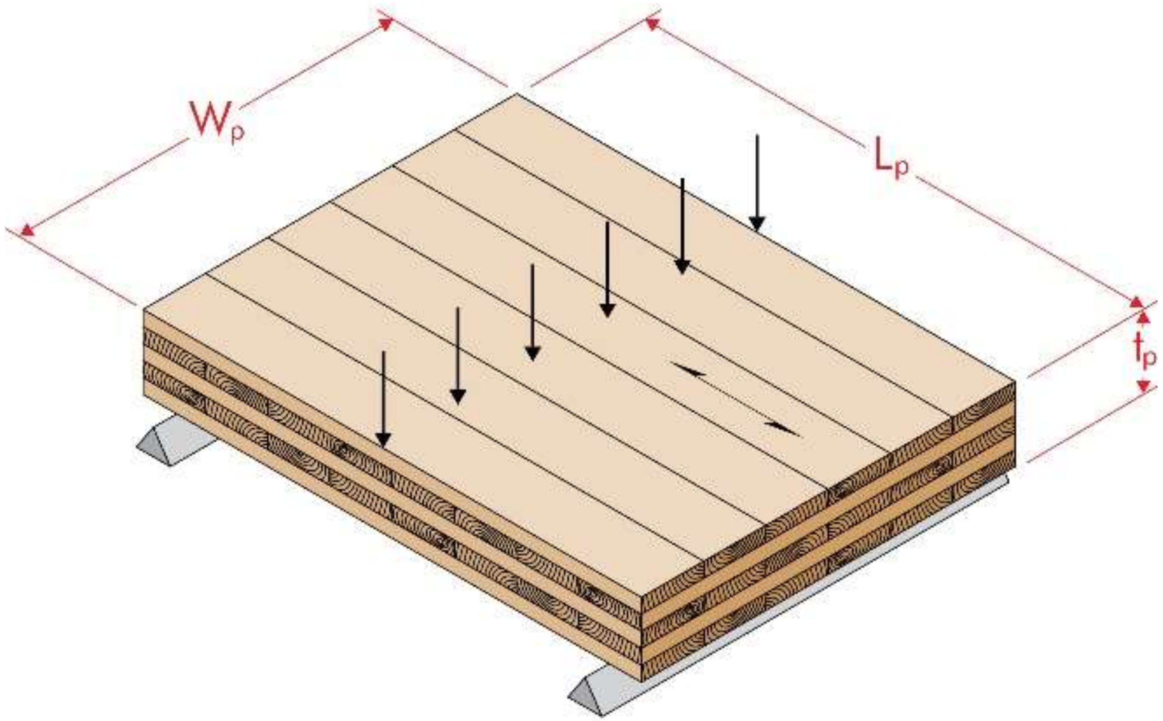
3+ layers of laminations
Solid Sawn or Structural Composite Lumber Laminations
Cross-Laminated Layup
Glued with Structural Adhesives

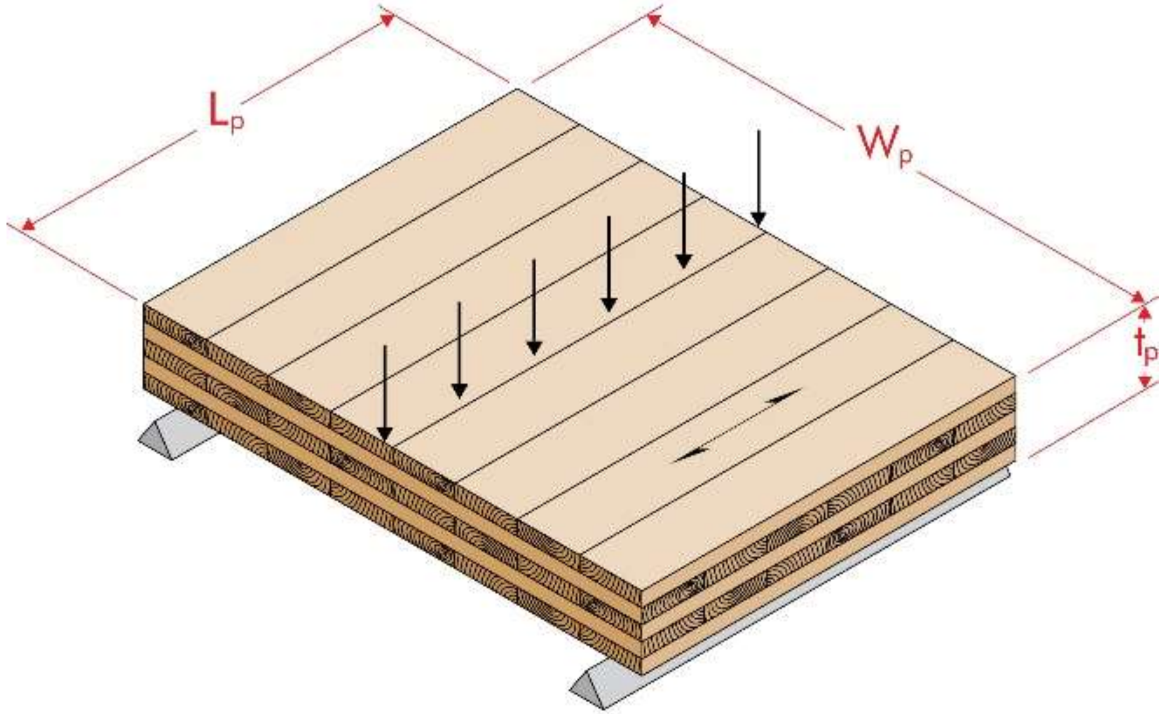




*All dimensions are approximate.
Consult with manufacturers

FLATWISE Panel Loading



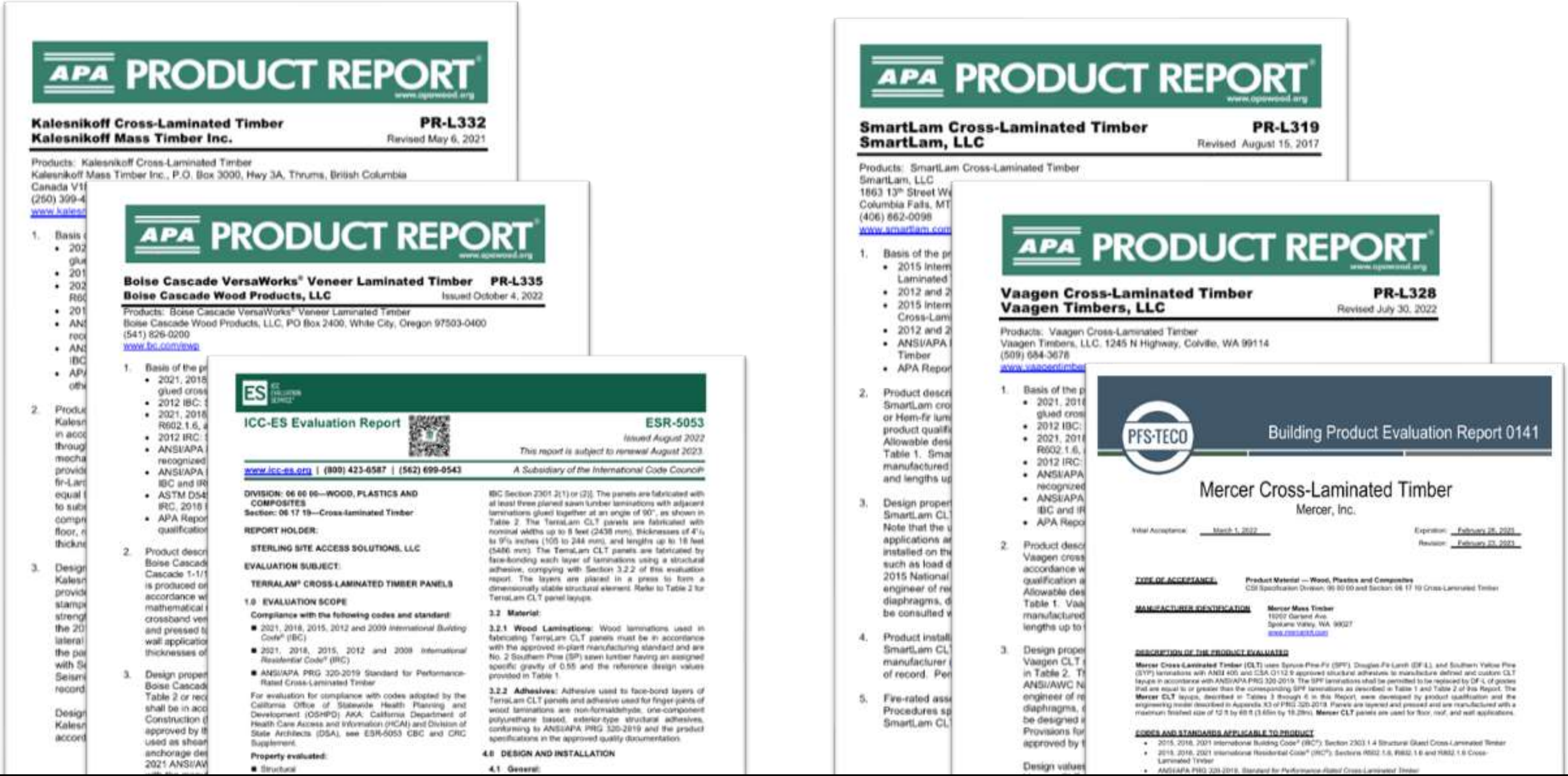


Span in MAJOR Strength Direction
“Parallel” Direction
Use subscript ‘0’ in Notation

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

Reference & Source: ANSI/APA PRG 320

3rd Party Product Qualification of CLT


APA PRODUCT REPORT
Kalesnikoff Cross-Laminated Timber — PR-L332
Kalesnikoff Mass Timber Inc. — Revised May 6, 2021
Products: Kalesnikoff Cross-Laminated Timber
Kalesnikoff Mass Timber Inc., P.O. Box 3000, Hwy 3A, Thrums, British Columbia

APA PRODUCT REPORT
Boise Cascade VersaWorks® Veneer Laminated Timber — PR-L335
Boise Cascade Wood Products, LLC — Issued October 4, 2022
Products: Boise Cascade VersaWorks® Veneer Laminated Timber
Boise Cascade Wood Products, LLC, PO Box 2400, White City, Oregon 97503-0400
(541) 826-0200
www.bc.com/ewp

ICC-ES Evaluation Report — ESR-5053
Issued August 2022
This report is subject to renewal August 2023.
www.icc-es.org | (800) 423-6587 | (562) 699-0543
A Subsidiary of the International Code Council®
DIVISION: 06 00 00—WOOD, PLASTICS AND COMPOSITES
Section: 06 17 19—Cross-laminated Timber
REPORT HOLDER:
STERLING SITE ACCESS SOLUTIONS, LLC
EVALUATION SUBJECT:
TERRALAM® CROSS-LAMINATED TIMBER PANELS
1.0 EVALUATION SCOPE

APA PRODUCT REPORT
SmartLam Cross-Laminated Timber — PR-L319
SmartLam, LLC — Revised August 15, 2017
Products: SmartLam Cross-Laminated Timber

APA PRODUCT REPORT
Vaagen Cross-Laminated Timber — PR-L328
Vaagen Timbers, LLC — Revised July 30, 2022
Products: Vaagen Cross-Laminated Timber
Vaagen Timbers, LLC, 1245 N Highway, Colville, WA 99114
(509) 684-3678

PFS·TECO
Building Product Evaluation Report 0141
Mercer Cross-Laminated Timber
Mercer, Inc.

CLT Product Reports

CLT Grade (basic or custom)

Layup

Panel Properties

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

CLT Grade	Major Strength Direction						Minor Strength Direction					
	$F_{b,0}$ (psi)	E_0 (10^6 psi)	$F_{t,0}$ (psi)	$F_{c,0}$ (psi)	$F_{v,0}$ (psi)	$F_{s,0}$ (psi)	$F_{b,90}$ (psi)	E_{90} (10^6 psi)	$F_{t,90}$ (psi)	$F_{c,90}$ (psi)	$F_{v,90}$ (psi)	$F_{s,90}$ (psi)
SL-V4	775	1.1	350	1,000	135	45	775	1.1	350	1,000	135	45

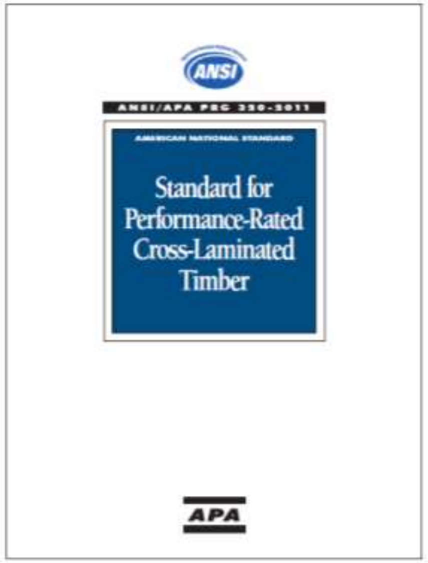
For SI: 1 psi = 0.006895 MPa

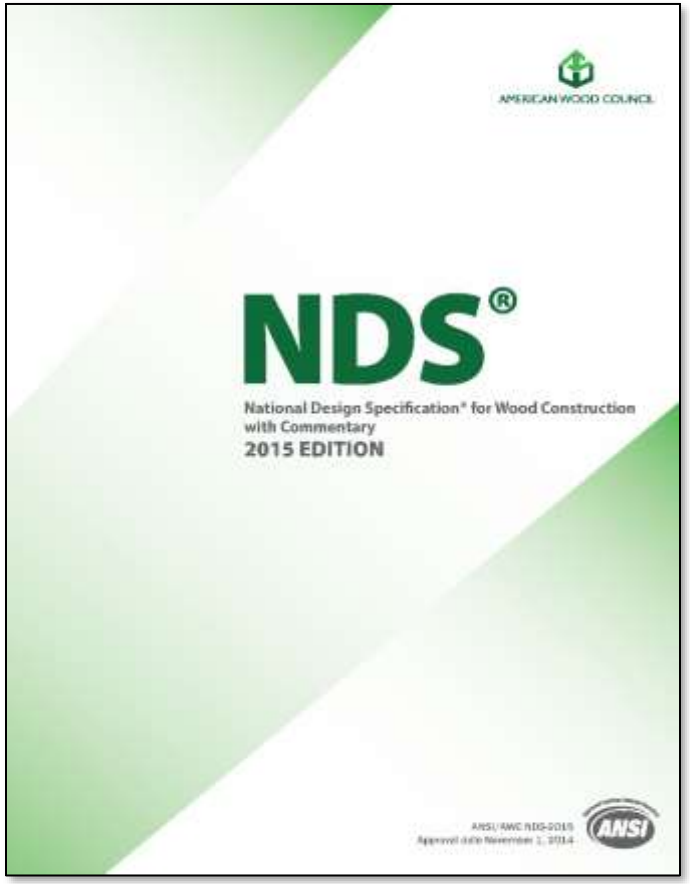
(a) Tabulated values are allowable design values and not permitted to be increased for the lumber flat use or size factor in accordance with the NDS. The design values shall be used in conjunction with the section properties provided by the CLT manufacturer based on the actual layup used in manufacturing the CLT panel (see Tables 2 and 3).

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

CLT Grade	Layup #	Thick-ness (in.)	Lamination Thickness (in.) in CLT Layup									Major Strength Direction				Minor Strength Direction			
			=	⊥	=	⊥	=	⊥	=	⊥	=	$F_bS_{eff,0}$ (lbf-ft/ft)	$EI_{eff,0}$ (10^6 lbf-in.²/ft)	$GA_{eff,0}$ (10^6 lbf/ft)	$V_{s,0}$ (lbf/ft)	$F_bS_{eff,90}$ (lbf-ft/ft)	$EI_{eff,90}$ (10^6 lbf-in.²/ft)	$GA_{eff,90}$ (10^6 lbf/ft)	$V_{s,90}$ (lbf/ft)
SL-V4[(b)]	3-alt	4 1/8	1 3/8	1 3/8	1 3/8							1,800	74	0.41	1,430	245	2.9	0.41	495
	4-maxx	5 1/2	1 3/8	1 3/8 x 2	1 3/8							2,925	161	0.49	1,740	975	23	0.85	990
	5-alt	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8					4,150	286	0.83	1,980	2,120	74	0.83	1,430
	5-maxx	6 7/8	1 3/8 x 2	1 3/8	1 3/8 x 2							5,150	355	1.4	2,460	245	2.9	0.86	495
	6-maxx	8 1/4	1 3/8 x 2	1 3/8 x 2	1 3/8 x 2							7,200	596	1.2	2,875	975	23	1.3	990
	7-alt	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8			7,325	707	1.2	2,500	4,825	283	1.2	1,960
	7-maxx	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8					[illegible]	[illegible]	1.7	3,200	2,120	74	1.3	1,430

Structural Design Standardization





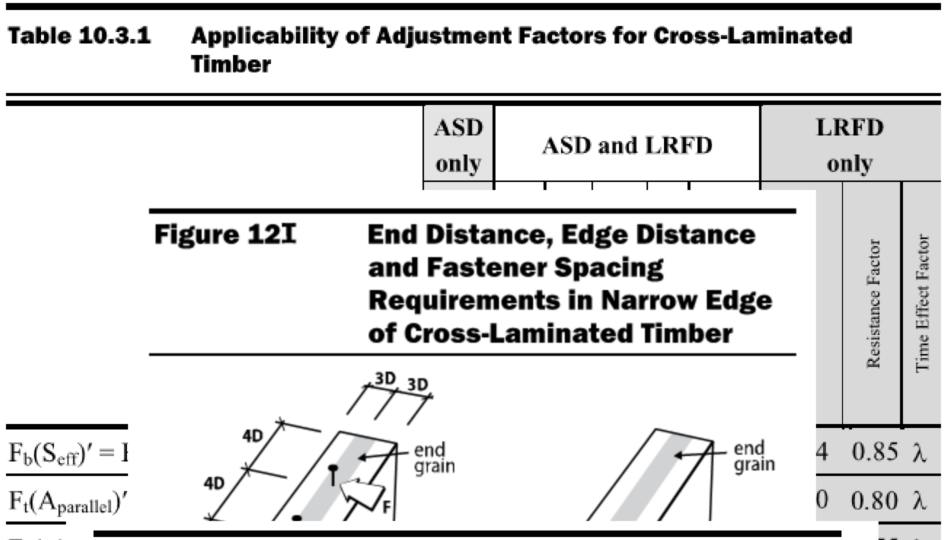
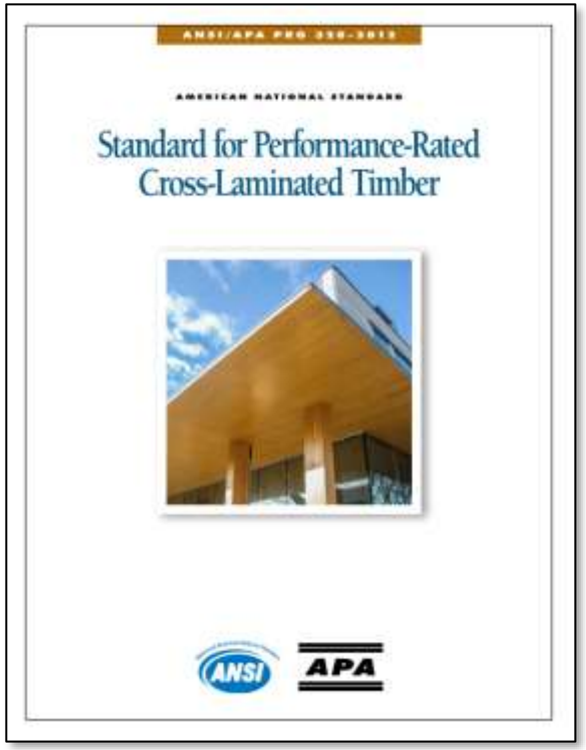


Table 16.2.1B Effective Char Depths (for CLT with β_n=1.5in./hr.)

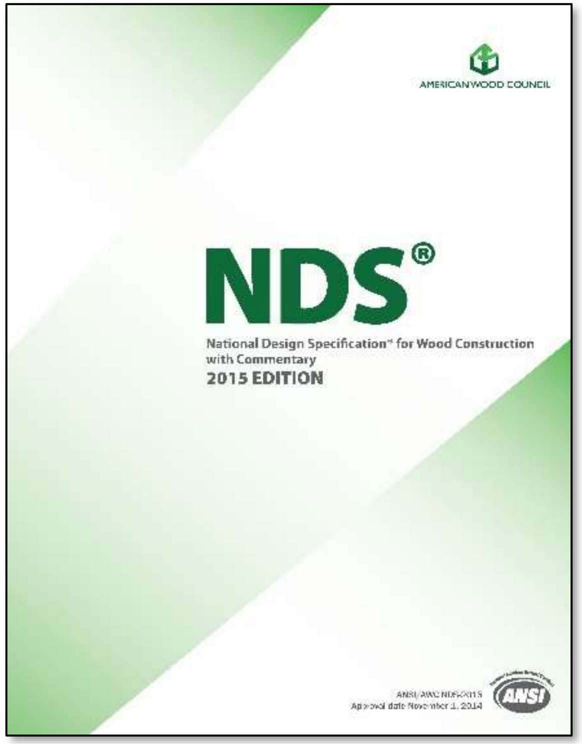
Required Fire Endurance (hr.)	Effective Char Depths, a_{char} (in.)								
	lamination thicknesses, h_{lam} (in.)								
	5/8	3/4	7/8	1	1-1/4	1-3/8	1-1/2	1-3/4	2
1-Hour	2.2	2.2	2.1	2.0	2.0	1.9	1.8	1.8	1.8
1½-Hour	3.4	3.2	3.1	3.0	2.9	2.8	2.8	2.8	2.6
2-Hour	4.4	4.3	4.1	4.0	3.9	3.8	3.6	3.6	3.6

National Design Specification for Wood Construction
2015 & 2018 Edition

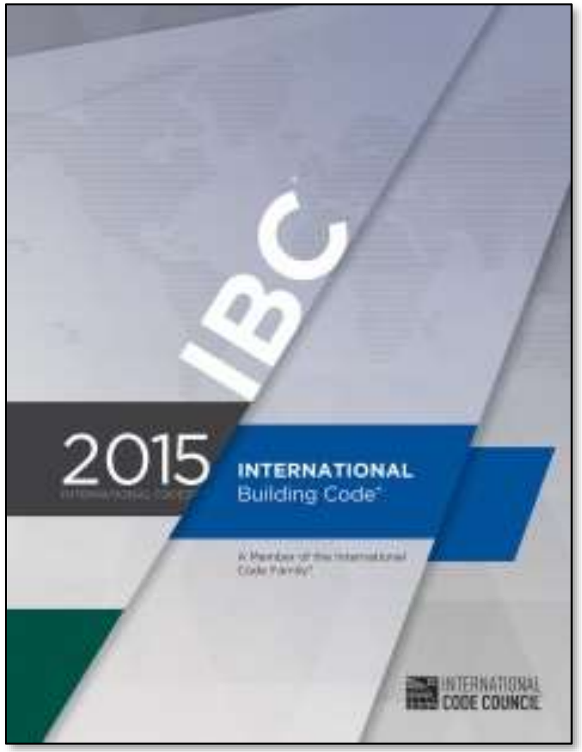
CLT in the U.S. Building Code - IBC 2015



ANSI/APA PRG 320 2011



AWC NDS 2015

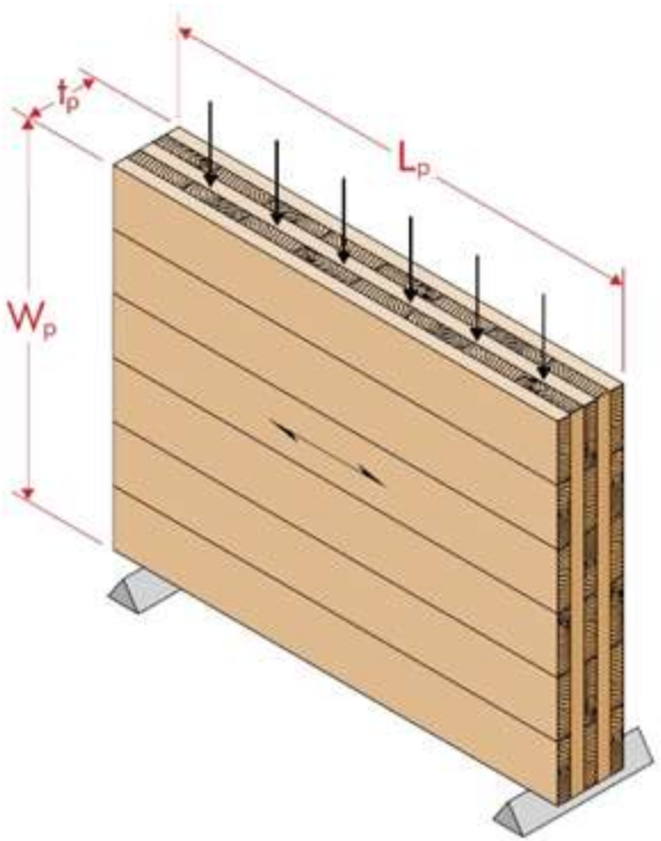


2015 International Building Code

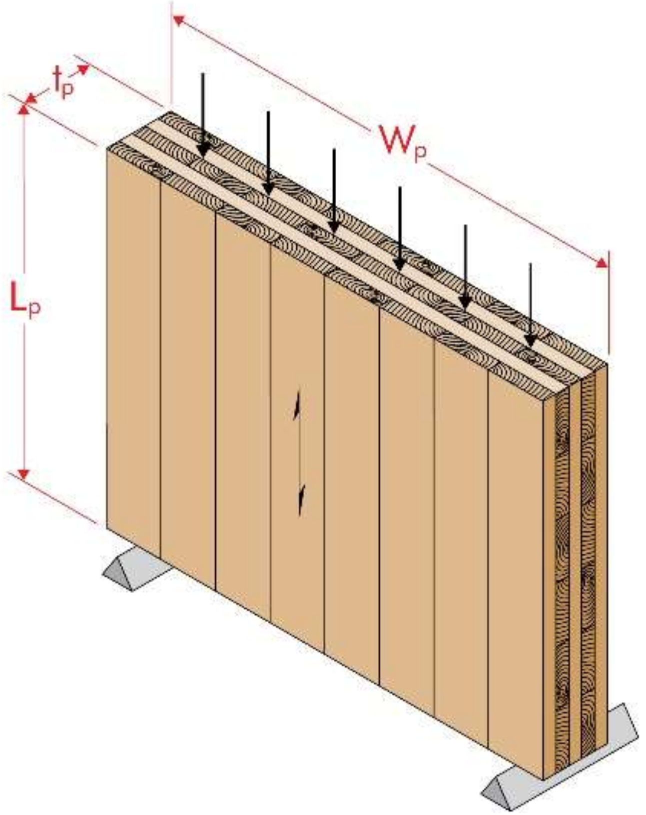
CLT Recognized in the Model Building Code!*

(*for gravity systems with existing Construction Types)

EDGEWISE Panel Loading



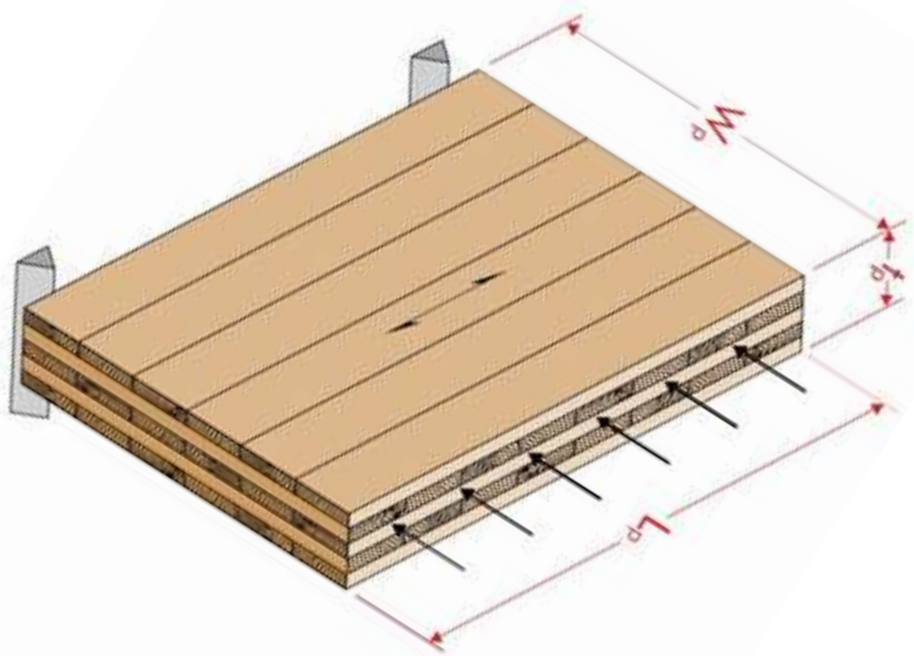
Span in MAJOR Strength Direction



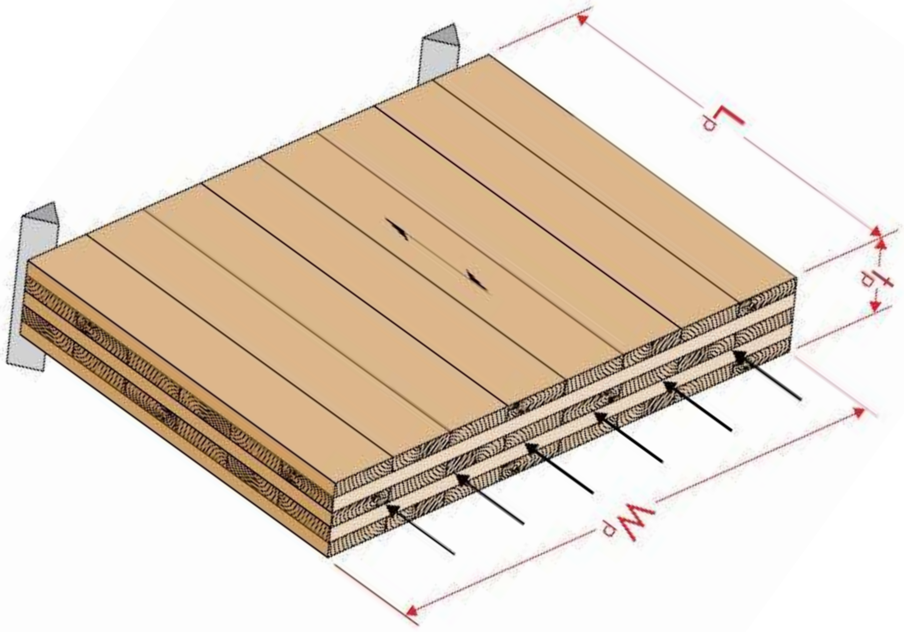
Span in MINOR Strength Direction

Reference & Source: ANSI/APA PRG 320-2017

EDGEWISE Panel Loading



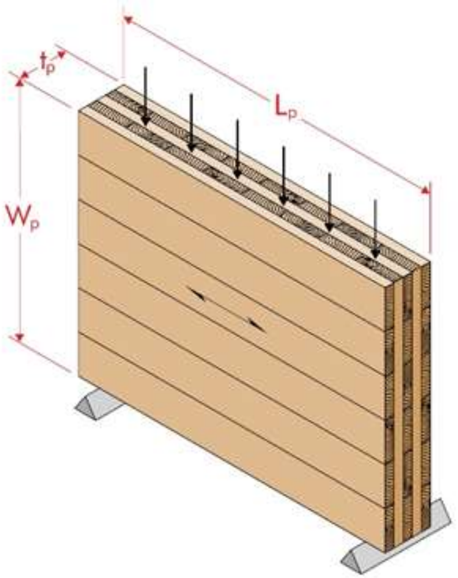
Span in MAJOR Strength Direction



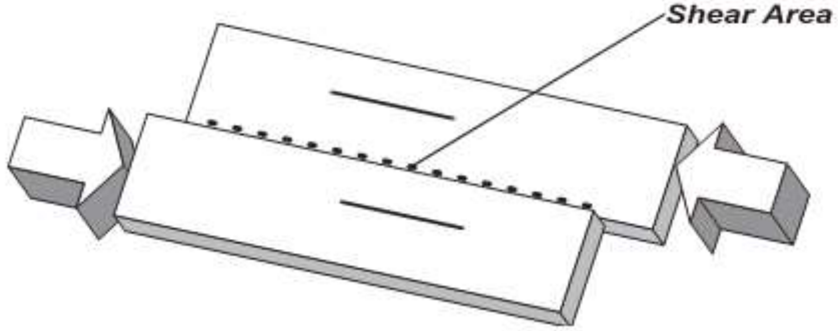
Span in MINOR Strength Direction

Reference & Source: ANSI/APA PRG 320-2017

Shear Force Terminology & Jargon



Source: ANSI/APA PRG 320-2017



Source: NDS 2015 Manual

Through-the-Thickness Shear
In-plane Shear Forces
EDGEWISE Shear in PRG 320-2017

NDS 2015: $F_v(t_v)$
PRG 320-2017: $F_{v,e,0}\, t_p$ & $F_{v,e,90}\, t_p$

CLT in In-Plane (Edgewise) Strength

TABLE 3—REFERENCE DESIGN VALUES FOR IN-PLANE SHEAR OF THE STRUCTURLAM CROSSLAM® CLT PANELS[1]

CLT LAYUP[9]	CLT PANEL THICKNESS DESIGNATION	FACE LAMINATION ORIENTATION[2] (psi)		FACE LAMINATION ORIENTATION[3] (lbf/ft of width)	
		∥[4]	⊥[4]	∥[4]	⊥[4]
V2M1	99 V	175[8]	235[8]	8,200[8]	11,000[8]
	169 V	175[8]	235[8]	14,000[8]	18,800[8]
	239 V	175[8]	235[8]	19,800[8]	26,600[8]
	309 V	175[8]	235[8]	25,600[8]	34,300[8]
V2M1.1	105V	195	290	9,700	14,400
	175V	270	290[6]	22,400	24,000[6]
	245V	270[5]	290[6]	31,300[5]	33,600[6]
	315V	270[5]	290[6]	40,200[5]	43,200[6]

Source: ICC-ES/APA Joint Evaluation Report *ESR 3631*

g Reference Design Values for Nordic X-Lam Listed in Table 1 (For Use in

			Major Strength Direction		Minor Strength Direction	
			$F_{v,e,0}$[(a)] (psi)	$G_{e,0}\, t_p$[(d)] (10^6 lbf/ft)	$F_{v,e,90}$[(a)] (psi)	$G_{e,90}\, t_p$[(d)] (10^6 lbf/ft)
			155[(b)]	1.36	190[(b)]	1.36
			155	1.52	190[(b)]	1.52
			155	1.79	190	1.79
			185[(c)]	2.23	215[(c)]	2.23
E1	140-4s	5 1/2	145	2.39	190[(b)]	2.39
	143-5s	5 5/8	185[(c)]	2.44	215[(c)]	2.44
	175-5s	6 7/8	185	2.99	215	2.99
	197-7s	7 3/4	155[(b)]	3.37	215[(c)]	3.37
	213-7l	8 3/8	185[(c)]	3.64	215[(c)]	3.64
	220-7s	8 5/8	185[(c)]	3.75	215[(c)]	3.75
	244-7s	9 5/8	185[(c)]	4.18	215[(c)]	4.18
	244-7l	9 5/8	185[(c)]	4.18	215[(c)]	4.18
	267-9l	10 1/2	155[(b)]	4.56	215[(c)]	4.56
	314-9l	12 3/8	185[(c)]	5.38	215[(c)]	5.38

Source: *APA Product Report PR-L306*

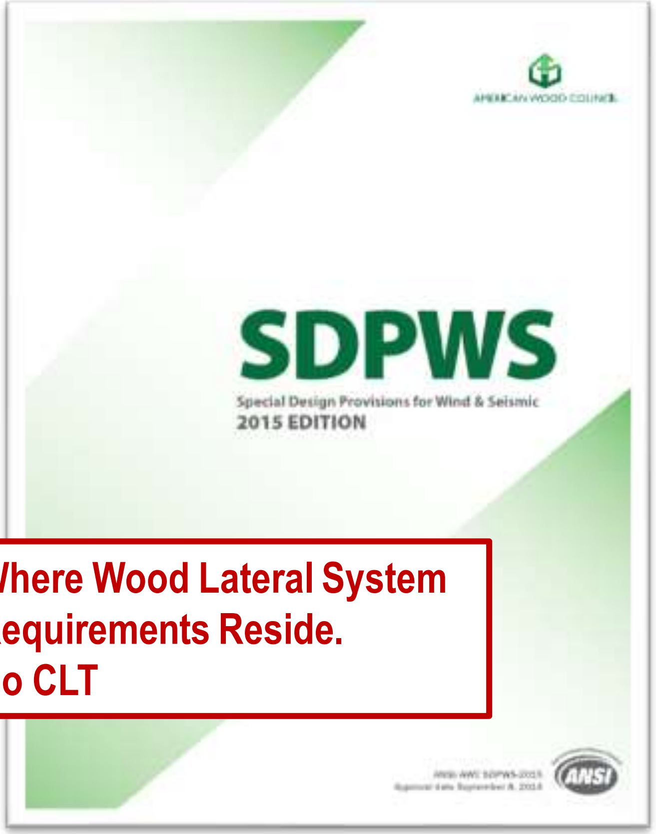
145 to 290 PSI Edgewise Shear Capacity
= 1.7 to 3.5 kips/ft (ASD)
per inch of thickness!

Consult with the Manufacturers for Values

Multiply by ***Cd = 1.6***
for short term ASD strength

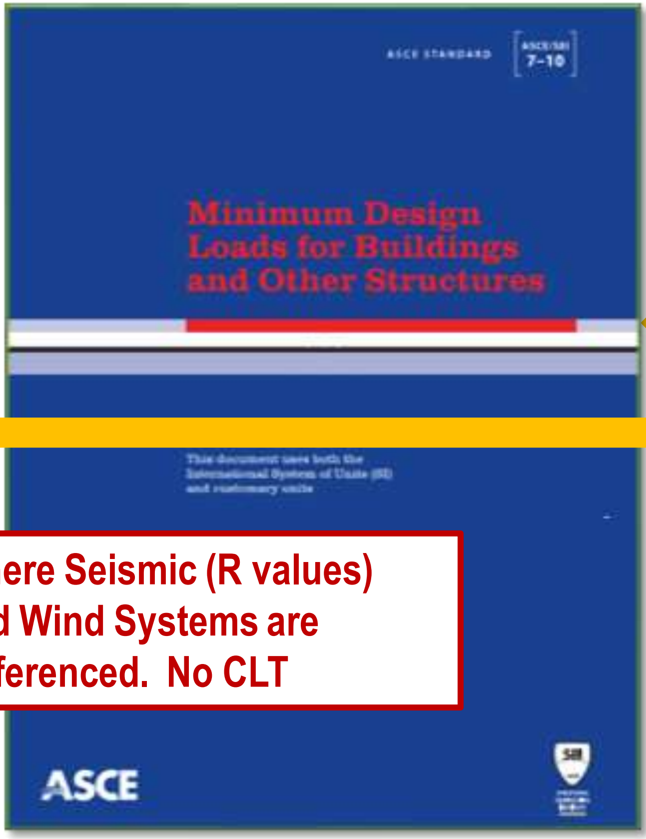
CLT Panels can have > 9 kips / ft in-plane shear capacity

CLT in the U.S. Building Code – IBC 2018 (Lateral)



Where Wood Lateral System Requirements Reside.
No CLT

AWC SDPWS 2015



Where Seismic (R values) and Wind Systems are Referenced. No CLT

ASCE/SEI 7-16

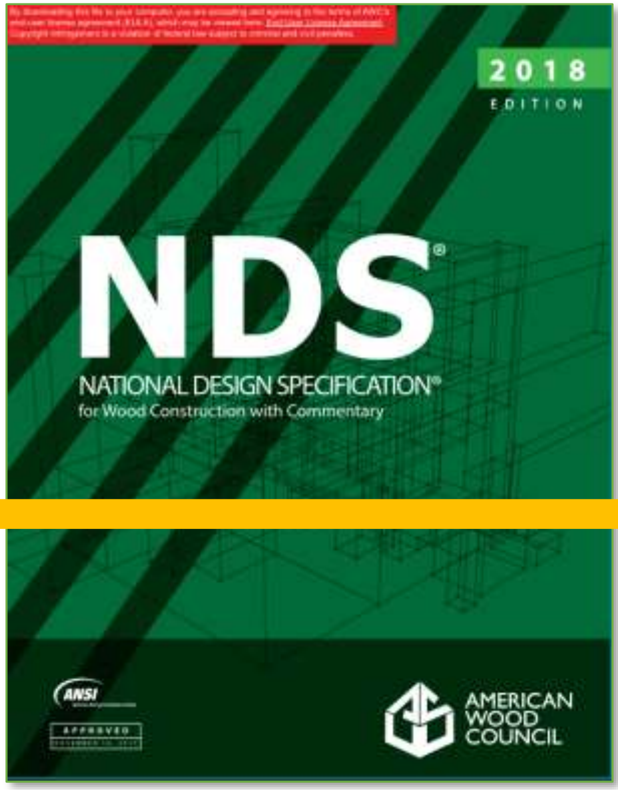
2018 International Building Code
2019 CBC

No explicitly recognized requirements for CLT Lateral Systems in 2018 IBC

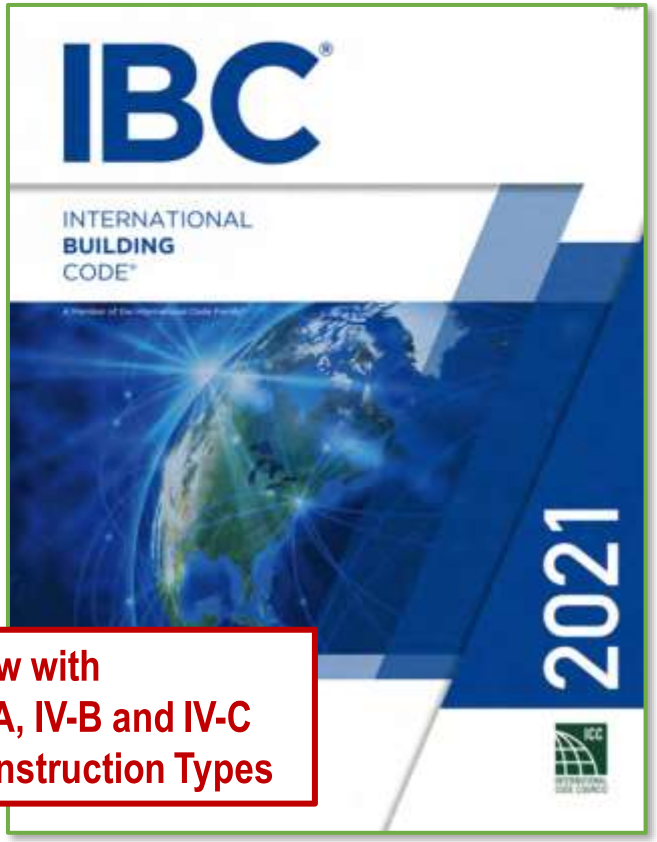
CLT in the U.S. Building Code – IBC 2021

With new and improved adhesive qualification tests

ANSI/APA PRG 320 2019



AWC NDS 2018



Now with IV-A, IV-B and IV-C Construction Types

2021 International Building Code

New Type IV Mass Timber Construction up to 18 Stories!

CLT in the U.S. Building Code – IBC 2021 (Lateral)

Now with CLT shear wall and diaphragm requirements

AWC SDPWS 2021

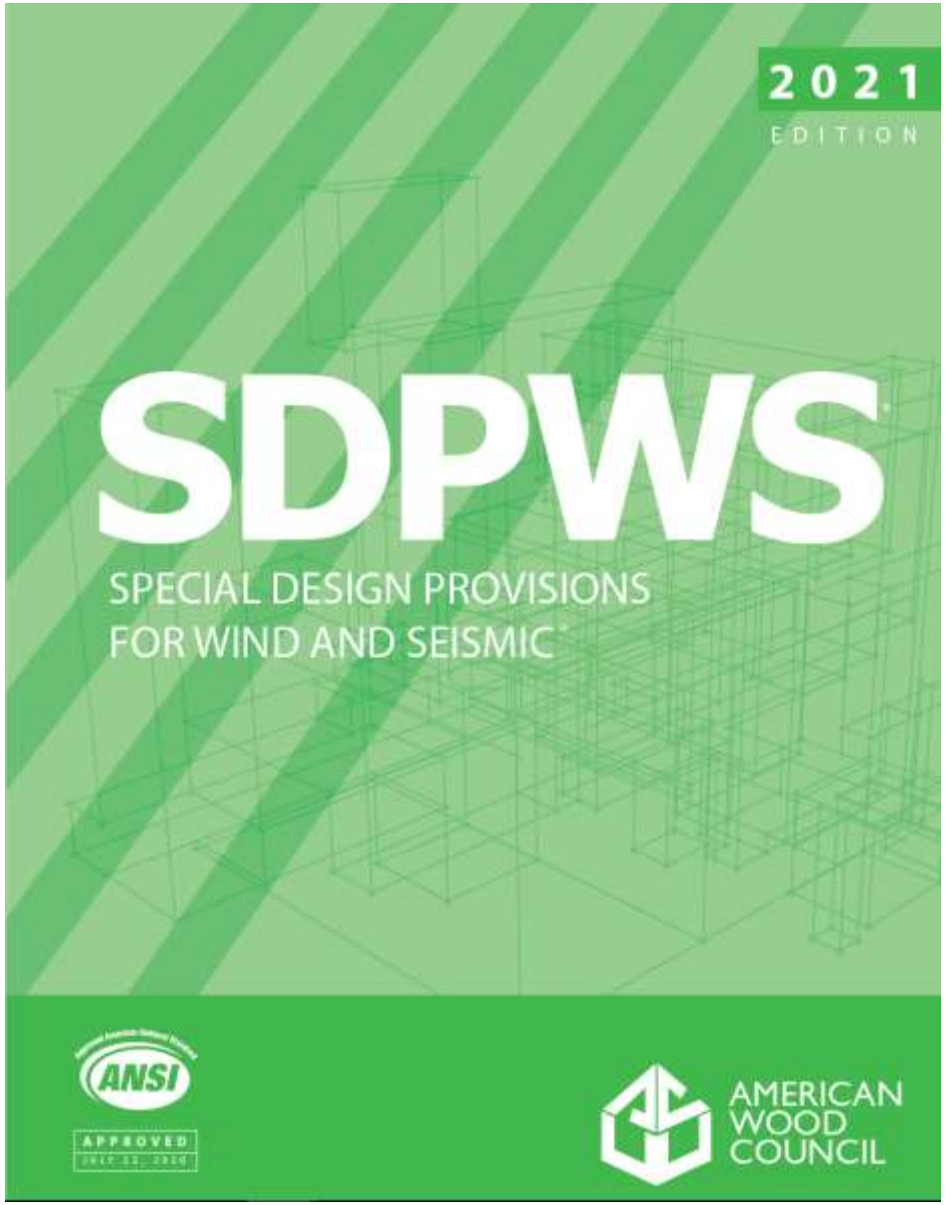
ASCE/SEI 7-16

2021 International Building Code

New Requirements for CLT Lateral Systems in SDPWS 2021!

Referenced from IBC 2021

2021 Special Design Provisions for Wind and Seismic



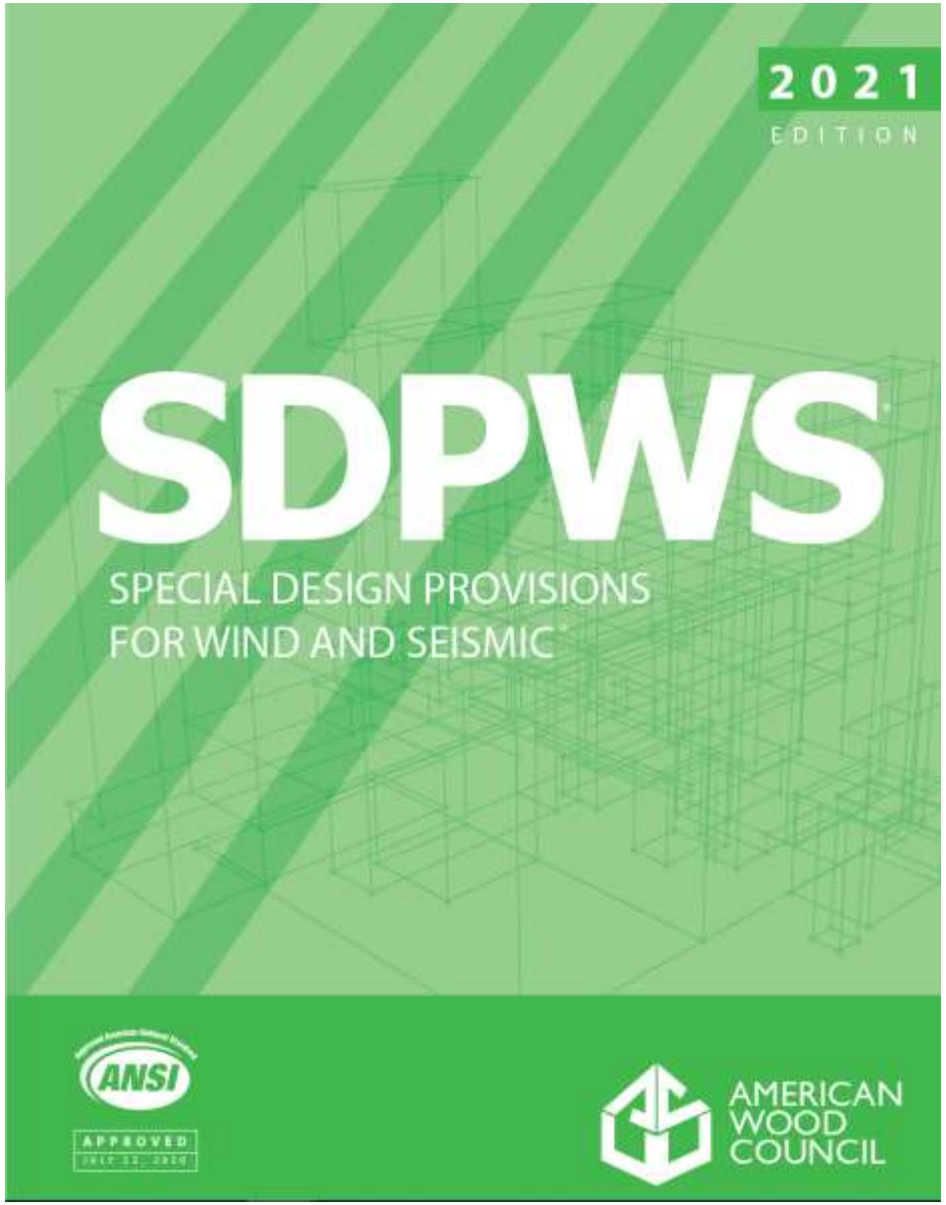
Top Changes Relevant to CLT Lateral Systems:

- New unified nominal shear capacity
- New CLT Shear Wall requirements
- New CLT Diaphragm requirements

View for free at awc.org

<u>PowerPoint IS NOT the CODE!</u>

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

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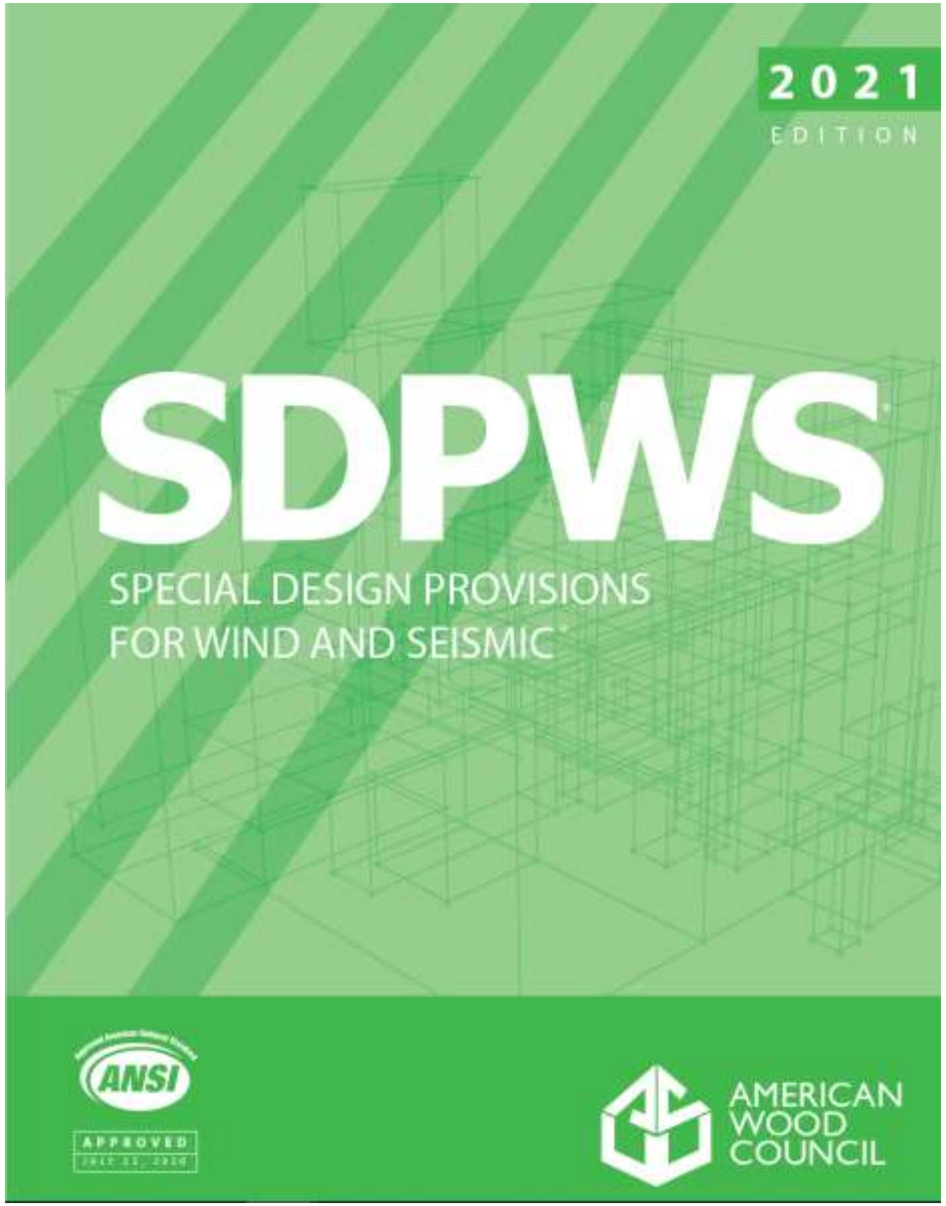
2021 SDPWS – Unified Nominal Shear Capacity



For sheathed wood frame shear walls and diaphragms, SDPWS 2015 has two nominal shear capacities

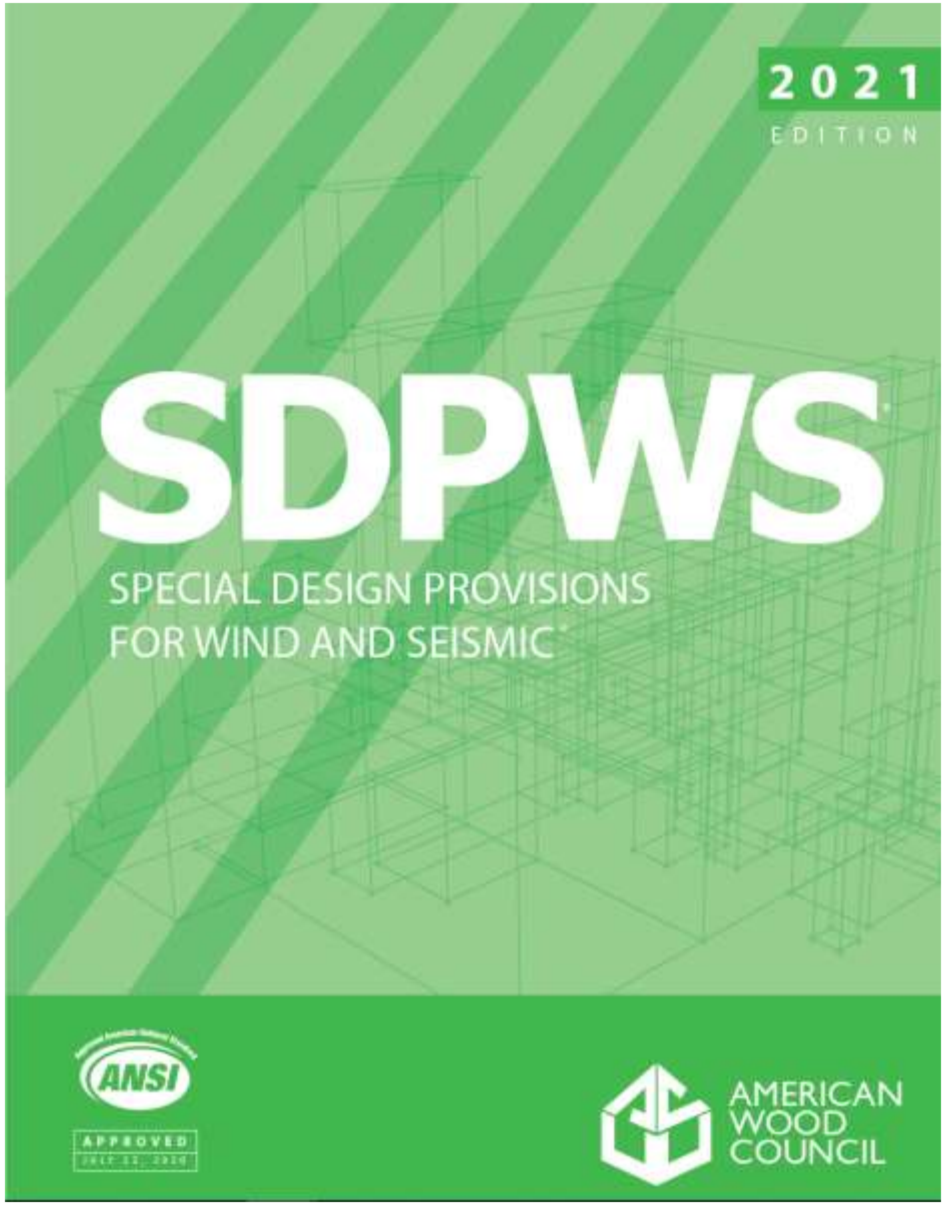
v_s Nominal shear capacity for seismic loads

v_w Nominal shear capacity for wind loads

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

v_n Nominal shear capacity

2021 SDPWS – Unified Nominal Shear Capacity

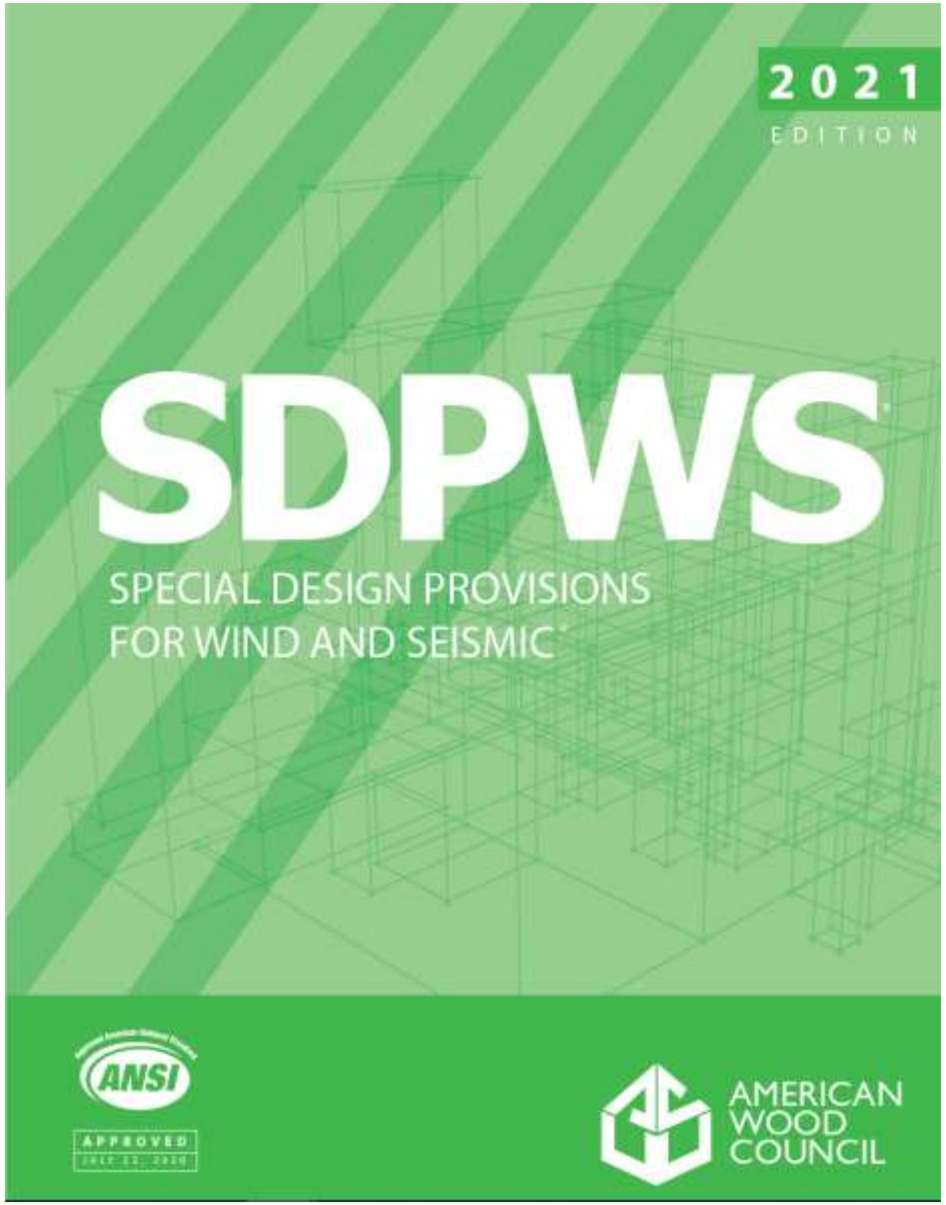


To calculate the ASD or LRFD shear capacity, SDPWS 2021 has different reduction factors for wind and seismic

	Design shear capacity	
	ASD	LRFD
Wind	$v_n/2.0$	$0.8\ v_n$
Seismic	$v_n/2.8$	$0.5\ v_n$

SDPWS 2021 Section 4.1.4

2021 Special Design Provisions for Wind and Seismic



Top Changes Relevant to CLT Lateral Systems:

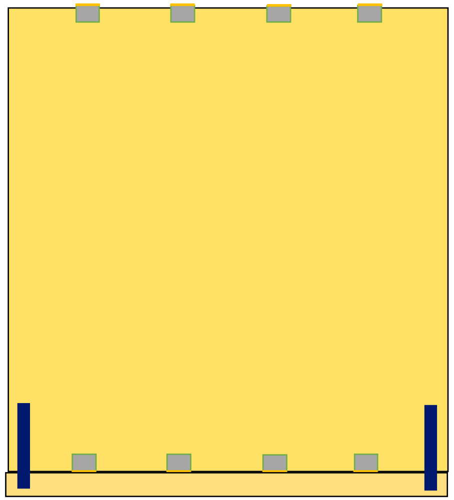
- New unified nominal shear capacity
- **<u>New CLT Shear Wall requirements</u>**
- New CLT Diaphragm requirements

View for free at awc.org

<u>PowerPoint IS NOT the CODE!</u>

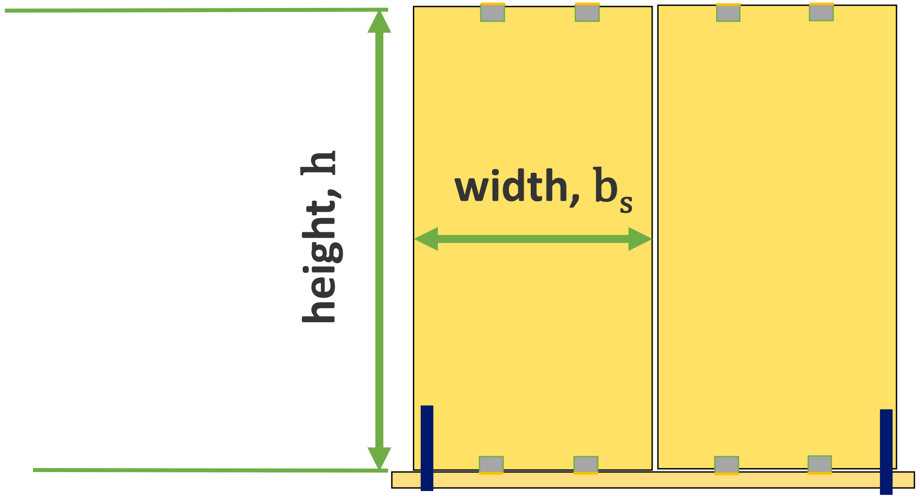
CLT Shear Walls in SDPWS 2021

(other) CLT Shear Walls
not meeting Appendix B

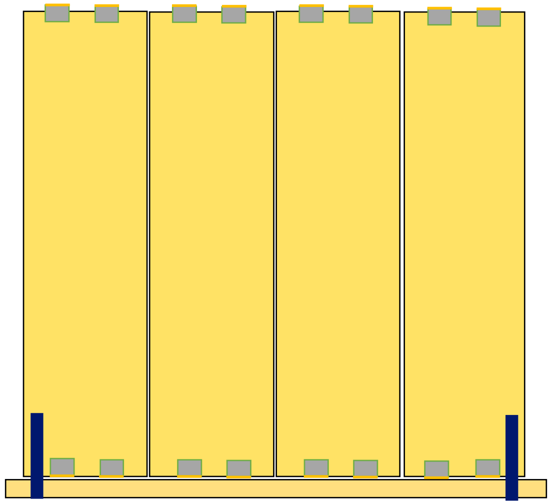


Seismic Design Category A
or SDC B and ≤ 65’ tall
in SDPWS 4.6.3 Exception

CLT Shear Walls
meeting SDPWS 2021 Appendix B



Panel aspect ratios
$2 \leq h/b_s \leq 4$



with shear resistance provided by high aspect ratio panels only (SDPWS B.3.7)

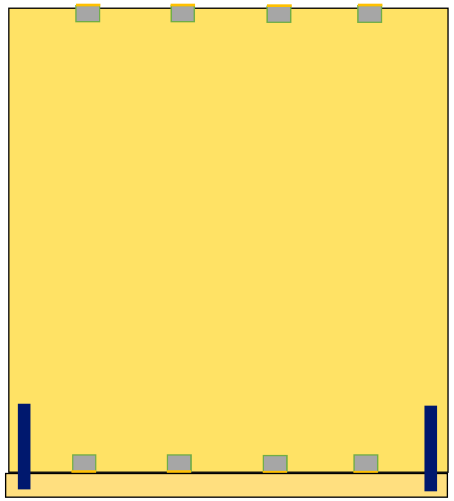
Panel aspect ratios
$h/b_s = 4$

R Values for CLT Shear Walls in SDPWS 2021

(other)

CLT Shear Walls

not meeting Appendix B



R = 1.5

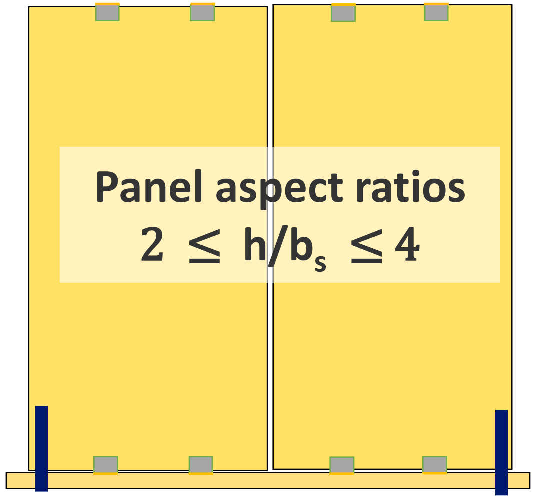
$C_d = 1.5$ $\Omega_o = 2.5$

In SDPWS 2021 4.6.3

Platform Framed

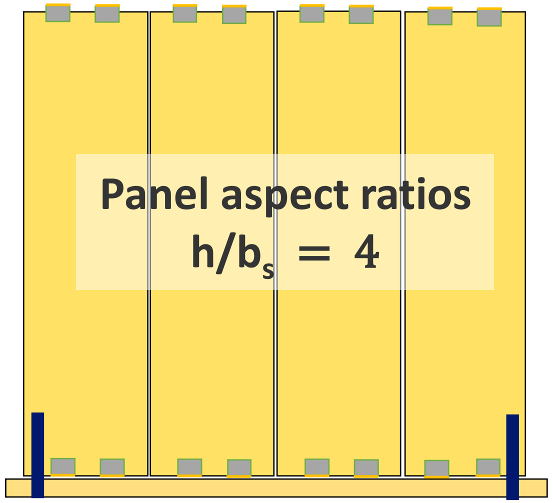
CLT Shear Walls

meeting SDPWS 2021 Appendix B



R = 3.0*

$C_d = 3.0$ $\Omega_o = 3.0$



R = 4.0*

$C_d = 4.0$ $\Omega_o = 3.0$

* ASCE 7-22

CLT in the U.S. Building Code – Lateral in IBC 2021

SDPWS 2015

Now with CLT shear wall and diaphragm requirements

AWC SDPWS 2021

Where Seismic (R values) and Wind Systems are Referenced. No CLT

ASCE/SEI 7-16

2021 International Building Code

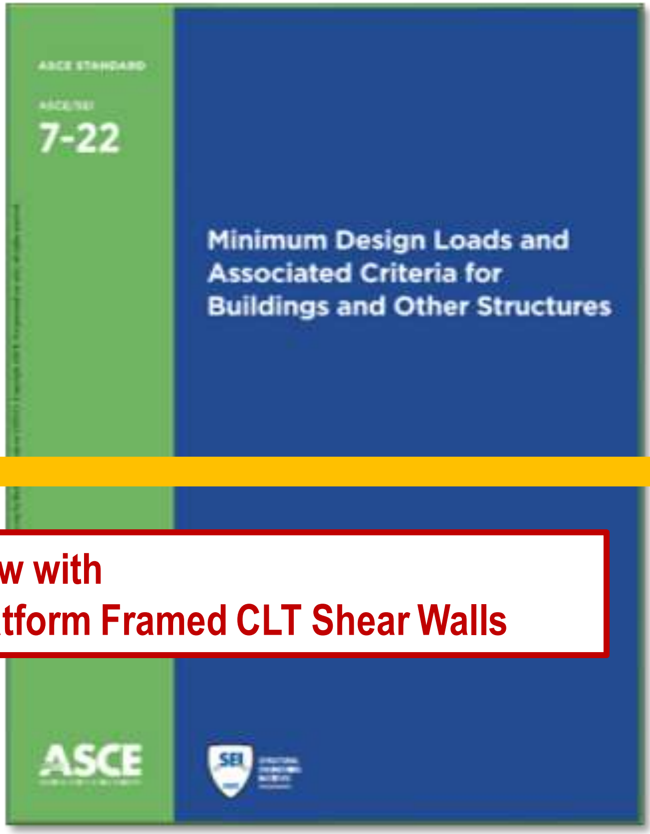
New Requirements for CLT Lateral Systems!

(but R values for CLT Shear Walls not in ASCE 7-16)

CLT in the U.S. Building Code – Lateral in the IBC 2024?

Now with CLT shear wall and diaphragm requirements

AWC SDPWS 2021



Now with
Platform Framed CLT Shear Walls

ASCE/SEI 7-22

To Be Made

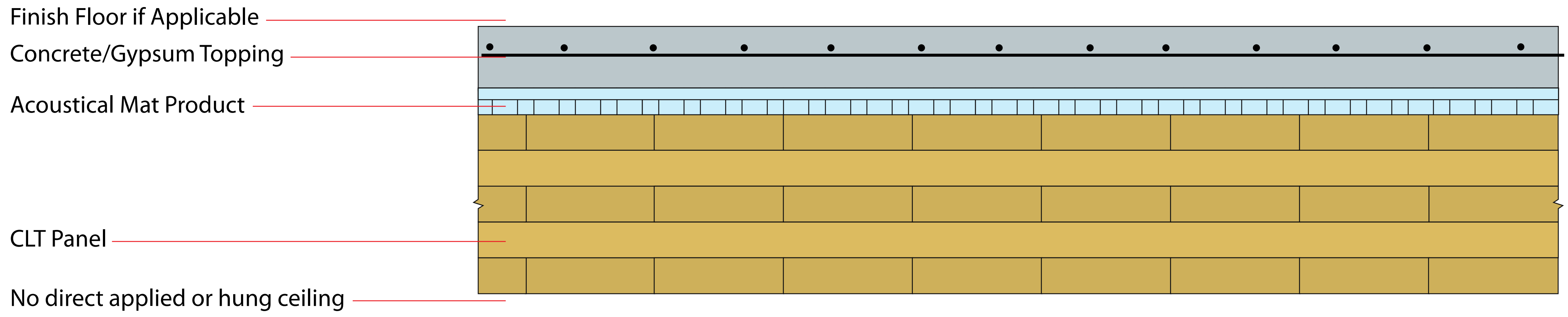
2024 IBC
(in process)

Future Full Recognition of CLT Shear Wall

Mass Timber Diaphragms

Diaphragm Strategies with Horizontal CLT

- Option 1: Structural Topping as Horizontal Diaphragm
- (1A) Structural Concrete Topping



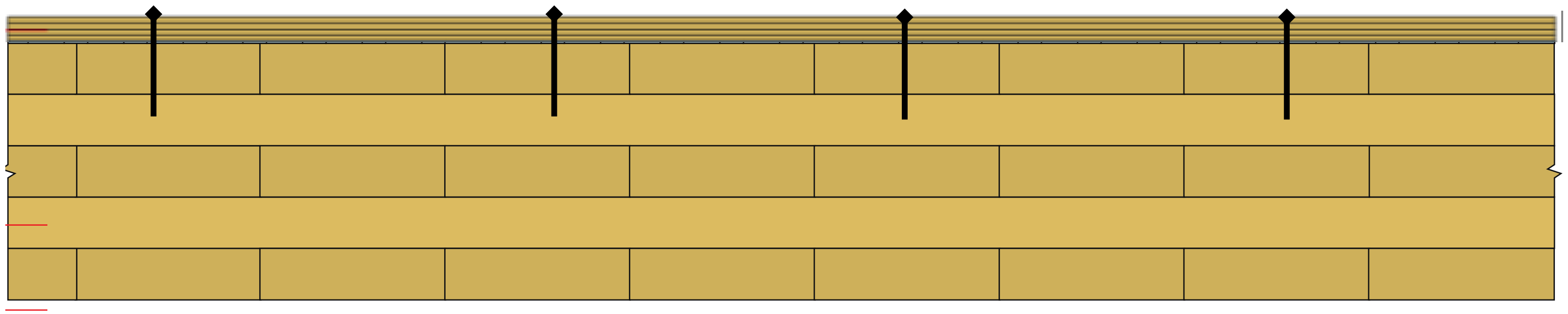
Careful detailing to provide adequate load path, minimum rebar cover, etc.

Diaphragm Strategies with Horizontal CLT

- Option 1: Structural Topping as Horizontal Diaphragm
- (1B) Wood Structural Panel Topping

WSP as diaphragm

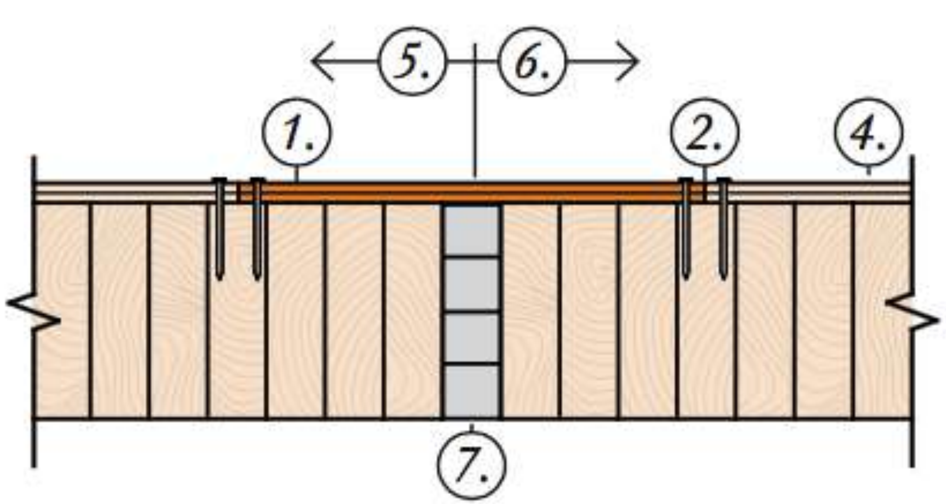
CLT Panel as laminated decking



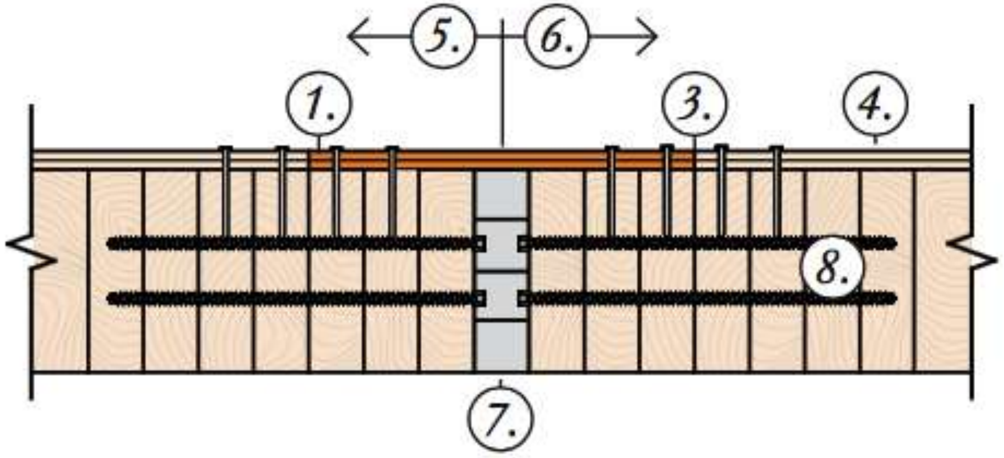
Classify as blocked WSP diaphragm per SDPWS 2015 4.2.7.1?

19/32” thick 4ft by 8ft panel vs 4 1/8” thick 8ft by 24 ft panel?

NLT Diaphragm Design



Typical Diaphragm



High Load Diaphragm

Figure 4.7: *Prefabricated Pre-sheathed Panels*

Key

1. *Field-intalled Plywood/OSB*
2. *Plywood/OSB splice location with typical diaphragm nailing*
3. *Plywood/OSB splice location for high load daiphragm nailing*
4. *Shop-installed plywood/OSB diaphragm sheathing*
5. *Prefabricated NLT panel A*
6. *Prefabricated NLT panel B*
7. *NLT expansion gap location fire stopped as required*
8. *Self-tapping screw pairs crossing plywood/ OSB splice location*

Source: NLT Design & Construction Guide

NLT Diaphragm Design

Pre-fabricated panels often pre-sheathed

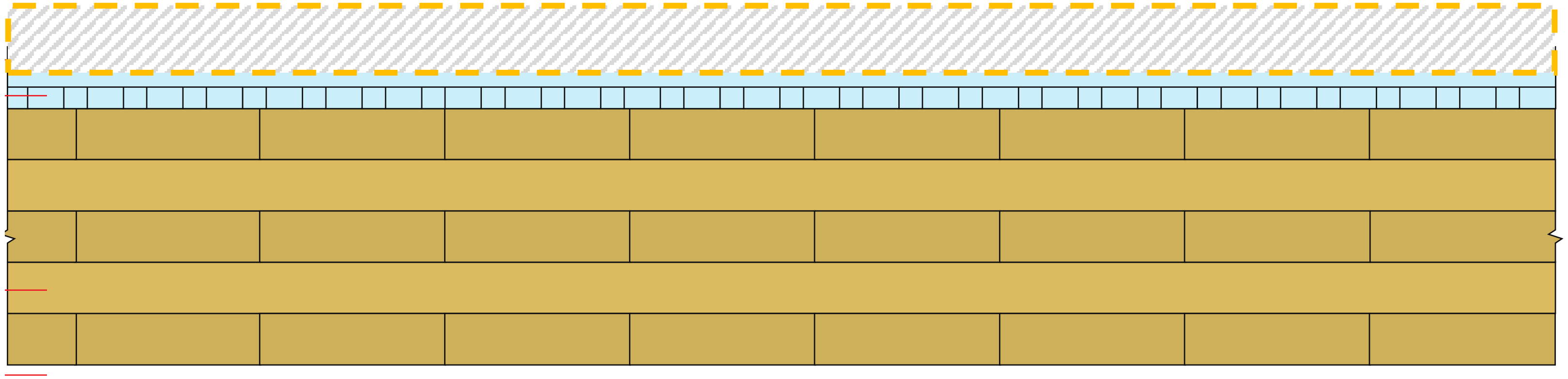
Once installed, add splice strips, tape joint if applicable

Diaphragm Strategies with Horizontal CLT

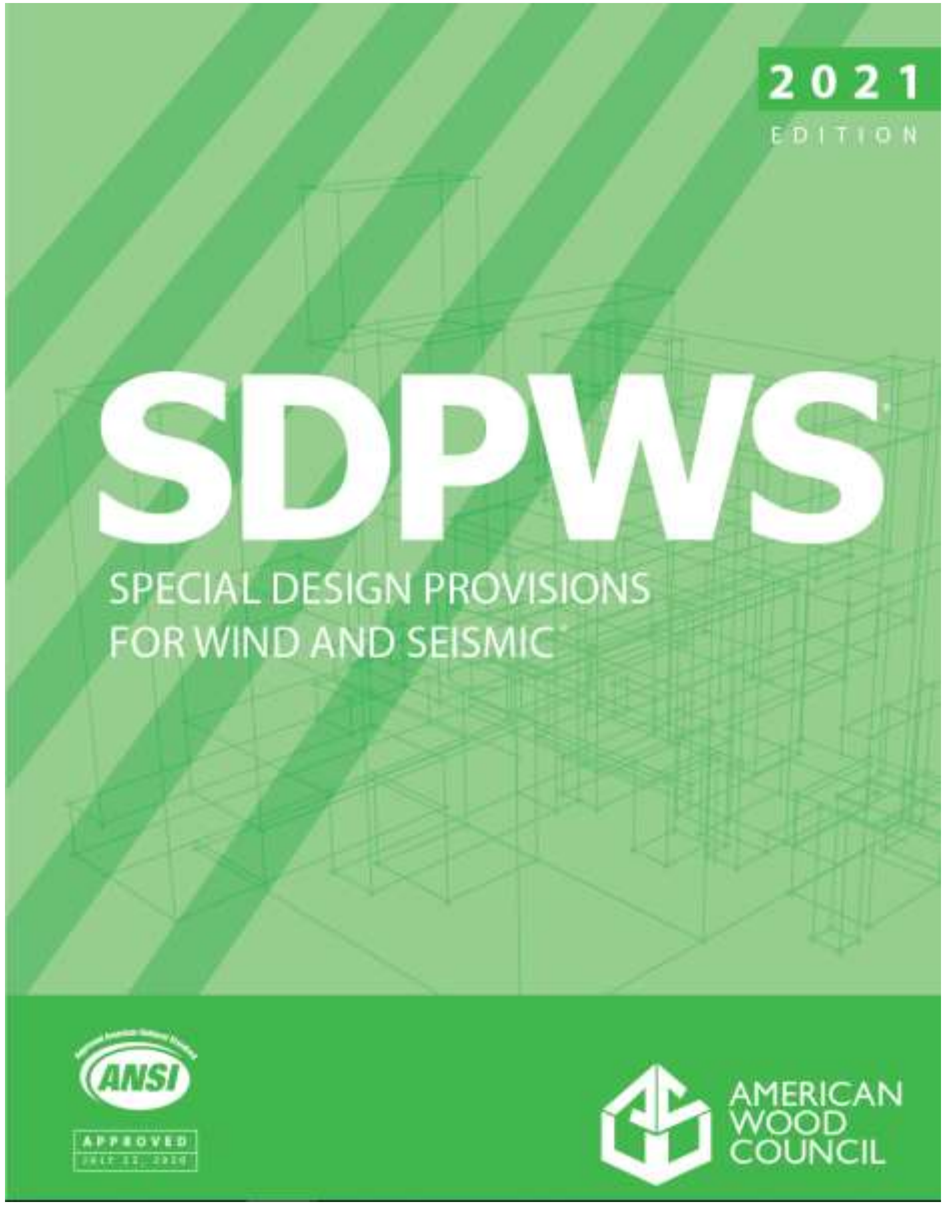
- Option 2: CLT as a Diaphragm

Topping and Flooring as needed

CLT Panel as Diaphragm



2021 Special Design Provisions for Wind and Seismic



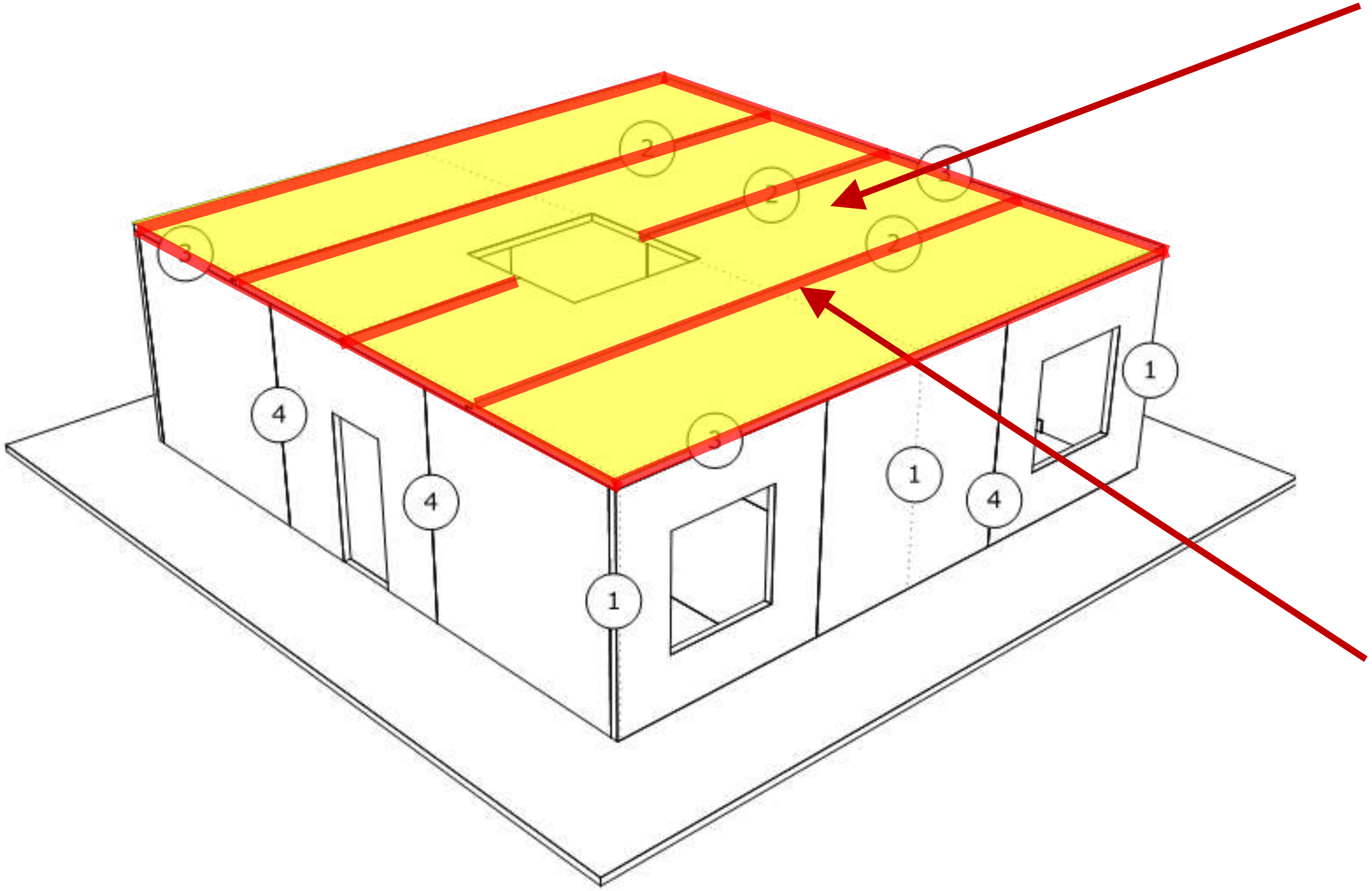
Top Changes Relevant to CLT Lateral Systems:

- New unified nominal shear capacity
- New CLT Shear Wall requirements
- **New CLT Diaphragm requirements**

View for free at awc.org

PowerPoint IS NOT the CODE!

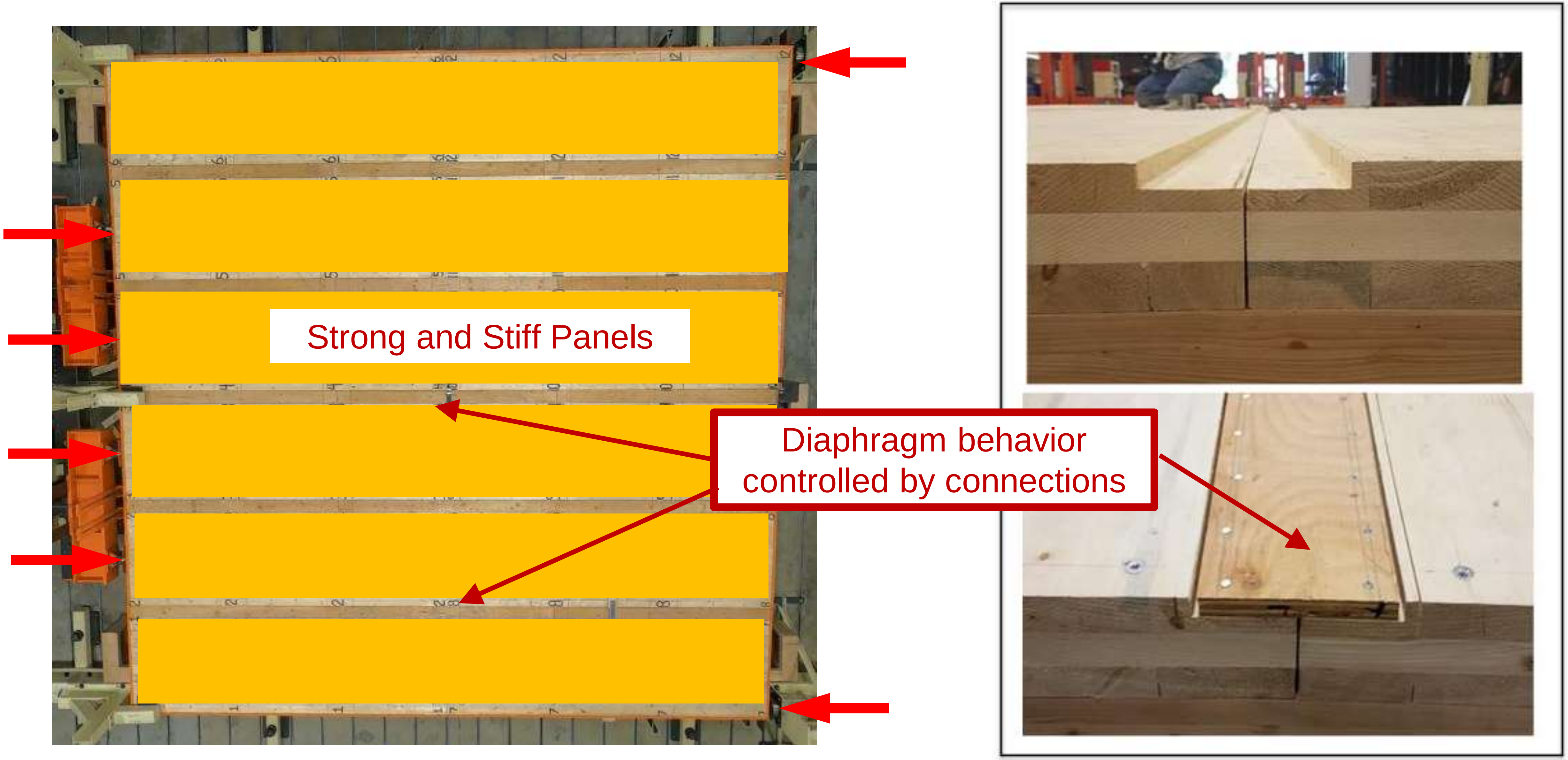
CLT Diaphragms



Strength of CLT rarely governs.

Strength of Connections covered by NDS and Proprietary Fastener Evaluation Reports

24’ x 24’ CLT Diaphragm Test with Plywood Spline by AWC



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 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 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, ϕ, and λ; and Z shall be controlled by Mode III_s 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 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.

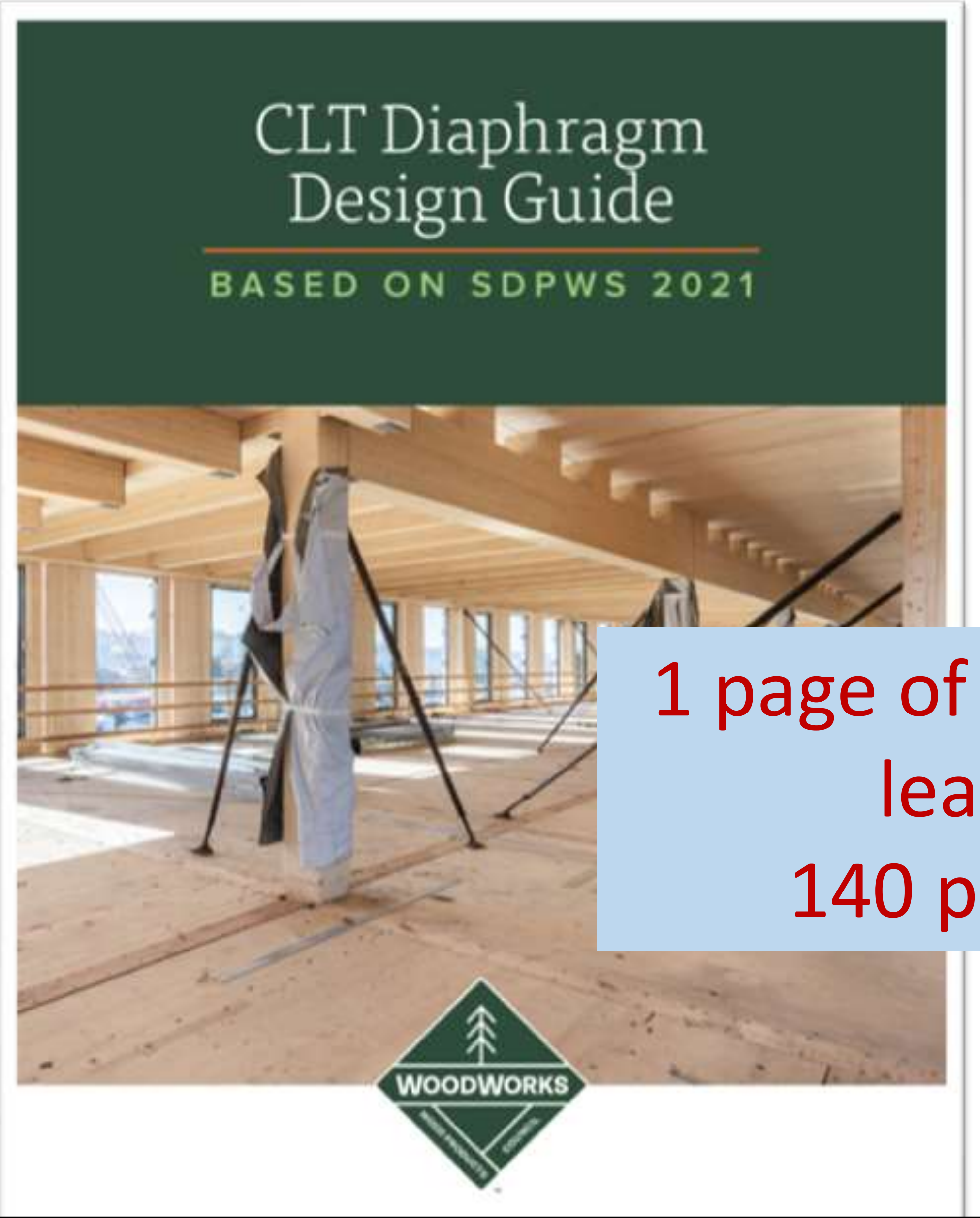
Exceptions:

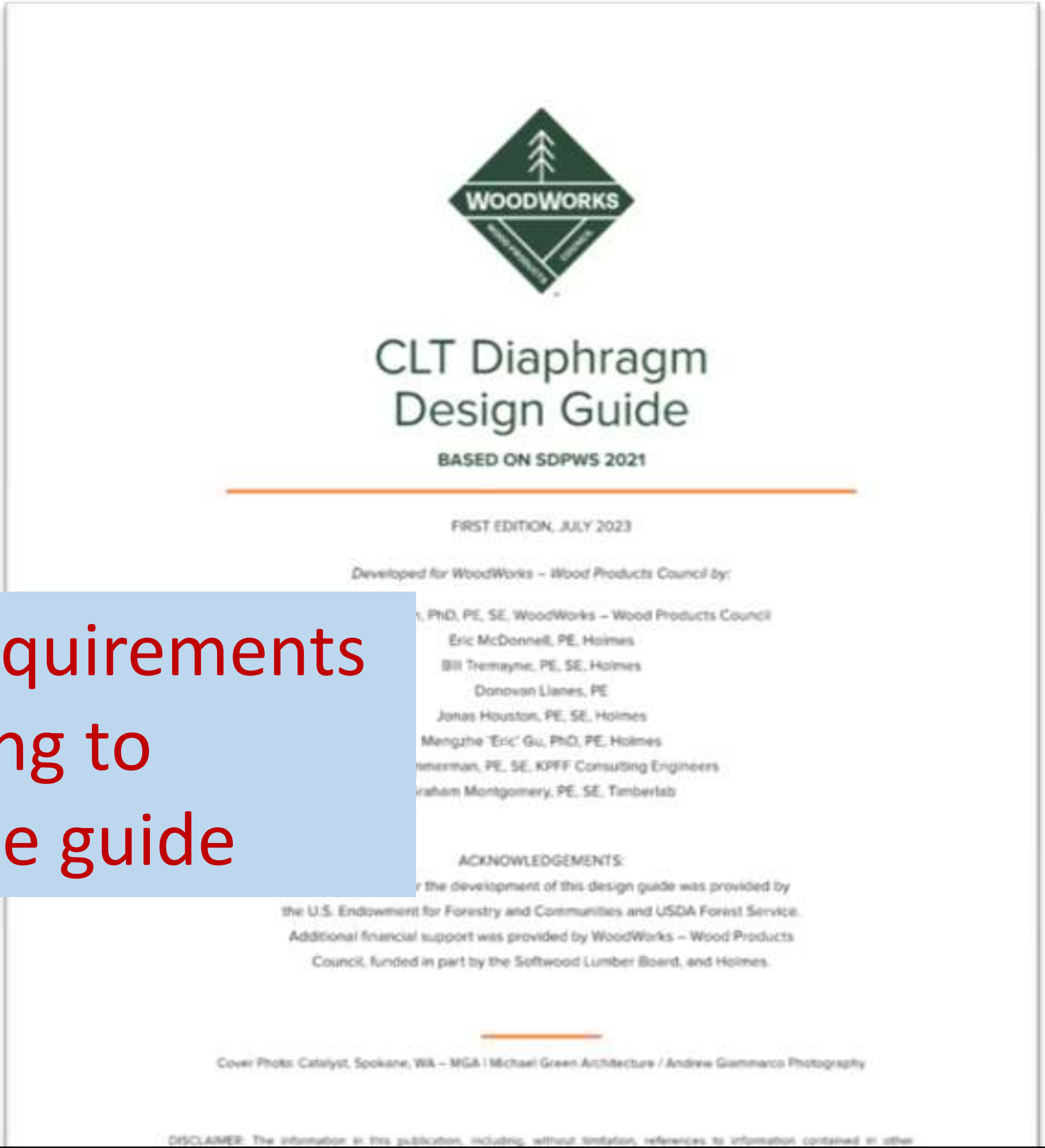
1. Wood elements and wood splice connections shall be permitted to be designed for 1.5 times the diaphragm forces associated with the shear forces induced by the wind design loads.
2. Where dowel-type fasteners are used in chord splice connections and the connection is controlled by Mode III_s or Mode 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.

Only 1 page of requirements for CLT Diaphragms

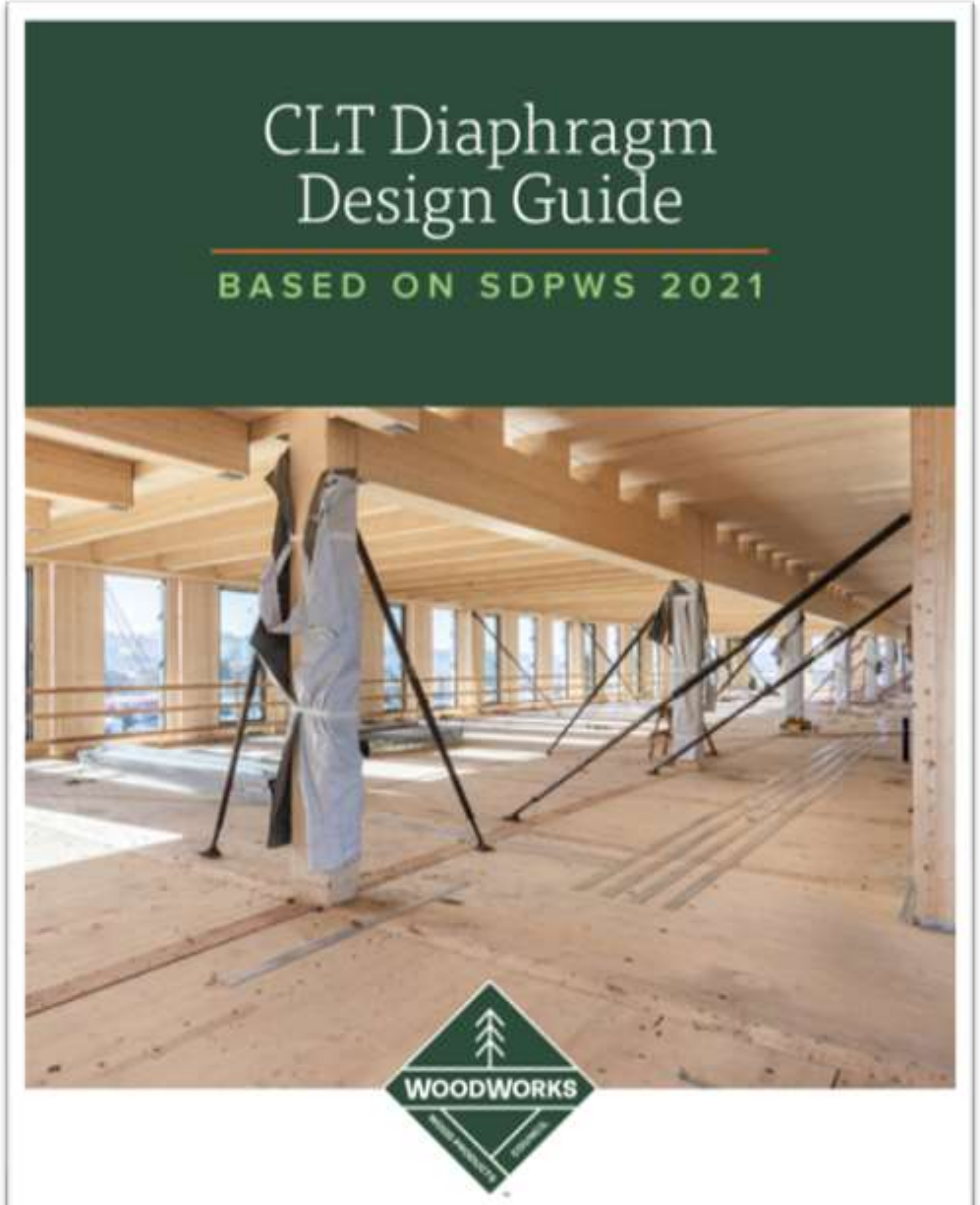
CLT Diaphragm Design Guide based on SDPWS 2021





1 page of requirements
leading to
140 page guide

CLT Diaphragm Design Guide based on SDPWS 2021



Chapter Organization

1. Introduction
2. Codes and Standards
3. Methodology of CLT Diaphragm Design
4. Diaphragm Shear Components
5. Diaphragm Boundary Elements
6. Diaphragm Deflection and Stiffness
7. Special Design Considerations
8. Example 12-Story Office with Distributed Frames
9. Example 12-Story Office with Reinforced Concrete Cores
10. Example 5-Story Residence with Wood-Frame Shear walls

Appendix A – Precalculated Design Capacities

Appendix B – Literature Review

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 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.

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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, ϕ, and λ; and Z shall be controlled by Mode III_s or Mode IV fastener yielding in accordance with NDS 12.3.1.
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4.5.4 Additional CLT Diaphragm Design Requirements

CLT diaphragms shall meet the following additional requirements:

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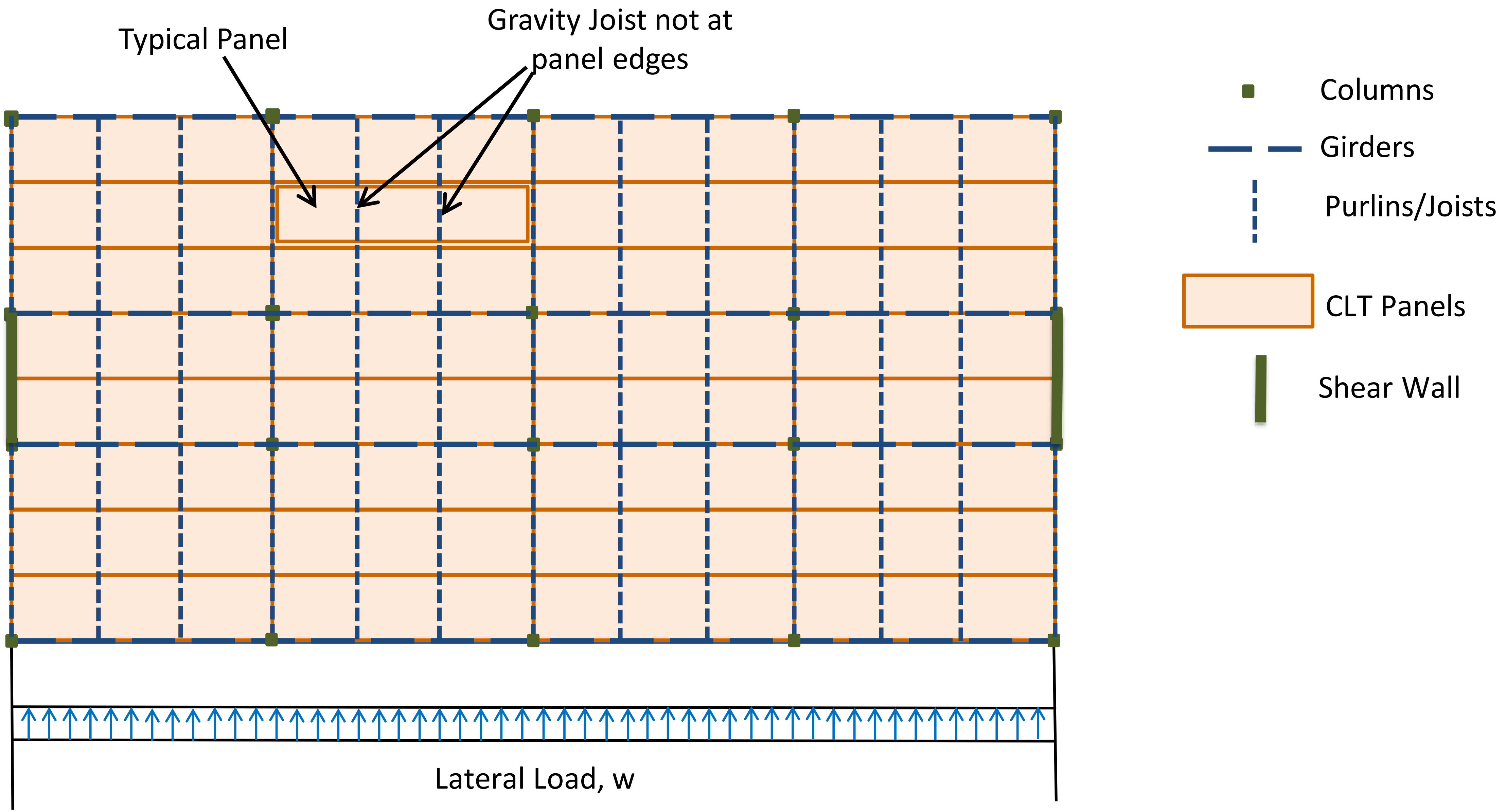
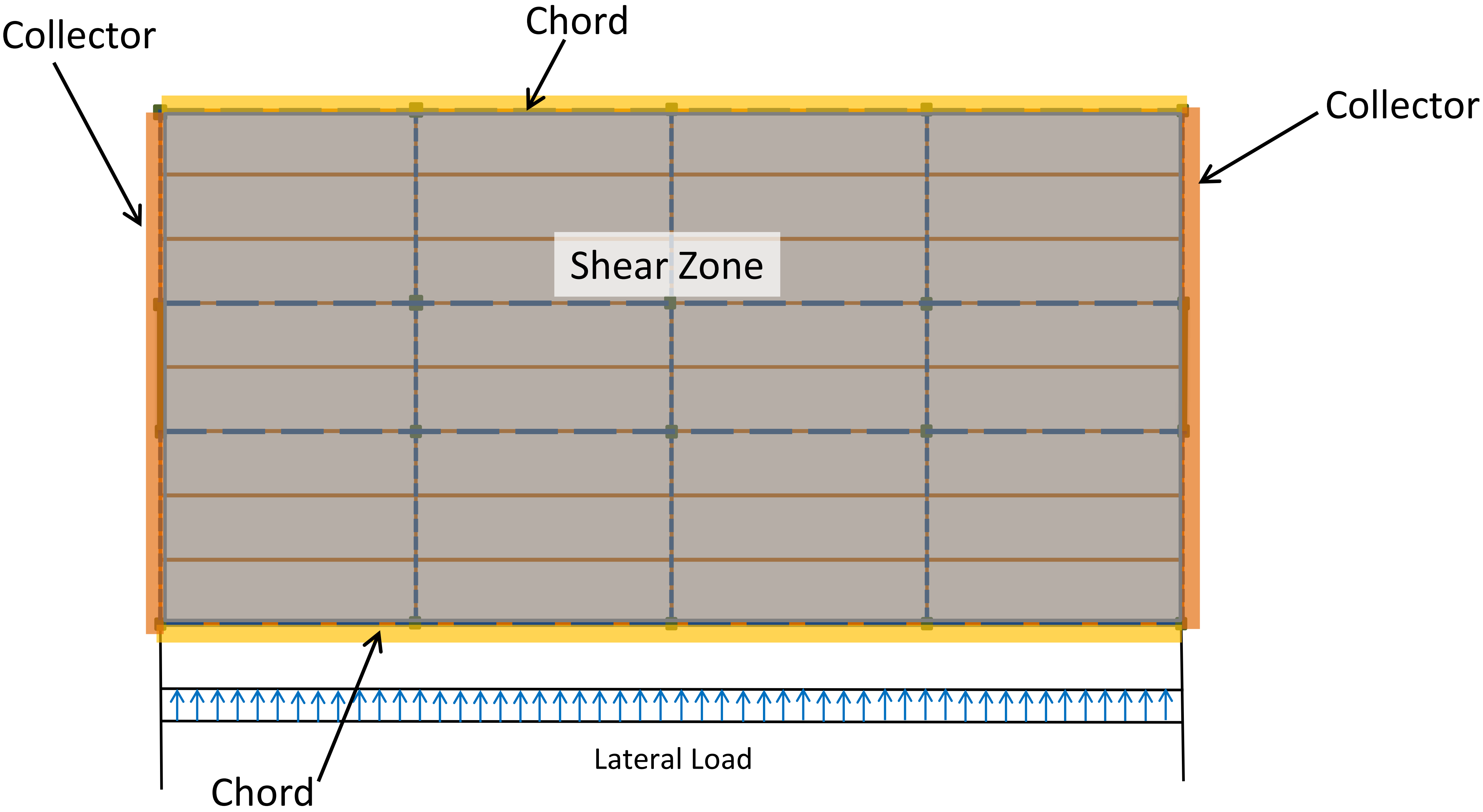
Requirements for the shear connections

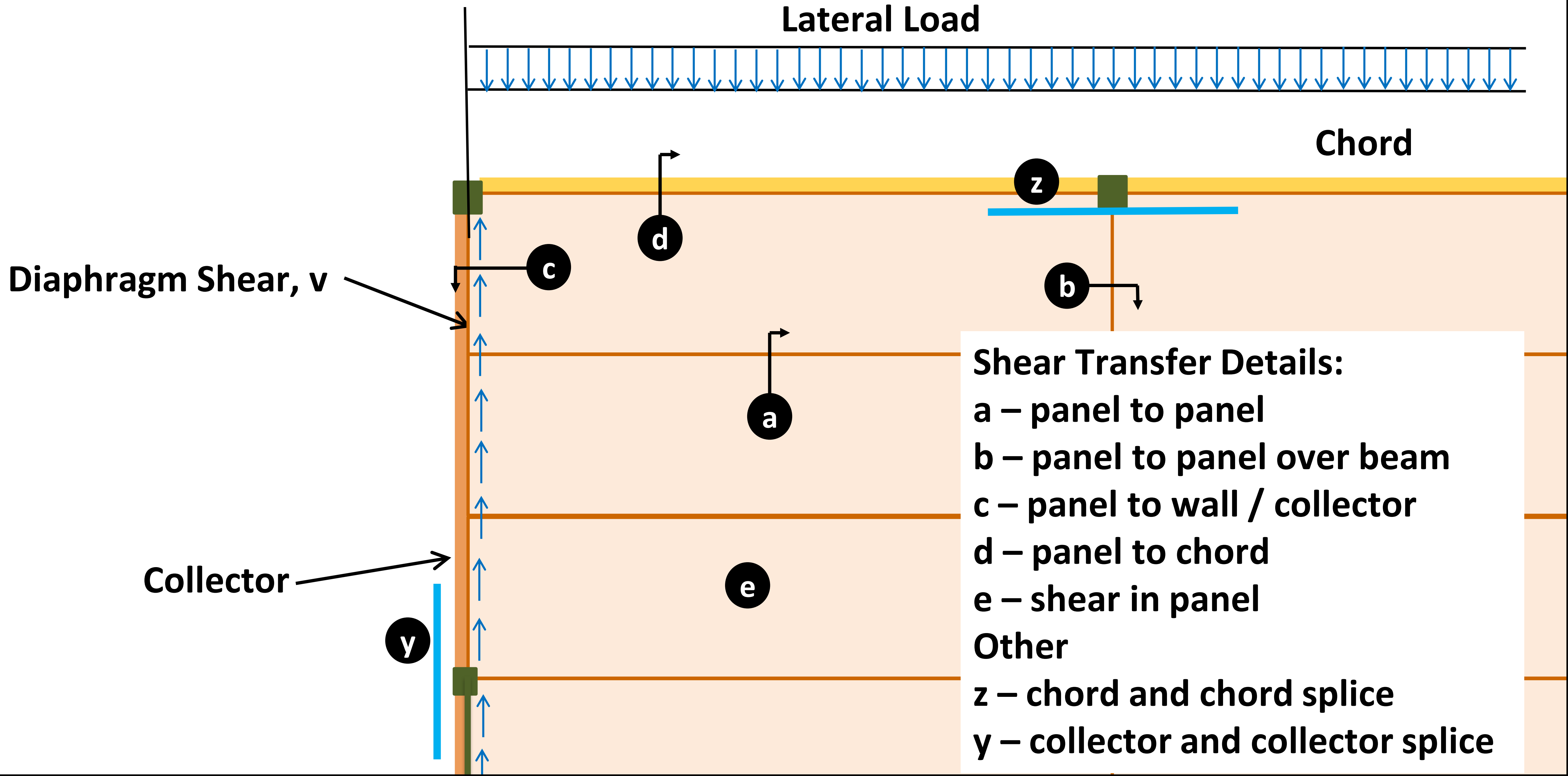
Generic Mass Timber Floor System



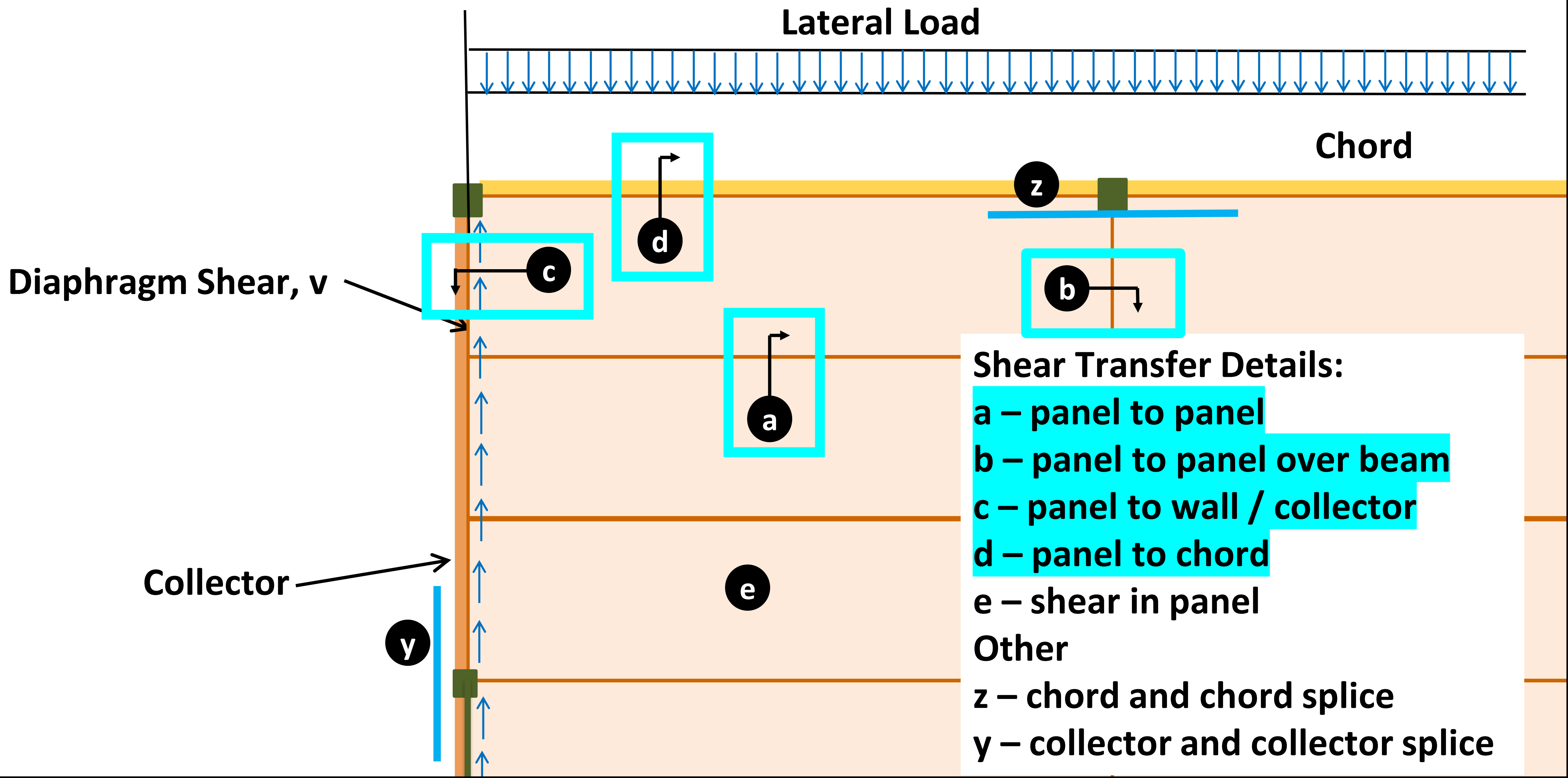
Example CLT Diaphragm Design



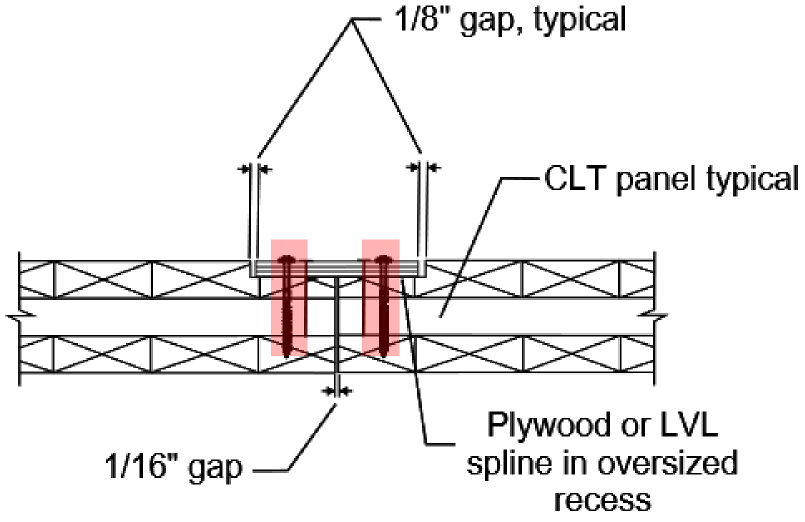
Example CLT Diaphragm Design



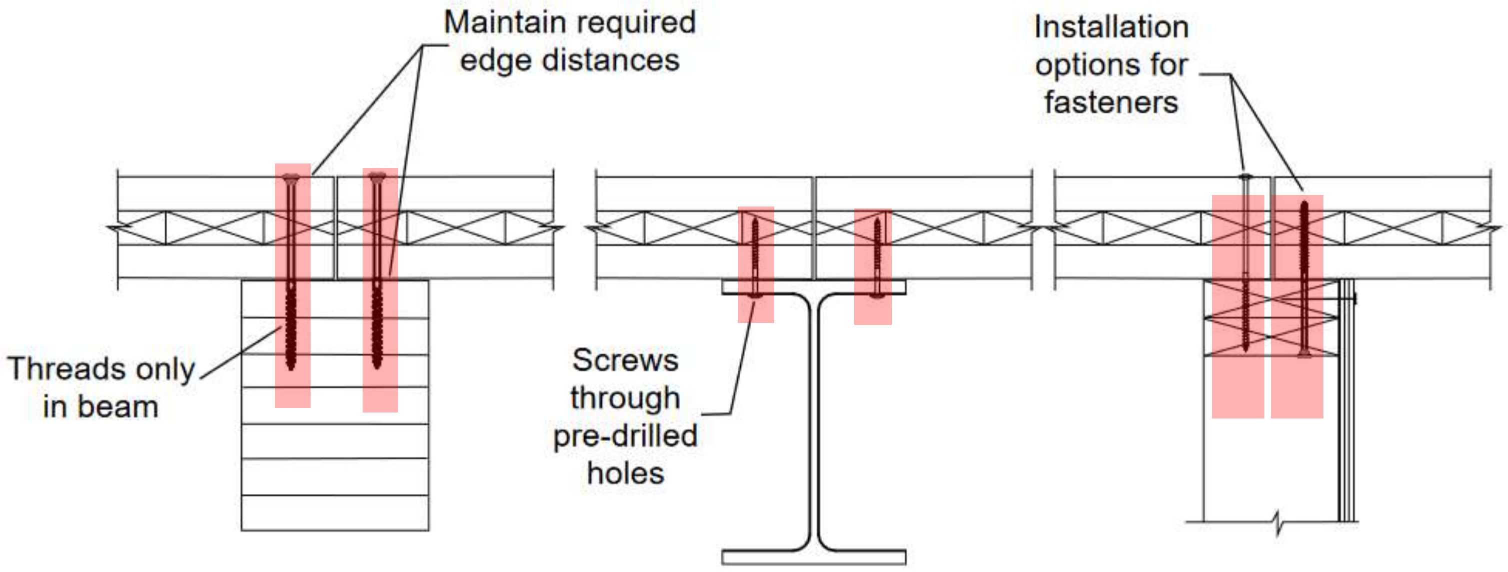
CLT Diaphragm Shear Transfer Connections



CLT Diaphragm Shear Connections



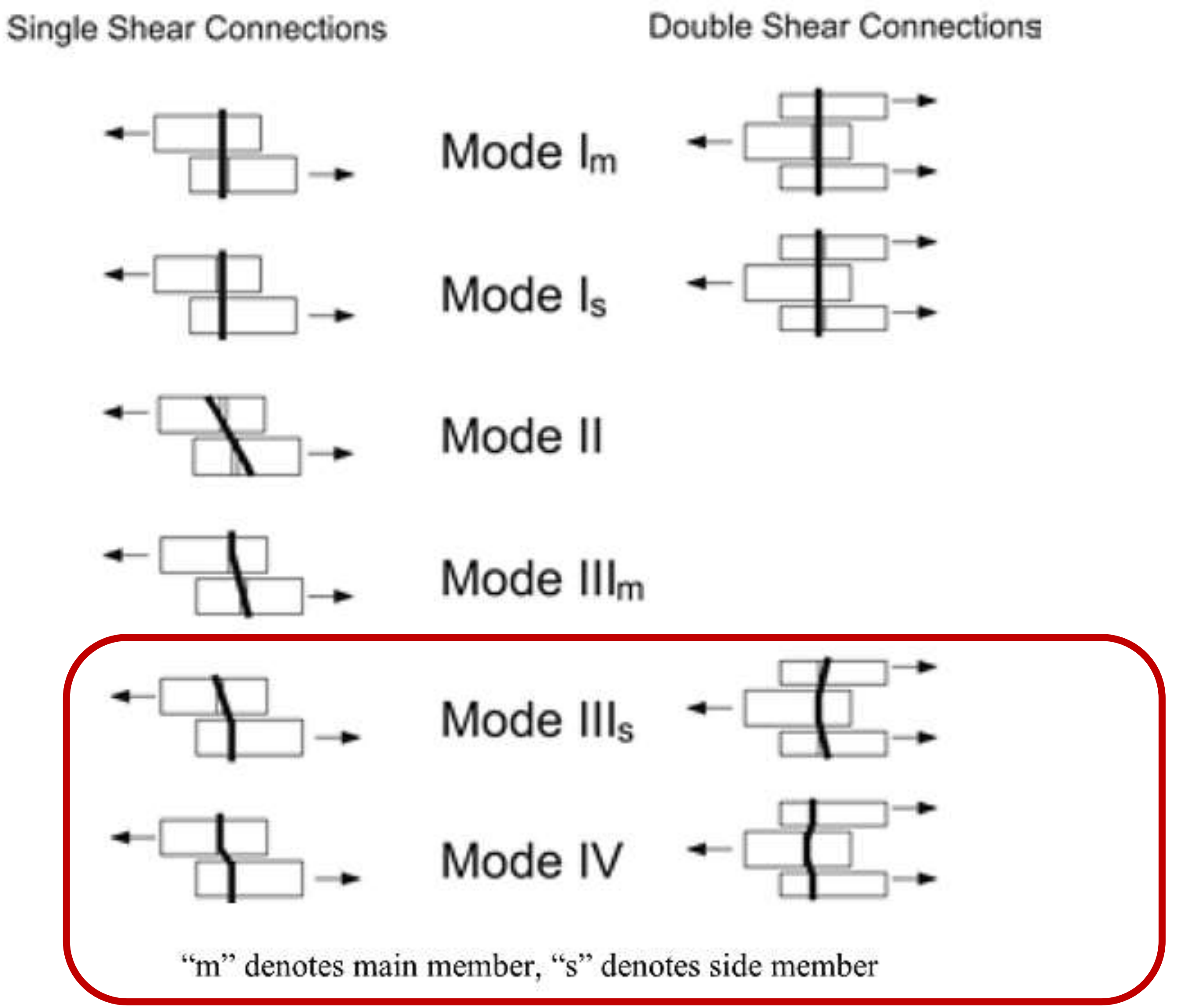
Section view



a) Over wood beam
b) Over steel beam
c) Over wood stud wall

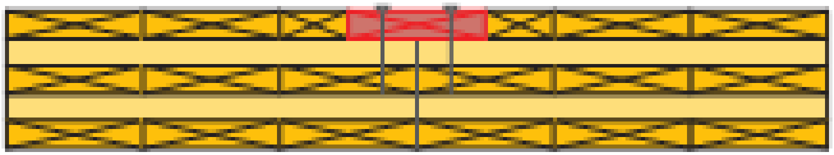
- Diaphragm **shear connections** at CLT panel edges:
- Use dowel-type fasteners in shear (nails, screws, bolts)
- Yield **Mode IIIs or Mode IV** per NDS 12.3.1 controls capacity

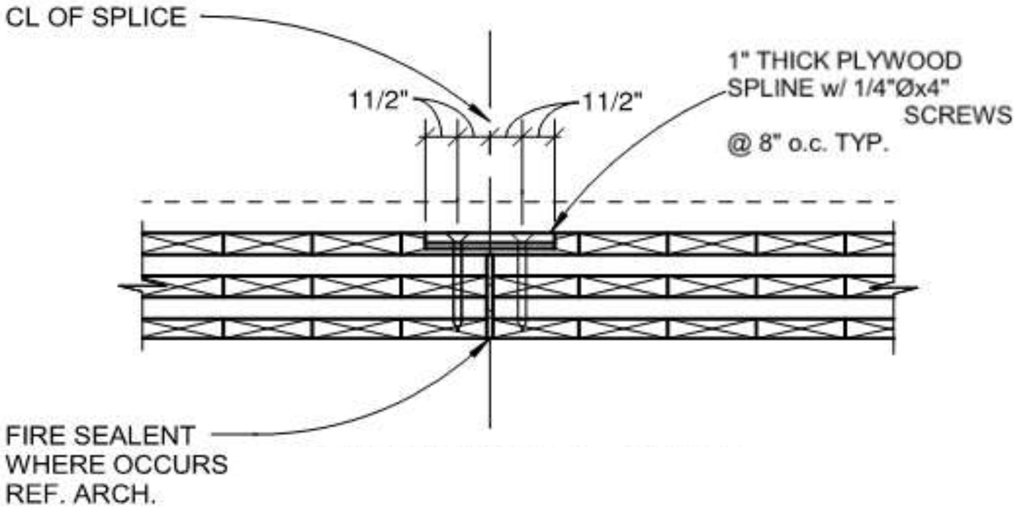
Connection Yield Modes Per the NDS

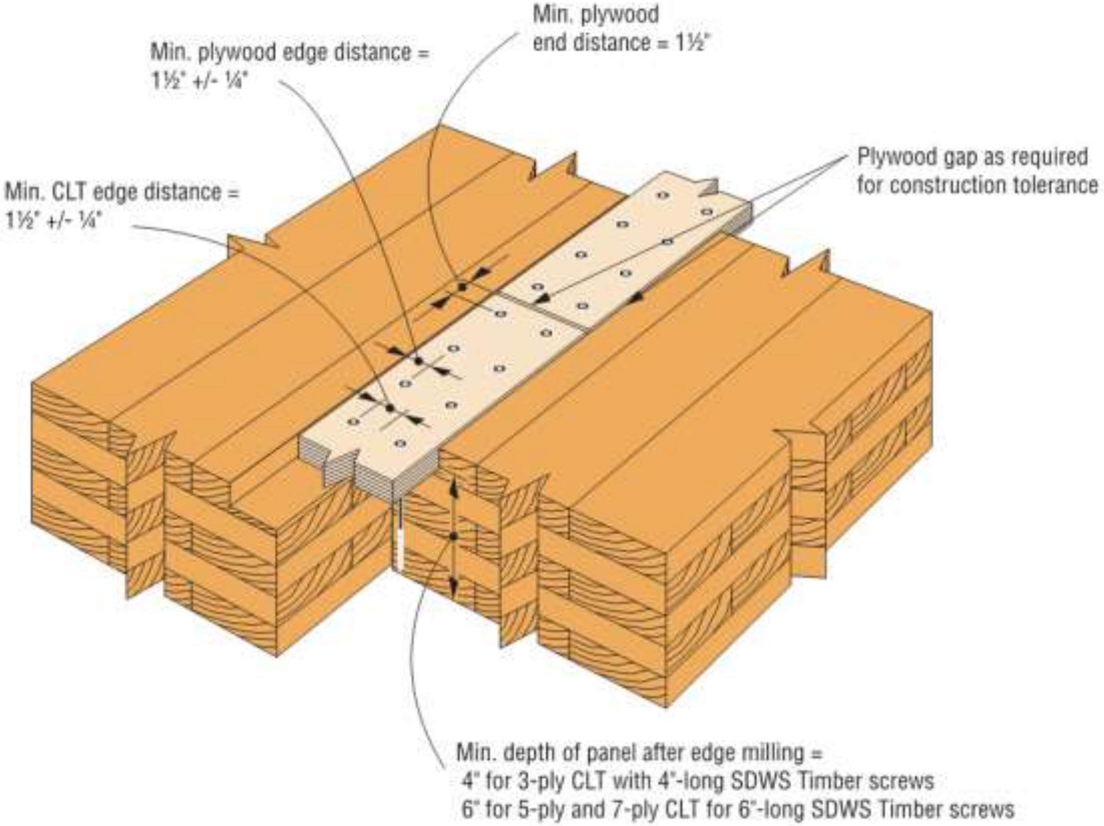


Panel to Panel Connection Styles

- Single Surface Spline



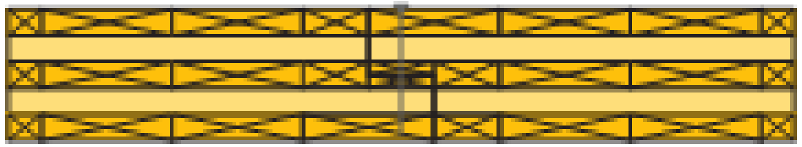


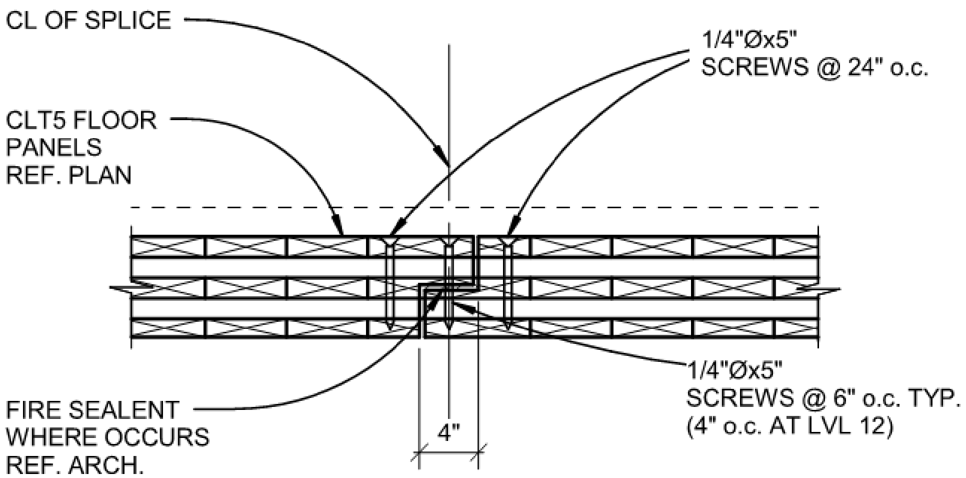


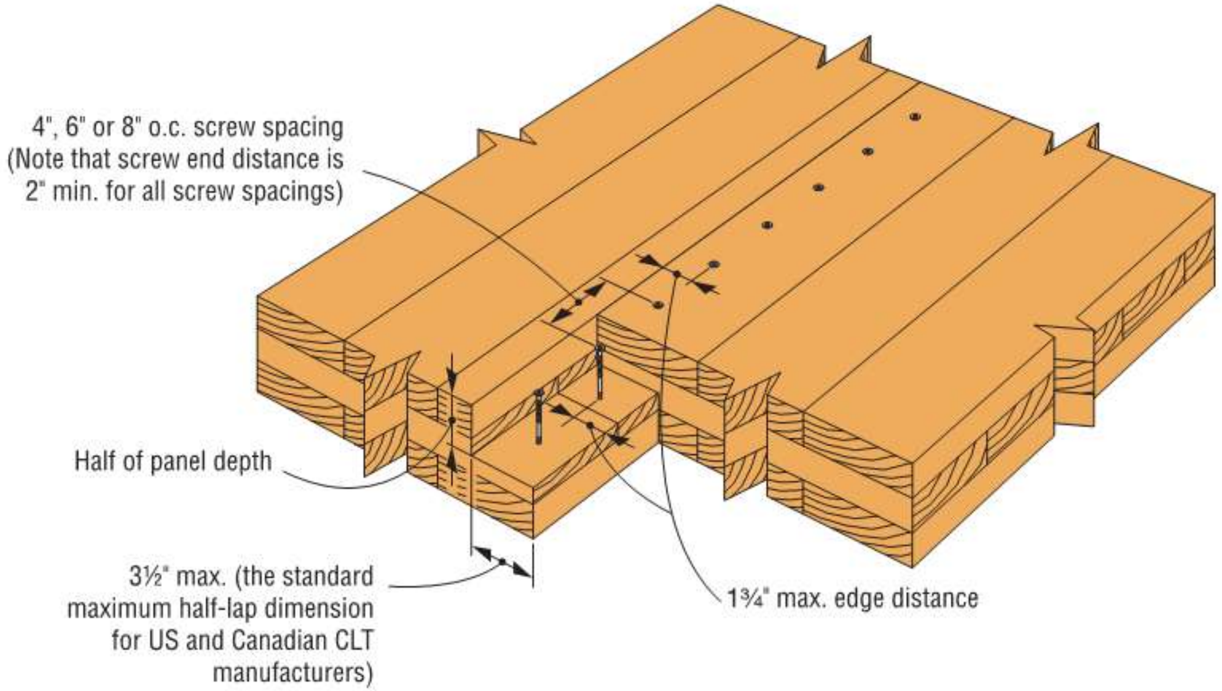
Source: Simpson Strong-Tie

Panel to Panel Connection Styles

- Half-Lap







Source: Simpson Strong-Tie

Fastener Vendor Design Support

SIMPSON Strong-Tie

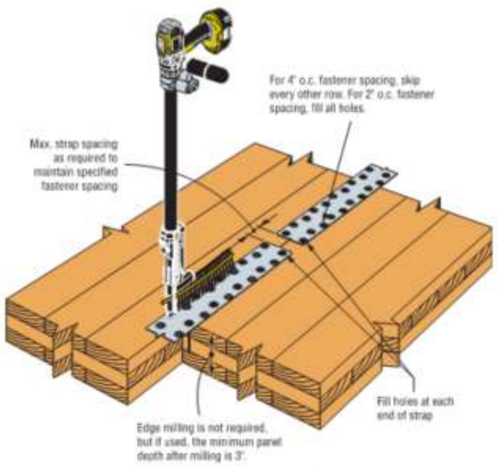
Quik Drive® Tool Setup

1. Assemble the Quik Drive PRO300SG2 cordless driver tool.
2. Remove the standard Quik Drive noseclip and replace with the PNOSECLIP-LDSS.
3. Calibrate the drive depth of the screw according to the instructions provided with the PNOSECLIP-LDSS. The ideal depth setting locates the bottom of the countersunk head just above the hole in the embossed feature.

Installation

1. Place the strap on the surface of the mass timber panels with the centerline notches aligned with joint between adjacent panels.
2. From a standing position, hold tool perpendicular to the face of the strap and place the noseclip over the embossed feature. Drive the screw. Repeat.
3. Use all specified fasteners.

The LDSS has also been tested with 0.148" x 2½" nails for specifiers or contractors who prefer a nailed connection. The embossed hole allows for the use of a power framing nailer using concentric, full round-head nails.



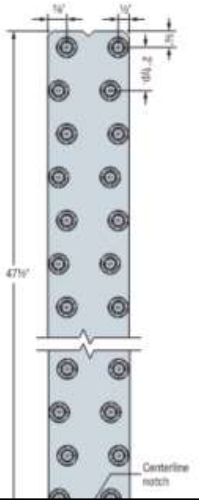
Typical LDSS48 Installation with WSV3S Screws at 4" o.c. in a Three-Ply CLT Panel (five-ply and seven-ply panel similar)

Light Diaphragm Spline Strap (LDSS) for Mass Timber

Model No.	Ga.	CLT Layup (min.)	Fasteners	Fastener Spacing (in.)	Allowable Shear Load (lb./ft.)				Slip Modulus Y (lb./in.)
					Wind		Seismic		
					DF/SP	SPF/HF	DF/SP	SPF/HF	
LDSS48	18	Three-ply	#9 x 3" WSV	4	1,030	1,030	1,030	1,030	6,330
				2	2,240	2,240	2,240	2,240	6,330
			0.148" x 2½"	4	430	430	430	430	7,685
				2	820	820	820	820	7,685

1. Allowable loads are based on the use of cross-laminated timber (CLT) grades E1-E4 and V1-V4 material conforming to APA PRG-320.
2. Allowable loads have been increased for wind or seismic loading with no further increase allowed; reduce where other loads govern.
3. Allowable loads are based on lesser of calculations per SDPWS 2021 or assembly tests with a safety factor.
4. Fastener failure modes are Mode IIIs or Mode IV.
5. **Nails:** 0.148" x 2½" = nail dimension listed diameter by length; **Screws:** #9 x 3" WSV = model WSV3S.
6. CLT panel minimum thickness is three-ply = 4.125".
7. The component of diaphragm deflection due to fastener slip at panel-to-panel joints calculated as $\delta_f = CLe_n$, where,
   $C = (1/P_L + 1/P_W)/2$
   P_L = Length of individual CLT panel (ft.); P_W = Width of individual CLT panel (ft.)
   L = Overall length of diaphragm (ft.)
   e_n = Design load per fastener (lb.) / Slip Modulus, Y (lb./in.)

(Reference — Applied Technology Council. 1981. *Guidelines for the design of horizontal wood diaphragms*. Redwood City, CA)



Product Information

Ordering SKU	Description	Quantity
LDSS48	Light Diaphragm Spline Strap (3¾" x 47¾" x 18 gauge)	1, 10 or 500

SIMPSON Strong-Tie

Table 1. Reference allowable load and slip modulus for SDWS Timber Screws (SDWS22400DB and SDWS22600DB) for CLT surface spline fastening with 1-1/8-in. APA rated Sturd-I-Floor wood structural panel, single-surface splines.		
CLT Wood Species Combination	Allowable load per Fastener (lb.)	Fastener slip modulus (in./K)
DFL	375	0.15
SPF SPF-S	335	0.15

1. Allowable loads are given at C_D=1.0 and maybe increased up to C_D=1.6 as permitted by the building code.
2. Applicable adjustments shall be applied following the ANSI/AWC NDS®-15 or NDS®-18.
3. Design values are applicable for all grain orientation combinations of major strength directions in the CLT and the wood structural panel spline and grades of CLT for the species combinations listed.
4. Designer is responsible to check shear capacity of spline (shear through the thickness and rolling shear).

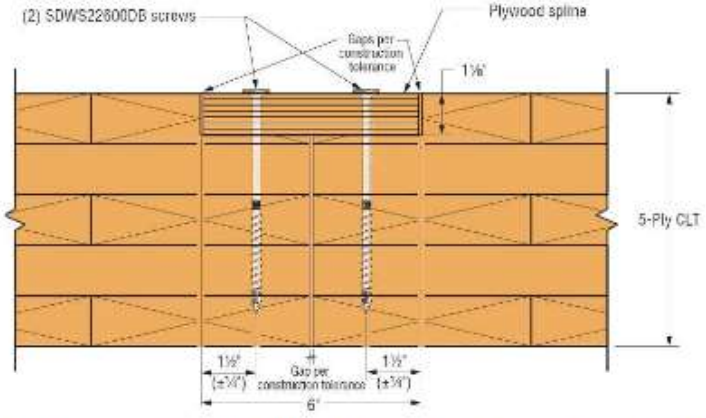
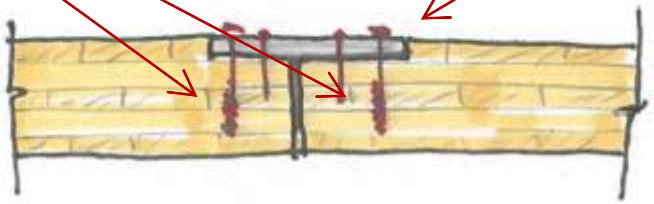


Figure 1: Typical end elevation – Single-surface spline with 5-ply CLT panels, 1-1/8-in. spline (plywood shown, 6-in. width), and 6-in. SDWS Timber screws (SDWS22600DB).

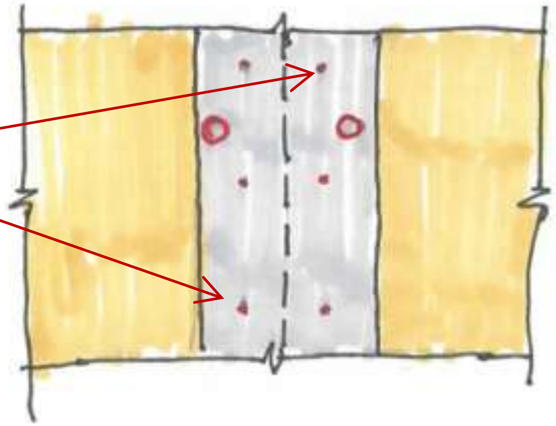
An Efficient Panel to Panel Connection

Self-Tapping Screws as “erection bolts” @ ~24” o.c

5 ½” to 5 7/8” plywood strip ¾” or 1” Thick

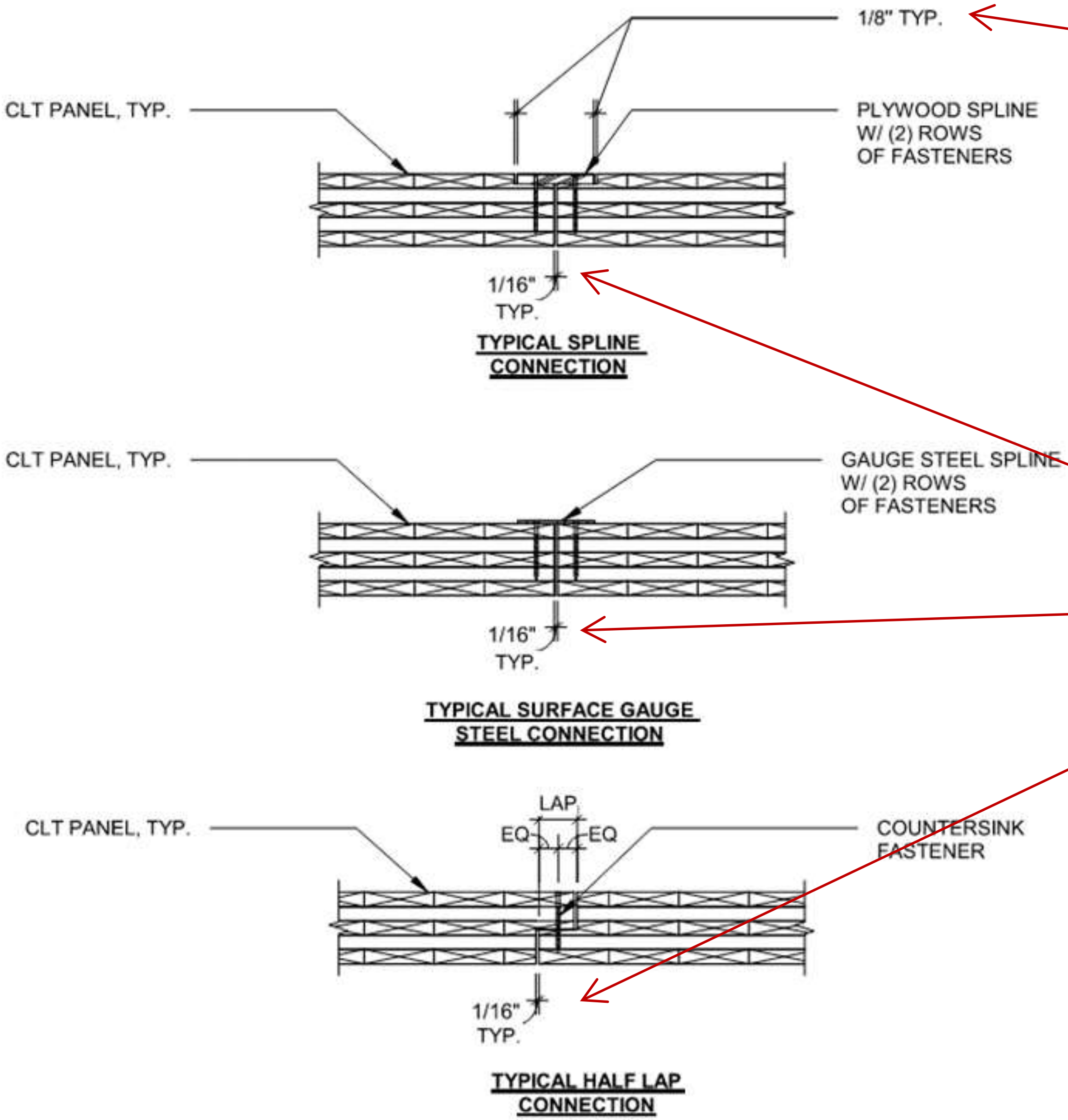


Nails at spacing required for shear transfer



Graphics: ASPECT Structural Engineers

Panel to Panel Connection Tolerances

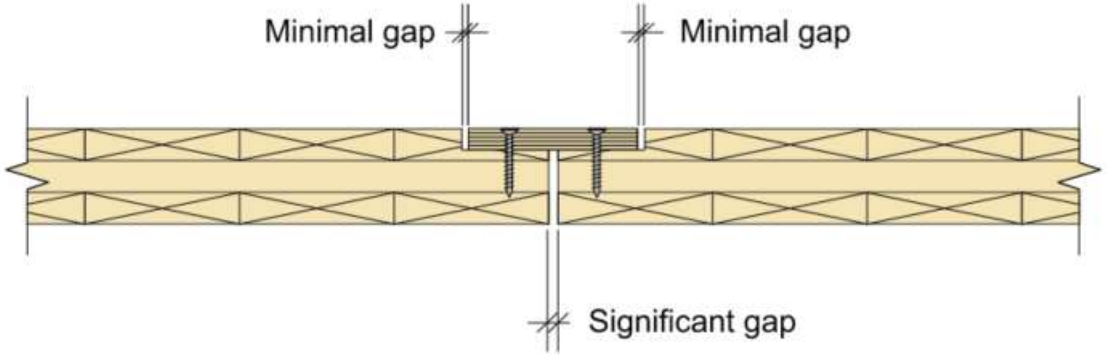


Specify gaps between splines and shoulders of CLT panel (like spacing of WSP panels)

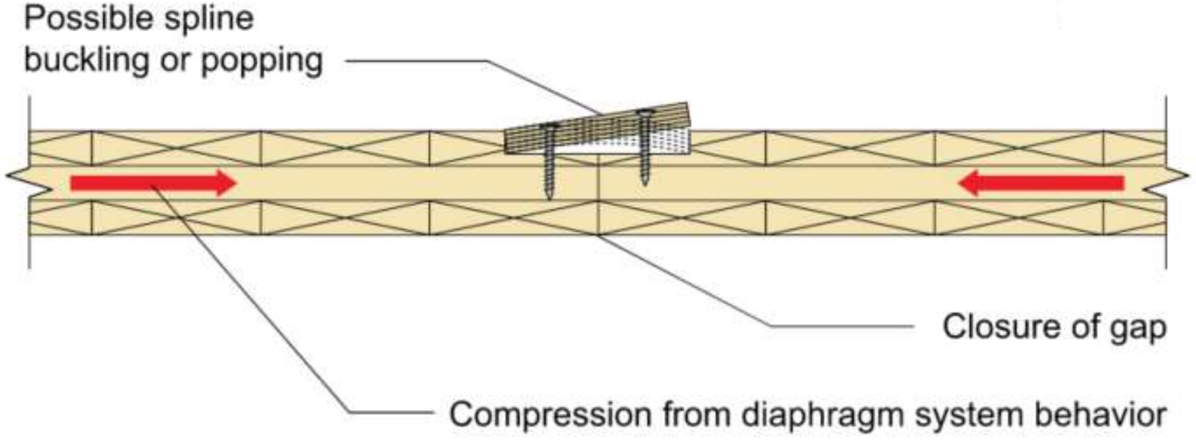
Plan for construction tolerances.

Panel to Panel Connection Tolerances

One reason for size of cut rabbet in CLT for spline to include gaps:



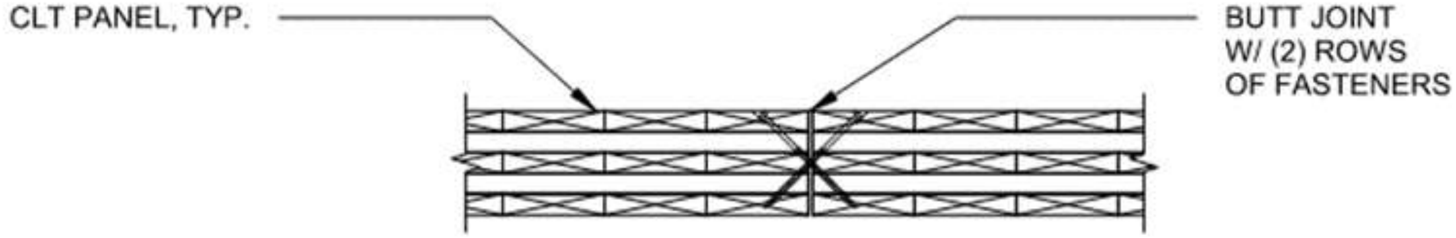
BUILT CONDITION



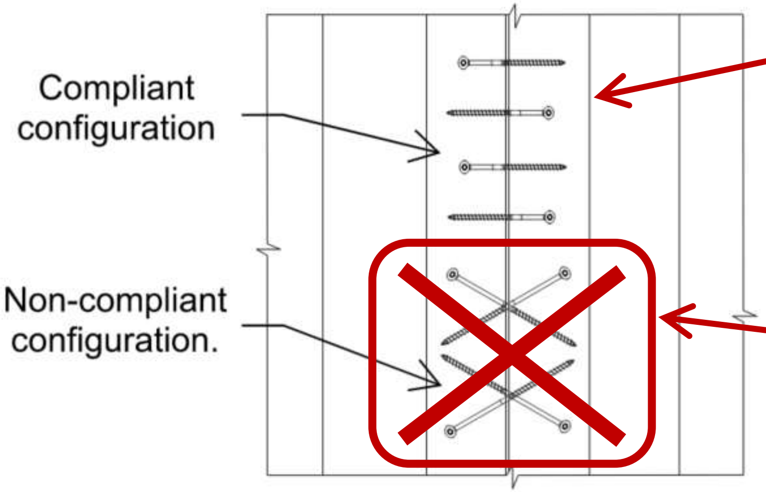
POTENTIAL BEHAVIOR UNDER HIGH DIAPHRAGM LOADING

Panel to Panel Connections Options

Is a butt joint with angled screws compliant?



Section View

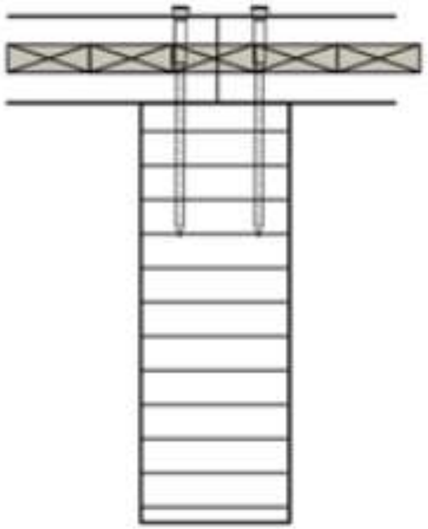


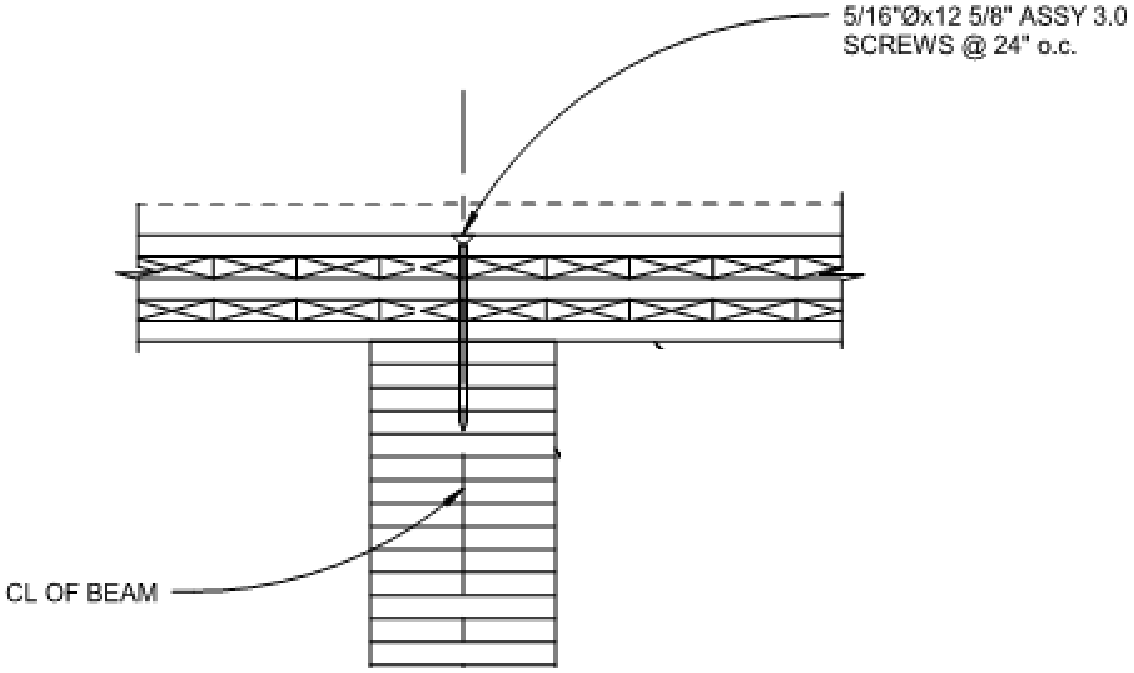
Shear resisted by dowels in shear. OK if Mode IIIs or IV

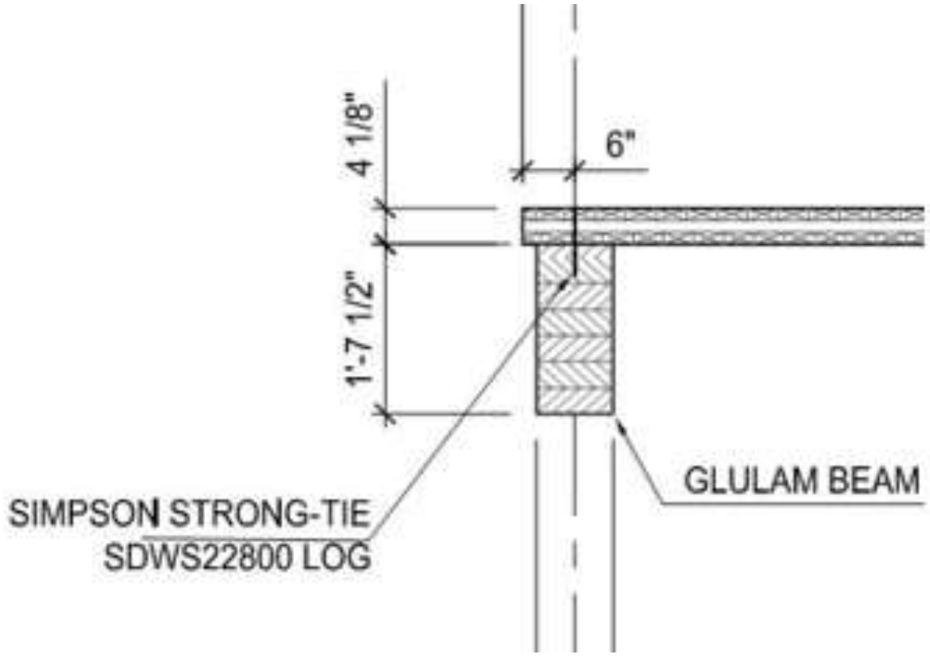
Shear resisted by dowels in tension & compression. Not compliant!

Plan View

Panel to Beam Connection Styles







CLT Diaphragm Shear Connection Design

Nominal capacity of CLT diaphragm shear connection fastener:

$$Z_n = 4.5\, Z^*$$

Where Z^* is reference lateral capacity of the fastener, Z, of NDS multiplied by all NDS adjustment factors *except* C_D, K_F, ϕ, $\lambda = 1.0$

SDPWS 2021 Section 4.5.4(1) and NDS Table 11.3.1

Table 11.3.1 Applicability of Adjustment Factors for Connections

	ASD Only	ASD and LRFD									LRFD Only		
	Load Duration Factor[1]	Wet Service Factor	Temperature Factor	Group Action Factor	Geometry Factor[3]	Penetration Depth Factor[3]	End Grain Factor[3]	Metal Side Plate Factor[3]	Diaphragm Factor[3]	Toe-Nail Factor[3]	Format Conversion Factor K_F	Resistance Factor ϕ	Time Effect Factor
Lateral Loads													
Dowel-type Fasteners (e.g. bolts, lag screws, wood screws, nails, spikes, drift bolts, & drift pins) $Z^* = Z \times$	1.0	C_M	C_t	C_g	C_Δ	-	C_{eg}	-	1.0	C_{tn}	1.0	1.0	1.0

Also 1.0 for CLT Diaphragm Shear Connections

SDPWS 2021 Section 4.5.4(1) and NDS Table 11.3.1

CLT Diaphragm Shear Connection Design

Nominal capacity of CLT diaphragm shear connection fastener:

$$Z_n = 4.5\ Z^*$$

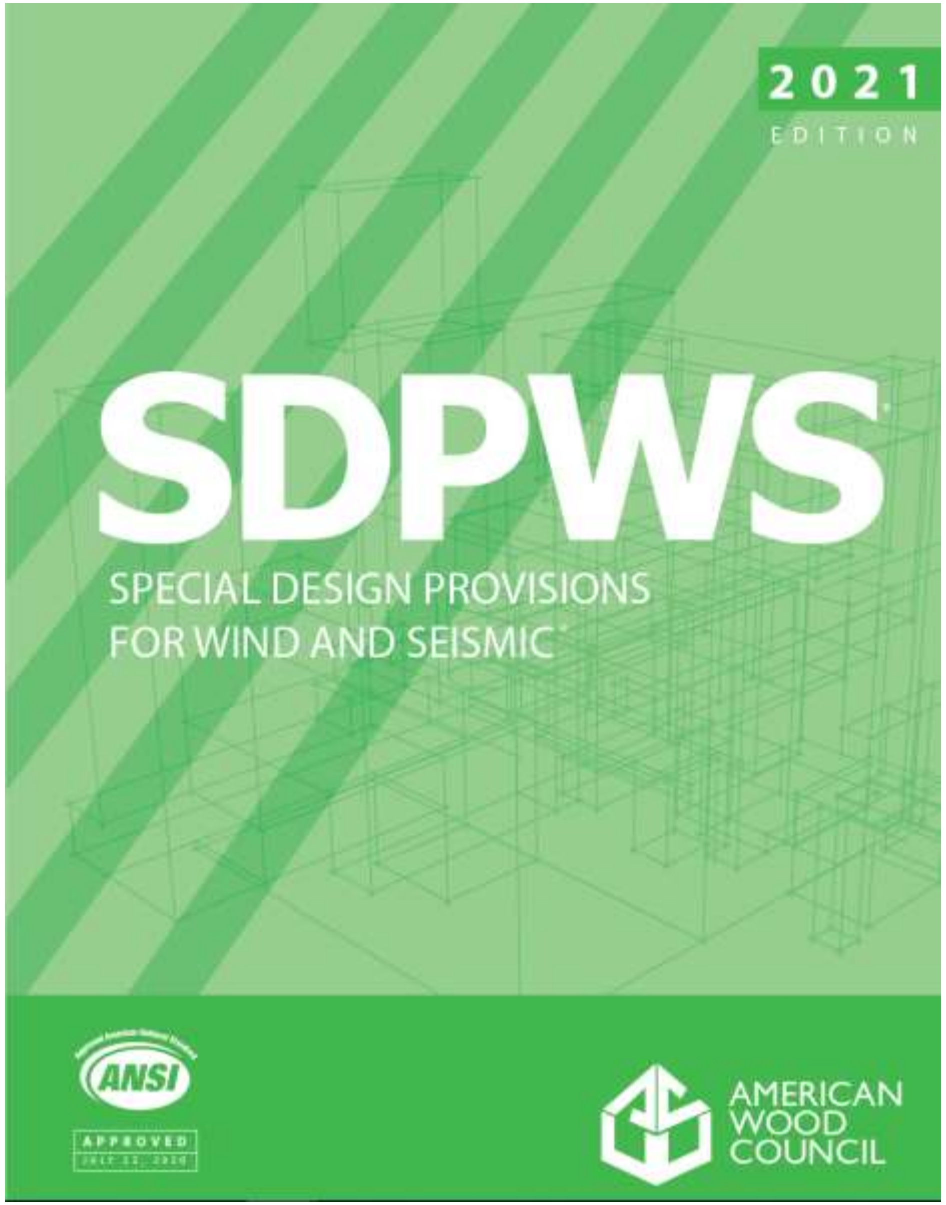
Where Z^* is reference lateral capacity of the fastener, Z, of NDS multiplied by all NDS adjustment factors *except* C_D, K_F, ϕ, λ = 1.0

Fastener with regular spacing, S, nominal unit shear connection capacity is:

$$v_n = Z_n/S = 4.5\ Z^*/S$$

SDPWS 2021 Section 4.5.4(1) and NDS Table 11.3.1

2021 SDPWS – Unified Nominal Shear Capacity



To calculate the ASD or LRFD shear capacity, SDPWS 2021 has different reduction factors for wind and seismic

	Design shear capacity	
	ASD	LRFD
Wind	$v_n/2.0$	$0.8\ v_n$
Seismic	$v_n/2.8$	$0.5\ v_n$

ASD seismic design capacity:

$4.5\ Z^* / 2.8 = 1.61\ Z^* \approx C_D\ Z = 1.6\ Z$

CLT Diaphragm Shear Connection Design

Fastener with regular spacing, S, nominal unit shear connection capacity is:

$$v_n = Z_n/\text{S} = 4.5\ Z^*/\text{S}$$

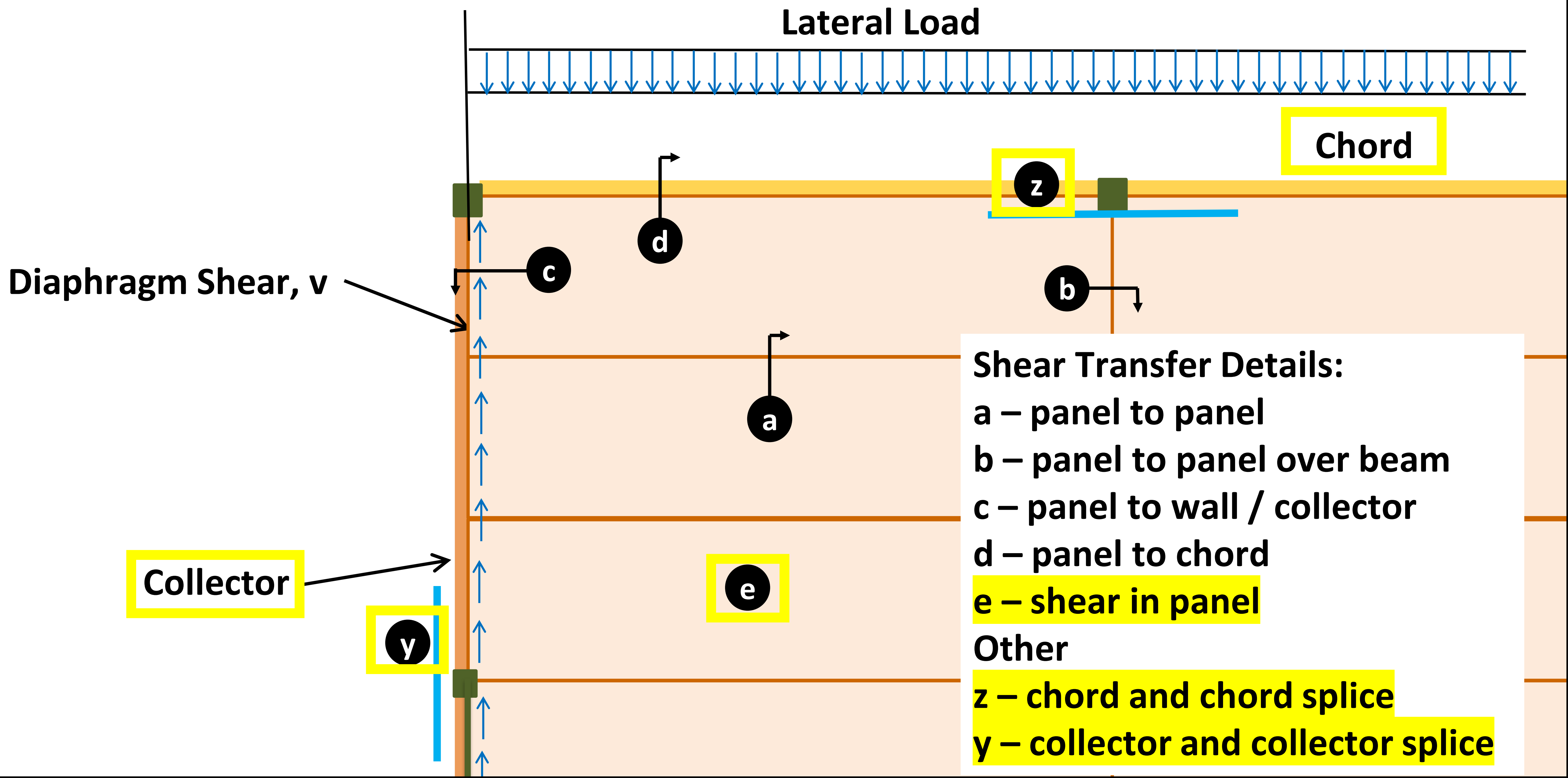
Required unit shear strength ≤ Design unit shear capacity

ASD $$v = v_{ASD} \leq \frac{v_n}{RF}$$ RF = 2.8 (seismic), = 2.0 (wind)

LRFD $$v = v_u \leq \phi v_n$$ ϕ = 0.5 (seismic), = 0.8 (wind)

SDPWS 2021 Section 4.1.4 and 4.5.4(1)

Other CLT Diaphragm Components



Other Diaphragm Components

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_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 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

tener 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_s 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.

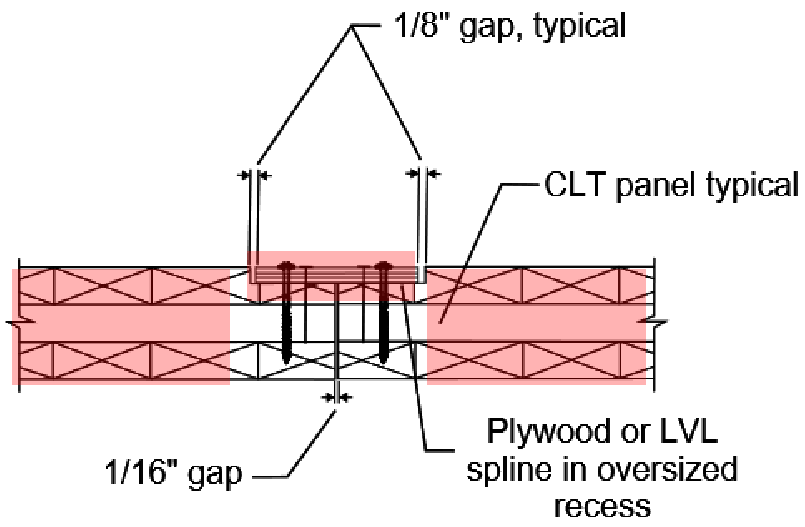
Diaphragm chord elements and chord splice connections using materials other than wood or steel shall be designed using provisions in NDS 1.4.

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.

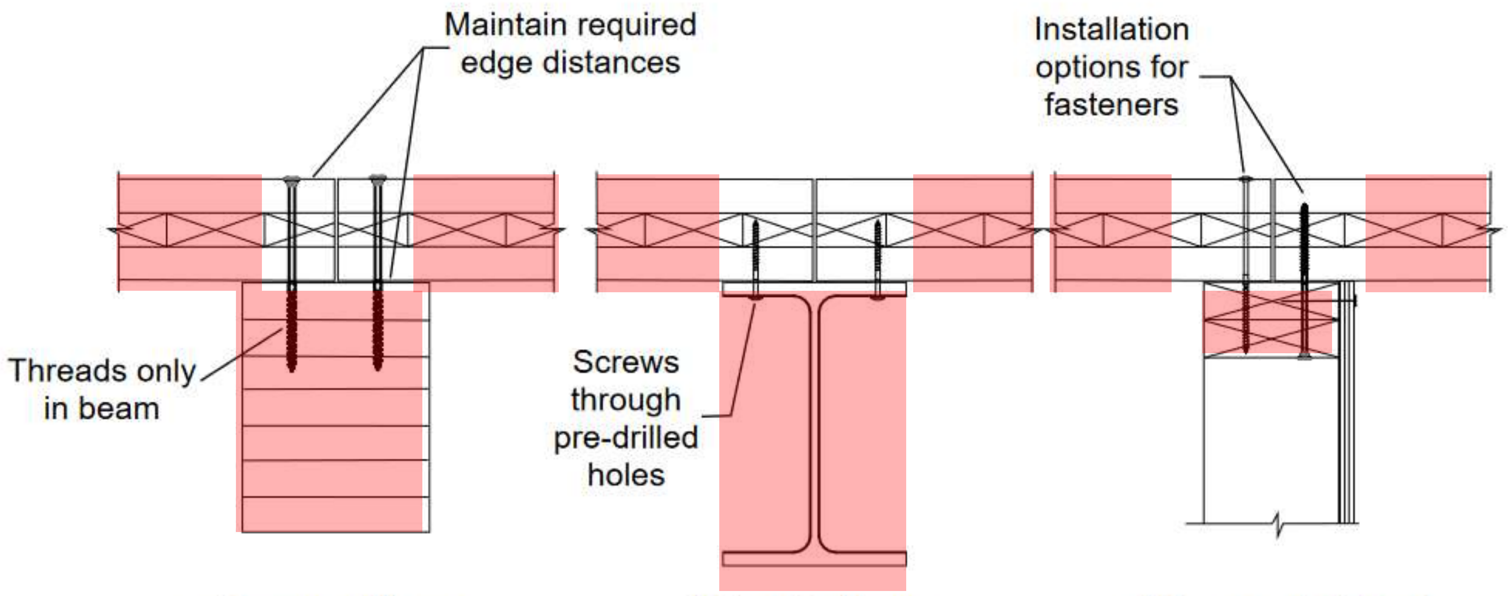
Exceptions:

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_s 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



Section view



a) Over wood beam b) Over steel beam c) Over wood stud wall

Other CLT Diaphragm Components

Increased Diaphragm Design Forces ≤ Design Capacity

$$\gamma_D \cdot v \leq v'$$

v = wind or seismic force demand

v' = Adjusted capacity calculated per the NDS *not 4.5 Z**

$\gamma_D =$ 2.0 for wood and steel components, except:
1.5 wood members resisting wind loads
1.5 chord splice connections controlled by Mode IIIs or IV (seismic)
1.0 chord splice connections controlled by Mode IIIs or IV (wind)

*See **SDPWS 2021 Section 4.5.4** for the full information*

Other CLT Diaphragm Components

$$R'_{NDS} \geq \gamma_D F_{design,ASD}$$

$$R'_{NDS} \geq \gamma_D F_{design,LRFD}$$

Component	Force Increase Factor γ_D	
	Seismic	Wind
Chord splice connections between wood elements where the connection is using fasteners in shear controlled by yield mode III_s or IV	1.5	1.0
Wood elements and connections between wood elements not meeting the above	2.0	1.5
Steel elements including connections between steel elements	2.0	2.0

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_s 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.

*See **SDPWS 2021 Section 4.5.4** for the full information*

Example Calculation – Shear through Surface Spline

4.5 Example Calculation of Surface Spline Connection

An example calculation for a single surface spline detail is provided in Figure 4.8.

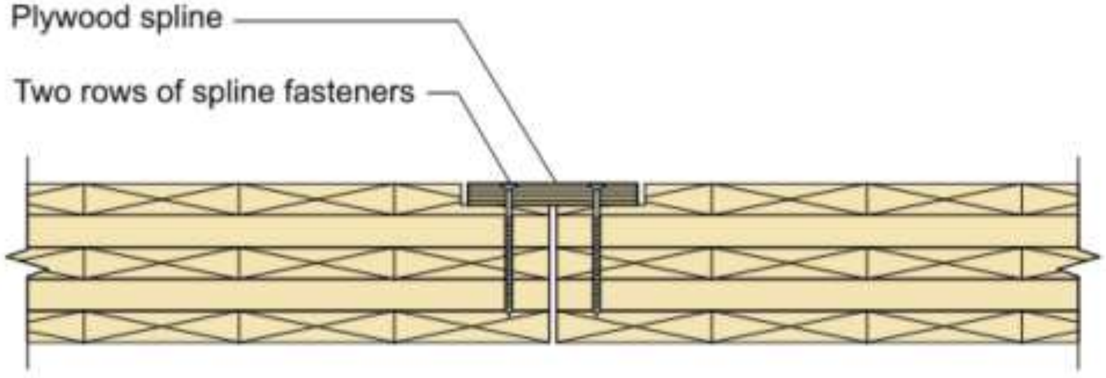


FIGURE 4.8: Example spline connection

- 10d common nails
- Group 1, 23/32-in.-thick, 48/24 span-rated, general sheathing grade 4-ply plywood spline
- CLT panel with specific gravity, G = 0.50

An ASCE 7-16 diaphragm unit shear wind demand of 1,600 lbf per ft at strength (LRFD) is assumed.

Example Calculation – Shear through Surface Spline

Calculate reference shear capacity of 10d nail connection the spline to the CLT panel following NDS 12.3

Specific Gravity:	$G := 0.5$	
Dowel diameter:	$D := 0.148\ in$	
Dowel length:	$l_{dowel} := 3\ in$	
Dowel bending yield strength:	$F_{yb} := 90000\ psi$	
Side member bearing length:	$l_s := 0.72\ in$	
Estimated length of tapered tip:	$E := 2 \cdot D = 0.296\ in$	per NDS §12.3.5.3
Main member bearing length:	$l_m := l_{dowel} - l_s - \frac{E}{2} = 2.132\ in$	
Main member bearing strength:	$F_{em} := 4650\ psi$	per NDS Table 12.3.3
Side member bearing strength:	$F_{es} := 3350\ psi$	per NDS Table 12.3.3B
Bearing strength ratio:	$R_e := \frac{F_{em}}{F_{es}} = 1.39$	
Bearing length ratio:	$R_t := \frac{l_m}{l_s} = 2.96$	
Reduction term:	$R_d := 2.2$	per NDS Table 12.3.1B

Example Calculation – Shear through Surface Spline

Calculate reference shear capacity of 10d nail connection the spline to the CLT panel following NDS 12.3

Strength fit factors per NDS Table 12.3.1A:

$$k_1 := \frac{\sqrt{R_e + 2 \cdot R_e^2 \cdot \left(1 + R_t + R_t^2\right) + R_t^2 \cdot R_e^3} - R_e \cdot \left(1 + R_t\right)}{1 + R_e} = 1.3$$

$$k_2 := -1 + \sqrt{2 \cdot \left(1 + R_e\right) + \frac{2 \cdot F_{yb} \cdot \left(1 + 2 \cdot R_e\right) \cdot D^2}{3 \cdot F_{em} \cdot l_m^2}} = 1.24; \quad k_3 := -1 + \sqrt{\frac{2 \cdot \left(1 + R_e\right)}{R_e} + \frac{2 \cdot F_{yb} \cdot \left(2 + R_e\right) \cdot D^2}{3 \cdot F_{em} \cdot l_s^2}} = 1.3$$

Single shear yield limit equations per NDS Table 12.3.1A:

Mode I_m: $$Z_{Im} := \frac{D \cdot l_m \cdot F_{em}}{R_d} = 666.9 \text{ lbf}$$

Mode I_s: $$Z_{Is} := \frac{D \cdot l_s \cdot F_{es}}{R_d} = 162.3 \text{ lbf}$$

Mode II: $$Z_{II} := \frac{k_1 \cdot D \cdot l_s \cdot F_{es}}{R_d} = 210.5 \text{ lbf}$$

Mode III_m: $$Z_{IIIm} := \frac{k_2 \cdot D \cdot l_m \cdot F_{em}}{\left(1 + 2 \cdot R_e\right) \cdot R_d} = 218.7 \text{ lbf}$$

Mode III_s: $$Z_{IIIs} := \frac{k_3 \cdot D \cdot l_s \cdot F_{em}}{\left(2 + R_e\right) \cdot R_d} = 86.4 \text{ lbf}$$

Mode IV: $$Z_{IV} := \frac{D^2}{R_d} \cdot \sqrt{\frac{2 \cdot F_{em} \cdot F_{yb}}{3 \cdot \left(1 + R_e\right)}} = 107.6 \text{ lbf}$$

Controlling: $Z := Z_{IIIs} = 86.4 \text{ lbf}$

CLT Diaphragm Design Guide Section 4.5

Example Calculation – Shear through Surface Spline

Calculate *nominal CLT diaphragm* shear capacity of nail (interior, dry application with sufficient edge distances):

Wet service factor:	$C_M := 1.0$	
Temperature factor:	$C_t := 1.0$	
Group action factor:	$C_g := 1.0$	
Geometry factor:	$C_\Delta := 1.0$	(determine a value if Ø > 1/4")
End grain factor:	$C_{eg} := 1.0$	
Diaphragm factor:	$C_{di} := 1.0$	
Toe nail factor:	$C_{tn} := 1.0$	
Adjusted design value	$Z_{star} := Z \cdot C_M \cdot C_t \cdot C_g \cdot C_\Delta \cdot C_{eg} \cdot C_{di} \cdot C_{tn} = 86\ lbf$	
Nominal strength:	$V_n := 4.5 \cdot Z_{star} = 389\ lbf$	per SDPWS §4.5.4 Item 1

ASD and LRFD *CLT diaphragm shear* capacity of nail:

Reduction factor:	$\Omega_D := 2.0$	per SDPWS §4.1.4 for wind design
ASD Adjusted strength:	$\frac{V_n}{\Omega_D} = 194\ lbf$	
Resistance factor:	$\phi_D := 0.8$	per SDPWS §4.1.4 for wind design
LRFD Adjusted strength:	$\phi_D \cdot V_n = 311\ lbf$	

Example Calculation – Shear through Surface Spline

Determine required nail spacing and compare resulting capacity with design shear demand (ASD)

$V_{design.ASD} := 0.6 \cdot 1600 \frac{lbf}{ft} = 960 \frac{lbf}{ft}$ ASD load combination factor of 0.6W applied

$s_{max} := \frac{\frac{V_n}{\Omega_D}}{V_{design.ASD}} = 2.43\ in$ maximum fastener spacing

$s := 2.0\ in$ specify 2.0 inches for design and construction

Check assumed Geometry Adjustment Factor depending on fastener diameter:

$C_\Delta := 1.0$ adjustment factor value confirmed per NDS 12.5.1

Determine design capacity and compute the DCR.

$v_n := V_n \cdot \frac{12 \frac{in}{ft}}{s} = 2333 \frac{lbf}{ft}$

$\frac{v_n}{\Omega_D} = 1166 \frac{lbf}{ft}$

1166 plf ASD wind shear capacity of nails
> ASD wind shear demand 960 plf

$DCR := \frac{V_{design.ASD}}{\frac{v_n}{\Omega_D}} = 0.82$ *DCR < 1.0. OK*

CLT Diaphragm Design Guide Section 4.5

Example Calculation – Shear through Surface Spline

Alternatively, use the pre-calculated design table in the Appendix A of the Guide, first calculate the required nominal fastener shear capacity (ASD or LRFD):

$$v_{n.req.ASD} := \frac{\Omega_D \cdot V_{design.ASD}}{C_M \cdot C_t \cdot C_g \cdot C_\Delta \cdot C_{eg} \cdot C_{di} \cdot C_{tn}}$$

$$v_{n.req.ASD} := \frac{2.0\left(960\ \frac{\text{lbf}}{\text{ft}}\right)}{1.0 \cdot 1.0 \cdot 1.0 \cdot 1.0 \cdot 1.0 \cdot 1.0 \cdot 1.0} = 1920\ \frac{\text{lbf}}{\text{ft}}$$

CLT Diaphragm Design Guide Section 4.5

Example Calculation – Shear through Surface Spline

Pre-calculated design tables in the Appendix A of the Guide

TABLE A.1.1: Example fastener properties for spline capacities

Fasten	Diameter, D[a]	Length[b]	Yield Strength
8d commor			
10d commo			
16d commo			
Example sc			
Example sc			

a. Diameter us
diameter, D
b. Minimum pe
and 6D for

TABLE A.1.2: Example WSP properties for spline capacities

Spline Sid
General sheath
Structural 1 she
General single
Structural 1 sing
General sheath
Structural 1 sing
General sheath
Structural 1 sing

TABLE A.1.3: Reference design value and controlling yield mode for fasteners in splines

Sp	Reference Lateral Design Value for Single Fastener, Z[a] (lbf)
General sh	
General sh	
General sh	
General sh	
General sh	
Structural	
Structural	
Structural	
Structural	
Structural	
General sh	

TABLE A.1.4: Nominal diaphragm shear capacity for spaced fastener in spline

Spline Material	Fastener	Nominal Diaphragm Shear Capacity of Fasteners, $v_n = 4.5Z'/S$, @ Spacing, $S^{a,c}$ (plf)					Reference Spline Shear Capacity, $F_v t_v^b$ (plf)
		12-in. o.c.	6-in. o.c.	4-in. o.c.	3-in. o.c.	2-in. o.c.	
CLT SG = 0.36							
General sheathing (23/32)	8d common nail	255	510	765	1,020	1,530	1,176
General sheathing (23/32)	10d common nail	296	592	888	1,184	1,776	1,176
General sheathing (23/32)	Example screw 1	266	531	797	1,062	1,593	1,176
General sheathing (23/32)	Example screw 2	321	641	962	1,283	1,924	1,176
Structural 1 sheathing (23/32)	8d common nail	311	623	934	1,245	1,868	1,512
Structural 1 sheathing (23/32)	10d common nail	359	718	1,077	1,436	2,154	1,512
Structural 1 sheathing (23/32)	Example screw 1	316	631	947	1,262	1,893	1,512
Structural 1 sheathing (23/32)	Example screw 2	385	771	1,156	1,542	2,313	1,512
General sheathing (7/8)	10d common nail	336	672	1,008	1,343	2,015	1,440

Example Calculation – Shear in Surface Spline

Using the pre-calculated design table in the Appendix A of the Guide, reference Appendix A.1.4 to find spline detail with required nominal capacity

TABLE A.1.4: Nominal diaphragm shear capacity for spaced fastener in spline *continued*

Spline Material	Fastener	Nominal Diaphragm Shear Capacity of Fasteners, $v_n = 4.5Z^*/S$, @ Spacing, $S^{a,c}$ (plf)					Reference Spline Shear Capacity, $F_v t_v{}^b$ (plf)
		12-in. o.c.	6-in. o.c.	4-in. o.c.	3-in. o.c.	2-in. o.c.	
CLT SG = 0.50							
General sheathing (23/32)	8d common nail	330	659	989	1,318	1,977	1,176
General sheathing (23/32)	10d common nail	388	776	1,164	1,552	2,328	1,176

> req. nominal 1920 plf

c. *Before using highlighted fastener capacity values, verify the adjusted design spline capacity is greater than the amplified demands per SDPWS §4.5.4:*

- (orange) *Verify adjusted spline capacity is greater than SDPWS §4.5.4.3 Exception 1 for wind design.*
- (green) *Verify adjusted spline capacity is greater than SDPWS §4.5.4.3 for seismic design and SDPWS 4.5.4.3 Exception 1 for wind design.*

CLT Diaphragm Design Guide Section 4.5

Example Calculation – Shear in Surface Spline

Check the plywood spline capacity per NDS against the increased load from SDPWS 4.5.4.3

Find the SDPWS increased ASD design shear:

$\gamma_D \cdot V_{design.ASD}$ = (1.5) 960 plf = 1440 plf

Compare to the NDS adjusted plywood spline capacity (ASD)

Reference in-plane shear capacity: $Fvtv := 98 \frac{lbf}{in} \cdot 12 \frac{in}{ft} = 1176 \frac{lbf}{ft}$ per APA D510 Table 9

Apply NDS adjustment factors: per NDS Table 9.3.1

Load duration factor: $C_D := 1.6$

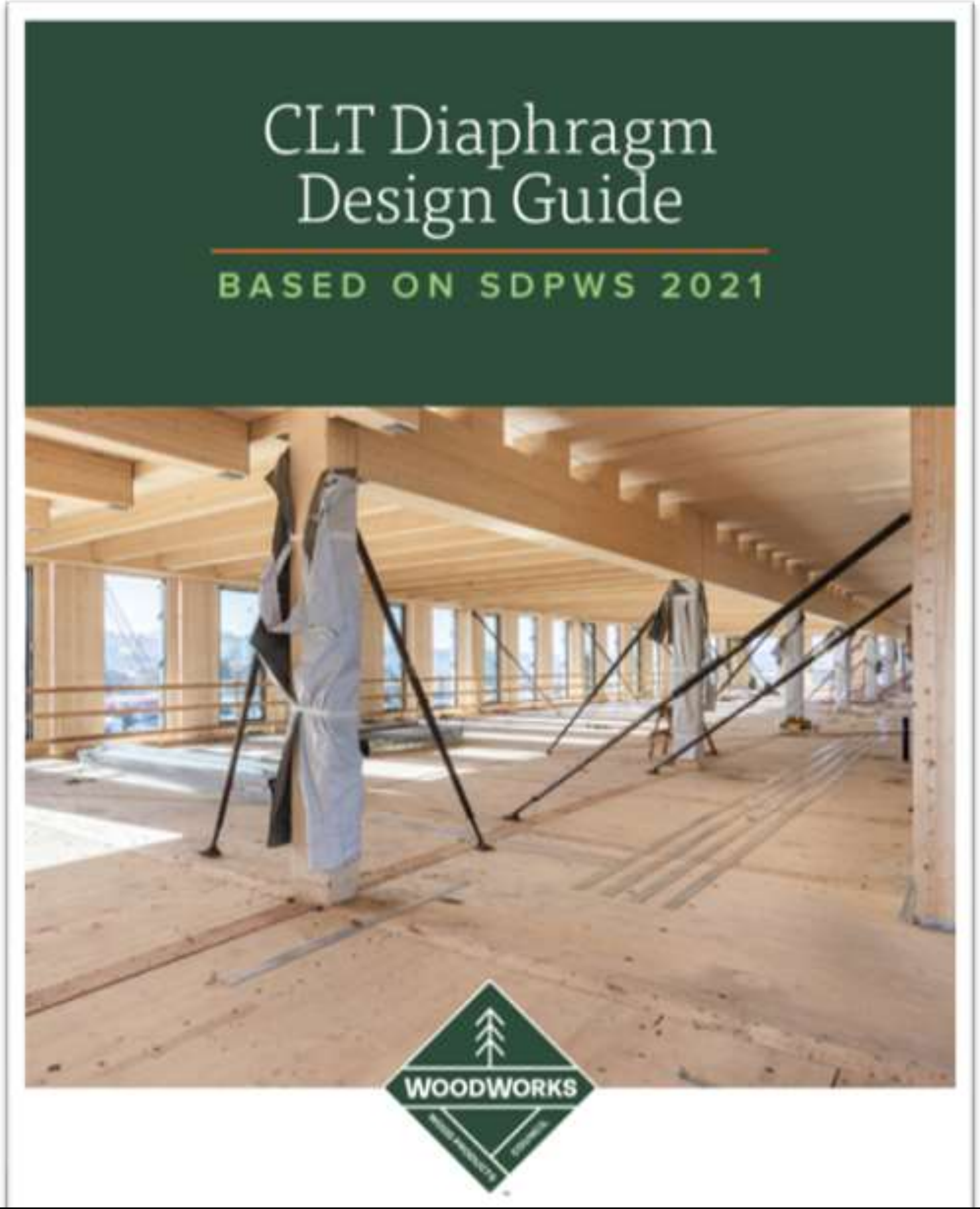
Wet service factor: $C_M := 1.0$

Temperature factor: $C_t := 1.0$

ASD adjusted strength: $Fvtv'_{NDS.ASD} := Fvtv \cdot C_D \cdot C_M \cdot C_t = 1882 \frac{lbf}{ft}$

> req. ASD shear 1440 plf, spline OK

CLT Diaphragm Design Guide based on SDPWS 2021



Chapter Organization

1. Introduction
2. Codes and Standards
3. Methodology of CLT Diaphragm Design
4. Diaphragm Shear Components
5. Diaphragm Boundary Elements
6. Diaphragm Deflection and Stiffness
7. Special Design Considerations
8. Example 12-Story Office with Distributed Frames
9. Example 12-Story Office with Reinforced Concrete Cores
10. Example 5-Story Residence with Wood-Frame Shear walls

Appendix A – Precalculated Design Capacities

Appendix B – Literature Review

QUESTIONS?

This concludes The American Institute of Architects Continuing Education Systems Course

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