CLT Shear Wall and Diaphragm Design in California

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Presented by

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Apex Plaza / Courtesy William McDonough + Partner

Course Description

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


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

Glued-Laminated Timber (GLT)

Plank orientation

Photo: StructureCraft

Photo: StructureCraft

Photo: Ema Peter

Photo: Manasc Isaac Architects/Fast + Epp

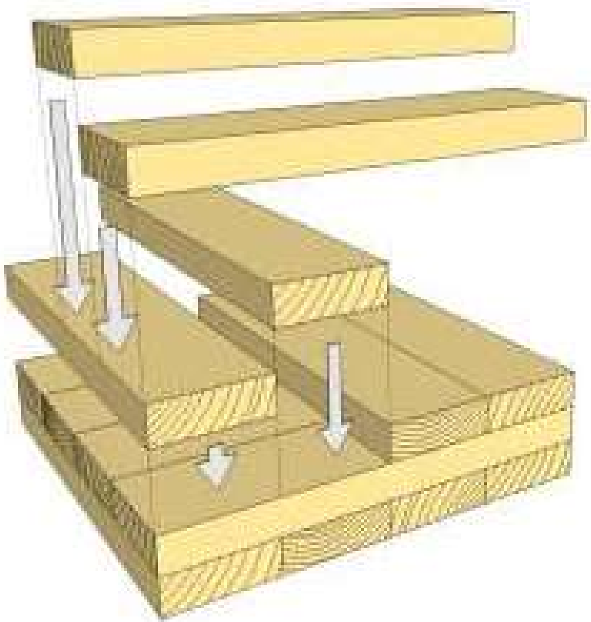
What is CLT?

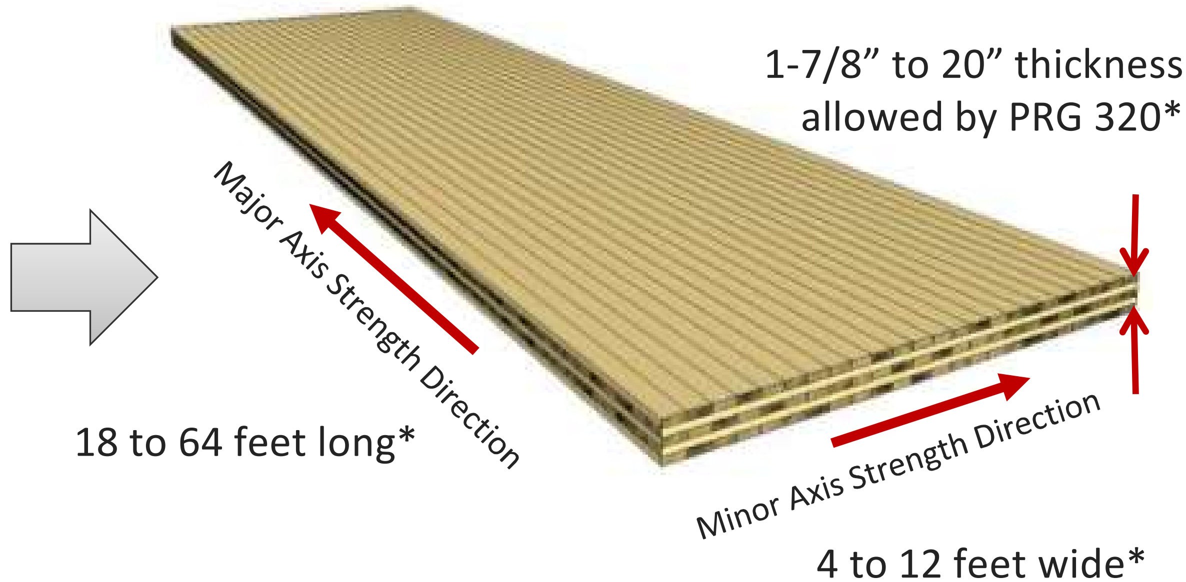
Solid-sawn or Structural Composite Lumber (SCL) laminations

3 layers minimum

Each layer rotated 90° (sim. to plywood sheathing)

Glued with structural adhesives

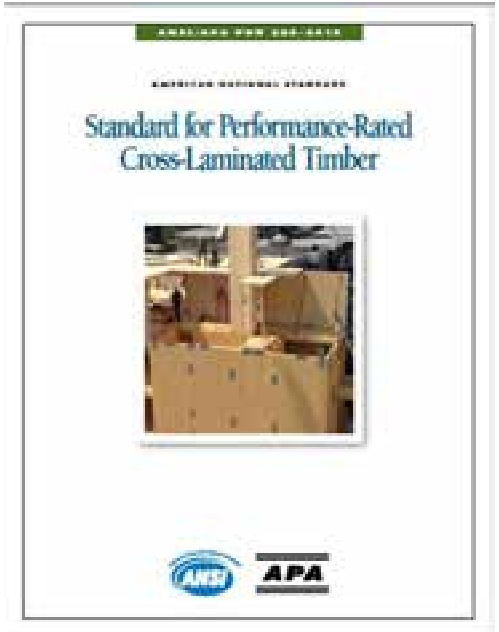




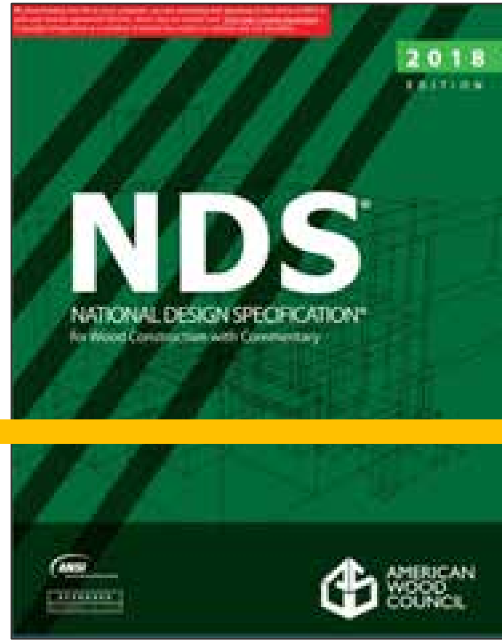
*All dimensions are approximate.
Check with specific manufacturers

CLT Gravity Systems

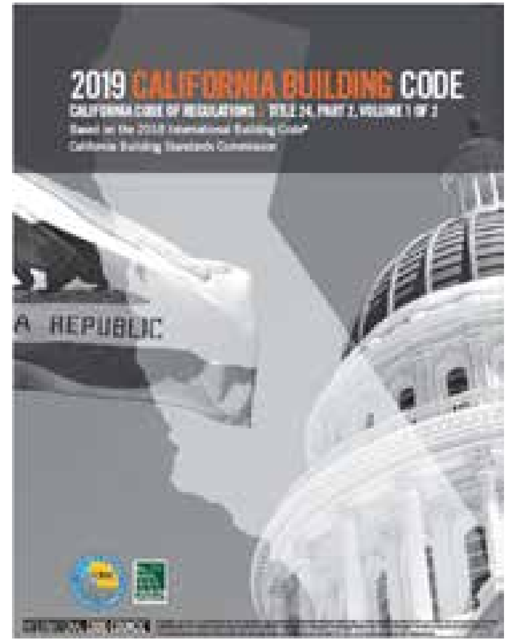
CLT in the 2019 CBC (Gravity)



PRG 320-2018



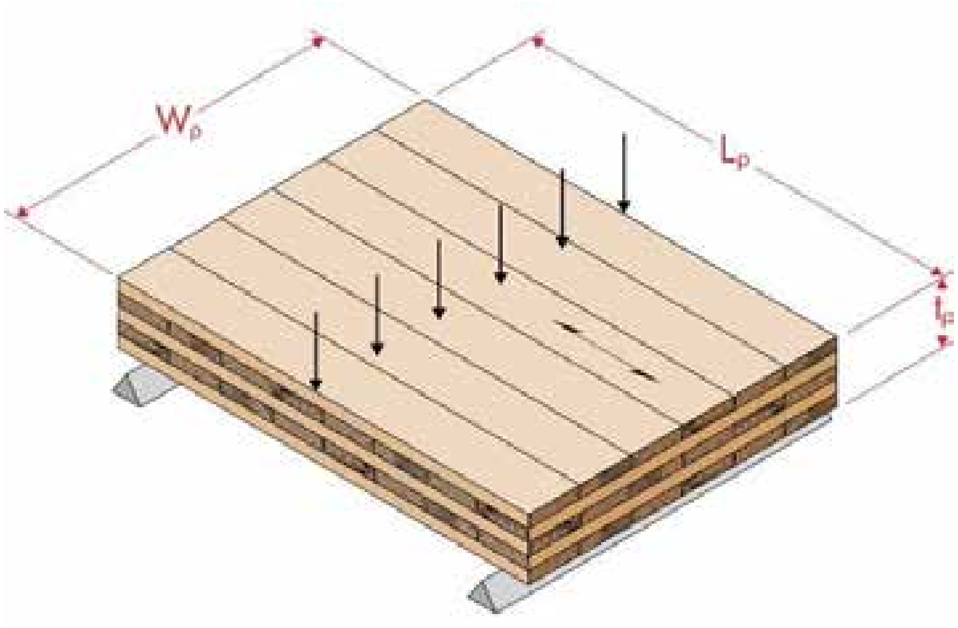
2018 NDS



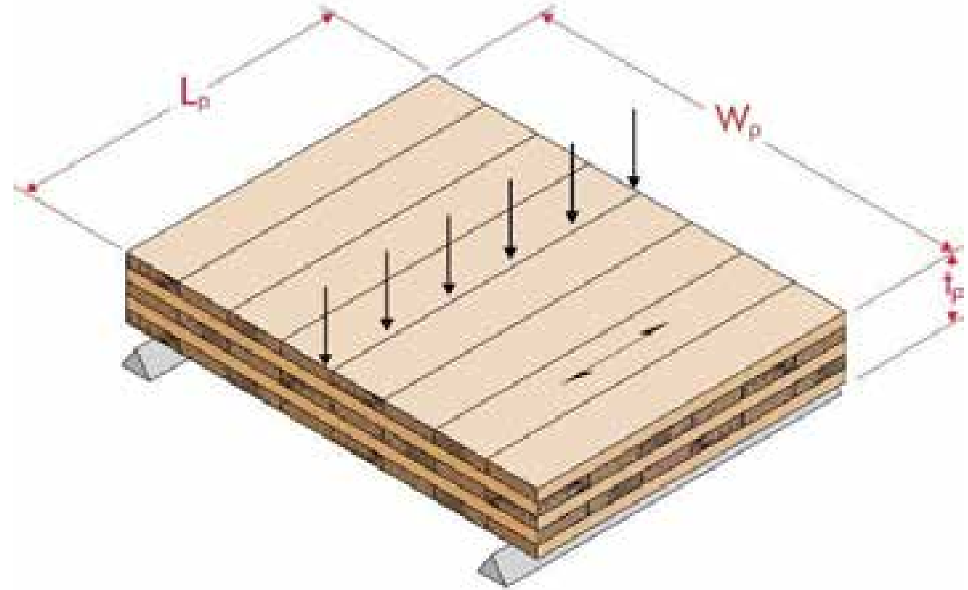
2019 California Building Code

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

PRG 320 Defined Layups

Layup

Panel Properties

CLT Basic Grades

TABLE A2

ASD REFERENCE DESIGN VALUES[a] FOR BASIC CLT GRADES AND LAYUPS (FOR USE IN THE U.S.)

		Lamination Thickness (in.) in CLT Layup							Major Strength Direction				Minor Strength Direction			
CLT Grade	t_p (in.)	=	⊥	=	⊥	=	⊥	=	$(F_bS)_{eff,f,0}$ (lbf-ft/ft of width)	$(EI)_{eff,f,0}$ (10^6 lbf-in.²/ft of width)	$(GA)_{eff,f,0}$ (10^6 lbf/ft of width)	$V_{s,0}$ (lbf/ft of width)	$(F_bS)_{eff,f,90}$ (lbf-ft/ft of width)	$(EI)_{eff,f,90}$ (10^6 lbf-in.²/ft of width)	$(GA)_{eff,f,90}$ (10^6 lbf/ft of width)	$V_{s,90}$ (lbf/ft of width)
E1	4 1/8	1 3/8	1 3/8	1 3/8					4,525	115	0.46	1,490	160	3.1	0.61	495
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8			10,400	440	0.92	2,480	1,370	81	1.2	1,490
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	18,375	1,089	1.4	3,475	3,150	313	1.8	2,480
E2	4 1/8	1 3/8	1 3/8	1 3/8					3,825	102	0.53	1,980	165	3.6	0.56	660
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8			8,825	389	1.1	3,300	1,440	95	1.1	1,980
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	15,600	963	1.6	4,625	3,300	364	1.7	3,300
E3	4 1/8	1 3/8	1 3/8	1 3/8					2,800	81	0.35	1,160	110	2.3	0.44	385
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8			6,400	311	0.69	1,930	955	61	0.87	1,160
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	11,325	769	1.0	2,700	2,210	234	1.3	1,930
E4	4 1/8	1 3/8	1 3/8	1 3/8					4,525	115	0.50	1,820	140	3.4	0.62	605
	6 7/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8			10,400	440	1.0	3,025	1,230	88	1.2	1,820
	9 5/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	1 3/8	18,400	1,089	1.5	4,225	2,850	338	1.9	3,025
	4 1/8	1 3/8	1 3/8	1 3/8					3,825	101	0.46	1,650	160	3.1	0.55	550

3rd Party Product Qualification of CLT

CLT Product Reports

CLT Custom Grades

Layup

Panel Properties

APA Product Report® PR-L319
Revised August 15 , 2017

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

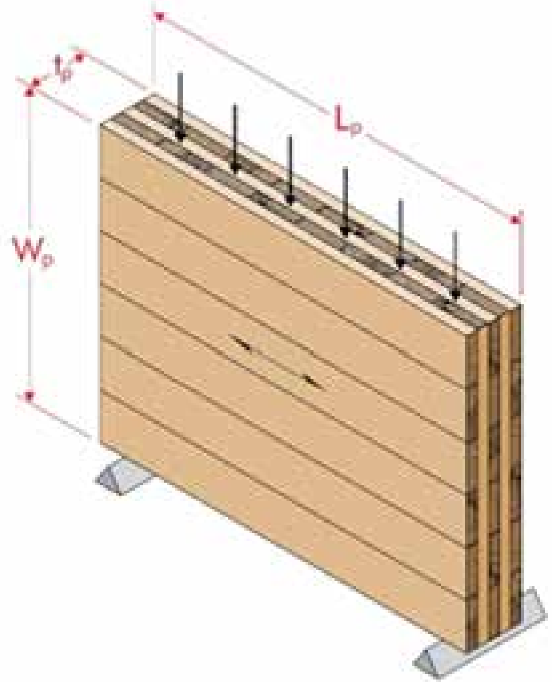
[a] Tabulated values are allowable design values and not permitted to be increased for the lumber flat use or size factor in accordance with the NDS. The design values shall be used in conjunction with the section properties provided by the CLT manufacturer based on the actual layup used in manufacturing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

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

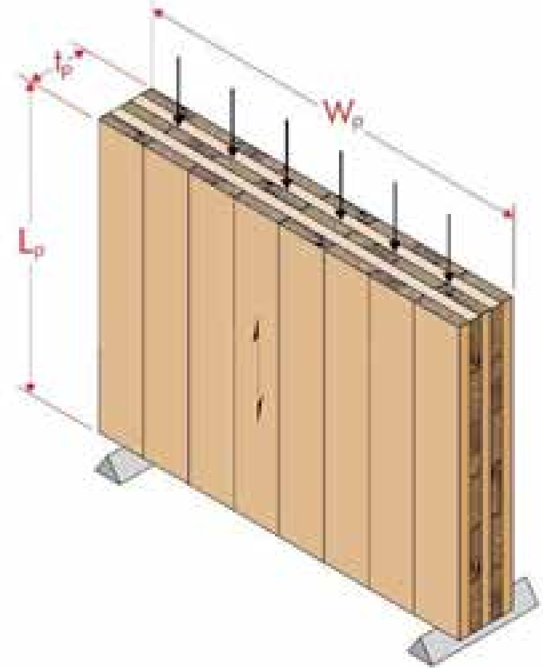
CLT Grade	Layup #	Thick-ness (in.)	Lamination Thickness (in.) in CLT Layup									Major Strength Direction				Minor Strength Direction			
			=	⊥	=	⊥	=	⊥	=	⊥	=	$F_bS_{eff,0}$ (lbf-ft/ft)	$EI_{eff,0}$ (10^6 lbf-in.^{2}/ft)	$GA_{eff,0}$ (10^6 lbf/ft)	$V_{s,0}$ (lbf/ft)	$F_bS_{eff,90}$ (lbf-ft/ft)	$EI_{eff,90}$ (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 [illegible]	1 3/8	1 3/8	1 3/8	1 3/8 [illegible]					9,425	909	1.7	3,200	2,120	74	1.3	1,430

CLT Lateral Systems

EDGEWISE Panel Loading



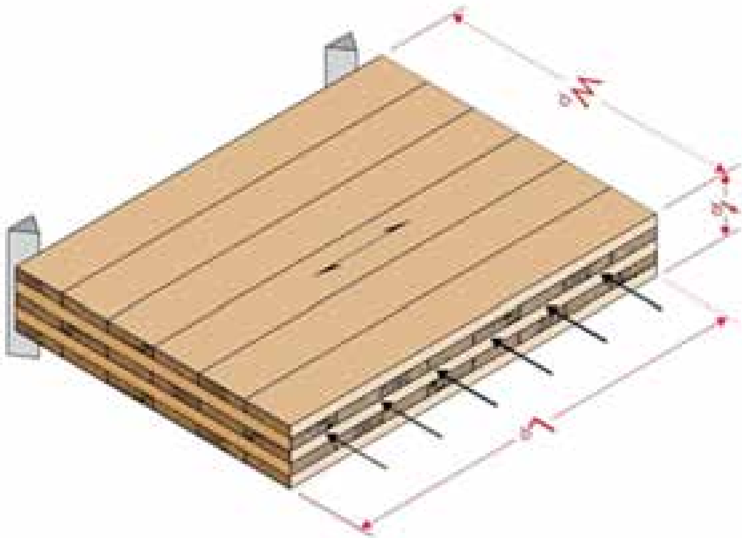
Span in MAJOR Strength Direction



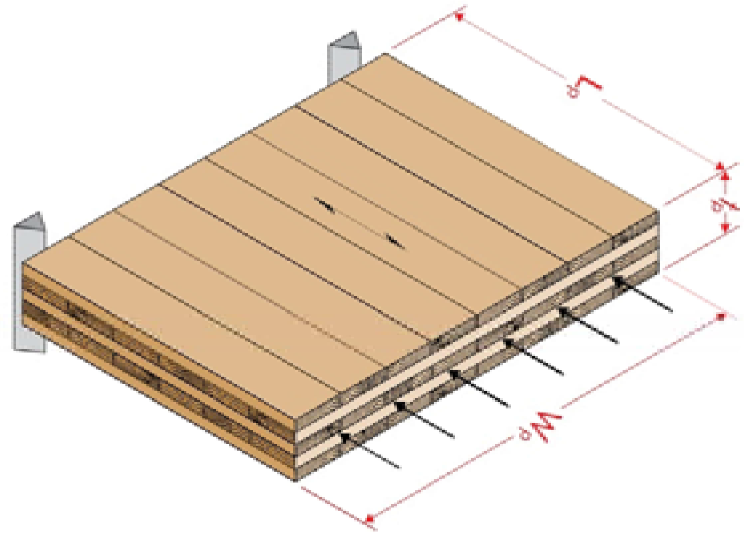
Span in MINOR Strength Direction

Source: PRG 320-2018

EDGEWISE Panel Loading



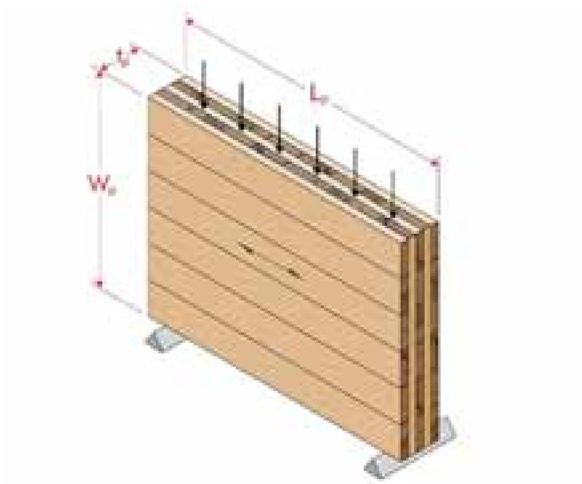
Span in MAJOR Strength Direction



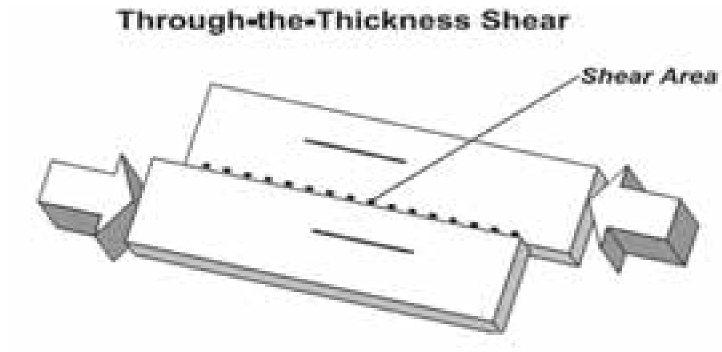
Span in MINOR Strength Direction

Source: PRG 320-2018

Shear Force Terminology



Source: PRG 320-2018



Source: 2018 NDS Commentary

Through-the-Thickness Shear
In-plane Shear Forces
EDGEWISE Shear in PRG 320-2018

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

CLT In-Plane (Edgewise) Strength

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

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

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

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
	[illegible]	5 1/2	145	2.39	190[b]	2.39
E1	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!

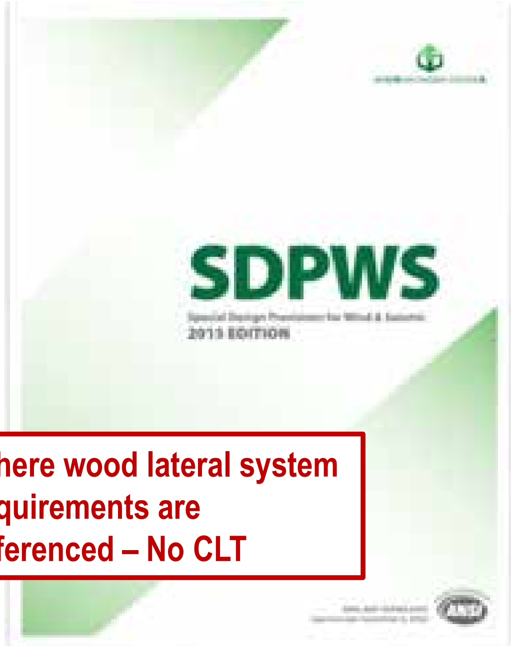
Consult with manufacturers for values

Multiply by ***Cd = 1.6***

for short term ASD strength

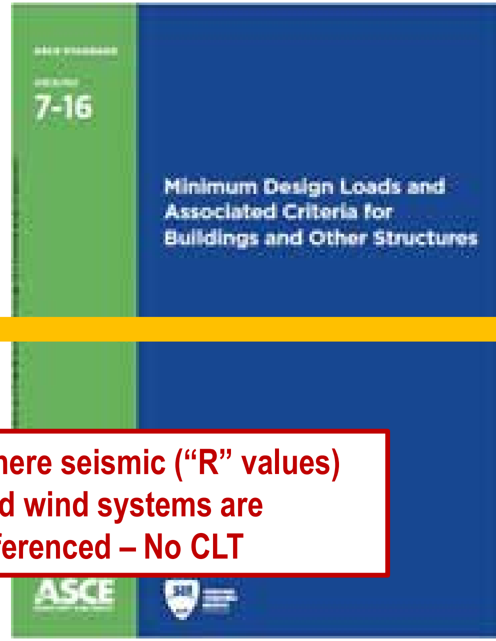
CLT Panels can have > 9 kips / ft in-plane shear capacity

CLT in the 2019 CBC (Lateral)



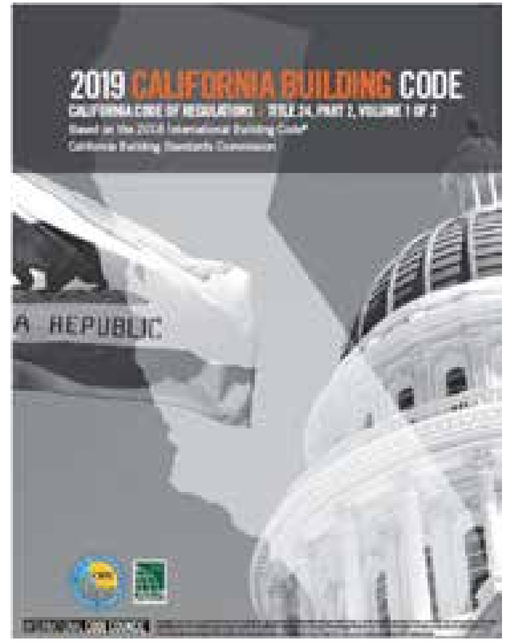
Where wood lateral system requirements are referenced – No CLT

2015 SDPWS



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

ASCE/SEI 7-16



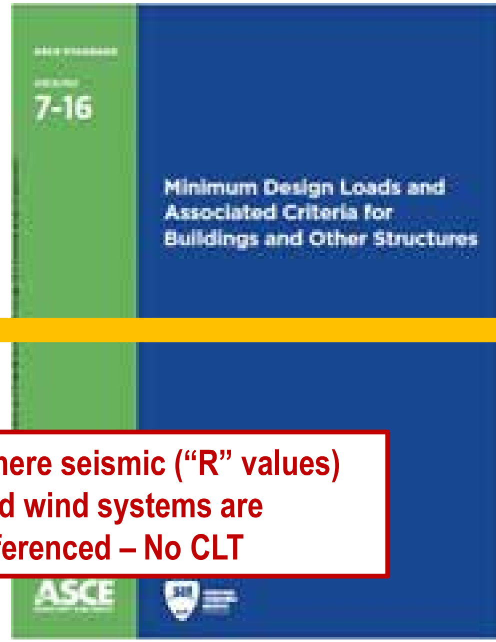
2019 California Building Code

CLT lateral systems (including “R” values for shear wall design) were <u>not</u> referenced in the 2019 CBC

CLT in the 2022 CBC (Lateral)

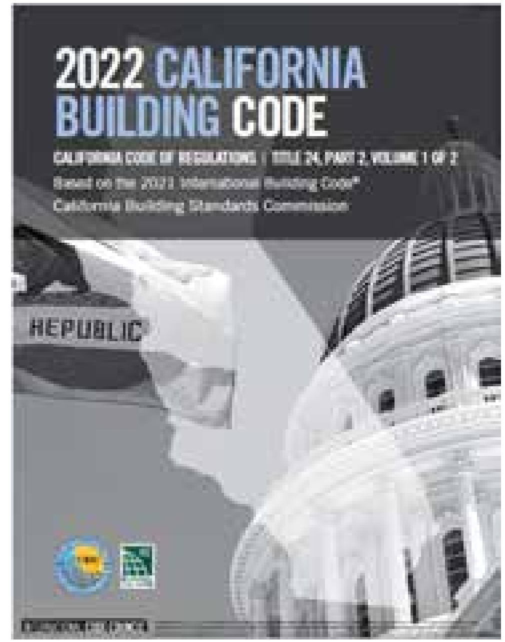
Now with CLT shear wall and diaphragm requirements

2021 SDPWS



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

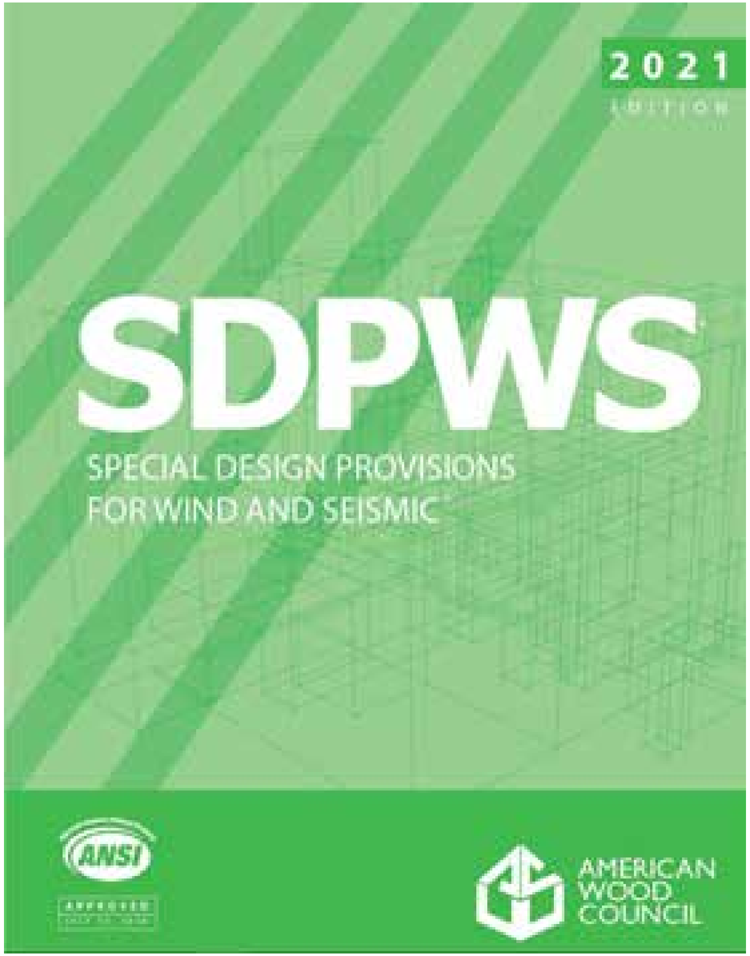
ASCE/SEI 7-16



2022 California Building Code

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

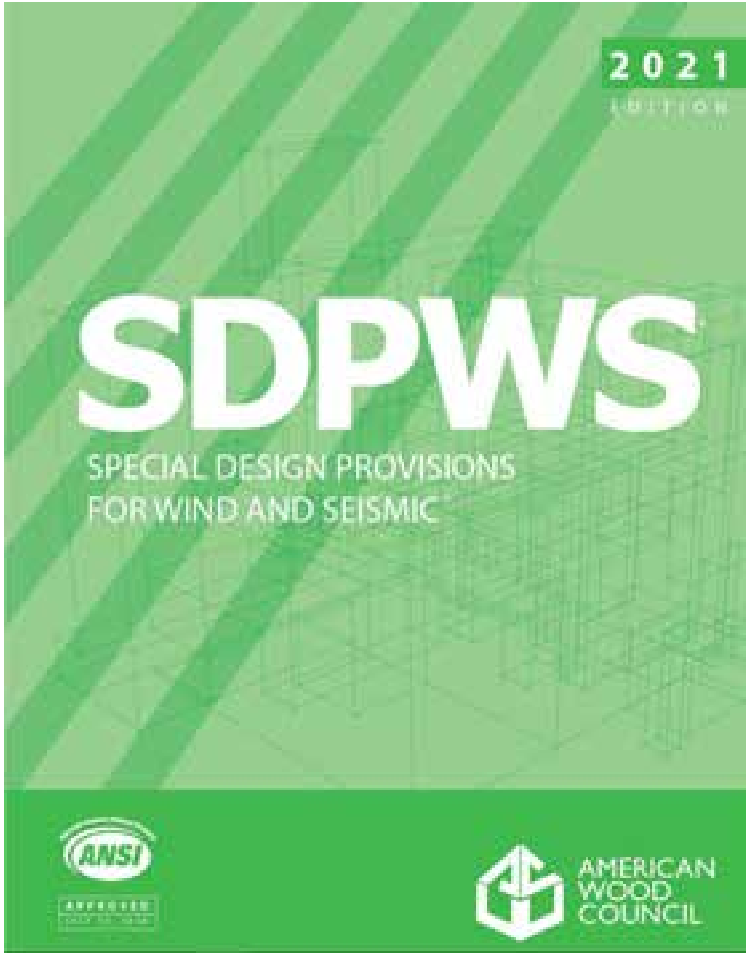


Top Changes Relevant to CLT Lateral Systems:

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

View for free at awc.org

2021 Special Design Provisions for Wind and Seismic

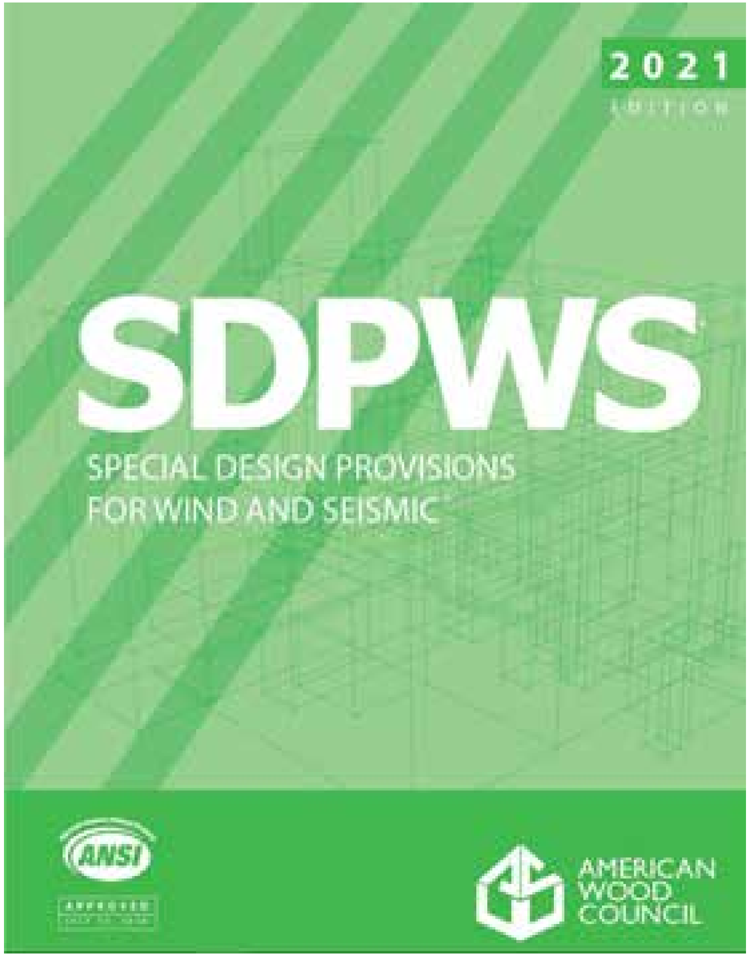


Top Changes Relevant to CLT Lateral Systems:

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

View for free at awc.org

2021 SDPWS – Unified Nominal Shear Capacity



For Wood Structural Panel (WSP) shear walls and diaphragms, the 2015 SDPWS has two nominal shear capacities:

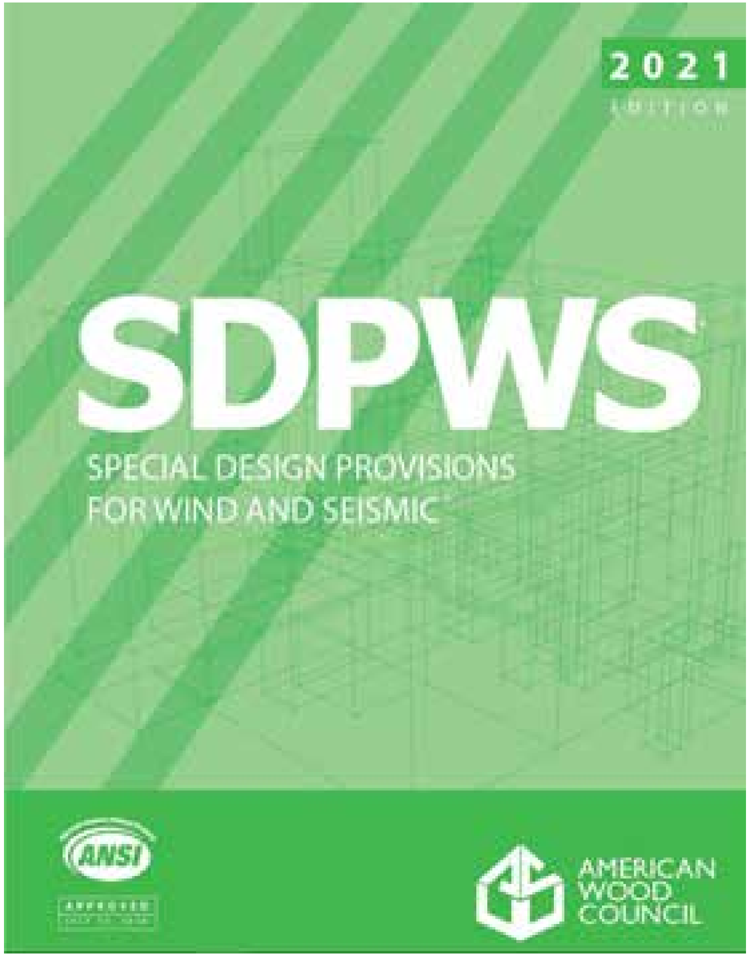
v_s Nominal shear capacity for seismic loads

v_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):

v_n Nominal shear capacity

2021 SDPWS – Unified Nominal Shear Capacity



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

Loading	ASD Design Capacity v_n / Ω_D	LRFD Design Capacity $\phi_D v_n$
Seismic	$v_n/2.8$	$0.50\ v_n$
Wind	$v_n/2.0$	$0.80\ v_n$

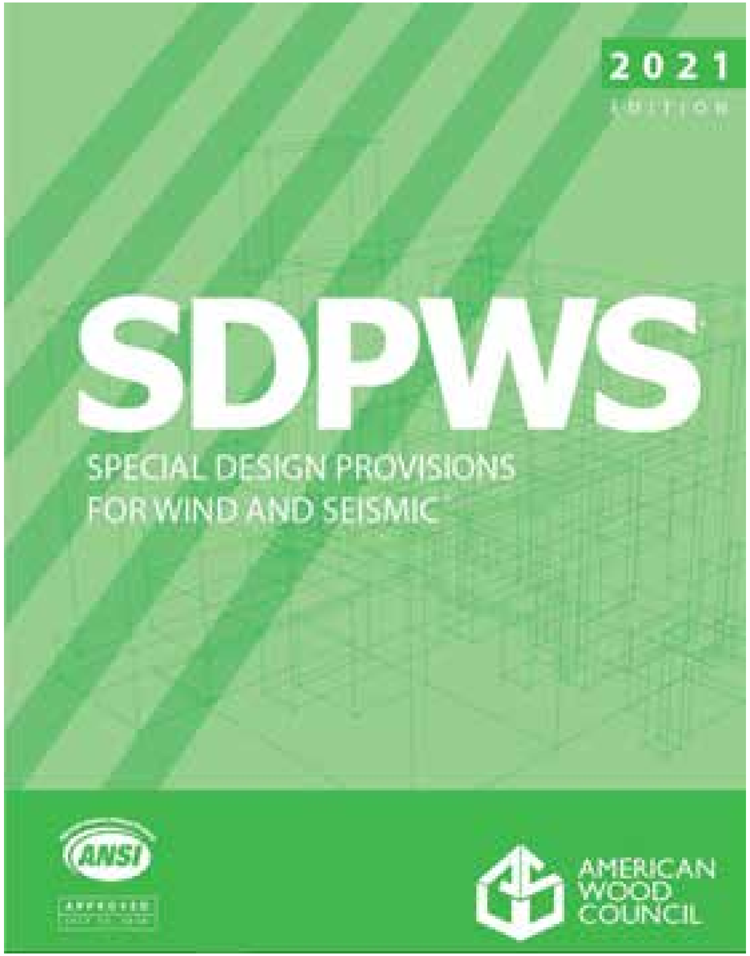
Source: 2021 SDPWS Section 4.1.4

CLT Shear Wall Design

CLT Shear Wall Design

Denver University Burwell Center for Career Achievement Photo Credit: WoodWorks

2021 Special Design Provisions for Wind and Seismic

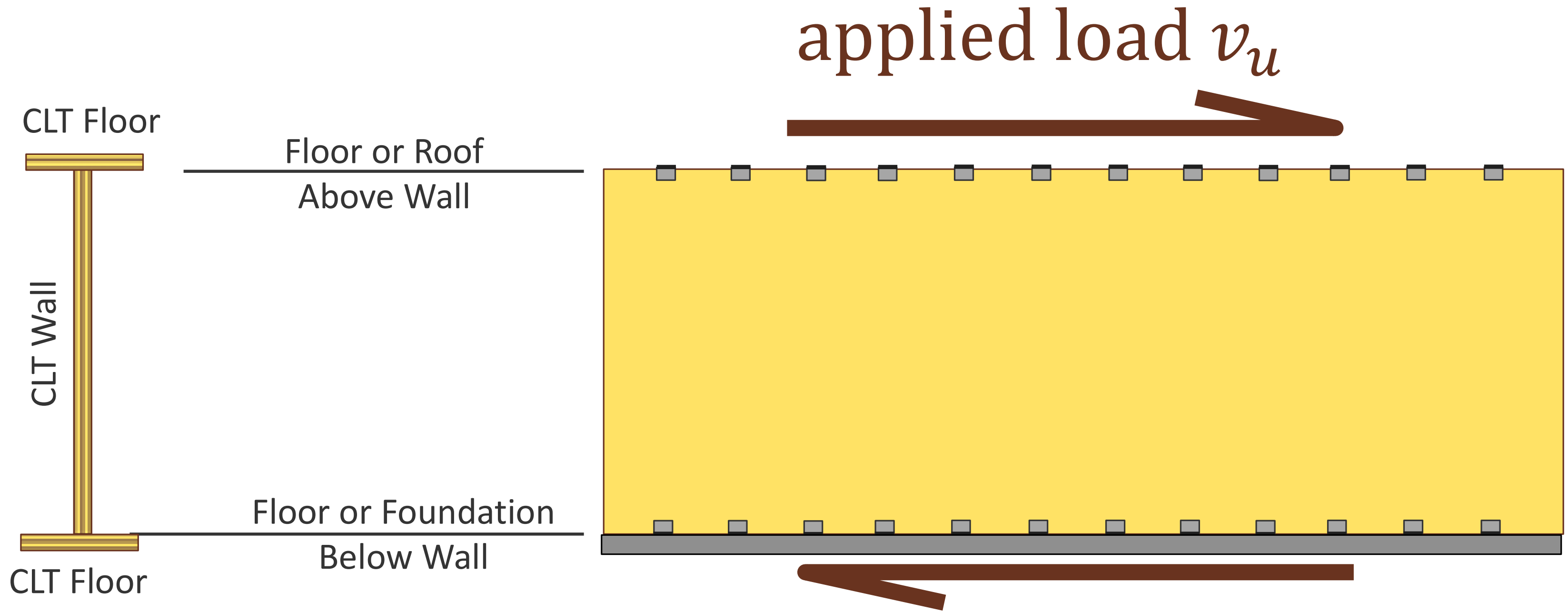


Top Changes Relevant to CLT Lateral Systems:

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

View for free at awc.org

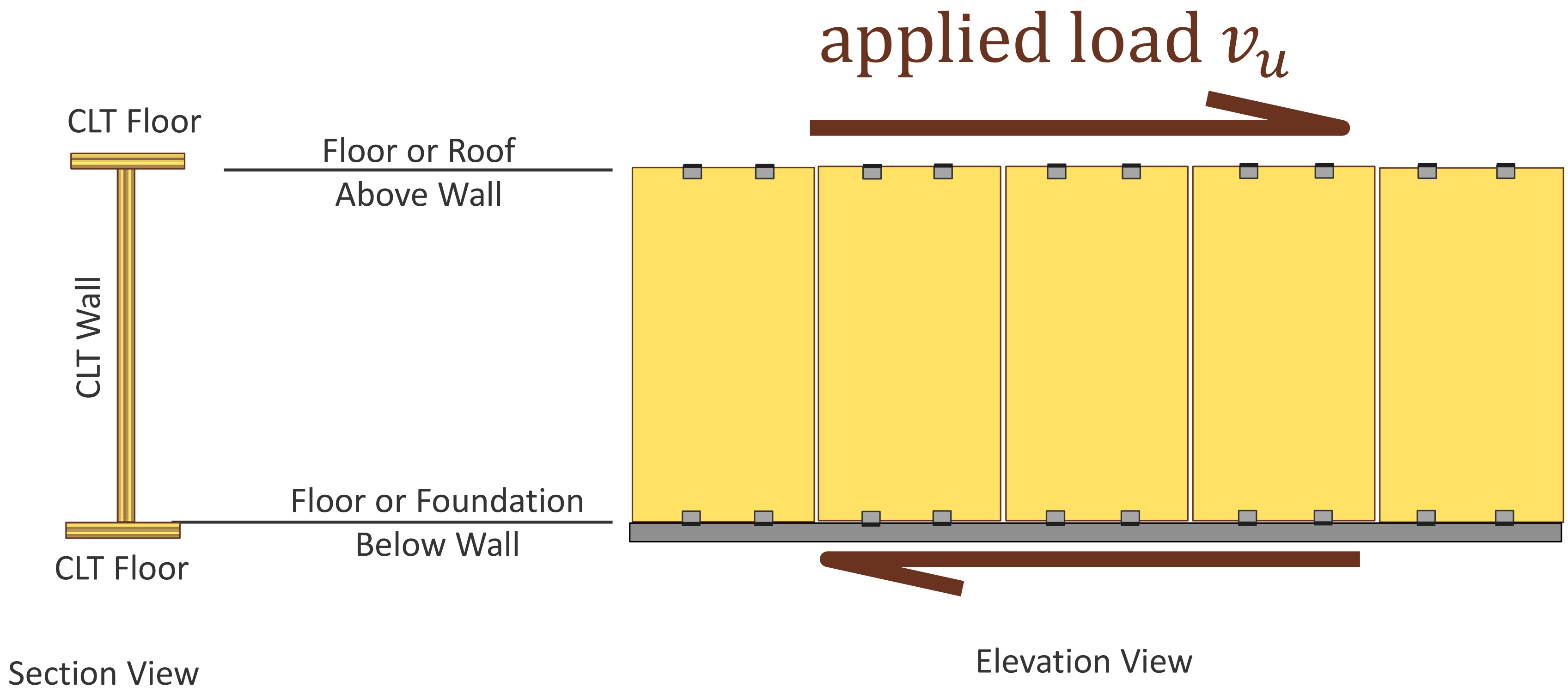
2021 SDPWS – CLT Shear Wall requirements



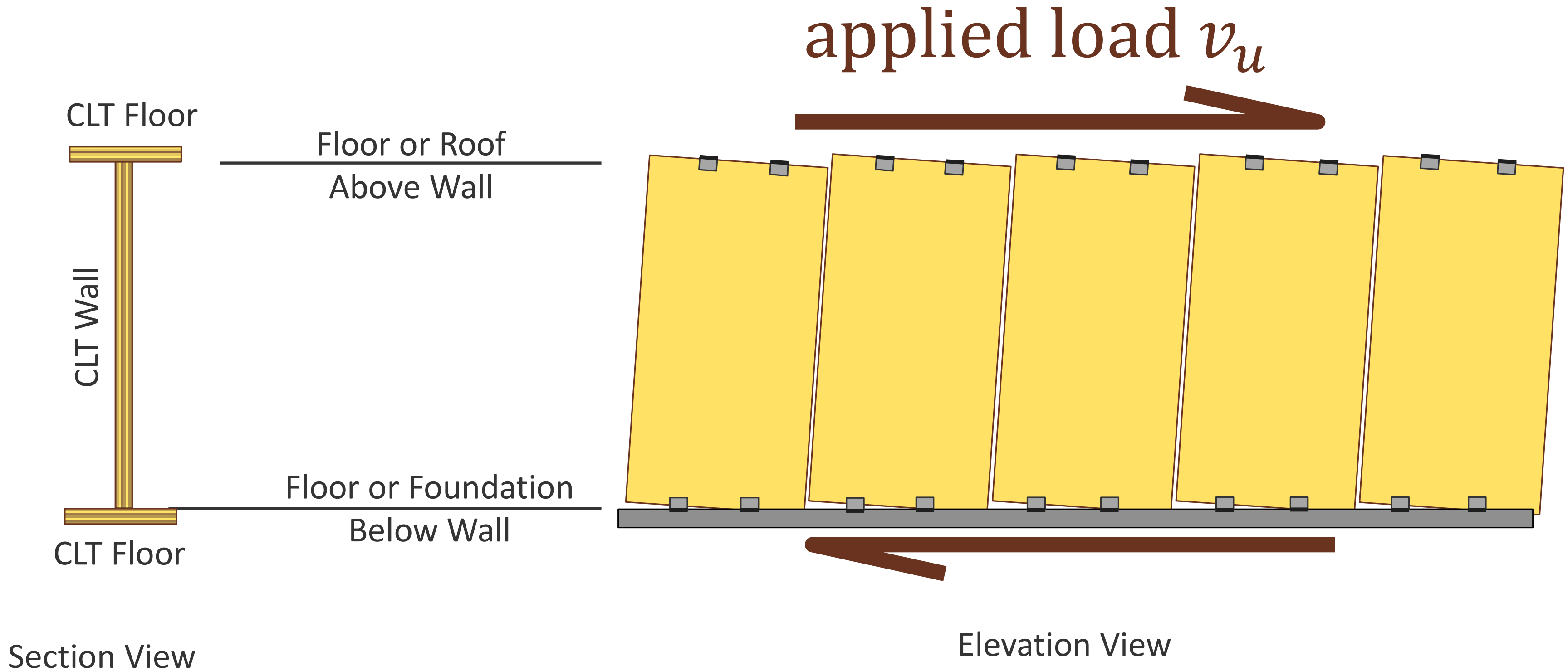
Section View

Elevation View

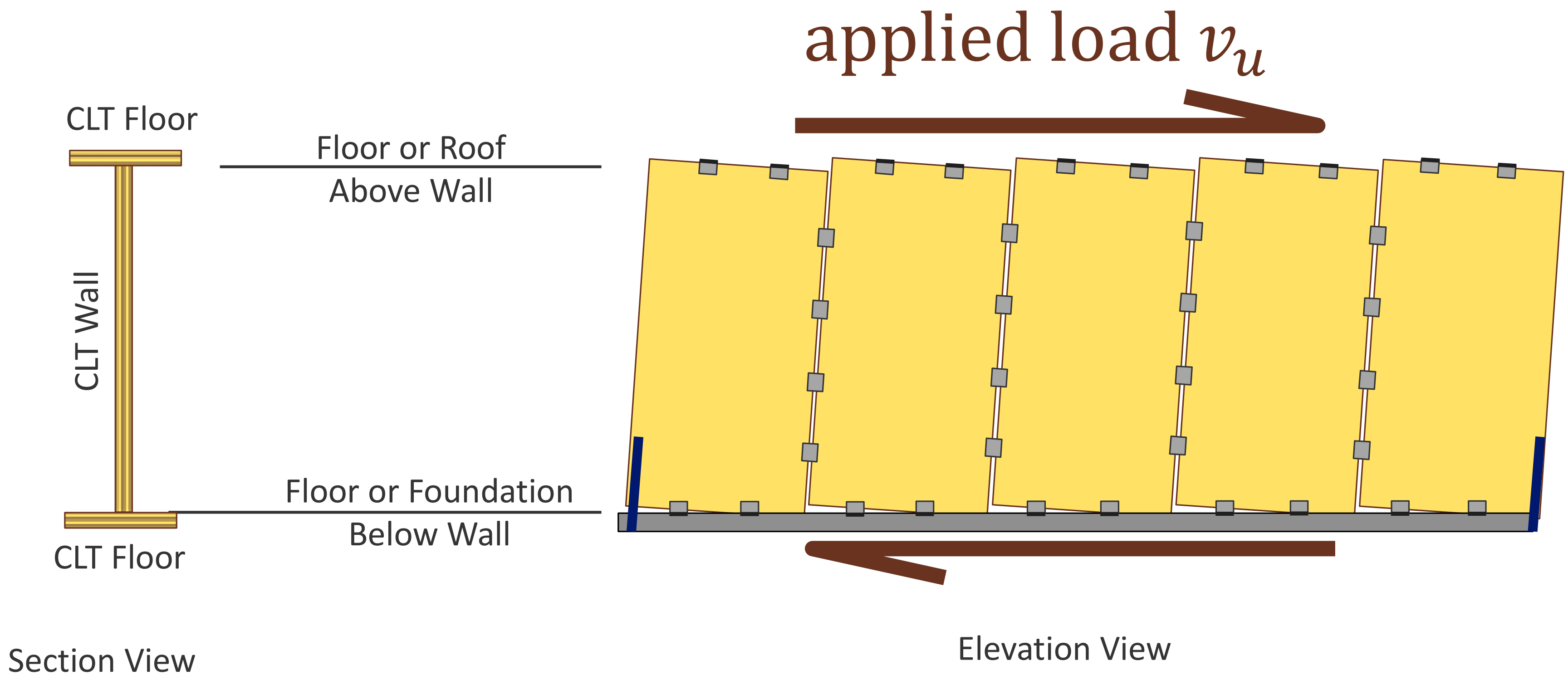
2021 SDPWS – CLT Shear Wall requirements



2021 SDPWS – CLT Shear Wall requirements

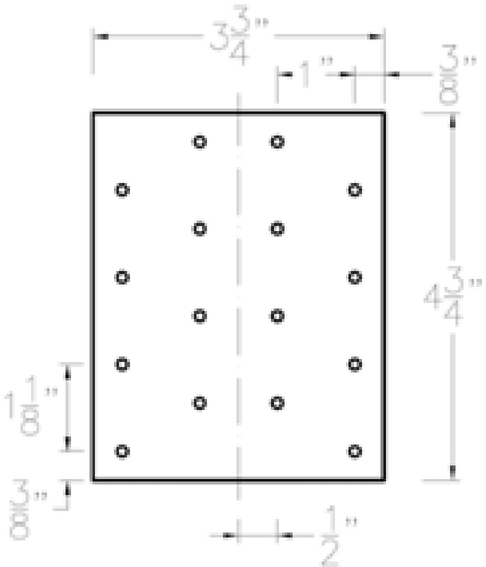


2021 SDPWS – CLT Shear Wall requirements



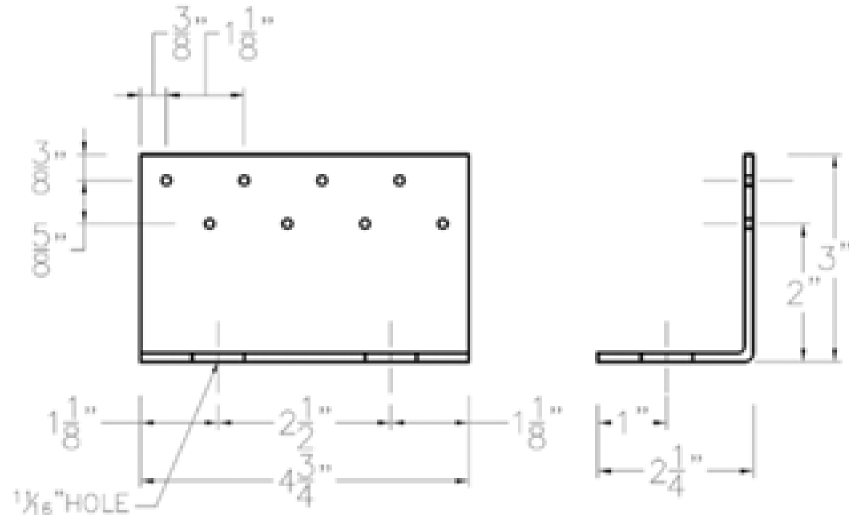
2021 SDPWS – CLT Shear Wall requirements

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

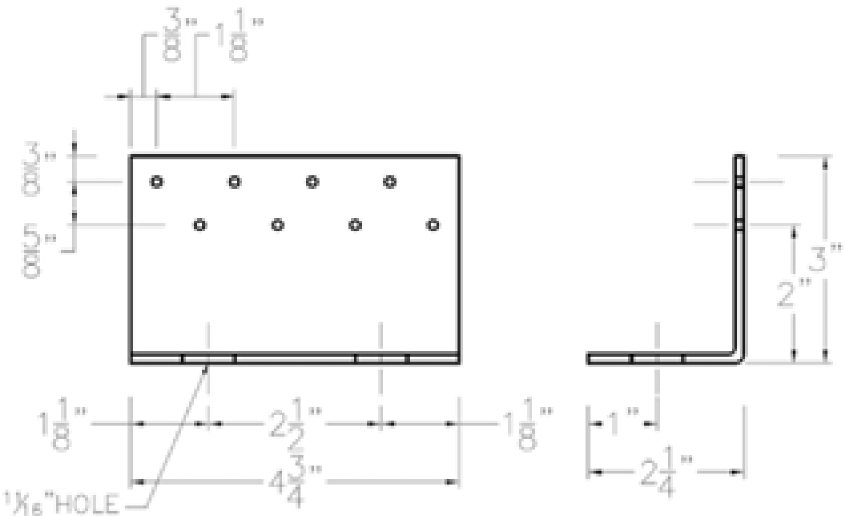
Panel to Platform Connection



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

2021 SDPWS – CLT Shear Wall requirements

Panel to Platform Connection



Nominal shear capacity of connector

v_n = 2605 C_G [lbs] per angle connector

C_G adjusts for specific gravity, G of CLT

C_G = 1.0	for G ≥ 0.42
= 0.86	for G = 0.35
= 1.0 – 2 (0.42-G)	for 0.42 > G > 0.35

Nominal unit shear capacity:

$v_n = n\ (2605 / b_s)\ C_G$ [lbs/ft]

2021 SDPWS – CLT Shear Wall requirements

(platform or balloon-framed)

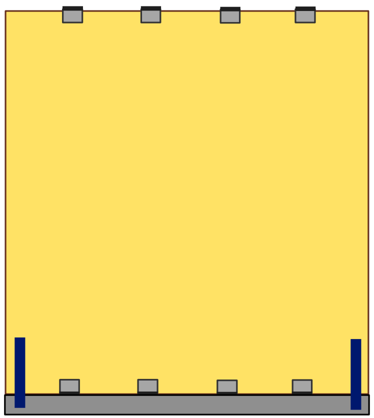
CLT Shear Walls

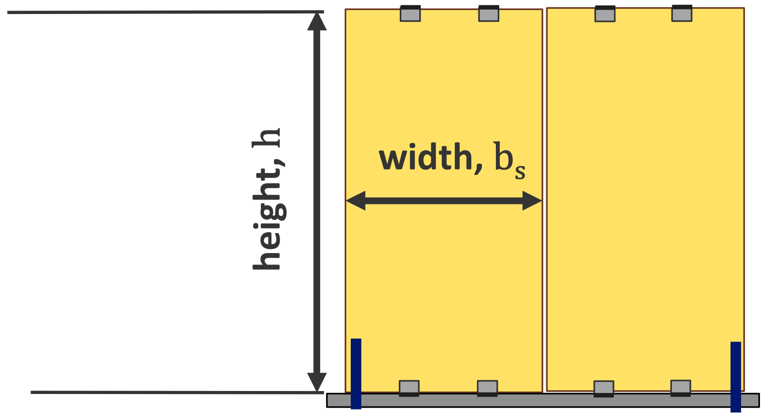
not meeting 2021 SDPWS Appendix B

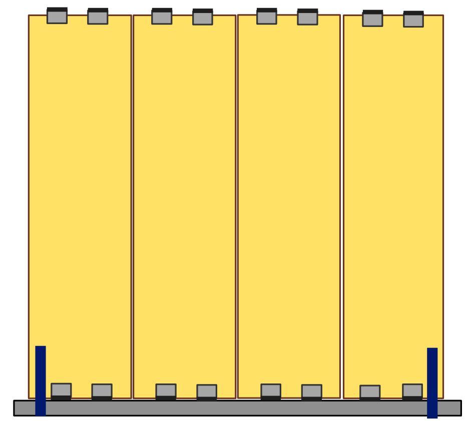
(platform-framed only)

CLT Shear Walls

meeting 2021 SDPWS Appendix B







Seismic Design Category A or B only (2021 SDPWS 4.6.3)

Panel aspect ratios
$2 \leq \mathbf{h/b_s} \leq 4$

Shear resistance provided by high aspect ratio panels only (2021 SDPWS B.3.7)

Panel aspect ratios
$\mathbf{h/b_s} = 4$

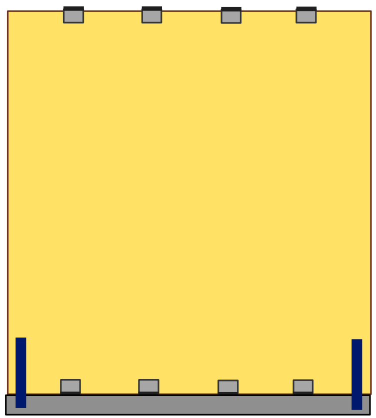
What “R” value can I use?

2021 SDPWS – “R” Values for CLT Shear Walls

(platform or balloon framed)

CLT Shear Walls

not meeting 2021 SDPWS Appendix B



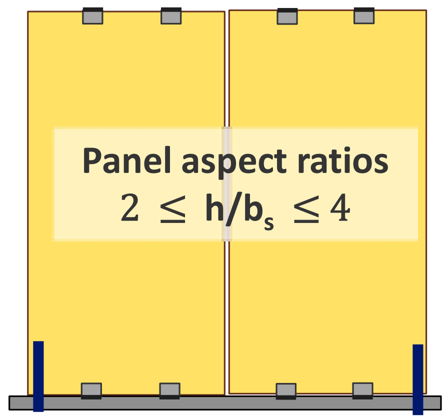
“R” = 1.5

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

(platform-framed only)

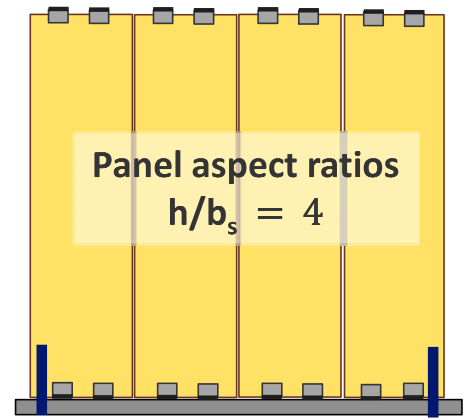
CLT Shear Walls

meeting 2021 SDPWS Appendix B



“R” = 3.0

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



“R” = 4.0

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

CLT in the 2025 CBC (Lateral)

Now with CLT shear wall and diaphragm requirements

2021 SDPWS

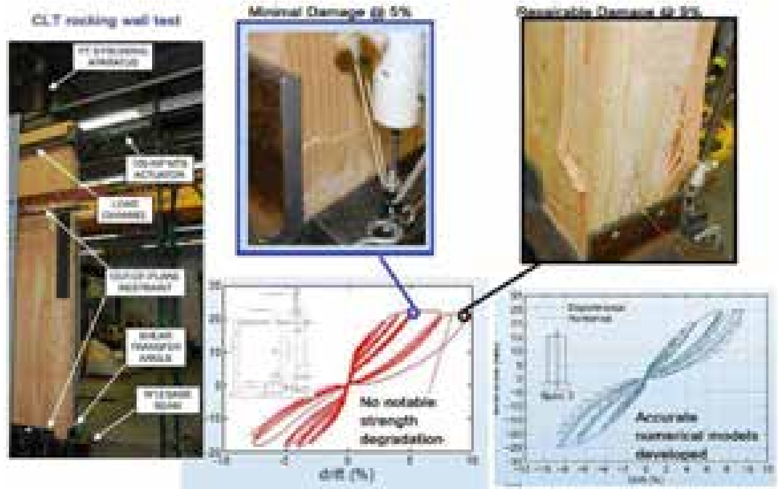
Will have “R” values for CLT shear walls

ASCE/SEI 7-22

2025 California Building Code

CLT lateral systems will be fully recognized in the 2025 CBC

CLT Post-Tensioned Rocking Shear Wall System Tests



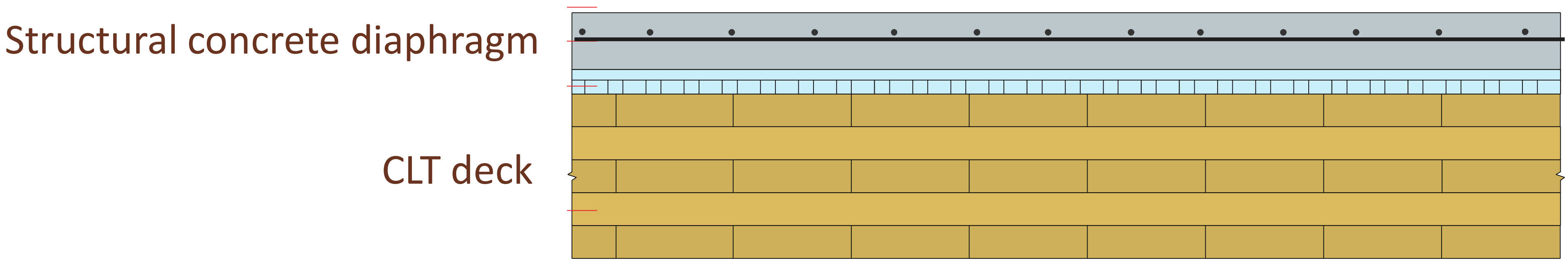
Source: S. PEI et al. http://nheritallwood.mines.edu/

CLT Diaphragm Design

CLT Horizontal Diaphragm Strategies (pre-2022 CBC)

Option 1: Separate diaphragm element over CLT

(1A) Structural concrete topping

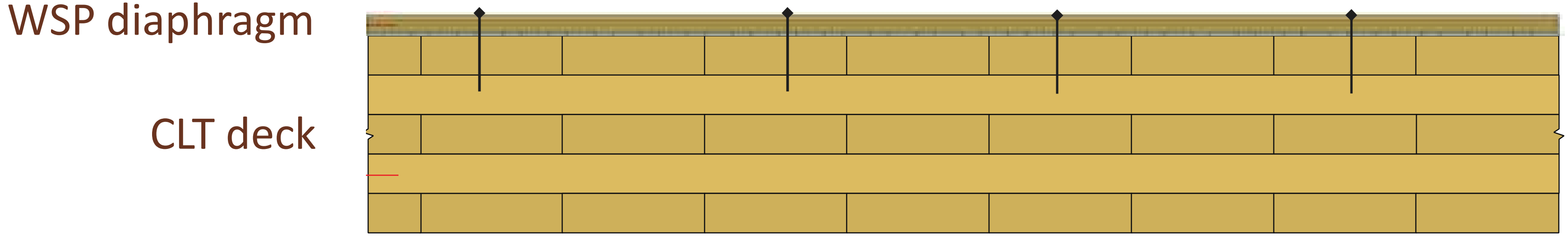


Careful detailing required to provide adequate load path, minimum rebar cover, etc.

CLT Horizontal Diaphragm Strategies (pre-2022 CBC)

Option 1: Separate diaphragm element over CLT

(1B) Wood Structural Panel (WSP) topping



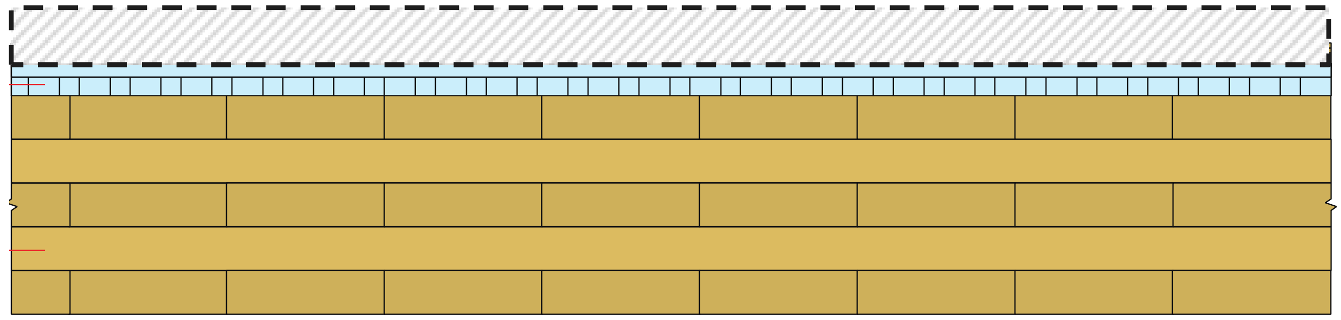
Classify as a blocked WSP diaphragm per 2015 SDPWS 4.2.7.1.1

CLT Horizontal Diaphragm Strategies (pre-2022 CBC)

Option 2: CLT as the diaphragm via the AMMR process (principals of engineering)

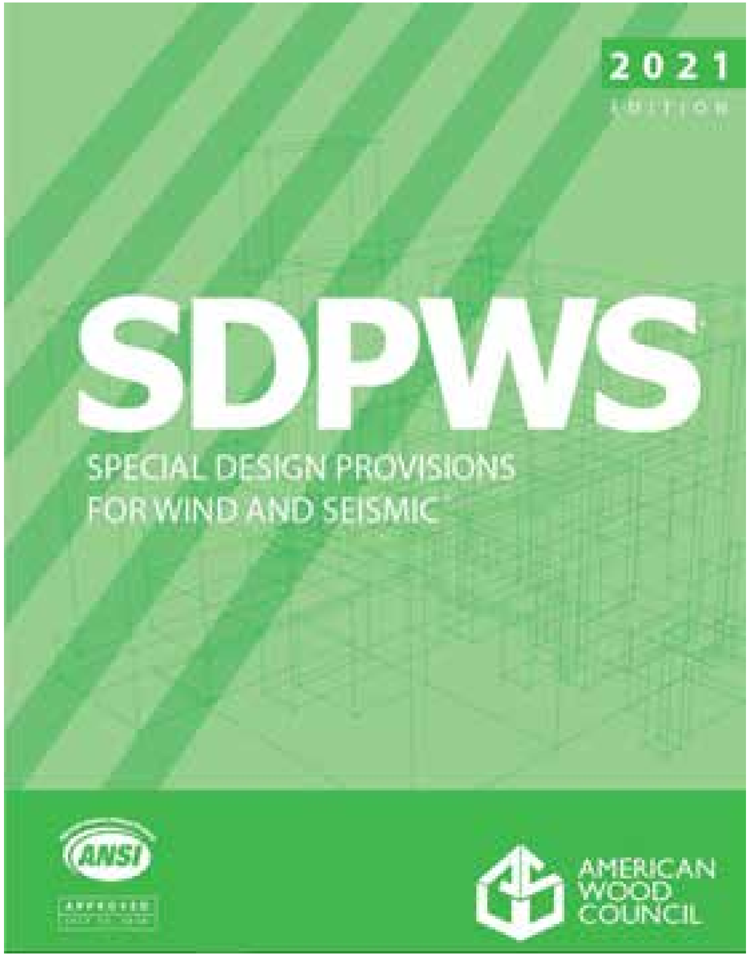
Cementitious topping as needed

CLT deck as the diaphragm



CLT diaphragms were not recognized in the 2019 CBC and Referenced Standards

2021 Special Design Provisions for Wind and Seismic

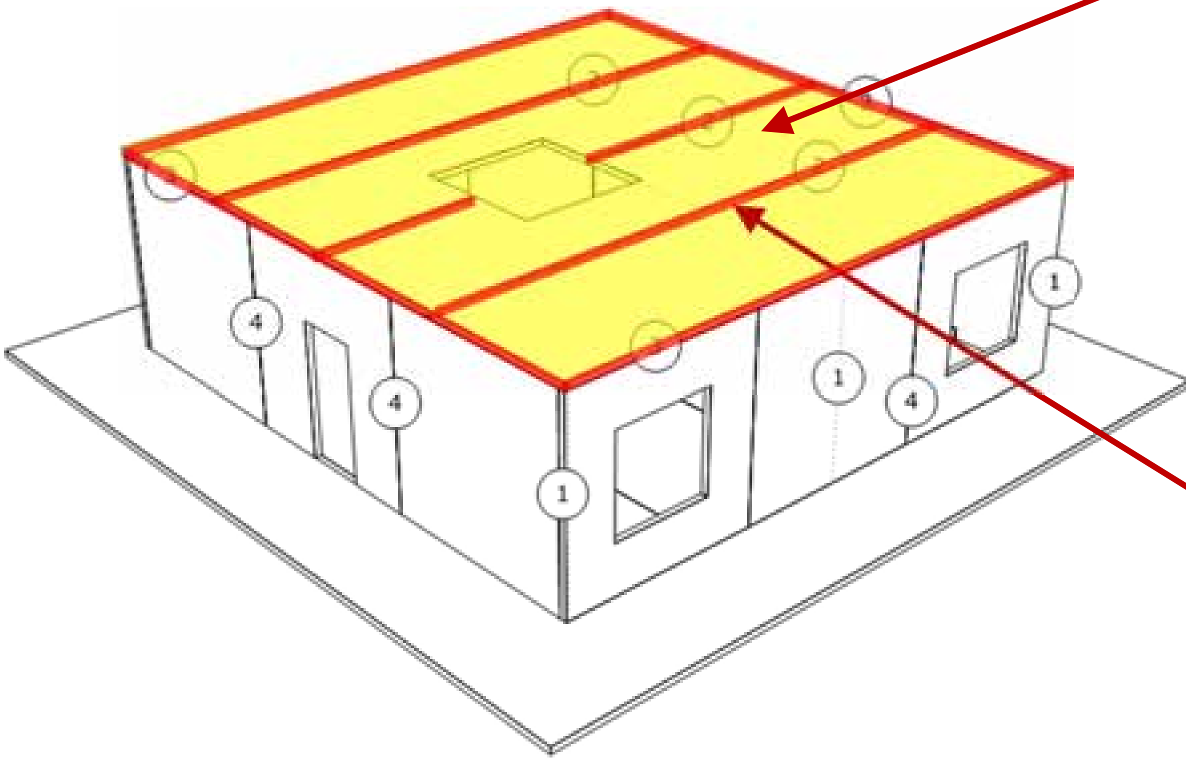


Top Changes Relevant to CLT Lateral Systems:

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

View for free at awc.org

CLT Diaphragms



Strength of CLT should never govern

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

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 IIIs 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.

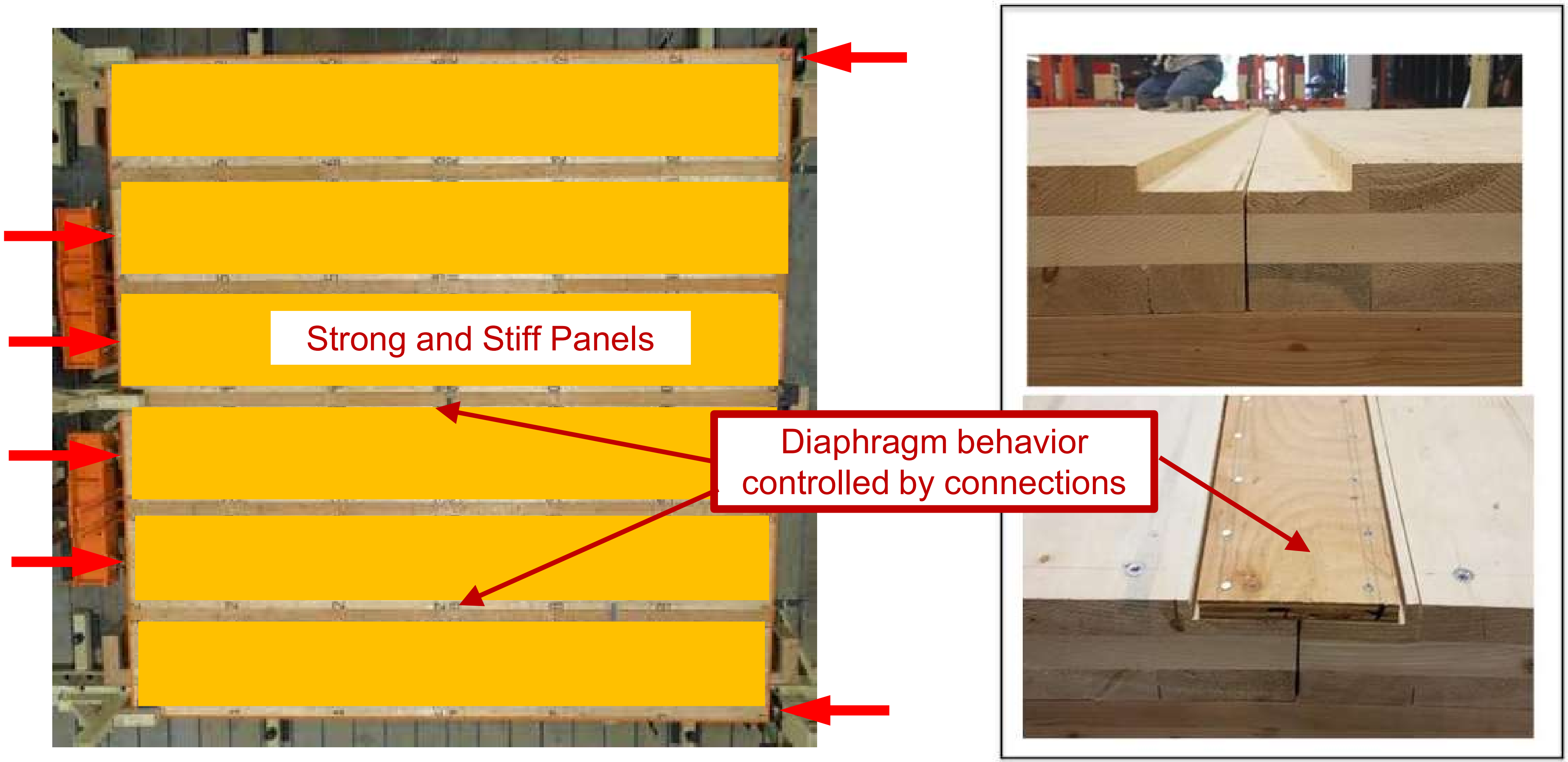
Exceptions:

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 IIIs 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

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



2021 Special Design Provisions for Wind and Seismic

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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 IIIs or Mode IV fastener yielding in accordance with NDS 12.3.1.
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CLT diaphragms shall meet the following additional requirements:

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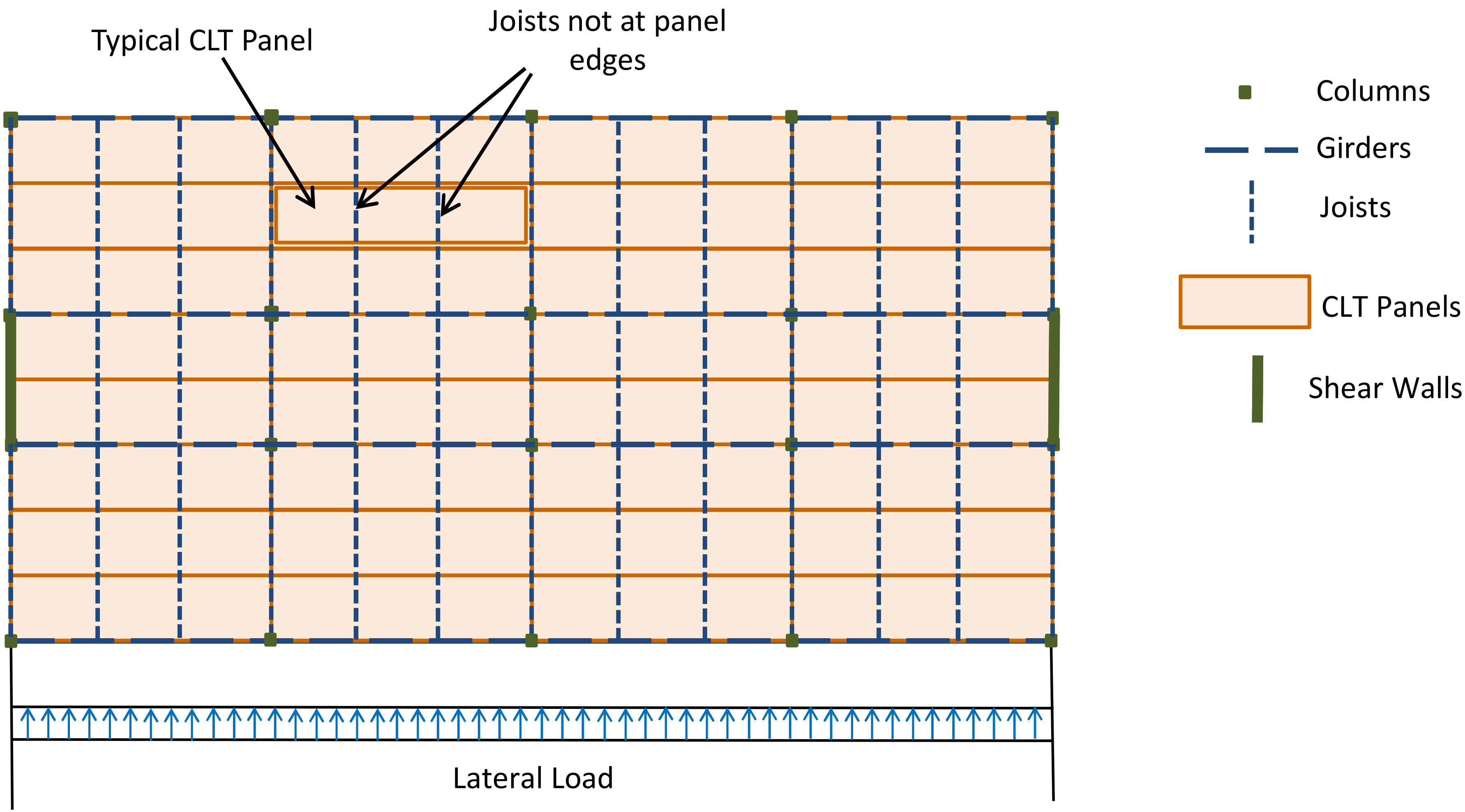
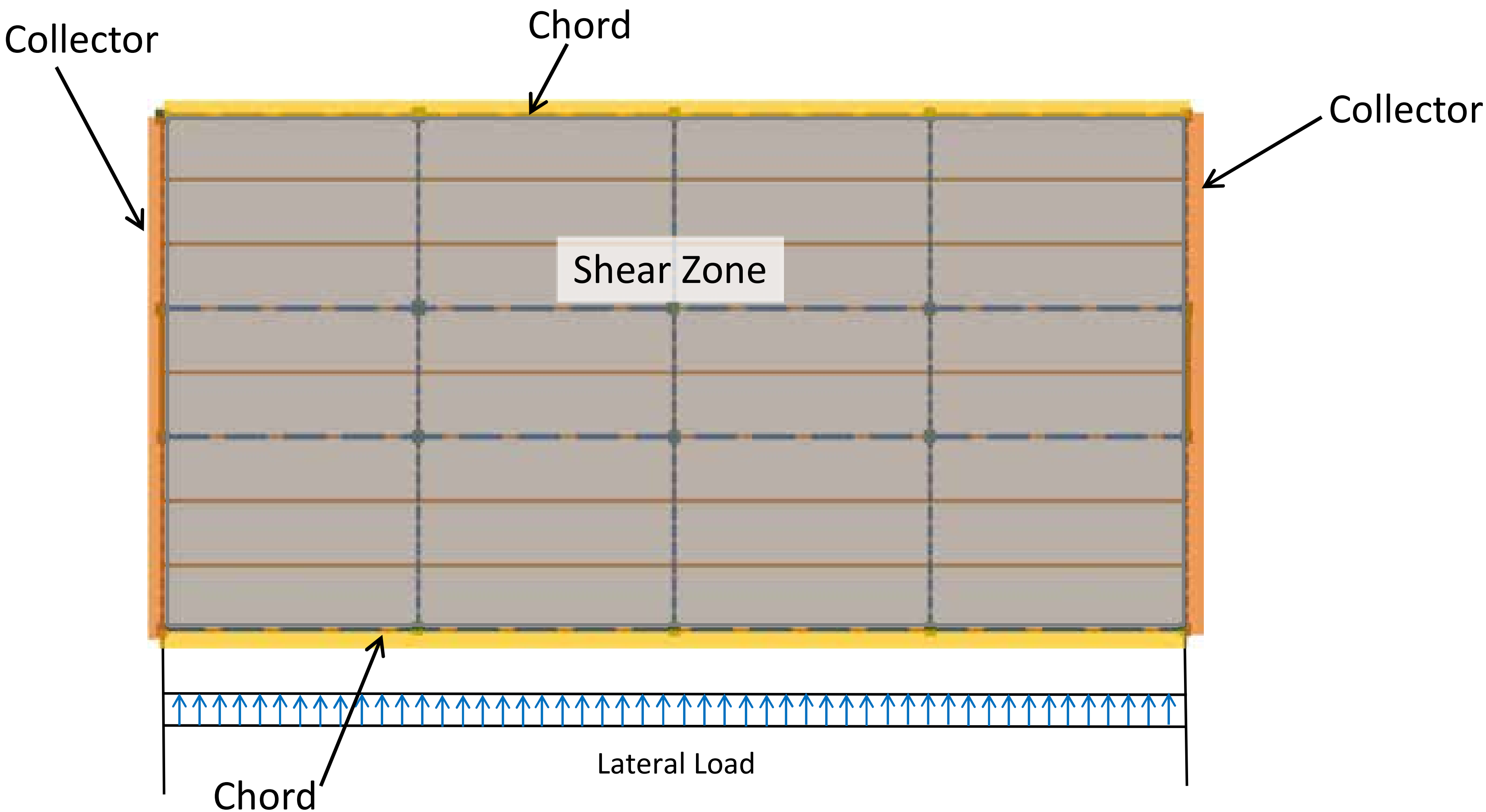
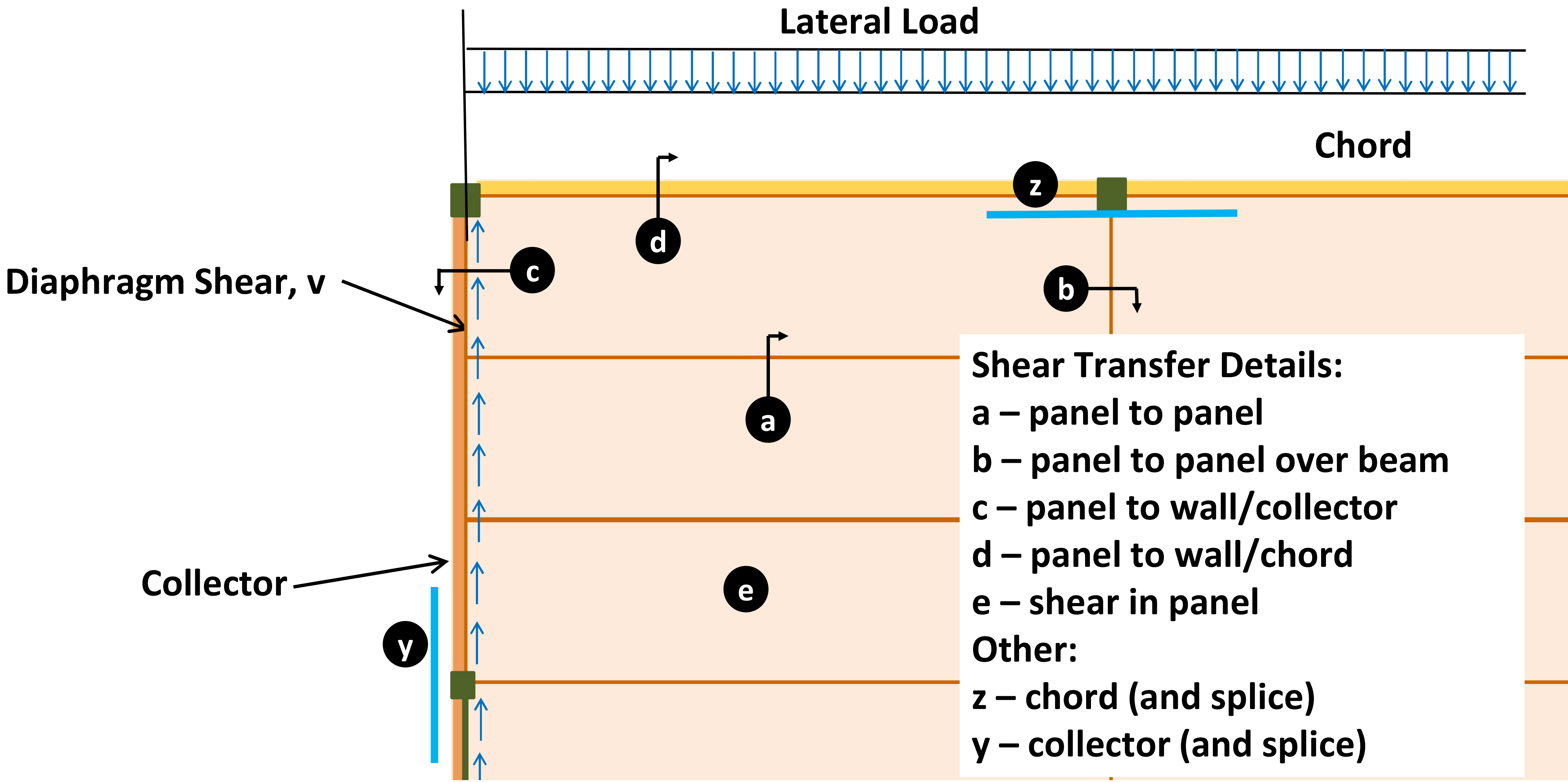
Generic CLT Floor/Roof Diaphragm



Generic CLT Floor/Roof Diaphragm

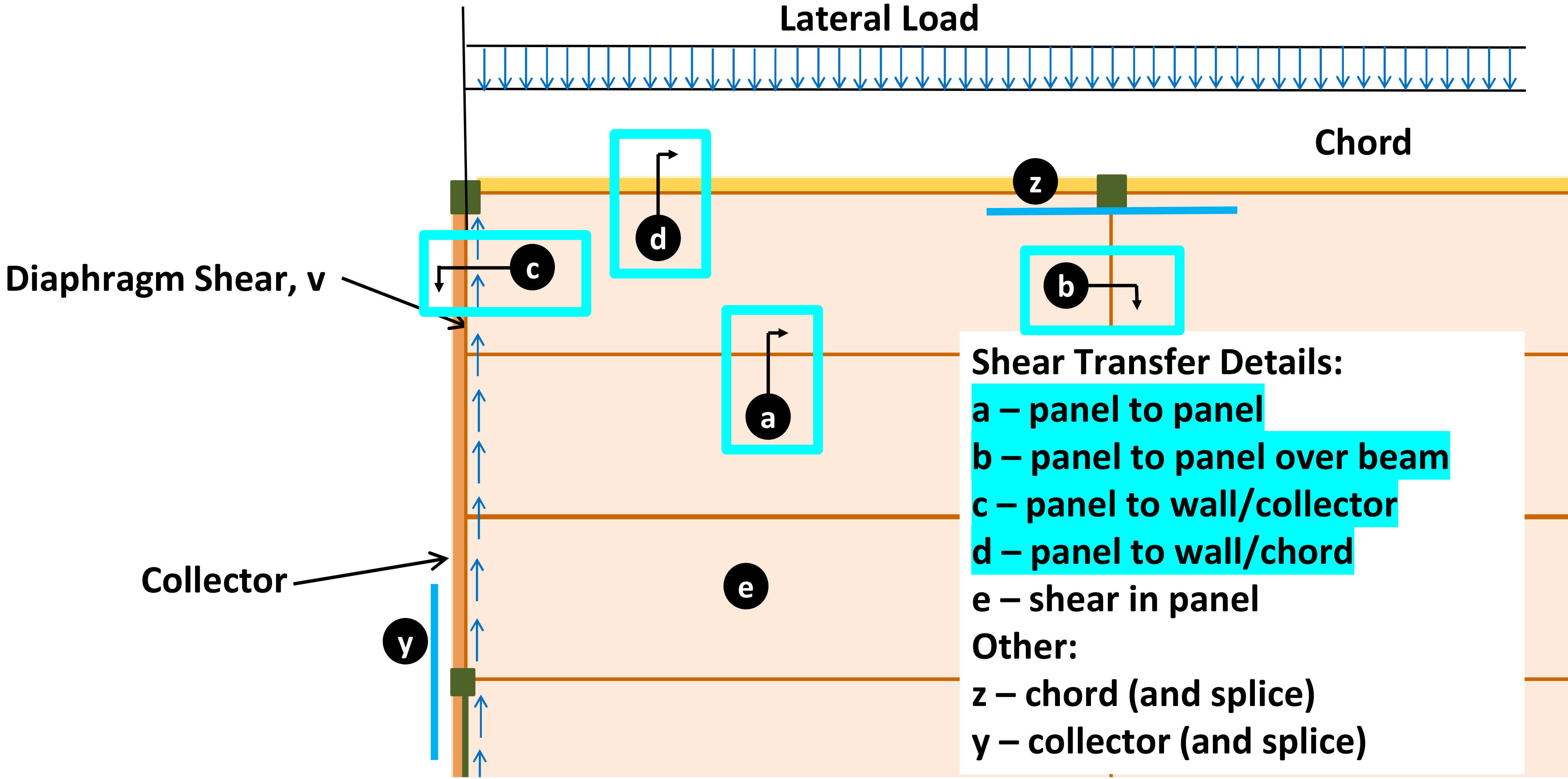


Generic CLT Floor/Roof Diaphragm



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



Shear Transfer Details:

a – panel to panel

b – panel to panel over beam

c – panel to wall/collector

d – panel to wall/chord

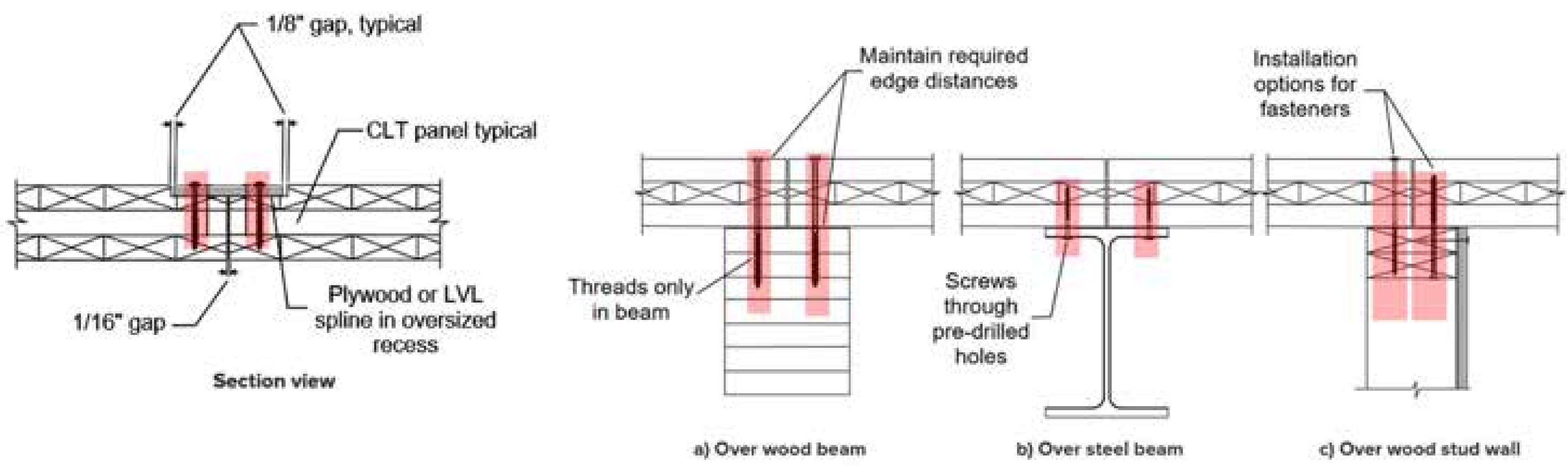
e – shear in panel

Other:

z – chord (and splice)

y – collector (and splice)

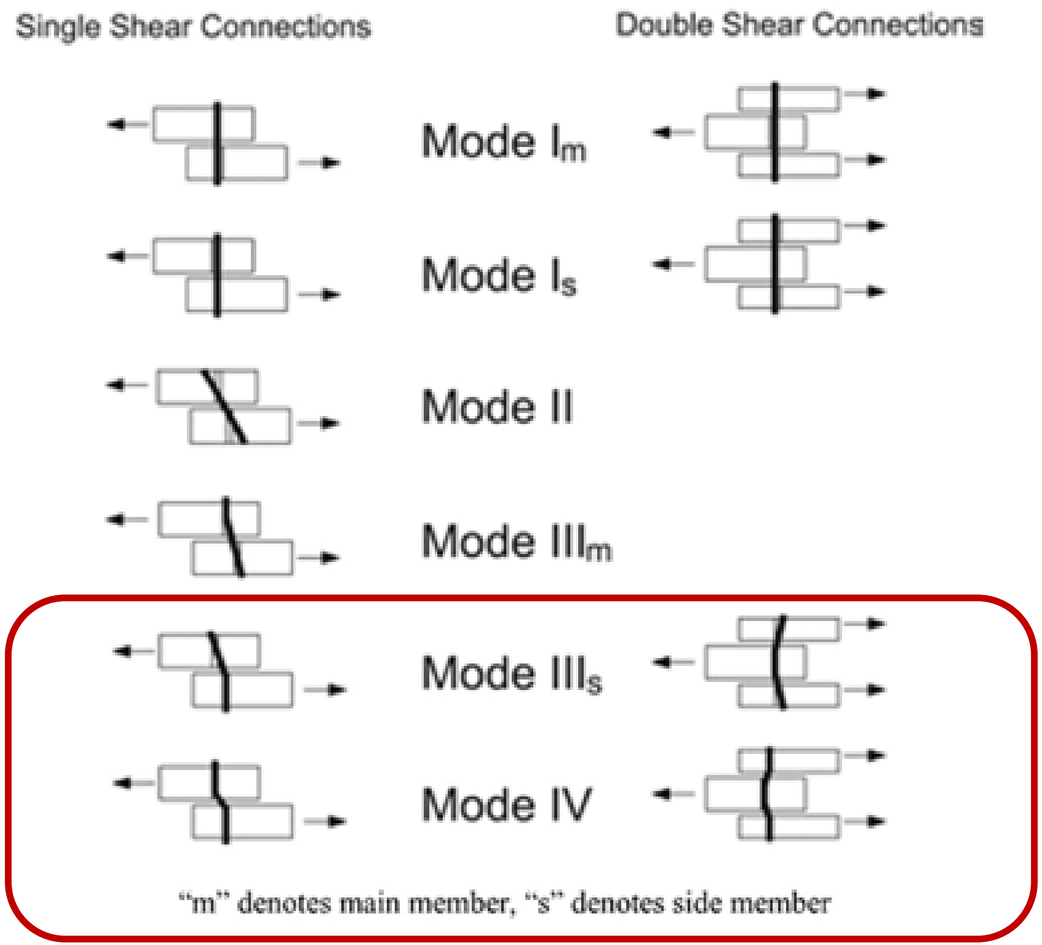
CLT Diaphragm Shear Transfer Connections



Diaphragm **shear transfer connections** at CLT panel edges:

- Use dowel-type fasteners in shear (nails, screws, bolts)
- Yield **Mode IIIs or IV** per NDS 12.3.1 must control capacity

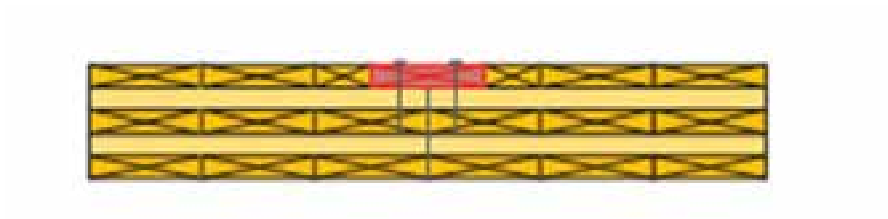
Connection Yield Modes Per the NDS

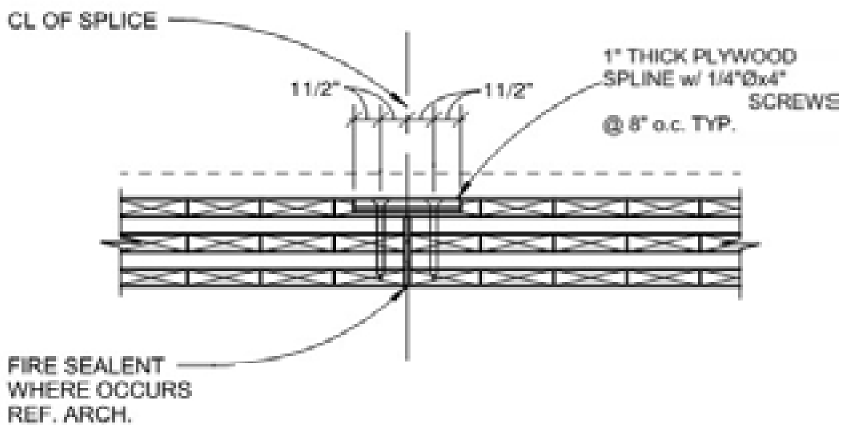


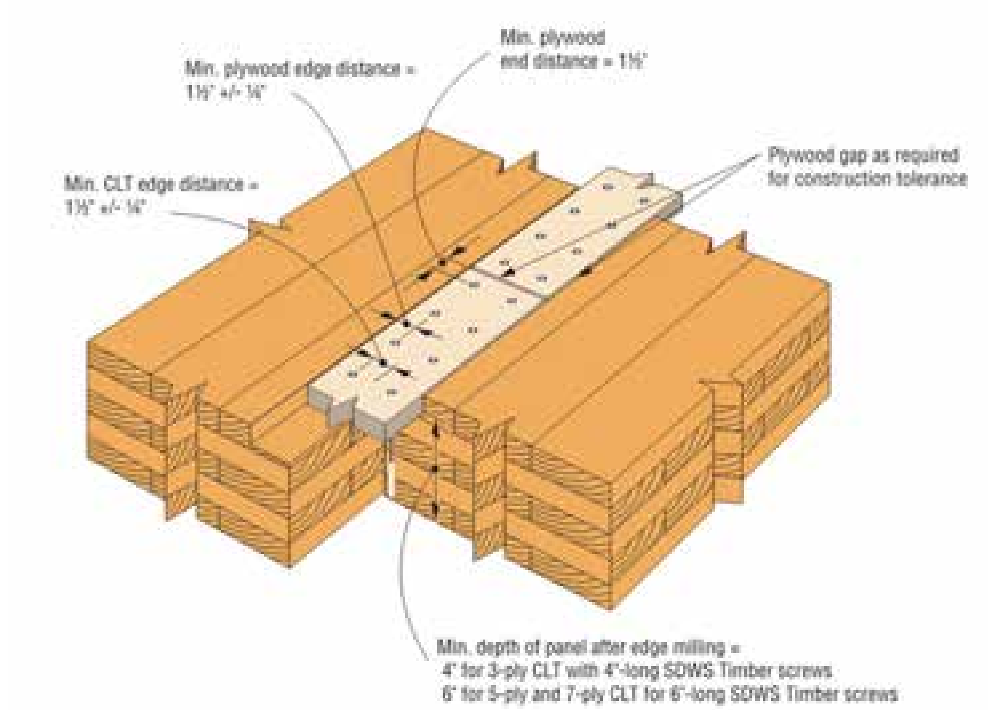
SB7

Panel to Panel Connection Styles

Top Surface Spline



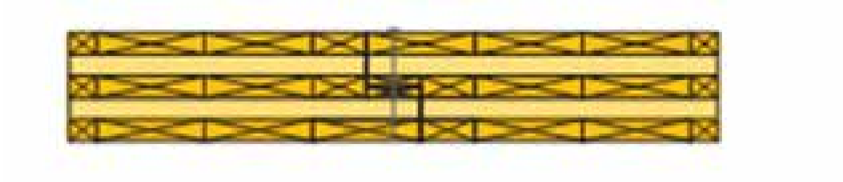


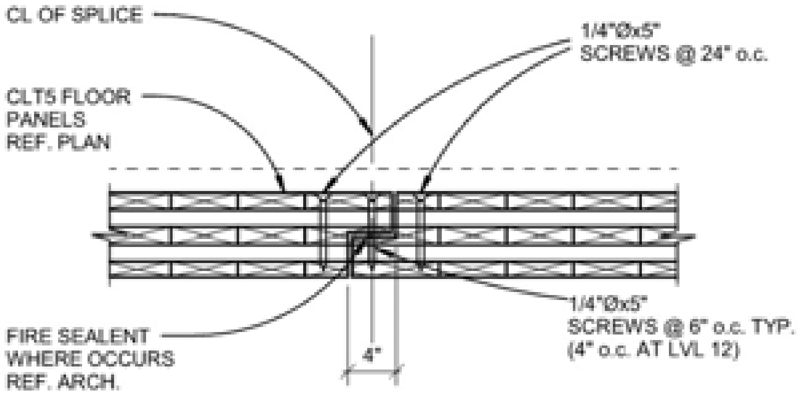


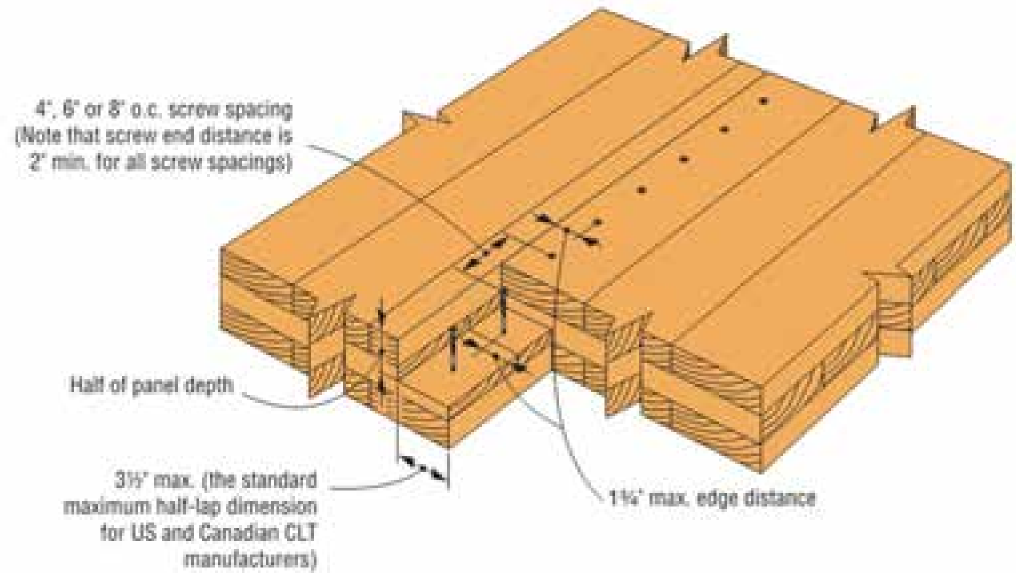
Source: Simpson Strong-Tie

Panel to Panel Connection Styles

Half-Lap







Source: Simpson Strong-Tie

CLT Diaphragm Shear Transfer Connection Design

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, ϕ, $\lambda = 1.0$

Source: 2021 SDPWS 4.5.4(1) and 2018 NDS Table 11.3.1

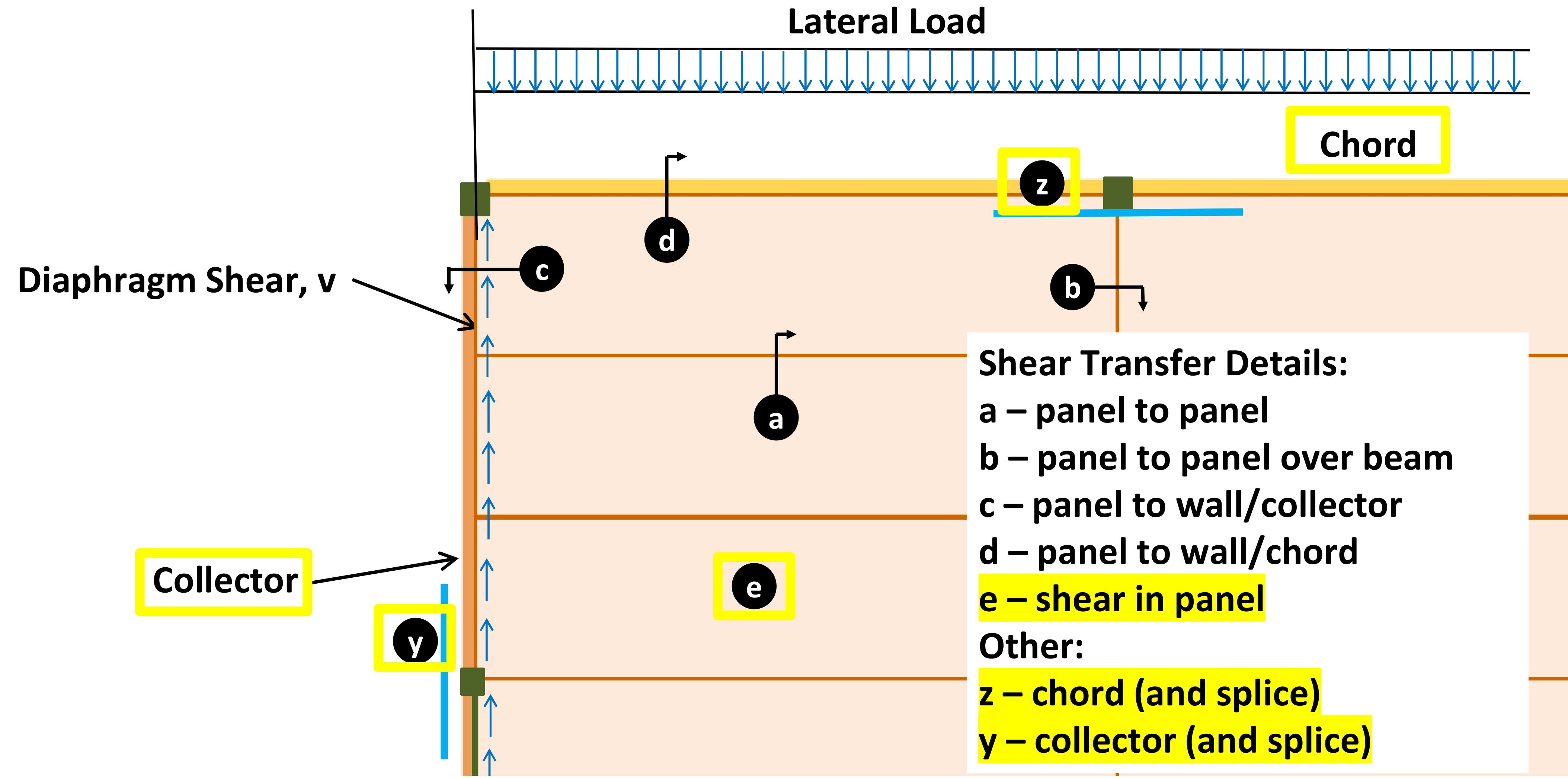
Table 11.3.1 Applicability of Adjustment Factors for Connections

	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) $Z^* = Z$ x	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 Transfer Connections

Source 2021 SDPWS 4.5.4(1) and 2018 NDS Table 11.3.1

Other CLT Diaphragm Components



Other CLT Diaphragm Components

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Other CLT Diaphragm Components

Amplified Diaphragm Design Forces ≤ Design Capacity

$$\gamma \cdot v \leq v'$$

v = wind or seismic force demand

$v' =$ Adjusted capacity calculated per the NDS *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 IIIs or IV (seismic)
1.0 for chord splice connections controlled by Mode IIIs or IV (wind)

See **2021 SPDWS 4.5.4 for the full information*

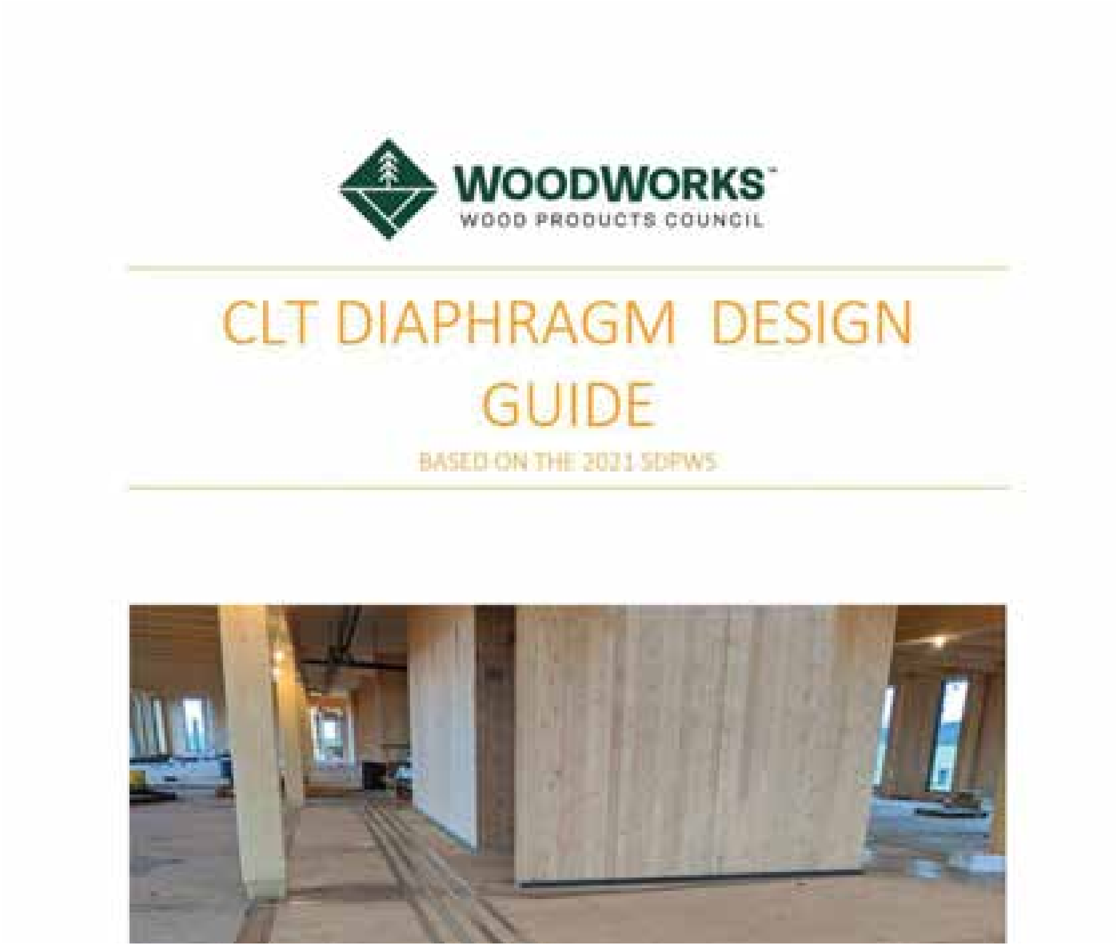
Additional Resources

Additional Resources

Available from woodworks.org

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

Additional Resources


WOODWORKS
WOOD PRODUCTS COUNCIL

CLT DIAPHRAGM DESIGN GUIDE

BASED ON THE 2021 SDPWS

Under Development By:

WoodWorks – Wood Products Council

Holmes Structures

kpff

Swinerton Mass Timber

Funded By:

U.S. Endowment for Forestry and Communities

USDA

Questions? Ask us anything.

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901 East Sixth, Thoughtbarn-Delineate Studio,
Leap!Structures, photo Casey Dunn