Introduction to Wood: Structural Lateral Framing Design

January 16, 2025

Presented by

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Cubix Othello / Jackson|Main Architecture / ABKJ / Photo Jackson|Main Architecture

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Course Description

This presentation will provide an introductory review of structural wood design for lateral (wind and seismic) loads, including traditional diaphragms and shear walls as well as alternate systems. Referenced codes and standards, design properties, design examples and detailing best practices will be covered.

Learning Objectives

1. Review wood's role and allowable uses as a structural lateral framing material under current building codes.
2. Discuss design considerations specific to wood diaphragms and associated chords and collectors that resist lateral forces in non-residential and multi-family buildings.
3. Identify code-compliant design processes for light wood frame shear walls and associated drag struts, hold downs and load transfer members.
4. Explore the variety of options for wood as a lateral force-resisting system and discuss how to efficiently utilize and design each.

Outline

- Lateral Design Introduction
- Diaphragms
- Shear Walls
- Other Lateral Options

Outline

- **Lateral Design Introduction**
- Diaphragms
- Shear Walls
- Other Lateral Options

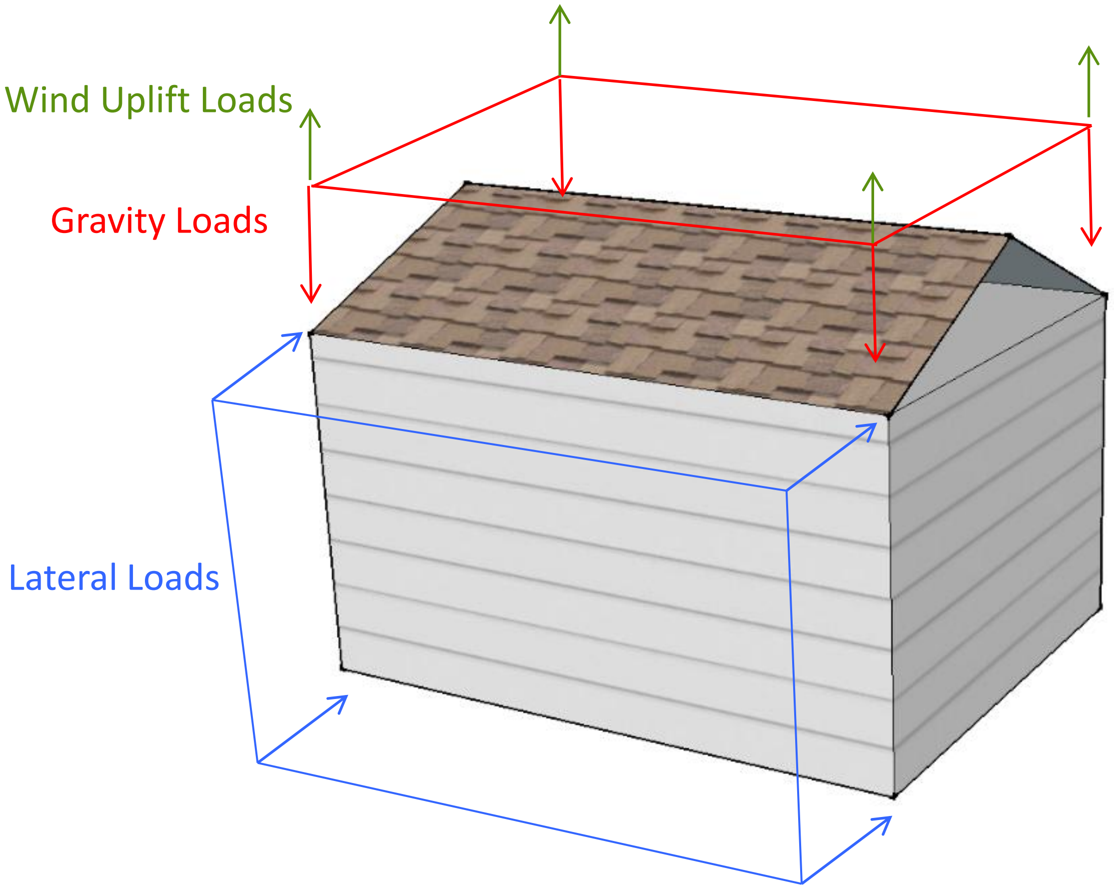
Structural Wood Design

Structural building design loads:

- Gravity
- Lateral

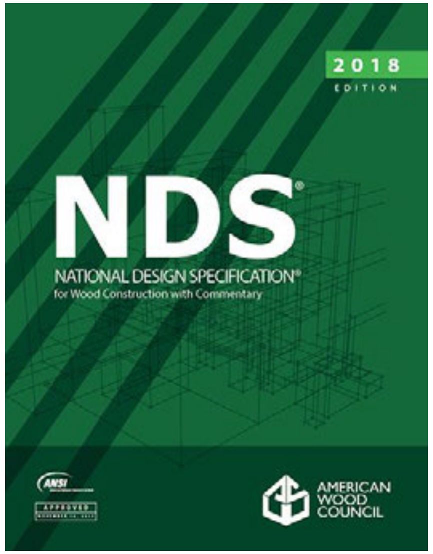
Lateral loads:

- Wind
- Seismic

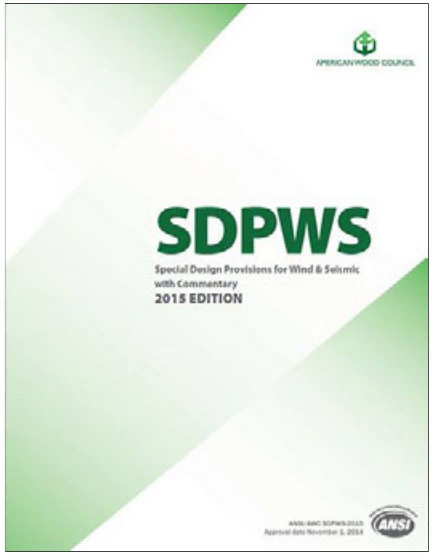


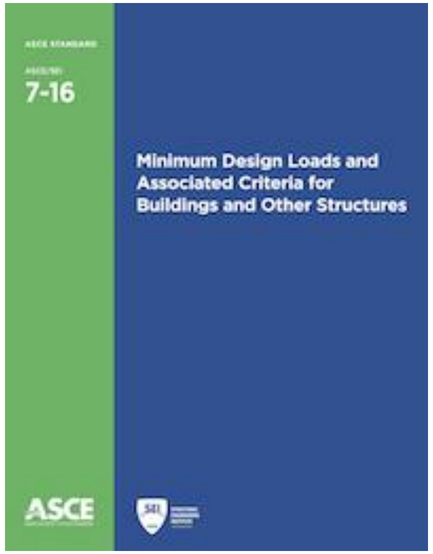
2018 IBC

2018 NDS



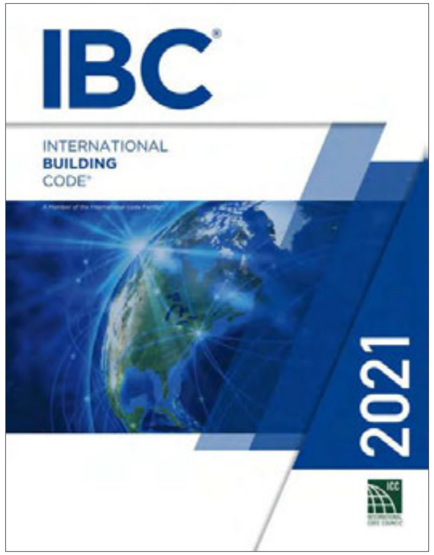
2015 SDPWS





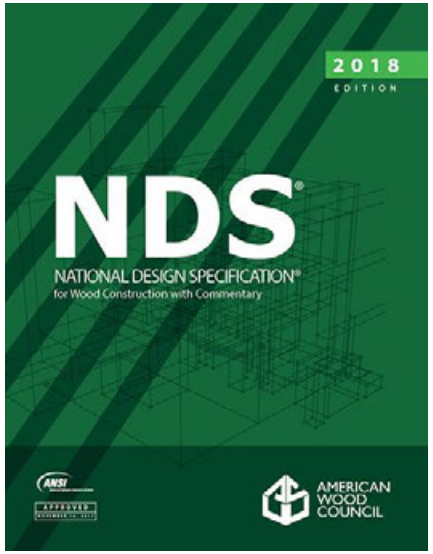
ASCE 7-16
(2016)

2021 IBC



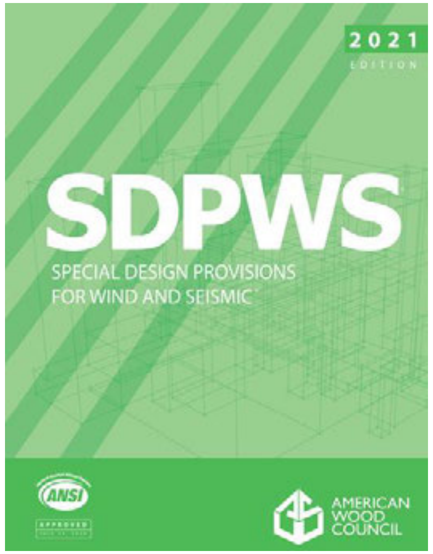
IBC®
INTERNATIONAL
BUILDING
CODE®
2021

2018 NDS

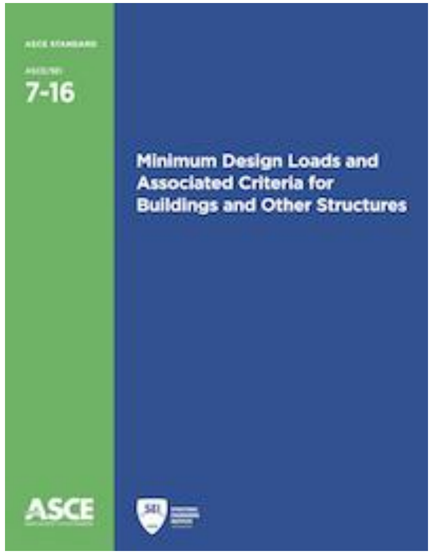


2018
EDITION
NDS®
NATIONAL DESIGN SPECIFICATION®
for Wood Construction with Commentary
AMERICAN
WOOD
COUNCIL

2021 SDPWS



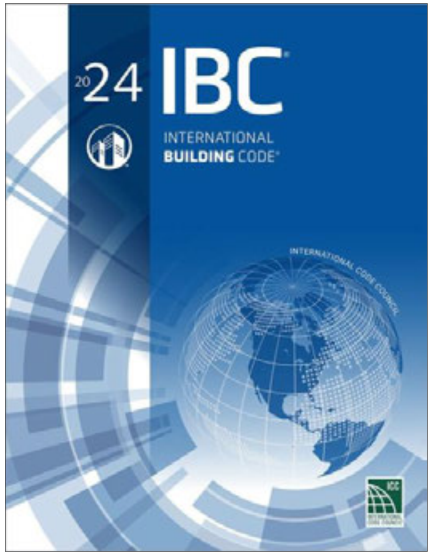
2021
EDITION
SDPWS
SPECIAL DESIGN PROVISIONS
FOR WIND AND SEISMIC
AMERICAN
WOOD
COUNCIL



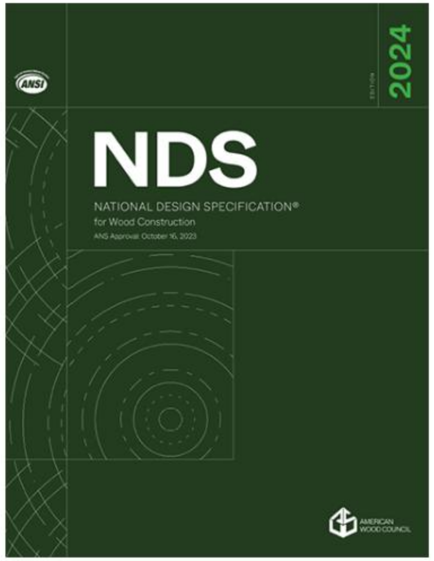
ASCE STANDARD
ASCE/SEI
7-16
Minimum Design Loads and
Associated Criteria for
Buildings and Other Structures
ASCE

ASCE 7-16
(2016)

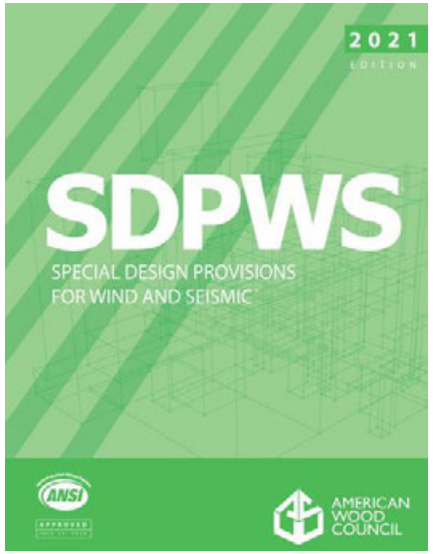
2024 IBC

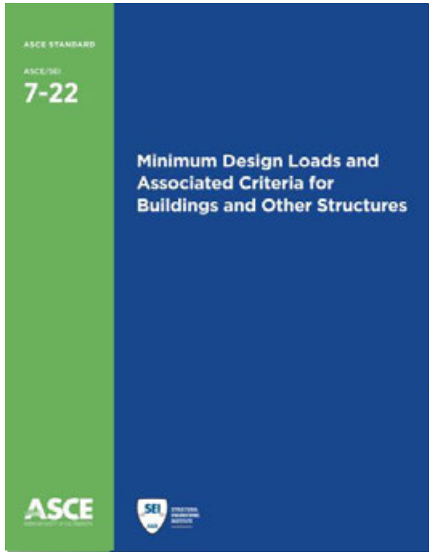


2024 NDS



2021 SDPWS





ASCE 7-22
(2022)

Structural Wood Design

ASD vs. LRFD

- SDPWS Section 2.1.2:
  - Engineered design of wood structures to resist wind and seismic forces shall be by one of the methods described in 2.1.2.1 [Allowable Stress Design (ASD)] and 2.1.2.2 [Load and Resistance Factor Design (LRFD)].

ASD

- Allowable Stress Design
- Based on allowable strengths and nominal (unfactored) loads

LRFD

- Load and Resistance Factor Design
- Based on nominal strengths and factored loads

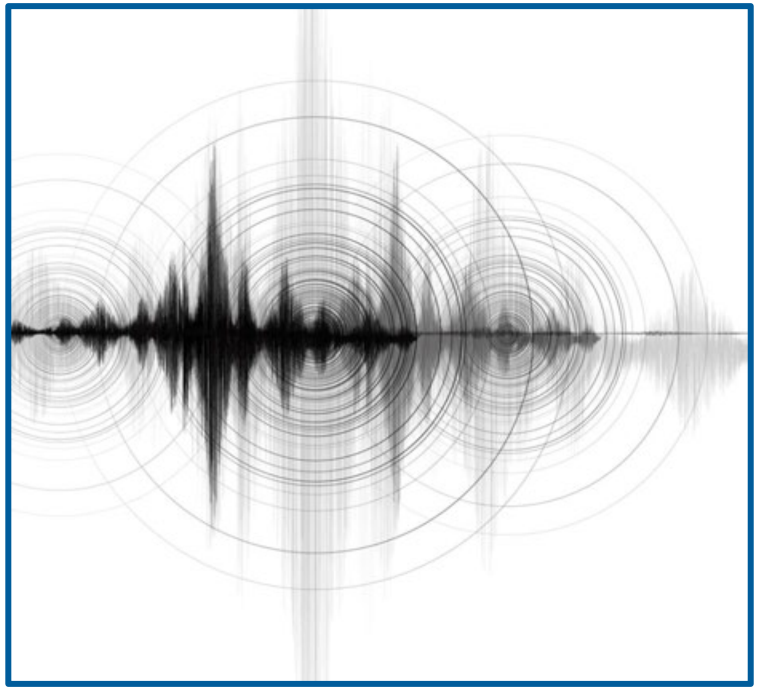
Wood Design: Lateral Loads

Wind forces

istockphoto, Juanmonino, 155442167

- Caused by wind pressures
- Magnitude based on exposed building area

Seismic forces

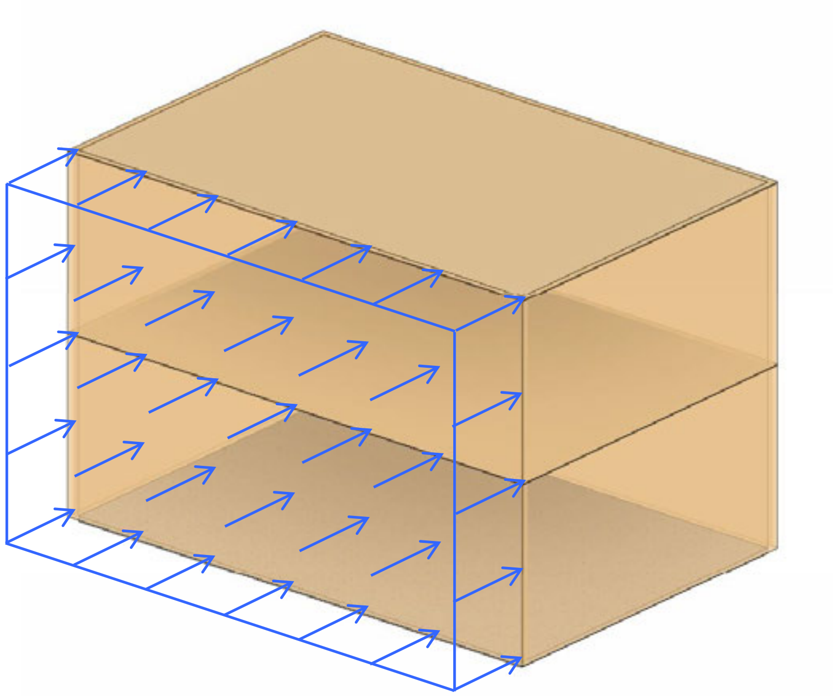


istockphoto, Varunyu, 908961098

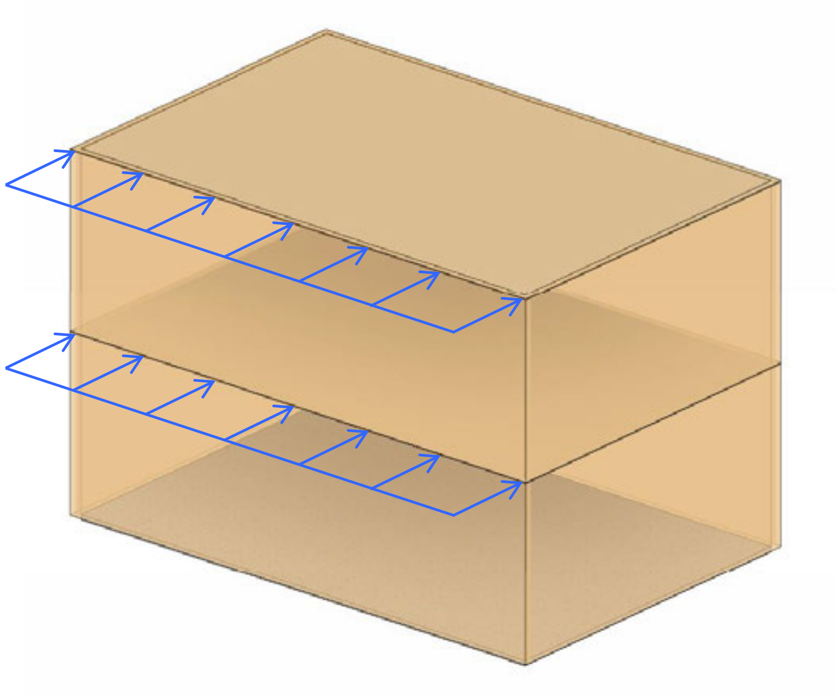
- Caused by ground movement
- Magnitude based on building weight

Wood Design: Lateral Loads

- Wind forces



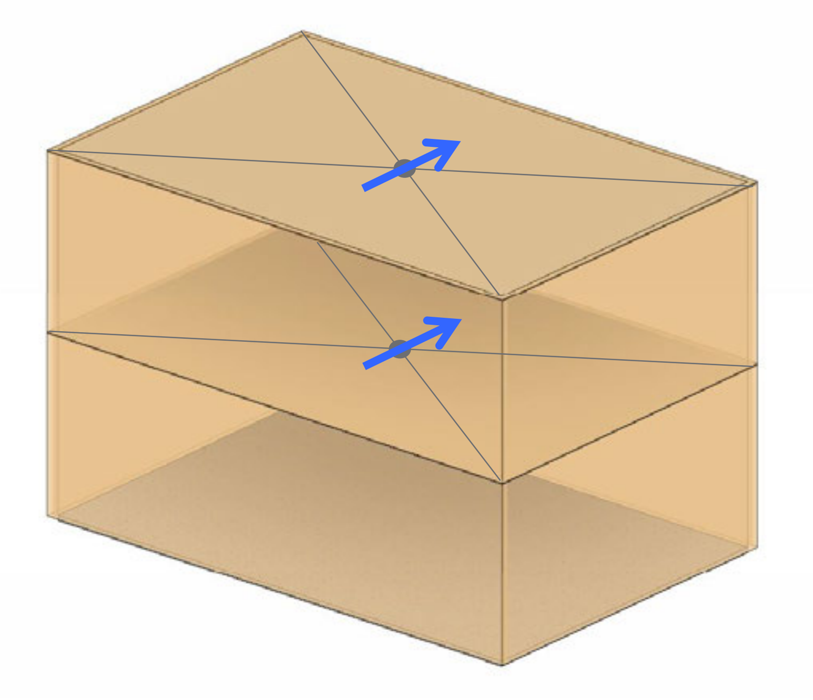
Surface pressure (psf)



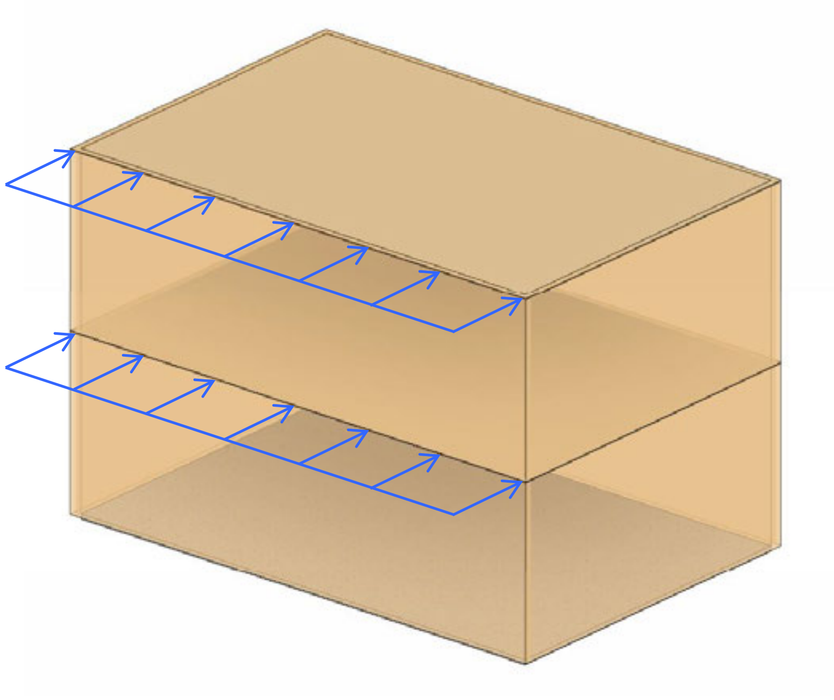
Linear floor load based on tributary height (plf)

Wood Design: Lateral Loads

- Seismic forces



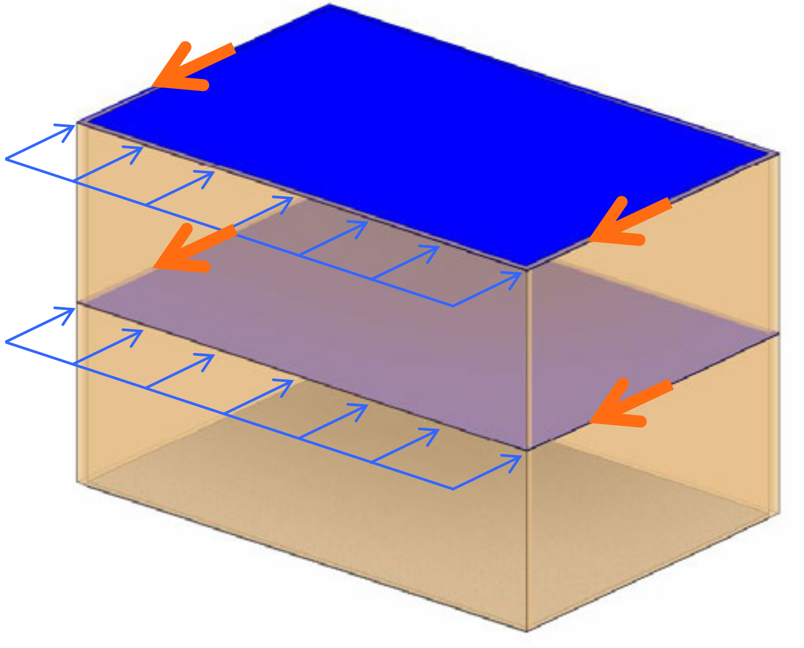
Loads based on
building weight (lb)



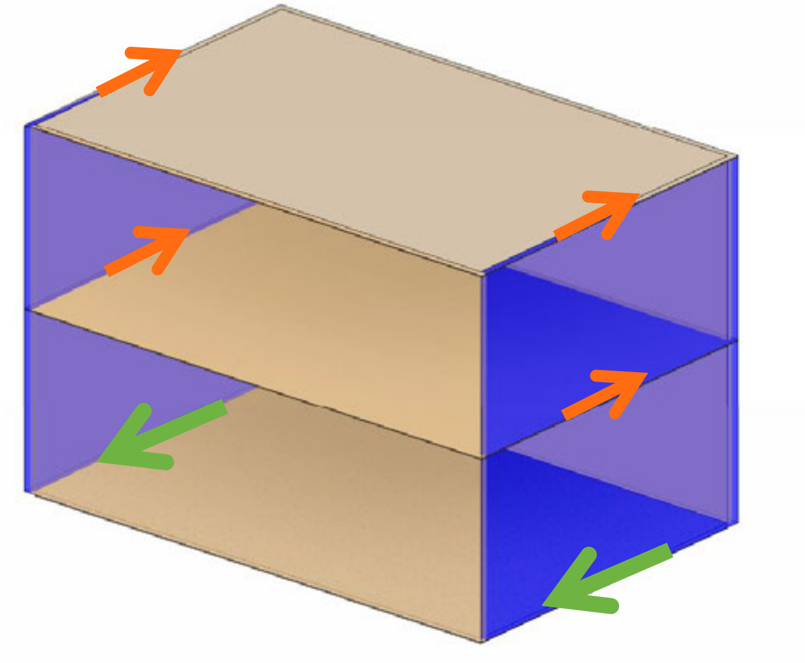
Loads distributed as
linear floor loads (plf)

Wood Design: Lateral Loads

- Lateral force resisting system
  - Diaphragms
  - Shear Walls



Diaphragms



Shear Walls

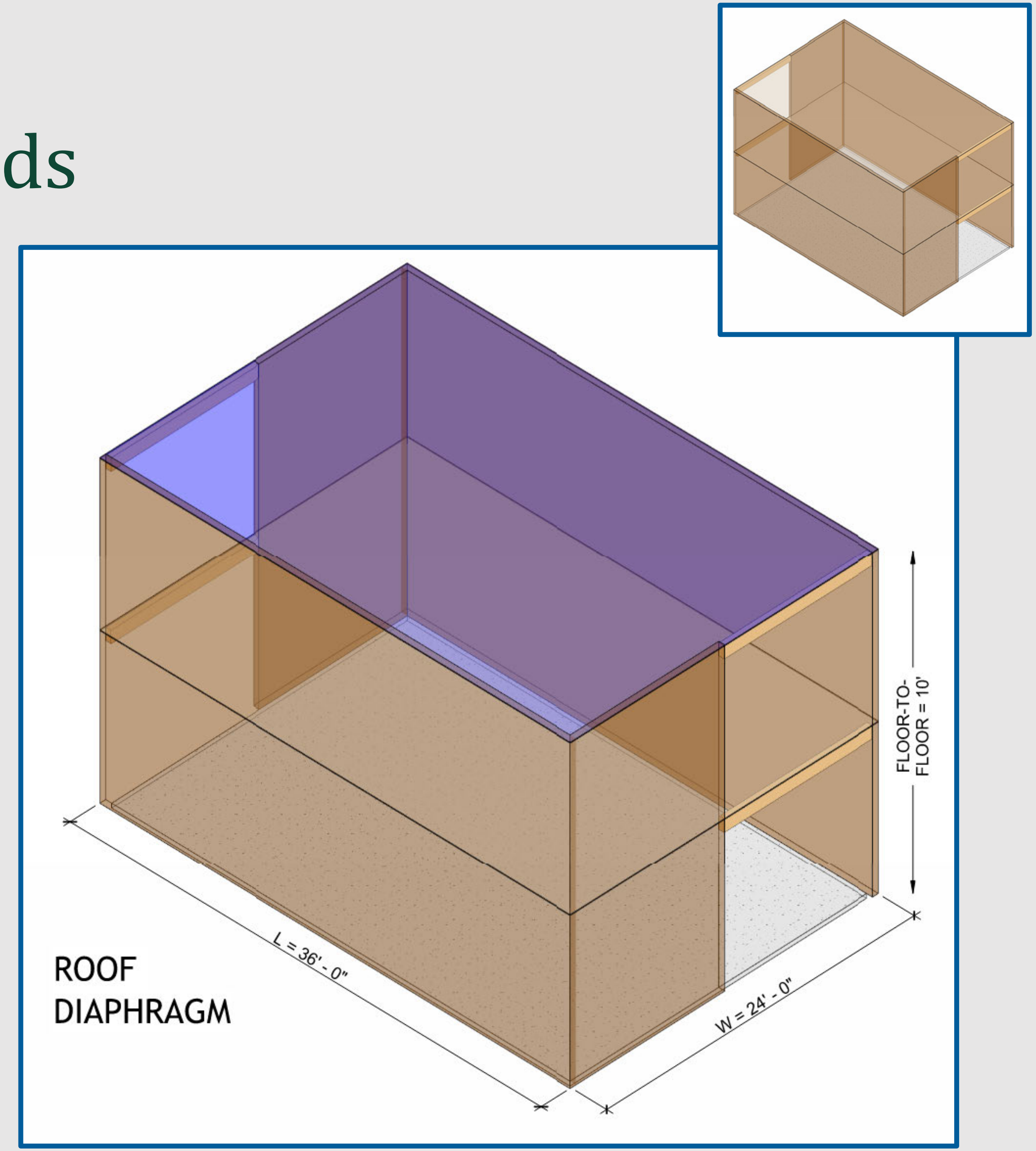
Design Example: Lateral Loads

Example building

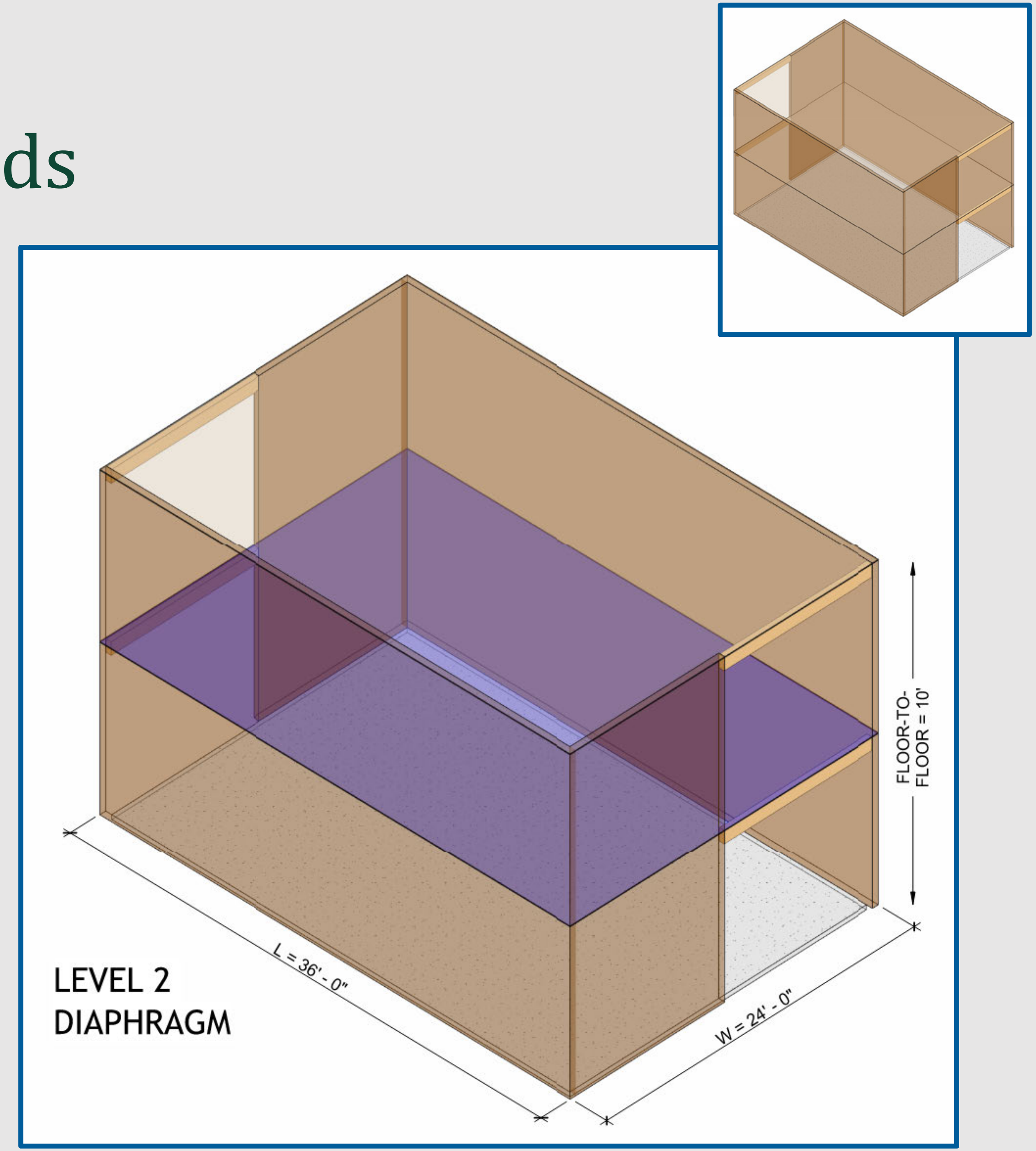
- 2-story
  - Diaphragms
    - L = 36 feet
    - W = 24 feet
  - Exterior shear walls
    - h = 10 feet

Lateral loading

- Wind: Applied to exterior
- Seismic: Based on seismic weight



Design Example: Lateral Loads



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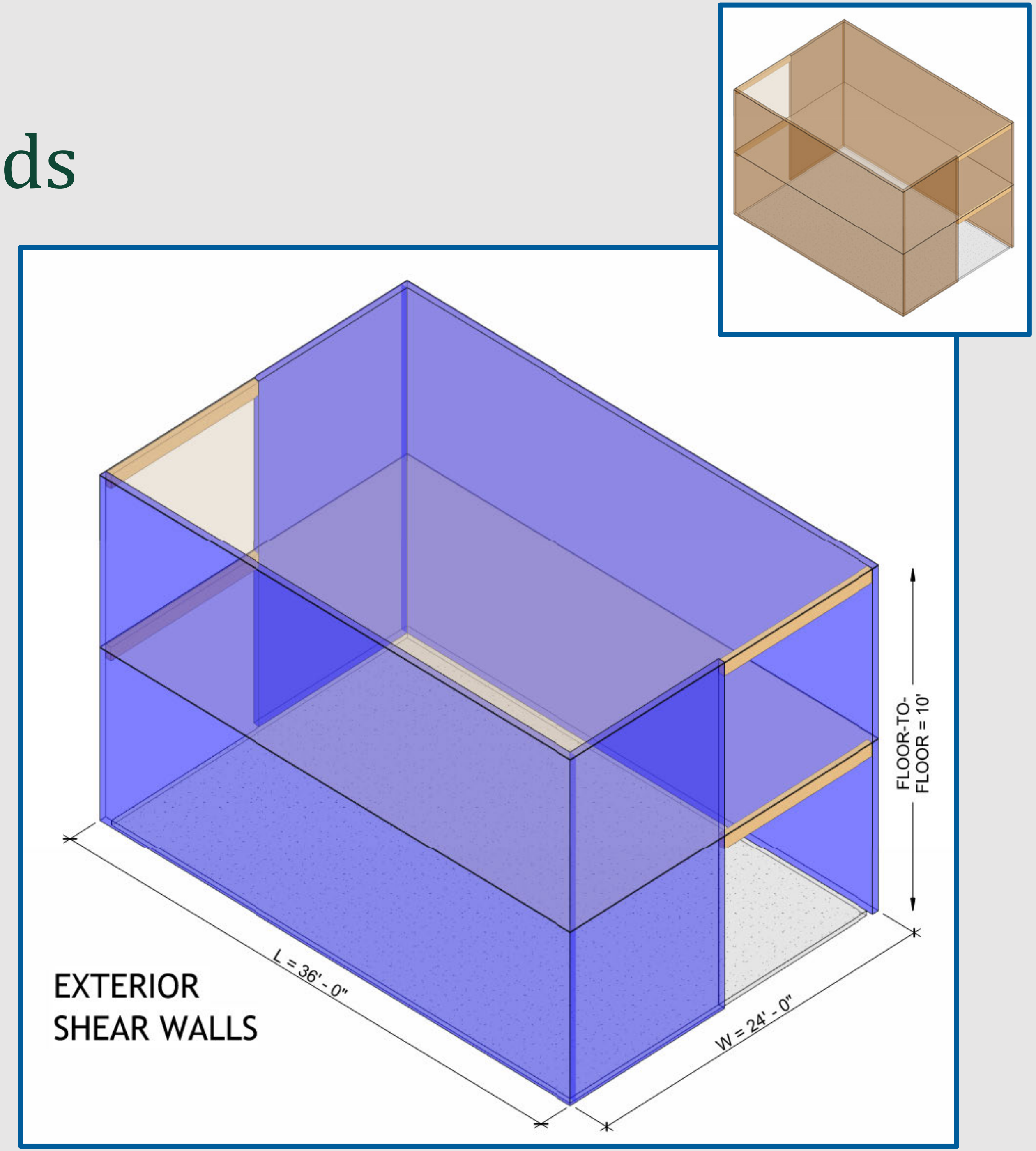
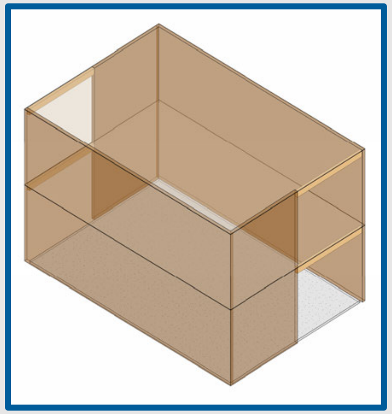
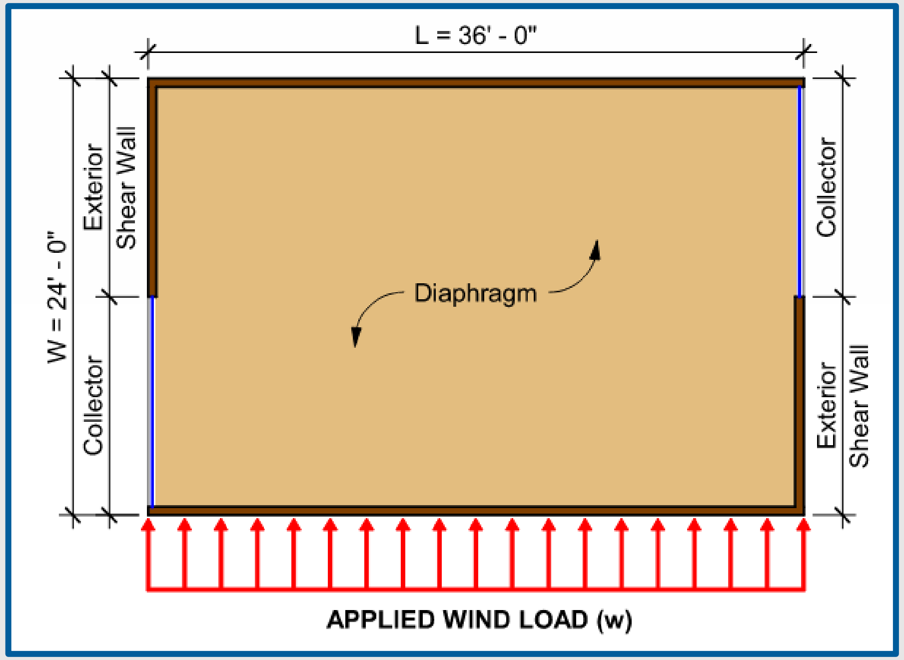


Design Example: Lateral Loads

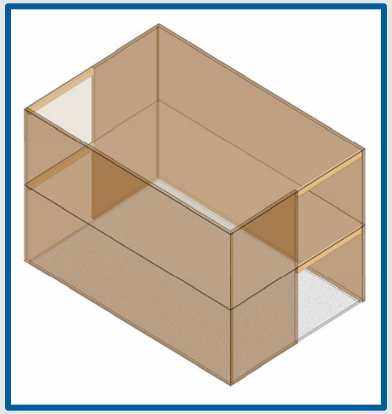


Wind load

- 25 psf (windward + leeward)
  - Roof trib. height = 5’
    - → Roof load: $25\ psf\ * 5\ ft = 125\ plf$
  - Level 2 trib. height = 10’
    - → Level 2 load: $25\ psf\ * 10\ ft = 250\ plf$

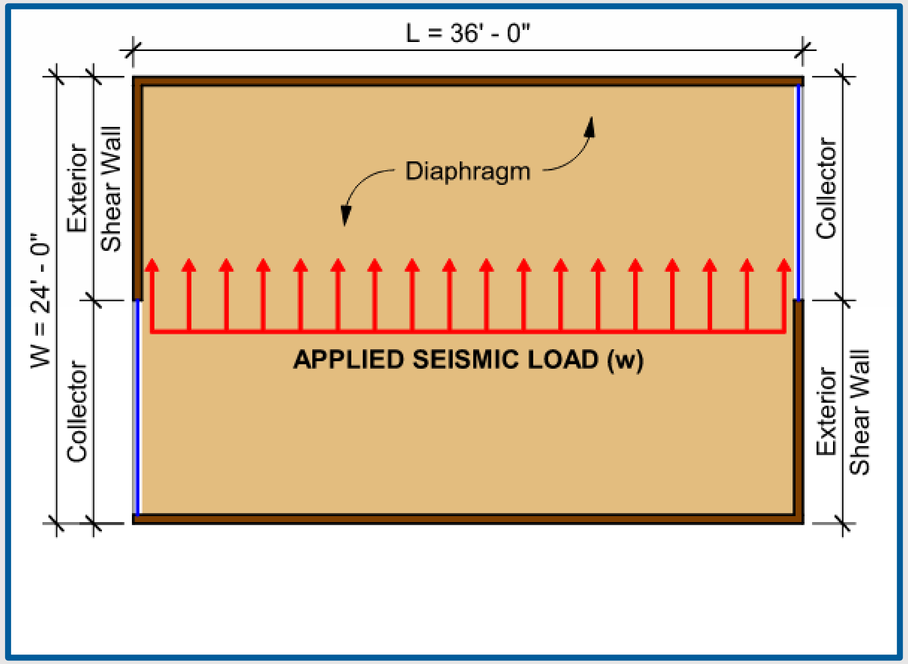


Design Example: Lateral Loads



Seismic load

- Story load based on seismic weight
  - Seismic load V per ASCE 7
  - Assume V = 9 kips
    - → Roof load: 4 kips
    - → Level 2 load: 5 kips
  - Distribute along building length, 36ft
    - → Roof load: $4kips/36ft = 111plf$
    - → Level 2 load: $5kips/36ft = 139plf$

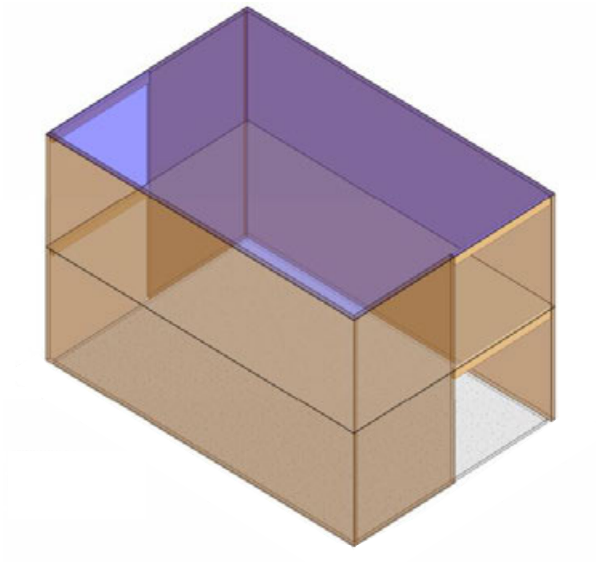


Outline

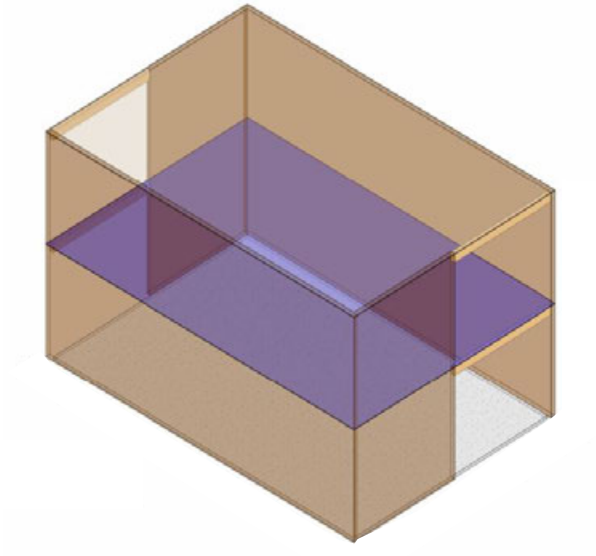
- Lateral Design Introduction
- **Diaphragms**
- Shear Walls
- Other Lateral Options

Wood Design: Diaphragms

- Diaphragms:
  - Roof
  - Floor
  - Other horizontal bracing systems

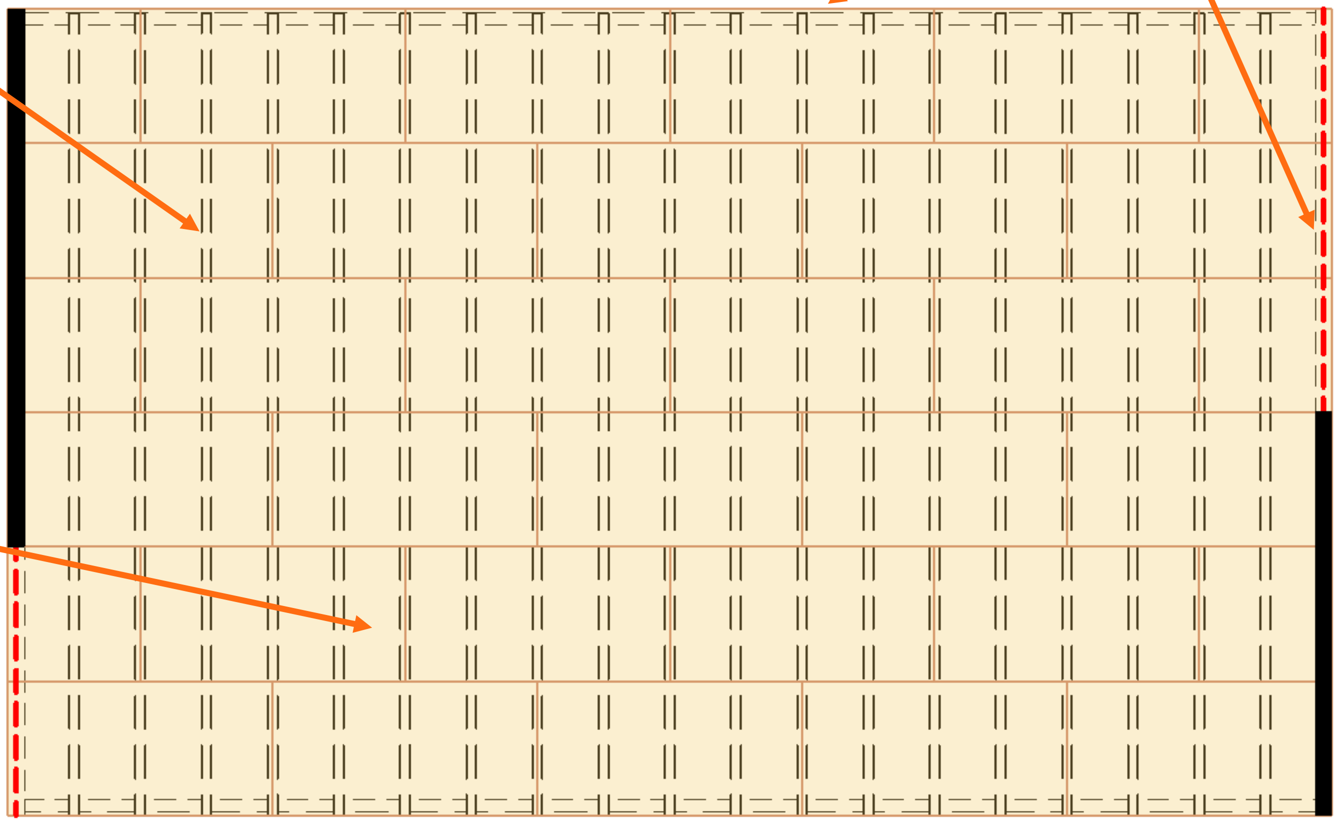


Roof Diaphragm



Floor Diaphragm

Wood Design: Diaphragms



Boundary Elements (Double Top Plates, Rim Joist, Truss, Beam, etc.)

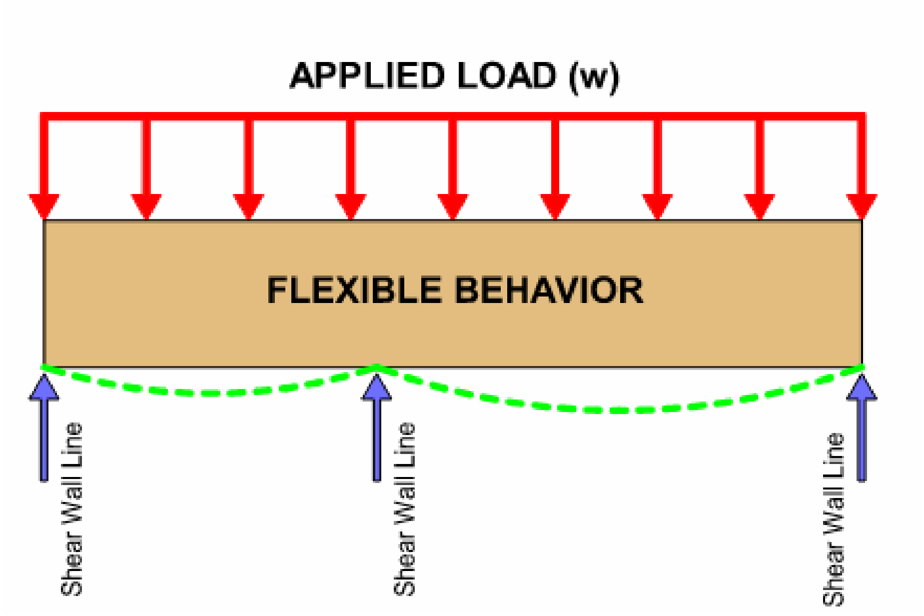
Floor or Roof Framing (Blocking if Required)

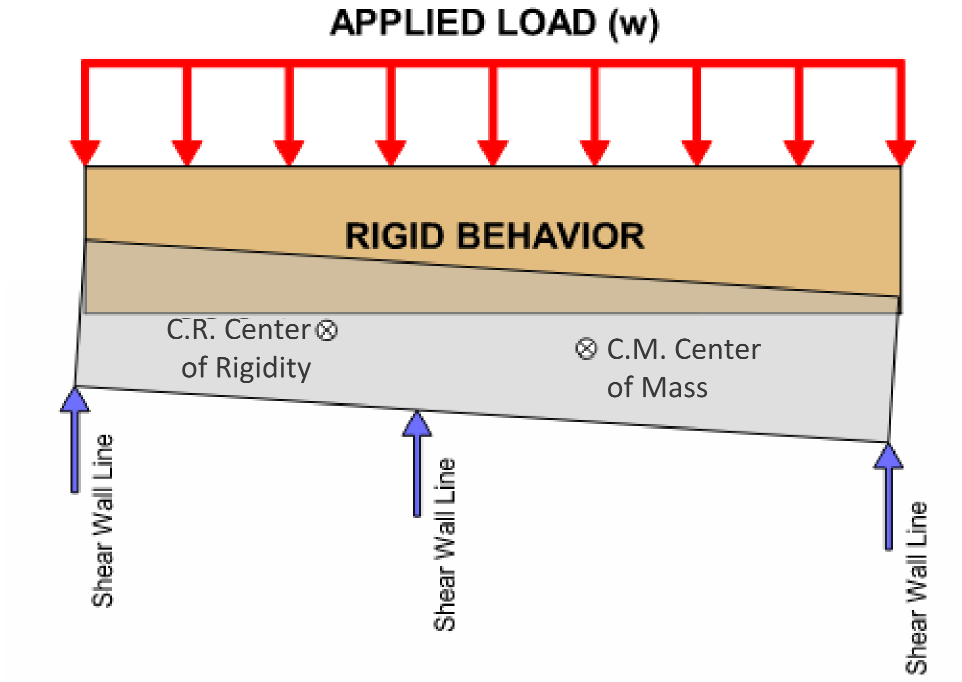
Sheathing:

- Wood Structural Panels (WSP's)
- Lumber

Wood Design: Diaphragms

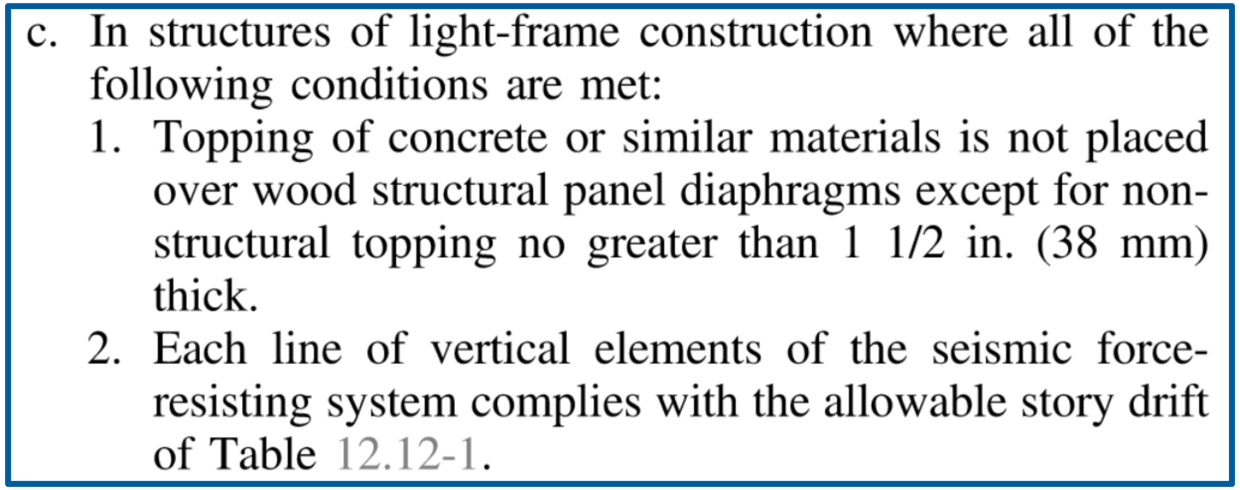
- Diaphragm flexibility (ASCE 7-16, Section 12.3.1):
  - Flexible
  - Rigid
  - Semi-Rigid





Wood Design: Diaphragms

- Light-frame wood diaphragms:
  - Traditionally idealized as flexible (ASCE 7-16, Section 12.3.1.1, Item c)



c. In structures of light-frame construction where all of the following conditions are met:

1. Topping of concrete or similar materials is not placed over wood structural panel diaphragms except for nonstructural topping no greater than 1 1/2 in. (38 mm) thick.
2. Each line of vertical elements of the seismic force-resisting system complies with the allowable story drift of Table 12.12-1.

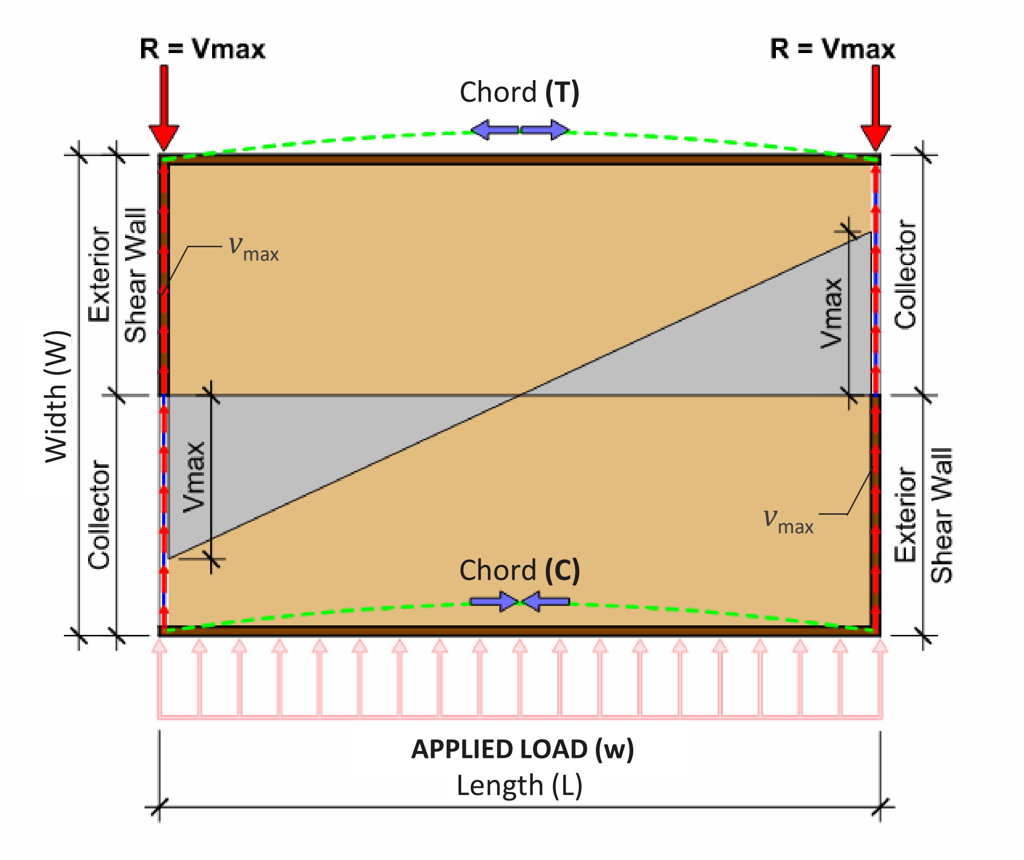
ASCE 7-16

- Consider diaphragm complexity!
  - Semi-rigid or rigid may be more appropriate

Wood Design: Diaphragms

Diaphragm design checks:

- Diaphragm: Aspect Ratio, Shear, Deflection
- Chords: Tension, Compression
- Collectors (Drag Struts): Tension, Compression



Wood Design: Diaphragms

- Nominal Unit Shear Capacities: 2021 SDPWS
  - Blocked Wood Structural Panel Diaphragms (Table 4.2A)
  - High Load Blocked Wood Structural Panel Diaphragms (Table 4.2B)
  - Unblocked Wood Structural Panel Diaphragms (Table 4.2C)
  - Horizontally or Diagonally-Sheathed Lumber Diaphragms (Table 4.2D)

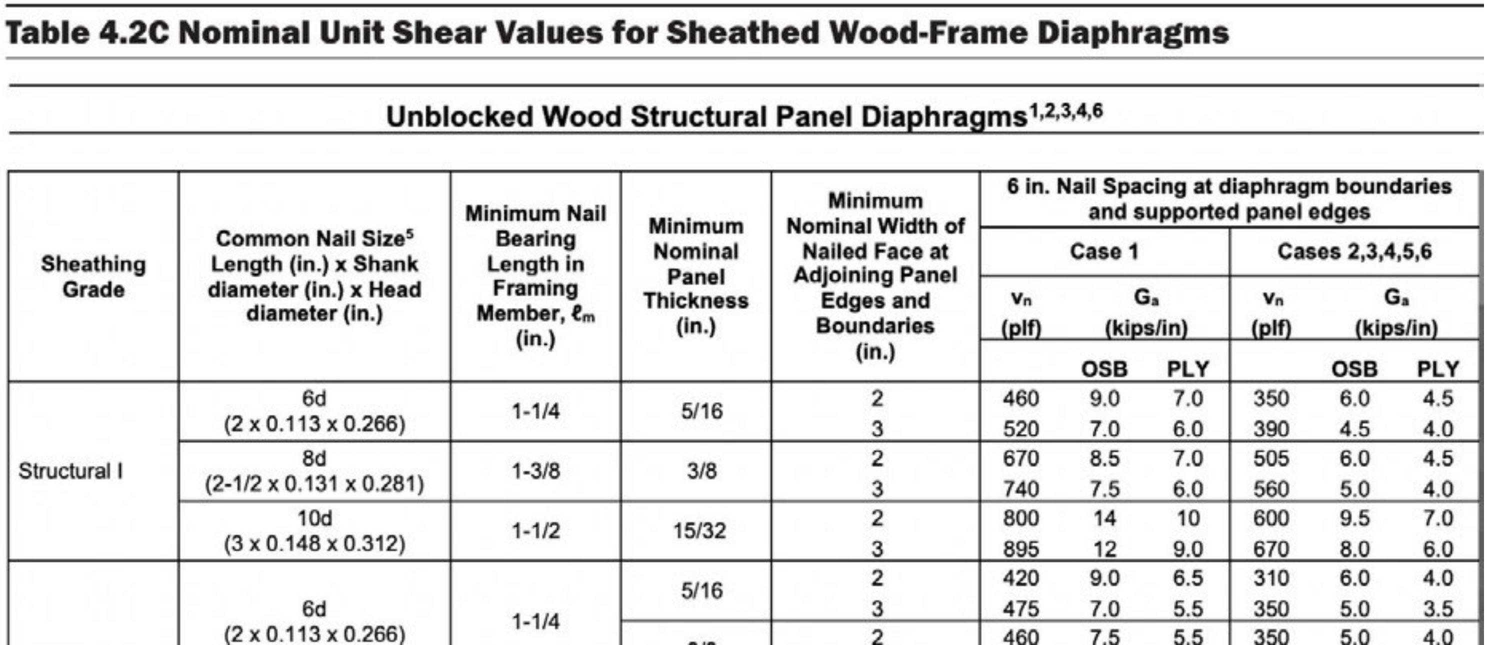


Table 4.2C Nominal Unit Shear Values for Sheathed Wood-Frame Diaphragms

Unblocked Wood Structural Panel Diaphragms[1,2,3,4,6]

Sheathing Grade	Common Nail Size[5] Length (in.) x Shank diameter (in.) x Head diameter (in.)	Minimum Nail Bearing Length in Framing Member, ℓ_m (in.)	Minimum Nominal Panel Thickness (in.)	Minimum Nominal Width of Nailed Face at Adjoining Panel Edges and Boundaries (in.)	6 in. Nail Spacing at diaphragm boundaries and supported panel edges					
					Case 1			Cases 2,3,4,5,6		
					v_n (plf)	G_a (kips/in)		v_n (plf)	G_a (kips/in)	
						OSB	PLY		OSB	PLY
Structural I	6d (2 x 0.113 x 0.266)	1-1/4	5/16	2	460	9.0	7.0	350	6.0	4.5
				3	520	7.0	6.0	390	4.5	4.0
	8d (2-1/2 x 0.131 x 0.281)	1-3/8	3/8	2	670	8.5	7.0	505	6.0	4.5
				3	740	7.5	6.0	560	5.0	4.0
	10d (3 x 0.148 x 0.312)	1-1/2	15/32	2	800	14	10	600	9.5	7.0
				3	895	12	9.0	670	8.0	6.0
	6d (2 x 0.113 x 0.266)	1-1/4	5/16	2	420	9.0	6.5	310	6.0	4.0
				3	475	7.0	5.5	350	5.0	3.5
				2	460	7.5	5.5	350	5.0	4.0

2021 SDPWS

Wood Design: Diaphragms

Nominal Unit Shear Capacities (2015 SDPWS):

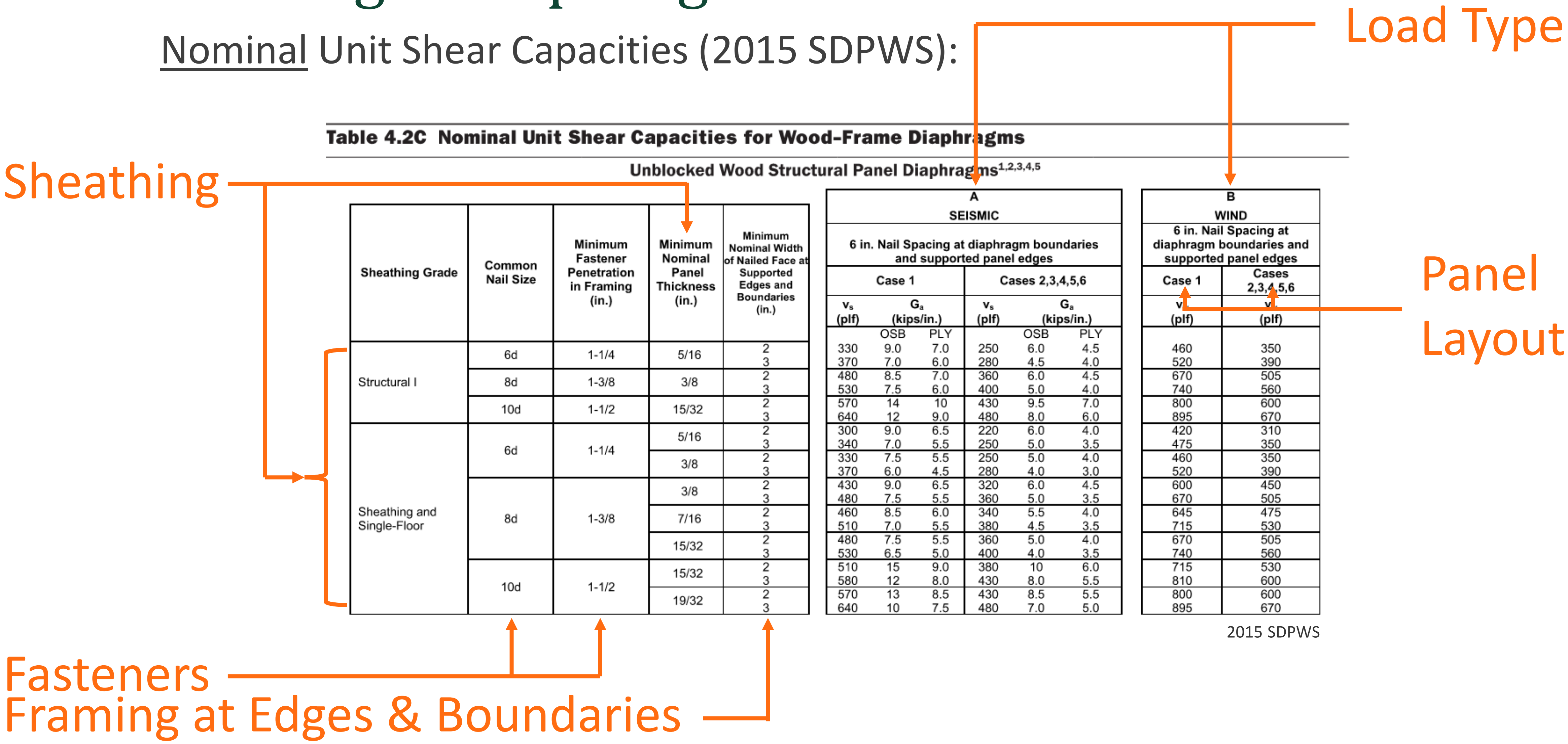


Table 4.2C Nominal Unit Shear Capacities for Wood-Frame Diaphragms

Unblocked Wood Structural Panel Diaphragms[1,2,3,4,5]

Sheathing Grade	Common Nail Size	Minimum Fastener Penetration in Framing (in.)	Minimum Nominal Panel Thickness (in.)	Minimum Nominal Width of Nailed Face at Supported Edges and Boundaries (in.)	A SEISMIC 6 in. Nail Spacing at diaphragm boundaries and supported panel edges						B WIND 6 in. Nail Spacing at diaphragm boundaries and supported panel edges	
					Case 1			Cases 2,3,4,5,6			Case 1	Cases 2,3,4,5,6
					v_s (plf)	G_a (kips/in.)		v_s (plf)	G_a (kips/in.)		v (plf)	v (plf)
						OSB	PLY		OSB	PLY		
Structural I	6d	1-1/4	5/16	2	330	9.0	7.0	250	6.0	4.5	460	350
				3	370	7.0	6.0	280	4.5	4.0	520	390
	8d	1-3/8	3/8	2	480	8.5	7.0	360	6.0	4.5	670	505
				3	530	7.5	6.0	400	5.0	4.0	740	560
	10d	1-1/2	15/32	2	570	14	10	430	9.5	7.0	800	600
				3	640	12	9.0	480	8.0	6.0	895	670
Sheathing and Single-Floor	6d	1-1/4	5/16	2	300	9.0	6.5	220	6.0	4.0	420	310
				3	340	7.0	5.5	250	5.0	3.5	475	350
			3/8	2	330	7.5	5.5	250	5.0	4.0	460	350
				3	370	6.0	4.5	280	4.0	3.0	520	390
	8d	1-3/8	3/8	2	430	9.0	6.5	320	6.0	4.5	600	450
				3	480	7.5	5.5	360	5.0	3.5	670	505
			7/16	2	460	8.5	6.0	340	5.5	4.0	645	475
				3	510	7.0	5.5	380	4.5	3.5	715	530
			15/32	2	480	7.5	5.5	360	5.0	4.0	670	505
				3	530	6.5	5.0	400	4.0	3.5	740	560
	10d	1-1/2	15/32	2	510	15	9.0	380	10	6.0	715	530
				3	580	12	8.0	430	8.0	5.5	810	600
			19/32	2	570	13	8.5	430	8.5	5.5	800	600
				3	640	10	7.5	480	7.0	5.0	895	670

2015 SDPWS

Load Type

Sheathing

Panel Layout

Fasteners

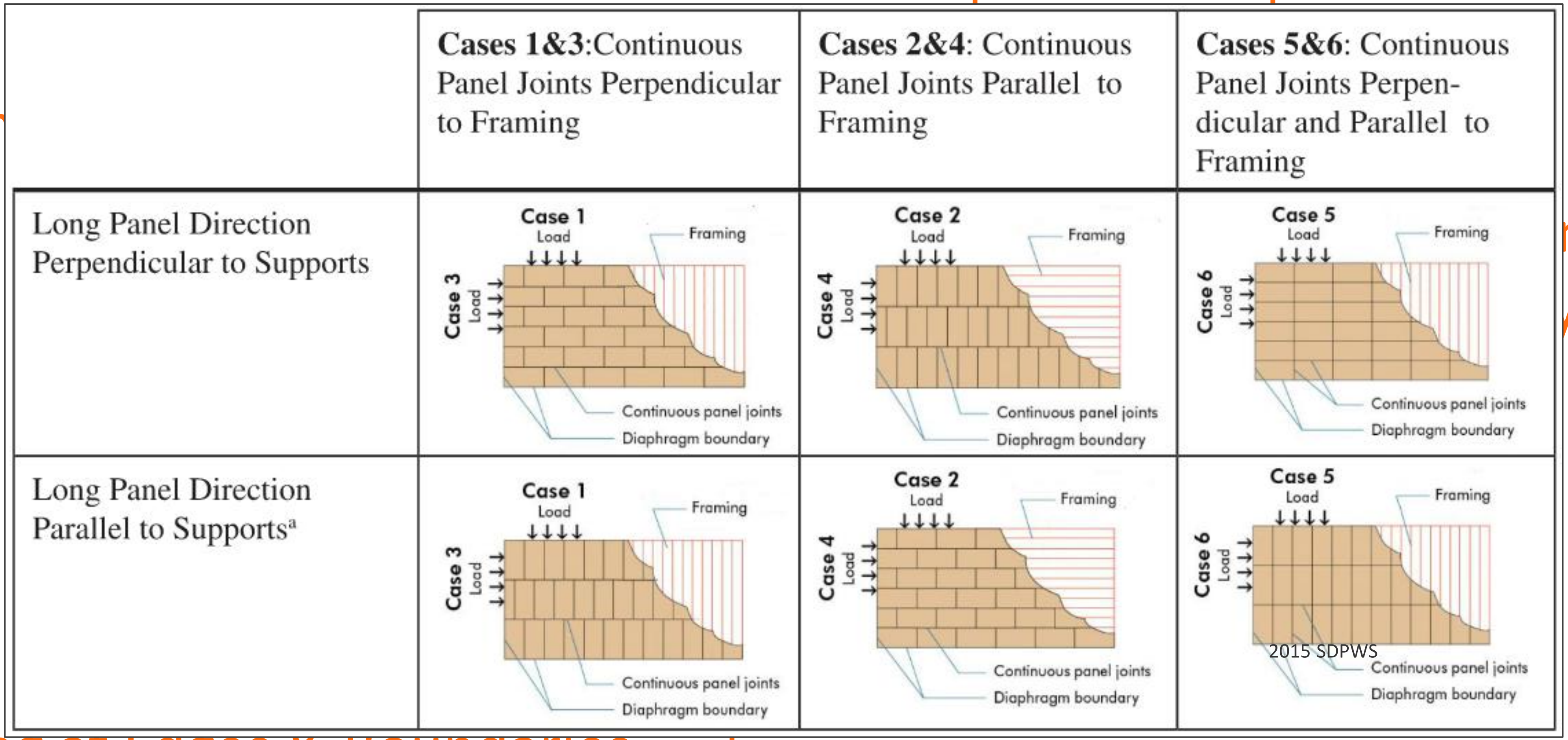
Framing at Edges & Boundaries

Wood Design: Diaphragms

Nominal Unit Shear Capacities (2015 SDPWS):

Load Type

Sheath



	Cases 1&3:Continuous Panel Joints Perpendicular to Framing	**Cases 2&4**: Continuous Panel Joints Parallel to Framing	**Cases 5&6**: Continuous Panel Joints Perpendicular and Parallel to Framing
Long Panel Direction Perpendicular to Supports	Case 1 Case 3	Case 2 Case 4	Case 5 Case 6
Long Panel Direction Parallel to Supports[a]	Case 1 Case 3	Case 2 Case 4	Case 5 Case 6

2015 SDPWS

nel

yout

Fasten

Framing at Edges & Boundaries

Wood Design: Diaphragms

Nominal Unit Shear Capacities (2021 SDPWS):

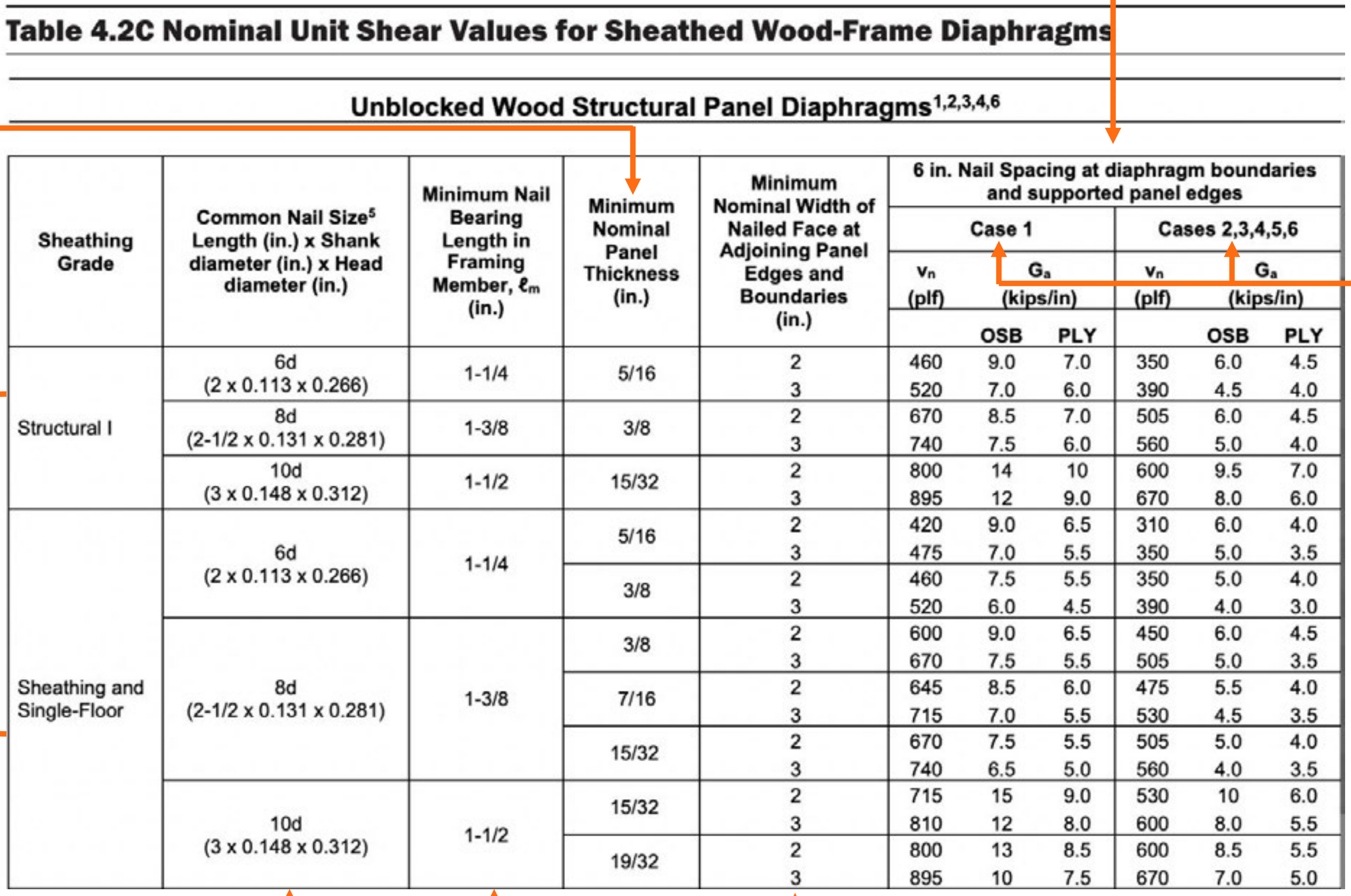
Single Table for Wind & Seismic

Sheathing

Panel Layout

Framing at Edges & Boundaries

Fasteners



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Structural I	6d (2 x 0.113 x 0.266)	1-1/4	5/16	2	460	9.0	7.0	350	6.0	4.5
				3	520	7.0	6.0	390	4.5	4.0
	8d (2-1/2 x 0.131 x 0.281)	1-3/8	3/8	2	670	8.5	7.0	505	6.0	4.5
				3	740	7.5	6.0	560	5.0	4.0
	10d (3 x 0.148 x 0.312)	1-1/2	15/32	2	800	14	10	600	9.5	7.0
				3	895	12	9.0	670	8.0	6.0
Sheathing and Single-Floor	6d (2 x 0.113 x 0.266)	1-1/4	5/16	2	420	9.0	6.5	310	6.0	4.0
				3	475	7.0	5.5	350	5.0	3.5
			3/8	2	460	7.5	5.5	350	5.0	4.0
				3	520	6.0	4.5	390	4.0	3.0
	8d (2-1/2 x 0.131 x 0.281)	1-3/8	3/8	2	600	9.0	6.5	450	6.0	4.5
				3	670	7.5	5.5	505	5.0	3.5
			7/16	2	645	8.5	6.0	475	5.5	4.0
				3	715	7.0	5.5	530	4.5	3.5
			15/32	2	670	7.5	5.5	505	5.0	4.0
				3	740	6.5	5.0	560	4.0	3.5
	10d (3 x 0.148 x 0.312)	1-1/2	15/32	2	715	15	9.0	530	10	6.0
				3	810	12	8.0	600	8.0	5.5
			19/32	2	800	13	8.5	600	8.5	5.5
				3	895	10	7.5	670	7.0	5.0

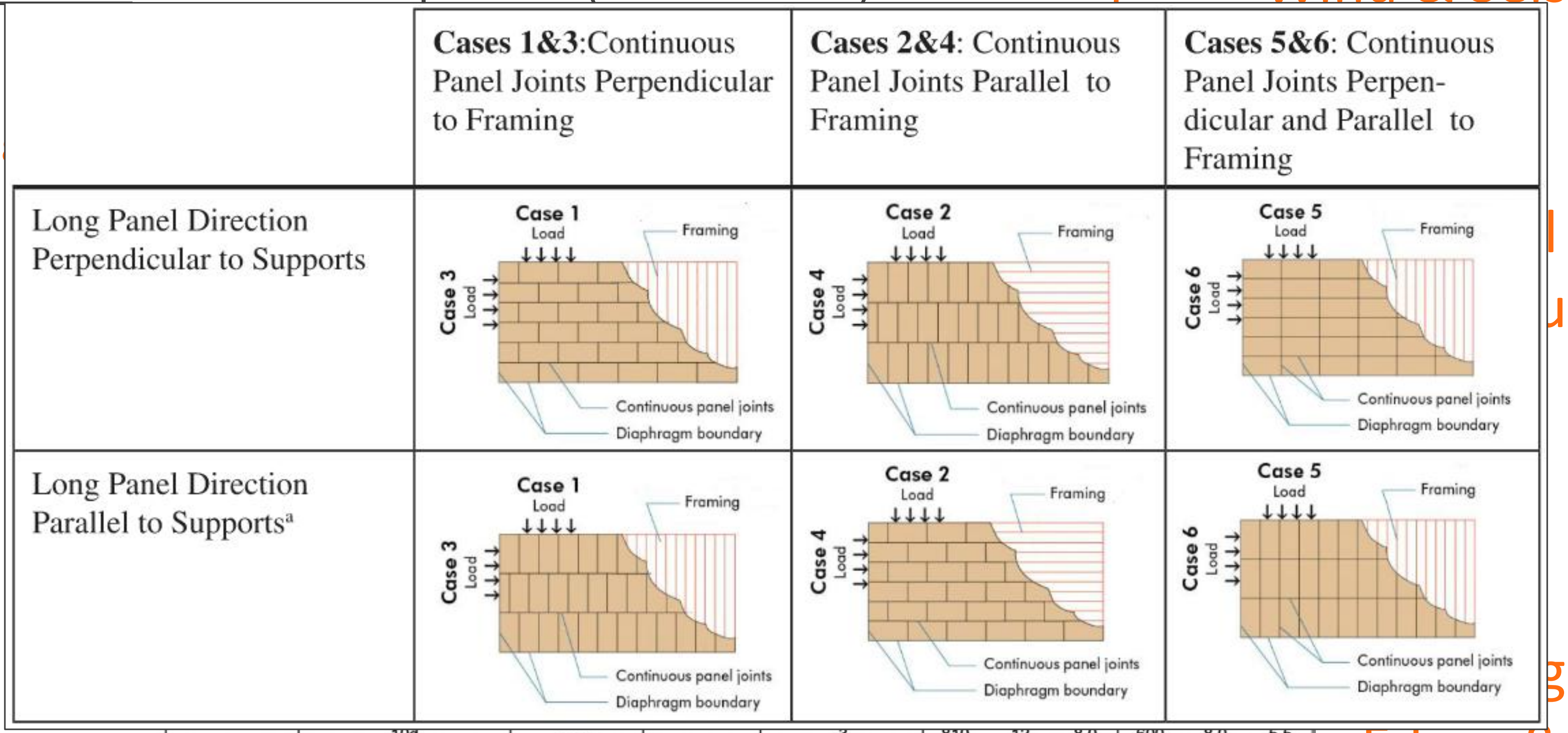
2021 SDPWS

Wood Design: Diaphragms

Nominal Unit Shear Capacities (2021 SDPWS):

Single Table for Wind & Seismic

Sheathin



	Cases 1&3:Continuous Panel Joints Perpendicular to Framing	**Cases 2&4**: Continuous Panel Joints Parallel to Framing	**Cases 5&6**: Continuous Panel Joints Perpendicular and Parallel to Framing
Long Panel Direction Perpendicular to Supports	Case 1 Load Framing Case 3 Load Continuous panel joints Diaphragm boundary	Case 2 Load Framing Case 4 Load Continuous panel joints Diaphragm boundary	Case 5 Load Framing Case 6 Load Continuous panel joints Diaphragm boundary
Long Panel Direction Parallel to Supports[a]	Case 1 Load Framing Case 3 Load Continuous panel joints Diaphragm boundary	Case 2 Load Framing Case 4 Load Continuous panel joints Diaphragm boundary	Case 5 Load Framing Case 6 Load Continuous panel joints Diaphragm boundary

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	10d (3 x 0.148 x 0.312)	1-1/2		3	810	12	8.0	600	8.0	5.5
			19/32	2	800	13	8.5	600	8.5	5.5
				3	895	10	7.5	670	7.0	5.0

2021 SDPWS

g at

Edges &

Boundaries

Fasteners

Wood Design: Diaphragms

Read the footnotes!

- Adjusted capacities:
  - 2015 SDPWS:
    - ASD: $v_{ASD} = v_{nom}/2.0$
    - LRFD: $v_{LRFD} = v_{nom} * 0.80$
  - 2021 SDPWS:
    - ASD, seismic: $v_{ASD} = v_{nom}/2.8$
    - ASD, wind: $v_{ASD} = v_{nom}/2.0$
    - LRFD, seismic: $v_{LRFD} = v_{nom} * 0.50$
    - LRFD, wind: $v_{LRFD} = v_{nom} * 0.80$

- Reduce capacities if not Douglas-Fir-Larch or Southern Pine

Wood Design: Diaphragms

- Aspect ratio requirements:

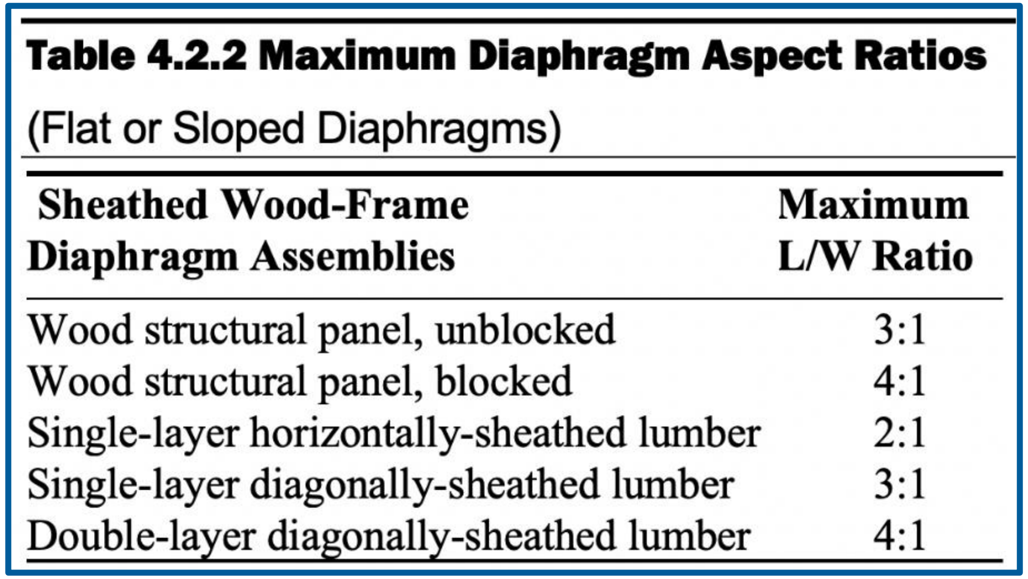
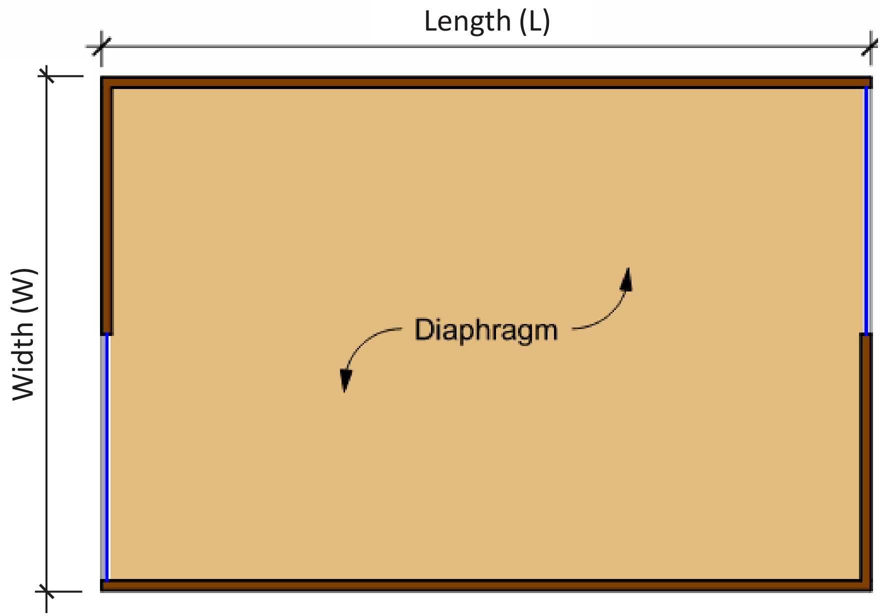


Table 4.2.2 Maximum Diaphragm Aspect Ratios

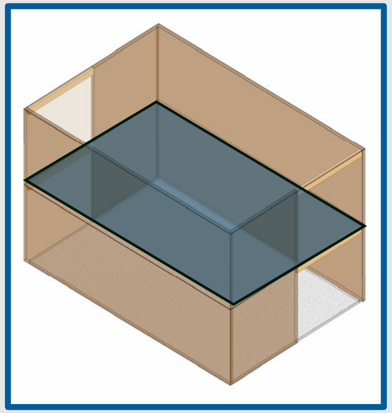
(Flat or Sloped Diaphragms)

Sheathed Wood-Frame Diaphragm Assemblies	Maximum L/W Ratio
Wood structural panel, unblocked	3:1
Wood structural panel, blocked	4:1
Single-layer horizontally-sheathed lumber	2:1
Single-layer diagonally-sheathed lumber	3:1
Double-layer diagonally-sheathed lumber	4:1

2021 SDPWS

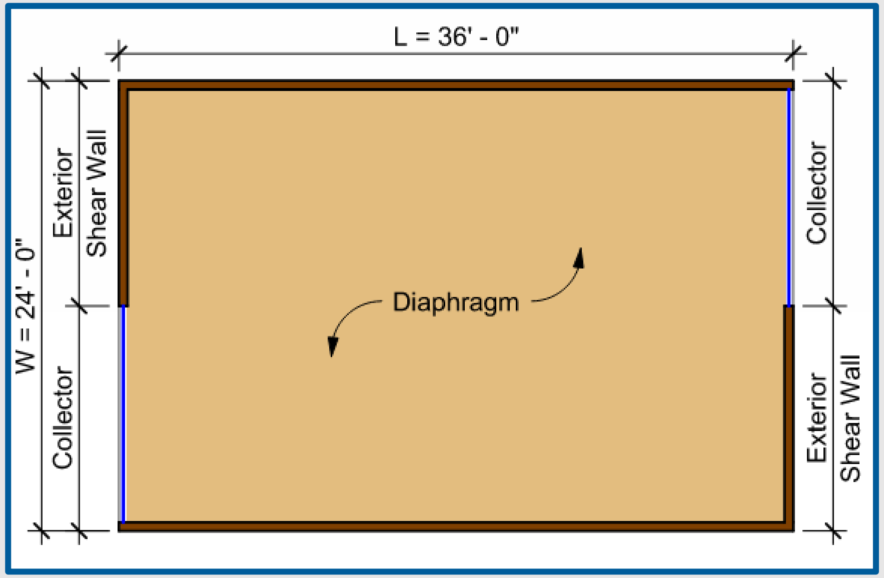


Design Example: Diaphragms



Diaphragm aspect ratio check (Level 2):

- L = 36 ft
- W = 24 ft
- Unblocked wood structural panels
  - $L/W = 36ft/24ft = 1.5 \rightarrow$ Aspect ratio OK



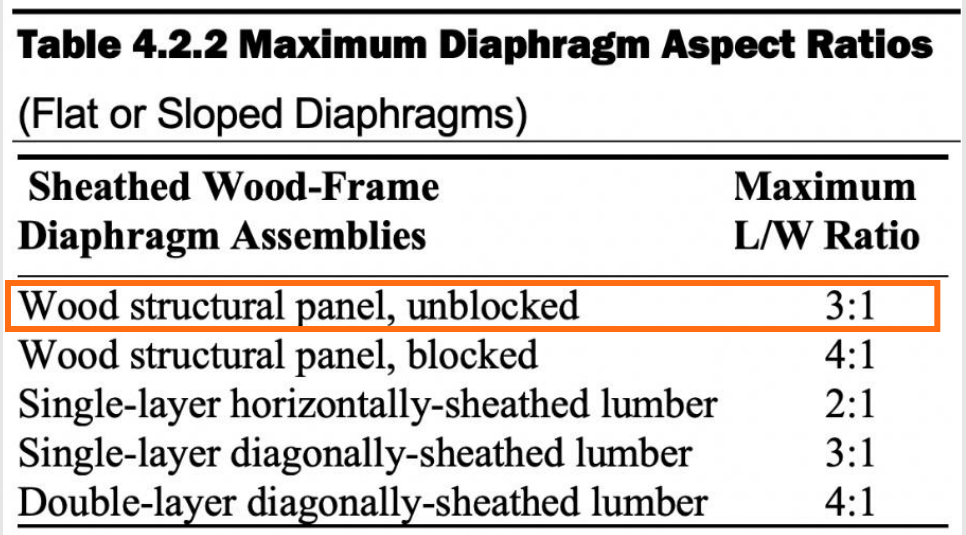


Table 4.2.2 Maximum Diaphragm Aspect Ratios

(Flat or Sloped Diaphragms)

Sheathed Wood-Frame Diaphragm Assemblies	Maximum L/W Ratio
Wood structural panel, unblocked	3:1
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Single-layer horizontally-sheathed lumber	2:1
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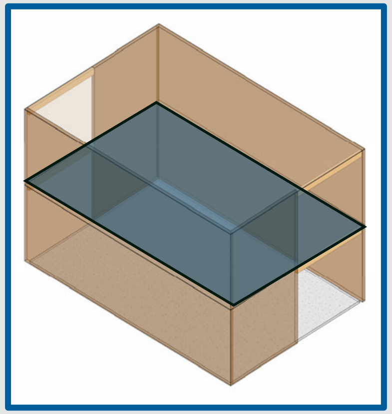
Double-layer diagonally-sheathed lumber	4:1

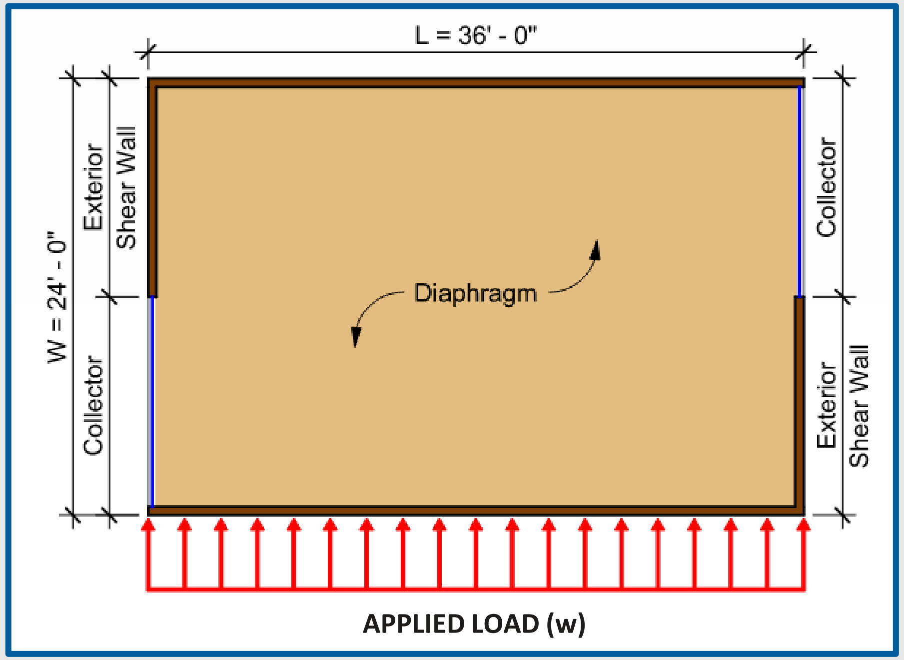
2021 SDPWS

Design Example: Diaphragms

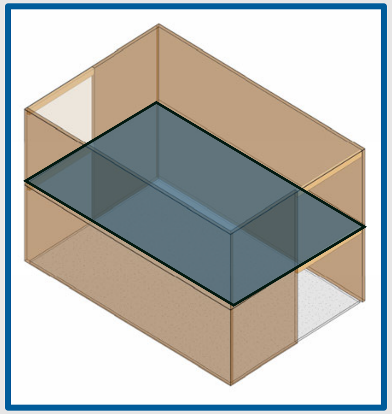


Diaphragm loads (Level 2):

- Assume flexible diaphragm (ASCE 7-16, Section 12.3.1.1, Item c)
- Wind:
  - Roof load: 125 plf
  - Level 2 load: 250 plf
- Seismic:
  - Roof load: 111 plf
  - Level 2 load: 139 plf

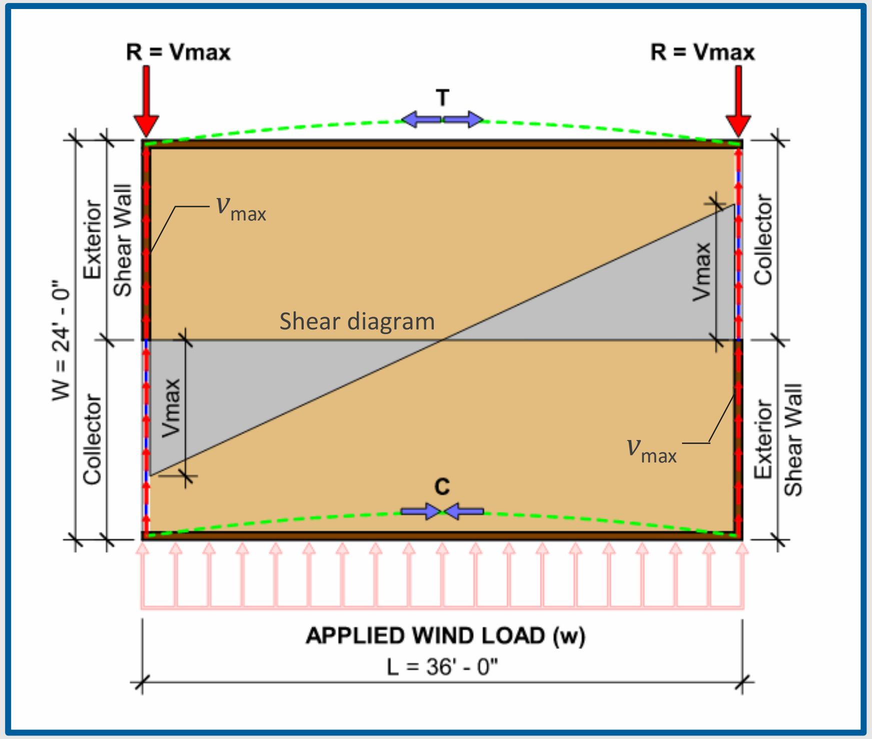


Design Example: Diaphragms

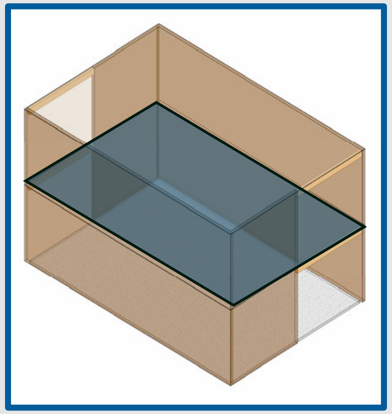


Diaphragm wind loads (Level 2):

- Wind: $w_{wind} = 250plf$
  - $R_w = V_{w,max} = \frac{w_{wind}*L}{2} = \frac{250plf*36ft}{2} = 4{,}500lb$
  - $v_{w,max} = \frac{V_{w,max}}{W} = \frac{4{,}500lb}{24ft} = 188plf$
  - $M_{w,max} = \frac{w_{wind}*L^2}{8} = \frac{250plf*(36ft)^2}{8} = 40{,}500ft\text{-}lb$
  - $T_{w,chord} = C_{w,chord} = \frac{M_{w,max}}{W}$
    $= \frac{40{,}500ft-lb}{24ft} = 1{,}688lb$



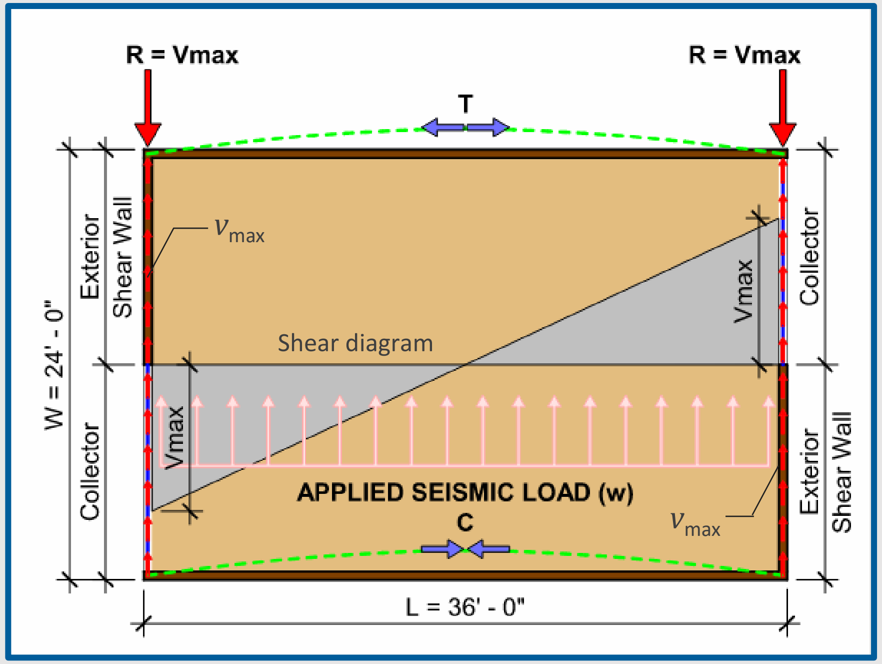
Design Example: Diaphragms



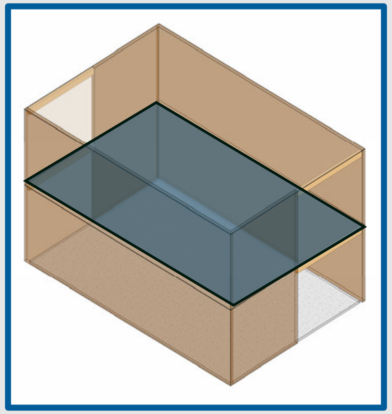
Diaphragm seismic loads (Level 2):

- Seismic: $w_{EQ} = 139plf$
  - $R_{EQ} = V_{EQ,max} = \frac{w_{EQ}*L}{2} = \frac{139plf*36ft}{2} = 2{,}502lb$
  - $v_{EQ,max} = \frac{V_{EQ,max}}{W} = \frac{2{,}502lb}{24ft} = 104plf$
  - $M_{EQ,max} = \frac{w_{EQ}*L^2}{8} = \frac{139plf*(36ft)^2}{8} = 22{,}518ft-lb$
  - $T_{EQ,chord} = C_{EQ,chord} = \frac{M_{EQ,max}}{W}$

    $= \frac{22{,}518ft-lb}{24ft} = 938lb$



Design Example: Diaphragms



Diaphragm shear check (Level 2):

- Diaphragm type: Unblocked WSP’s (Table 4.2C)
- Sheathing type: 3/8” Structural I OSB
- Fastener type & spacing at boundaries & panel edges: 8d @ 6” o.c.
- Framing width at edges & boundaries: 2x

- Nominal capacity: $v_{nom} = 505plf$

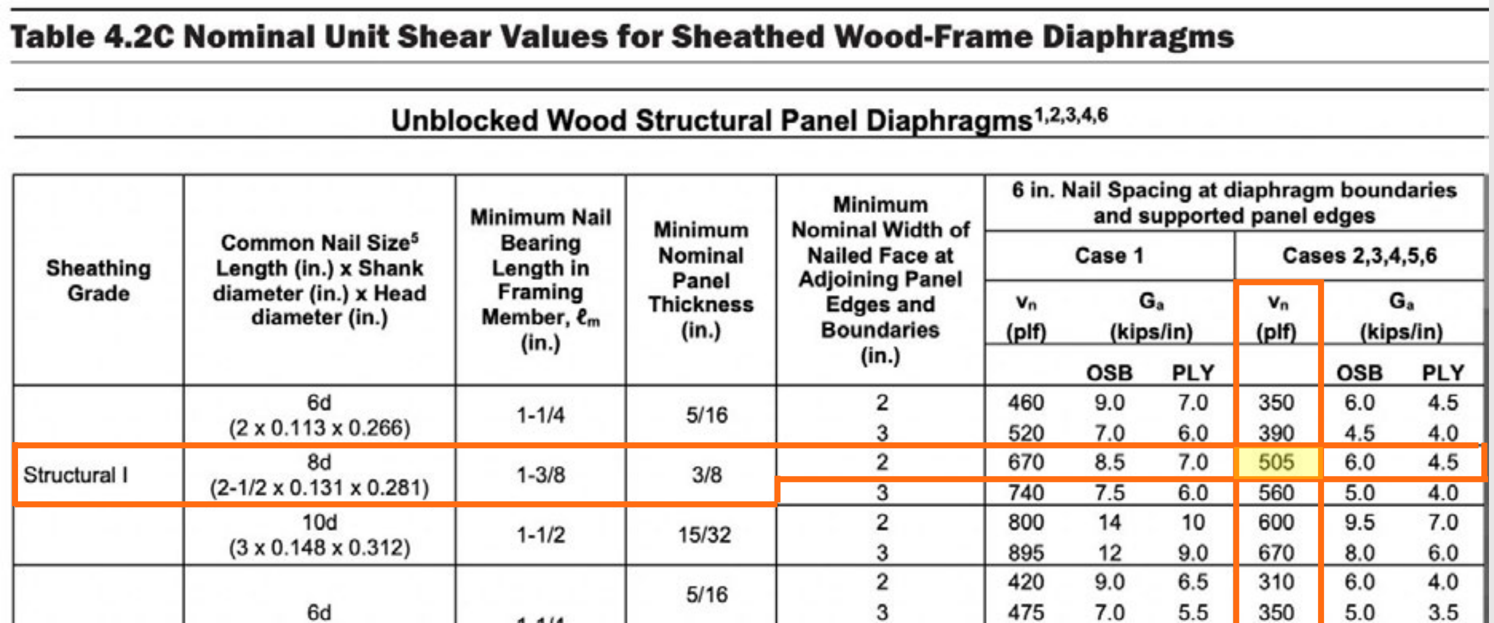


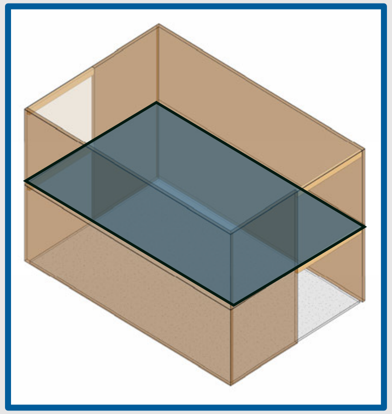
Table 4.2C Nominal Unit Shear Values for Sheathed Wood-Frame Diaphragms

Unblocked Wood Structural Panel Diaphragms[1,2,3,4,6]

Sheathing Grade	Common Nail Size[5] Length (in.) x Shank diameter (in.) x Head diameter (in.)	Minimum Nail Bearing Length in Framing Member, ℓ_m (in.)	Minimum Nominal Panel Thickness (in.)	Minimum Nominal Width of Nailed Face at Adjoining Panel Edges and Boundaries (in.)	6 in. Nail Spacing at diaphragm boundaries and supported panel edges					
					Case 1			Cases 2,3,4,5,6		
					v_n (plf)	G_a (kips/in)		v_n (plf)	G_a (kips/in)	
						OSB	PLY		OSB	PLY
	6d (2 x 0.113 x 0.266)	1-1/4	5/16	2	460	9.0	7.0	350	6.0	4.5
				3	520	7.0	6.0	390	4.5	4.0
Structural I	8d (2-1/2 x 0.131 x 0.281)	1-3/8	3/8	2	670	8.5	7.0	505	6.0	4.5
				3	740	7.5	6.0	560	5.0	4.0
	10d (3 x 0.148 x 0.312)	1-1/2	15/32	2	800	14	10	600	9.5	7.0
				3	895	12	9.0	670	8.0	6.0
	6d		5/16	2	420	9.0	6.5	310	6.0	4.0
				3	475	7.0	5.5	350	5.0	3.5

2021 SDPWS

Design Example: Diaphragms



Diaphragm shear check (Level 2):

- Allowable (adjusted) diaphragm shear capacity:
  - Nominal shear capacity from Table 4.2C: $v_{nom} = 505plf$
  - Adjusted wind shear capacity (ASD): $v_{w,cap} = v_{nom}/2.0 = 253plf$
  - Adjusted seismic shear capacity (ASD): $v_{EQ,cap} = v_{nom}/2.8 = 180plf$

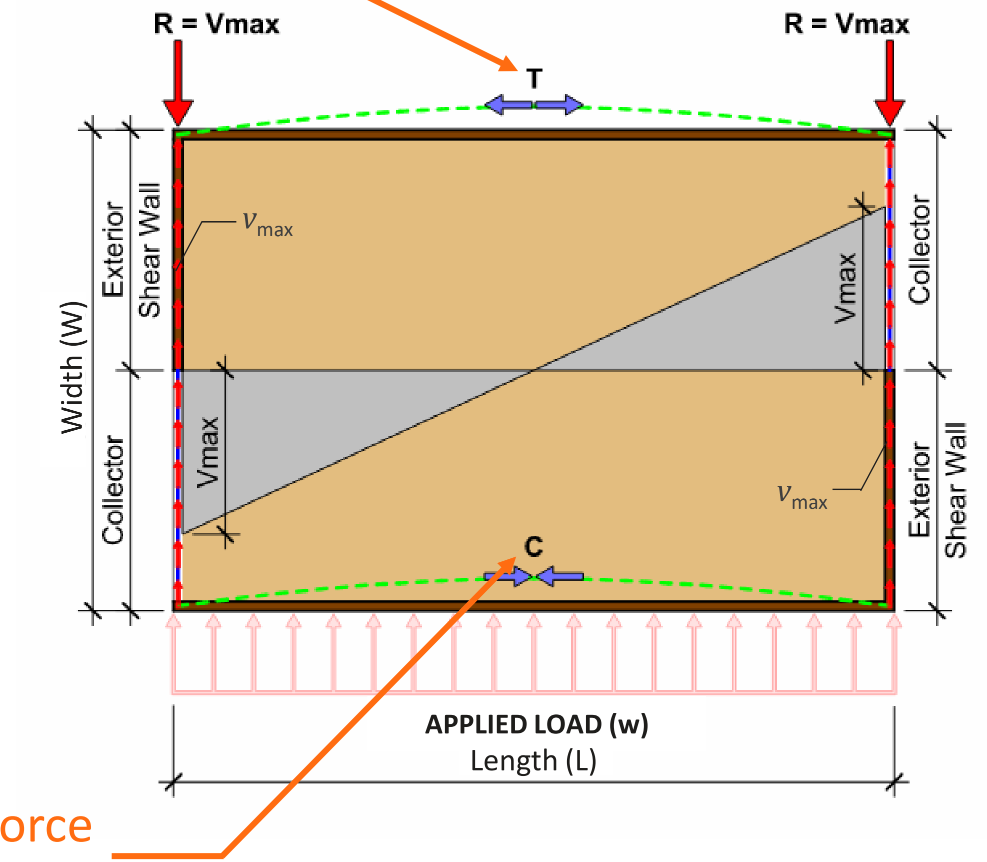
- Shear forces:
  - Wind: $v_{w,max} = 188plf < v_{w,cap} = 253plf$ → OK for wind
  - Seismic: $v_{EQ,max} = 104plf < v_{EQ,cap} = 180plf$ → OK for seismic

Wood Design: Diaphragms

Diaphragm chords:

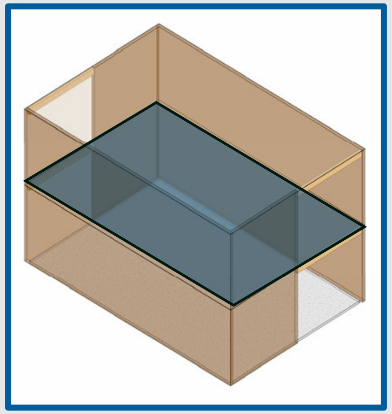
- Chord forces:
  - $T_{chord} = C_{chord} = \frac{M}{W}$
- Chord stresses:
  - Tension: $f_t \leq F'_t$
    - $f_t = \frac{T_{chord}}{A_{chord}}$
  - Compression : $f_c \leq F'_c$
    - $f_c = \frac{C_{chord}}{A_{chord}}$

Chord force (Tension)



Chord force (Compression)

Design Example: Diaphragms



Chord check (Level 2):

- Wall top plates: (2) 2x6 Douglas-Fir-Larch #2
  - Assume (1) 2x6 effective chord: $A_{chord} = 8.25in^2$
- Chord forces & stresses:
  - Wind: $T_{w,chord} = C_{w,chord}$

    $= 1{,}688lb$

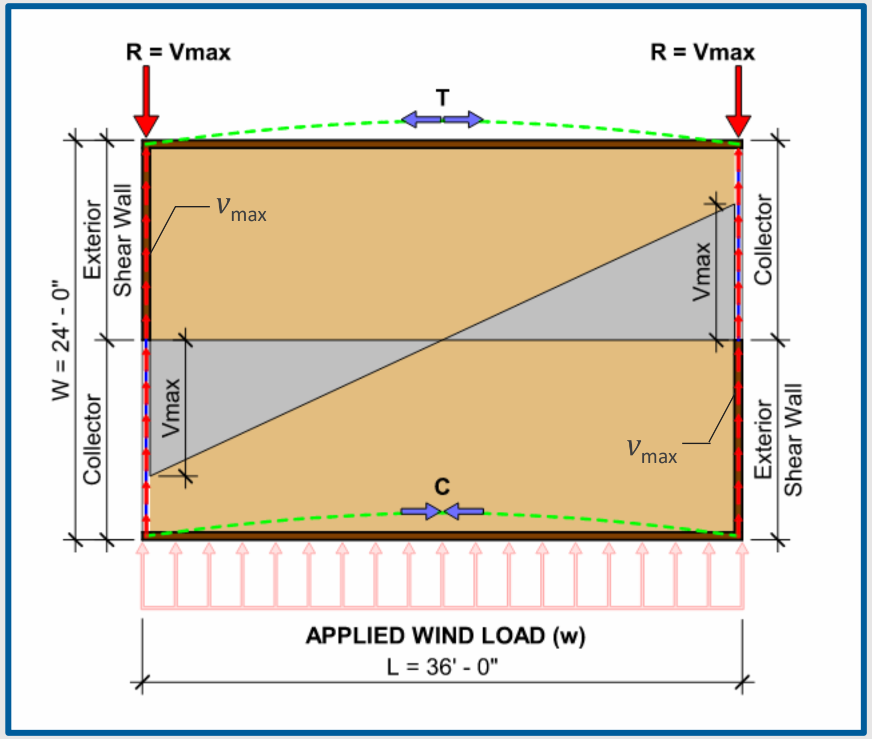
    $\rightarrow t_{w,chord} = c_{w,chord}$

    $= 1{,}688lb/8.25in^2 = \boxed{205psi}$
  - Seismic: $T_{EQ,chord} = C_{EQ,chord}$

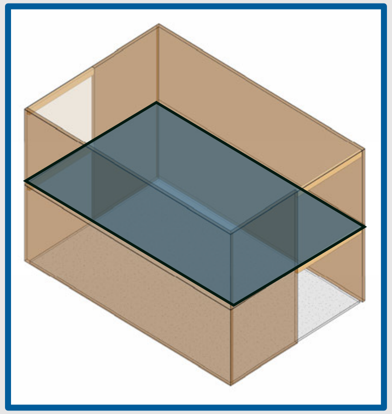
    $= 938lb$

    $\rightarrow t_{EQ,chord} = c_{EQ,chord}$

    $= 938lb/8.25in^2 = 114psi$



Design Example: Diaphragms



Chord check (Level 2):

- Chord stress: $t_{chord} = c_{chord} = 205psi$

- Chord capacity:
  - Compression: $F_c = 1{,}350psi$ (2018 NDS Supp. Table 4A)
    - Load duration factor C_D = 1.6
    - Assume other adjustment factors = 1.0
    - $F_c' = 1.6 * 1{,}350psi = 2{,}160psi > c_{chord} \ = 205psi$ → Compression OK
  - Tension: $F_t = 575psi$ (2018 NDS Supplement Table 4A)
    - Load duration factor C_D = 1.6
    - Assume other adjustment factors = 1.0
    - $F_t' = 1.6 * 575psi = 920psi > t_{chord} \ = 205psi$ → Tension OK

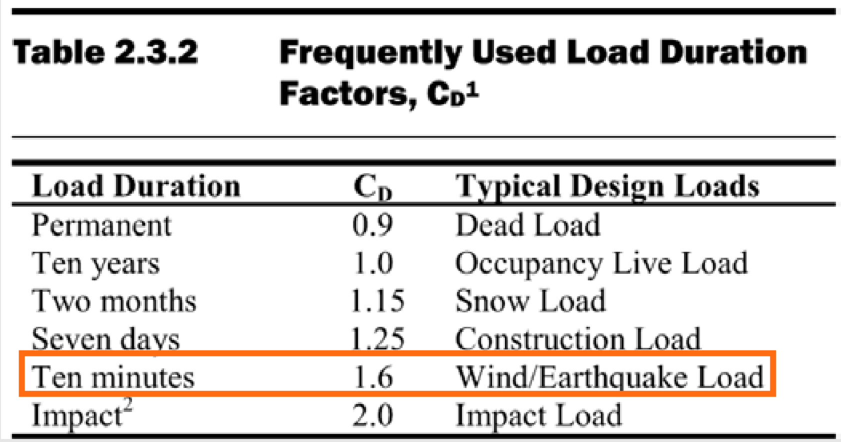


Table 2.3.2 Frequently Used Load Duration Factors, C_D[1]

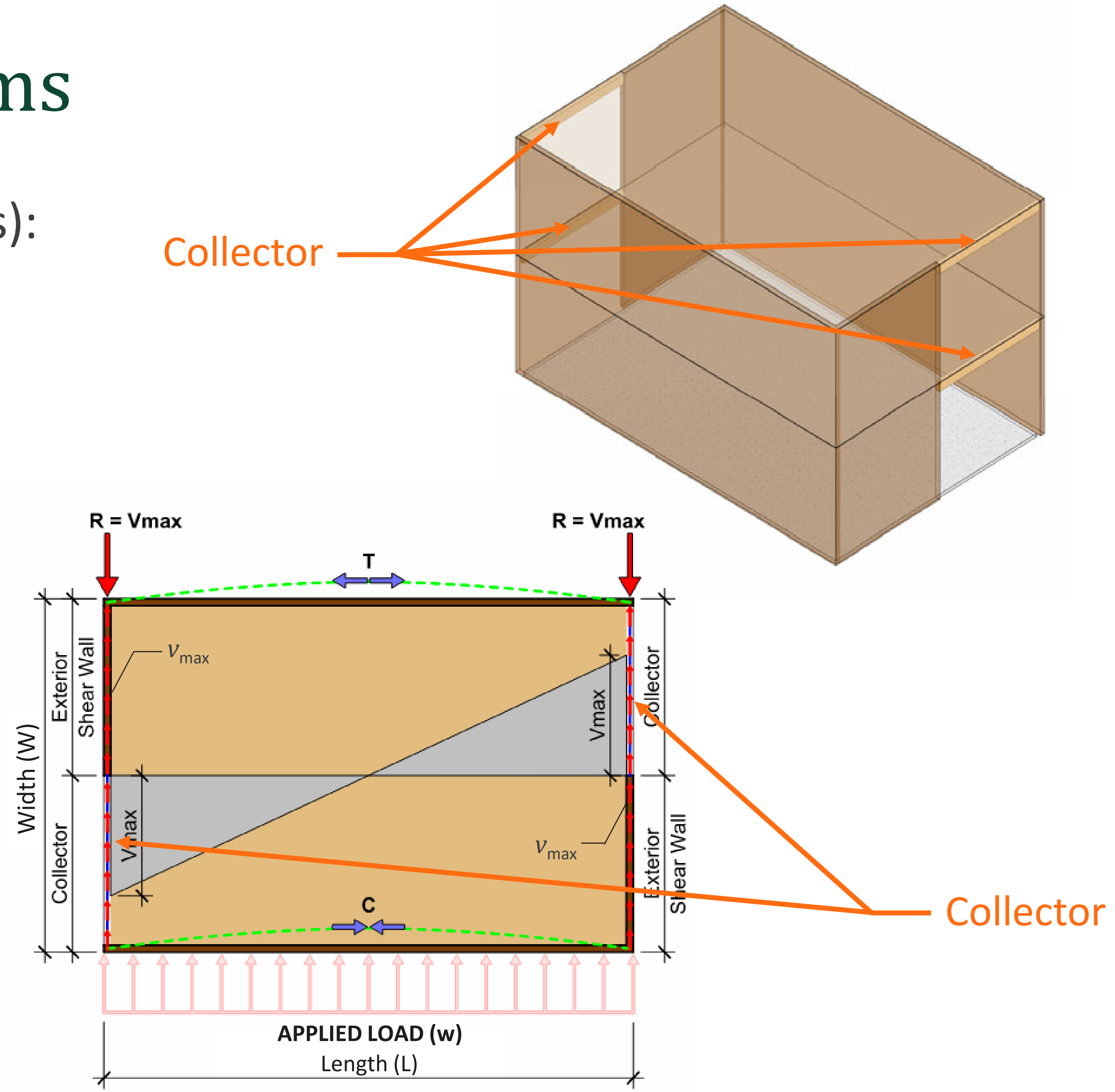
Load Duration	C_D	Typical Design Loads
Permanent	0.9	Dead Load
Ten years	1.0	Occupancy Live Load
Two months	1.15	Snow Load
Seven days	1.25	Construction Load
Ten minutes	1.6	Wind/Earthquake Load
Impact[2]	2.0	Impact Load

2018 NDS

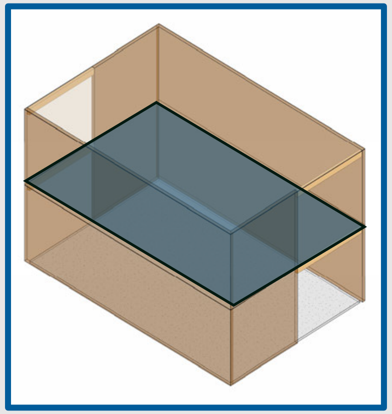
Wood Design: Diaphragms

Diaphragm collectors (drag struts):

- Collector forces:
  - $T_{collect} = C_{collect} = v * l_{collect}$
- Collector stresses:
  - Tension: $f_t \leq F'_t$
    - $f_t = \frac{T_{collect}}{A_{collect}}$
  - Compression : $f_c \leq F'_c$
    - $f_c = \frac{C_{collect}}{A_{collect}}$



Design Example: Diaphragms



Collector check (Level 2):

- Wall top plates: (2) 2x6 Douglas-Fir-Larch #2
  - Assume (1) 2x6 effective chord: $A_{chord} = 8.25in^2$
- Collector forces & stresses:
  - Wind: $T_{w,collect} = C_{w,collect}$

    $= 188plf * 12ft = 2{,}260lb$

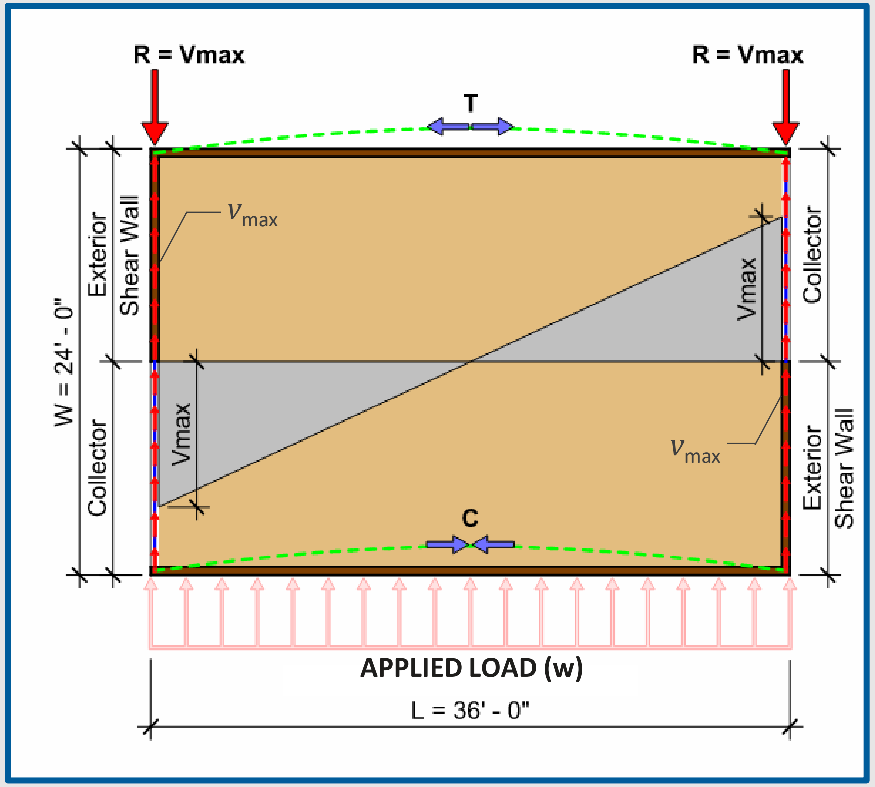
    $\rightarrow t_{w,collect} = c_{w,collect}$

    $= 2{,}260lb/8.25in^2 = \boxed{274psi}$
  - Seismic: $T_{EQ,collect} = C_{EQ,collect}$

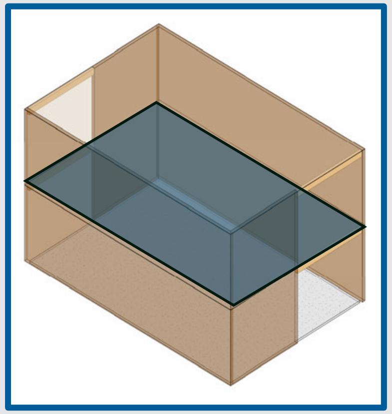
    $= 104plf * 12ft = 1{,}248lb$

    $\rightarrow t_{EQ,collect} = c_{EQ,collect}$

    $= 1{,}248lb/8.25in^2 = 151psi$



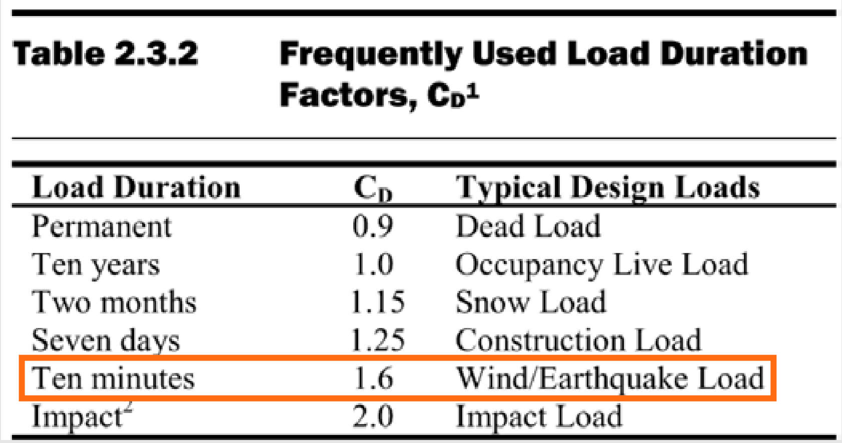
Design Example: Diaphragms



Collector check (Level 2):

- Collector stress: $t_{collect} = c_{collect} = 274psi$

- Collector capacity:
  - Compression: $F_c = 1{,}350psi$ (2018 NDS Supp. Table 4A)
    - Load duration factor C_D = 1.6
    - Assume other adjustment factors = 1.0
    - $F_c' = 1.6 * 1{,}350psi = 2{,}160psi > c_{collect}$ → Compression OK
  - Tension: $F_t = 575psi$ (2018 NDS Supplement Table 4A)
    - Load duration factor C_D = 1.6
    - Assume other adjust. factors = 1.0
    - $F_t' = 1.6 * 575psi = 920psi > t_{collect}$ → Tension OK



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Seven days	1.25	Construction Load
Ten minutes	1.6	Wind/Earthquake Load
Impact[2]	2.0	Impact Load

2018 NDS

Wood Design: Diaphragms

- Deflection (2021 SDPWS Equation 4.2-1):
  - $\delta_{dia} = \underbrace{\frac{5*v*L^3}{8*E*A*W}}_{\text{chord deformation}} + \underbrace{\frac{0.25*v*L}{1{,}000*G_a}}_{\text{panel shear + nail slip}} + \underbrace{\frac{\sum x*\Delta_c}{2*W}}_{\text{chord splice slip}}$
    - $v =$ unit shear force
    - $E =$ modulus of elasticity of chords
    - $A =$ cross sectional area of chord
    - $G_a =$ apparent shear stiffness
    - $L =$ diaphragm length
    - $W =$ diaphragm width
    - $x =$ distance from chord splice to support
    - $\Delta_c =$ chord splice slip (calculate per 2021 SDPWS Commentary)

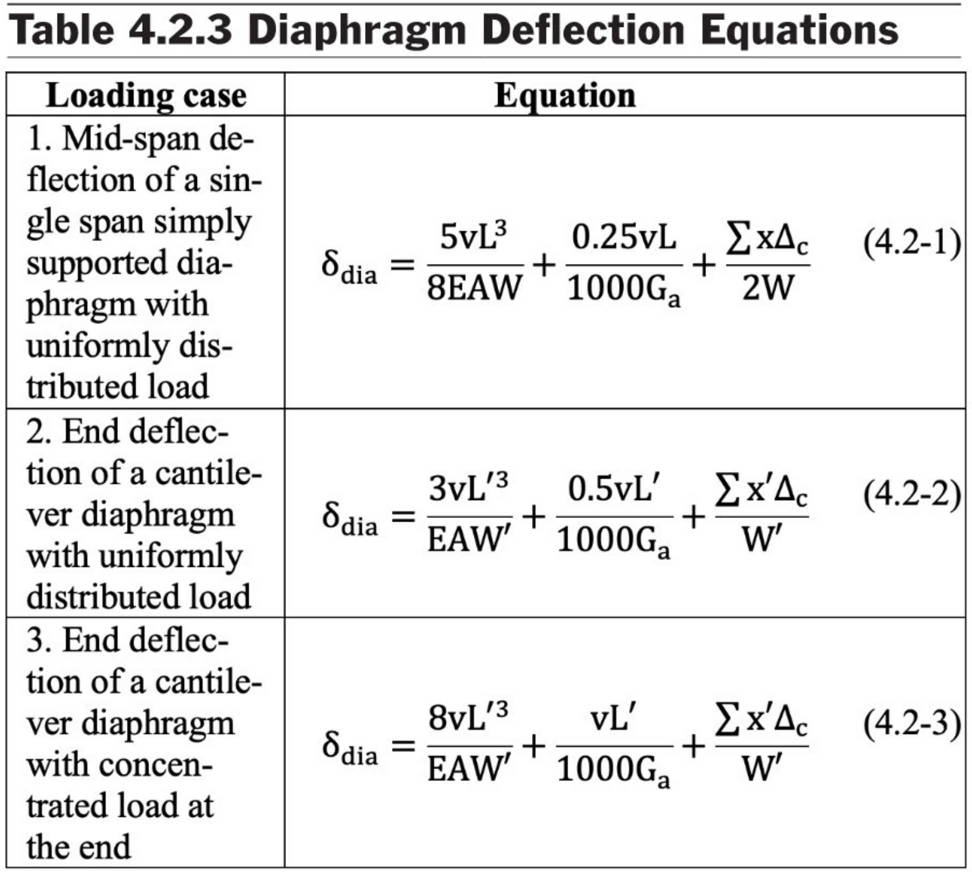
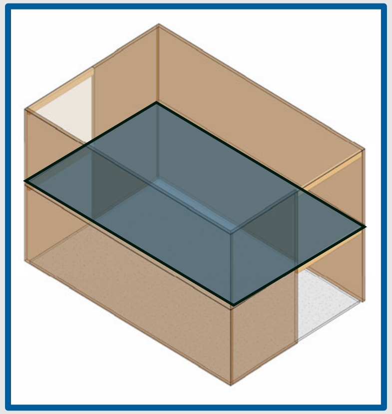


Table 4.2.3 Diaphragm Deflection Equations

Loading case	Equation	
1. Mid-span deflection of a single span simply supported diaphragm with uniformly distributed load	$\delta_{dia} = \frac{5vL^3}{8EAW} + \frac{0.25vL}{1000G_a} + \frac{\sum x\Delta_c}{2W}$	(4.2-1)
2. End deflection of a cantilever diaphragm with uniformly distributed load	$\delta_{dia} = \frac{3vL'^3}{EAW'} + \frac{0.5vL'}{1000G_a} + \frac{\sum x'\Delta_c}{W'}$	(4.2-2)
3. End deflection of a cantilever diaphragm with concentrated load at the end	$\delta_{dia} = \frac{8vL'^3}{EAW'} + \frac{vL'}{1000G_a} + \frac{\sum x'\Delta_c}{W'}$	(4.2-3)

2021 SDPWS

Design Example: Diaphragms



- Deflection check (Level 2): $\delta_{dia} = \frac{5*v*L^3}{8*E*A*W} + \frac{0.25*v*L}{1{,}000*G_a} + \frac{\sum x*\Delta_c}{2*W}$
  - $v_w = 188plf$
  - $L = 36ft$
  - $W = 24ft$
  - $A_{chord} = 8.25in^2$
  - $x_{chord} = 12ft$
  - $E_{chord} = 1{,}600{,}000psi$ (2018 NDS Supplement Table 4A)
  - $G_a = 6.0$ (2021 SDPWS Table 4.2C)
  - Calculated $\Delta_c = 0.05in$

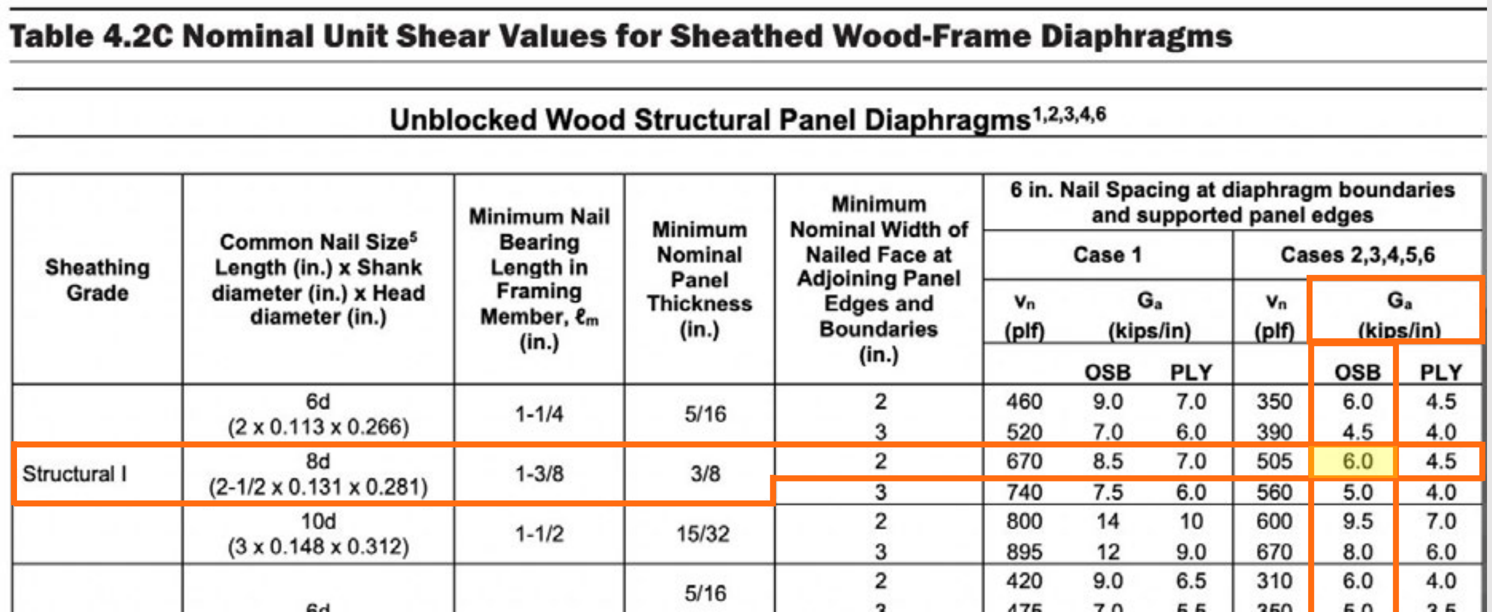


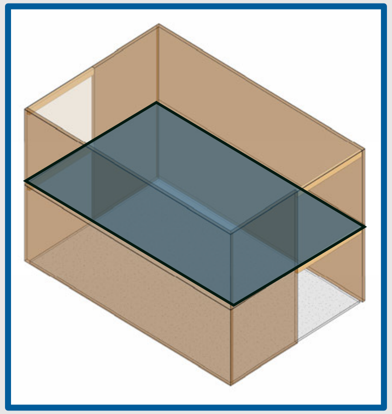
Table 4.2C Nominal Unit Shear Values for Sheathed Wood-Frame Diaphragms

Unblocked Wood Structural Panel Diaphragms[1,2,3,4,6]

Sheathing Grade	Common Nail Size[5] Length (in.) x Shank diameter (in.) x Head diameter (in.)	Minimum Nail Bearing Length in Framing Member, ℓ_m (in.)	Minimum Nominal Panel Thickness (in.)	Minimum Nominal Width of Nailed Face at Adjoining Panel Edges and Boundaries (in.)	6 in. Nail Spacing at diaphragm boundaries and supported panel edges					
					Case 1			Cases 2,3,4,5,6		
					v_n (plf)	G_a (kips/in)		v_n (plf)	G_a (kips/in)	
						OSB	PLY		OSB	PLY
	6d (2 x 0.113 x 0.266)	1-1/4	5/16	2	460	9.0	7.0	350	6.0	4.5
				3	520	7.0	6.0	390	4.5	4.0
Structural I	8d (2-1/2 x 0.131 x 0.281)	1-3/8	3/8	2	670	8.5	7.0	505	6.0	4.5
				3	740	7.5	6.0	560	5.0	4.0
	10d (3 x 0.148 x 0.312)	1-1/2	15/32	2	800	14	10	600	9.5	7.0
				3	895	12	9.0	670	8.0	6.0
	6d		5/16	2	420	9.0	6.5	310	6.0	4.0
				3	475	7.0	5.5	350	5.0	3.5

2021 SDPWS

Design Example: Diaphragms

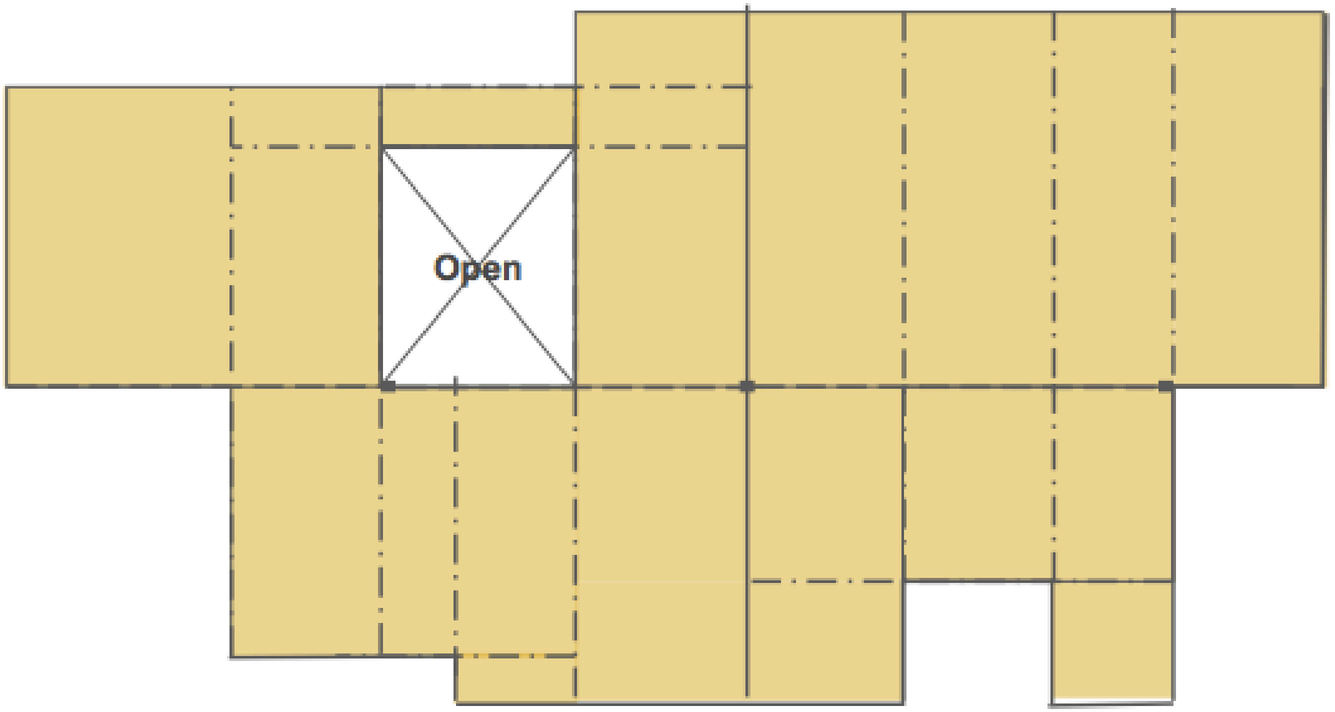


- Deflection check (Level 2): $\delta_{dia} = \frac{5*v*L^3}{8*E*A*W} + \frac{0.25*v*L}{1{,}000*G_a} + \frac{\sum x*\Delta_c}{2*W}$
  - Chord deformation: $\frac{5*v*L^3}{8*E*A*W} = \frac{5*188plf*(36ft)^3}{8*1{,}600{,}000psi*8.25in^2*24ft} = 0.017in$
  - Panel shear + nail slip: $\frac{0.25*v*L}{1{,}000*G_a} = \frac{0.25*188plf*36ft}{1{,}000*6.0kips/in} = 0.282in$
  - Chord splice slip: $\frac{\sum x*\Delta_c}{2*W} = \frac{2*(12ft*0.05in)}{2*24ft} = 0.025in$
- $\delta_{w,dia} = 0.017in + 0.282in + 0.025in = 0.324in$
- Deflection check for Seismic must be performed using strength level design loads (multiply ASD loads by 1.4)

Wood Design: Diaphragms

Additional considerations:

- Offsets, re-entrant corners, discontinuities, openings
- Open front/cantilever configurations
- Concentrated, localized loads
- Sub-diaphragm aspect ratios

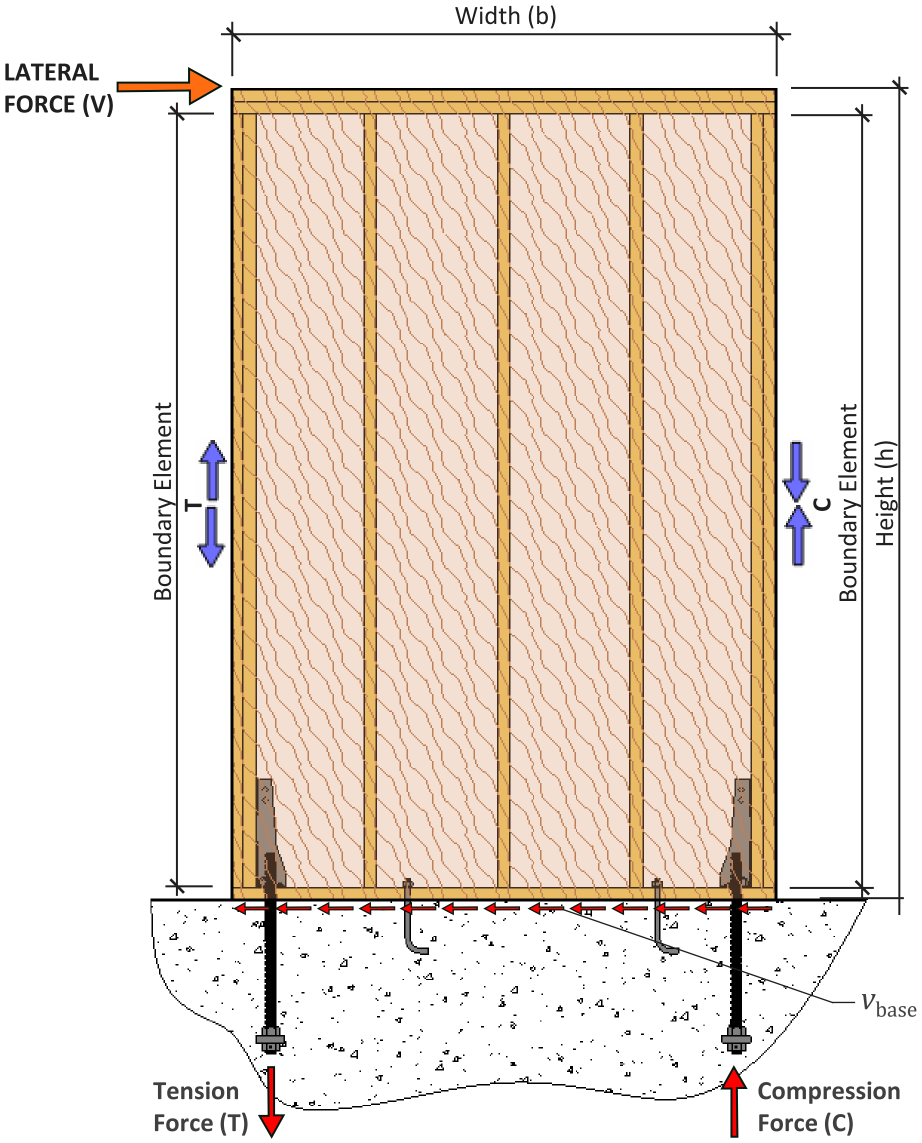


Outline

- Lateral Design Introduction
- Diaphragms
- **Shear Walls**
- Other Lateral Options

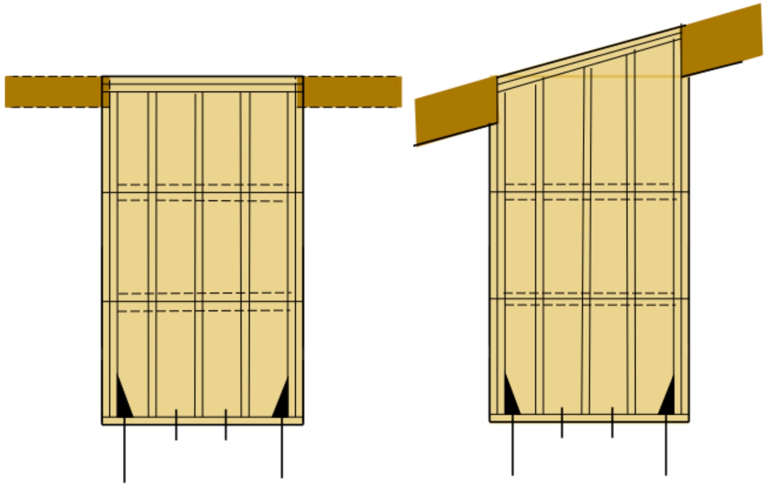
Wood Design: Shear Walls

- Shear Walls:
  - Specially detailed vertical components
  - Not all walls are shear walls

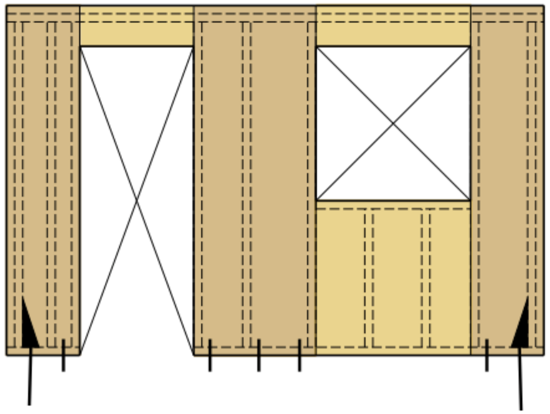


Wood Design: Shear Walls

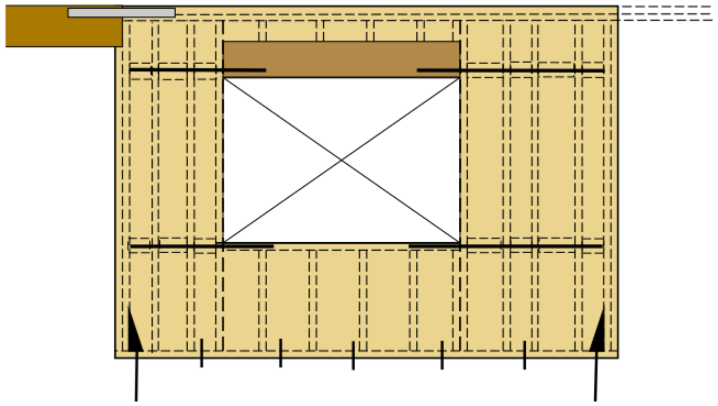
Shear wall types:



Solid or Segmented Walls

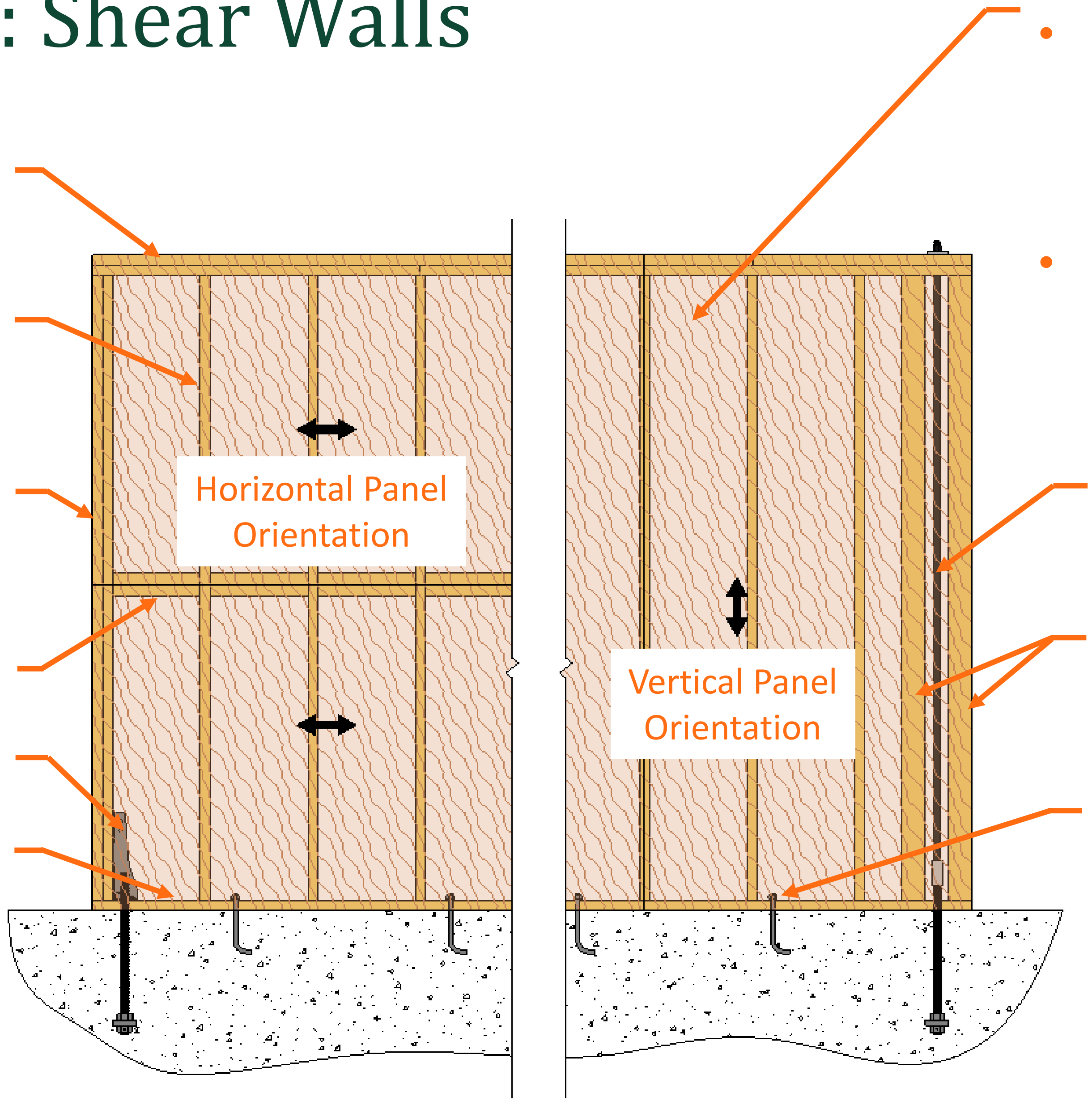


Perforated Walls



Force Transfer Around Openings Walls

Wood Design: Shear Walls



Top Plate

Typical Wall Stud Framing

Boundary Element (End Post)

Blocking

Hold Down

Bottom Plate

Sheathing:
- Wood Structural Panel (WSP)
  - Vertical Panels (can eliminate blocking)
  - Horizontal Panels
- Lumber

Hold Down Device (Continuous Tie-Down)

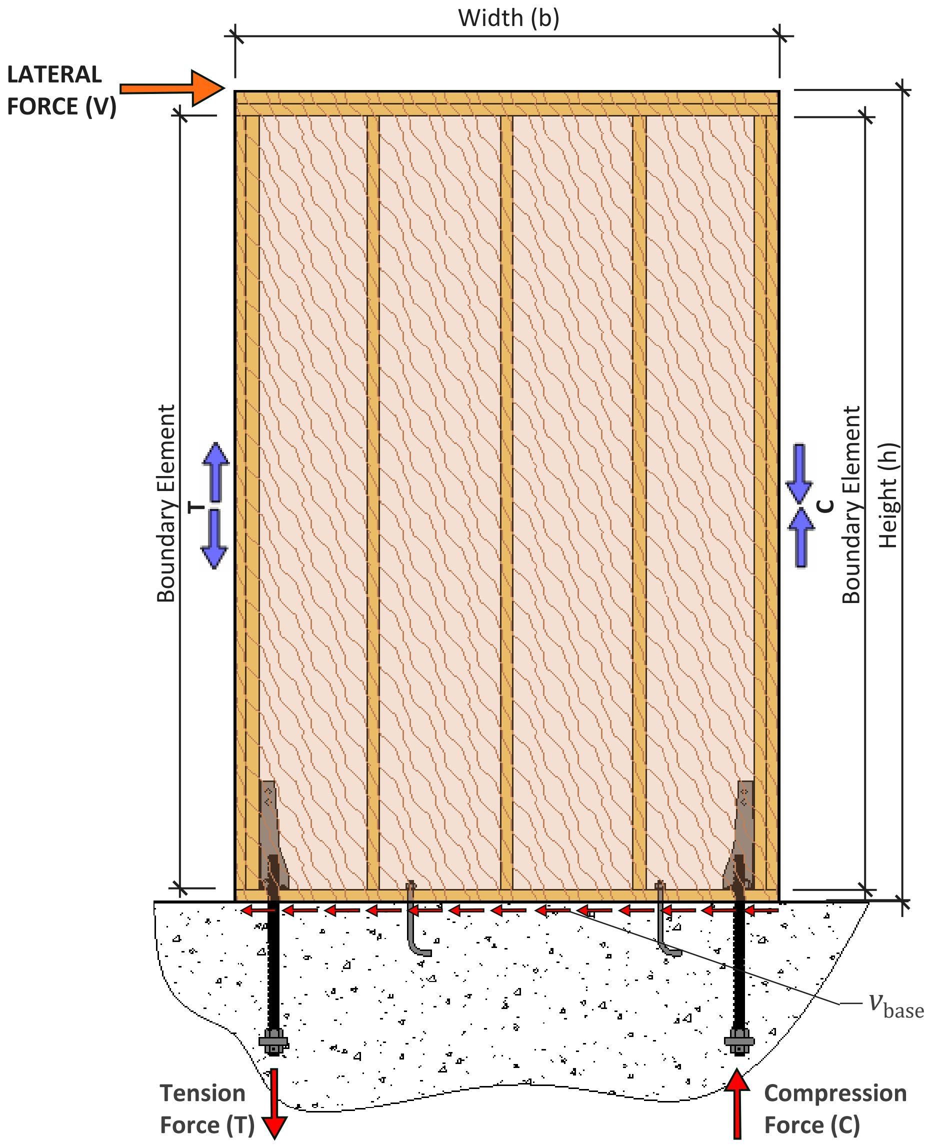
Boundary Element (Solid or Engineered)

Sill Anchors

Wood Design: Shear Walls

Shear wall design checks:

- Shear wall: Aspect ratio, shear, deflection
- Boundary elements: Tension, compression
- Anchorage: Hold downs, shear



Wood Design: Shear Walls

- Aspect ratio requirements
  - Aspect ratios > 3.5:1 not allowed
- Shear capacity reductions:
  - Wood structural panels > 2:1
  - Structural fiberboard panels > 1:1

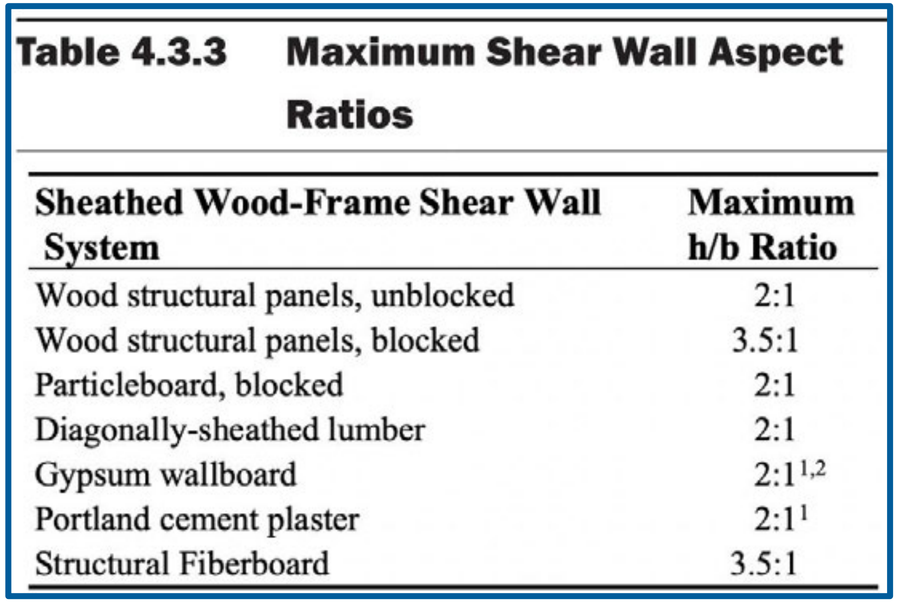
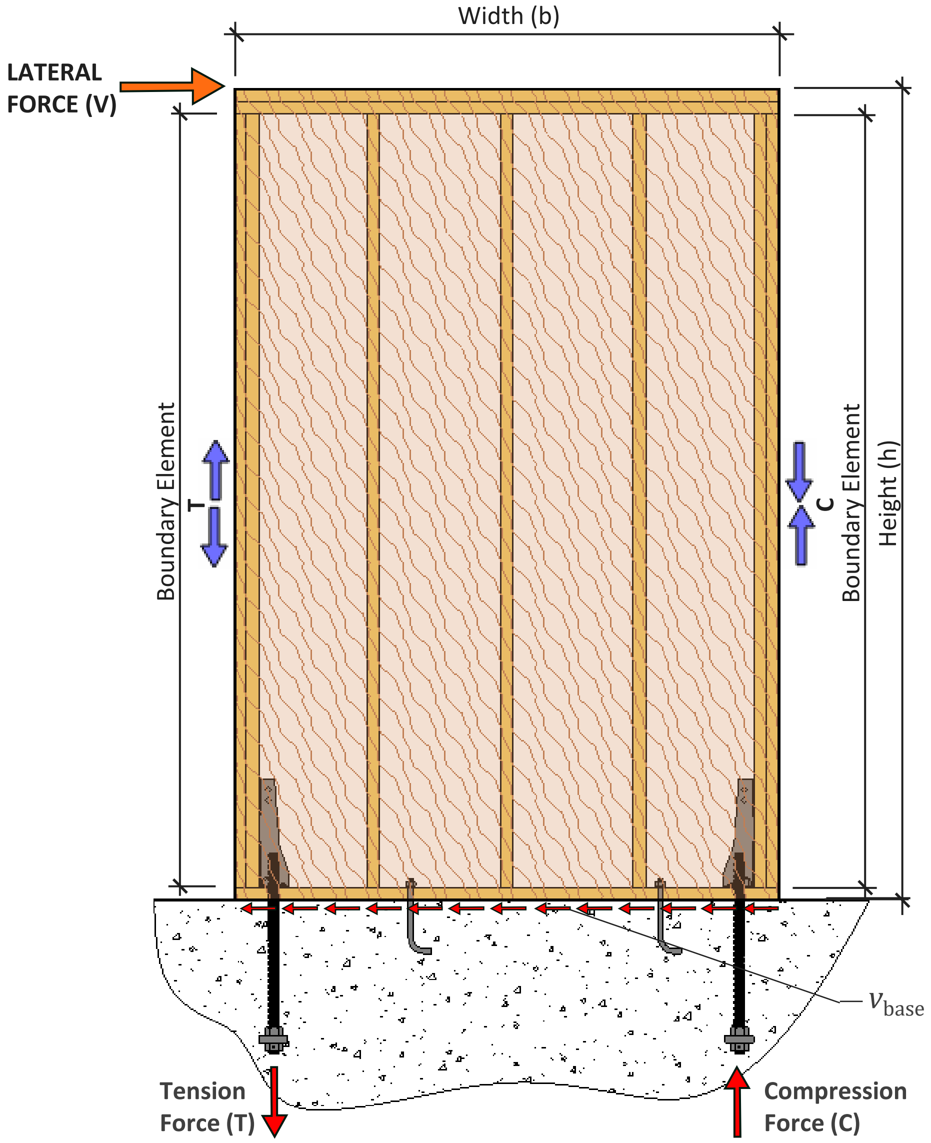


Table 4.3.3 Maximum Shear Wall Aspect Ratios

Sheathed Wood-Frame Shear Wall System	Maximum h/b Ratio
Wood structural panels, unblocked	2:1
Wood structural panels, blocked	3.5:1
Particleboard, blocked	2:1
Diagonally-sheathed lumber	2:1
Gypsum wallboard	2:1[1,2]
Portland cement plaster	2:1[1]
Structural Fiberboard	3.5:1

AWC SDPWS, 2021



Design Example: Shear Walls

Aspect ratio check

- h = 9 ft
- b = 12 ft
- Blocked wood structural panel
  - $h/b = 9ft/12ft = 0.75$

    → Aspect ratio OK

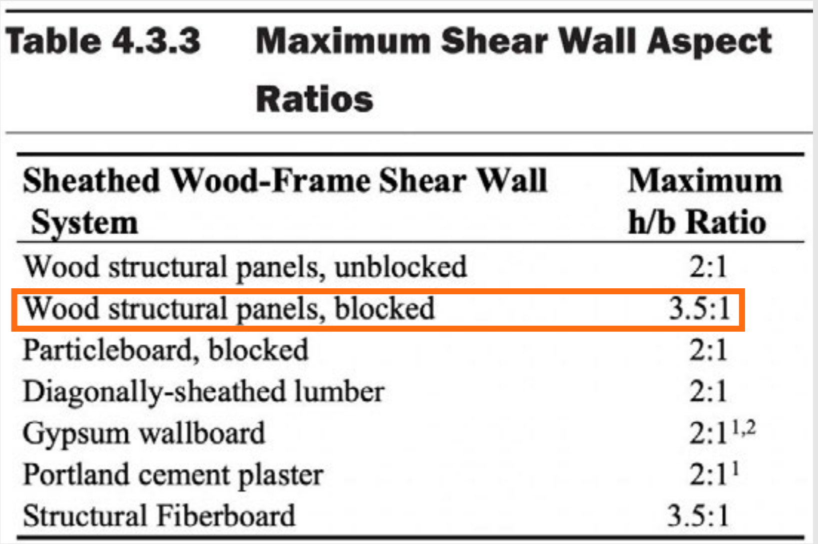
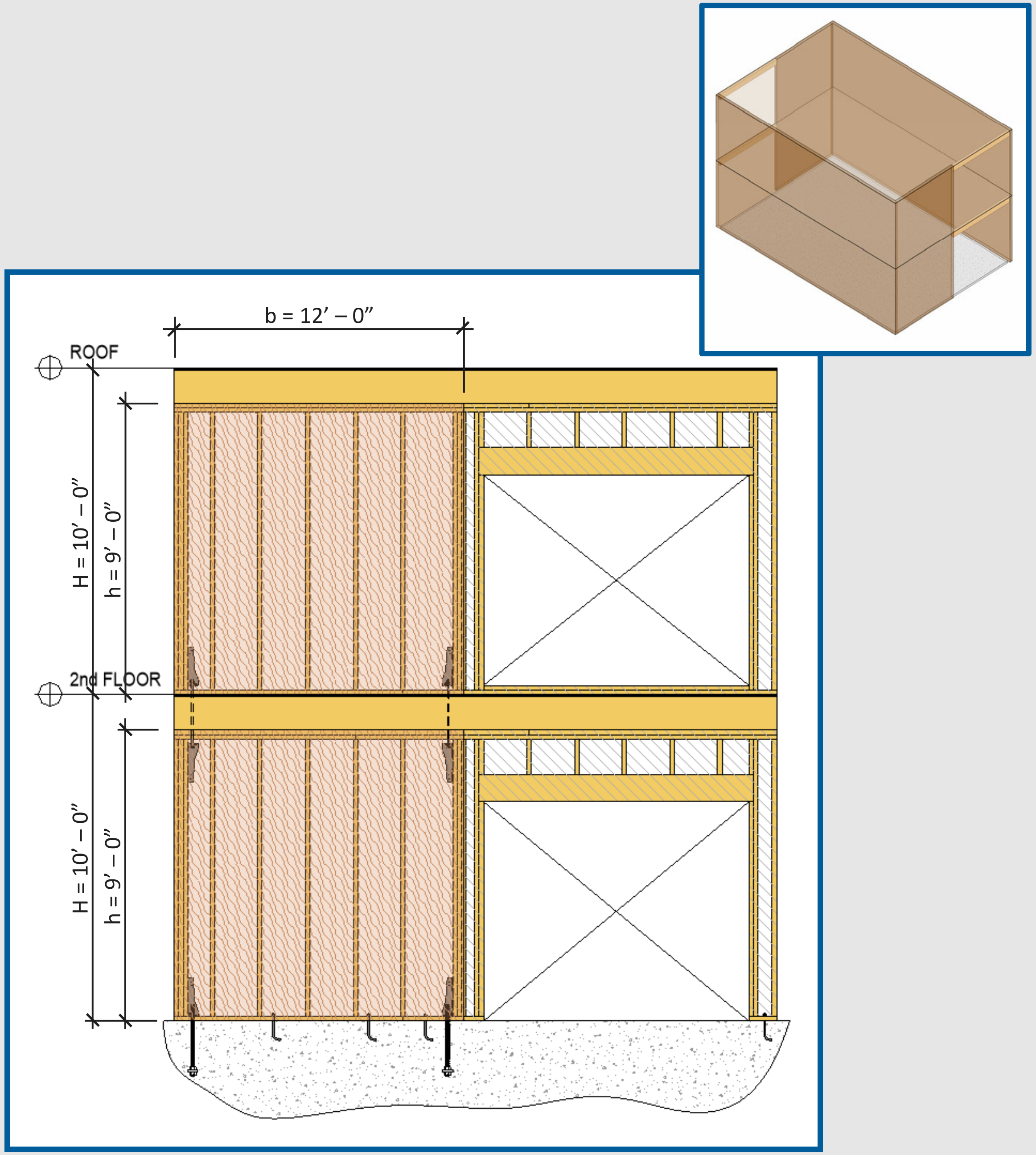


Table 4.3.3 Maximum Shear Wall Aspect Ratios

Sheathed Wood-Frame Shear Wall System	Maximum h/b Ratio
Wood structural panels, unblocked	2:1
Wood structural panels, blocked	3.5:1
Particleboard, blocked	2:1
Diagonally-sheathed lumber	2:1
Gypsum wallboard	2:1[1,2]
Portland cement plaster	2:1[1]
Structural Fiberboard	3.5:1

AWC SDPWS, 2021



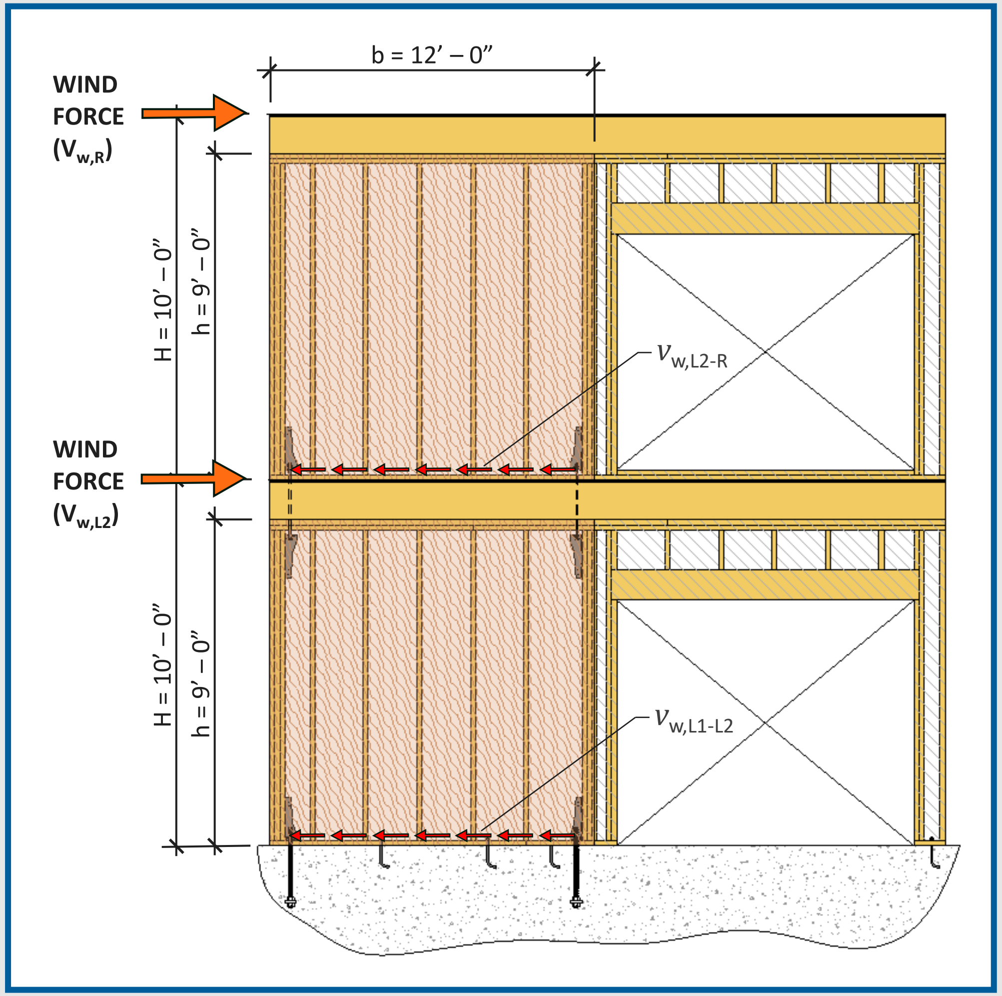
Design Example: Shear Walls

Shear wall wind loads

- Wind:
    - $w_{wind,R} = 125plf \, , w_{wind,L2} = 250plf$
    - $V_{w,R} = \frac{w_{wind,R} * L}{2} = \frac{125plf * 36ft}{2} = 2{,}250lb$
    - $V_{w,L2} = \frac{w_{wind,L2} * L}{2} = \frac{250plf * 36ft}{2} = 4{,}500lb$
        - $V_{w,L2-R} = V_{w,R} = 2{,}250lb$

          $\rightarrow v_{w,L2-R} = \frac{2{,}250lb}{12ft} = 188plf$
        - $V_{w,L1-L2} = V_{w,R} + V_{w,L2} = 6{,}750lb$

          $\rightarrow v_{w,L1-L2} = \frac{6{,}750lb}{12ft} = 563plf$



Design Example: Shear Walls

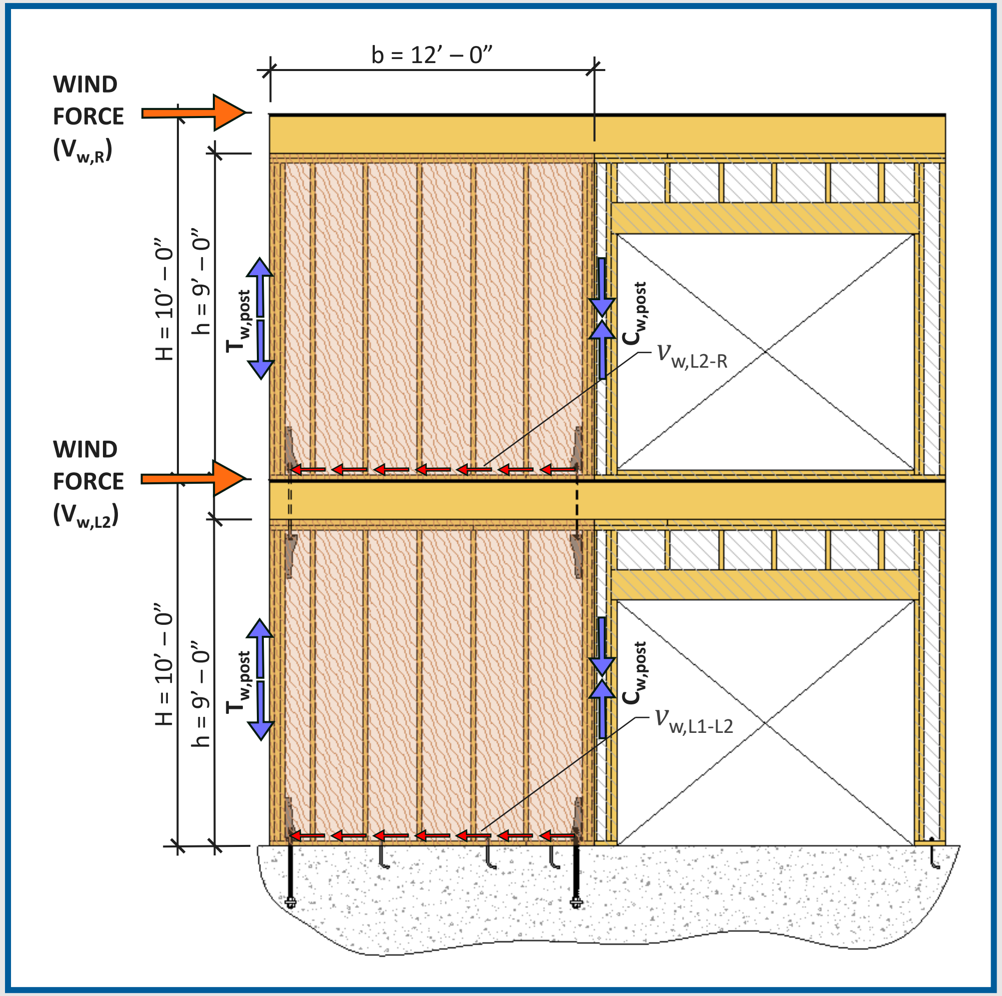
Shear wall wind loads – T/C forces

- Wind: $V_{w,R} = 2{,}250lb, V_{w,L2} = 4{,}500lb$
  - $M_{w,L2} = V_{w,R} * H = 2{,}250lb * 10ft = 22{,}500ft * lb$
    - $T_{w,L2-R} = C_{w,L2-R}$

      $= 22{,}500ft * lb/12ft = 1{,}875lb$
  - $M_{w,L1} = V_{w,L2} * H + V_{w,R} * (2 * H) =$

    $4{,}500lb * 10ft + 2{,}250\ lb\ * 20ft = 90{,}000ft * lb$
    - $T_{w,L1-L2} = C_{w,L1-L2}$

      $= 90{,}000ft * lb/12ft = 7{,}500lb$



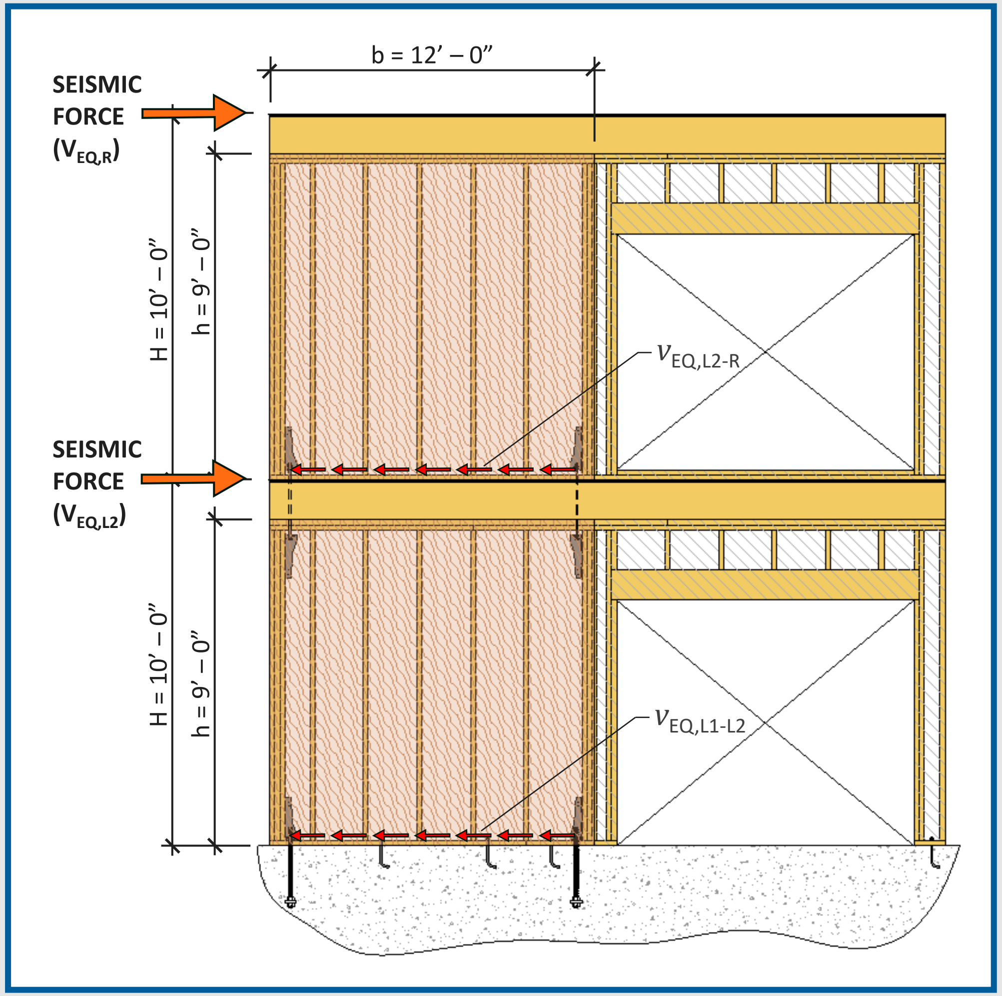
Design Example: Shear Walls

Shear wall seismic loads

- Seismic:
  - $w_{EQ,R} = 111plf, w_{EQ,L2} = 139plf$
  - $V_{EQ,R} = \frac{w_{EQ,R}*L}{2} = \frac{111plf*36ft}{2} = 2{,}000lb$
  - $V_{EQ,L2} = \frac{w_{EQ,L2}*L}{2} = \frac{139plf*36ft}{2} = 2{,}500lb$
    - $V_{EQ,L2-R} = V_{EQ,R} = 2{,}000lb$

      $\rightarrow v_{EQ,L2-R} = \frac{2{,}000lb}{12ft} = 167plf$
    - $V_{EQ,L1-L2} = V_{EQ,R} + V_{EQ,L2} = 4{,}500lb$

      $\rightarrow v_{EQ,L1-L2} = \frac{4{,}500lb}{12ft} = 375plf$



Design Example: Shear Walls

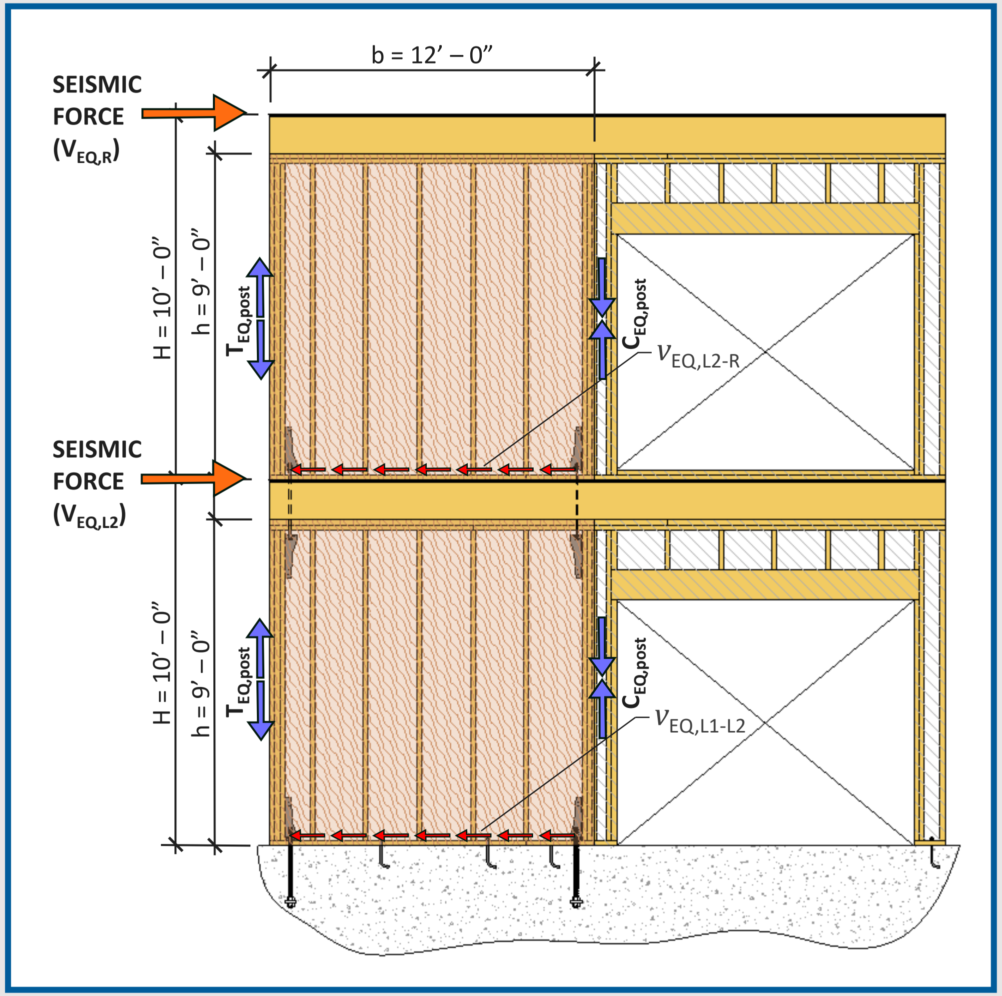
Shear wall seismic loads

- Seismic: $V_{EQ,R} = 2{,}000lb, V_{EQ,L2} = 2{,}500lb$
  - $M_{EQ,L2} = V_{EQ,R} * H = 2{,}000lb * 10ft = 20{,}000ft * lb$
    - $T_{EQ,L2-R} = C_{EQ,L2-R}$

      $= 20{,}000ft * lb/12ft = 1{,}667lb$
  - $M_{EQ,L1} = V_{EQ,L2} * H + V_{EQ,R} * (2 * H) =$

    $2{,}500lb * 10ft + 2{,}000lb * 20ft = 65{,}000ft * lb$
    - $T_{EQ,L1-L2} = C_{EQ,L1-L2}$

      $= 65{,}000ft * lb/12ft = 5{,}417lb$



Wood Design: Shear Walls

- Shear capacities: AWC SDPWS Tables
  - Wood panels (Table 4.3A)
  - Gypsum panels (Table 4.3B)
  - Plaster walls (Table 4.3C)
  - Horizontal or diagonal lumber sheathed (Table 4.3D)

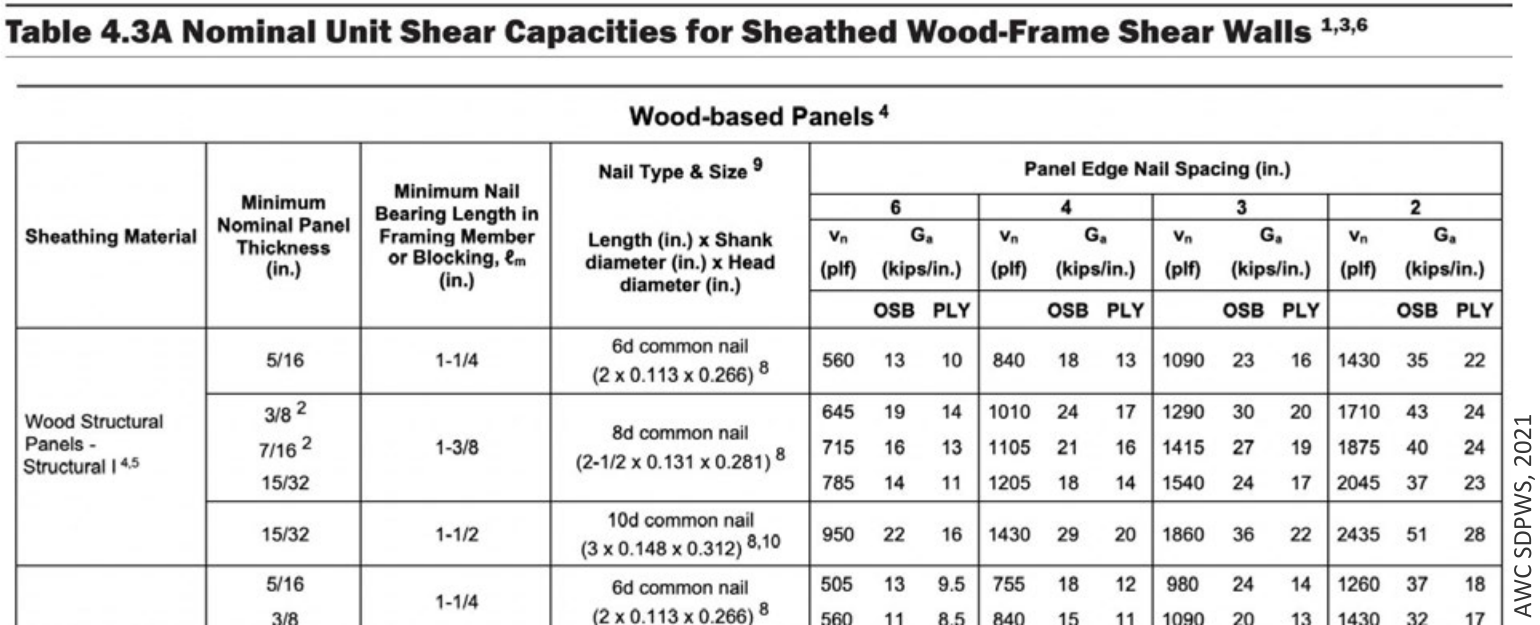


Table 4.3A Nominal Unit Shear Capacities for Sheathed Wood-Frame Shear Walls [1,3,6]

Wood-based Panels [4]

Sheathing Material	Minimum Nominal Panel Thickness (in.)	Minimum Nail Bearing Length in Framing Member or Blocking, ℓ_m (in.)	Nail Type & Size [9] Length (in.) x Shank diameter (in.) x Head diameter (in.)	Panel Edge Nail Spacing (in.)											
				6			4			3			2		
				v_n (plf)	G_a (kips/in.)		v_n (plf)	G_a (kips/in.)		v_n (plf)	G_a (kips/in.)		v_n (plf)	G_a (kips/in.)	
					OSB	PLY		OSB	PLY		OSB	PLY		OSB	PLY
Wood Structural Panels - Structural I [4,5]	5/16	1-1/4	6d common nail (2 x 0.113 x 0.266) [8]	560	13	10	840	18	13	1090	23	16	1430	35	22
	3/8 [2]	1-3/8	8d common nail (2-1/2 x 0.131 x 0.281) [8]	645	19	14	1010	24	17	1290	30	20	1710	43	24
	7/16 [2]			715	16	13	1105	21	16	1415	27	19	1875	40	24
	15/32			785	14	11	1205	18	14	1540	24	17	2045	37	23
	15/32	1-1/2	10d common nail (3 x 0.148 x 0.312) [8,10]	950	22	16	1430	29	20	1860	36	22	2435	51	28
	5/16	1-1/4	6d common nail (2 x 0.113 x 0.266) [8]	505	13	9.5	755	18	12	980	24	14	1260	37	18
	3/8			560	11	8.5	840	15	11	1090	20	13	1430	32	17

AWC SDPWS, 2021

Wood Design: Shear Walls

Shear Wall Nominal Capacities (SDPWS 2015):

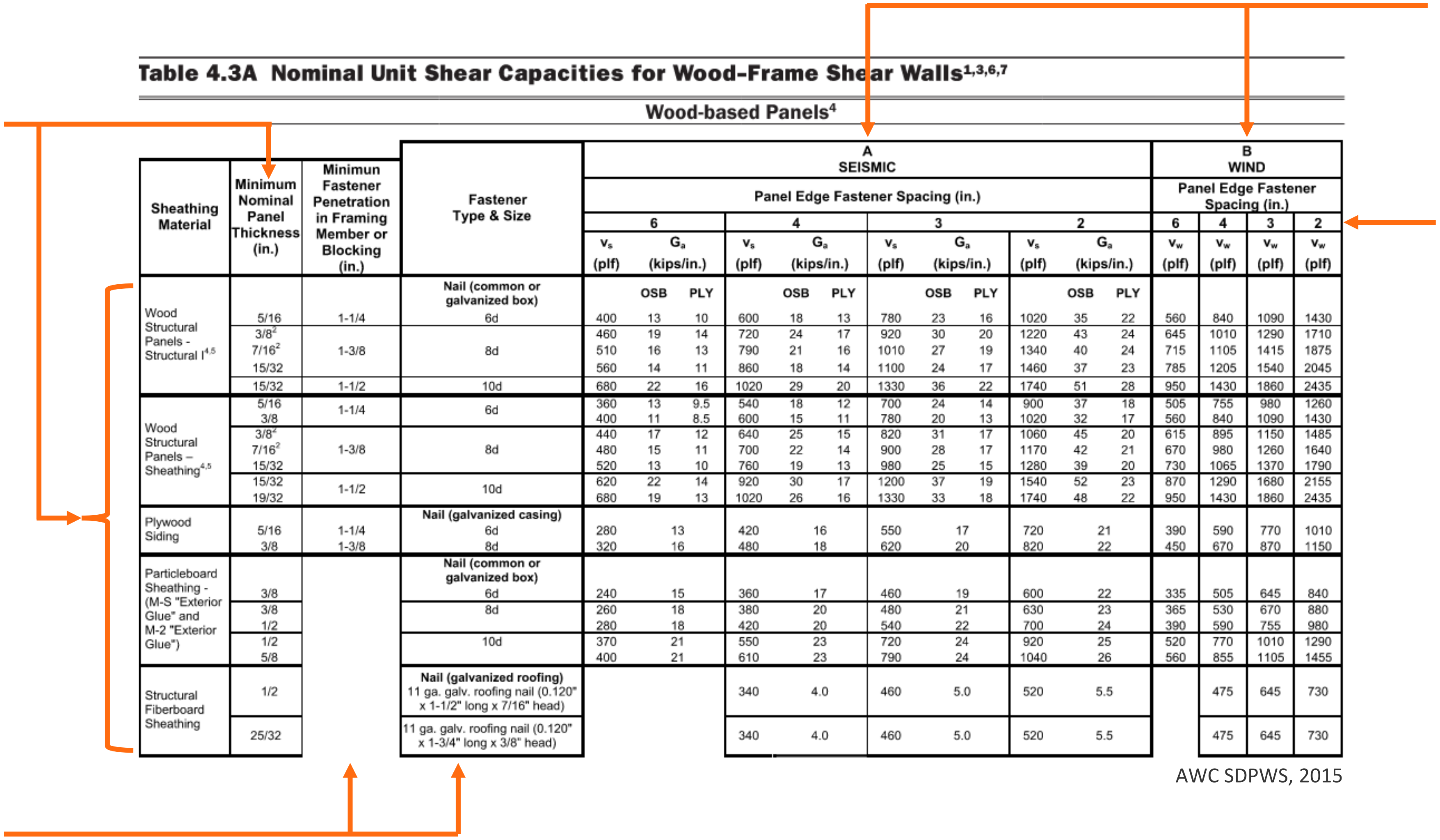


Table 4.3A Nominal Unit Shear Capacities for Wood-Frame Shear Walls[1,3,6,7]

Wood-based Panels[4]

Sheathing Material	Minimum Nominal Panel Thickness (in.)	Minimun Fastener Penetration in Framing Member or Blocking (in.)	Fastener Type & Size	A SEISMIC												B WIND			
				Panel Edge Fastener Spacing (in.)												Panel Edge Fastener Spacing (in.)			
				6			4			3			2			6	4	3	2
				v_s (plf)	G_a (kips/in.)		v_s (plf)	G_a (kips/in.)		v_s (plf)	G_a (kips/in.)		v_s (plf)	G_a (kips/in.)		v_w (plf)	v_w (plf)	v_w (plf)	v_w (plf)
Wood Structural Panels - Structural I[4,5]			**Nail (common or galvanized box)**		**OSB**	**PLY**		**OSB**	**PLY**		**OSB**	**PLY**		**OSB**	**PLY**				
	5/16	1-1/4	6d	400	13	10	600	18	13	780	23	16	1020	35	22	560	840	1090	1430
	3/8[2]	1-3/8	8d	460	19	14	720	24	17	920	30	20	1220	43	24	645	1010	1290	1710
	7/16[2]			510	16	13	790	21	16	1010	27	19	1340	40	24	715	1105	1415	1875
	15/32			560	14	11	860	18	14	1100	24	17	1460	37	23	785	1205	1540	2045
	15/32	1-1/2	10d	680	22	16	1020	29	20	1330	36	22	1740	51	28	950	1430	1860	2435
Wood Structural Panels – Sheathing[4,5]	5/16	1-1/4	6d	360	13	9.5	540	18	12	700	24	14	900	37	18	505	755	980	1260
	3/8			400	11	8.5	600	15	11	780	20	13	1020	32	17	560	840	1090	1430
	3/8[2]	1-3/8	8d	440	17	12	640	25	15	820	31	17	1060	45	20	615	895	1150	1485
	7/16[2]			480	15	11	700	22	14	900	28	17	1170	42	21	670	980	1260	1640
	15/32			520	13	10	760	19	13	980	25	15	1280	39	20	730	1065	1370	1790
	15/32	1-1/2	10d	620	22	14	920	30	17	1200	37	19	1540	52	23	870	1290	1680	2155
	19/32			680	19	13	1020	26	16	1330	33	18	1740	48	22	950	1430	1860	2435
Plywood Siding	5/16	1-1/4	**Nail (galvanized casing)** 6d	280	13		420	16		550	17		720	21		390	590	770	1010
	3/8	1-3/8	8d	320	16		480	18		620	20		820	22		450	670	870	1150
Particleboard Sheathing - (M-S "Exterior Glue" and M-2 "Exterior Glue")	3/8		**Nail (common or galvanized box)** 6d	240	15		360	17		460	19		600	22		335	505	645	840
	3/8		8d	260	18		380	20		480	21		630	23		365	530	670	880
	1/2			280	18		420	20		540	22		700	24		390	590	755	980
	1/2		10d	370	21		550	23		720	24		920	25		520	770	1010	1290
	5/8			400	21		610	23		790	24		1040	26		560	855	1105	1455
Structural Fiberboard Sheathing	1/2		**Nail (galvanized roofing)** 11 ga. galv. roofing nail (0.120" x 1-1/2" long x 7/16" head)				340	4.0		460	5.0		520	5.5			475	645	730
	25/32		11 ga. galv. roofing nail (0.120" x 1-3/4" long x 3/8" head)				340	4.0		460	5.0		520	5.5			475	645	730

AWC SDPWS, 2015

Load Type

Sheathing

Fastener Spacing

Fasteners

Wood Design: Shear Walls

Shear Wall Nominal Capacities (SDPWS 2021):

Single Table for Wind and Seismic

Sheathing

Fastener Spacing

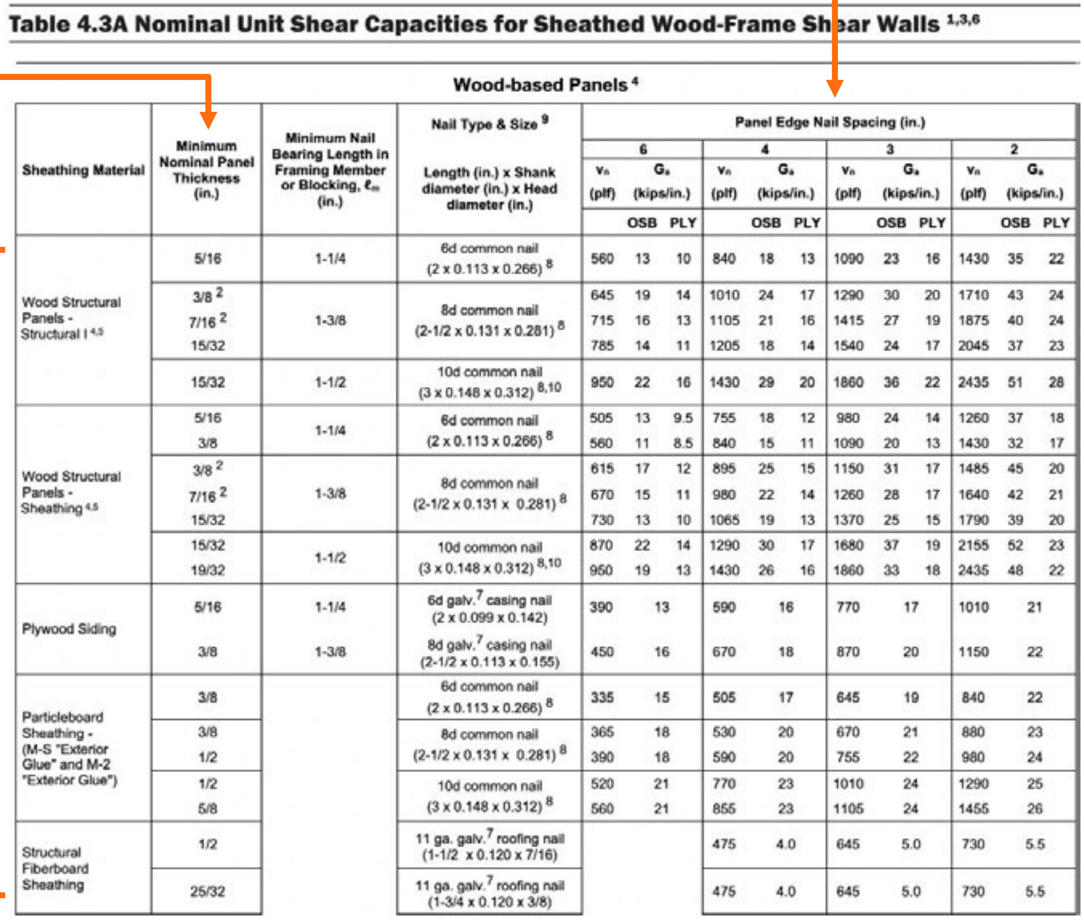


Table 4.3A Nominal Unit Shear Capacities for Sheathed Wood-Frame Shear Walls [1,3,6]

Wood-based Panels [4]

Sheathing Material	Minimum Nominal Panel Thickness (in.)	Minimum Nail Bearing Length in Framing Member or Blocking, ℓ_m (in.)	Nail Type & Size [9] Length (in.) x Shank diameter (in.) x Head diameter (in.)	Panel Edge Nail Spacing (in.)											
				6			4			3			2		
				v_n (plf)	G_a (kips/in.)		v_n (plf)	G_a (kips/in.)		v_n (plf)	G_a (kips/in.)		v_n (plf)	G_a (kips/in.)	
					OSB	PLY		OSB	PLY		OSB	PLY		OSB	PLY
Wood Structural Panels - Structural I [4,5]	5/16	1-1/4	6d common nail (2 x 0.113 x 0.266) [8]	560	13	10	840	18	13	1090	23	16	1430	35	22
	3/8 [2]	1-3/8	8d common nail (2-1/2 x 0.131 x 0.281) [8]	645	19	14	1010	24	17	1290	30	20	1710	43	24
	7/16 [2]			715	16	13	1105	21	16	1415	27	19	1875	40	24
	15/32			785	14	11	1205	18	14	1540	24	17	2045	37	23
	15/32	1-1/2	10d common nail (3 x 0.148 x 0.312) [8,10]	950	22	16	1430	29	20	1860	36	22	2435	51	28
Wood Structural Panels - Sheathing [4,5]	5/16	1-1/4	6d common nail (2 x 0.113 x 0.266) [8]	505	13	9.5	755	18	12	980	24	14	1260	37	18
	3/8			560	11	8.5	840	15	11	1090	20	13	1430	32	17
	3/8 [2]	1-3/8	8d common nail (2-1/2 x 0.131 x 0.281) [8]	615	17	12	895	25	15	1150	31	17	1485	45	20
	7/16 [2]			670	15	11	980	22	14	1260	28	17	1640	42	21
	15/32			730	13	10	1065	19	13	1370	25	15	1790	39	20
	15/32	1-1/2	10d common nail (3 x 0.148 x 0.312) [8,10]	870	22	14	1290	30	17	1680	37	19	2155	52	23
	19/32			950	19	13	1430	26	16	1860	33	18	2435	48	22
Plywood Siding	5/16	1-1/4	6d galv.[7] casing nail (2 x 0.099 x 0.142)	390	13		590	16		770	17		1010	21	
	3/8	1-3/8	8d galv.[7] casing nail (2-1/2 x 0.113 x 0.155)	450	16		670	18		870	20		1150	22	
Particleboard Sheathing - (M-S "Exterior Glue" and M-2 "Exterior Glue")	3/8		6d common nail (2 x 0.113 x 0.266) [8]	335	15		505	17		645	19		840	22	
	3/8		8d common nail (2-1/2 x 0.131 x 0.281) [8]	365	18		530	20		670	21		880	23	
	1/2			390	18		590	20		755	22		980	24	
	1/2		10d common nail (3 x 0.148 x 0.312) [8]	520	21		770	23		1010	24		1290	25	
	5/8			560	21		855	23		1105	24		1455	26	
Structural Fiberboard Sheathing	1/2		11 ga. galv.[7] roofing nail (1-1/2 x 0.120 x 7/16)				475	4.0		645	5.0		730	5.5	
	25/32		11 ga. galv.[7] roofing nail (1-3/4 x 0.120 x 3/8)				475	4.0		645	5.0		730	5.5	

2021 AWC SDPWS

Fasteners

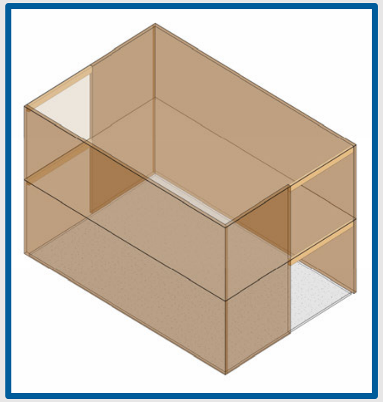
Wood Design: Shear Walls

Read the footnotes!

- Adjusted capacities:
  - SDPWS 2015:
    - ASD: $v_{ASD} = v_{nom}/2.0$
    - LRFD: $v_{LRFD} = v_{nom} * 0.80$
  - SDPWS 2021:
    - ASD, seismic: $v_{ASD} = v_{nom}/2.8$
    - ASD, wind: $v_{ASD} = v_{nom}/2.0$
    - LRFD, seismic: $v_{LRFD} = v_{nom} * 0.50$
    - LRFD, wind: $v_{LRFD} = v_{nom} * 0.80$

- Reduce capacities if not Douglas-Fir-Larch or Southern Pine

Design Example: Shear Walls



Shear wall check (lower story)

- Shear wall:
  - Sheathing = 15/32” Structural I, Blocked
  - Fasteners = 8d, 3” O.C. at edges, 12” O.C. at intermediate framing
- Nominal capacity: $v_{nom} = 1{,}540 plf$

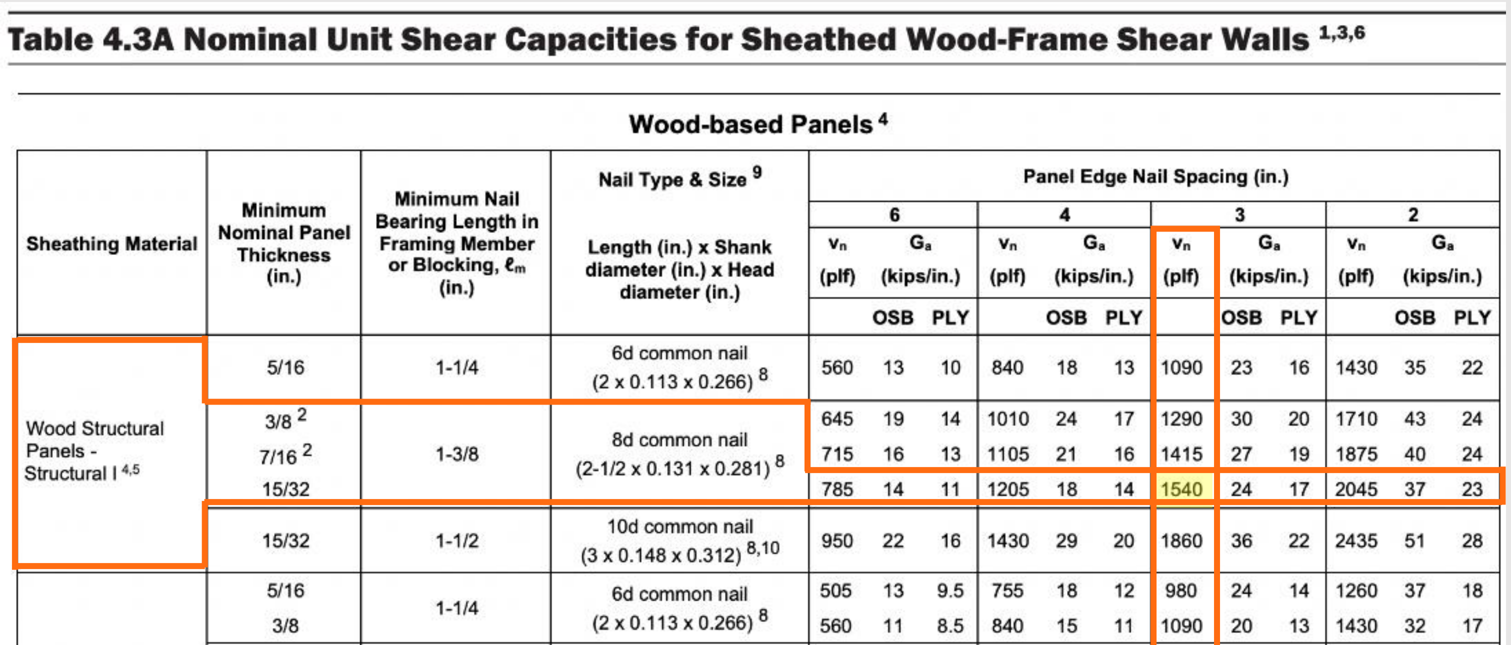


Table 4.3A Nominal Unit Shear Capacities for Sheathed Wood-Frame Shear Walls [1,3,6]

Wood-based Panels [4]

Sheathing Material	Minimum Nominal Panel Thickness (in.)	Minimum Nail Bearing Length in Framing Member or Blocking, ℓ_m (in.)	Nail Type & Size [9] Length (in.) x Shank diameter (in.) x Head diameter (in.)	Panel Edge Nail Spacing (in.)											
				6			4			3			2		
				v_n (plf)	G_a (kips/in.)		v_n (plf)	G_a (kips/in.)		v_n (plf)	G_a (kips/in.)		v_n (plf)	G_a (kips/in.)	
					OSB	PLY		OSB	PLY		OSB	PLY		OSB	PLY
Wood Structural Panels - Structural I [4,5]	5/16	1-1/4	6d common nail (2 x 0.113 x 0.266) [8]	560	13	10	840	18	13	1090	23	16	1430	35	22
	3/8 [2]	1-3/8	8d common nail (2-1/2 x 0.131 x 0.281) [8]	645	19	14	1010	24	17	1290	30	20	1710	43	24
	7/16 [2]			715	16	13	1105	21	16	1415	27	19	1875	40	24
	15/32			785	14	11	1205	18	14	1540	24	17	2045	37	23
	15/32	1-1/2	10d common nail (3 x 0.148 x 0.312) [8,10]	950	22	16	1430	29	20	1860	36	22	2435	51	28
	5/16	1-1/4	6d common nail (2 x 0.113 x 0.266) [8]	505	13	9.5	755	18	12	980	24	14	1260	37	18
	3/8			560	11	8.5	840	15	11	1090	20	13	1430	32	17

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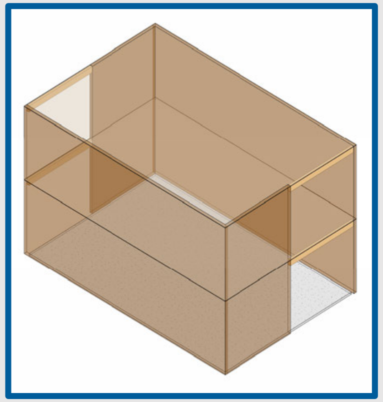
Design Example: Shear walls



Shear wall check (lower story)

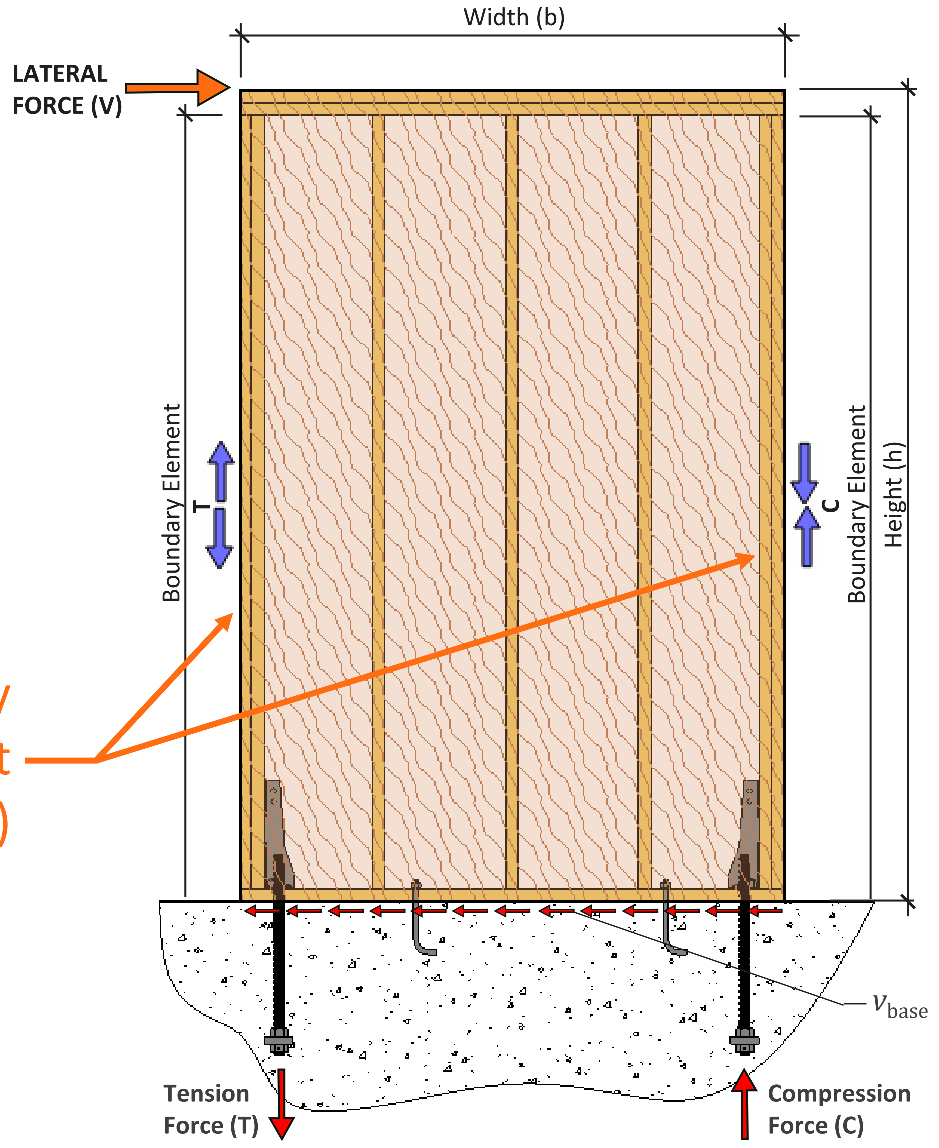
- Shear wall capacity:
  - Nominal capacity: $v_{nom} = 1540plf$
  - Wind capacity (ASD): $v_{w,cap} = v_{nom}/2.0 = 770plf$
  - Seismic capacity (ASD): $v_{EQ,cap} = v_{nom}/2.8 = 550plf$

- Shear wall check:
  - Wind design load: $v_{w,max} = 563plf < v_{w,cap} = 770plf$ → OK for wind
  - Seismic design load: $v_{EQ,max} = 375plf < v_{EQ,cap} = 550plf$ → OK for seismic

Wood Design: Shear Walls

Boundary Element

- End post force:
  - For single story: $T_{post} = C_{post} = \frac{V*h}{l}$
- End post checks:
  - Tension: $f_t \leq F'_t$
    - $f_t = \frac{T_{chord}}{A_{chord}}$
  - Compression : $f_c \leq F'_c$
    - $f_c = \frac{C_{chord}}{A_{chord}}$



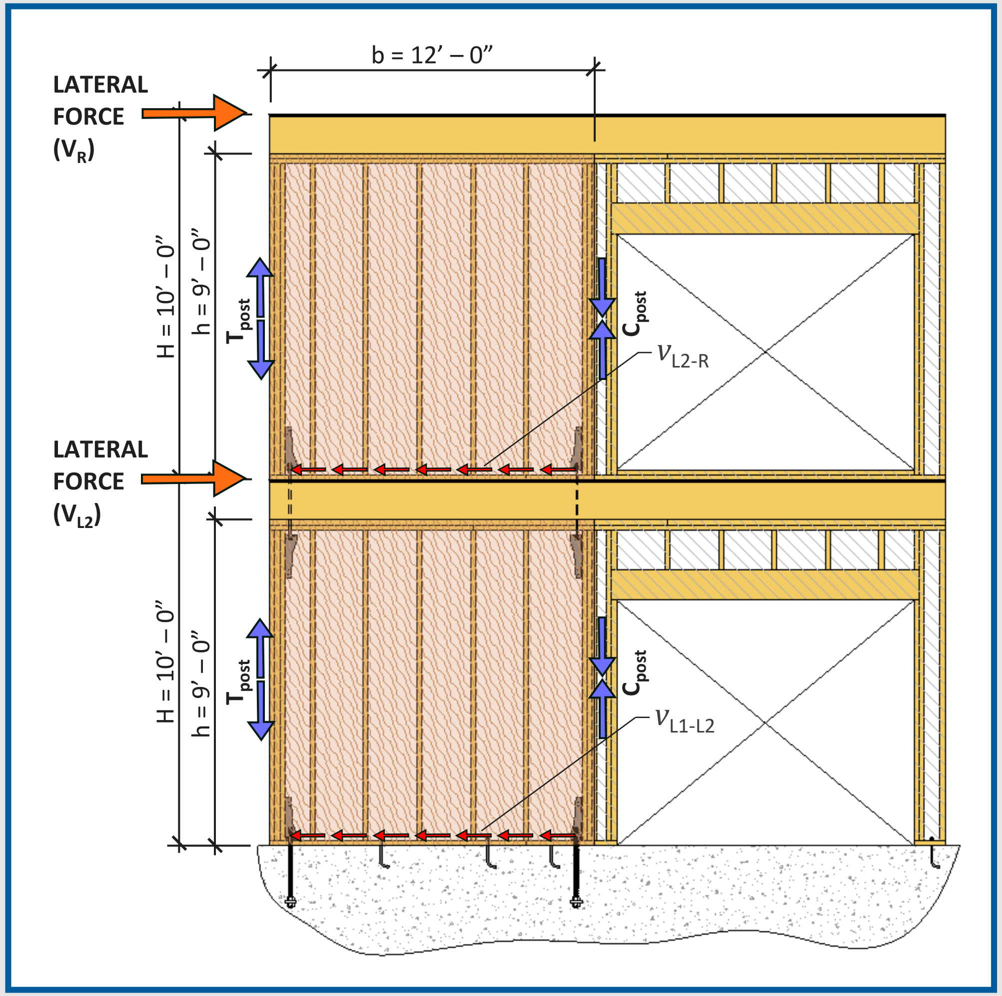
Boundary Element (End Post)

Design Example: Shear Walls

Boundary Element: End Posts

- (2)2x6 Douglas Fir-Larch #2
  - $A_{post} = 2 * (1.5in * 5.5in) = 16.5in^2$

- Post forces (L1-L2)
  - Wind: $T_{w,post,L1-L2} = C_{w,post,L1-L2} = 7{,}500lb$
    - $t_{w,post,L1-L2} = c_{w,post,L1-L2}$
      $= 7{,}500lb/16.5in^2 = \boxed{455psi}$
  - Seismic: $T_{EQ,post,L1-L2} = C_{EQ,post,L1-L2} = 5{,}417lb$
    - $t_{EQ,post,L1-L2} = c_{EQ,post,L1-L2}$
      $= 5{,}417lb/16.5in^2 \ = 328psi$



Design Example: Shear Walls

End Posts: $t_{post,L1-L2} = c_{post,L1-L2} = 455psi$

- End post capacity:
  - Tension: $F_t = 575\ psi$ (NDS Supplement Table 4A)
    - Load duration factor C_D = 1.6
    - $F_t' = 1.6 * 575\ psi = 920psi > t_{post,L1-L2}\ = 455psi$ → Tension OK
  - Compression: $F_c = 1{,}350\ psi$ (NDS Supplement Table 4A)
    - Load duration factor C_D = 1.6
    - Column stability factor C_P = 0.514
    - Assume other adjust. factors = 1.0
    - $F_c' = 1.6 * 0.514 * 1{,}350\ psi = 1{,}110psi > c_{post,L1-L2}\ = 455psi$ → Compression OK

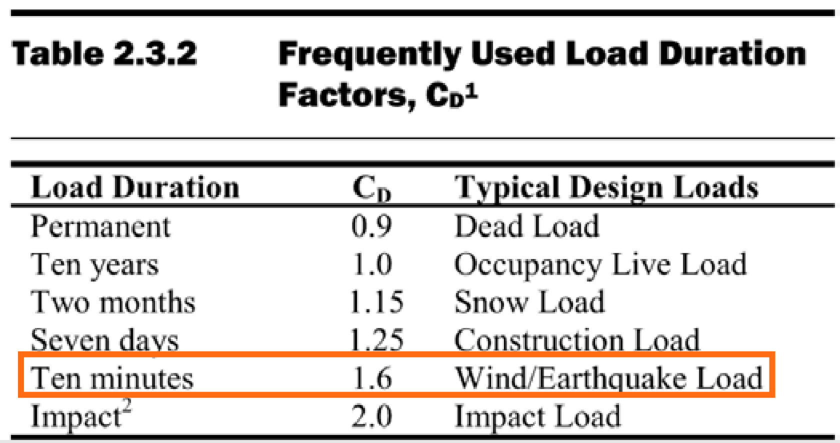


Table 2.3.2 Frequently Used Load Duration Factors, C_D[1]

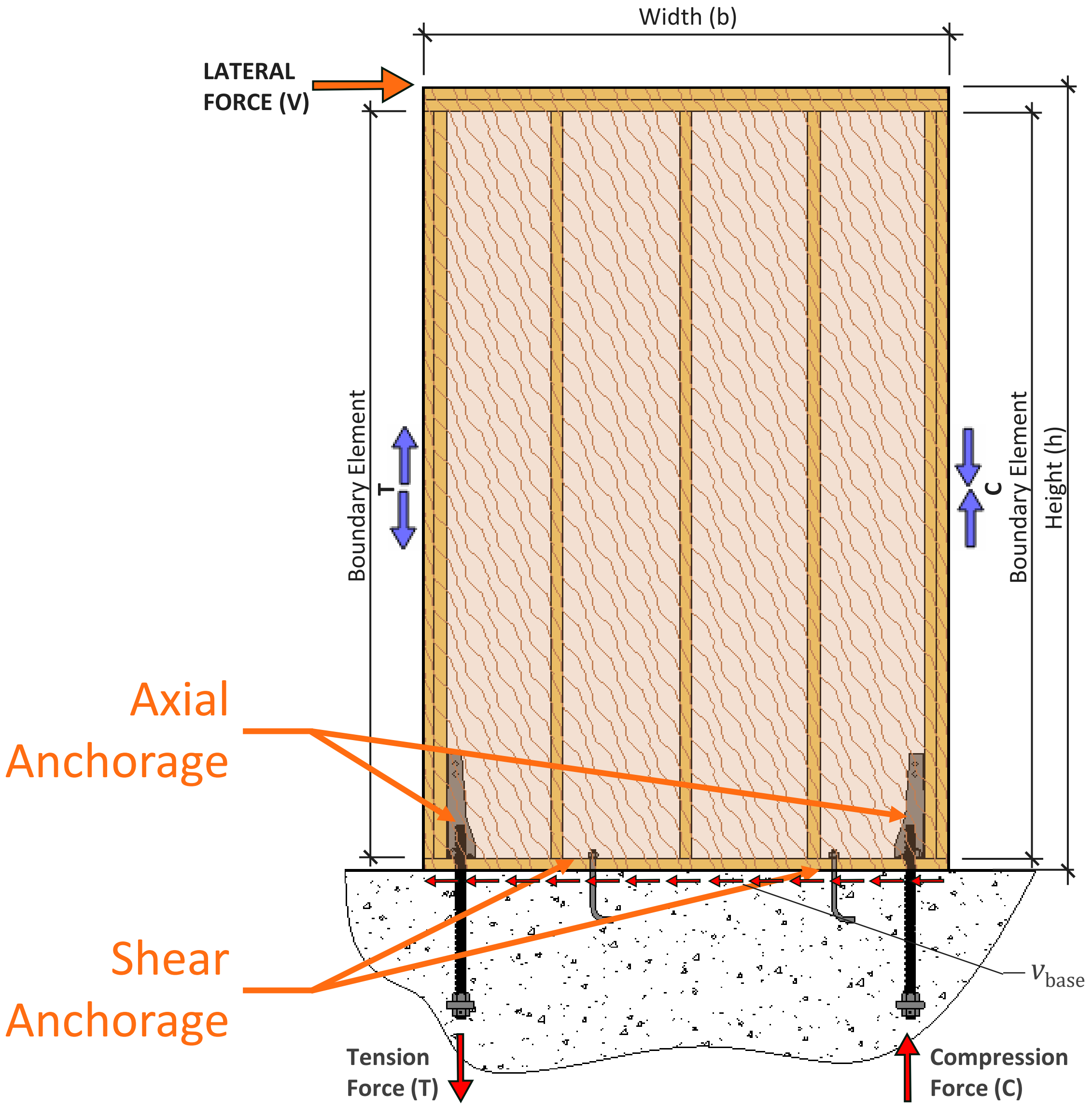
Load Duration	C_D	Typical Design Loads
Permanent	0.9	Dead Load
Ten years	1.0	Occupancy Live Load
Two months	1.15	Snow Load
Seven days	1.25	Construction Load
Ten minutes	1.6	Wind/Earthquake Load
Impact[2]	2.0	Impact Load

AWC NDS, 2018

Wood Design: Shear Walls

Anchorage

- Axial:
  - Tension / Compression at ends of wall segment
- Shear:
  - Wall below: Fasteners (nails, etc.)
  - Foundation below: Anchor bolts

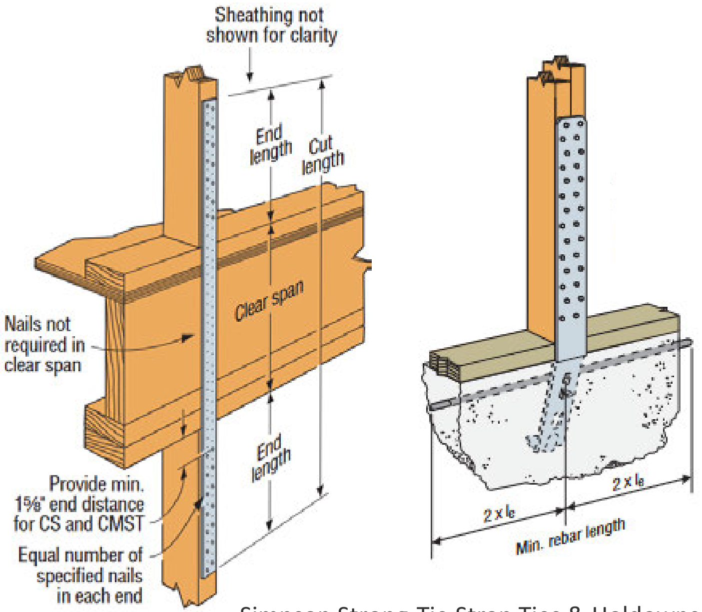


Axial Anchorage

Shear Anchorage

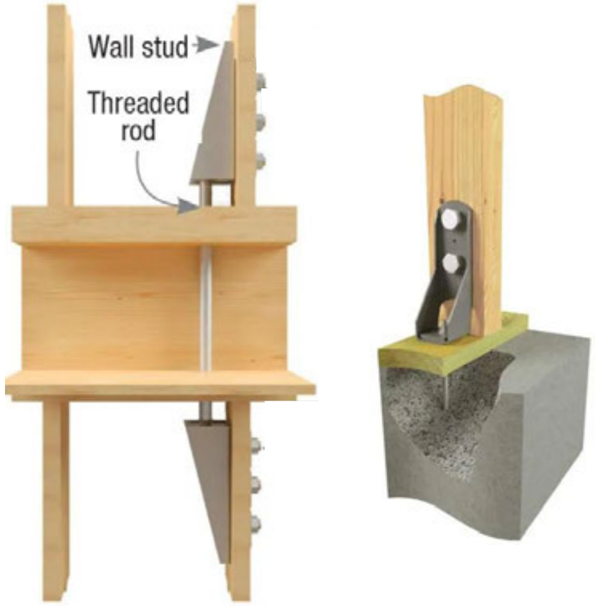
Wood Design: Shear Walls

Hold down types:



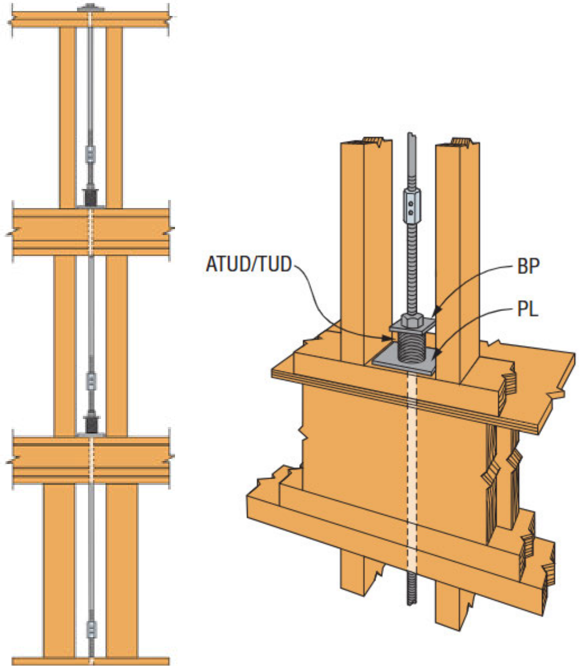
Simpson Strong-Tie Strap Ties & Holdowns

Straps



MiTek Holdowns

Bucket style



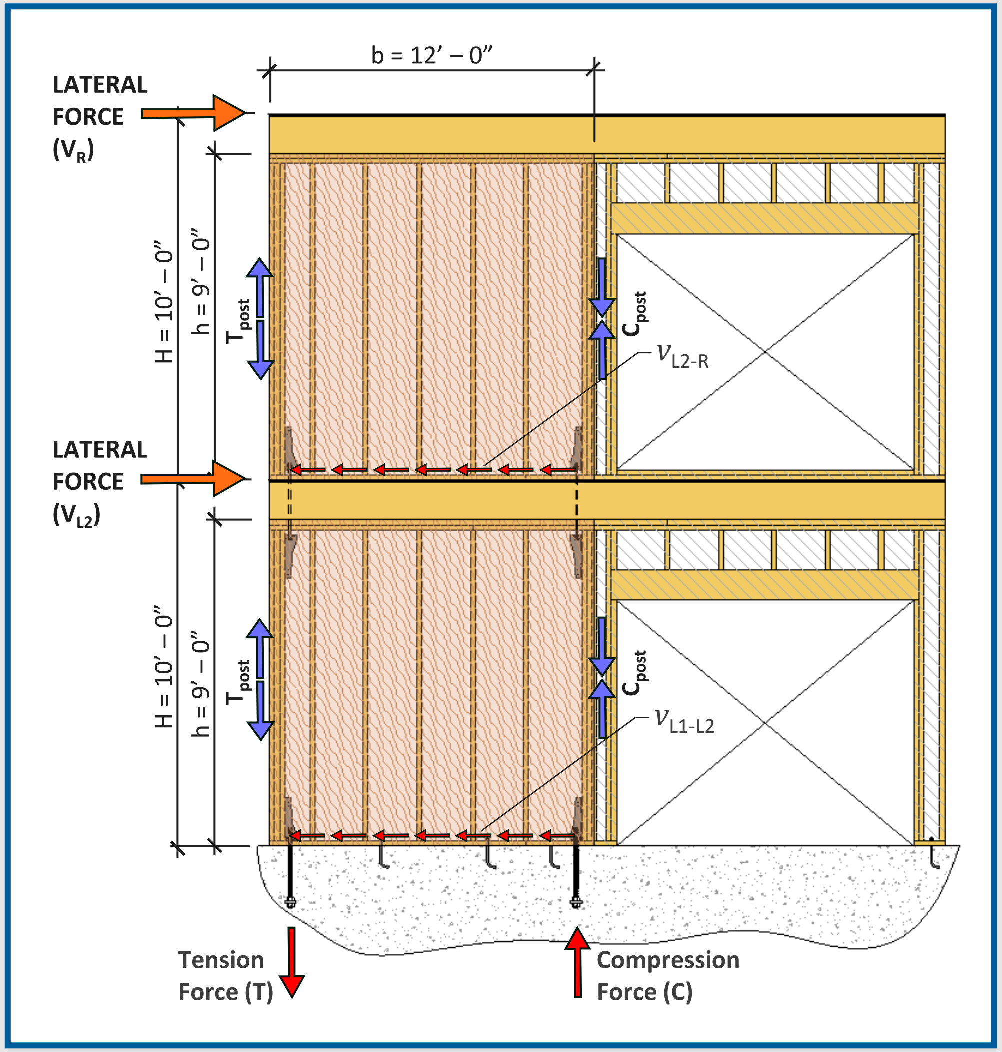
Simpson Strong-Tie Anchor Tie Down System & Take-Up Device

Continuous Rod System

Design Example: Shear Walls

Anchorage

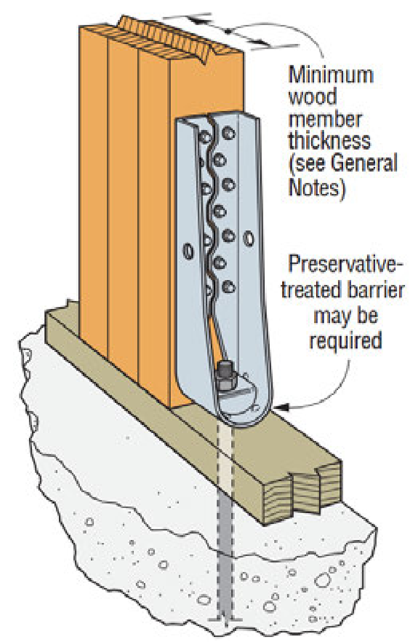
- Anchorage forces (L1)
  - Wind: $T_{w,post,L1-L2} = C_{w,post,L1-L2}$
    $= \boxed{7{,}500lb}$
  - Seismic: $T_{EQ,post,L1-L2} = C_{EQ,post,L1-L2}$
    $= 5{,}417lb$

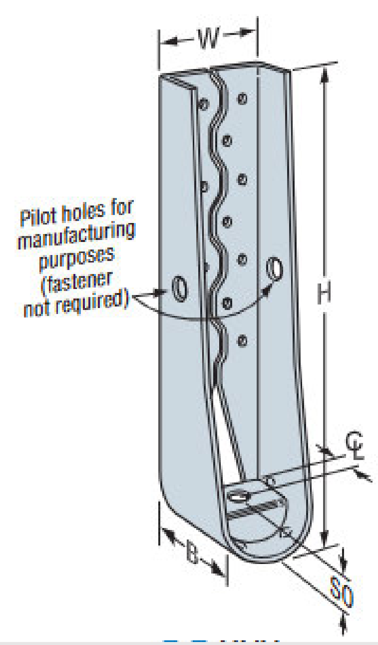


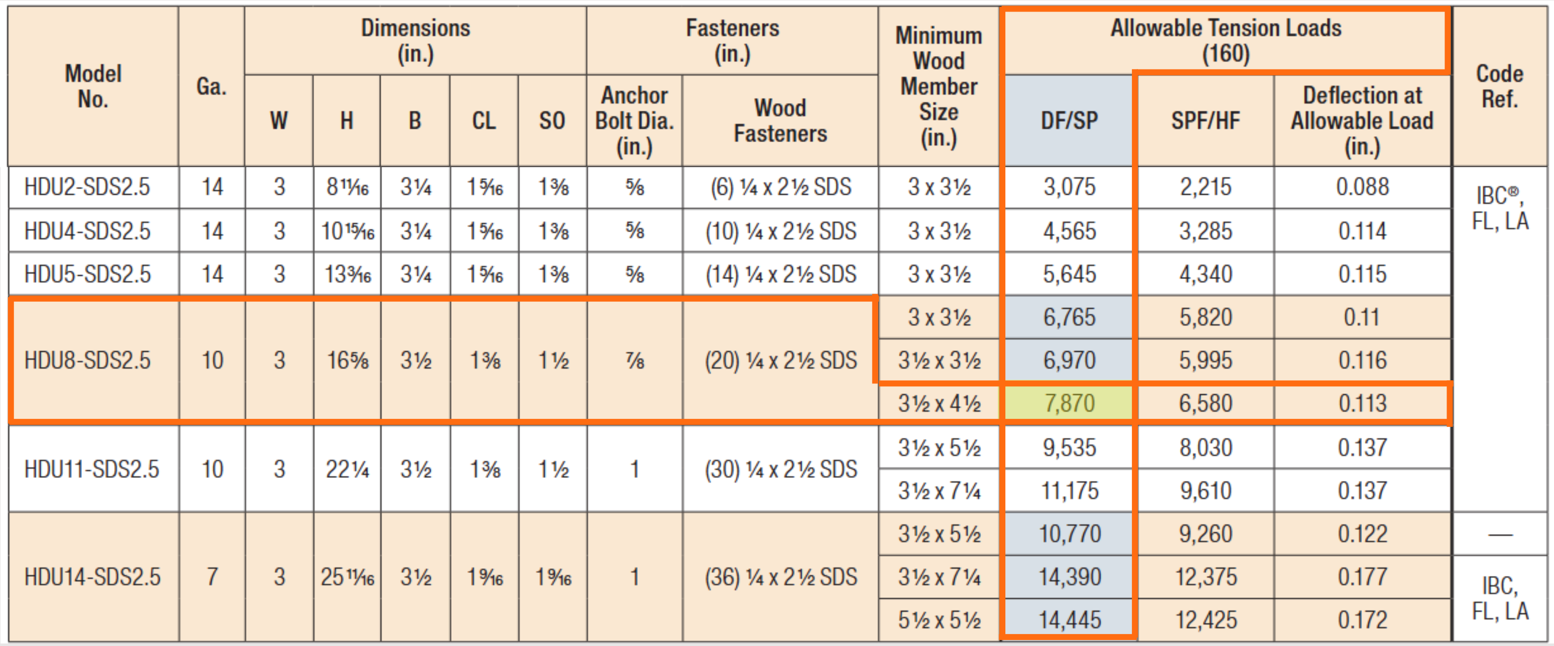
Design Example: Shear Walls

Anchorage: Axial

- Tension: $T_{post,L1-L2} = 7{,}500 lb$
- Proprietary hold down







Model No.	Ga.	Dimensions (in.)					Fasteners (in.)		Minimum Wood Member Size (in.)	Allowable Tension Loads (160)			Code Ref.
		W	H	B	CL	SO	Anchor Bolt Dia. (in.)	Wood Fasteners		DF/SP	SPF/HF	Deflection at Allowable Load (in.)	
HDU2-SDS2.5	14	3	8¹¹⁄₁₆	3¼	1⁵⁄₁₆	1⅜	⅝	(6) ¼ x 2½ SDS	3 x 3½	3,075	2,215	0.088	IBC®, FL, LA
HDU4-SDS2.5	14	3	10¹⁵⁄₁₆	3¼	1⁵⁄₁₆	1⅜	⅝	(10) ¼ x 2½ SDS	3 x 3½	4,565	3,285	0.114	
HDU5-SDS2.5	14	3	13³⁄₁₆	3¼	1⁵⁄₁₆	1⅜	⅝	(14) ¼ x 2½ SDS	3 x 3½	5,645	4,340	0.115	
HDU8-SDS2.5	10	3	16⅝	3½	1⅜	1½	⅞	(20) ¼ x 2½ SDS	3 x 3½	6,765	5,820	0.11	
									3½ x 3½	6,970	5,995	0.116	
									3½ x 4½	7,870	6,580	0.113	
HDU11-SDS2.5	10	3	22¼	3½	1⅜	1½	1	(30) ¼ x 2½ SDS	3½ x 5½	9,535	8,030	0.137	
									3½ x 7¼	11,175	9,610	0.137	
HDU14-SDS2.5	7	3	25¹¹⁄₁₆	3½	1⁹⁄₁₆	1⁹⁄₁₆	1	(36) ¼ x 2½ SDS	3½ x 5½	10,770	9,260	0.122	—
									3½ x 7¼	14,390	12,375	0.177	IBC, FL, LA
									5½ x 5½	14,445	12,425	0.172	

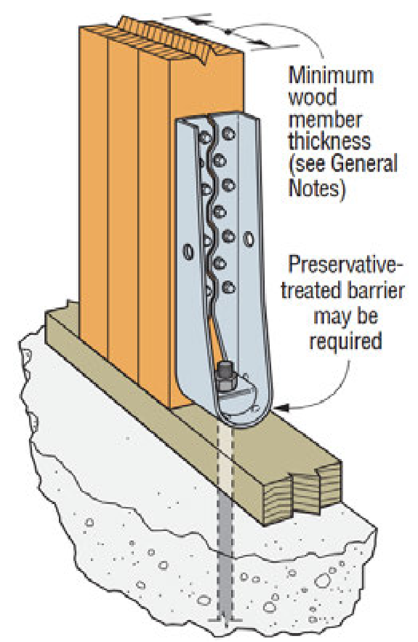
Simpson Strong-Tie HDU Holdown

Design Example: Shear Walls

Anchorage: Axial

- Compression: $C_{post,L1-L2} = 7{,}500lb$
    - $c_{post,L1-L2} = 7{,}500lb/24.75in^2 = 303psi$

- Bearing check of wall bottom plate
    - $F_{c\perp} = 625\ psi$ (NDS Supplement Table 4A)
        - Assume adjustment factors = 1.0
        - $F'_{c\perp} = 625\ psi > C_{post,L1-L2}\ = 303psi$ → Bearing OK



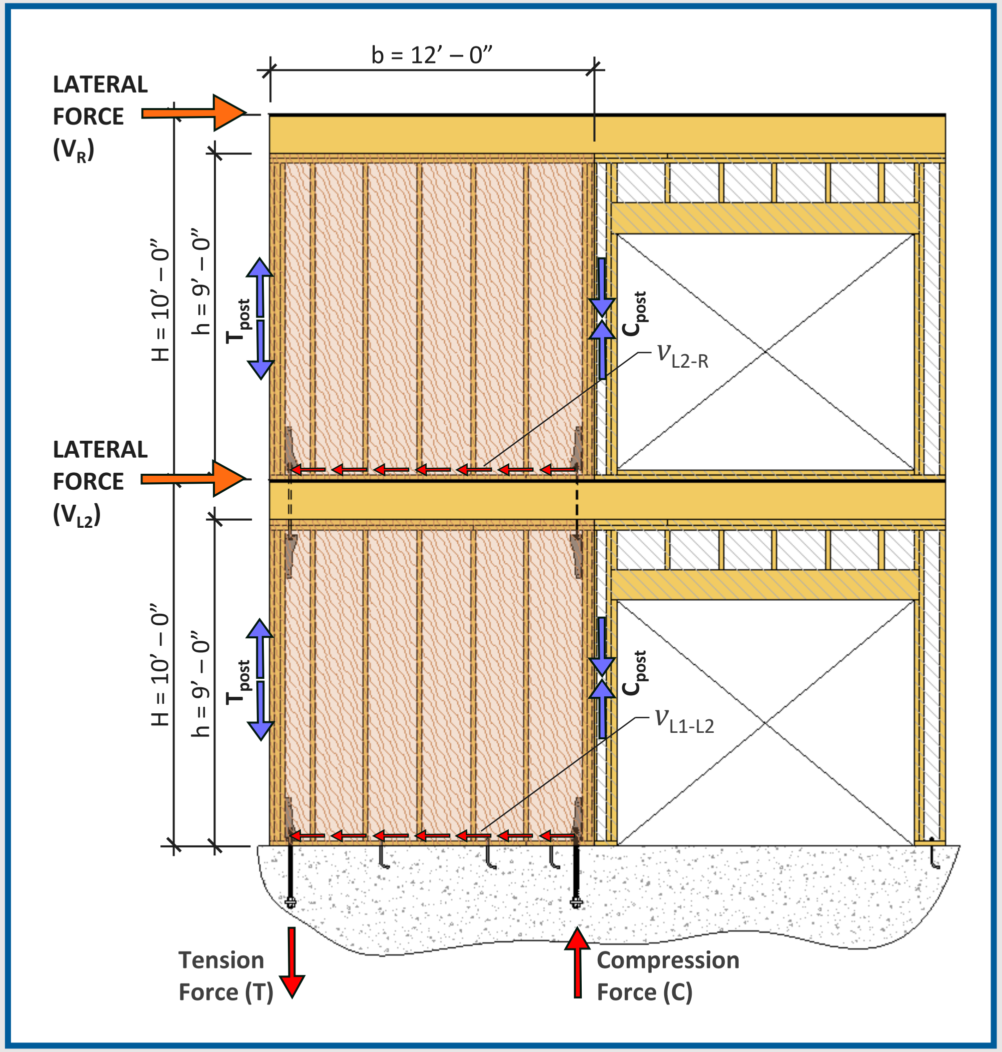
Simpson Strong-Tie
HDU Holdown

Design Example: Shear Walls

Anchorage: Shear

- Shear load:
  - Wind: $V_{w,L1} = \boxed{6{,}750lb}$
  - Seismic: $V_{EQ,L1} = 4{,}500lb$
- ½"Ø Anchor bolts into foundation
  - ASD capacity = 650 lb (NDS Table 12E)
    - Load duration factor C_D = 1.6

      → Adjusted capacity = 1040 lb
    - $6{,}750lb/1040lb = 6.5$ → (7) anchor bolts
    - $(12ft - 2 * 4.5\text{in})/8\ spaces = 16"\ spacing$
  - Note: Connection to foundation also must be checked



Wood Design: Shear Walls

- Deflection
  - $\delta_{sw} = \frac{8 * v * h^3}{E * A * b} + \frac{v * h}{1{,}000 * G_a} + \frac{h * \Delta_a}{b}$ (SPDWS Equation 4.3-1)

end post deformation

panel shear + nail slip

wall anchorage deformation

- $v =$ unit shear
- $E =$ modulus of elasticity of end posts
- $A =$ cross sectional area of end posts
- $G_a =$ apparent shear stiffness
- $b =$ shear wall length
- $h =$ shear wall height
- $\Delta_a =$ vertical deformation of wall anchorage system

Wood Design: Shear Walls

- Deflection: $\delta_{sw} = \frac{8*v*h^3}{E*A*b} + \frac{v*h}{1{,}000*G_a} + \frac{h*\Delta_a}{b}$ (SPDWS Equation 4.3-1)
  - $v_w = \boxed{563plf}$
    $1.4 * v_{EQ} = 525plf$
  - $b = 12ft$
  - $h = 9ft$
  - $A_{post} = 24.75in^2$
  - $E_{post} = 1{,}600{,}000psi$

  (NDS Supplement Table 4A)
  - $G_a = 24\text{kips/in}$
  - Δ_a= vertical deformation of wall anchorage system

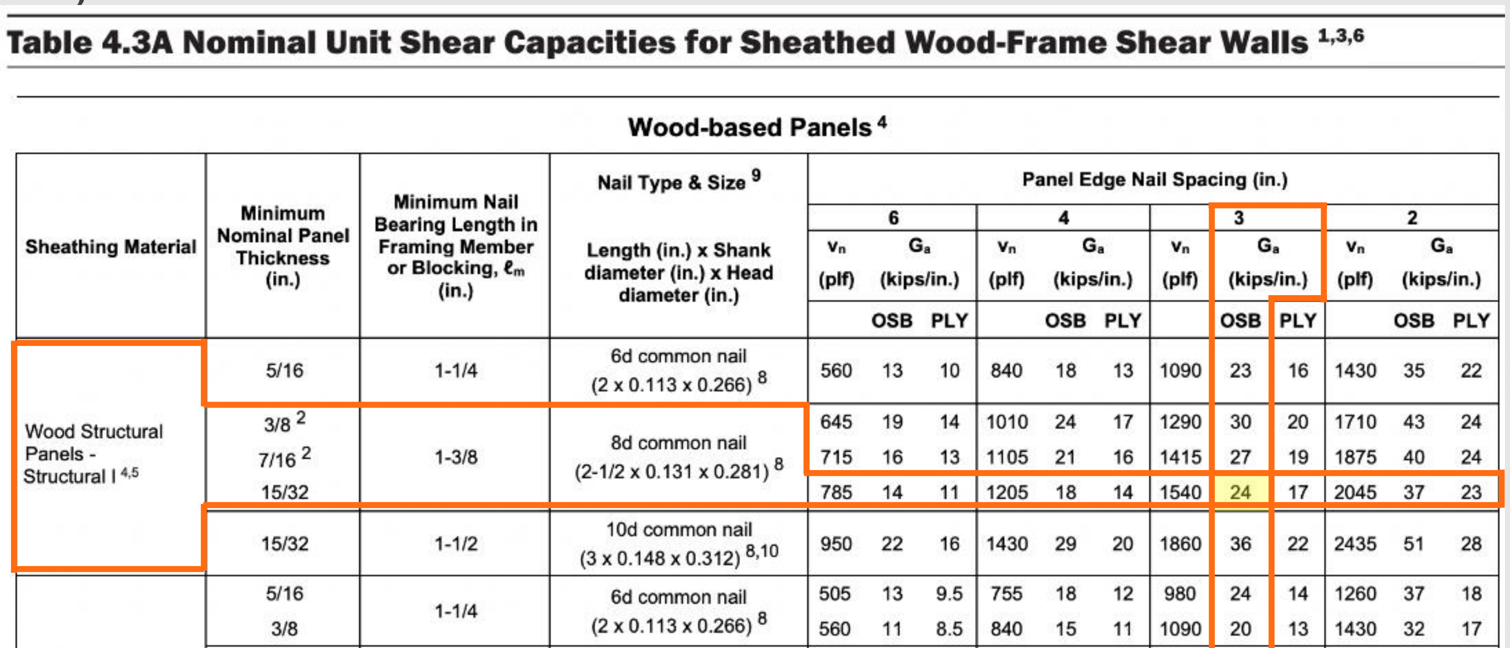


Table 4.3A Nominal Unit Shear Capacities for Sheathed Wood-Frame Shear Walls [1,3,6]

Wood-based Panels [4]

Sheathing Material	Minimum Nominal Panel Thickness (in.)	Minimum Nail Bearing Length in Framing Member or Blocking, ℓ_m (in.)	Nail Type & Size [9] Length (in.) x Shank diameter (in.) x Head diameter (in.)	Panel Edge Nail Spacing (in.)											
				6			4				3		2		
				v_n (plf)	G_a (kips/in.)		v_n (plf)	G_a (kips/in.)		v_n (plf)	G_a (kips/in.)		v_n (plf)	G_a (kips/in.)	
					OSB	PLY		OSB	PLY		OSB	PLY		OSB	PLY
Wood Structural Panels - Structural I [4,5]	5/16	1-1/4	6d common nail (2 x 0.113 x 0.266) [8]	560	13	10	840	18	13	1090	23	16	1430	35	22
	3/8 [2]	1-3/8	8d common nail (2-1/2 x 0.131 x 0.281) [8]	645	19	14	1010	24	17	1290	30	20	1710	43	24
	7/16 [2]			715	16	13	1105	21	16	1415	27	19	1875	40	24
	15/32			785	14	11	1205	18	14	1540	24	17	2045	37	23
	15/32	1-1/2	10d common nail (3 x 0.148 x 0.312) [8,10]	950	22	16	1430	29	20	1860	36	22	2435	51	28
	5/16	1-1/4	6d common nail (2 x 0.113 x 0.266) [8]	505	13	9.5	755	18	12	980	24	14	1260	37	18
	3/8			560	11	8.5	840	15	11	1090	20	13	1430	32	17

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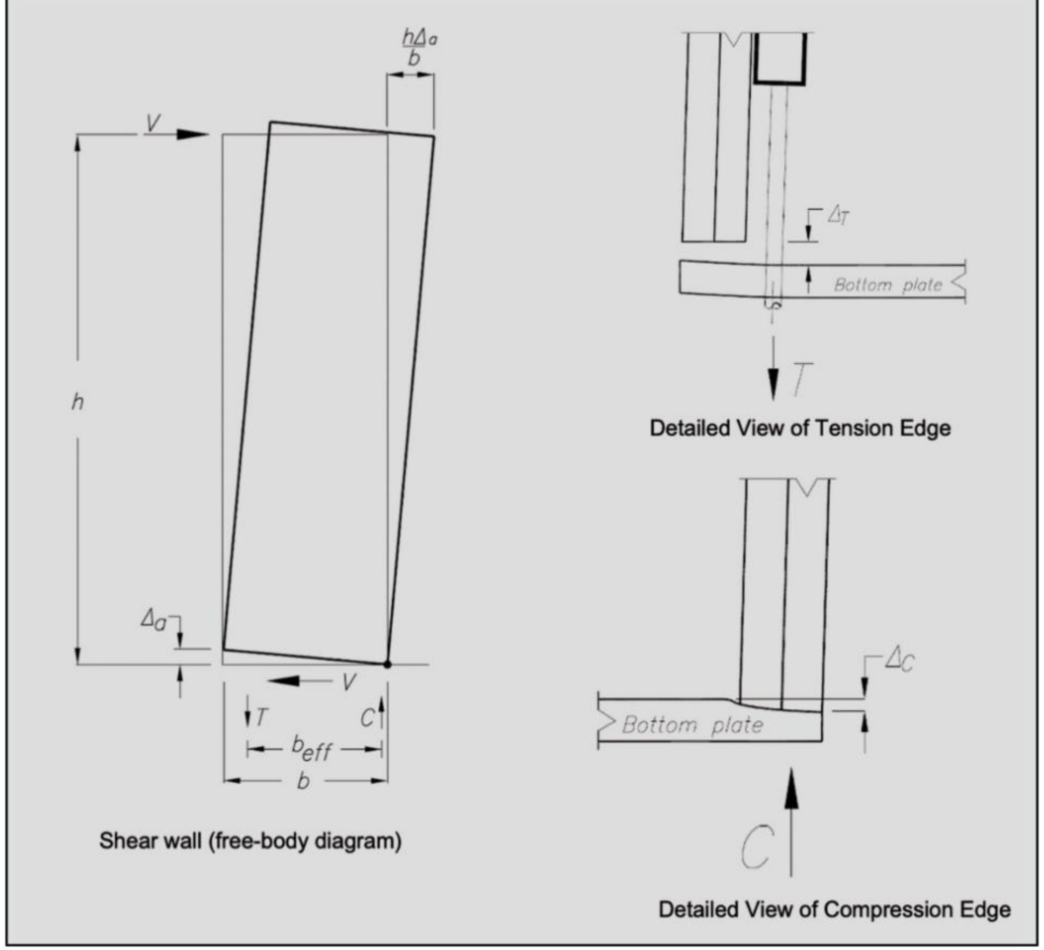
Wood Design: Shear Walls

- Deflection: Calculation of Δ_a
  - $\Delta_a = (\Delta_T + \Delta_C) * \frac{b}{b_{eff}}$
    - $b = 12ft$
    - $b_{eff} = 12ft - \frac{4.5in}{2} - \left(4.5in + 1\frac{3}{8}in\right) = 11.3ft$
    - $\Delta_T = 0.113in$ (per manufacturer)
    - Δ_C:
      - $c_{post,L1-L2} = 7{,}500lb/24.75in^2 = 303psi$
      - At $0.73 * F_{c\perp}$, $\Delta_{0.02} = 0.02in$ (NDS 4.2.6)
      - $F_{c\perp} = 625psi \rightarrow 0.73 * F_{c\perp} = 456psi$
      - $\Delta_C = \Delta_{0.02} * \frac{c_{post,L1-L2}}{0.73 * F_{c\perp}} = 0.02 * \frac{303psi}{456psi} = 0.013in$

$$\rightarrow \Delta_a = (0.113in + 0.013in) * \frac{12ft}{11.3ft} = 0.134in$$

Figure C4.3.4B **Rigid Body Overturning Component of Shear Wall Deflection**



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Wood Design: Shear Walls

- Deflection: Calculation of Δ_a
  - $\Delta_a = (\Delta_T + \Delta_C) * \frac{b}{b_{eff}}$
    - $b = 12ft$
    - $b_{eff} = 12ft - \frac{4.5in}{2} - \left(4.5in + 1\frac{3}{8}in\right) = 11.3ft$
    - $\Delta_T = 0.113in$ (per manufacturer)
    - Δ_C:
      - $c_{post,L1-L2} = 7{,}500lb/24.75in^2 \ = 303psi$
      - At $0.73 * F_{c\perp}$, $\Delta_{0.02} = 0.02in$ (NDS 4.2.6)
      - $F_{c\perp} = 625psi \rightarrow 0.73 * F_{c\perp} = 456psi$
      - $\Delta_C = \Delta_{0.02} * \frac{c_{post,L1-L2}}{0.73 * F_{c\perp}} = 0.02 * \frac{303psi}{456psi} = 0.013in$

$$\rightarrow \Delta_a = (0.113in + 0.013in) * \frac{12ft}{11.3ft} = 0.134in$$

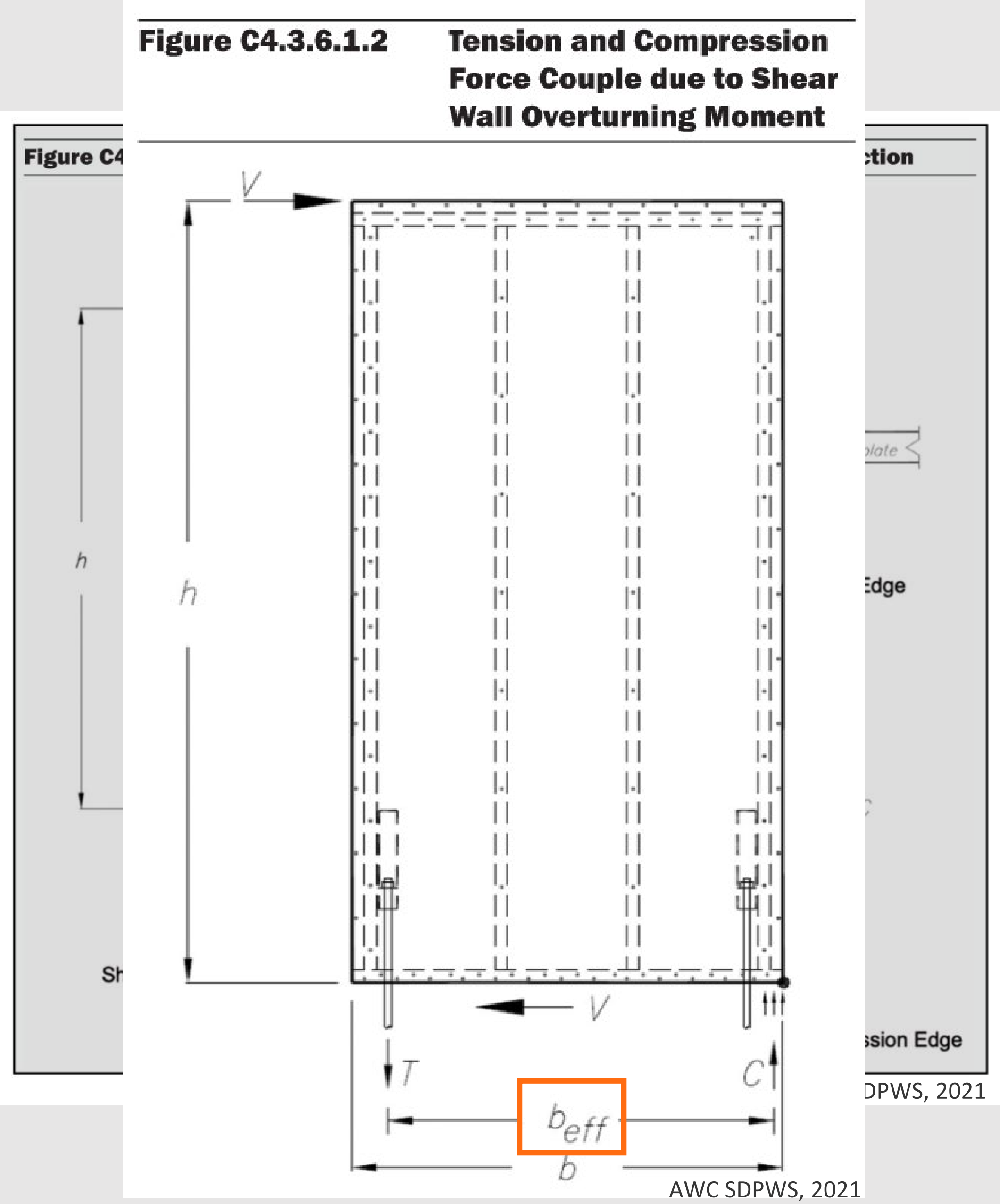

Figure C4.3.6.1.2 **Tension and Compression Force Couple due to Shear Wall Overturning Moment**

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Design Example: Shear Walls

- Deflection: $\delta_{sw} = \frac{8*v*h^3}{E*A*b} + \frac{v*h}{1{,}000*G_a} + \frac{h*\Delta_a}{b}$ (SPDWS Equation 4.3-1)
  - End post deformation: $\frac{8*v*h^3}{E*A*b} = \frac{8*563plf*(9ft)^3}{1{,}600{,}000psi*24.75in^2*12ft} = 0.007in$
  - Panel shear + nail slip: $\frac{v*h}{1{,}000*G_a} = \frac{563plf*9ft}{1{,}000*24kips/in} = 0.211in$
  - Wall anchorage deformation: $\frac{h*\Delta_a}{b} = \frac{9ft*0.134in}{12ft} = 0.101in$
- $\delta_{sw} = 0.007in + 0.211in + 0.101in = 0.32in$
- Deflection check for Seismic must be performed using <u>strength level</u> design loads (multiply ASD loads by 1.4)

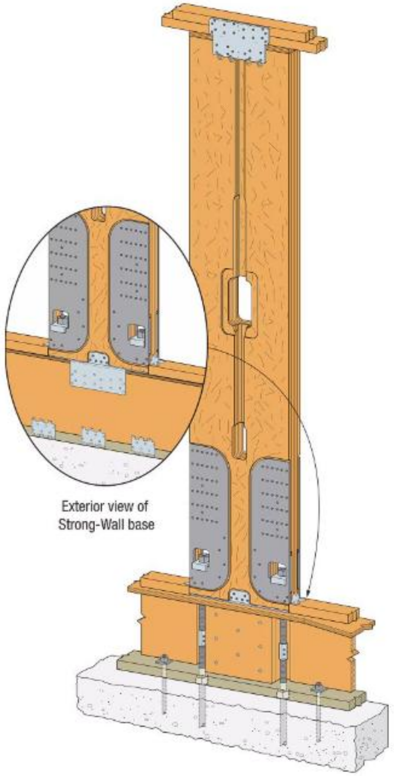
Outline

- Lateral Design Introduction
- Diaphragms
- Shear Walls
- **Other Lateral Options**

Wood Design: Other Lateral Options

Proprietary Systems

- Panels
- Braced Frames
- Portal Frames



Simpson Strong-Tie
Strong-Wall

MiTek
Hardy Frame Panel

Simpson Strong-Tie
Strong-Wall

MiTek
Hardy Frame Braced Frame

Wood Design: Other Lateral Options

Heavy Timber Braced Frames

Apex Plaza, William McDonough + Partners,
Simpson Gumpertz & Heger, photo Prakash Patel

Wood Design: Other Lateral Options

Wood/Steel Hybrid Systems

MSU STEM Teaching and Learning Facility / Integrated Design Solutions / SDI Structures / Photo Kevin Marshall/Integrated Design Solutions

Wood Design: Other Lateral Options

Mass Timber Panels

340+ Dixwell / GOA / ODEH Engineers - WSP / Photo GOA

Wood Design: Other Lateral Options

Concrete or Masonry Cores

1510 Webster / oWow / DCI Engineers / Photo Flor Projects

QUESTIONS?

This concludes The American Institute of Architects Continuing Education Systems Course

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Funding provided in part by the Softwood Lumber Board

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