AMERICAN WOOD COUNCIL

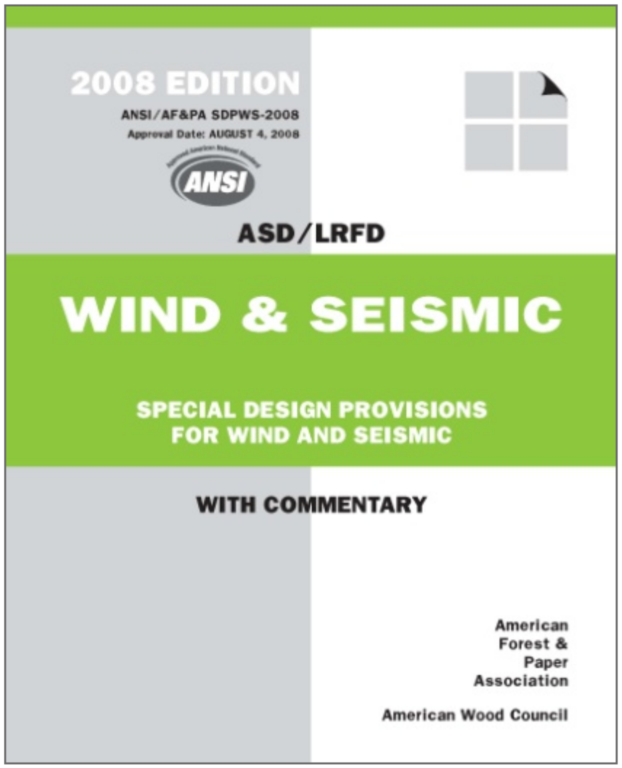
Shearwall Basics Using SDPWS

American Wood Council

Copyright Materials

SDPWS and IBC

2008 SDPWS is referenced in 2012 IBC



2012 IBC

SECTION 2305 GENERAL DESIGN REQUIREMENTS FOR LATERAL FORCE-RESISTING SYSTEMS

2305.1 General. Structures using **wood-frame shear walls or wood-frame diaphragms to resist wind, seismic or other lateral loads shall be designed and constructed in accordance with AF&PA SDPWS** and the applicable provisions of Sections 2305, 2306 and 2307.

Significant Changes to 2012 IBC

2306.3 ~~Wood structural panel shear walls.~~ Wood-frame shear walls. ~~Wood structural panel~~ Wood-frame shear walls shall be designed and constructed in accordance with AF&PA SDPWS. ~~Wood structural panel shear walls are permitted to resist horizontal forces using the allowable capacities~~ Where panels are fastened to framing members with staples, requirements and limitations of AF&PA SDPWS shall be met and the allowable shear values set forth in Table ~~2306.3.~~ 2306.3(1), 2306.3(2) or 2306.3(3) shall be permitted. ~~Allowable capacities in Table 2306.3~~ The allowable shear values in Tables 2306.3(1) and 2306.3(2) are permitted to be increased 40 percent for wind design. Panels complying with ANSI/APA PRP-210 shall be permitted to use design values for Plywood Siding in the AF&PA SDPWS.

NEW ANSI/APA PRP-210 Plywood Siding

- **Durability**
- **Thickness by thickness**
- **Siding shear walls**

Significant Changes to 2012 IBC

- **Shear wall deflection with staples**
- **~~Wood structural panels~~ Wood-frame**
- **Allowable shear tables –~~nails and~~ staples only**
- **SDPWS**

2305.3 Shear wall deflection. The deflection of wood-frame shear walls shall be determined in accordance with AF&PA SDPWS. The deflection (Δ) of a blocked wood structural panel shear wall uniformly fastened throughout with staples is permitted to be calculated in accordance with Equation 23-2.

$$\Delta = \frac{8vh^3}{EAb} + \frac{vh}{Gt} + 0.75he_n + d_a\frac{h}{b} \qquad \textbf{(Equation 23-2)}$$

Significant Changes to 2012 IBC

4.3.7 Shear Wall Systems

4.3.7.1 Wood Structural Panel Shear Walls: Shear walls sheathed with wood structural panel sheathing shall be permitted to be used to resist seismic and wind forces. The size and spacing of fasteners at shear wall boundaries and panel edges shall be as provided in Table 4.3A. The shear wall shall be constructed as follows:

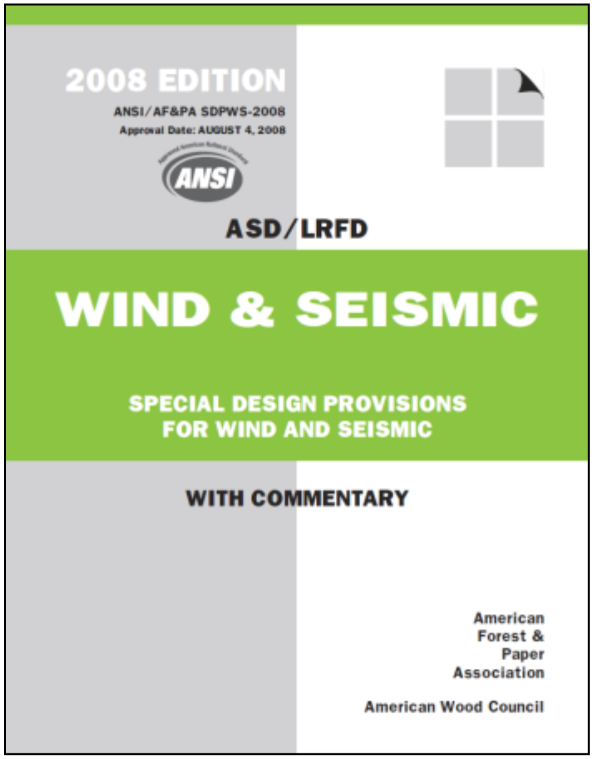
4. The width of the nailed face of framing members and blocking shall be 2" nominal or greater at adjoining panel edges except that a 3" nominal or greater width at adjoining panel edges and staggered nailing at all panel edges are required where:
   a. Nail spacing of 2" on center or less at adjoining panel edges is specified, or
   b. 10d common nails having penetration into framing members and blocking of more than 1-1/2" are specified at 3" on center, or less at adjoining panel edges, or
   c. Required nominal unit shear capacity on either side of the shear wall exceeds 700 plf in Seismic Design Category D, E, or F.

Exception: Where the width of the nailed face of framing members is required to be 3" nominal, two framing members that are 2" in nominal thickness shall be permitted to be used provided they are fastened together with fasteners designed in accordance with the *NDS* to transfer the induced shear between members. When fasteners connecting the two framing members are spaced less than 4" on center, they shall be staggered.

SDPWS

2008 SDPWS

- **Engineered**
- **Res and Non-Res**
- **ASD & LRFD**
- **Efficiencies in designs**
- **Shear wall provisions**
  - **Segmented**
  - **Perforated**
  - **Force Transfer Around Openings**



Chapter 4 – Nominal Design Value

- Wind nominal unit shear capacity v_w
  - IBC allowable stress design value x 2.8
- Seismic nominal unit shear capacity v_s
  - $v_s = v_w / 1.4$

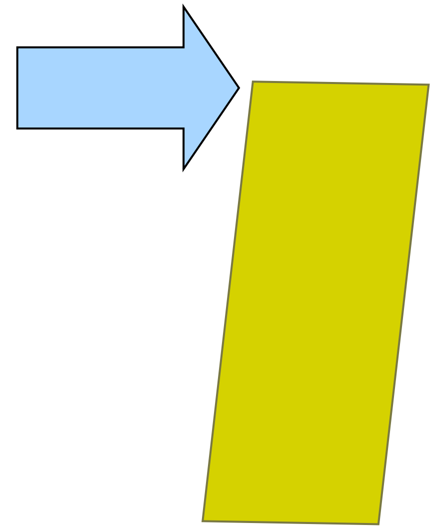
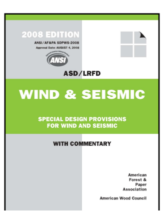


Table 4.3A Nominal Unit Shear Capacities for Wood-Frame Shear Walls[1,3]

Wood-based Panels (Excluding Plywood for G_a)[4]

Sheathing Material	Minimum Nominal Panel Thickness (in.)	Minimum Fastener Penetration in Framing (in.)	Fastener Type & Size	A SEISMIC Panel Edge Fastener Spacing (in.)								B WIND 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]	5/16	1-1/4	Nail (common or galvanized box) 6d	400	13.0	600	18.0	780	23.0	1020	35.0	560	840	1090	1430
	3/8[2]	1-3/8	8d	460	19.0	720	24.0	920	30.0	1220	43.0	645	1010	1290	1710
	7/16[2]			510	16.0	790	21.0	1010	27.0	1340	40.0	715	1105	1415	1875
	15/32			560	14.0	860	18.0	1100	24.0	1460	37.0	785	1205	1540	2045
	15/32	1-1/2	10d	680	22.0	1020	29.0	1330	36.0	1740	51.0	950	1430	1860	2435



Adjustment for Design Level

Nominal unit shear values adjusted in accordance with <u>4.3.3</u> to determine ASD allowable unit shear capacity and LRFD factored unit resistance.

ASD unit shear capacity, v_s:

v_s = 510 plf / 2.0 = 255 plf

ASD reduction factor

Reference nominal value

LRFD unit shear capacity, v_s:

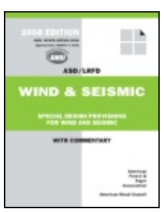
v_s = 510 plf x 0.80 = 408 plf

LRFD resistance factor

Reference nominal value

4.3.3 Unit Shear Capacities

The ASD allowable unit shear capacity shall be determined by dividing the tabulated nominal unit shear capacity, modified by applicable footnotes, by the ASD reduction factor of 2.0. The LRFD factored unit resistance shall be determined by multiplying the tabulated nominal unit shear capacity, modified by applicable footnotes, by a resistance factor, ϕ_D, of 0.80. No further increases shall be permitted.

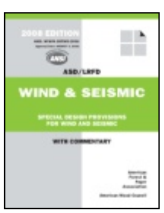


Adjustment for Framing G

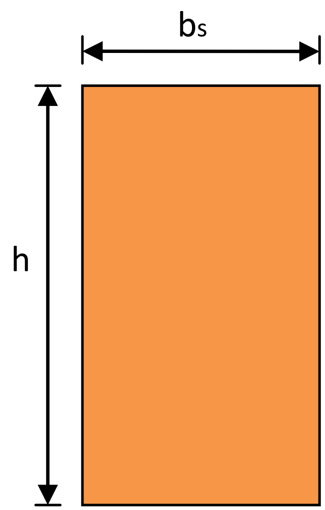
- **Reduced nominal unit shear capacities determined by multiplying the tabulated nominal unit shear capacity by the Specific Gravity Adjustment Factor**
  - SG Adjustment Factor = $[1.0-(0.50-G)] < 1.0$

- **Example SG Adjustment Factors**

Species Combination	**Specific Gravity, G**	**FACTOR = 1.0 - (0.50 - G)**
Southern Pine	0.55	1.00
Douglas Fir-Larch	0.50	1.00
Hem Fir	0.43	0.93
Spruce Pine-Fir	0.42	0.92
Western Woods	0.36	0.86



Adjustment for Aspect Ratio



Aspect Ratio: h:b_s

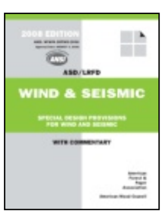
For wood structural panel <u>resisting seismic</u> where 2:1 < h:b_s $\leq$ 3.5:1,

multiply v_s by $2b_s/h$

Table 4.3.4 Maximum Shear Wall Aspect Ratios

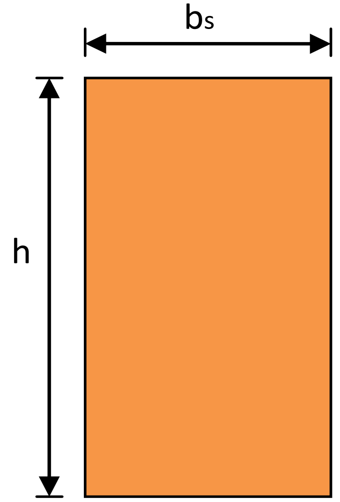
Shear Wall Sheathing Type	Maximum h/b_s Ratio
Wood structural panels, unblocked	2:1
Wood structural panels, blocked	3.5:1[1]
Particleboard, blocked	2:1
Diagonal sheathing, conventional	2:1
Gypsum wallboard	2:1[2]
Portland cement plaster	2:1[2]
Structural Fiberboard	3.5:1[3]

1 For design to resist seismic forces, the shear wall aspect ratio shall not exceed 2:1 unless the nominal unit shear capacity is multiplied by $2b_s/h$.
2 Walls having aspect ratios exceeding 1.5:1 shall be blocked shear walls.
3 For design to resist seismic forces, the shear wall aspect ratio shall not exceed 1:1 unless the nominal unit shear capacity is multiplied by the Aspect Ratio Factor (Seismic) = $0.1+0.9b_s/h$. The value of the Aspect Ratio Factor (Seismic) shall not be greater than 1.0. For design to resist wind forces, the shear wall aspect ratio shall not exceed 1:1 unless the nominal unit shear capacity is multiplied by the Aspect Ratio Factor (Wind) = $1.09-0.09h/b_s$. The value of the Aspect Ratio Factor (Wind) shall not be greater than 1.0.



Adjustment for Aspect Ratio

Example aspect ratio factors for wood structural panel

Shear wall height, h, and width, b_s	h, (ft)	b_s, (ft)	h/b_s	ASPECT RATIO FACTOR = $2b_s/h$
	8	4	2	1.00
	8	3.2	2.5	0.80
	8	2.7	3	0.67
	8	2.3	3.5	0.57

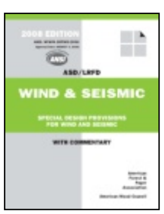


Table Footnotes are Important

1. Nominal unit shear values shall be adjusted in accordance with 4.3.3 to determine ASD allowable unit shear capacity and LRFD factored unit resistance. For general construction requirements see 4.3.6. For specific requirements, see 4.3.7.1 for wood structural panel shear walls, 4.3.7.2 for particleboard shear walls, and 4.3.7.3 for fiberboard shear walls. See Appendix A for common and box nail dimensions.

2. Shears are permitted to be increased to values shown for 15/32 inch sheathing with same nailing provided (a) studs are spaced a maximum of 16 inches on center, or (b) panels are applied with long dimension across studs.

3. For species and grades of framing other than Douglas-Fir-Larch or Southern Pine, reduced nominal unit shear capacities shall be determined by multiplying the tabulated nominal unit shear capacity by the Specific Gravity Adjustment Factor = [1-(0.5-G)], where G = Specific Gravity of the framing lumber from the NDS (Table 11.3.2A). The Specific Gravity Adjustment Factor shall not be greater than 1.

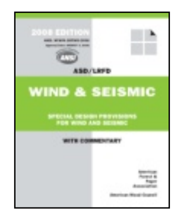
Table Footnotes are Important

4. Apparent shear stiffness values Ga, are based on nail slip in framing with moisture content less than or equal to 19% at time of fabrication and panel stiffness values for shear walls constructed with either OSB or 3-ply plywood panels. When 4-ply or 5-ply plywood panels or composite panels are used, Ga values shall be permitted to be increased by 1.2.

5. Where moisture content of the framing is greater than 19% at time of fabrication, Ga values shall be multiplied by 0.5.

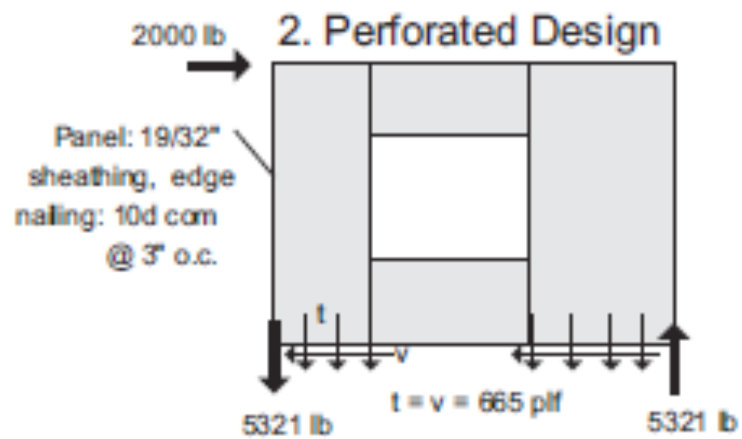
6. Where panels are applied on both faces of a shear wall and nail spacing is less than 6 in. on center on either side, panel joints shall be offset to fall on different framing members. Alternatively, the width of the nailed face of framing members shall be 3 in. nominal or greater at adjoining panel edges and nails at all panel edges shall be staggered.

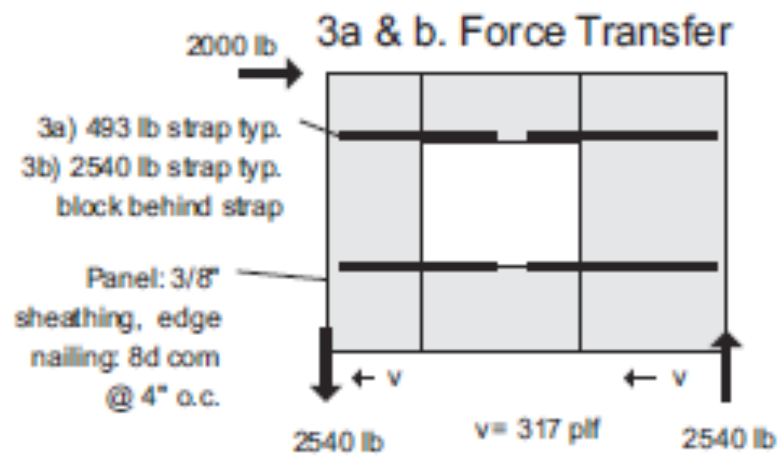
7. Galvanized nails shall be hot-dipped or tumbled.

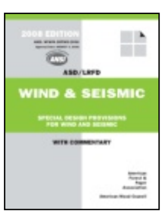


Additional Resources

- **Force transfer around openings**
  - Design of Wood Structural Panel Shear Walls with Openings - a Comparison of Methods; Wood Design Focus 2005
  - Design of Wood Structures; McGraw Hill 2007
- **Perforated shear wall method**
  - Perforated Shear Wall Design; Wood Design Focus Spring 2002



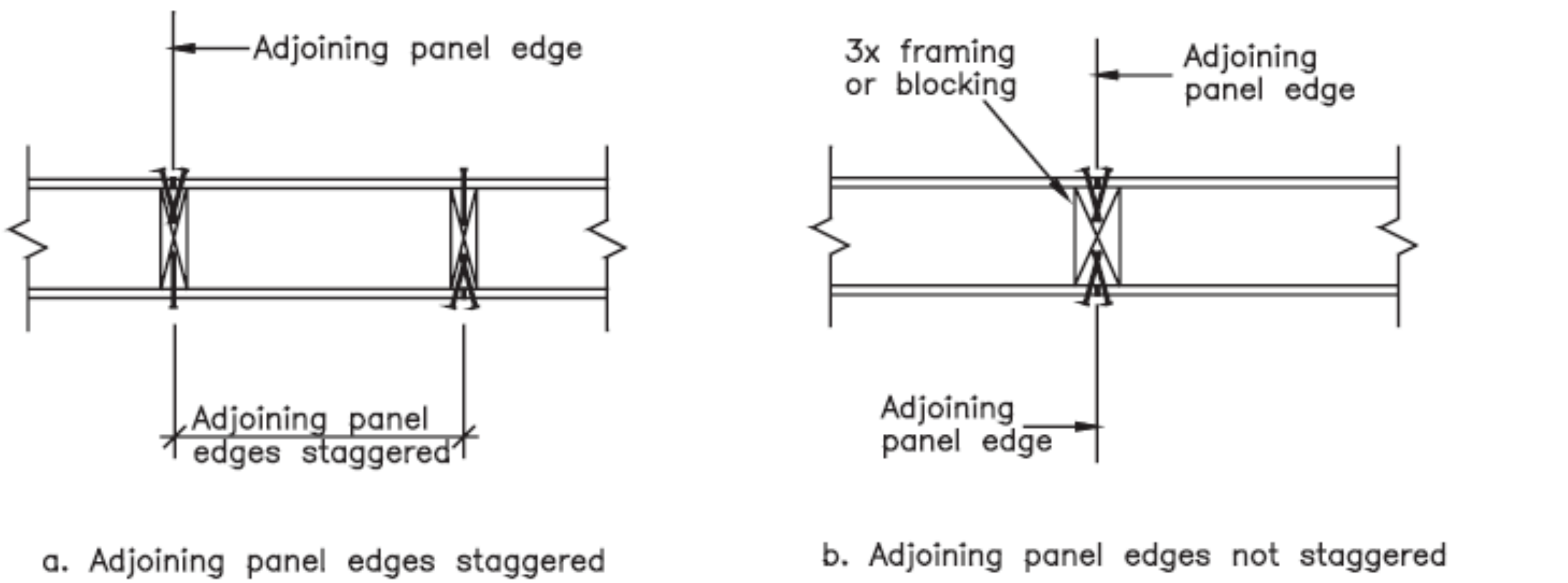


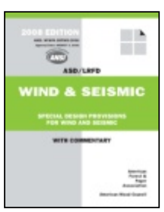


3x at Adjoining Panel Edge

Table 4.3A footnote 6. 3x framing required to reduce potential for splitting at <u>adjoining panel edge</u> where WSP is nailed on each face and nail spacing is less than 6 in. o.c.

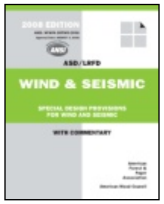
Figure C4.3.3 Detail for Adjoining Panel Edges where Structural Panels are Applied to Both Faces of the Wall



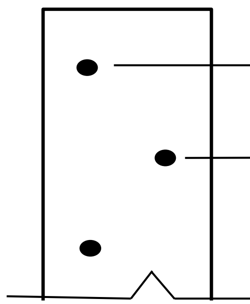


3x at Adjoining Panel Edge

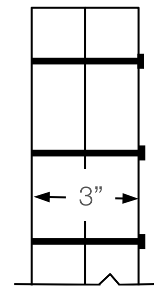
- **Section 4.3.7.1(4). 3x framing also required at adjoining panel edges where:**
  - **Nail spacing of 2 in. o.c.**
  - **10d common nails having penetration of more than 1-1/2 in. at 3 in. o.c. or less**
  - **Nominal unit shear capacity on either side exceeds 700 plf in SDC D, E, or F.**
- **Exception: (2) 2x framing permitted in lieu of (1) 3x where fastened in accordance with the NDS to transfer the induced shear between members.**



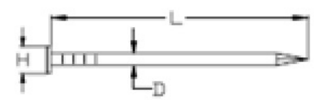
(2) 2x At Adjoining Panel Edge



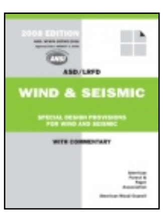
Fastener spacing – 2x stud to 2x stud connection



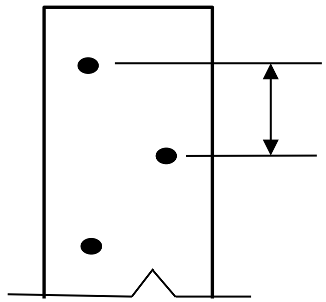
Approximate stud to stud connection spacing for wood structural panel (WSP) walls sheathed on one side.

Nail size and sheathing	**Sheathing to frame lateral value per NDS (G=0.5 framing)**	 **Fastener spacing (in.) for 2x stud-to-2x stud connection (10d common nail, Z = 118 lbf)**			
		Panel edge nail spacing (in.)			
	Z (lbf)	**6**	**4**	**3**	**2**
6d common, 3/8" WSP (G=0.5)	54	12.0	8.0	6.0	4.0
8d common, 3/8" WSP (G=0.5)	71	9.1	6.1	4.5	3.0
8d common, 7/16" WSP (G=0.5)	73	8.8	5.9	4.4	2.9
10d common, 19/32" WSP (G=0.42)	95	6.8	4.5	3.4	2.3

* Spacing based on 8' wall and assuming only 87.5" of stud height available for stud-to-stud fastening.



(2) 2x At Adjoining Panel Edge



Fastener spacing – 2x stud to 2x stud connection

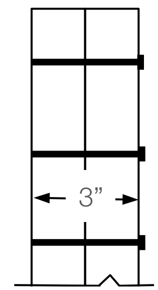
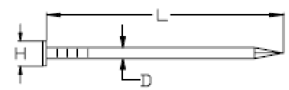
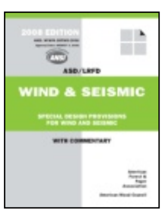


Table. Approximate stud to stud connection spacing for wood structural panel (WSP) walls sheathed on one side.

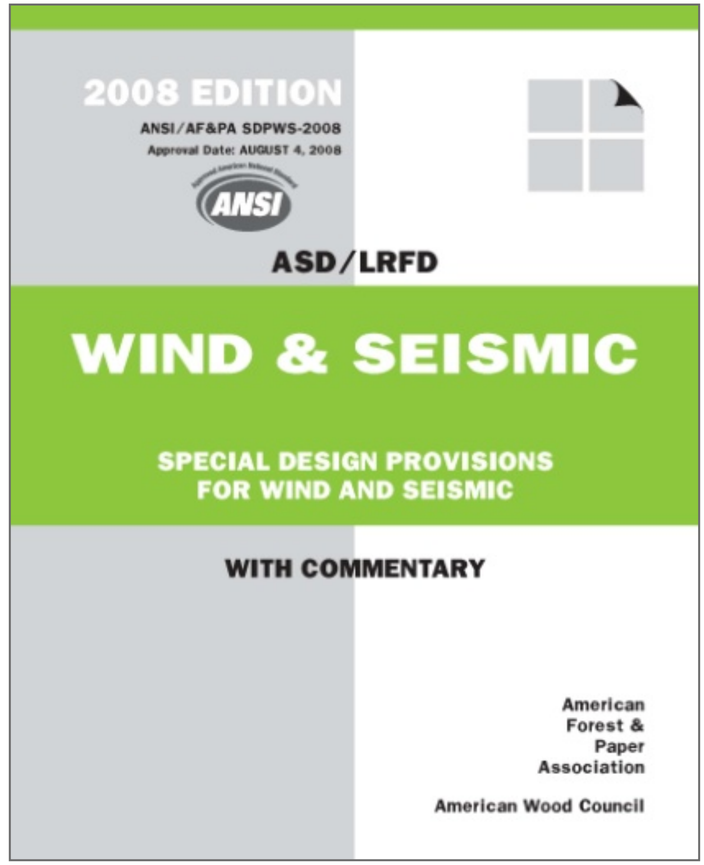
Nail size and sheathing	Sheathing to frame lateral value per NDS (G =0.5 framing)	 Fastener spacing (in.) for 2x stud-to-2x stud connection (10d common nail, Z = 118 lbf)				 Fastener spacing (in.) for 2x stud-to-2x stud connection (SDS 1/4 x 3, Z = 280 lbf)			
		Panel edge nail spacing (in.)				Panel edge nail spacing (in.)			
	Z (lbf)	6	4	3	2	6	4	3	2
6d common, 3/8" WSP (G=0.5)	54	12.0	8.0	6.0	4.0	28.4	18.9	14.2	9.5
8d common, 3/8" WSP (G=0.5)	71	9.1	6.1	4.5	3.0	21.6	14.4	10.8	7.2
8d common, 7/16" WSP (G=0.5)	73	8.8	5.9	4.4	2.9	21.0	14.0	10.5	7.0
10d common, 19/32" WSP (G=0.42)	95	6.8	4.5	3.4	2.3	16.1	10.7	8.1	5.4

*Spacing based on 8' wall height and assuming only 87.5" of stud height available for stud-to-stud fastening.



(2) 2x at Adjoining Panel Edges

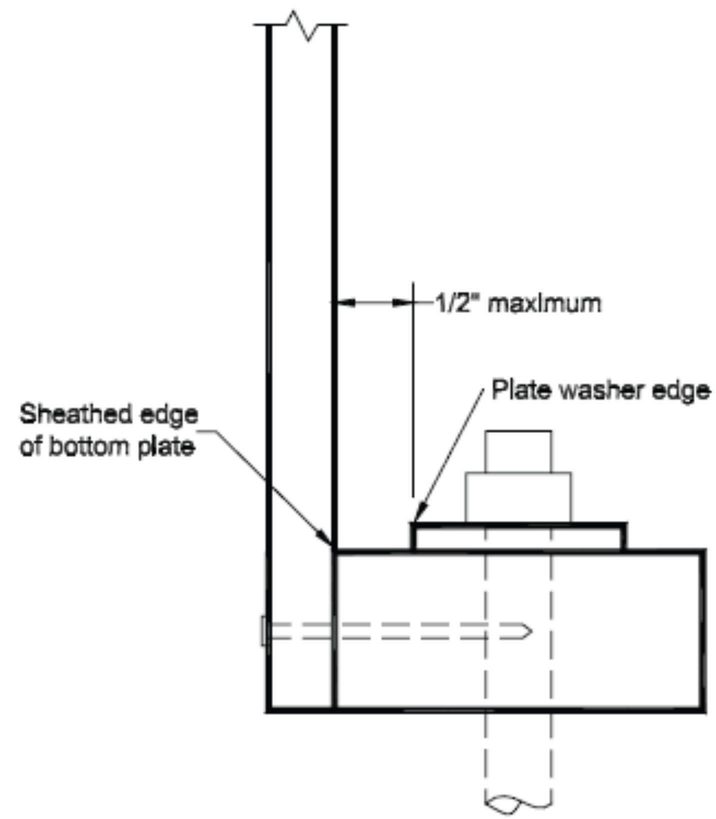
C4.3.7.1(4): A single 3x framing member is specified at adjoining panel edges for cases prone to splitting and where nominal unit shear capacity exceeds 700 plf in seismic design categories (SDC) D, E, and F. An alternative to single 3x framing, included in *SDPWS*, and based on principles of mechanics, is the use of 2-2x "stitched" members adequately fastened together. Cyclic tests of shear walls confirms that use of 2-2x members nailed (22, 25, and 30) or screwed (33) together results in shear wall performance that is comparable to that obtained by use of a single 3x member at the adjoining panel edge. Attachment of the 2-2x members to each other is required to equal or exceed design unit shear forces in the shear wall. As an alternative, a capacity-based design approach can be used where the connection between the 2-2x members equals or exceeds the capacity of the sheathing to framing attachment. Where fastener spacing in the "stitched" members at adjoining panel edges is closer than 4″ on center, staggered placement is required.

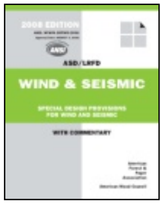


Foundation Bottom Plate

- **Plate washer**
  - **Must extend to within ½ in. of sheathed edge of bottom plate**
- **Exceptions**
  - **Lower capacity sheathing materials (nominal unit shear is 400 plf or less)**
  - **Hold-downs are sized for full overturning – neglecting dead load**

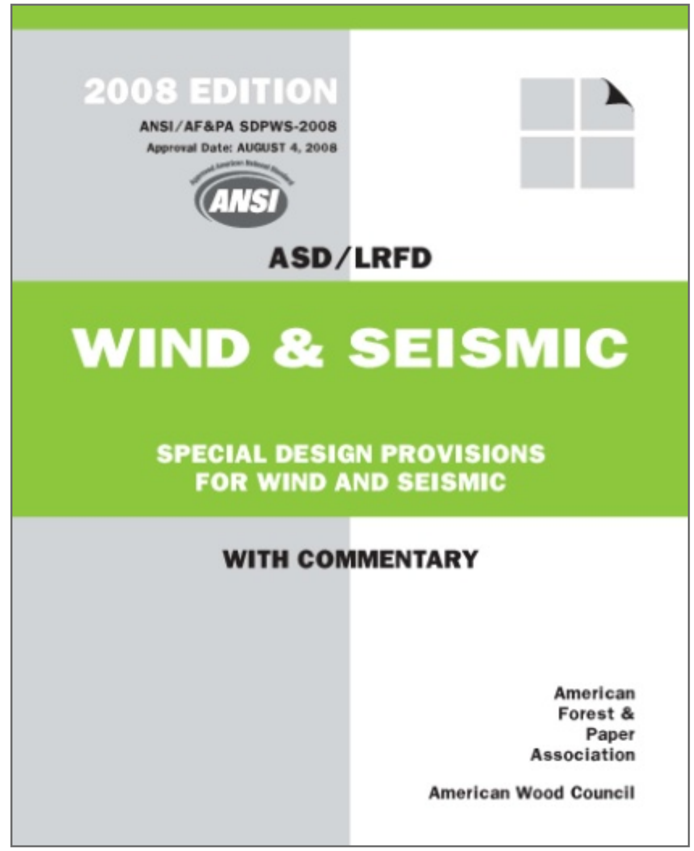
Figure C4.3.6.4.3 Distance for Plate Washer Edge to Sheathed Edge





Minimum Panel Width

- **Blocked wood structural panel shear wall**
  - no minimum panel width
  - SDPWS 4.3.7.1
  - “Panels shall not be less than 4 ft x 8 ft, except at boundaries and changes in framing. All edges of all panels shall be supported by and fastened to members or blocking”



Questions?

www.awc.org

info@awc.org

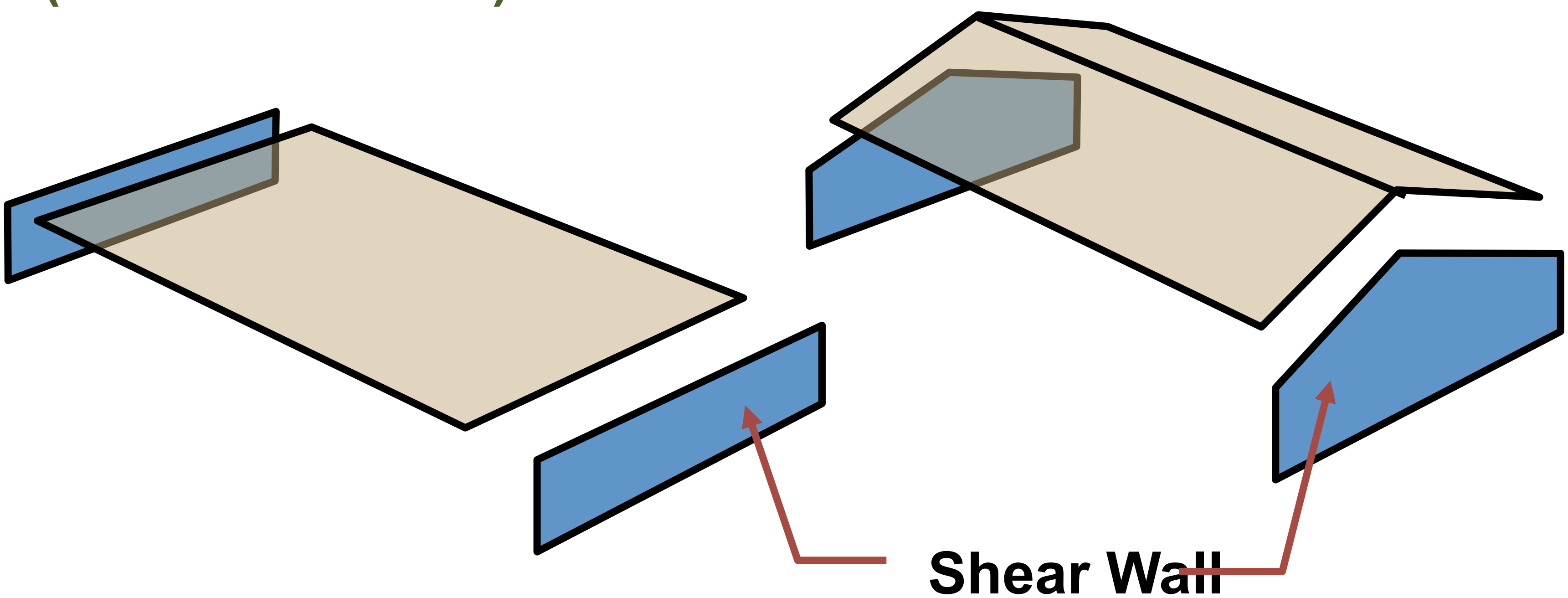
AMERICAN WOOD COUNCIL

Shear Wall Design for Non-Residential and Multi-Family Buildings

Code Definitions

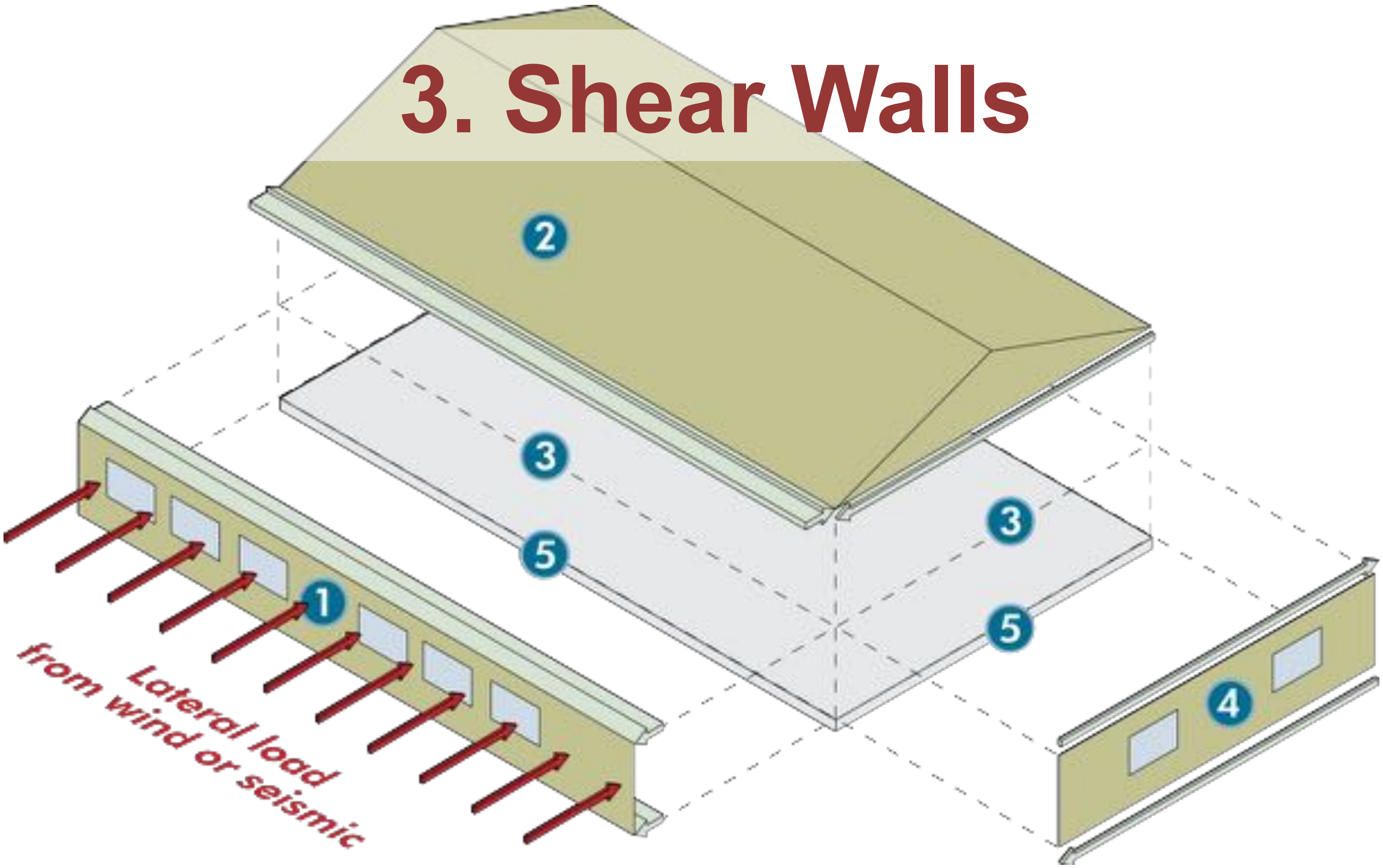
Shear Wall

- A wall designed to resist lateral forces parallel to the plane of wall (IBC Sec. 2302.1)



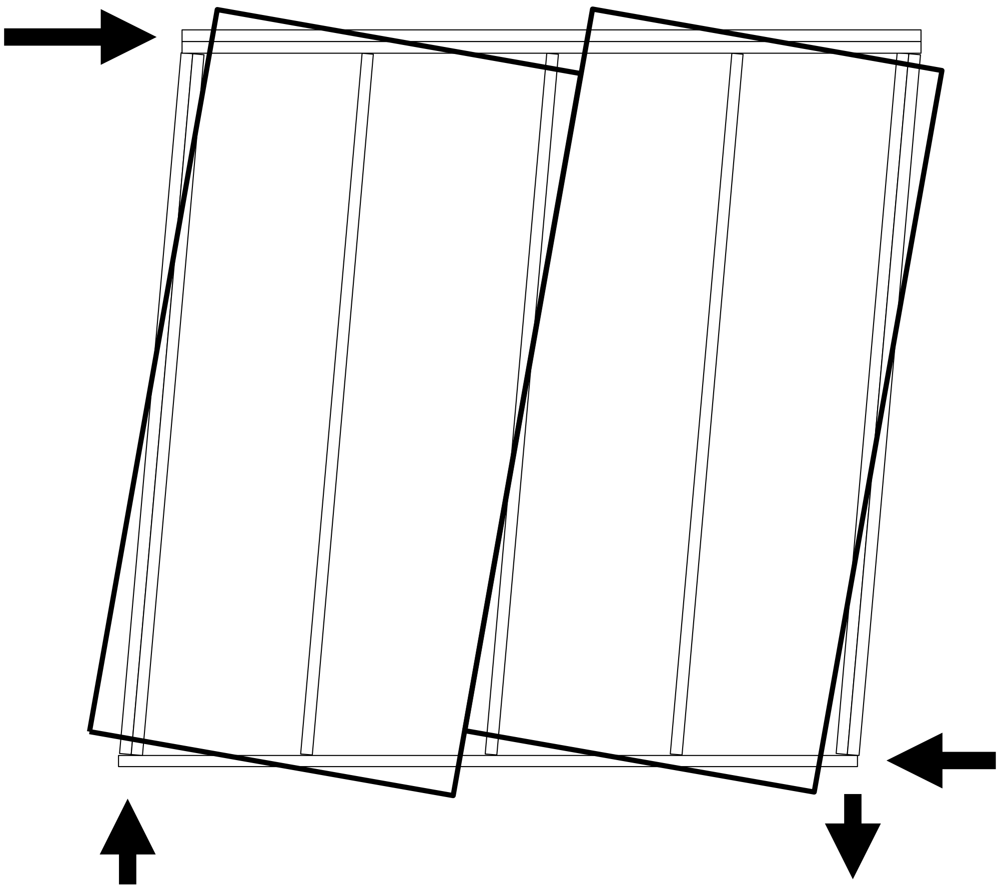
Load Path Components

3. Shear Walls



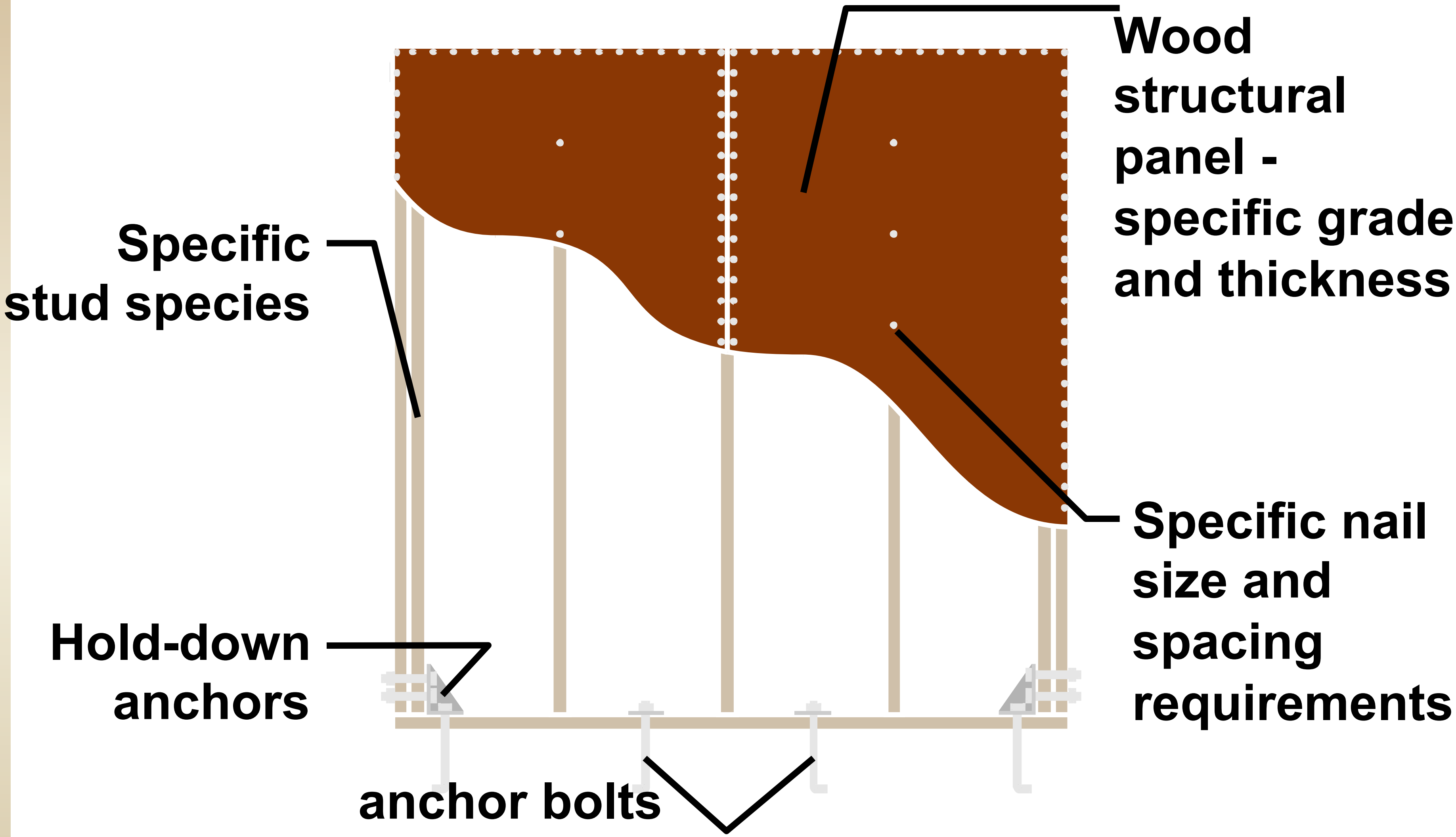
Shear Wall Design: Loads

- Nailing from panels to framing resists shear in wall



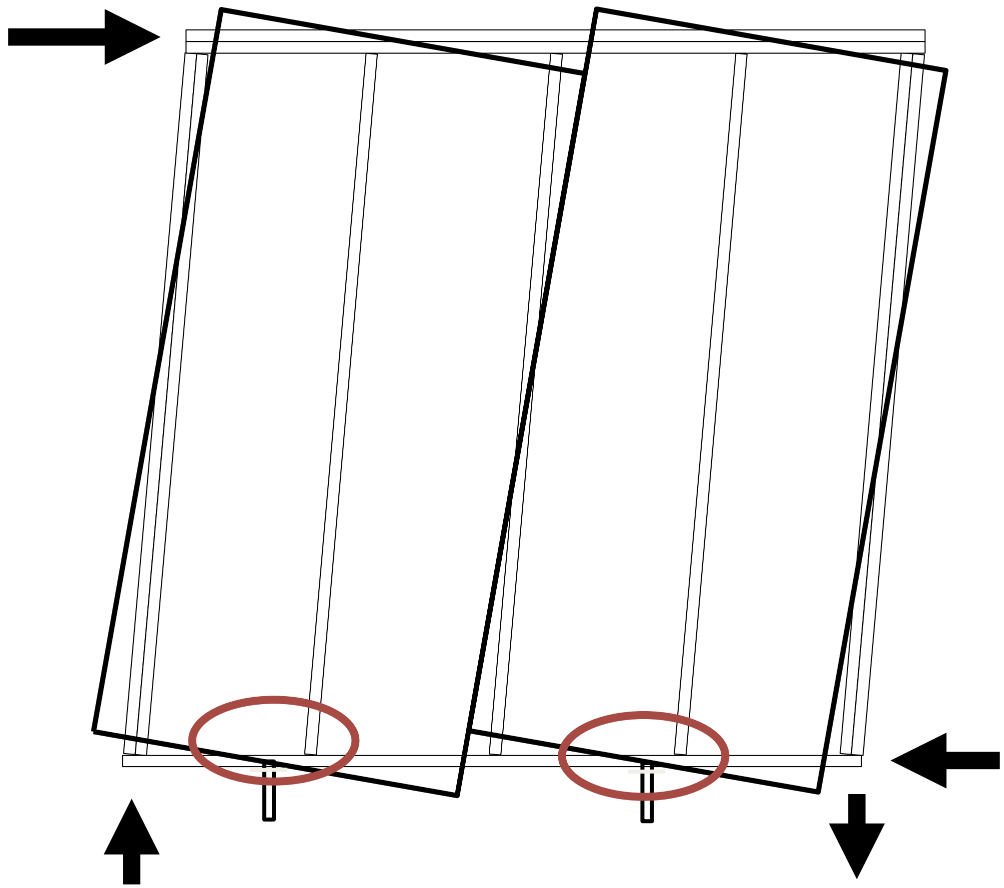
Failure Mode

Shear Wall Design



Shear Wall Design: Loads

- Anchor bolts resist base shear

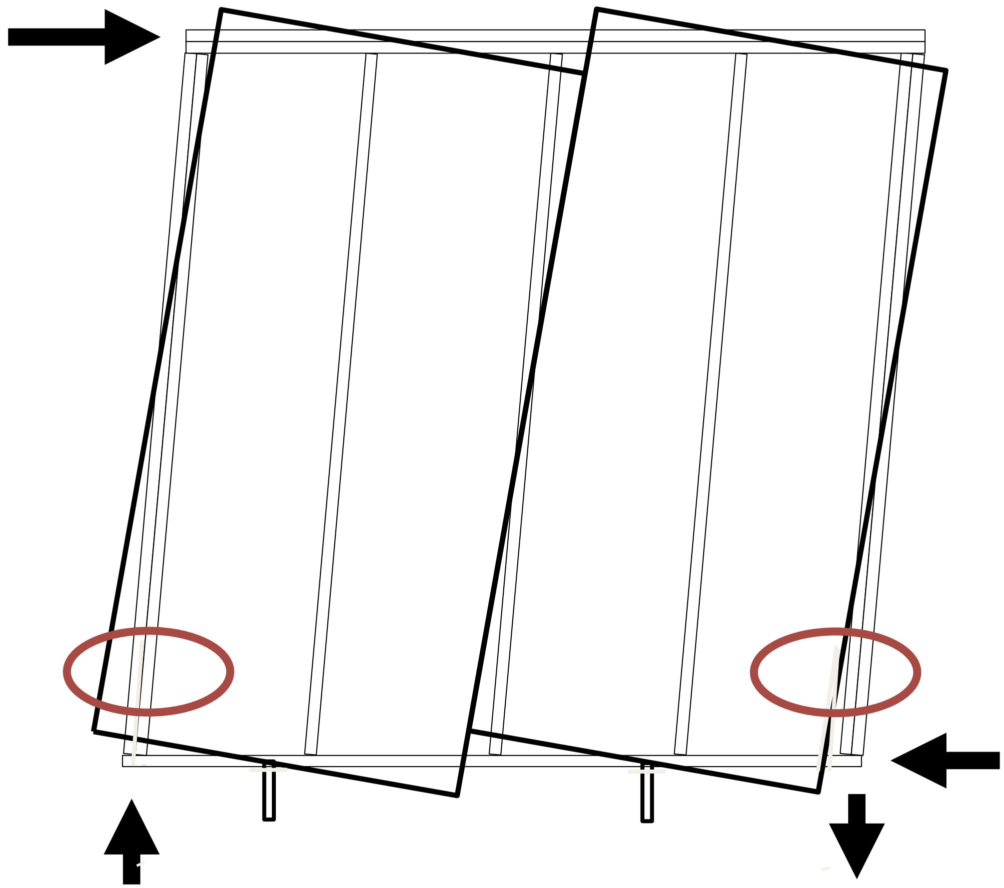


Foundation Anchorage

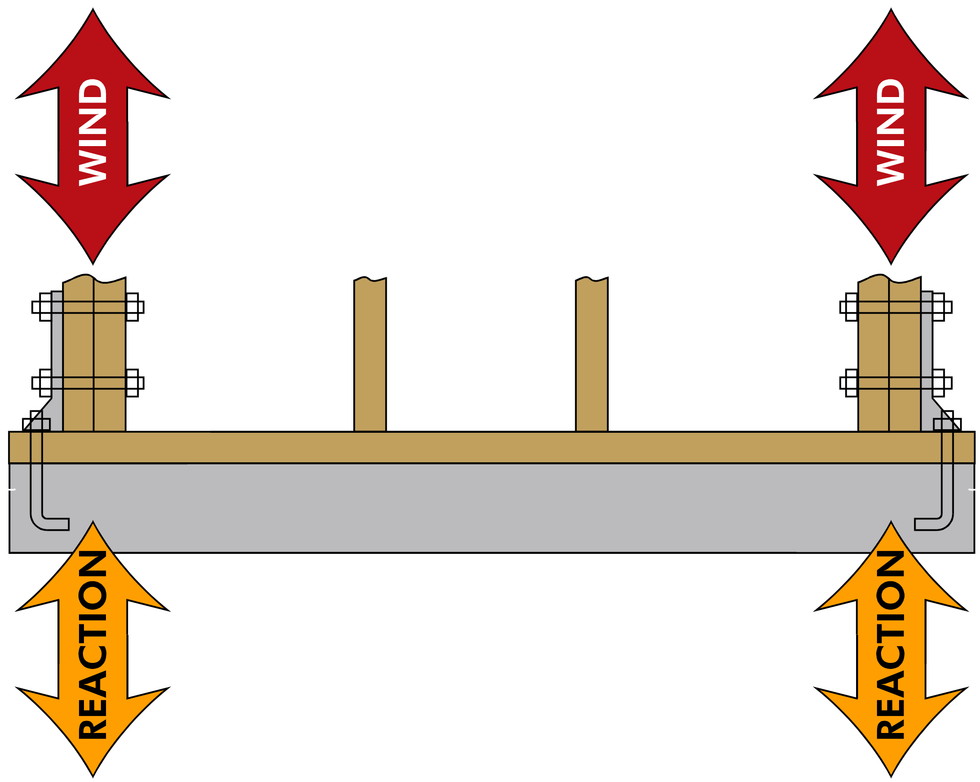
Hurricane Katrina

Shear Wall Design: Loads

- **Hold downs resist overturning**



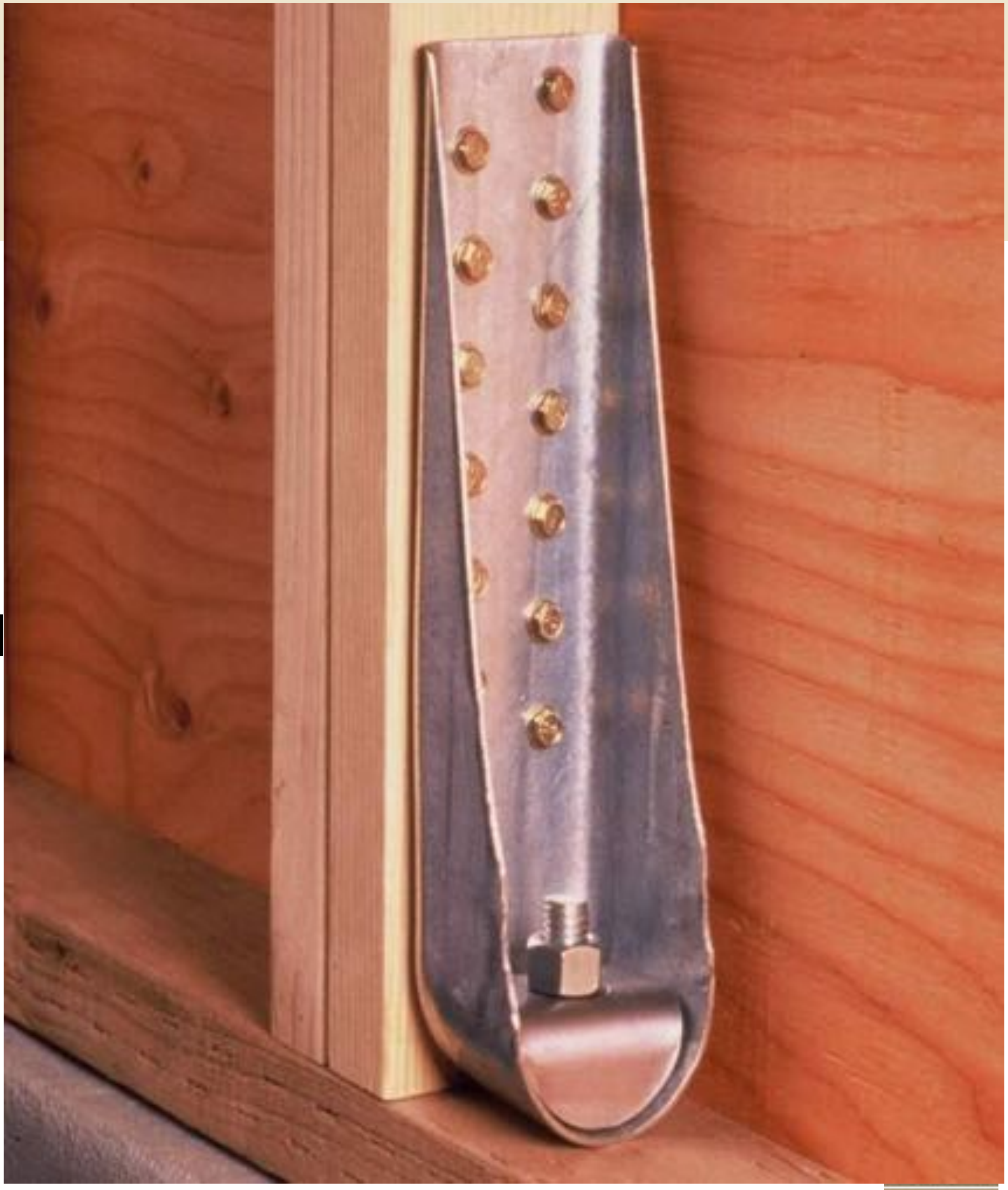
Shearwall Hold-Down Anchors



Hold-down Anchor

Hold-down Anchor

- Low-slip fasteners
- Pre-deformed base
- A plus in seismic load



Hold-down Anchor

- Multi-story apps.
- Self-tightening
- A plus in taller structures

Typ. Failure Modes – Edge Tear, Nail Yield, Nail Pull Through

Typ. Failure Modes – Nails Worked in Lumber

Typ. Failure Modes – Nails Yield

End Post (Chord) Failure

End Post (Chord) Failure

Design Methods (SDPWS)

1. **Segmented Shear Walls**
2. **Shear Walls with Openings**
   - **a. force transfer around openings**
   - **b. perforated shear walls**

Shear Wall Design

Segmented

1. Aspect Ratio for seismic 2:1
2. Aspect ratio up to 3.5:1, if allowable shear is reduced by 2w/h

SDPWS 4.3.5.1

Force Transfer

1. Code does not provide guidance for this method
2. Different approaches using rational analysis could be used

SDPWS 4.3.5.2

Perforated

1. Code provides specific requirements
2. The capacity is determined based on empirical equations and tables

SDPWS 4.3.5.3

Shearwall Minimum Aspect Ratios **h/b_s**

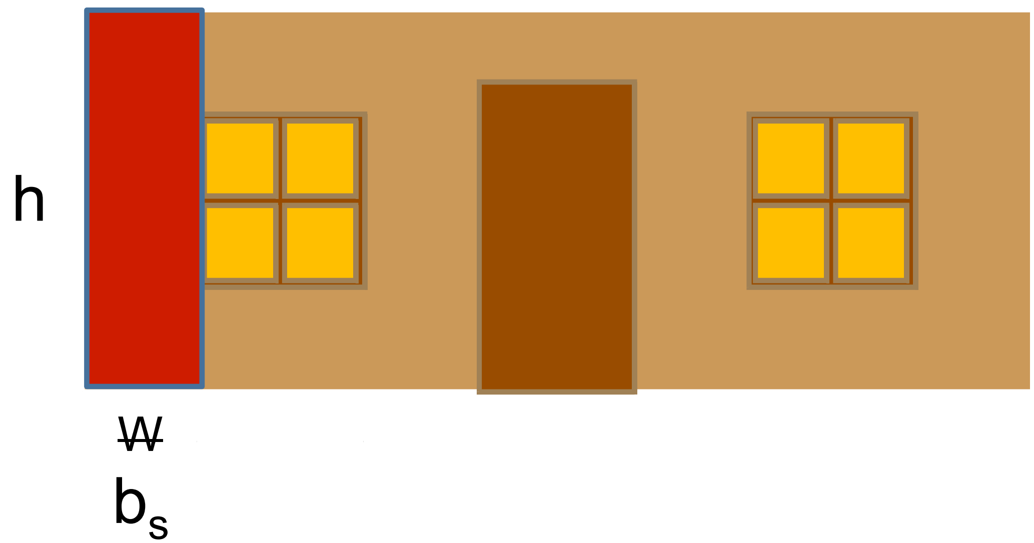
Minimum width:

b_s **= h/2**

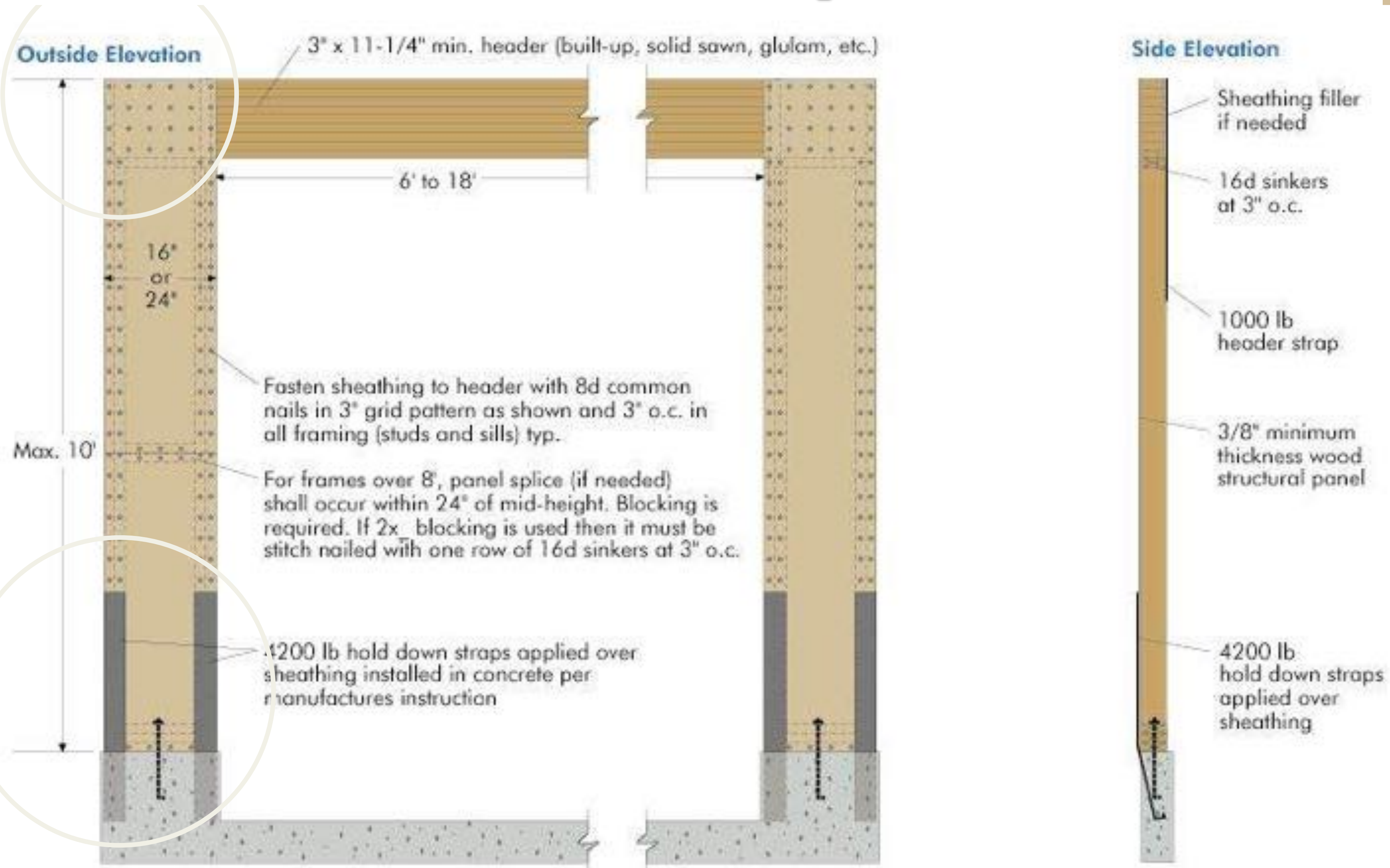
exception: 3.5:1 can be used

b_s **= h/3.5**

with penalty ($2b_s/h$)

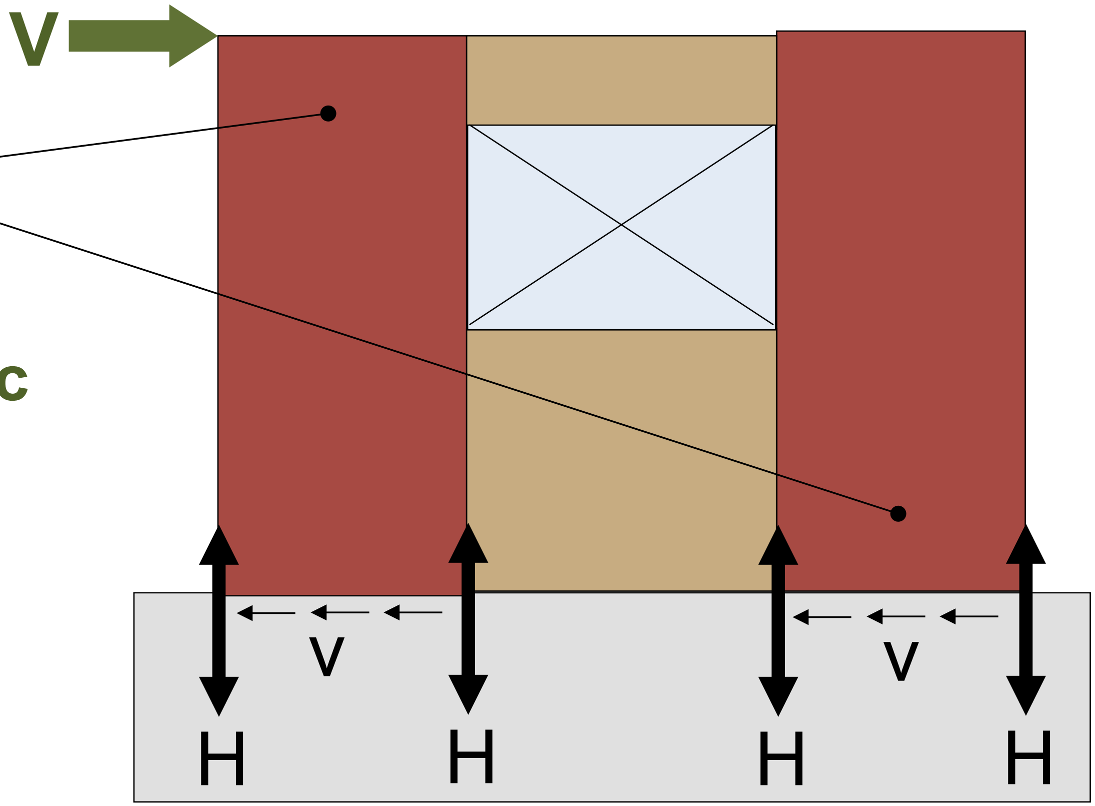


Site Built Portal Frame
Reference: APA Report TT-100



Segmented (Traditional) Wood Shear Walls (SDPWS 4.3.5.1)

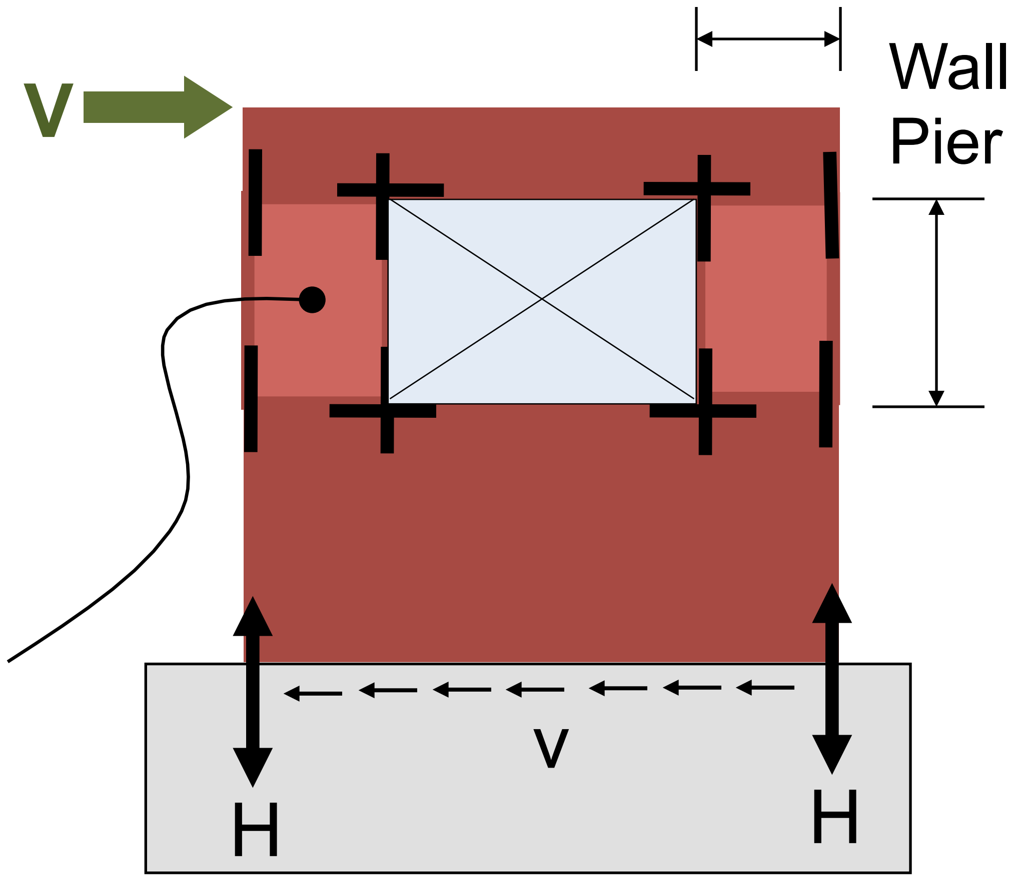
- Only full height segments are considered
- Max aspect ratio
  - 2:1 – for seismic
  - 3.5:1 – for wind
- Current Code design values based on data dating back to 1950's.



Aspect ratio applies to full height segment (dotted)

Shear Wall With Opening – Force Transfer Around Openings (SDPWS 4.3.5.2)

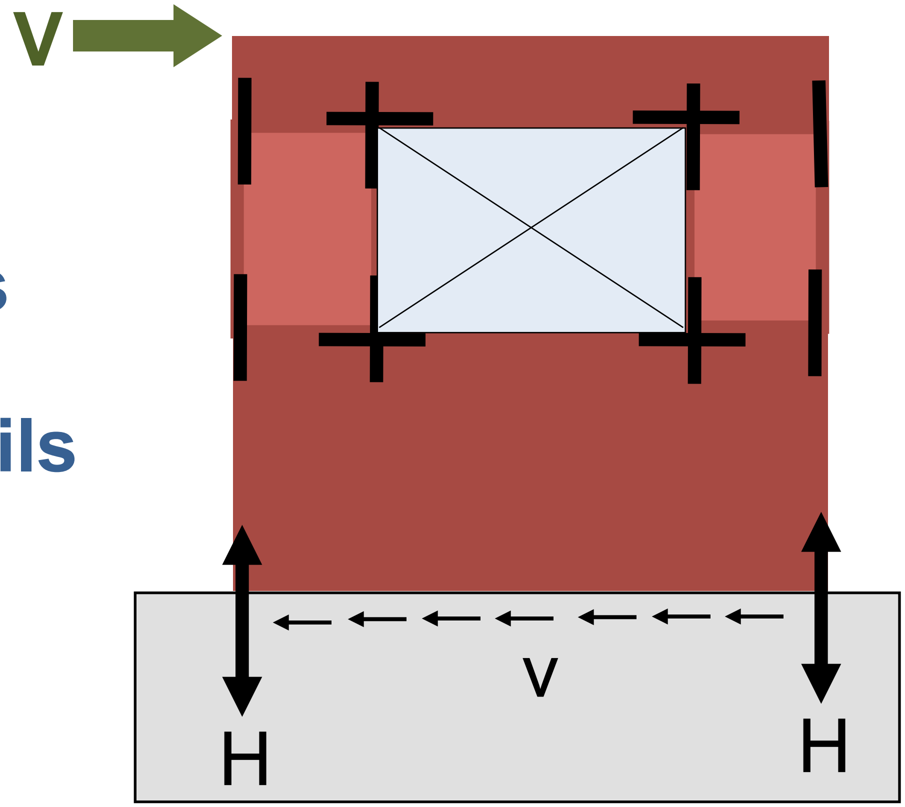
- Openings accounted for by strapping or framing
  - "based on a rational analysis"
- H/w ratio defined by wall pier



Aspect ratio applies to wall pier segment (dotted)

Shear Wall With Opening – Force Transfer Around Opening

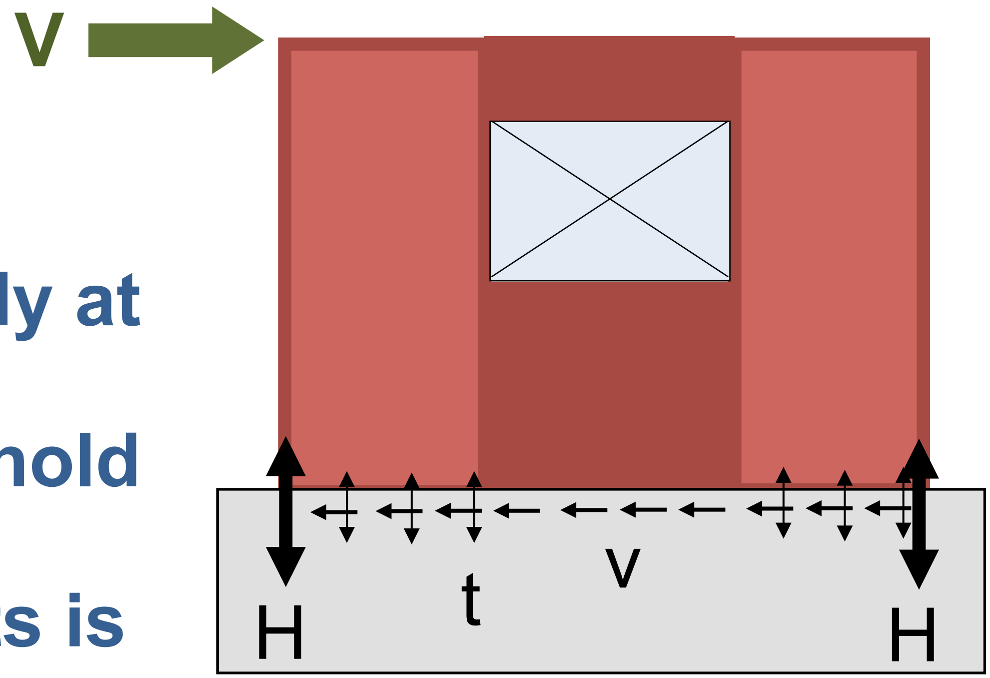
- Hold-downs only at ends
- Extra calculations and added construction details (connections & blocking)
  - Uses traditional design values



Aspect ratio applies to wall pier segment (dotted)

Shear Wall With Opening – Perforated Shear Wall (SDPWS 4.3.5.3)

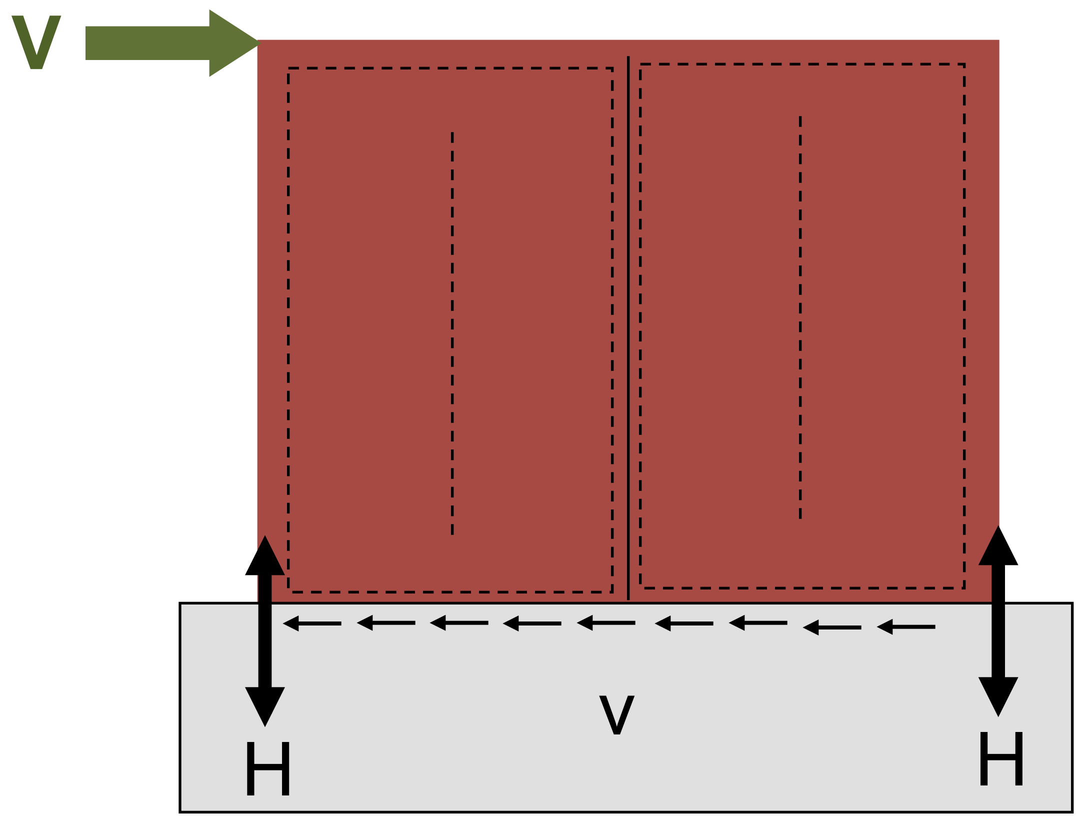
- Openings accounted for by empirical adjustment factor
- Hold-downs only at ends
- Uplift between hold downs, t, at full height segments is also required



Aspect ratio applies to full height segment (dotted)

Wood Shear Wall Capacity

- For:
  - 8d com. @ 4" edge nail spacing
  - 7/16" OSB Sheathing Grade
- Go to Table 4.3A SDPWS

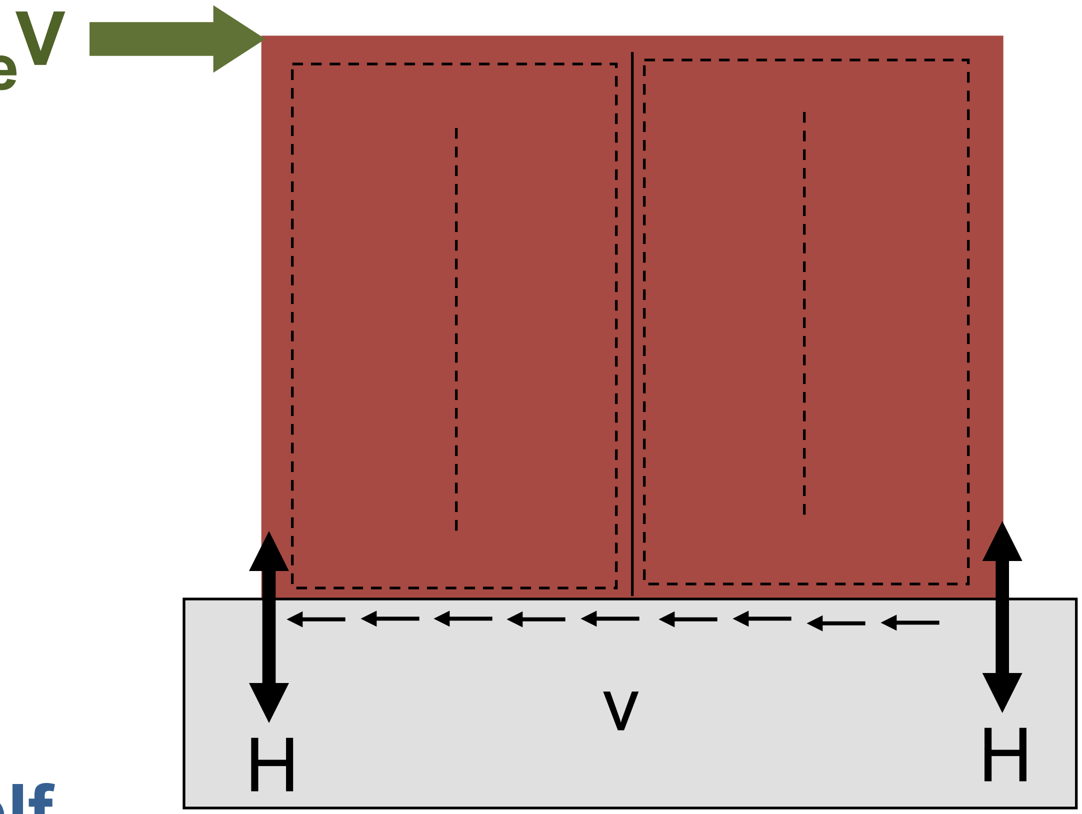


Wood Shear Wall Capacity

Sheathing Material	Minimum Nominal Panel Thickness (in.)	Minimun Fastener Penetration in Framing Member or Blocking (in.)	Fastener Type & Size	B WIND Panel Edge Fastener Spacing (in.) 6 v_w (plf)	4 v_w (plf)	3 v_w (plf)	2 v_w (plf)
Wood Structural Panels - Structural I[4,5]			Nail (common or galvanized box)				
	5/16	1-1/4	6d	560	840	1090	1430
	3/8[2]	1-3/8	8d	645	1010	1290	1710
	7/16[2]			715	1105	1415	1875
	15/32			785	1205	1540	2045
	15/32	1-1/2	10d	950	1430	1860	2435
Wood Structural Panels – Sheathing[4,5]	5/16	1-1/4	6d	505	755	980	1260
	3/8			560	840	1090	1430
	3/8[2]	1-3/8	8d	615	895	1150	1485
	7/16[2]			670	980	1260	1640
	15/32			730	1065	1370	1790
	15/32	1-1/2	10d	870	1290	1680	2155
	19/32			950	1430	1860	2435

Wood Shear Wall Capacity

- **For:**
  - **8d com. @ 4” edge nail spacing**
  - **7/16” OSB Sheathing Grade**

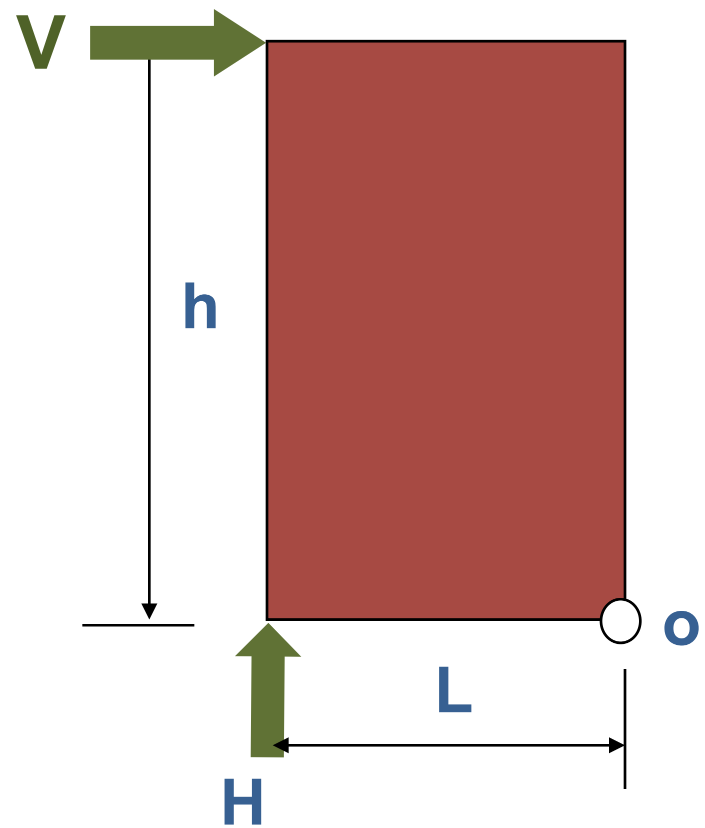


- **From Table 4.3A (SDPWS)**
- **Wall capacity = 980 plf / 2 = 490 plf**

For a wall length of 8-ft, the total capacity = 3920 lbs

Overturning:
Sizing the Hold Down (no DL)

- Sum moment about o:
  - V*h = H*L
- Rearranging:
  - H = V*h/L
- Letting v=V/L:
  - H = v*h

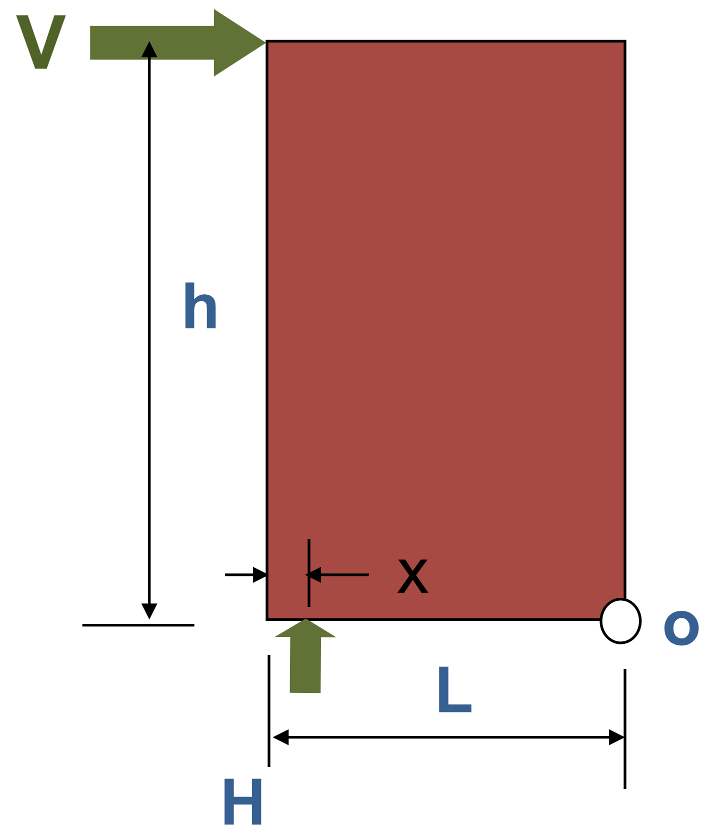


Is L the true effective length?

Sizing the Hold Down (no DL)

- Let x represent the distance from edge of wall to hold down rod

- Summing moments simplifies to:
  - H = V*h/(L-x) or
  - H = v*h*L/(L-x)

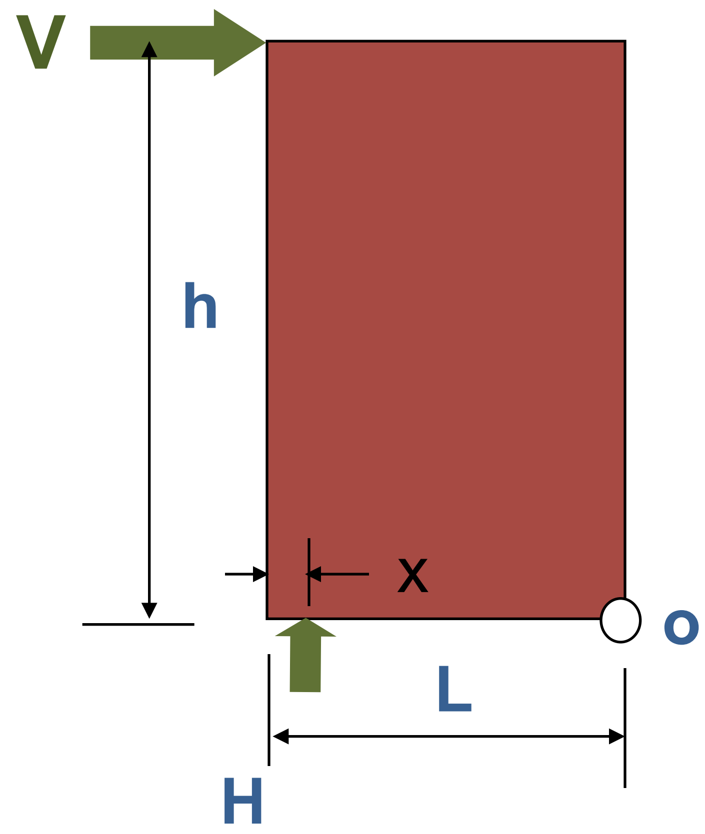


Is this reduced length precision accurate?

Sizing the Hold Down (no DL)

- APA testing (1:1 aspect ratio) shows using H=v*h matches reality better than "reduced length"

- The dead load assumed to counteract H is probably at least an equally important consideration

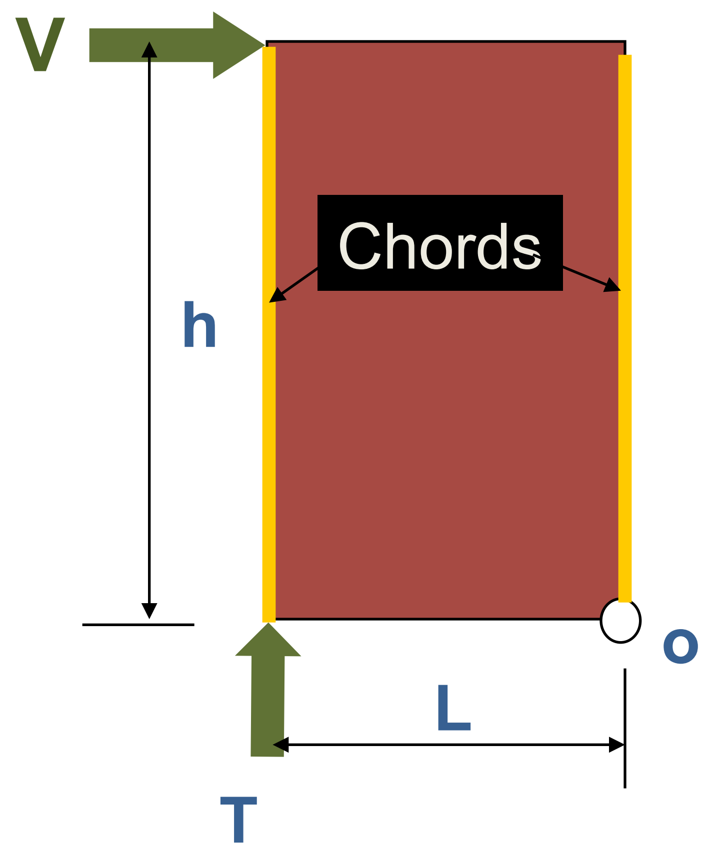


Don't Forget to Check the Chord Size and Strength!

4x4 shear wall end post failed in tension

Sizing the Chords (no DL)

- Tension chords
  - The end studs
  - Sized as hold down forces are
  - Designed as tension members
- Compression chords should include DL



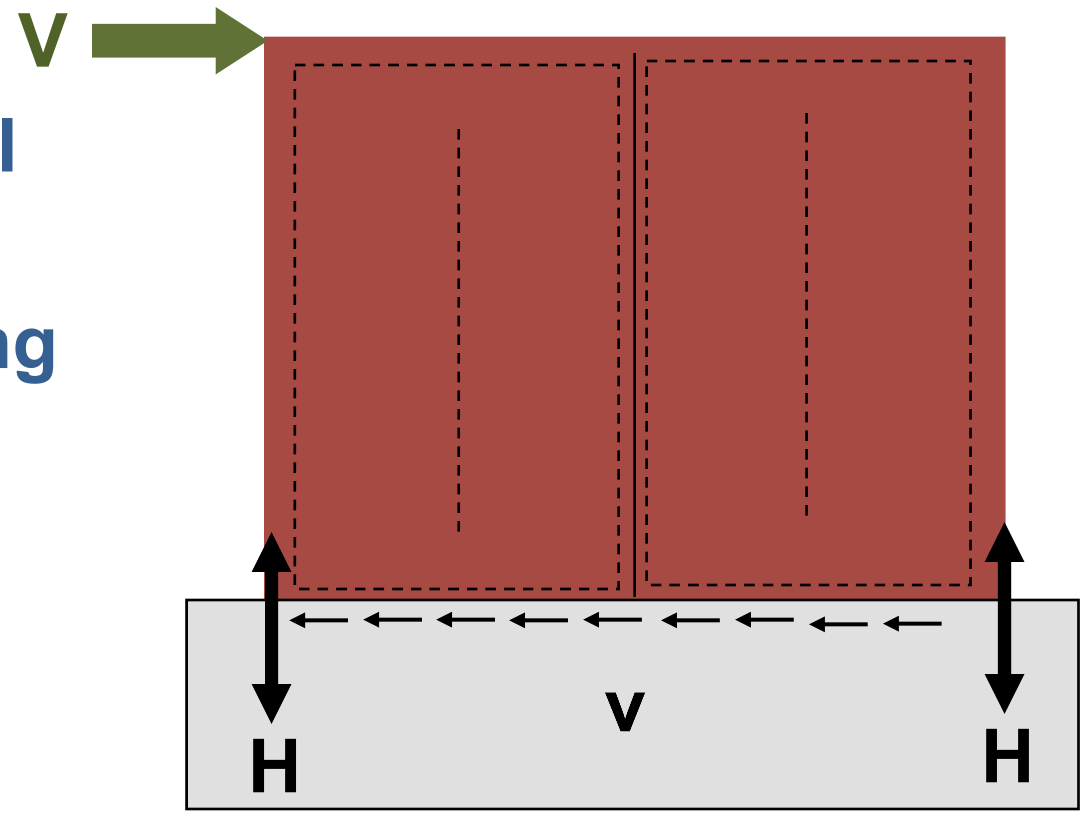
Chord forces can become quite large in highly loaded stacked shear walls!

Sizing Hold Down Example (no DL)

- Given 350 plf ASD capacity wall

- What's overturning force required?

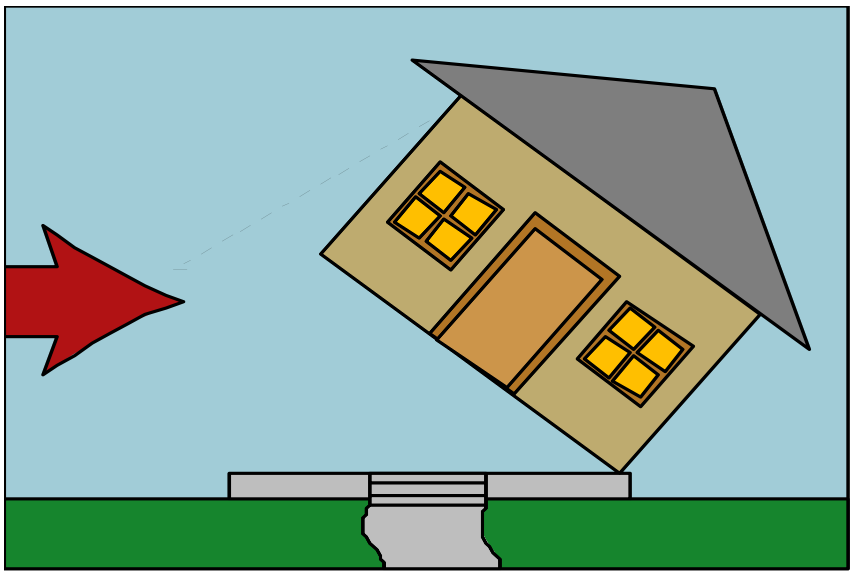
H = 350 plf x 8-ft
= 2800 lbf



Overturning Forces

- **Every structure shall be designed to resist overturning effects (IBC 1604.4)**

Overturning



Overturning Forces

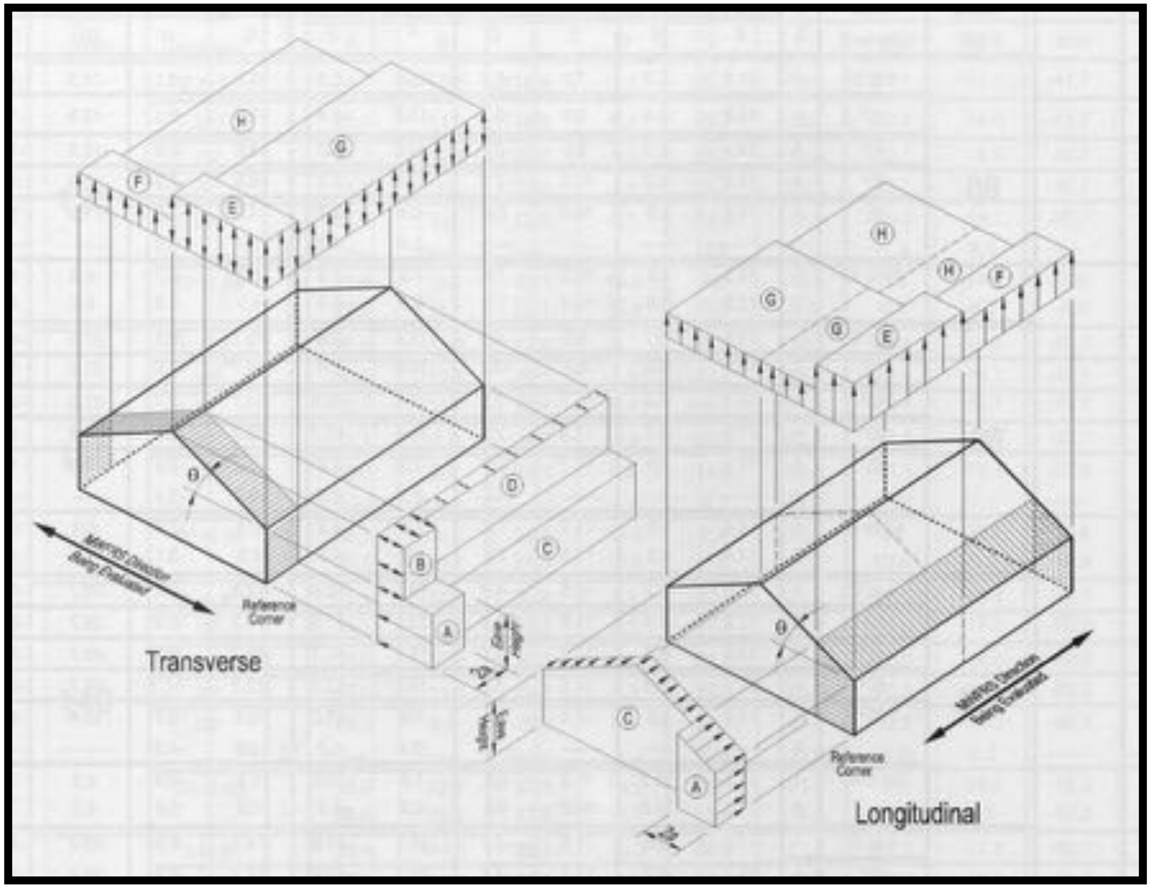
- **Only 0.6 x design dead load can be used to resist overturning from wind or earthquake (IBC 1605.3, ASCE 7 Sec. 2.4)**

Overturning Forces
How Much Dead Load?

- The amount of dead load available to resist overturning depends on:
  - Rational analysis
  - Framing system and configuration
  - Engineering judgment

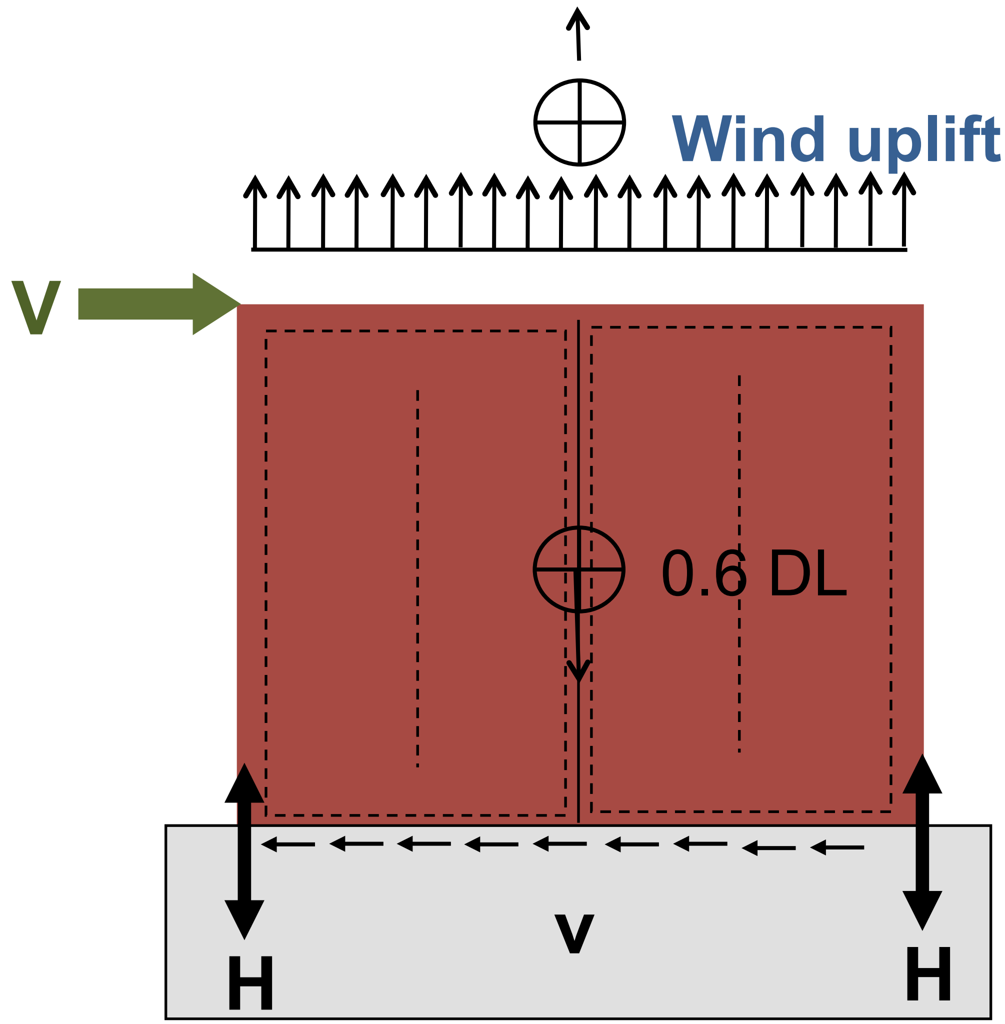
Wind: Shear and Uplift

- **Wind produces uplift and shear at the same time**



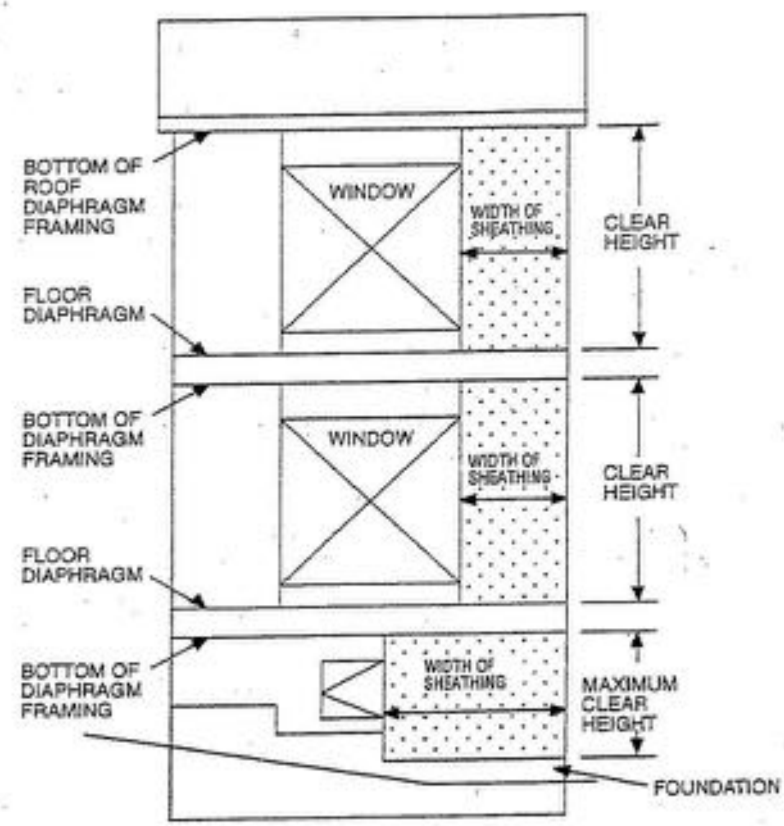
Loads and Forces on Shear Wall

- The load combinations and analysis of shear, uplift and dead load can be complex
- Breyer et al. has design examples



Height to width ratio (SDPWS 4.3.4.1)

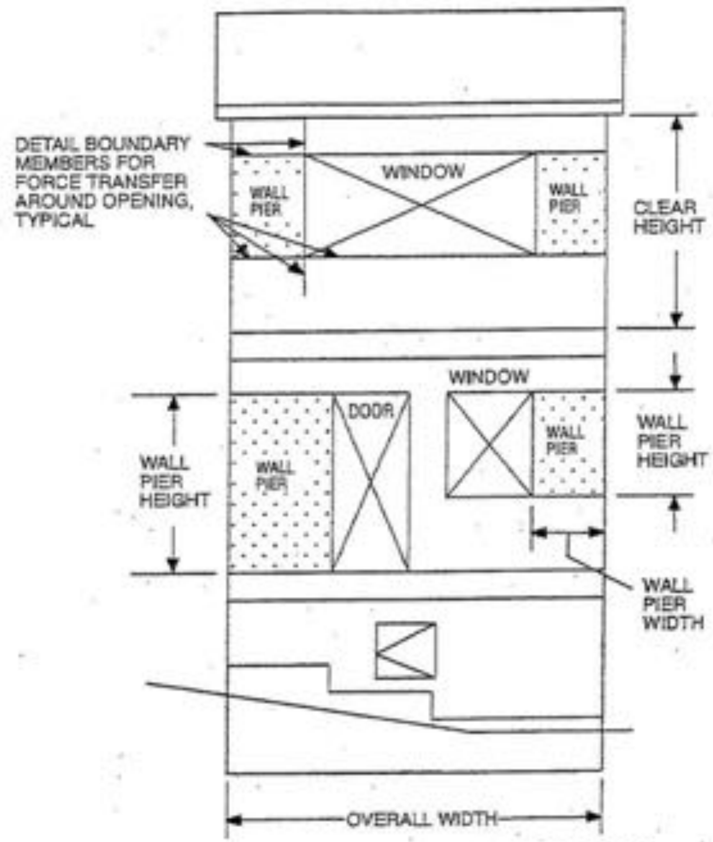
- **For shear walls and perforated shear walls**
- **h:w must not exceed 2:1 (seismic) or 3.5:1 (wind) ratio**



(a) HEIGHT-TO-WIDTH RATIO FOR SHEAR WALLS AND PERFORATED SHEAR WALLS

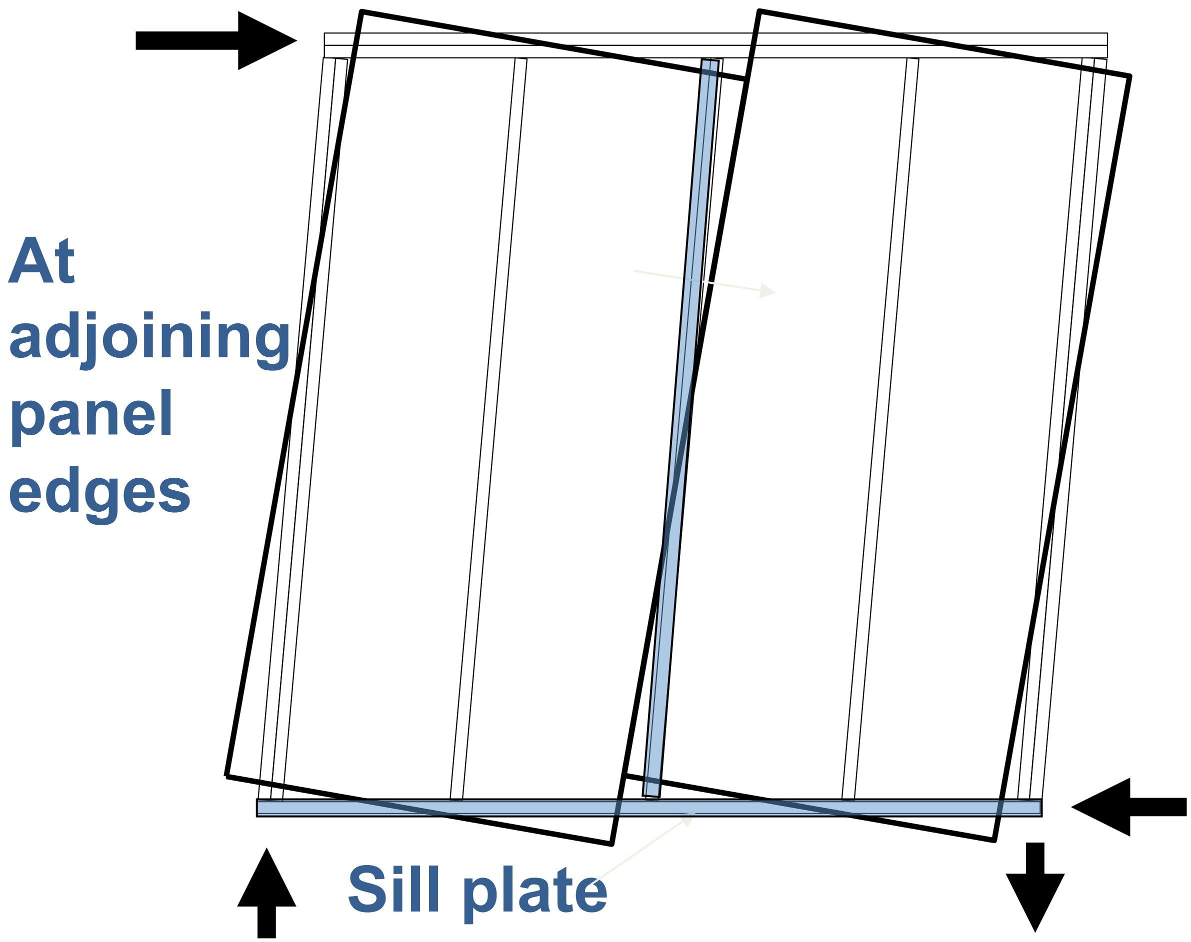
Height to width ratio (SDPWS 4.3.4.2)

- For force transfer around opening shear walls
- h:w must not exceed 2:1 (seismic) or 3.5:1 (wind) ratio



(b) HEIGHT-TO-WIDTH RATIO WITH DESIGN FOR FORCE TRANSFER AROUND OPENINGS

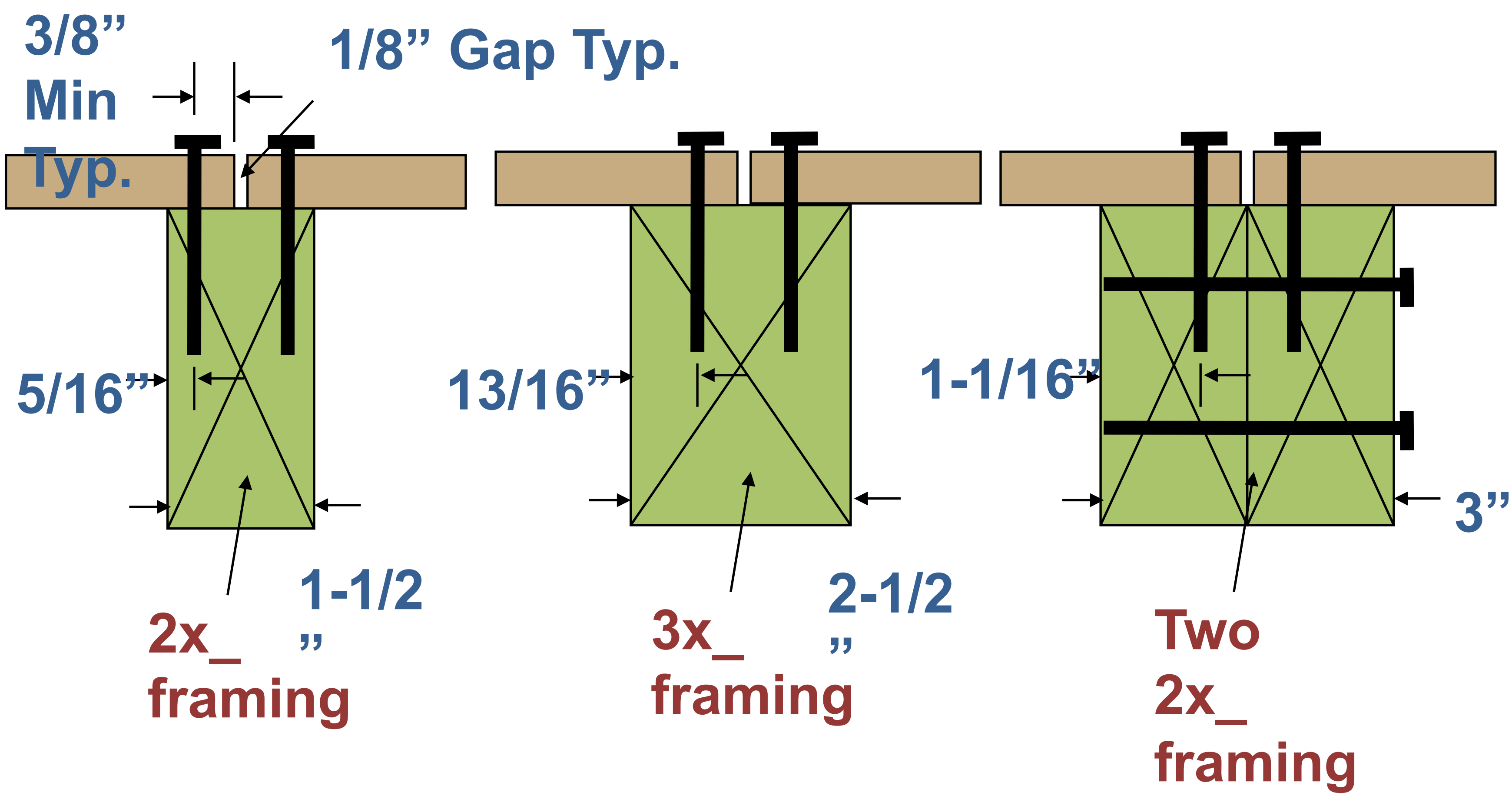
Shear Wall 3x Requirements



Shear Walls: 3x’s

- 3x’s at adjoining panels required when:
  - Allowable shear > 700 plf in SDC D-F (SDPWS 4.3.7.1(4))
  - Double sided walls do not have panels offset (SDPWS Table 4.3A footnote 6)
  - Nails are spaced 2” o.c. (SDPWS 4.3.7.1(4))
  - 10d nails are spaced 3” o.c. and have penetration >1.5” (SDPWS 4.3.7.1(4))
- See footnotes to shear wall tables!

Framing at Adjoining Panel Edges



Two 2x stitch nailed per SDPWS 4.3.7.1(4)) Exception

Summing Shear Capacities

- **Two sides sheathed = twice the strength (perforated: nominal unit capacity = 2435 plf max for wind, SDPWS 4.3.5.3)**

- **For wind design:**
  - **Gypsum shear wall strength can be added to wood shear wall strength (SDPWS 4.3.3.3.2)**

Shear Walls: Wind v. Seismic

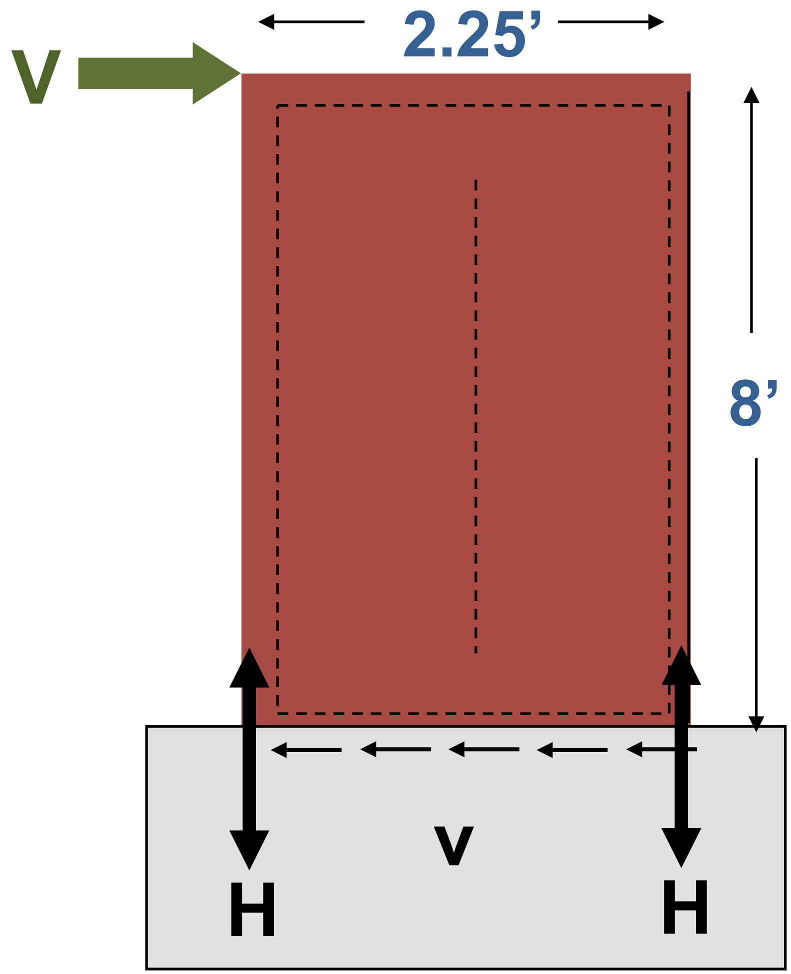
- **Wind Design:**
  - **40% increased capacity**
  - **Gypsum strength can be added**
  - **3.5:1 max. aspect ratio**

- **Seismic Design:**
  - **Requires 3x framing more often (SDC D-F)**
  - **2:1 max. aspect ratio without penalty**
    - **3.5:1 permitted with penalty (2w/h)**

Shear Walls: Wind v. Seismic

Given:

- 7/16” OSB
- 8d common
- 3”/ 6” edge/field nail spacing
- Gypsum on opposite face



Shear Walls: Wind v. Seismic

- **Wind Capacity:**
  - **V=(630 plf) x 2.25' = 1418 lb**

Length of wall

From table

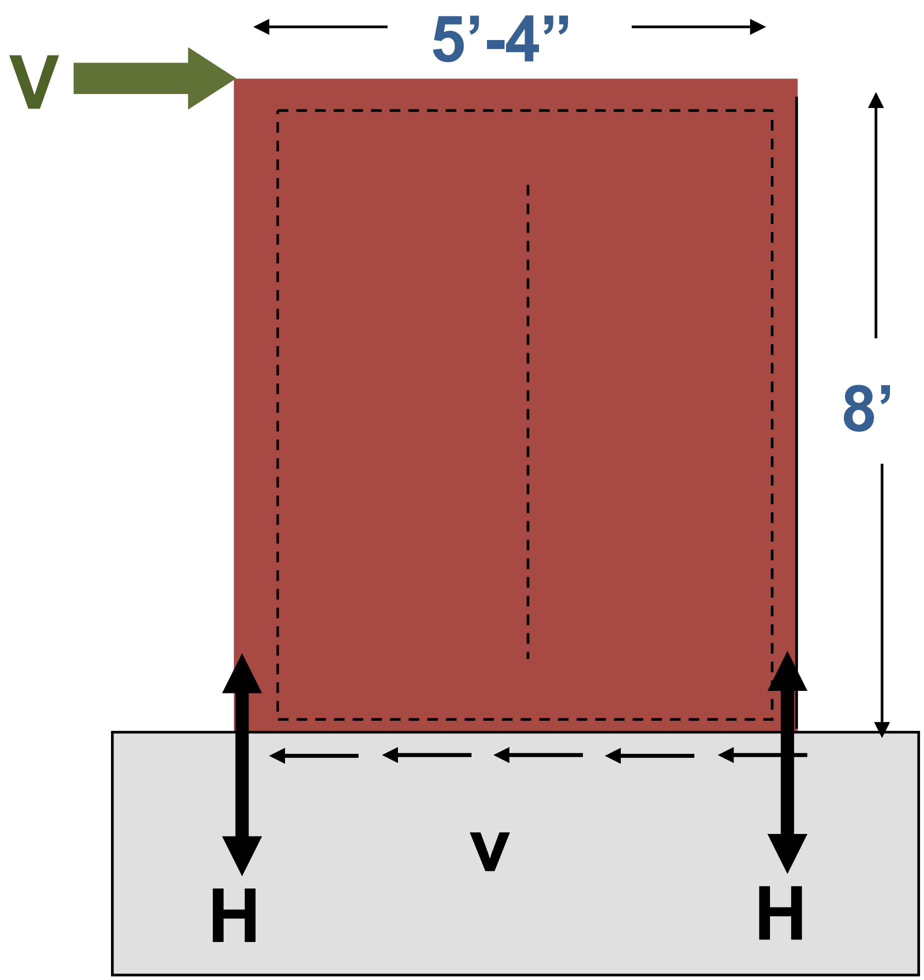
- **Seismic Capacity:**
  - **V=450 plf x 2(2.25')/8' x 2.25' = 570 lb**

When less than 2:1 aspect ratio, 2w/h adjustment

Shear Walls: Wind v. Seismic

Given:

- 7/16” OSB
- 8d common
- 3”/ 6” edge/field nail spacing
- Gypsum on opposite face



Shear Walls: Wind v. Seismic

- **Wind Capacity:**
  - **V=(630 plf +100 plf) x 5.33’ = <u>3891 lb</u>**

Length of wall

For gypsum from table

From table

- **Seismic Capacity:**
  - **V=450 plf x 5.33’ = 2399 lb**

High Load Shear Walls Maximum ASD Capacity

For two sides sheathed with Wood Structural Panels:

- **Wind maximum = 1740 plf x 1.4 = 2436 plf**
- **Earthquake maximum = 1740 plf**

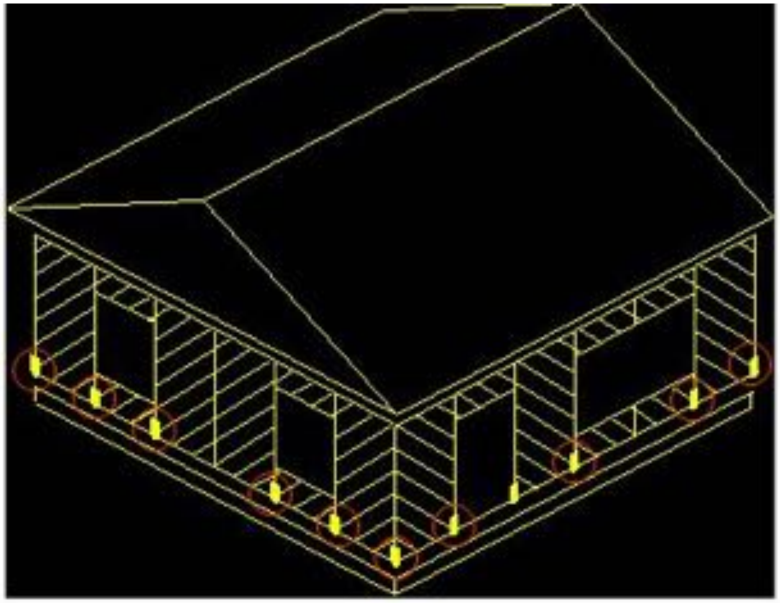
High Load Shear Walls
Boundary Elements

- **Hold down and chord force's due to lateral load only:**
- **H = 2435 plf x 8' = 19,480 lbs**
- **Hold down and chord forces can get very large!**

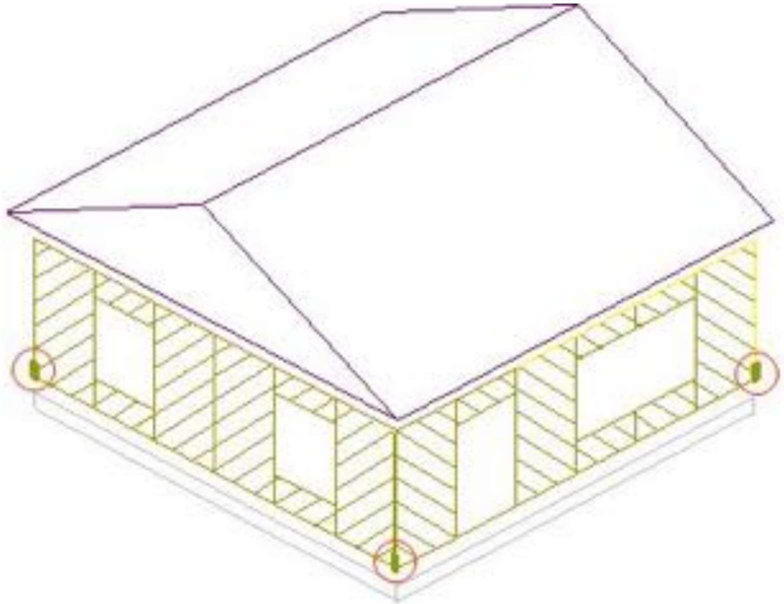
Designing Shear Walls With Openings SDPWS 4.3.5

- Force transfer around openings
- Perforated

Reducing Hold-Down Anchorage



Segmented Shearwalls



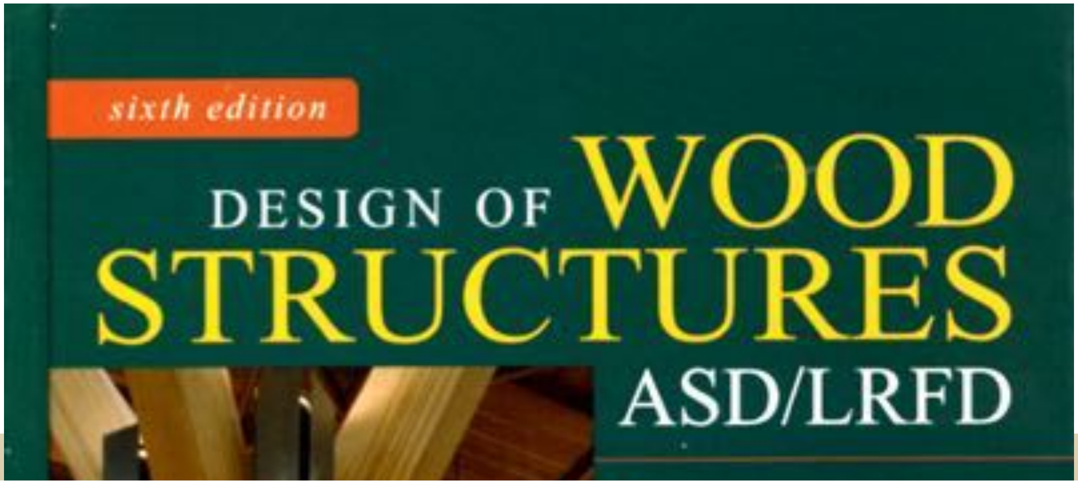
Continuous Shearwalls

Force Transfer Around Openings

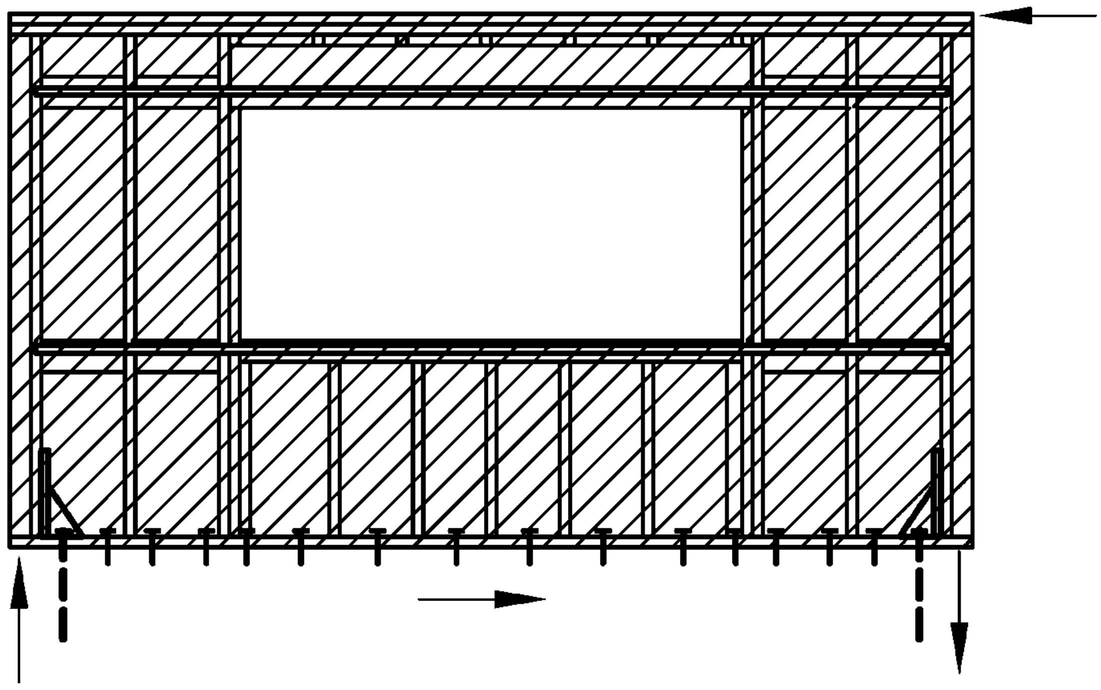
Design shall be based on rational analysis

The following method is described in detail in Design of Wood Structures

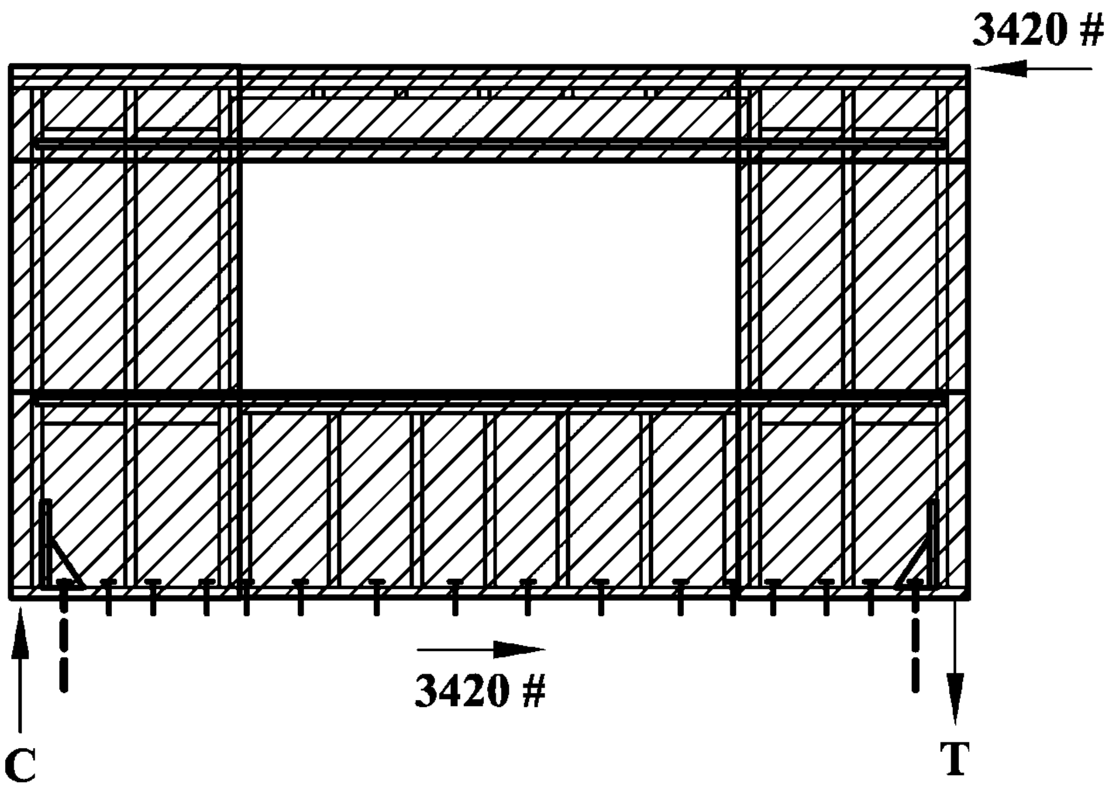
From Kelly Cobeen, S.E. used with permission



One-Story Wall Design: Transfer Around Openings - Concept

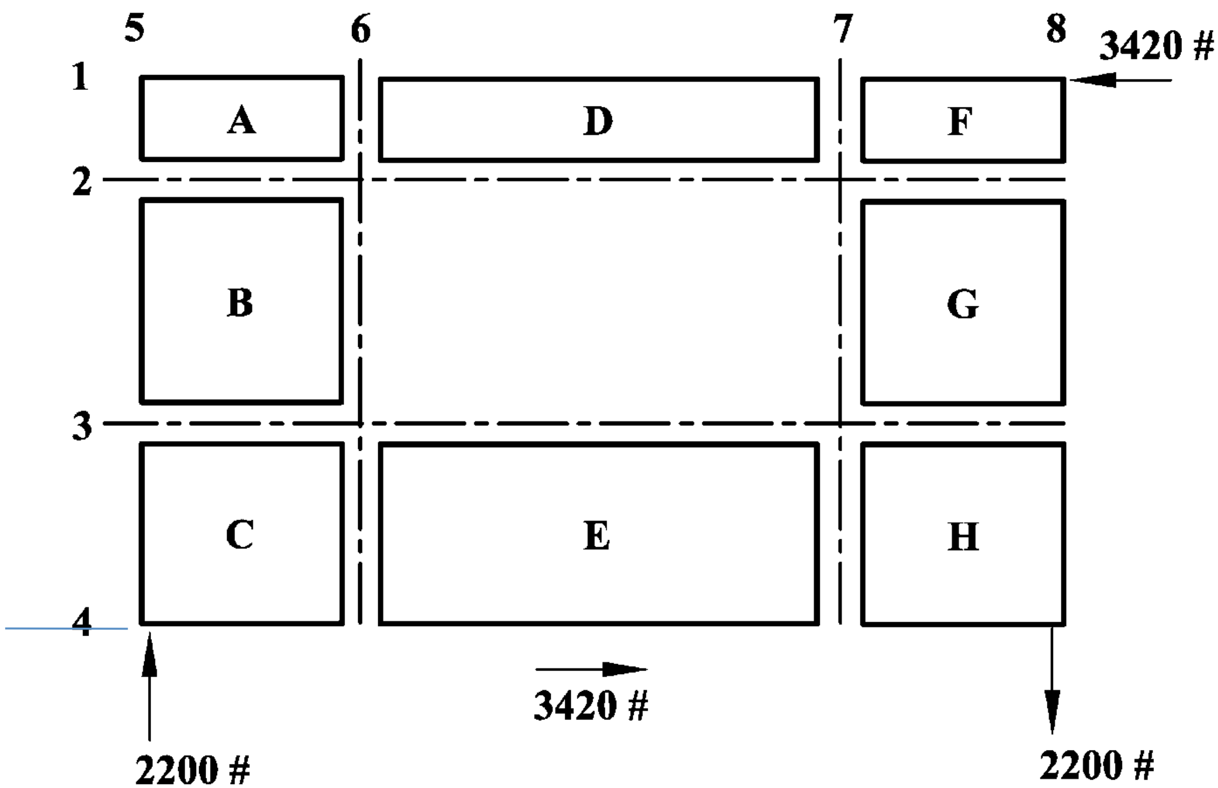


One-Story Wall Design: Transfer Around Openings - Analysis



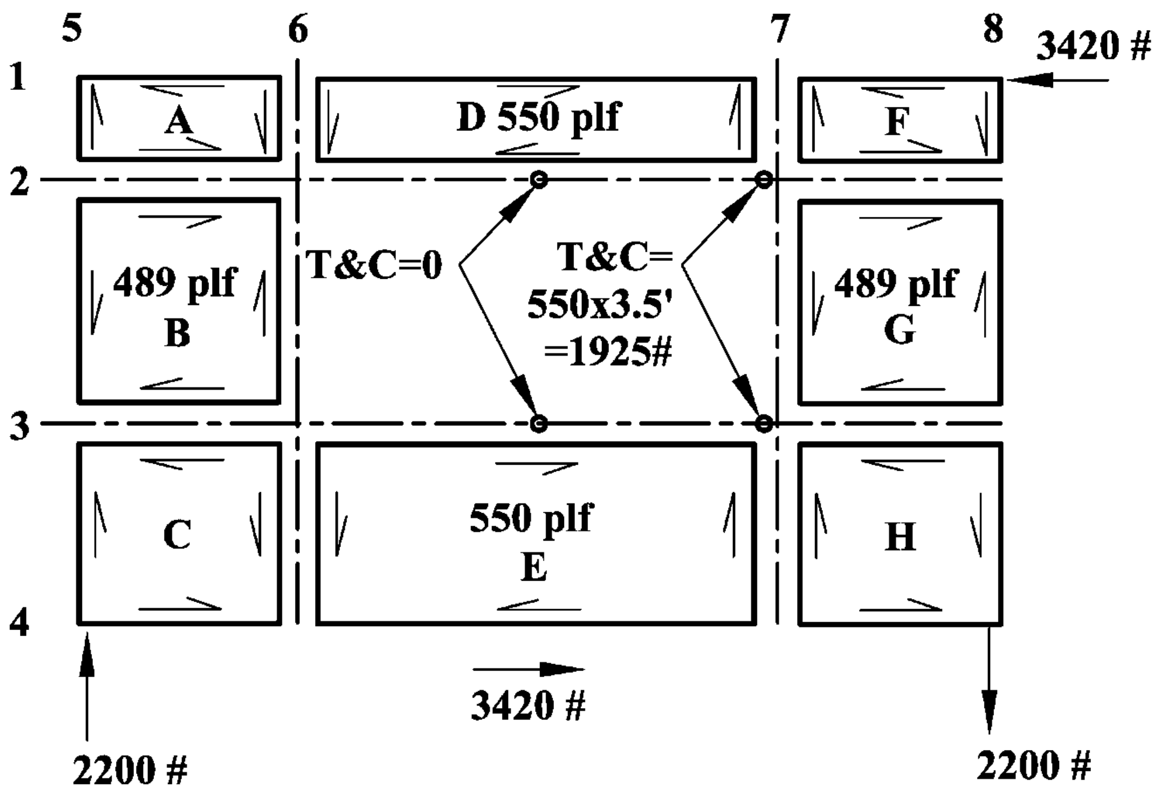
T = C = 3420 x 9' / 14' = 2200 #

One-Story Wall Design: Transfer Around Openings - Analysis



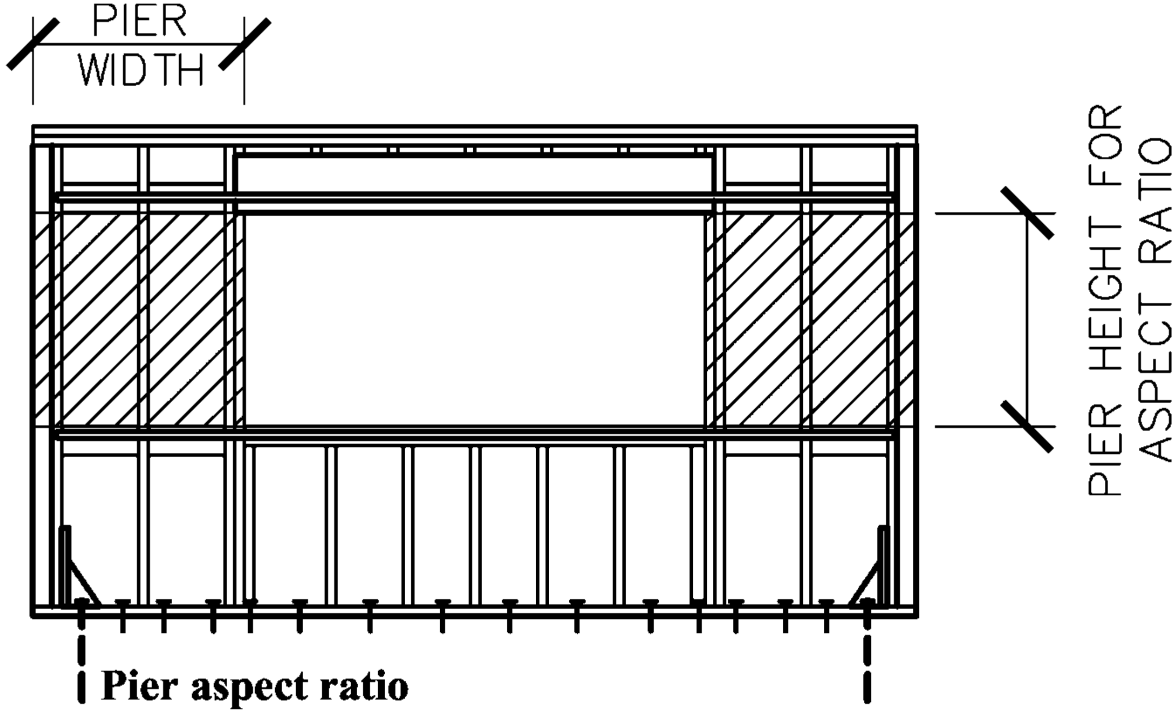
B & G: HORIZ v = 3420 # / (3.5' + 3.5') = 489 plf
D & E: VERT v = 2200 # / (1.5' + 2.5') = 550 plf

One-Story Wall Design: Transfer Around Openings - Analysis



F & H: HORIZ v = (1925 # / 3.5') - 489 plf = 61 plf
A & C: HORIZ v = 61 plf by symmetry

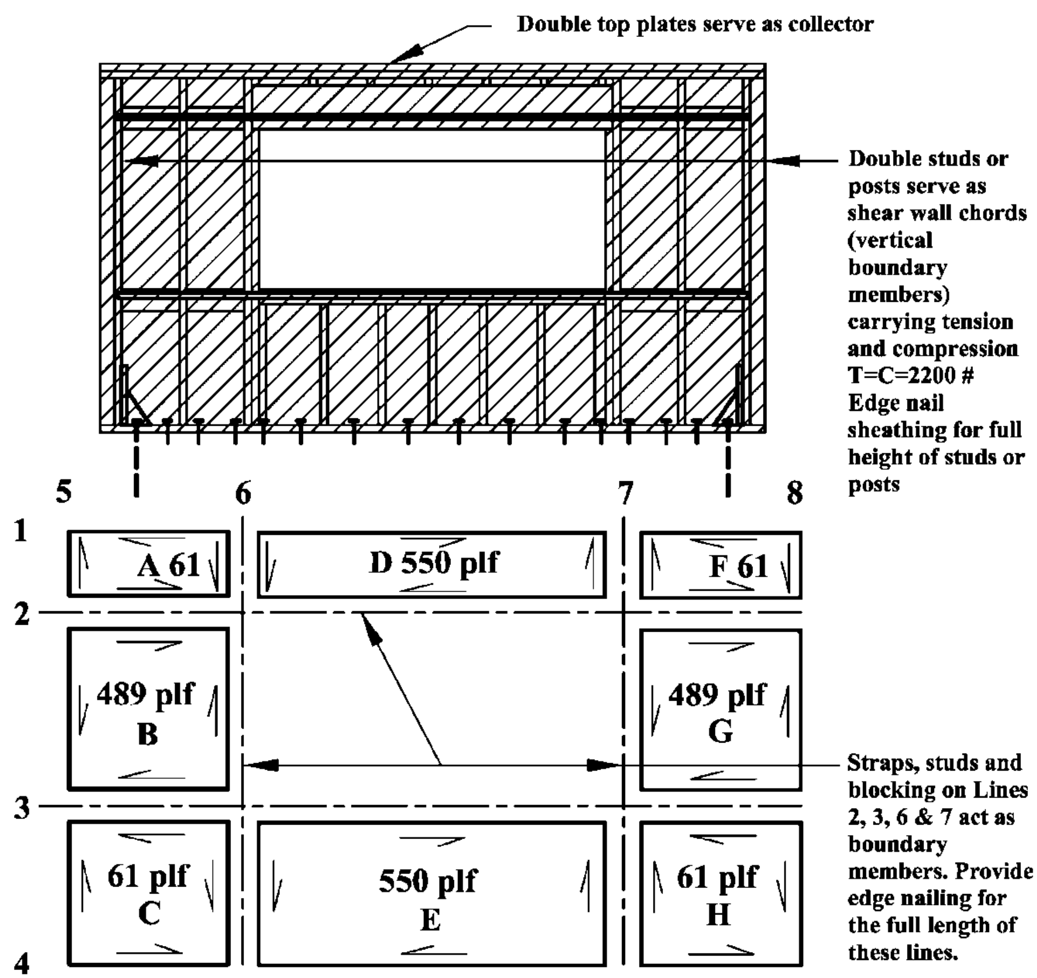
One-Story Wall Design: Transfer Around Openings - Aspect Ratio



Pier aspect ratio
= pier height / pier width = 5'/ 3.5' = 1.43

For aspect ratio < 2, no allowable shear adjustment required

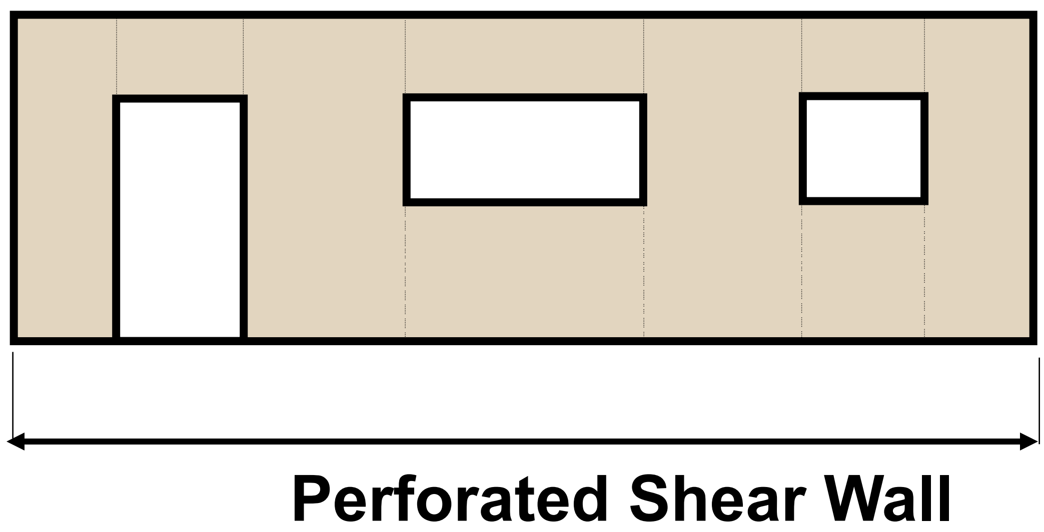
One-Story Wall Design: Transfer Around Openings - Boundary Members



Perforated Shear Wall Design

Definition SDPWS 4.3.5.3

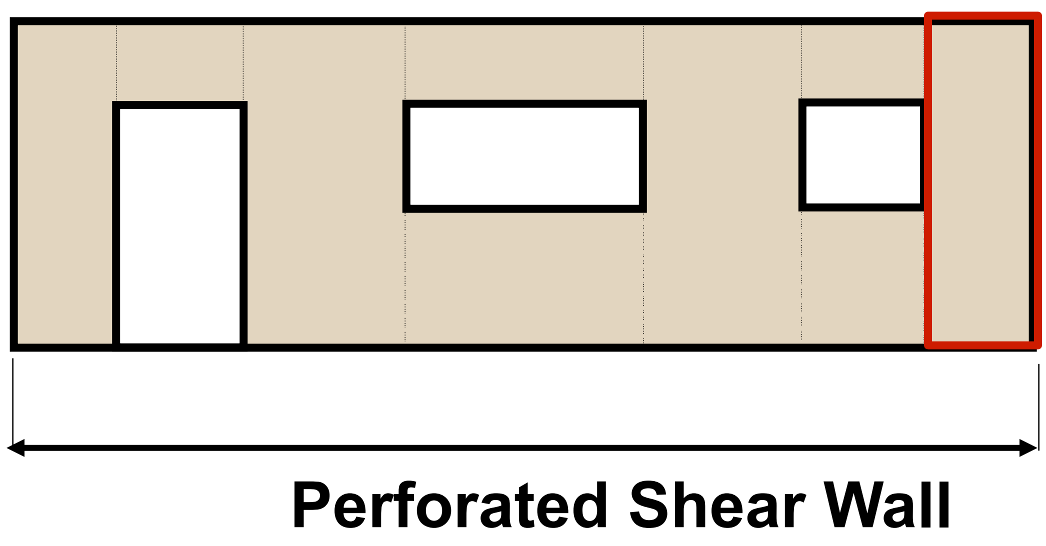
Perforated Shear Wall – a wood structural panel sheathed shear wall with openings that has not been specifically designed and detailed for force transfer around the openings



Perforated Shear Wall Design

Definition SDPWS 4.3.4.1

Perforated Shear Wall segment – full height segment meeting aspect ratio limits



Perforated Shear Wall Design

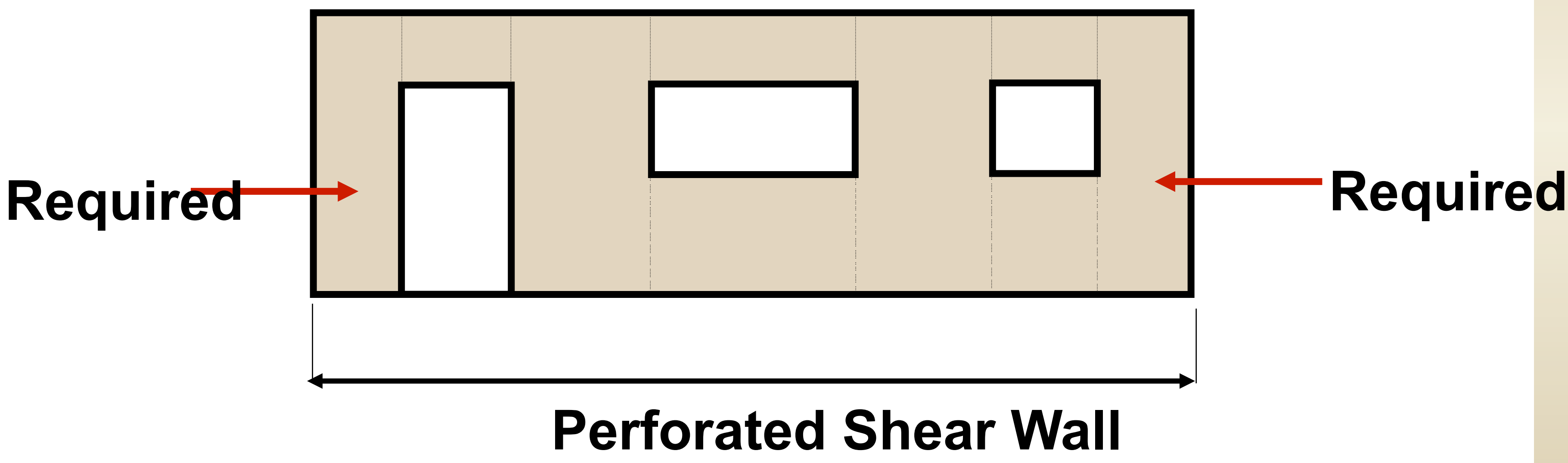
Code sets specific limitations on the use of this method

- **Limitations**
- **(SDPWS 4.3.5.3)**

Perforated Shear Wall Design

Limitations

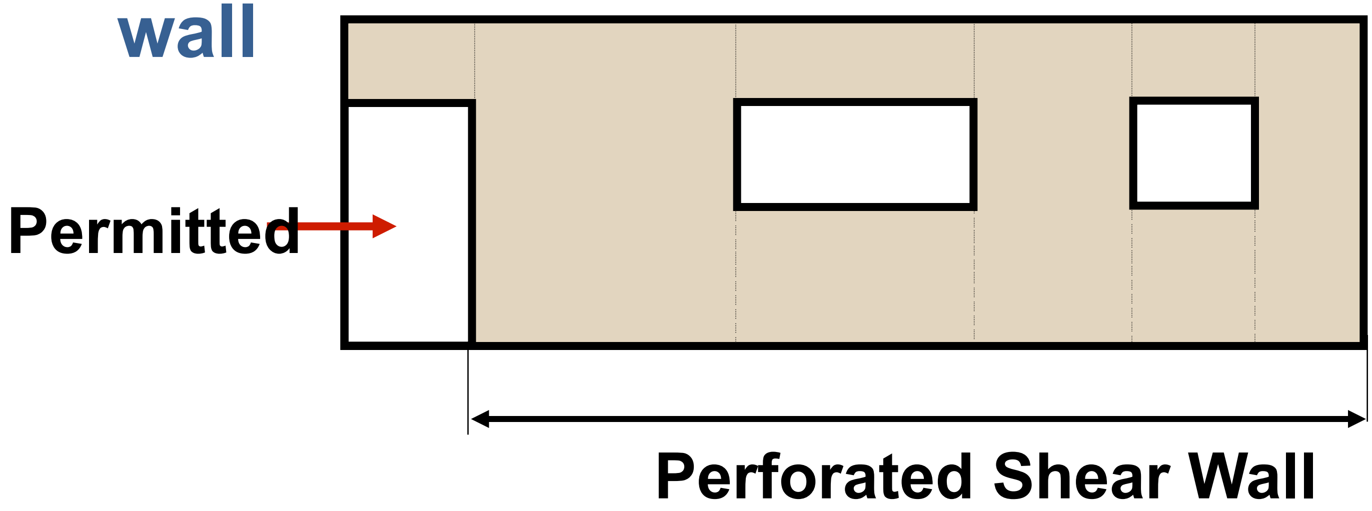
1. Perforated Shear Wall segment required at each end of perforated shear wall



Perforated Shear Wall Design

Limitations

1. Openings are allowed beyond the ends of the perforated shear wall, but should not be included in the width of perforated shear wall



Perforated Shear Wall Design

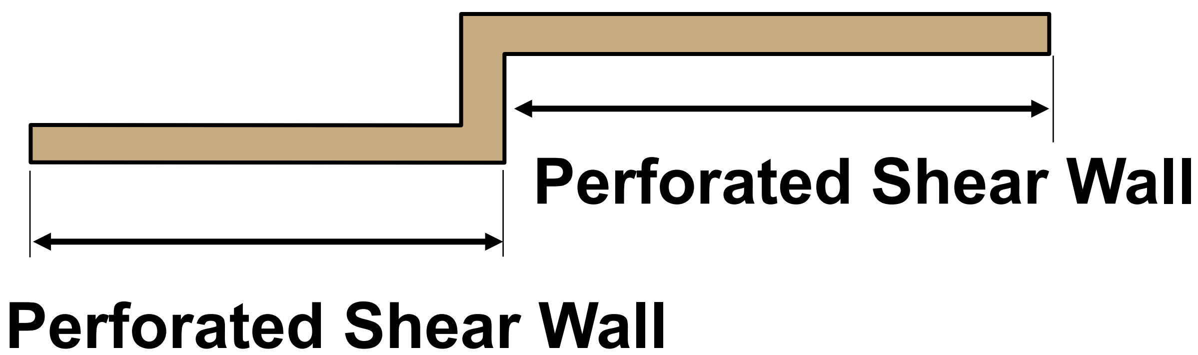
Limitations

2. Nominal unit shear capacity for wind shall not exceed 2435 plf

Perforated Shear Wall Design

Limitations

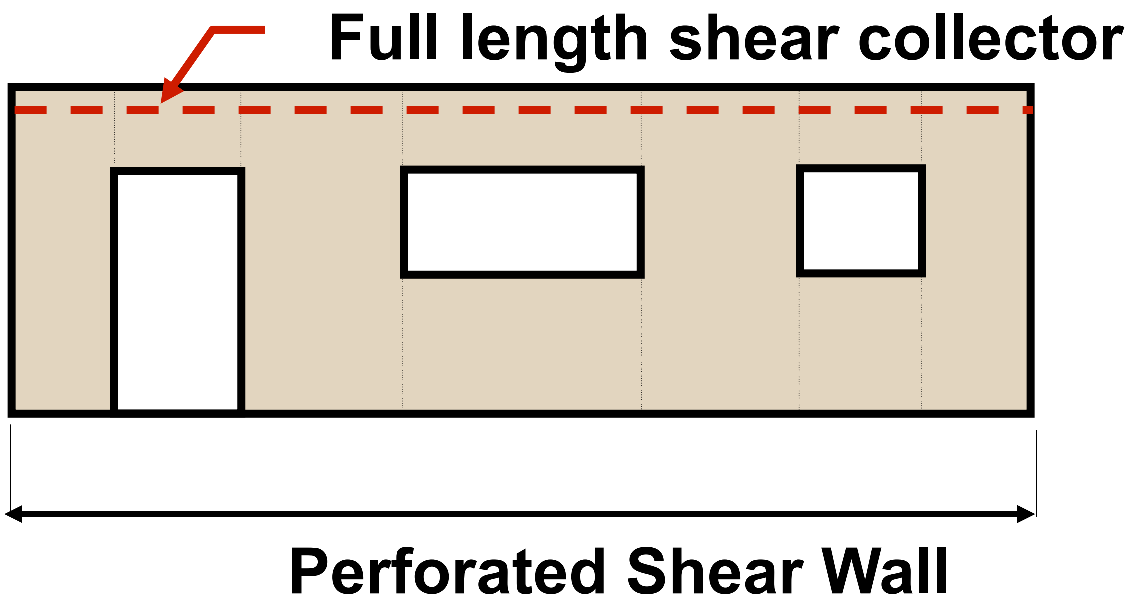
3. Out-of-plane offsets occur, walls shall be considered as separate perforated shear walls



Perforated Shear Wall Design

Limitations

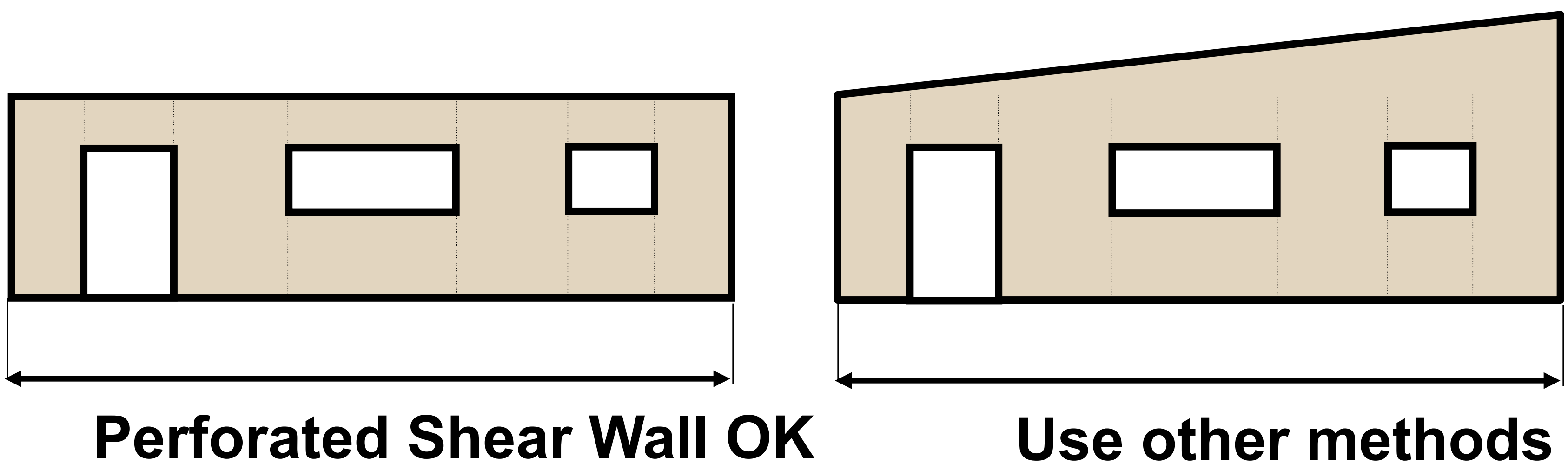
4. Collectors for shear transfer shall be provided through the full length of the perforated shear wall



Perforated Shear Wall Design

Limitations

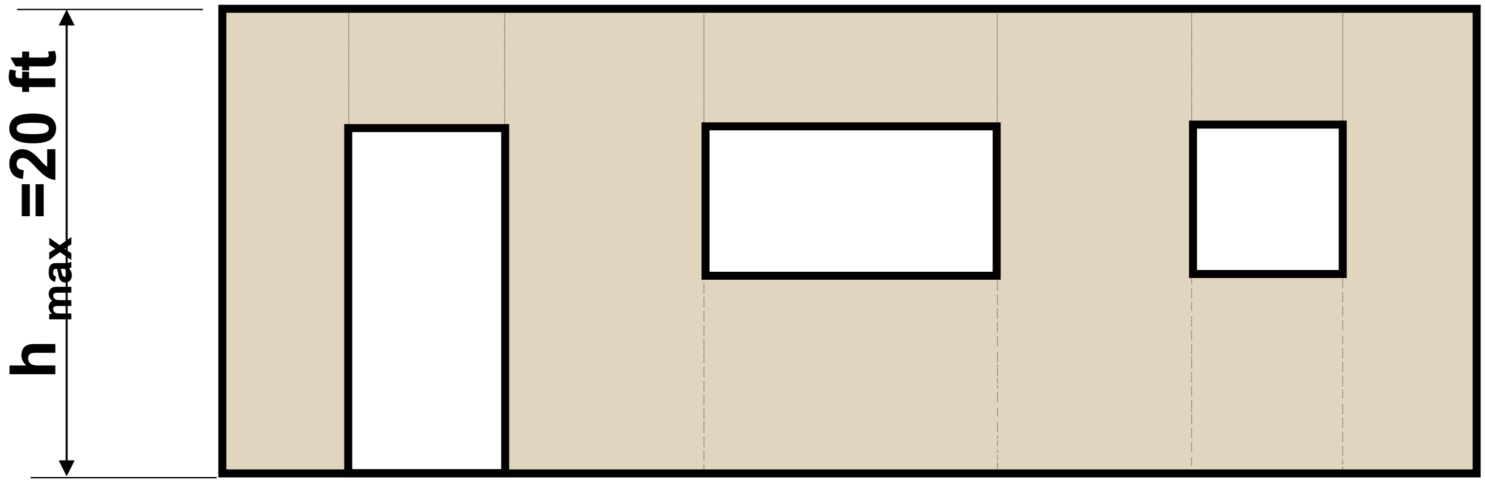
5. A perforated wall shall have uniform top of wall and bottom of wall elevation. (otherwise use different method)



Perforated Shear Wall Design

Limitations

6. Maximum Perforated Wall height is 20 ft



Perforated Shear Wall Design

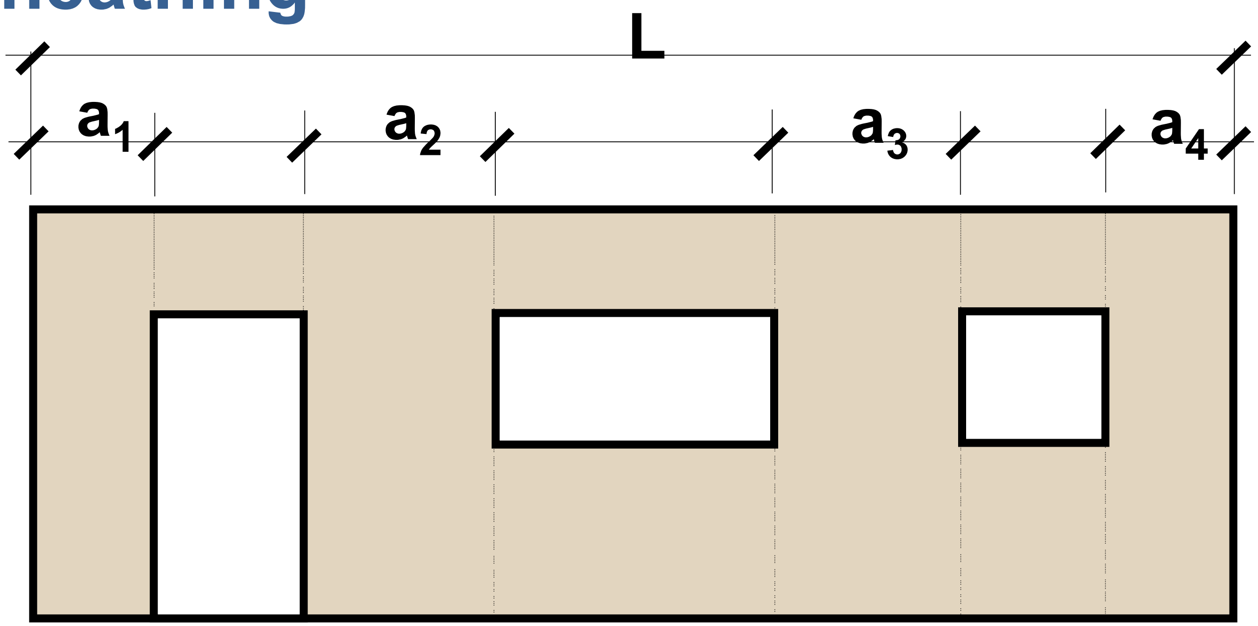
- **Perforated Shear Wall Resistance**

- **(SDPWS 4.3.3.5)**

Perforated Shear Wall Design

Resistance

1. Calculating percentage (%) of full-height sheathing

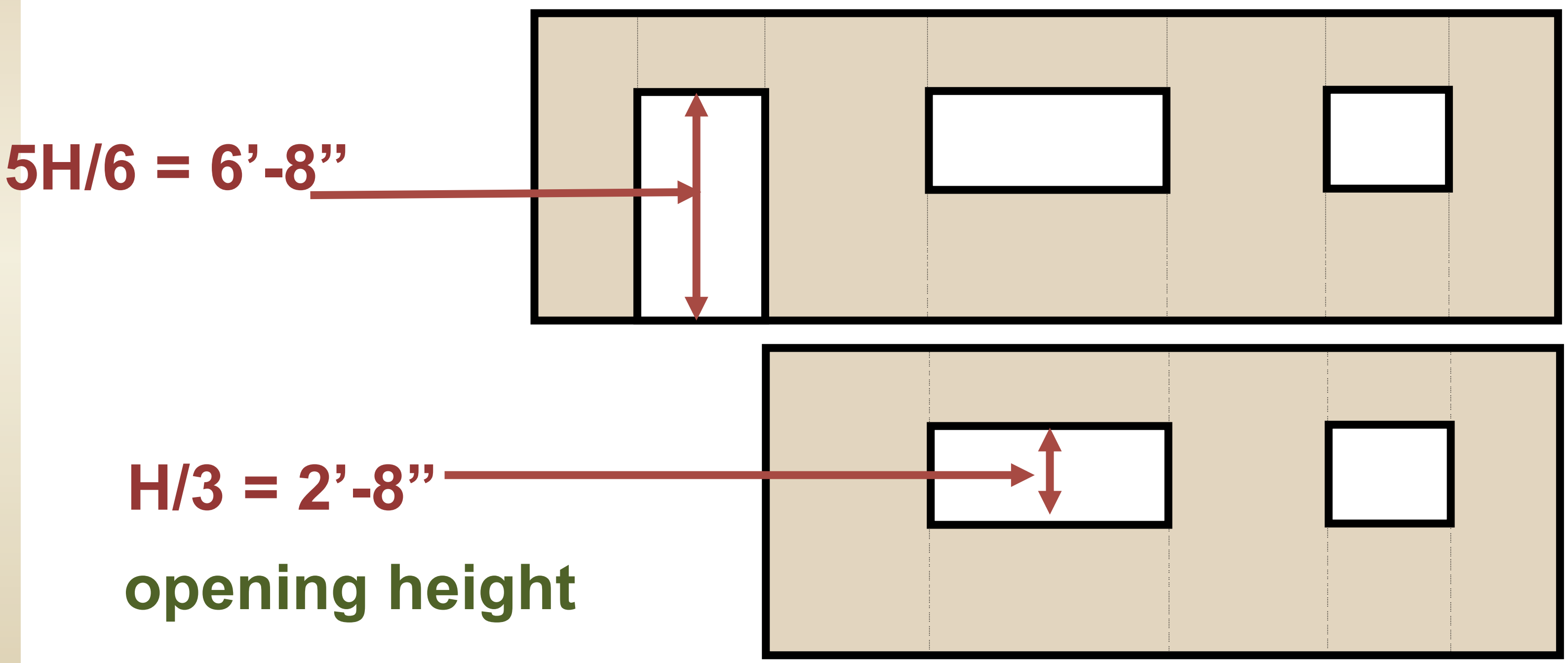


$$\% = (a_1+a_2+a_3+a_4)/L$$

Perforated Shear Wall Design

Resistance

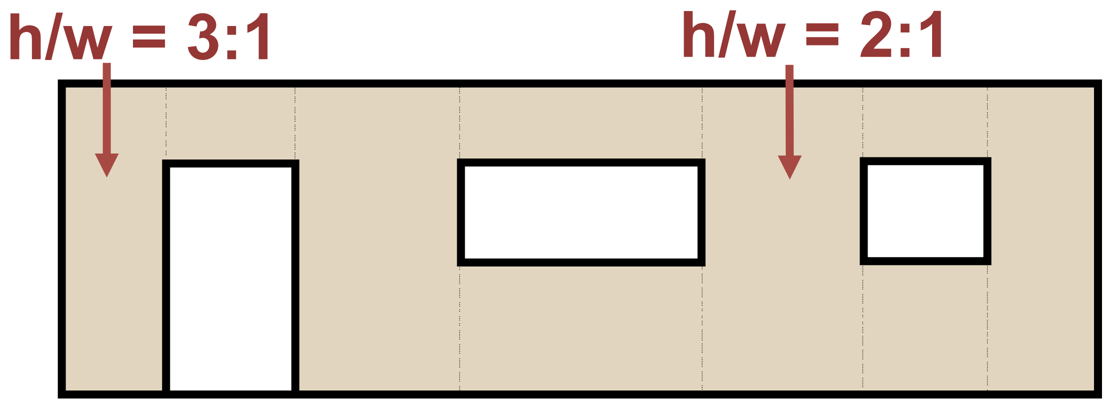
2. The maximum opening height is the maximum opening clear height



Perforated Shear Wall Design

Resistance

3. The unadjusted shear resistance shall be the allowable shear set in Table 2306.4.1 for h/w ratio of any perforated shear wall segments that do not exceed 2:1 for seismic forces and 3.5:1 for other forces.



Perforated Shear Wall Design

Maximum h/w ratio requirements for Perforated Shear Walls

Load	Maximum h/w Ratio
Seismic	2:1
Seismic (shear values in table adjusted by 2w/h)	2:1 < h/w < 3.5:1
Other than seismic	3.5 : 1

Based on SDPWS Table 4.3.4

Maximum Shear Wall Aspect Ratios

Perforated Shear Wall Design

Resistance

4. The adjusted shear resistance shall be calculated by multiplying the unadjusted shear resistance by the shear resistance adjustment factors of SDPWS Table 4.3.3.5 (interpolations are allowed)

Perforated Shear Wall Design

SDPWS Table 4.3.3.5 Shear Resistance Adjustment Factor, C_O

WALL HEIGHT (h)	MAXIMUM OPENING HEIGHT RATIO[a] AND HEIGHT				
	h/3	h/2	2h/3	5h/6	h
8'-0"	2'-8"	4'-0"	5'-4"	6'-8"	8'-0"
10'-0"	3'-4"	5'-0"	6'-8"	8'-4"	10'-0"
Percent Full-Height Sheathing[b]	Shear Capacity Adjustment Factor				
10%	1.00	0.69	0.53	0.43	0.36
20%	1.00	0.71	0.56	0.45	0.38
30%	1.00	0.74	0.59	0.49	0.42
40%	1.00	0.77	0.63	0.53	0.45
50%	1.00	0.80	0.67	0.57	0.50
60%	1.00	0.83	0.71	0.63	0.56
70%	1.00	0.87	0.77	0.69	0.63
80%	1.00	0.91	0.83	0.77	0.71
90%	1.00	0.95	0.91	0.87	0.83
100%	1.00	1.00	1.00	1.00	1.00

Shear Capacity Adjustment

Table 4.3.3.5 Shear Capacity Adjustment Factor, C_o

Wall Height, h	Maximum Opening Height[1]				
	h/3	h/2	2h/3	5h/6	h
8' Wall	2'-8"	4'-0"	5'-4"	6'-8"	8'-0"
10' Wall	3'-4"	5'-0"	6'-8"	8'-4"	10'-0"
Percent Full-Height Sheathing[2]	Effective Shear Capacity Ratio				
10%	1.00	0.69	0.53	0.43	0.36
20%	1.00	0.71	0.56	0.45	0.38
30%	1.00	0.74	0.59	0.49	0.42
40%	1.00	0.77	0.63	0.53	0.45
50%	1.00	0.80	0.67	0.57	0.50
60%	1.00	0.83	0.71	0.63	0.56
70%	1.00	0.87	0.77	0.69	0.63
80%	1.00	0.91	0.83	0.77	0.71
90%	1.00	0.95	0.91	0.87	0.83
100%	1.00	1.00	1.00	1.00	1.00

1 The maximum opening height shall be taken as the maximum opening clear height in a perforated shear wall. Where areas above and/or below an opening remain unsheathed, the height of each opening shall be defined as the clear height of the opening plus the unsheathed areas.

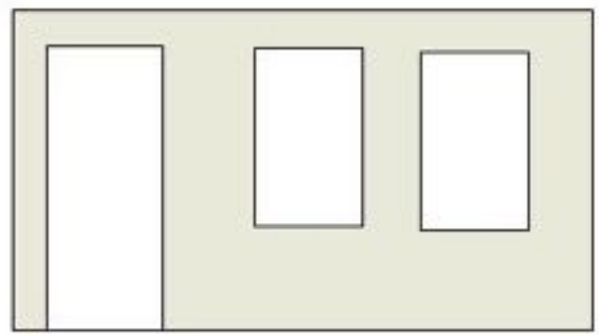
2 The sum of the perforated shear wall segment lengths, ΣL_i, divided by the total length of the perforated shear wall, L_{tot}. Lengths of perforated shear wall segments with aspect ratios greater than 2:1 shall be adjusted in accordance with Section 4.3.4.3.

Shear Capacity Adjustment

Equation for Perforated Shearwalls

$$C_o = \left(\frac{r}{3-2r}\right)\frac{L_{tot}}{\sum L_i}$$

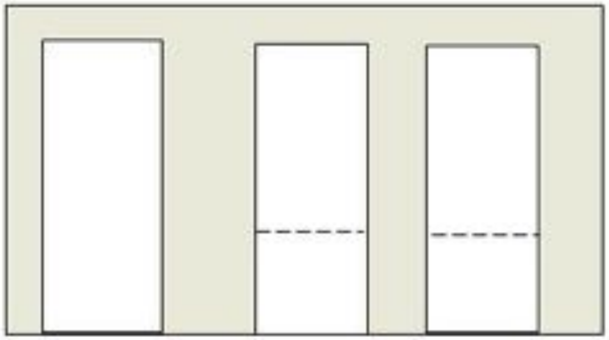
$$r = \frac{1}{1+\dfrac{A_o}{h\sum L_i}}$$



Shear Capacity Adjustment

Equation for Perforated Shearwalls

- Alternative to tabulated values – Section 4.3.3.5
  - Allows more efficient designs
    - Actual area of openings
  - Table requires maximum opening size
    - Example: 1 door & 2 windows
    - Table assumes windows are same height as door
    - Takes away panel shear area

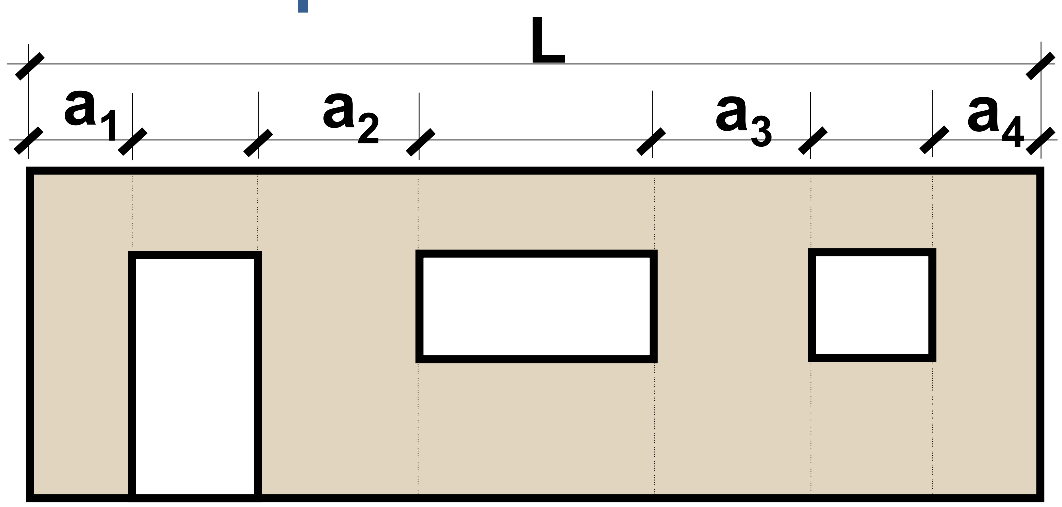


Table

Perforated Shear Wall Design

Resistance

5. The perforated shear wall resistance shall be equal to the shear resistance times the sum of the width of the perforated shear wall segments.



$V = (v_{allowable}) \times (2w/h) \times (C_O) \times (a1+a2+a3+a4)$

Perforated Shear Wall Design

- **Uplift Anchorage**

- **Should either comply with the additional prescriptive code requirements or calculated using principles of mechanics.**

Perforated Shear Wall Design

4.3.6.4.2 Uplift Anchorage at Shear Wall Ends: Where the dead load stabilizing moment is not sufficient to prevent uplift due to overturning moments on the wall (from 4.3.6.1.1 or 4.3.6.1.2), an anchoring device shall be provided at the end of each shear wall.

Shear in Perforated Shear Wall

Shear Resistance Adjustment Factor

$$T = \frac{Vh}{C_o \Sigma L_i}$$

Sum of width of perforated wall segments

Perforated Shear Wall Design

4.3.6.4.1.1 In-plane Shear Anchorage for Perforated Shear Walls: The maximum induced unit shear force, v_{max}, transmitted into the top of a perforated shear wall, out of the base of the perforated shear wall at full height sheathing, and into collectors connecting shear wall segments, shall be calculated in accordance with the following:

$$v = \frac{V}{C_o \Sigma L_i}$$

Shear Resistance Adjustment Factor

Sum of width of perforated wall segments

Perforated Shear Wall Design

4.3.6.4.2.1 Uplift Anchorage for Perforated Shear Walls: In addition to the requirements of 4.3.6.4.2, perforated shear wall bottom plates at full height sheathing shall be anchored for a uniform uplift force, t, equal to the unit shear force, v_{max}, determined in 4.3.6.4.1.1, or calculated by rational analysis.

$$t = \boxed{v = \frac{V}{C_o \Sigma L_i}}$$

Perforated Shear Wall Design

Summary

- **Prescribed forces for shear and uplift connections ensure that the capacity of the wall is governed by the sheathing to framing attachment (shear wall nailing) and not bottom plate attachment for shear and/or uplift.**

Method Comparison Summary

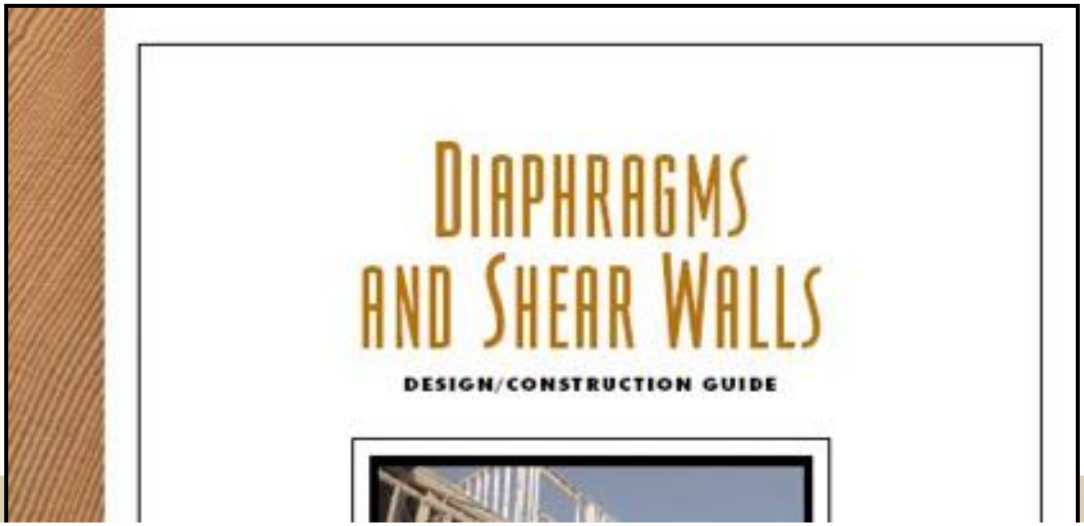
- **Which method works “best” will depend**

Reference:

Examples of:

Shear Wall Design

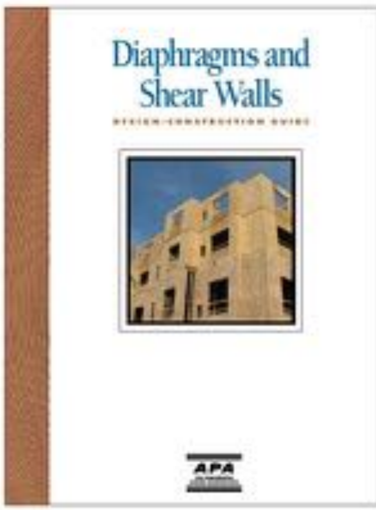
Deflection Calculations



APA Publications and Website

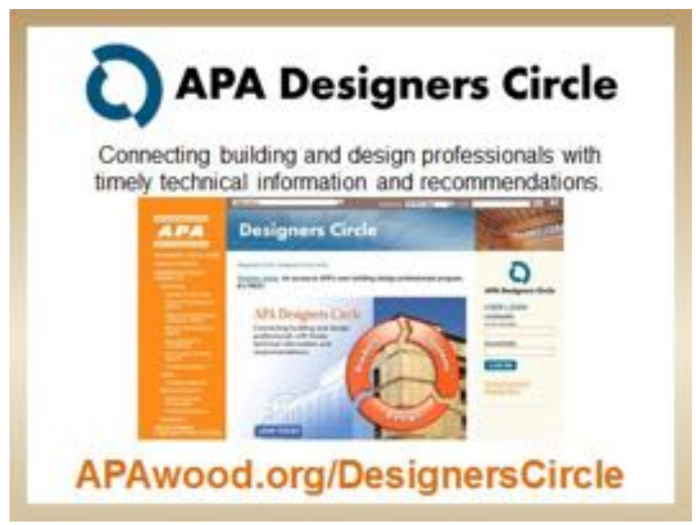
Free APA publications

www.APAwood.org



APA Designers Circle

APAwood.org/DesignersCircle



Questions?

APA

Bryan Readling, P.E.
bryan.readling@apawood.org

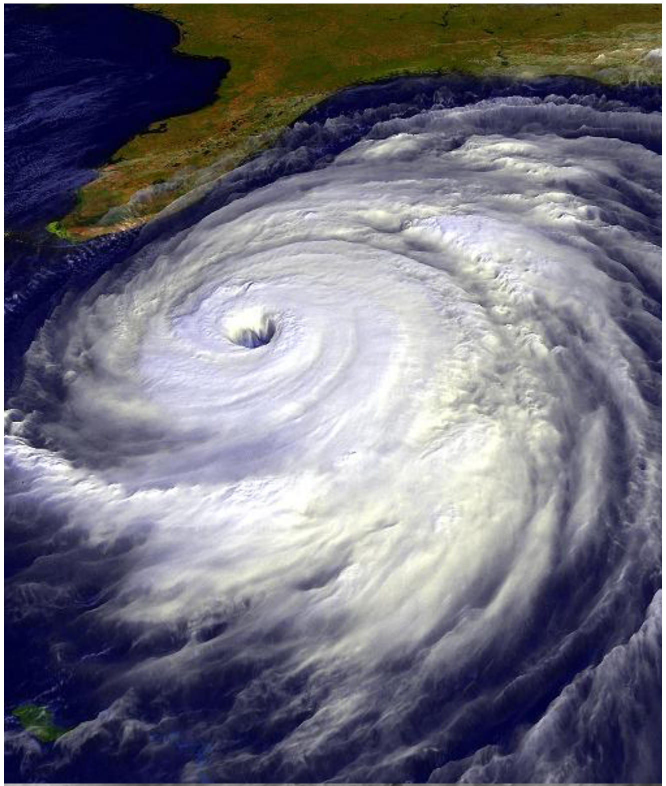
APA Help Desk

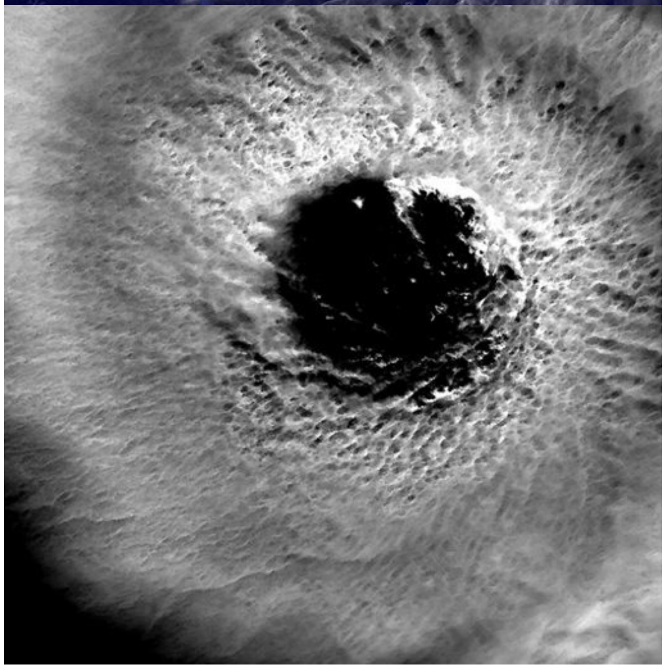
help@apawood.org

253-620-7400

WoodWorks™
WOOD PRODUCTS COUNCIL

Alternate Wood Frame and Hybrid Lateral Force Resisting Systems





October, 2015

Engineered Shear Wall Systems w/ WSP

Stapled Shear Walls

- Capacities in IBC 2306

Mid-Ply Shear Walls

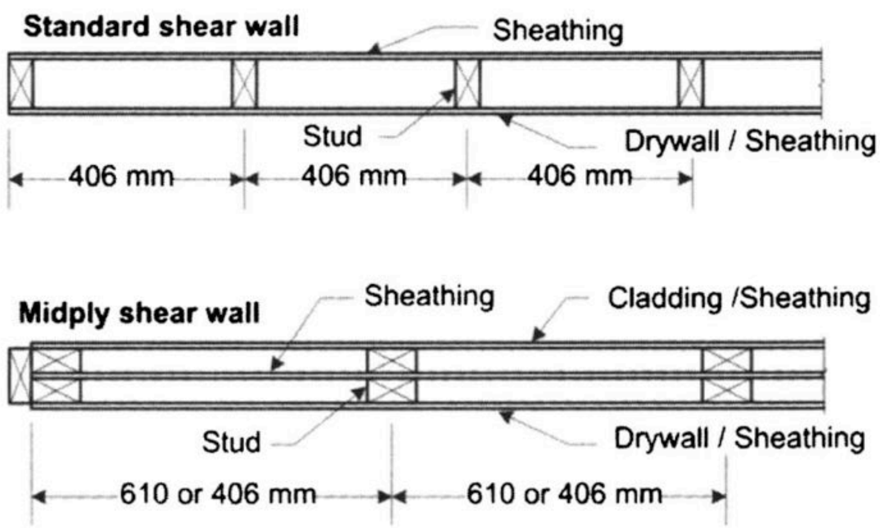


Fig. 1. Cross section of typical standard shear wall and midply wall

Source: Journal of Structural Engineering, 2007

Source: nees.org

Gypsum Shearwalls

- Lower capacities than WSP Shearwalls (about 1/3 capacity)
- SDPWS Table 4.3C, Section 4.3.7.5 provides capacities & requirements
- Not permitted in SDC E or F

Non-WSP Engineered Shear Wall Systems

Proprietary Trussed Shear Walls

Manufacturer Provides Capacities & Stamped Design

Source: smartcomponents.us

Non-WSP Engineered Shear Wall Systems

Horizontal & Diagonal Board Sheathing

Source: firstdayonpei

Capacities in AWC's SDPWS
Table 4.3D

Source: johnotvos

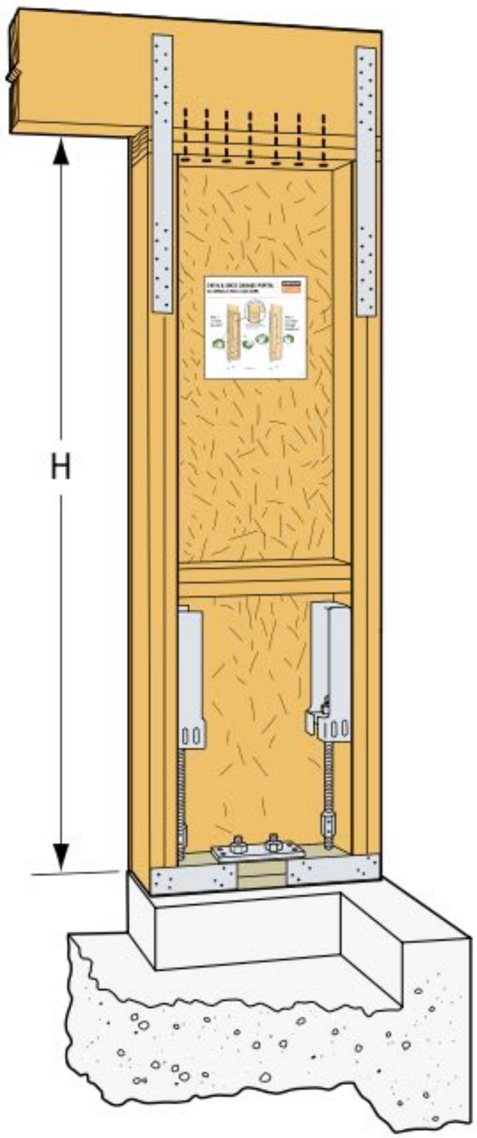
Open Front & Narrow Walls

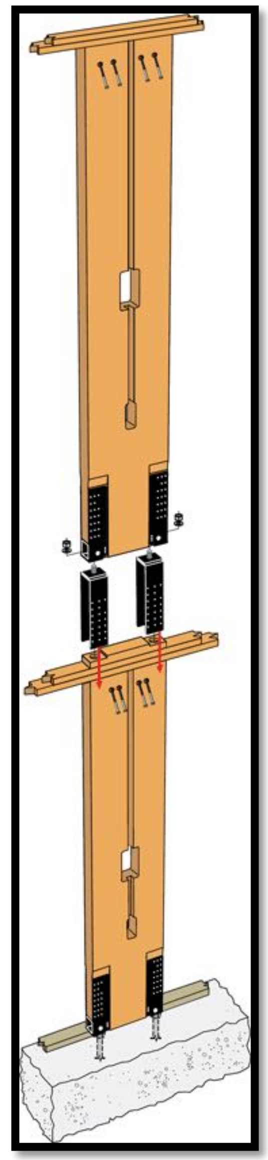
Using Prefab Shearwalls

Considerations:

- Engineered Narrow Wall Section
- Proprietary
- Large Hold-down forces
- Deflections
- Manufacturer Provides Wall Capacity

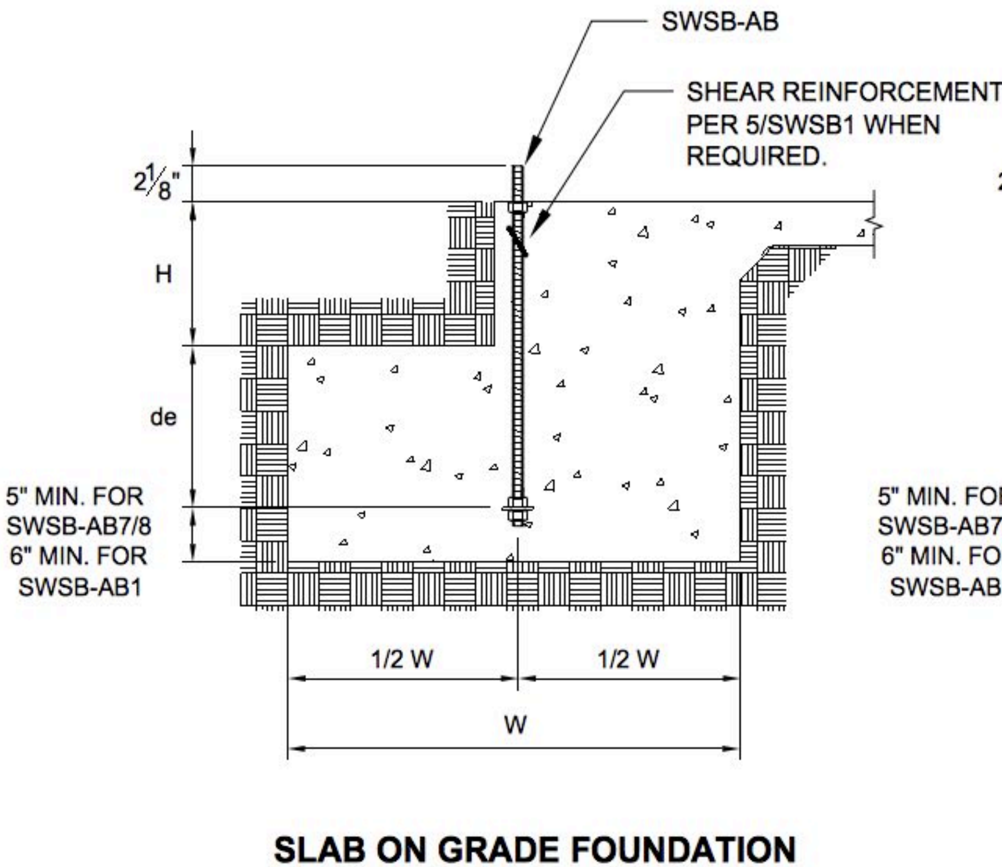
Proprietary Portal Frame Systems

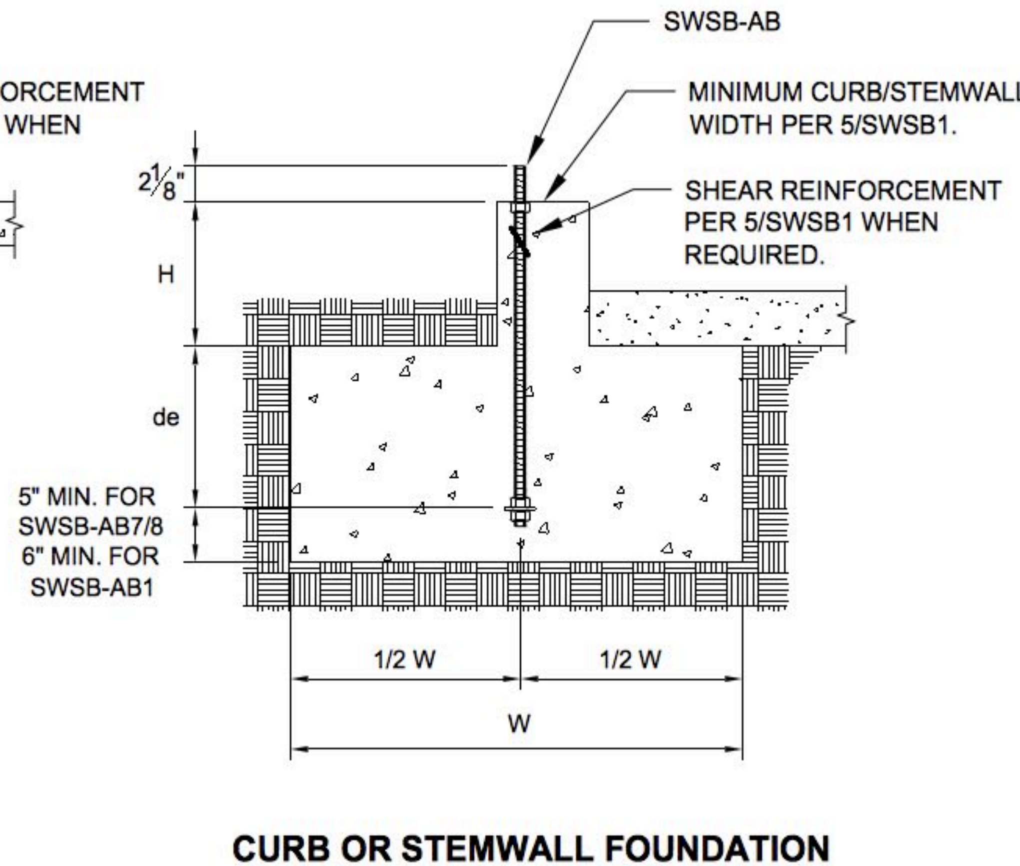




Source: strongtie.com

Prefab Shearwall Anchorage

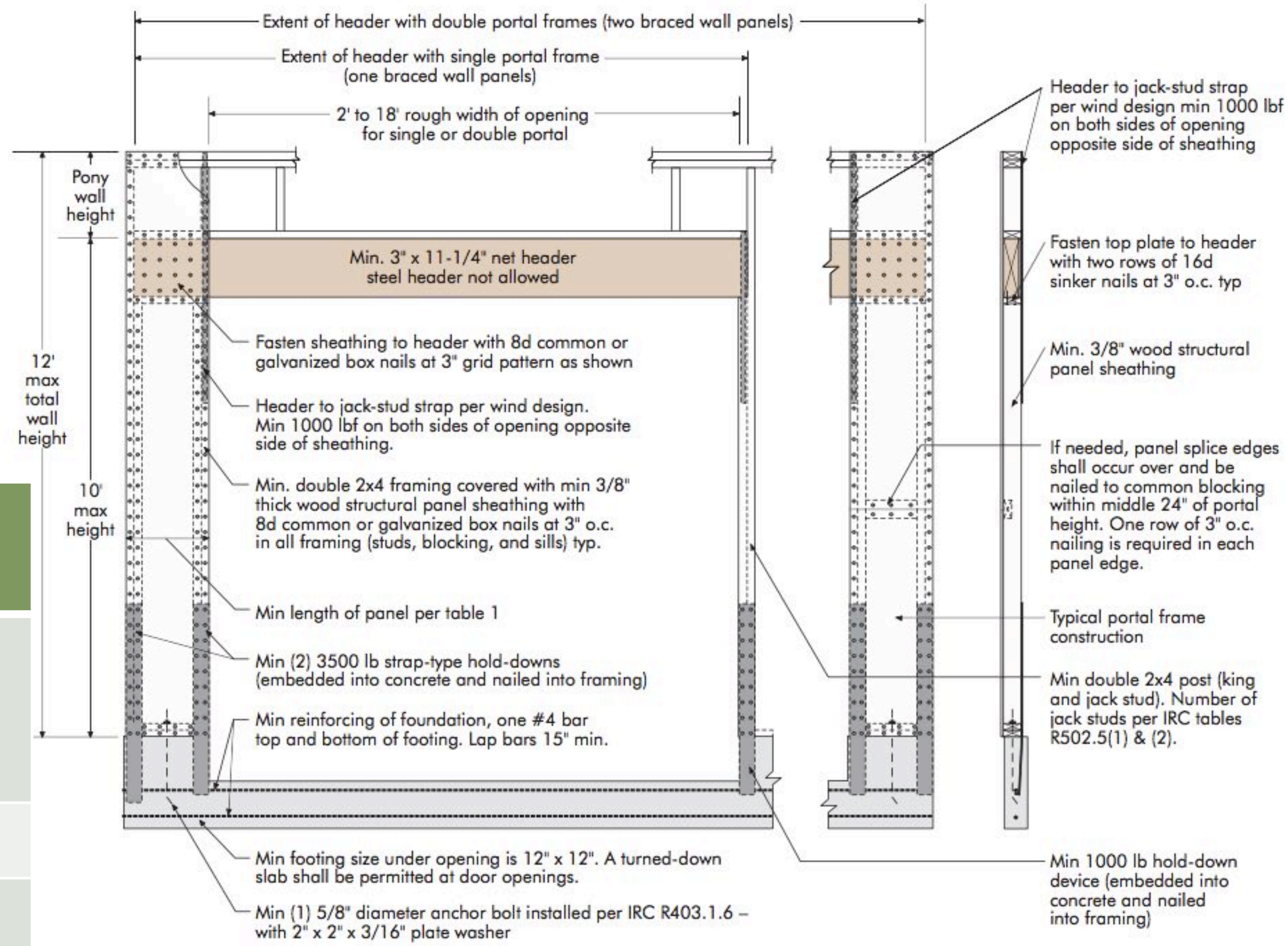




Source: strongtie.com

Portal Frame Systems

Figure 1. Construction Details for APA Portal-Frame Design with Hold Downs



Allowable Design Shear Values		
Min. Width (in.)	Max. Height (ft.)	Shear (lb)
16	8	850
	10	625
24	8	1,675
	10	1,125

APA Report TT-100F

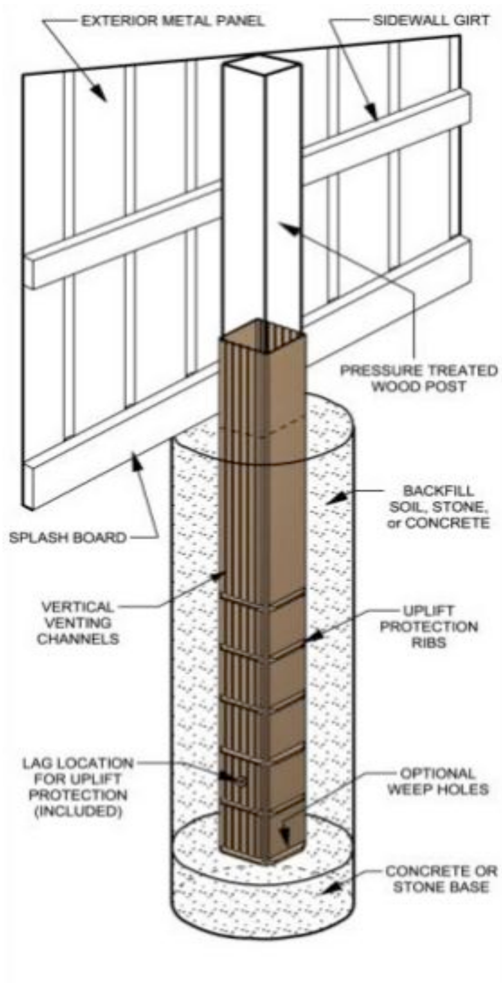
Hybrid Wood/Steel Prefab Shearwalls

Source: hardyframe.com

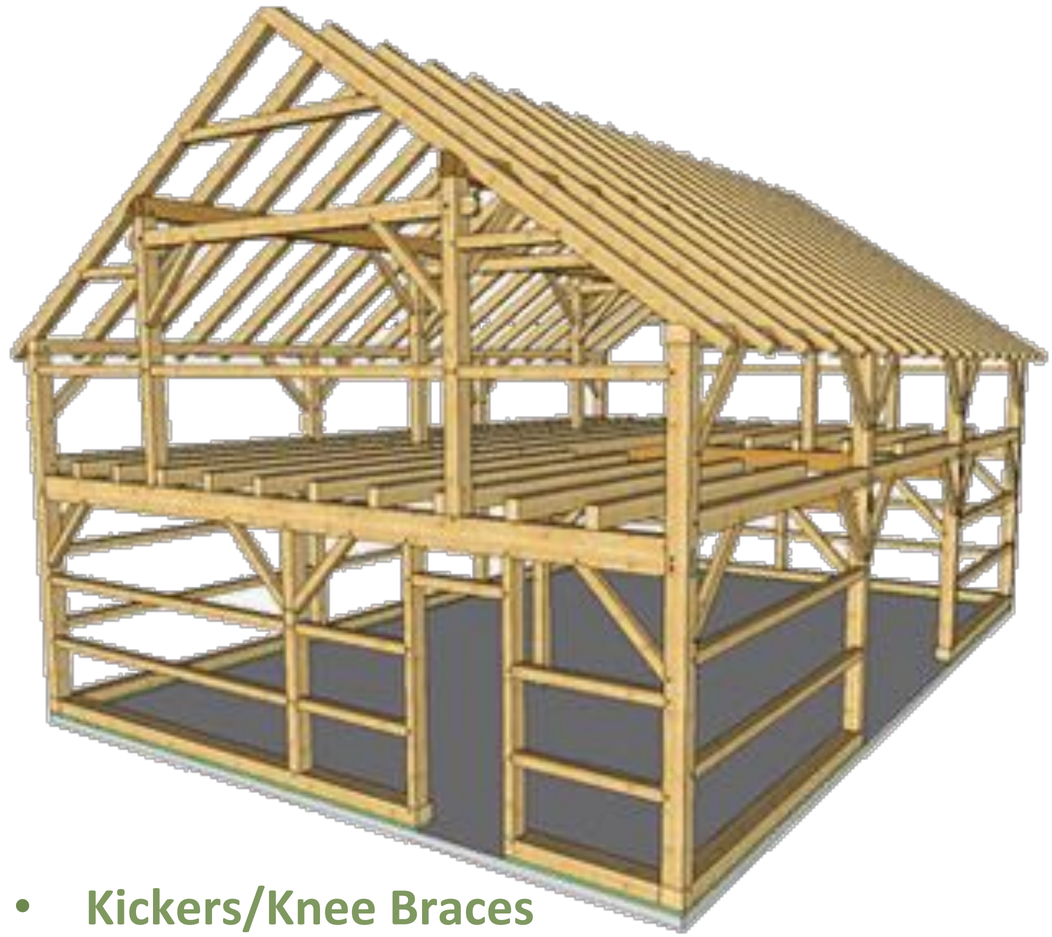
Hybrid Wood/Steel Prefab Shearwalls

Source: hardyframe.com

Post Frame Buildings – Lateral Options



Embedded/ Cantilever Columns



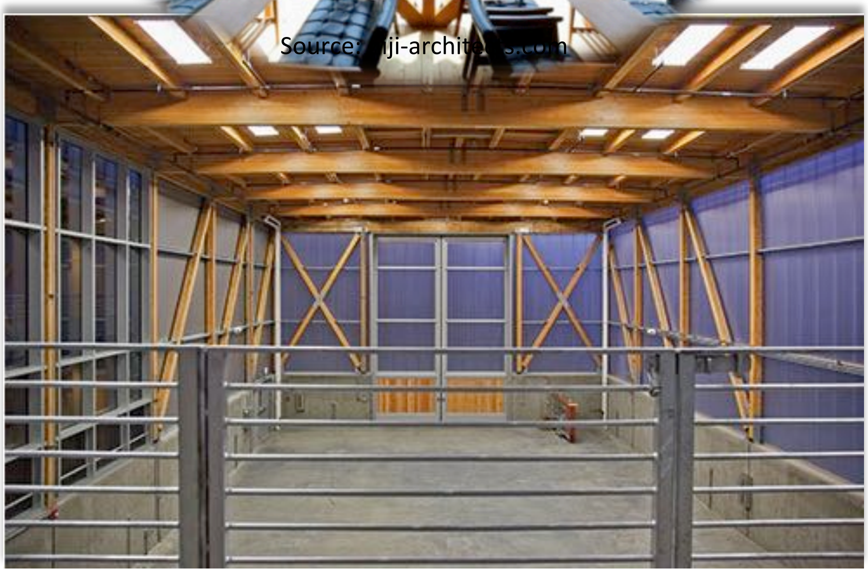
- **Kickers/Knee Braces**
- **Sheathed Walls/Roof**
- **Steel Rod X-Bracing**
- **Others**

Source: newenglandbarn.com

Heavy Timber Braced Frames (HTBF)

Heavy timber braced frames are becoming a preferred alternative vertical/ lateral resisting system due to cost, performance and aesthetics.

Source: [illegible]iji-archite[illegible]s.com



Source: naturallywood.com

Hybrid Wood/Steel Braced Frames

The Bullitt Center
Architect: The Miller Hull Partnership
Photo: John Stamets

Questions?

It's Lunch Time!

Visit www.woodworks.org for more educational materials, case studies, design examples, a project gallery, and more