Description

This course discusses the purpose of shear walls and reviews their design and use in light-frame wood construction using the 2018 International Building Code® (IBC®), 2015 Special Design Provisions for Wind and Seismic (SDPWS) and 2018 National Design Standard® (NDS®).

Objectives

Upon completion, participants will be better able to:

- Understand whether a wall is a prescriptive braced wall or engineered shear wall
- Identify code requirements and referenced standards applicable to shear wall design
- Identify typical wood framed shear walls
Objectives

- Analyze a typical shear wall design – does it meet code and standard requirements?
- Identify connections to floor or roof and foundation
- Determine whether connections are of sufficient size to transfer loads

About me

Sandra Hyde, P.E.
Senior Staff Engineer
International Code Council

Portland, OR
Tel: 888-422-7233 x7755
Email: shyde@iccsafe.org

About you

- Plan review engineers
- Engineers and Architects
- Plans examiners
- Inspectors
- Special inspectors
- Manufacturers
Course Overview

- Module 1: Prescriptive vs. engineered wood walls
- Module 2: Typical shear walls
- Module 3: Segmented shear wall design
- Module 4: Identifying collectors
- Module 5: Perforated shear wall design
- Module 6: Identifying anchorage
- Module 7: Calculation of anchorage capacity

Module 1:
Prescriptive vs. Engineered wood walls

Prescriptive vs. Engineered Wood Walls

1. What is the purpose of a wall?
2. Prescriptive braced wall panels
3. Engineered shear walls
   - Segmented Shear Walls
   - Shear Walls with Openings (Force Transfer)
   - Perforated Shear Walls
What is the purpose of wall sheathing?

Wall sheathing resists loads that act horizontally.
- Wind
- Earthquake
- Fluid

These loads are called 'lateral loads'.

Vertical Loads

Wall sheathing does not resist vertical (gravity) loads.

Vertical loads are resisted by studs, top and bottom plates, headers and columns – the ‘framing’.

Vertical (Gravity) Load Path

1. Ridge Beam
2. Post
3. Header
4. Jack Studs
5. Sill Plate
6. Foundation
7. Ground

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Lateral Loads

Lateral (Sideways) Load Path

Wall sheathing resists loads that act horizontally.

Panel resistance imparted to wall framing (Prevents hinging)

Lateral Forces

Wind

Force = Pressure \times Area

Seismic

Force = Mass \times Acceleration

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Lateral Forces

Effects of Forces
Racking  Base Shear  Overturning

Resisted by Bracing  Resisted by Anchors  Resisted by hold-downs & Dead Load

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Lateral Forces

Racking

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Lateral Forces

Base Shear

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Lateral Forces

Overturning

Lateral Forces

Anchors

Lateral Forces

hold-down
Lateral Load Path

1. Load on wall
2. Transfer to roof
3. Connections
4. Transfer to wall
5. Transfer to foundation

Prescriptive Braced Wall Panels

= Conventional Light-frame Construction

- IBC Section 2308
- No engineering required
- Typically without hold-downs
- Limitations
  - 1-3 stories maximum
  - Wind < 130 mph (exc for 140 mph)
  - SDC A-E

Uniform Building Code – 1927
All exterior walls and partitions shall be thoroughly and effectively angle braced.

All exterior walls and main cross stud partitions shall be effectively and thoroughly braced at each end, or as near thereto as possible, and at least every 25 feet of length by one of the following methods:

A. Nominal 1-inch by 4-inch...
B. Wood boards of 5/8-inch...
C. Plywood sheathing...
D. Fiberboard sheathing...
E. Gypsum sheathing...
F. Particleboard sheathing...
Prescriptive Braced Wall Panels

International Building Code - 2000

- Bracing percentage requirement added
- Continuous wood structural panel bracing method added
- Alternate bracing methods added

Engineered Shear Walls

A shear wall is the portion of a wall line that is designed to resist lateral forces.

Applications:
- Any building size/shape
- Wind – no limit
- SDC – no limit
- Calculations required

Typically with hold-downs

Shear Walls

- Are vertical cantilevered diaphragms
- Resist lateral forces of shear in the diaphragm
- Resist compression and tension in the boundary members.
Shear Walls

Out-of-plane – the wall the wind pushes is loaded out-of-plane.

In-plane – walls resisting the wind load (side walls) are loaded in-plane.

Shear Wall Loads

Shear walls transfer loads from roof and floor diaphragms to the story below.
Shear Wall Loads

Loading of the shear wall = Load Path
1. Wind pushes against the wall.
2. WSP sheathing spans from the foundation to the top plate on the wind wall, distributing half the wind load to the foundation and half the load to the roof or floor diaphragm.
3. The diaphragm distributes the load to the shear walls.

Shear Walls - Deformation

In-plane shear walls resist loads by racking. A shear wall becomes trapezoidal in shape.

Shear Walls

Wood Shear Walls:
- Sheathed with wood structural panels (WSP)
- Nailed on all edges
- WSP placed vertically
- Have a minimum size dependent on whether the individual WSP in shear walls are blocked
Shear Walls
Requirements for typical wood shear walls:
- Must be blocked at shear wall edges.
- A hold-down device, if required, must be connected to the edge members (studs) of the shear wall.
- The shear wall sheathing must be edge nailed to the stud that is connected to the hold-down device.
- The shear wall sheathing must be edge nailed to the top and bottom (perimeter) members of the shear wall.

Blocked Shear Walls
Shear walls are connected along a wall line by struts or collectors that transfer load from one shear wall to another.
Shear Walls
Continuous strut or collector

Which elements act as collectors in this wall?

Shear Wall - Collector
Struts and collectors frame open sections of a diaphragm passing loads from one shear wall to another.
### Shear Walls

- At the base of a shear wall, shear is resisted by the anchor bolts.
- Overturning moment is resisted by the hold-down devices.

### Shear Wall – Aspect Ratio

- Blocked minimum: 3.5:1
- Unblocked minimum: 2:1

### Segmented Shear Walls

Requirements:
- Individual 4’ by 8’ or longer full-height wall segments = 1 shear wall
- No openings within shear wall segments
- With out-of-plane offsets, the shear wall on each side of the offset is considered part of a separate shear wall line
- Collectors are provided along the entire length of the shear wall line.
Segmented Shear Wall – Aspect Ratio

Minimum aspect ratio

Shear Walls with Openings (Force Transfer)

Force Transfer design assumes the entire wall is one shear wall.

Requirements:
• Framing, blocking and straps around openings are designed to transfer loads
• Look for blocking in full-height areas at the same height as the window framing – top and bottom
• Straps will be laid horizontally across headers and plates and into blocking in the full-height sections of walls (next slide).

Shear Walls with Openings (Force Transfer)

Straps tie header or plate to blocking in the full-height sections of walls. This allows the wall to move as one unit. Hold-downs are placed at the ends of the walls.
Force Transfer
SW–Aspect Ratio

The aspect ratio applies to:

1. Overall shear wall height and width including openings
2. Each wall pier at the sides of openings

Force Transfer – Wall Pier

Perforated Shear Walls

Design considers a single shear wall with openings

- Reduced shear strength based on size of openings
- Fewer anchors and hold-downs required
- No additional blocking and straps required
Perforated Shear Walls

Attributes:
- Assumes single-sided WSP with 10d nails at 2” o.c. at panel edges
- Walls sheathed on both sides do not have an increase in design strength (no testing done)
- Wall capacity is greater than the capacity of the full-height segments within the wall considered alone

Perforated Shear Walls

Requirements:
- Full-height segments at each end of wall with maximum aspect ratio of 2:1
- Allowable shear from Table 4.3A divided by 2.0 for ASD values must be 490 plf or less
- Collector the full length of the wall (continuous top plates)
- Max. height is 20 ft
- Uniform height

Perforated Shear Wall – Aspect Ratio

Each shear wall segment within the perforated shear wall must meet the minimum aspect ratios:
- Blocked: min 3.5:1
- Unblocked: min 2:1
Shear Wall - Anatomy

Shear walls include:
- Wall sheathing – wood structural panel, gypsum board, etc.
- 2x4 or 2x6 framing
- Top plates
- Bottom plates
- Headers, jack studs or cripple studs in perforated and force transfer shear walls
- Fasteners
- Anchor bolts, hold-downs
- Steel plates where required around openings
Shear Wall - Anatomy

Where overturning loads are too high (uplift), shear walls have hold-downs added to the ends of the wall. These hold-downs tie the end of the shear wall into the foundation.
### Shear Wall - Anatomy

Hold-down at floor compressing upper story wall, floor, and top plate of wall below.

Hold-down at ceiling compressing top plate, floor, and bottom plate of story above.

### Lumber – Studs and Plates

The National Design Specification® (NDS®) for Wood Construction by the American Wood Council (AWC) is used to specify wood products in the design of wood construction.

The 2018 NDS® is referenced in the 2018 IBC.

### Species and Grade

The most wood common species in the US are:

- Douglas Fir.
- Southern Pine.
- A combined group of Spruce, Pine, and Fir.

<table>
<thead>
<tr>
<th>Common Species</th>
<th>Harvest Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Douglas Fir – Larch (DFL) or (DF)</td>
<td>Northwestern US and Western Canada</td>
</tr>
<tr>
<td>Southern Pine (SP)</td>
<td>Southeastern US</td>
</tr>
<tr>
<td>Spruce-Pine-Fir (SPF)</td>
<td>Throughout the US and Canada</td>
</tr>
</tbody>
</table>
Sheathing Attachment

Sheathing Attachment
Adhesive attachment of wall sheathing alone or with mechanical fasteners not permitted in SDC D-F.
(SDPWS 4.3.6.3.1)

Load Duration Factor, $C_D$

<table>
<thead>
<tr>
<th>Load Duration</th>
<th>$C_D$</th>
<th>Typical Design Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permanent</td>
<td>0.9</td>
<td>Dead Load</td>
</tr>
<tr>
<td>10 years</td>
<td>1.0</td>
<td>Occupancy Live Load</td>
</tr>
<tr>
<td>2 months</td>
<td>1.15</td>
<td>Snow Load</td>
</tr>
<tr>
<td>10 minutes</td>
<td>1.6</td>
<td>Wind, Earthquake Load</td>
</tr>
<tr>
<td>Impact</td>
<td>2.0</td>
<td>Impact Load</td>
</tr>
</tbody>
</table>

Load Combination Equations

The largest load duration factor is applied.

<table>
<thead>
<tr>
<th>Load Combination</th>
<th>Shortest Duration</th>
<th>$C_D$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D + 0.6W$</td>
<td>$D$</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>$W$</td>
<td>1.00</td>
</tr>
<tr>
<td>$D + 0.7E$</td>
<td>$D$</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>$E$</td>
<td>1.00</td>
</tr>
<tr>
<td>$D + 0.75(0.6W + 0.75(L_r or S or R))$</td>
<td>$D$</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>$W$</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>$L_r$</td>
<td>1.25</td>
</tr>
<tr>
<td></td>
<td>$S$</td>
<td>1.15</td>
</tr>
<tr>
<td></td>
<td>$R$</td>
<td>1.00</td>
</tr>
</tbody>
</table>
### Load Combination Equations

<table>
<thead>
<tr>
<th>Load Combination</th>
<th>Shortest Duration</th>
<th>$C_D$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D + 0.75(0.7E) + 0.75L + 0.75(L_r + S + R)$ (EQN. 16-14)</td>
<td>$D$</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>$E$</td>
<td>1.60</td>
</tr>
<tr>
<td></td>
<td>$L$</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>$L_r$</td>
<td>1.25</td>
</tr>
<tr>
<td></td>
<td>$S$</td>
<td>1.15</td>
</tr>
<tr>
<td></td>
<td>$R$</td>
<td>1.00</td>
</tr>
<tr>
<td>$0.6D + 0.6W$</td>
<td>(EQN. 16-15)</td>
<td>$D$</td>
</tr>
<tr>
<td></td>
<td>$W$</td>
<td>1.60</td>
</tr>
<tr>
<td>$0.6D + 0.7E$</td>
<td>(EQN. 16-16)</td>
<td>$D$</td>
</tr>
<tr>
<td></td>
<td>$E$</td>
<td>1.60</td>
</tr>
</tbody>
</table>

### Double-sided Shear Walls

Shear capacity for walls sheathed with WSP on both sides varies according to the method in which the shear wall is designed.

- **Segmented** vs **Perforated**

  - Force transfer

  SDPWS 4.3.3.3, 4.3.5.3

### Double-sided Shear Walls – Segmented and Force Transfer Methods

Shear capacity for walls sheathed with WSP on both sides is 2x the shear capacity listed for single sided WSP for shear walls designed with the following methods …

- Segmented
- Force transfer
Double-sided Shear Walls – Perforated Method

For perforated shear walls, no testing of double-sided WSP has been done. The capacity is the same as single-sided shear walls.

Non-wood Sheathed Shear Walls

Other options: Aspect Ratio

- Gypsum board 2:1
- Structural fiberboard 3.5:1
- Particleboard 2:1
- Lath and Plaster 2:1
- Diagonal board sheathing 2:1

Many of these methods are only allowed in seismic design categories (SDC) A-C.

Gypsum Board Shear Walls

Shear walls made of gypsum board have a capacity determined by SDPWS Table 4.3C.

Fasteners:

1/2" sheathing
- 0.120" nail x 1-3/4" long, min 7/16" head, diamond point, galvanized

5/8" sheathing
- 6d galvanized common nail x 1-7/8" long, 1/4" head
- Wallboard nail (0.0915" x 1-7/8" long, 19/64" head)
- 0.120" nail x 1-3/4" long, min 3/8" head
Structural Fiberboard Shear Walls

Shear walls made of structural fiberboard have a capacity determined by SDPWS Table 4.3A.

Fasteners:
- 1/2" sheathing: 11 gage galvanized roofing nail (0.120" x 1-1/2" long x 7/16" head)
- 25/32" sheathing: 11 gage galvanized roofing nail (0.120" x 1-3/4" long x 3/8" head)

Module 3:
Segmented Shear Wall Design

Typical Shear Wall

Per SDPWS Table 4.3A
- Edge nailing at 2" to 6" on center
- Field nailing of 6" o.c. or 12" o.c.
- Nail head above the surface of the WSP
- A minimum of 1.5" embedment into the stud
- Blocking behind all edges
Shear Wall Nailing Pattern

For example:
Edge nailing 3” o.c.
Field nailing 6” o.c.
Blocked wall

Shear Wall Nailing Pattern

For 7/16” WSP and minimum 2” long nails (8d); nailing 3/6 gives a nominal shear strength of 1415 plf (lbs per foot).
This gives an ASD shear strength of 708 plf (1415/2.0).

Shear Wall Nailing Pattern

Using the tables of SDPWS §4.3, all field nailing must be a max. of 6 in. on center. Nails must be a min. of 3/8 in. from edge of panel.

Except, where panels are 15/32 inch thick or studs are less than 24 inches on center, 12 inch o.c. field nailing may be used.
**Minimum Stud Size**

Studs must be at least 2" nominal width

- Exempt, studs at adjoining panel edges must be a minimum of 3" nominal when ...
  - Nail spacing is 2" p.c. or less
  - 10d nails or larger have minimum penetration of 1.5 inches at 3" p.c. or less
  - Nominal unit shear capacity of 700+ plf in SDC D, E or F

SDPWS §4.3.7.1 Item 5

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**Unblocked Shear Walls**

Shear walls may be unblocked if a reduction is taken in shear capacity.

The reduction ranges from 0-60% based on nail and stud spacing.

Walls are limited to 16 feet in height.

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**Wood Structural Panels Over Gypsum Sheathing**

WSP may be applied directly over gypsum board onto studs

Shear panel capacity increases slightly with the double layer of material.

Requirements for construction are the same as a single layer of wood structural panel.
Wood Structural Panels Over Gypsum Sheathing

Minimum nail embedment into the stud remains the same.

Minimum nail length:
7/16" (WSP) + 5/16" (GB) + 1-3/8" = 2-1/8"

Wood Structural Panels Over Gypsum Sheathing

For 7/16" WSP over GB and minimum 2.5" long nails (10d); nailing 3" edge, 6" field gives a nominal shear strength of 1290 plf. This gives an ASD shear strength of 645 plf (1290/2.0).

Reactions Within the Shear Wall

Diaphragm shear, \( V_d \)
Tension chord
Compression chord
Overturning reaction, \( R \) (tension in hold-down)
Sill plate anchors resist shear
Shear reaction, \( V \) (occurs at level of sill plate)
Overturning reaction, \( R \) (compression of sill plate)
Reactions Within the Shear Wall

Diaphragm Shear – the force transferred from floor or roof diaphragm to top of shear wall. Gravity drags this force from the top of the shear wall down toward the foundation.

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Reactions Within the Shear Wall

Tension chord – the force transferred from the diaphragm pulls the top plates up and toward the right in the graphic. The far left stud is stretched up in its connection to the top plates, i.e. stretched in tension.

The hold-down keeps the end of the shear wall from lifting up.

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Reactions Within the Shear Wall

Compression chord – the force transferred from the diaphragm presses the top plates down and toward the right in the graphic. The far right stud is pressed down at its connection to the top plates, i.e. in compression.

The stud must not punch through the sill plate or floor framing below, nor may the end of the stud crush (broom).
Reactions Within the Shear Wall

Shear reaction – the force transferred from the diaphragm is resisted at the bottom of the wall by shear reaction. This is a sliding force. The anchor bolts resist the shear reaction keeping the wall in place on the foundation.

Reactions Within the Shear Wall

Overturning forces – the force transferred from the diaphragm to top of shear wall pulls up on the far left side of the wall and down on the far right side of the wall. This force is resisted by the hold-down in tension and the sill plates in compression.

Reactions Within the Shear Wall

With lateral motion, nails attaching the WSP sheathing to the top plate will bend distributing the lateral force into the wall frame and allowing transfer of the forces toward the foundation.
Reactions Within the Shear Wall

Looking at the reaction in a cross section of the wall, nails attaching the WSP sheathing to the studs bend, distributing additional lateral force into the wall frame and allowing transfer of the forces toward the foundation.

Shear Walls – Calculating Loads

Wall Shear, $v_w$

$$v_w = \frac{F}{L_1 + L_2}$$

Shear Wall Length, $SWL = L_1 + L_2$

Shear Wall Capacity

$$V_{ASD} = \frac{V_n}{2.0}$$
Shear Wall Calculation

Given:
- Force, \( F \) = 12,000 lbs
- Top plates 2 – 2x4 DF-L
- Sill plates 2 – 2x4 treated HF

Shear Wall 1

Shear Wall 2

\[
L_1 = 12 \text{ ft} \\
L_2 = 24 \text{ ft}
\]

SWL = \( L_1 + L_2 \) = 36 ft

\[
V_{w1} = \frac{F \cdot L_1}{L_1 + L_2} = \frac{12,000 \cdot 12}{36} = 4000 \text{ lbs}
\]

\[
V_{w2} = \frac{F \cdot L_2}{L_1 + L_2} = \frac{12,000 \cdot 24}{36} = 8000 \text{ lbs}
\]
Prescriptive Top Plate Splice Nailing

Nail each side of splice

(8) 0.162” x 3-1/2” or (12) 0.131” x 3” nails

IBC §2308.5.3.2, Table 2304.10.1 Fastening Schedule, Item 13

Shear Wall Calculation

Given:
F = 12,000 lbs

Top plates 2 - 2x4 DF-L
Sill plates 2 - 2x4 treated HF

V_{w1} = 4000 lbs
V_{w2} = 8000 lbs

Shear Wall Calculation

Shear to transfer = F / L_{TC} = 12,000 / 44 ft = 273 lbs/ft

Force to transfer = V x L_{NSWC} = 273 plf x 8 ft = 2184 lbs
**Shear Wall Calculation**

Required Collector Tensile Area, \( A = \frac{F}{F'} \)

\( F = 2184 \text{ lbs} \)
\( F' \) is calculated in the table below:

<table>
<thead>
<tr>
<th>DFL #2</th>
<th>( F_t ) (psi)</th>
<th>( C_D )</th>
<th>( C_E )</th>
<th>( C_{DA} )</th>
<th>( F'_t ) (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>575</td>
<td>1.6</td>
<td>1.5</td>
<td>1.0</td>
<td></td>
<td>1380</td>
</tr>
</tbody>
</table>

\( F = 2184 \text{ lbs} \)
\( F'_t = 1380 \text{ psi} \)

\( A = \frac{F}{F'_t} = \frac{2184 \text{ lbs}}{1380 \text{ psi}} = 1.6 \text{ in}^2 \)

Where 1 stud is …

1.5in x 3.5in = 5.25 in²

Given 2 top plates:

\( A = (2) 2 \times 4 = 10.5 \text{ in}^2 \)

10.5 in² > 1.6in²

**Shear Wall Calculation**

Nail Capacity, \( Z \) - assume 10d common

\( F = 2184 \text{ lbs} \)
\( Z' \) is calculated in the table below:

<table>
<thead>
<tr>
<th>DFL #2</th>
<th>( G )</th>
<th>( Z ) (lbs)</th>
<th>( C_D )</th>
<th>( Z' ) (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>118</td>
<td>1.6</td>
<td></td>
<td>189</td>
</tr>
</tbody>
</table>
Shear Wall Calculation

Nail Capacity, Z - assume 10d common

\( F = 2184 \text{ lbs} \)

\( Z' = 189 \text{ lb/nail} \)

Min. # nails required = \( \frac{2184 \text{ lb}}{189 \text{ lb per nail}} = 12 \)

Assume 2 rows of nails spaced 12 in. on center

\( DFL_{\text{Chord Length}} = \frac{F}{2 \text{ rows of nails}} \)

\( = 6 \text{ nails x 12 in/nail} = 6 \text{ ft} \) ✔ OK

Module 5:

Perforated Shear Wall Design

Simple Wall with Two Shear Segments

Given:
- Force, \( F = 8,000 \text{ lbs} \)

Top plates 2 – 2x4 DF-L
- Sill plates 2 – 2x4 treated HF

Collector Length - \( L_C \)

\( L_C = 25\text{ ft} \)
**Simple Wall with Two Shear Segments**

Capacity

Nail at 3\(\frac{1}{2}\)\(\frac{1}{2}\), 7/16" plywood

From Table 4.3A, \(v_{ASD} = 505\) plf

\[ C_0 = \frac{(r/(3-2r)) \times (L_C/\Sigma L_i)}{2} = \frac{0.88/(3-2\times0.88)}{25/22} = 0.81 \]

where

- \(r\) – sheathing ratio
- \(L_C\) – total length of perforated wall
- \(L_i\) – length of full-height segment
- \(A_0\) – total area of openings
- \(h\) – height of wall

\[ \Sigma L_i = 14\text{ ft} + 8\text{ ft} = 22\text{ ft} \]

From Table 4.3.3.5, \(C_0\) based on opening height and percent full height sheathing

Assume opening height = \(h\)

\(\%\) full-height sheathing = 22 ft / 25 ft = 0.88 round to 80%

\[ C_0 = 0.71 \]

\[ V = C_0 \times v_{ASD} \times \Sigma L_i = 0.71 \times 505\text{ plf} \times 22\text{ ft} = 7888\text{ lbs} \]
Simple Wall with Two Shear Segments

Force = 8,000 lbs

Shear Capacity, \( V = 7888 \text{ lbs} \) or 8,999 lbs by calculation

Force = 8,000 lbs

Collector Length - \( L_c = 32\text{ ft} \)

Complex Wall with Multiple Openings

Given:

Force, \( F \)

\( F = 8,000 \text{ lbs} \)

Top plates 2 – 2x4 DF-L

Sill plates 2 – 2x4 treated HF

Collector Length - \( L_c = 32\text{ ft} \)

Capacity – from table:

Nail at 3"/6", 7/16" plywood

From Table 4.3A, \( v_{ASD} = 505 \text{ plf} \)

\( \Sigma L_i = 5\text{ ft} + 7\text{ ft} + 4\text{ ft} = 16\text{ ft} \)

- From Table 4.3.3.5, \( C_0 \) based on opening height and percent full height sheathing
- 2 ft segment gives ratio of 8'/2' = 4.1 > 3.5:1, segment length insufficient.
Complex Wall with Multiple Openings

\[ \nu_{ASD} = 505 \text{ plf} \]
\[ \% \sum L_i/L_C = 16 \text{ ft} / 32 \text{ ft} = 0.5 \]

Max opening – near full height, use \( h \) in table

\[ C_0 = 0.50 \]
\[ V = C_0 \nu_{ASD} \sum L_i = 0.50 \times 505 \text{ plf} \times 16 \text{ ft} = 4,040 \text{ lbs} \]

Module 6:

Identifying anchorage

Shear wall anchorage

- Anchor bolts resist shear (sliding force) at base of shear wall
- Hold-downs resist tension forces (uplift) at outer corner of wall
Shear wall anchorage – anchor bolts

Anchor bolt requirements:
- Minimum embedment of 7 inches
  - 10” min. length for 2x sill plates
  - 12” min. length for 3x sill plates
- When WSP shear capacity > 400 plf
  - Min. 0.229” x 3” x 3” slotted steel plate
    - washer
  - Extends within ¼ in. of edge of plate
  - Note: an exception to use standard washers

Overturning anchorage – hold-downs

Hold-downs consist of:
- Metal bracket nailed or screwed to corner studs
- Headed anchor bolt set into the concrete
- At the base of the anchor bolt is a washer and 2 nuts for bearing

Overturning anchorage – straps

Straps are used to connect upper story shear walls to floor framing and walls below

Anchor straps are used to connect bottom story shear walls into the foundation below. Note – reinforcement is required at the anchor
Anchor bolts – in-plane shear

Determine unit shear, \( \nu \) per foot of shear wall

1. Divide \( V_w/L \)
2. Check anchor capacity against \( \nu \)

(1) \( \nu = \frac{4000 \text{ lbs}}{12 \text{ ft}} = 334 \text{ plf} \)

(2) Calculate anchor bolt capacity using IBC

Anchor Bolts and 2018 IBC

1905.1.8 ACI 318, Section 17.2.3.

- Modify ACI 318 Sections 17.2.3.4.2, 17.2.3.4.3(d) and 17.2.3.5.2 to read as follows:
  - 17.2.3.4.2 – Where the tensile component of the earthquake force applied to anchors is >20% of the total factored anchor tensile force, anchors and their attachments designed in accordance with 17.2.3.4.3. The anchor design tensile strength determined in accordance with 17.2.3.4.4.

  Exception: Anchors designed to resist wall out-of-plane forces with design strengths equal to or greater than the force determined in accordance with ASCE 7 Equation 12.11-1 or 12.14-10 shall be deemed to satisfy Section 17.2.3.4.3(d).
Anchor Bolts and 2018 IBC

1905.1.8 ACI 318, Section 17.2.3.

17.2.3.4.3(d) – The anchor designed for the maximum tension with $E$ increased by $G$. The anchor design tensile strength shall be calculated from 17.2.3.4.4.

17.2.3.5.2 – Where the earthquake force shear component applied to anchors > 20% of the total, anchors and their attachments designed in accordance with 17.2.3.5.3.

Exceptions:

Anchor Bolts and 2018 IBC

For calculation of in-plane shear strength, … in-plane shear strength in accordance with Sections 17.5.2 and 17.5.3 need not be computed. … Section 17.2.3.5.3 shall satisfy requirements if the following is met:

1. The allowable in-plane shear strength of the anchor is determined in accordance with AWS NDS Table 11E for lateral design values parallel to grain.
2. The maximum anchor nominal diameter is 5/8 inches.
3. Anchor bolts are embedded into concrete a minimum of 7 inches.
4. Anchor bolts are located a minimum of 1-3/4 inches from the edge of the concrete parallel to the length of the wood sill plate.
5. Anchor bolts are located a minimum of 15 anchor diameters from the edge of the concrete perpendicular to the length of the wood sill plate.

2018 Wood Framed Shear Walls

Anchor Bolts and the NDS

From NDS Table 11E – wood to concrete bolted connection

$Z' = Z \times C_d$

$Z' = 590 \text{ lbs} \times 1.6$

$Z' = 944 \text{ lbs}$

$944 \text{ lbs} / 334 \text{ plf} = 2.8 \text{ ft max. spacing of anchor bolts, use 2.5 ft}$
Hold-downs – overturning (tension)

Determine required hold-down capacity

1.  \( T = F \times h \times L \)
2.  Check hold-down capacity against uplift

Shear Wall 1

\( V_w1 = 4000 \text{ lbs} \)

\( V_w2 = 8000 \text{ lbs} \)

44 ft

\( F = 12,000 \text{ lbs} \)

Shear Wall 2

1.  \( T_{SW1} = 4000 \text{ lbs} \times 16 \text{ ft} / 12 \text{ ft} = 5334 \text{ lbs} \)
2.  Look up hold-down capacity from manufacturer literature

Assuming SPF plate, for 5334 lbs min, use HDU8-SDS2.5 with min 3 studs and SSTB28 anchor bolts

Hold-downs – overturning (tension)

Determine required hold-down capacity

1.  \( T_{SW2} = 8000 \text{ lbs} \times 16 \text{ ft} / 24 \text{ ft} = 5334 \text{ lbs} \)
2.  Look up hold-down capacity from manufacturer literature

Assuming SPF plate, for 5334 lbs min, use HDU8-SDS2.5 with min 3 studs and SSTB28 anchor bolts
Wood Shear Wall Books

- Based on the 2009 IBC, 2005 NDS and 2008 SDPWS
- Useful information on design and construction
- Construction do’s and don’ts

Useful Books

- Building Code Essentials – Based on the 2018 IBC, Steve Thomas, 2018, ICC

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