Description

AWC's 2015 Special Design Provisions for Wind and Seismic (SDPWS) is referenced in the 2015 International Building Code (IBC) for design of structures using wood shear walls and diaphragms to resist wind and seismic lateral loads. Provisions in the SDPWS contain the equal deflection requirement for distribution of shear to shear walls in a line which can be met either by calculation of shear wall deflections or use of reduced design unit shear strength. This course will discuss the 2015 SDPWS provisions for distributing shear using the deflection calculation approach and effects on calculated design shear capacity of a shear wall line. It will be compared to the adjustment factor approach which permits distribution of shear in proportion to strength where reduced strengths are determined by use of the $2b/h$ factor for wood structural panels. Allowable stress design (ASD) examples, excerpted from the 2015 SDPWS Commentary are included.
Learning Objectives

On completion of this course, participants will

• Be able to understand the 2015 SDPWS provisions for distribution of shear to shear walls in a line
• Be familiar with the 2015 SDPWS provisions for shear distribution based on either i) deflection calculation, or ii) use of reduced shear strengths in accordance with the 2bs/h factor for wood structural panels
• Be able to understand how distribution of shear provisions affects design shear capacity of shear walls in a line
• Be familiar with new strength reductions for shear walls based on shear wall aspect ratio

Polling Question

What is your profession?

a) Architect
b) Engineer
c) Code Official
d) Building Designer
e) Other
Outline

- Code Acceptance
- Distribution of Shear Provisions
  - Deflection Calculation Approach
  - Adjustment Factor Approach
- Aspect Ratio Factor (Strength)
- Design Examples

Code Acceptance

- 2015 IBC
  - References 2015 SDPWS in Section 2305 for lateral design and construction
4.3.3.4.1 Shear distribution to individual shear walls in a shear wall line shall provide the same calculated deflection, $\delta_w$, in each shear wall.

Exceptions:
1. Where nominal shear capacities of all wood structural panel shear walls with aspect ratios ($h/b$) greater than 2:1 are multiplied by $2b_h$ for design, shear distribution to individual full-height wall segments shall be permitted to be taken as proportional to the shear capacities of individual full height wall segments used in design. Where multiplied by $2b_h$, the nominal shear capacities need not be reduced by the adjustment in 4.3.4.2.

**Table 4.3.4 Maximum Shear Wall Aspect Ratios**

<table>
<thead>
<tr>
<th>Shear Wall Sheathing Type</th>
<th>Maximum $h/b$, Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood structural panels, unblocked</td>
<td>2:1</td>
</tr>
<tr>
<td>Wood structural panels, blocked</td>
<td>3:1</td>
</tr>
<tr>
<td>Particleboard, blocked</td>
<td>2:1</td>
</tr>
<tr>
<td>Diagonal sheathing, conventional</td>
<td>2:1</td>
</tr>
<tr>
<td>Gypsum wallboard</td>
<td>2:1</td>
</tr>
<tr>
<td>Portland cement plaster</td>
<td>2:1</td>
</tr>
<tr>
<td>Structural Fiberboard</td>
<td>3:1</td>
</tr>
</tbody>
</table>

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 $2b_h$.
2. Walls having aspect ratios exceeding 3:1 shall be blocked shear walls.

Table 4.3.4 Maximum Shear Wall Aspect Ratios

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</table>

1. 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) = 1.00-0.009h, The value of the Aspect Ratio Factor (Wind) 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).
**Distribution of Shear to Shear Walls in a Line**

**4.3.3.4.1 Deflection calculation approach**

- Distribute shear to provide same deflection in each shear wall
- Account for distribution of shear based on stiffness of each shear wall. Distribution of shear is not directly proportional to shear wall length
- Utilize shear wall deflection equation from SDPWS 4.3.2:

$$\delta_{sw} = \frac{8v^2h^3}{EAb} + \frac{vh}{1000G_s} + \frac{h\Delta_v}{b}$$

**EQ. 4.3-1**

**Exceptions:**
1. Where nominal shear capacities of all wood structural panel shear walls with aspect ratios \((h/b)\) greater than 2.1 are multiplied by \(2b/h\) for design, shear distribution to individual full-height wall segments shall be permitted
to be taken as proportional to the shear capacities of individual full-height wall segments used in design. Where multiplied by \(2b/h\), the nominal shear capacities need not be reduced by the adjustment in 4.3.4.2.

2. For wood structural panel shear walls with aspect ratios \((h/b)\) greater than 2.1, the nominal shear capacity shall be multiplied by the Aspect Ratio Factor (SRF) = 1.25 - 0.125b/h. For structural fiberboard shear walls with aspect ratios \((h/b)\) greater than 1.1, the nominal shear capacity shall be multiplied by the Aspect Ratio Factor (SRF) = 1.00 - 0.09h/b.
4.3.3.4.1 - Exception, Adjustment factor approach (2b_s/h) for WSP

- For wood structural panel shear walls, distribute shear in proportion to reduced strengths in accordance with 2b_s/h factor (e.g. v_s x 2b_s/h)
- 2b_s/h factor applies where h/b_s > 2:1
- Accounts for reduced stiffness of high aspect ratio shear walls
- Not cumulative with aspect ratio factor for strength (4.3.4.2)
- Applies to both wind and seismic

<table>
<thead>
<tr>
<th>Aspect Ratio Factor (Stiffness)</th>
<th>2:1</th>
<th>3:1</th>
<th>3½:1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspect Ratio, h/b_s</td>
<td>1.00</td>
<td>0.67</td>
<td>0.57</td>
</tr>
<tr>
<td>2b_s/h</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Aspect Ratio Factor (Strength)

4.3.4.2 For wood structural panel shear walls with aspect ratios (h/b_s) greater than 2:1, the nominal shear capacity shall be multiplied by the Aspect Ratio Factor (WSP) = 1.25 - 0.125h/b_s. For structural fiberboard shear walls with aspect ratios (h/b_s) greater than 1:1, the nominal shear capacity shall be multiplied by the Aspect Ratio Factor (fiberboard) = 1.09 - 0.09 h/b_s.
Aspect Ratio Factor (Strength)

4.3.4.2 – Shear Wall Aspect Ratio Factors (for strength)

- For wood structural panel shear walls with h/b_s > 2:1, unit shear capacities are determined by multiplying by the Aspect Ratio Factor: 1.25 – 0.125 h/b_s
- Applies to segmented and FTAO shear walls
- Applies to wind and seismic
- 4.3.4.2 Aspect Ratio Factor (strength) is less severe than adjustment for stiffness (where 4.3.3.4.1 Exception is used)

### 4.3.4.2 Aspect Ratio Factor (Strength)

<table>
<thead>
<tr>
<th>Aspect Ratio, h/b_s</th>
<th>2:1</th>
<th>3:1</th>
<th>3½:1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.25-0.125 h/b_s</td>
<td>1.00</td>
<td>0.875</td>
<td>0.813</td>
</tr>
</tbody>
</table>

Comparison

Always controls? Not cumulative

### 4.3.3.4.1 Exception, Adjustment Factor (Stiffness)

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<tr>
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### 4.3.4.2 Aspect Ratio Factor (Strength)

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<td>0.875</td>
<td>0.813</td>
</tr>
</tbody>
</table>
Polling Question

Which is true with respect to the $2b_s/h$ adjustment factor approach for WSP in SDPWS 4.3.3.4.1?

a) The $2b_s/h$ factor applies where $h/b_s > 2:1$

b) Not cumulative with aspect ratio factor for strength in 4.3.4.2

c) Applies only to seismic design

d) All of the above

e) a) and b) only

Example 1 - Deflection Calculation Approach

Example Assumptions

• Blocked Wood Structural Panels (WSP)
• 15/32 OSB
• 2x4 Douglas Fir framing
• 8d common (or galvanized box) nails at 6” o.c. edge spacing
• Seismic nominal unit shear = 520 plf
• Apparent shear stiffness, $G_s = 13$ kips/in
• End posts – double 2x4’s, $EA = 16,800,000$ lb
• Vertical elongation of wall anchorage system = 1/8” at 3,500 lbs
• Stiffness of wall anchorage system; $k = 3500$ lbs/0.125 in = 28,000 lbs/in
### Example 1 - Deflection Calculation Approach

#### Table 4.3A Nominal Unit Shear Capacities for Wood-Frame Shear Walls

<table>
<thead>
<tr>
<th>Sheathing Material</th>
<th>Minimum Nominal Panel Thickness (in.)</th>
<th>Minimum Fastener Penetration in Framing member or sheathing (in.)</th>
<th>Panel Type &amp; Size</th>
<th>SEISMIC Panel Edge Fastener Spacing (in.)</th>
<th>( f_p ) (kip/lin.)</th>
<th>( f_c ) (kip/lin.)</th>
<th>( f_f ) (kip/lin.)</th>
<th>( f_s ) (kip/lin.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood Structural Panel - Structural</td>
<td>7 1/4</td>
<td>1 1/4</td>
<td>OSB PLY</td>
<td>670</td>
<td>23</td>
<td>23</td>
<td>1020</td>
<td>23</td>
</tr>
<tr>
<td>Wood Structural Panel - Structural</td>
<td>7 1/2</td>
<td>1 1/4</td>
<td>OSB PLY</td>
<td>670</td>
<td>23</td>
<td>23</td>
<td>1020</td>
<td>23</td>
</tr>
<tr>
<td>Wood Structural Panel - Structural</td>
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<td>1 1/4</td>
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**SDPWS Example C4.3.3.4.1-1**

![Diagram](image)
**Example 1 - Deflection Calculation Approach**

**Shear Wall 1 (SW1)**

Nominal unit shear capacity for seismic = 520 plf (SDPWS Table 4.3A)

**SW1 Aspect ratio (h/b₅)**

= 8'/8' = 1.0

Aspect Ratio Factor (WSP) for strength = 1.0 (SDPWS 4.3.4.2)

ASD unit shear capacity for seismic, $\nu_{SW1} = \frac{520 \text{ plf}}{2 \times 1.0} = 260 \text{ plf}$

**Example 1 - Deflection Calculation Approach**

**Shear Wall 2 (SW2)**

Nominal unit shear capacity for seismic = 520 plf (SDPWS Table 4.3A)

**SW2 Aspect ratio (h/b₅)**

= 8'/2.3' = 3.5

Aspect Ratio Factor (WSP) for strength = 1.25 – 0.125h/b₅ (SDPWS 4.3.4.2)

= 1.25 – 0.125 x 8'/2.3' = 0.81

ASD unit shear capacity for seismic, $\nu_{SW2} = \frac{520 \text{ plf}}{2 \times 0.81} = 210 \text{ plf}$
Example 1 – Deflection Calculation Approach

- Maximum design unit shear in each shear wall segment based on 4.3.4.2 Aspect Ratio Factor (Strength)

- Next step – address distribution of shear based on 4.3.3.4.1 (i.e. distribution based on relative stiffness of SW1 and SW2)

\[ \delta_{SW1} = \frac{8 v_{SW1}^2 h^3}{E A b_{SW1}} + \frac{v_{SW1} h}{1000 G_a} + \frac{h \Delta_a}{b_{SW1}} \]

\[ \delta_{SW1} = 0.008 + 0.16 + 0.074 = 0.242 \text{ in} \]

where:
- \( v_{SW1} = 260 \text{ plf} \)
- \( h = 8 \text{ ft} \)
- \( EA = 16,800,000 \text{ lb} \)
- \( b_{SW1} = 8 \text{ ft} \)
- \( G_a = 13 \text{ kips/in} \)
- \( \Delta_a,SW1 = 0.074 \text{ in.} \)
Example 1 - Deflection Calculation Approach

**SW1 Vertical Elongation Of Wall Anchorage System**

Overturning anchorage force = 260 plf x 8 ft = 2,080 lbs

Anchorage system stiffness, k = 3,500 lbs / 0.125 in. = 28,000 lbs/in.

\[ \Delta_{aSW1} = \frac{2,080 \text{ lbs}}{3,500 \text{ lbs} \times 0.125 \text{ in.}} = 0.074 \text{ in.} \]

Calculations for elongation of wall anchorage system ignores:

- effect of dead load
- compression deformation in wood framing

---

Example 1 - Deflection Calculation Approach

**Part 2 – Determine Unit Shear in SW2 that produces the same deflection as SW1**

\[ V_{SW2} = \frac{\delta}{8h^3 + \frac{h}{E} + \frac{h^2}{1000G_a} + \frac{kb_{SW2}}{k}} = 141 \text{ plf} \]

where:

- \( \delta = 0.242 \text{ in.} \) same as \( \delta_{aSW1} \)
- \( h = 8 \text{ ft} \)
- \( EA = 16,800,000 \text{ lb} \times \text{ft} \)
- \( k = 2.3 \text{ ft} \)
- \( G_a = 13 \text{ kips/lin.} \)
- \( k = 28,000 \text{ lb/lin.} \)
Example 1 - Equal Deflection Approach

Part 2 – Simplification of term 3:

\[
\delta_{sw} = \frac{8vh^3}{EAb} + \frac{vh}{1000G_a} + \frac{h\Delta_a}{b}
\]

Solve for elongation in terms of induced unit shear, \( v \):

\[\Delta_a = v_{SW} \frac{h}{k}\]

By substitution, third term becomes:

\[h^2 \frac{v_{SW}}{kb}\]

---

Example 1 - Deflection Calculation Approach

SW2 Vertical Elongation of Wall Anchorage System

Determine \( \Delta_{asw2} \) for unit shear force =141 plf

Overtwining anchorage force = 141 plf x 8 ft = 1,128 lbs

\[\Delta_{asw2} = 1,128 \text{ lbs} / 28,000 \text{ lbs/in.} = 0.040 \text{ in.}\]

Calculations for elongation of wall anchorage system ignores:

- effect of dead load
- compression deformation in wood framing
Example 1 - Deflection Calculation Approach

**Confirm SW2 Provides Same Deflection as SW1**

\[
\delta_{SW2} = \frac{8y_{SW2}h^3}{EAb_{SW2}} + \frac{v_{SW2}h}{1000G_s} + \frac{h\Delta_{x,SW2}}{b_{SW2}}
\]

\[
\delta_{SW2} = 0.015 + 0.087 + 0.140 = 0.242 \text{ in}
\]

\[\delta_{aSW1} = 0.242 \text{ in} \quad \text{OK}\]

---

**Part 3 – Sum Design Strengths of SW1 and SW2**

\[V_{SW1} = 260 \text{ plf} \times 8 \text{ ft} = 2080 \text{ lb}\]

\[V_{SW2} = 141 \text{ plf} \times 2.3 \text{ ft} = 324 \text{ lb}\]

\[V_{\text{shear wall line}} = 2080 \text{ lb} + 324 \text{ lb} = 2404 \text{ lb}\]
Polling Question

Example 1 illustrates which of the following for high aspect ratio shear walls?

a) Has lower strength than a low aspect ratio shear wall.
b) Has lower deflection than a low aspect ratio shear wall.
c) Anchorage slip may contribute considerably to wall deflection.
d) All of the above.
e) a and c
Example 2 – $2b_s/h$ Adjustment Method

Shear Wall 1 (SW1)

Nominal unit shear capacity for seismic = 520 plf (SDPWS Table 4.3A)

SW1 Aspect ratio ($h/b_s$) = 1.0

Adjustment factor (based on stiffness) = $2b_s/h = 1.0$

(SDPWS 4.3.3.4.1 Exception 1)

Aspect Ratio Factor (WSP) for Strength = 1.0 (SDPWS 4.3.4.2)

ASD unit shear capacity for seismic

$V_{SW1} = 520 \text{ plf} / 2 \times 1.0 = 260 \text{ plf}$
Example 2 – 2bₙ/h Adjustment Method

Shear Wall 2 (SW2)

Nominal unit shear capacity for seismic = 520 plf (SDPWS Table 4.3A)

SW2 Aspect ratio (h/bₙ) = 3.5

Aspect Ratio Adjustment (stiffness) = 2bₙ/h = 0.57
(SDPWS 4.3.3.4.1 Exception 1)

Aspect Ratio Factor (WSP) for strength = 0.81 (SDPWS 4.3.4.2)

ASD unit shear capacity for seismic

V_{SW2} = 520 \text{ plf} / 2 \times 0.57 = 148 \text{ plf}

Compared to 141 plf from Example 1

---

Example 2 – 2bₙ/h Adjustment Method

Sum Design Strengths

\[
\begin{align*}
V_{SW1} &= 260 \text{ plf} \times 8 \text{ ft} = 2080 \text{ lb} \\
V_{SW2} &= 148 \text{ plf} \times 2.3 \text{ ft} = 340 \text{ lb} \\
V_{\text{Shear wall line}} &= 2080 \text{ lb} + 340 \text{ lb} = 2420 \text{ lb}
\end{align*}
\]

Compared to 2404 lbs from Example 1
### Equalized Deflection Approach C4.3.3.4.1-1

#### High aspect ratio segment:
capacity reduced by Aspect Ratio Factor

#### Software solution: iterative design solution to distribute forces into each segment until equal deflections.

<table>
<thead>
<tr>
<th>SHEAR RESULTS (Flexible seismic design)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N-S</td>
</tr>
<tr>
<td>-----</td>
</tr>
<tr>
<td>Line 1</td>
</tr>
<tr>
<td>Wall 1-1</td>
</tr>
<tr>
<td>Wall 1-3</td>
</tr>
</tbody>
</table>

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Capacity exception approach C4.3.3.4.1-2

Aspect ratio adjustment

High aspect ratio segment: capacity reduced by aspect ratio adjustment

Alternative software solution: non-iterative design solution using aspect ratio adjustment of high aspect ratio walls to reduce capacity and distribute forces into each segment regardless of deflection.
**Software solution:**

**Choice of Distribution method and Deflection equation**

- Distribution choices: Equal deflection or Capacity exception

- Deflection equation choices: 3-term or 4-term
Polling Question

The simplified approach allows distribution of force to a line based on segment lengths.

a) True
b) False

Questions?

This concludes The American Institute of Architects Continuing Education Systems Course

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