Seismic & Wind Design Considerations for Wood Framed Structures

Presented by Karyn Beebe, P.E., LEED AP
APA –
The Engineered Wood Association

Quality Services Division

Technical Services Division

Field Services Division

Market Communications Division
“Any system of method of construction to be used shall be based on a **rational analysis** in accordance with well established principles of mechanics. Such analysis shall result in a system that provides a **complete load path** capable of transferring loads from their point of origin to the load-resisting elements.”

(CBC 2010 1604.4)
Vertical (Gravity) Load Path
Lateral Loads: National Issue

Wind Hazard

Earthquake Hazard
Lateral Loads (Wind)

\[ F = PA \]

Effort is devoted to determining:

P – wind pressure
Lateral Loads (Seismic)

\[ F = ma \]

Effort is devoted to determining:

\( a \) – acceleration
Wood – Light and Flexible
General Modes of Failure

- Uplift
- Base Shear
- Racking
- Overturning
3-D Connector
Lateral Forces

Racking – Rowlett/Garland Tornados 2015
Overturning
March 2017
Texas Straight Line Winds
APA Publications

Building for High Wind Resistance in Light-Frame Wood Construction

MIDWEST TORNADOES

Tornados of the South

Texas Straight-Line Wind Damage Assessment Report

Texas Tornado Damage Assessment Report
General Lateral Load Path

- Roof (horizontal diaphragm) carries load to end walls
- Wind load, (lb per sq ft)
- Side wall carries load to roof diaphragm at top, and to foundation at bottom
- End wall (vertical diaphragm or shear wall) carries load to foundation

\[ v \text{ (lb per lin ft of diaphragm width)} = \frac{wL}{2b} \]

\[ w \text{ (lb per lin ft of wall)} = F \frac{h}{2} \]

\[ T \text{ (lb)} = C = vh \]
2012 International Building Code (IBC)

2012 IBC
- Chapter 16 Loads
- ASCE 7-10
Governing Codes for Engineered Wood Design

2012 IBC

- Chapter 23 Wood
- NDS-2012 (National Design Specification for Wood Construction)
- SDPWS-08
2012 IBC

SDPWS-08 (Special Design Provisions for Wind and Seismic)

- Free download
- Sparse Chapter 23
Wood Structural Panels are by definition either Plywood or OSB (2302 & R202)
Wood Shear Wall and Diaphragms Design

- Function of: fastener’s size, spacing and panel thickness
- Values in Tables in SDPWS-08
- Alternately, capacities can be calculated by principles of mechanics
Wood's Strength Direction

- **Rated Sheathing**
  - Floor, wall or roof
  - Plywood or OSB

APA

RATED SHEATHING

32/16
SIZED FOR SPACING
EXPOSURE 1
THICKNESS 0.451 IN.
000

PS 2-10 SHEATHING
PRP-108 HUD-UM-40

15/32 CATEGORY

Roof Covering
Shear Wall and Diaphragm Tables

- Tables removed from Ch 23 except for staples
- SDPWS-08 lists nominal values – require adjusting for ASD or LRFD
# Wood Diaphragms Design

## Table 4.2B Nominal Unit Shear Capacities for Wood-Frame Diaphragms

### Unblocked Wood Structural Panel Diaphragms

<table>
<thead>
<tr>
<th>Sheathing and Single-Floor</th>
<th>Common Nail Size</th>
<th>Minimum Fastener Penetration in Framing (in.)</th>
<th>Minimum Nominal Panel Thickness (in.)</th>
<th>Minimum Nominal Framing Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural 1</td>
<td>6d</td>
<td>1-1/4</td>
<td>5/16</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>8d</td>
<td>1-3/8</td>
<td>3/8</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>10d</td>
<td>1-1/2</td>
<td>15/32</td>
<td>3</td>
</tr>
</tbody>
</table>

### A - SEISMIC

**Edge Nail Spacing: 6 in.**

<table>
<thead>
<tr>
<th>Cases</th>
<th>$v_s$ (plf)</th>
<th>$G_a$ (kips/in.)</th>
<th>$v_s$ (plf)</th>
<th>$G_a$ (kips/in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>330</td>
<td>9.0</td>
<td>250</td>
<td>6.0</td>
</tr>
<tr>
<td></td>
<td>370</td>
<td>7.0</td>
<td>280</td>
<td>4.5</td>
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<tr>
<td></td>
<td>480</td>
<td>8.5</td>
<td>360</td>
<td>6.0</td>
</tr>
<tr>
<td></td>
<td>530</td>
<td>7.5</td>
<td>400</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>570</td>
<td>14.0</td>
<td>430</td>
<td>9.5</td>
</tr>
<tr>
<td></td>
<td>640</td>
<td>12.0</td>
<td>480</td>
<td>8.0</td>
</tr>
</tbody>
</table>

### B - WIND

**Edge Nail Spacing: 6 in.**

<table>
<thead>
<tr>
<th>Cases</th>
<th>$v_w$ (plf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>460</td>
</tr>
<tr>
<td></td>
<td>520</td>
</tr>
<tr>
<td></td>
<td>670</td>
</tr>
<tr>
<td></td>
<td>740</td>
</tr>
<tr>
<td></td>
<td>800</td>
</tr>
<tr>
<td></td>
<td>895</td>
</tr>
</tbody>
</table>

---

*Notes:*

1. *Note A*
2. *Note B*
3. *Note C*
4. *Note D*
4.2.3 Unit Shear Capacities

The nominal unit shear capacities for seismic design are provided in Column A of Tables 4.2A, 4.2B, and 4.2C; and for wind design in Column B of Tables 4.2A, 4.2B, and 4.2C. The ASD allowable unit shear capacity shall be determined by dividing the nominal unit shear capacity by the ASD reduction factor of 2.0. No further increases shall be permitted. The LRFD factored unit resistance shall be determined by multiplying the nominal unit shear capacity by a resistance factor, $\phi_D$, of 0.80.
Flexible, Rigid or Semi-Rigid
SDPWS 4.2.5

Which do you have?

- Idealized as flexible
- Idealized as rigid
  - Deflection of Diaphragm \( \leq 2 \times \) Shear walls
- Semi-rigid
- Envelope
Flexible v. Rigid

- **Flexible**
  - Stiffness: 2K
  - Weight: .25wL

- **Rigid (no Torsion)**
  - Stiffness: K
  - Weight: .40wL

- **Comparison**
  - 2K
  - .25wL
  - .50wL
  - .20wL
  - .40wL

- **Dimensions**
  - L/2
  - L/2
Open Front Wood Diaphragms (SDPWS -08 4.2.5)

- **Open front**
  - Changes consistent with ASCE 7-10
  - Increased limitations on story drift and building configuration
Prescribed Rigid Wood Diaphragms (SDPWS -08 4.2.5)

- Open front
  - w/ torsional irreg. L’/W’ <= 0.67:1 for multistory, 1:1 for 1-story
  - L’ <= 35’
Deflections (4-term eqn’s)

- **Shear Wall (IBC §2305.3.2)**

\[
\Delta = \frac{8vh^3}{EAb} + \frac{vh}{G_v t_v} + 0.75he_n + \frac{h}{b}d_a
\]

- **Diaphragm (IBC §2305.2.2)**

\[
\Delta = \frac{5vL^3}{8EAb} + \frac{vL}{4G_v t_v} + 0.188Le_n + \frac{\sum(\Delta cX)}{2b}
\]

APA L350 (www.apawood.org) has comprehensive listing of input parameters and examples
Deflection (3-term eqn.)

- **Diaphragm (SDPWS §4.2.2)**

\[
\Delta = \frac{5vL^3}{8EAW} + \frac{0.25vL}{1000G_a} + \sum \frac{(\Delta_cX)}{2W}
\]

- \(G_a\) values for blocked and unblocked diaphragms
High load diaphragms
High Load Diaphragms

- SDPWS-08 4.2.7.1.2
- Uses multiple rows of nails
- ASD capacity up to 1800 plf (seismic)
- ASD capacity up to 2520 plf (wind)
- Shall be subject to special inspection IAW CBC Section 1704.6.1
Footnotes to High-Load Diaphragm Table

Loads were limited by lumber splitting.
High-Load Diaphragm Fastening Pattern
(SDPWS-15 Fig 4C)

3” nominal, two lines of fasteners
Wood's Strength Direction

- **Rated Sheathing**
  - Floor, wall or roof
  - Plywood or OSB

APA

RATED SHEATHING
32/16
SIZED FOR SPACING
EXPOSURE 1
THICKNESS 0.451 IN.

PS 2-10 SHEATHING
PRP-108 HUD-UM-40

15/32 CATEGORY
Height to width ratio (SDPWS-08 Figure 4D & 4E)

- For shear walls and perforated shear walls
- h:w must not exceed 2:1 or 3.5:1 ratio
Height to width ratio (SDPWS-08 Figure 4F)

- For force transfer around opening shear walls
  - h:w must not exceed 2:1 or 3.5:1 ratio
**Aspect ratio**
(SDPWS-15 4.3.4.2)

- Definition of h and w is the same as previous code
- ALL shear walls with $2:1 < \text{aspect ratios} \leq 3.5:1$ shall apply reduction factor, aspect ratio factor
- Aspect Ratio Factor (WSP) = $1.25 - 0.125\frac{h}{bs}$
  - Formerly applied only to high seismic

Excerpt Fig 4D
h:w ratio Segmented

Excerpt Fig. 4E
h:w ratio FTAO
Shear distribution to shear walls in line (SDPWS-15 4.3.3.4.1)

- Individual shear walls in line shall provide the same calculated deflection. Exception:
  - Nominal shear capacities of shear walls having $2:1 < \text{aspect ratio} \leq 3.5:1$ are multiplied by $2bs/h$ for design. Aspect ratio factor (4.3.4.2) need not be applied.
Aspect ratio for Perforated Shear Walls (SDPWS-15 4.3.4.3)

- For wall segments $2:1 < \text{aspect ratio} \leq 3.5:1$
  - Multiply those segments by $2bs/h$ in order to calculate $L_i$ and $\Sigma L_i$
  - Sections 4.3.4.2 and 4.3.3.4.1 don’t apply
Shear Wall Design Challenges (SDPWS 4.3.5)

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

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

**Perforated**
1. Code provides specific requirements
2. The capacity is determined based on empirical equations and tables
Segmented Wood Shear Walls

- Only full height segments are considered.
- Max aspect ratio:
  * 2:1 – without adjustment
  * 3.5:1 – with adjustment high seismic only
- Changes for SDPWS-15

Aspect ratio $h:b_s$ as shown in figure.
- Openings accounted for by strapping or framing
  - “based on a rational analysis”
- Hold-downs only at ends
- H/w ratio defined by wall pier

Aspect ratio h:b as shown in figure
Perforated Shear Wall

- 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)
Shear Wall Design Challenges
Joint research project

- APA - The Engineered Wood Association (Skaggs & Yeh)
- University of British Columbia (Lam & Li),
- USDA Forest Products Laboratory (Rammer & Wacker)

Study was initiated in 2009 to:

- Examine the variations of walls with code-allowable openings
- Examines the internal forces generated during full-scale testing
- Evaluate the effects of size of openings, size of full-height piers, and different construction techniques
- Create analytical modeling to mimic testing data
Different Techniques for FTAO

- **Drag Strut Analogy**
  - Forces are collected and concentrated into the areas above and below openings
  - Strap forces are a function of opening and pier widths
Different Techniques for FTAO

- **Cantilever Beam Analogy**
  - Forces are treated as moment couples
  - Segmented panels are piers at sides of openings
  - Strap forces are a function of height above and below opening and pier widths
Different Techniques for FTAO

- **Diekmann**
  - Assumes wall behaves as monolith
  - Internal forces resolved via principles of mechanics
Design Examples

2,000 lbf

2.3'

4'

4'

8'

10.3'
Design Example Summary

- **Drag Strut Analogy**
  - $F_1 = 284 \text{ lbf}$
  - $F_2 = 493 \text{ lbf}$

- **Cantilever Beam Analogy**
  - $F_1 = 1,460 \text{ lbf}$
  - $F_2 = 2,540 \text{ lbf}$

- **Diekmann Method**
  - $F_1 = 567 \text{ lbf}$
  - $F_2 = 986 \text{ lbf}$
**Test Plan**

**Wall 1**
Objective: Est. baseline case for 3.5:1 segmented wall

**Wall 2**
Objective: No FTAO, compare to Wall 1. $C_0 = 0.93$. Examine effect of sheathing above and below opening w/ no FTAO. Hold down removed.

**Wall 3**
Objective: No FTAO, compare to Wall 1 and 2. Examine effect of compression blocking.

**Wall 4**
Objective: FTAO, compare to Wall 1. Examine effect of straps

Wall is symmetric, sheathing and force transfer load measurement on right pier not shown for clarity
Test Plan

Wall 5

Objective: FTAO, compare to Wall 4. Examine effect of straps with larger opening.

Wall is symmetric, sheathing and force transfer load measurement on right pier not shown for clarity.

Wall 6

Objective: Compare to Wall 4. Examine effect of sheathing around opening.

Wall is symmetric, sheathing and force transfer load measurement on right pier not shown for clarity.

Wall 7

Objective: Est. baseline case for 2:1 segmented wall.

Wall 8

Objective: Compare FTAO to Wall 7.

Wall is symmetric, sheathing and force transfer load measurement on right pier not shown for clarity.
Wall 9
Objective: Compare FTAO to Wall 7 and 8. Collect FTAO data for wall with larger opening.
Wall is symmetric, sheathing and force transfer load measurement on right pier not shown for clarity.

Wall 10
Objective: FTAO for 3.5:1 Aspect ratio pier wall. No sheathing below opening. Two hold downs on pier (fixed case).
Wall is symmetric, sheathing and force transfer load measurement on right pier not shown for clarity.

Wall 11
Objective: FTAO for 3.5:1 Aspect ratio pier wall. No sheathing below opening. One hold downs on pier (pinned case).
Wall is symmetric, sheathing and force transfer load measurement on right pier not shown for clarity.

Wall 12
Objective: FTAO for asymmetric multiple pier wall.
FTAO with multiple openings and asymmetric piers.
## Measured vs Predicted Strap Forces

<table>
<thead>
<tr>
<th>Wall ID</th>
<th>Measured Strap Forces (lbf) (1)</th>
<th>Drag Strut Technique</th>
<th>Cantilever Beam Technique</th>
<th>Diekmann Technique</th>
<th>Thompson Technique</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Top / Bottom</td>
<td>Top / Bottom</td>
<td>Top / Bottom</td>
<td>Top / Bottom</td>
<td>Top / Bottom</td>
</tr>
<tr>
<td>Wall 4a</td>
<td>687 / 1,485</td>
<td>178% / 82%</td>
<td>652% / 183%</td>
<td>132% / 406%</td>
<td>115% / 129%</td>
</tr>
<tr>
<td>Wall 4b</td>
<td>560 / 1,477</td>
<td>219% / 83%</td>
<td>800% / 184%</td>
<td>133% / 499%</td>
<td>115% / 129%</td>
</tr>
<tr>
<td>Wall 4c</td>
<td>668 / 1,316</td>
<td>183% / 93%</td>
<td>670% / 207%</td>
<td>149% / 418%</td>
<td>129% / 125%</td>
</tr>
<tr>
<td>Wall 4d</td>
<td>1,006 / 1,665</td>
<td>122% / 73%</td>
<td>445% / 164%</td>
<td>118% / 278%</td>
<td>102% / 125%</td>
</tr>
<tr>
<td>Wall 5b</td>
<td>1,883 / 1,809</td>
<td>65% / 68%</td>
<td>327% / 256%</td>
<td>173% / 204%</td>
<td>160% / 125%</td>
</tr>
<tr>
<td>Wall 5c</td>
<td>1,611 / 1,744</td>
<td>76% / 70%</td>
<td>382% / 265%</td>
<td>187% / 238%</td>
<td>166% / 125%</td>
</tr>
<tr>
<td>Wall 5d</td>
<td>1,633 / 2,307</td>
<td>75% / 53%</td>
<td>377% / 201%</td>
<td>141% / 235%</td>
<td>125% / 125%</td>
</tr>
<tr>
<td>Wall 6a</td>
<td>421 / 477</td>
<td>291% / 256%</td>
<td>1063% / 571%</td>
<td>410% / 663%</td>
<td>357% / 277%</td>
</tr>
<tr>
<td>Wall 6b</td>
<td>609 / 614</td>
<td>201% / 199%</td>
<td>735% / 444%</td>
<td>319% / 458%</td>
<td>277% / 120%</td>
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<tr>
<td>Wall 8a</td>
<td>985 / 1,347</td>
<td>118% / 86%</td>
<td>808% / 359%</td>
<td>138% / 269%</td>
<td>120% / 150%</td>
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<tr>
<td>Wall 8b</td>
<td>1,493 / 1,079</td>
<td>78% / 108%</td>
<td>533% / 449%</td>
<td>124% / 177%</td>
<td>150% / 172%</td>
</tr>
<tr>
<td>Wall 9a</td>
<td>1,675 / 1,653</td>
<td>69% / 70%</td>
<td>475% / 383%</td>
<td>185% / 217%</td>
<td>166% / 172%</td>
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<tr>
<td>Wall 9b</td>
<td>1,671 / 1,594</td>
<td>69% / 73%</td>
<td>476% / 397%</td>
<td>185% / 218%</td>
<td>166% / 172%</td>
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<tr>
<td>Wall 10a</td>
<td>1,580 / n.a. (5)</td>
<td>73% / n.a. (5)</td>
<td>496% / n.a. (5)</td>
<td>n.a. (5) / n.a. (5)</td>
<td>n.a. (5) / n.a. (5)</td>
</tr>
<tr>
<td>Wall 10b</td>
<td>2,002 / n.a. (5)</td>
<td>58% / n.a. (5)</td>
<td>391% / n.a. (5)</td>
<td>n.a. (5) / n.a. (5)</td>
<td>n.a. (5) / n.a. (5)</td>
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<tr>
<td>Wall 11a</td>
<td>2,466 / n.a. (5)</td>
<td>47% / n.a. (5)</td>
<td>318% / n.a. (5)</td>
<td>n.a. (5) / n.a. (5)</td>
<td>n.a. (5) / n.a. (5)</td>
</tr>
<tr>
<td>Wall 11b</td>
<td>3,062 / n.a. (5)</td>
<td>38% / n.a. (5)</td>
<td>256% / n.a. (5)</td>
<td>n.a. (5) / n.a. (5)</td>
<td>n.a. (5) / n.a. (5)</td>
</tr>
<tr>
<td>Wall 12a</td>
<td>807 / 1,163</td>
<td>81% / 94%</td>
<td>593% / 348%</td>
<td>128% / n.a. (5)</td>
<td>n.a. (5) / n.a. (5)</td>
</tr>
<tr>
<td>Wall 12b</td>
<td>1,083 / 1,002</td>
<td>60% / 109%</td>
<td>442% / 403%</td>
<td>138% / n.a. (5)</td>
<td>n.a. (5) / n.a. (5)</td>
</tr>
</tbody>
</table>
Testing Observation

Wall 4

- Narrow piers
- Deep sill
Wall 5

- Increased opening from Wall 4
- Shallow sill

![Graph showing strap forces around openings vs. applied top of wall load (lbf)]

- Top East
- Top West
- Bottom West
- Bottom East

![Diagram of Wall 5 with 2x flatwise blocking and measurements]

5'-0" 1'-10"

Wall 5d
Local Response

Comparison of opening size vs. strap forces

- Compared Wall 4 to 5
Global Response

- Comparison of opening size vs. strap forces
- Wall 4 vs. 5 reduction in stiffness with larger opening
- Wall 4 & 5d demonstrated increased stiffness as well as strength over the segmented walls 1 & 2
- Larger openings resulting in both lower stiffness and lower strength.
- Relatively brittle nature of the perforated walls
- Shear walls resulted in sheathing tearing
Other Testing Observations

Failure modes expected (Wall 5)

- Relatively brittle nature of the perforated walls
  - Shear walls resulted in sheathing tearing
- Concentration of forces from analysis (Thompson)
  - Drives shear type and nailing
Other Testing Observations

Failure modes

- Contributions of wall segments
  - Variable stiffness
  - Banging effect
C-shaped Panels

- APA FTAO Test Wall 6
- Framing status quo
- Reduce/eliminate strap force
Advancements in FTAO

Strapping Above and Below Openings

- SDWPS Section 4.3.5.2 specifies collectors
  - Full length horizontal elements. Top & Bottom Plates, drag struts, beams, etc..
  - Transfer forces from diaphragm into shear wall

- Strapping is not a collector
  - Can be discontinuous
  - Resists internal tension forces not shear
  - Similar to hold downs at end of wall
Conclusions

- 12 assemblies tested, examining the three approaches to designing and detailing walls with openings
  - Segmented
  - Perforated Shear Wall
  - Force Transfer Around Openings
- Walls detailed for FTAO resulted in better global response
Conclusions

- Comparison of analytical methods with tested values for walls detailed as FTAO
  - The drag strut technique was consistently un-conservative
  - The cantilever beam technique was consistently ultra-conservative
  - Thompson provides similar results as Diekmann
  - Thompson & Diekmann techniques provided reasonable agreement with measured strap forces

- Better guidance to engineers will be developed by APA for FTAO
  - Summary of findings for validation of techniques
  - New tools for IBC wall bracing
Enter “Force Transfer” or “M410”

149 pages, 28.5 MB

Report Available
www.apawood.org/publications
Multiple Openings

- APA FTAO Testing Wall 12
  - Multiple openings
  - Asymmetric pier widths
- Diekmann Rational Analysis
Advancements in FTAO

- SEAOC Convention 2015 Proceedings
- Basis of APA Technical Note Form T555

2015 SEAOC CONVENTION PROCEEDINGS

Advancements in Force Transfer Around Openings for Wood Framed Shear Walls

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Abstract
A joint research project of APA – The Engineered Wood Association, University of British Columbia (UBC), and USDA Forest Products Laboratory was initiated in 2009 to examine the variations of walls with code-allowable openings. This study examines the internal forces generated during these tests and evaluates the effects of size of openings, size of full-height piers, and different analysis techniques, including the segmented method, the perforated

Introduction
Force transfer around openings (FTAO) is a popular method of shear wall analysis for wood-framed shear walls. However, the analysis method varies from engineer to engineer, published design examples typically assume the wall is symmetric around a single opening, and until recently, this design method has not been tested.
The method assumes the following:

- The unit shear above and below the openings is equivalent.
- The corner forces are based on the shear above and below the openings and only the piers adjacent to that unique opening.
- The tributary length of the opening is the basis for calculating the shear to each pier. This tributary length is the ratio of the length of the pier multiplied by the length of the opening it is adjacent to, then divided by the sum of the length of the pier and the length of the pier on the other side of the opening.
  - For example, $T_1 = (L_1 \times L_{o1})/(L_1 + L_2)$
Diekmann Technique: Conceptual Keys

The method assumes the following:

- The shear of each pier is the total shear divided by the L of the wall, multiplied by the sum of the length of the pier and its tributary length, divided by the length of the pier:
  
  \[(V/L)(L_1+T_1)/L_1\]

- The unit shear of the corner zones is equal to subtracting the corner forces from the panel resistance, R. R is equal to the shear of the pier multiplied by the pier length:
  
  \[V_{a1} = (v_1L_1 - F_1)/L_1\]
Diekmann Technique: Conceptual Keys

The method assumes the following:

- Once the entire segment shears have been calculated, then the design is checked by summing the shears vertically along each line. The first and last line equal the hold-down force, and the rest should sum to zero.
Deflection Calculations - Concept

\[ \Delta = \text{average}(\delta_1^+, \delta_2^+, \delta_3^+, \delta_1^-, \delta_2^-, \delta_3^-) \]
Deflection Calculations

- Wall drift estimation when using FTAO
- Historical 4-term deflection equation
  - Average deflection, varying h
Force Transfer Around Openings (FTAO)
VERSATILE SHEAR WALL ANALYSIS METHOD LENDS GREATER DESIGN FLEXIBILITY

Wood structural panel sheathed shear walls and diaphragms are the primary lateral-load-resisting elements in wood-frame construction. As wood-frame construction is continuously evolving, designers in many parts of the U.S. are optimizing design solutions that require the understanding of force transfer between elements in the lateral load-resisting system.

The force transfer around openings (FTAO) method of shear wall analysis offers some advantages compared to other methods:
- More versatility, because the FTAO method allows for the use of narrower wall segments while meeting required height-to-width ratios, and
- A high likelihood that fewer hold-downs will be required.

Technical Note: Design for Force Transfer Around Openings
This technical note presents a rational analysis for applying FTAO to walls with asymmetric piers and walls with multiple openings. It is based upon APA modeling and testing and uses methodology that assists the design professional in solving for the required sheathing, nailing, hold-downs, straps, and maximum deflection.

APA Force Transfer Around Openings Calculator
This calculator is an Excel-based tool for professional designers that uses FTAO methodology to calculate maximum hold-down force for uplift resistance, the required horizontal strap force for the tension straps above and below openings, the maximum shear force to determine sheathing attachment, and the maximum deflection of the wall.

Webinar:
Resolving Wood Shear Wall Design Puzzles with Force Transfer Around Openings, DE5415, AWC
Provides an overview of the force transfer around openings (FTAO) shear wall design approach, recent research in this area, and a side-by-side comparison of design results between segmented, perforated, and FTAO design methods. AIA, ICC, and NCSEA credits available. Presented by Jared Hensley, PE, APA Engineered Wood Specialist.

LEARN MORE
Technical Note: Design for Force Transfer Around Openings (FTAO)

- APA Form T555

- Presents a rational analysis for applying FTAO to walls with asymmetric piers and walls with multiple openings

- Based on Wall 12 testing configuration
**FTAO Technical Note: Form T555**

- Provides a design example for FTAO wall with two window openings
- FTAO Calculator: Companion to Technical Note

**EXAMPLE: FTAO CALCULATIONS WITH TWO WINDOW OPENINGS**

Given a 28-feet long wall that is 8 feet tall with a 1.750 pound/sq. ft. snow, the shear wall is designed using F500 around two windows with different properties.

**Figure 3: Multiple Opening FTAO Design Example**

The following example was based on calculations from AWA’s FTAO (Force Transfer Around Openings) calculator worksheet available for free download at www.awasnow.com/F500. One may observe minor mathematical differences as a result of numerical rounding in this publication.

1. Calculate the hold-down force: $H_i = \frac{3,750 \times 0.5}{7} = 1,538$ lb
2. Solve for the unit shear above and below the openings: $v_i = \frac{1,538}{2} = 769$ lb
3. Find the total horizontal force above and below the openings.
   a. First opening: $O_1 = v_i x_1 = 769 \times 6.5 = 5,005$ lb
   b. Second opening: $O_2 = v_i x_2 = 769 \times 2 = 1,538$ lb
4. Calculate the center forces:
   a. $F_1 = O_1 x_1 = 5,005 \times 6.5 = 32,533$ lb
   b. $F_2 = O_2 x_2 = 1,538 \times 2 = 3,076$ lb
   c. $F_3 = O_2 x_3 = 1,538 \times 8 = 12,304$ lb
   d. $F_4 = O_1 x_4 = 5,005 \times 8 = 40,040$ lb

Form No. T555 © 2018 AWA - The Engineered Wood Association - www.awasnow.org
APA FTAO Calculator

- Excel-based tool released January 2018
- Based on design methodology developed by Diekmann
- Calculates:
  - Max hold-down force for uplift resistance
  - Required horizontal strap force above and below openings
  - Max shear force for sheathing attachments
  - Max deflection
- Design example corresponds with FTAO Technical Note (Form T555)
APA FTAO Calculator

www.apawood.org/FTAO

Force Transfer Around Openings Calculator

The force transfer around openings (FTAO) method of shear wall analysis is an approach that aims to reinforce the wall such that it performs as if there was no opening. This approach lends certain advantages over segmented shear walls: more versatility, because it allows for narrower wall segments while still meeting the height-to-width ratios and, often, fewer required hold-downs.

Force Transfer Around Openings (FTAO) Calculator Instructions

The APA Force Transfer Around Openings (FTAO) Calculator is divided into three worksheets: shear wall with one opening, shear wall with two openings, and shear wall with three openings. Each calculation tab will produce the maximum hold-down force for uplift resistance, the required horizontal strap force for the tension straps above and below openings, the maximum shear force to determine sheathing attachment, and the maximum deflection of the wall system.

To use the calculator, input the required information into the ORANGE input cells; definitions for the required cell inputs can be found below. Move quickly between input cells by using the TAB key. Certain input cells, such as the Hold-Down Capacity input in the deflection calculation, have comment dialogue to clarify the input.

Variables for Shear Wall Calculations

\[ V = \text{Applied shear as lateral force at top of wall in pounds (lb).} \]
\[ L(i) = \text{Length of individual wall pier segment as indicated by L1, L2, L3 and L4 measured in feet (ft).} \]
\[ Lo(i) = \text{Length for individual clear openings as indicated by Lo1, Lo2 and Lo3 measured in feet (ft).} \]
\[ ho1 = \text{Maximum clear opening height of any opening in the wall system. Will be reported as ho1, ho2 and ho3 measured in feet (ft).} \]
\[ ha1 = \text{Height of continuous sheathing above the opening in correlation with ho1 above. Will be reported as ha1, ha2 and ha3 measured in feet (ft).} \]
\[ hb1 = \text{Height of continuous sheathing below the opening in correlation with ho1 above. Will be reported as hb1, hb2 and hb3 measured in feet (ft).} \]
\[ h_{wall} = \text{Total calculated height of shear wall from bottom of sill plate to top of top plate measured in feet (ft). Calculated as the summation of ho1, ha1, and hb1.} \]
\[ L_{wall} = \text{Total calculated length of shear wall measured in feet (ft). Calculated as the summation of L(i) and Lo(i).} \]

Variables for Shear Wall Deflection Calculations
FTAO Calculator: Design Example

www.apawood.org/FTAO
FTAO Calculator: One Opening

www.apawood.org/FTAO

---

**Force Transfer Around Openings Calculator**

ONE OPENING

The force transfer around openings (FTAO) method of shear wall analysis is an approach that aims to reinforce the wall such that it performs as if there was no opening. This approach finds certain advantages over segmented (plywood) diaphragms, because it allows for narrower wall segments while still meeting the strength/weight ratios and, often, fewer required hold-downs.

<table>
<thead>
<tr>
<th>Project Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code:</td>
</tr>
<tr>
<td>Designer:</td>
</tr>
<tr>
<td>Client:</td>
</tr>
<tr>
<td>Project:</td>
</tr>
<tr>
<td>Wall Line:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Shear Wall Calculation Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>V (lb)</td>
</tr>
<tr>
<td>L1 (ft)</td>
</tr>
<tr>
<td>L2 (ft)</td>
</tr>
<tr>
<td>h_wall (ft)</td>
</tr>
<tr>
<td>l_wall (ft)</td>
</tr>
<tr>
<td>Opening 1</td>
</tr>
<tr>
<td>ha1</td>
</tr>
<tr>
<td>ho1</td>
</tr>
<tr>
<td>hb1</td>
</tr>
<tr>
<td>l01</td>
</tr>
</tbody>
</table>

1. Hold-down forces: \( H = \frac{V h_{wall}}{l_{wall}} \)

2. Unit shear above + below opening
   \( V_1 = \frac{V l_1}{l_1 + l_1} \)
   \( V_2 = \frac{V l_2}{l_2 + l_2} \)

6. Unit shear beside opening
   \( V_1 = \frac{V l_1 l_2}{l_1 + l_2} \)
   \( V_2 = \frac{V l_1 l_2}{l_1 + l_2} \)

---

**Note:**

- \( V_1 \) and \( V_2 \) should be checked to ensure they meet the design criteria.
- Adjustments may be necessary based on the specific project requirements.
### FTAO Calculator: Two Openings

www.apawood.org/FTAO

---

#### Project Information

- **Code:**
- **Client:**
- **Project:**
- **Wall Line:**

#### Force Transfer Around Openings Calculator

**TWO OPENINGS**

The force transfer around openings (FTAO) method of shear wall design is an approach that aims to reinforce the wall such that it performs as if there was no opening. This approach offers certain advantages over segmented shear walls, more generally, because it allows for non-corner wall segments while still meeting the height-to-width ratios and, often, fewer required hold-downs.

#### Shear Wall Calculation Variables

<table>
<thead>
<tr>
<th>Opening 1</th>
<th>Opening 2</th>
<th>Wall Pier Aspect Ratio</th>
<th>Adj. Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>L2</td>
<td>h11</td>
<td>h22</td>
</tr>
<tr>
<td>L2</td>
<td>L3</td>
<td>h12</td>
<td>h22</td>
</tr>
<tr>
<td>h1</td>
<td>L3</td>
<td>h21</td>
<td>h22</td>
</tr>
<tr>
<td>L1</td>
<td>L2</td>
<td>ho1</td>
<td>ho2</td>
</tr>
<tr>
<td>Lo1</td>
<td>L3</td>
<td>Le1</td>
<td>Le2</td>
</tr>
</tbody>
</table>

#### Instructions & Definitions

1. **Hold-down forces:**
   - \( H = \frac{Vh_{wall}}{L_{wall}} \)

2. **Unit shear above/below opening:**
   - First opening: \( v1 = \frac{v01}{h(a1+b1)} = \)
   - Second opening: \( v2 = \frac{v02}{h(a2+b2)} = \)

6. **Unit shear beside opening:**
   - \( V_1 = \frac{V}{(L1+T1)}/L1 = \)
   - \( V_2 = \frac{V}{(L2+T2+T3)}/L2 = \)
   - \( V_3 = \frac{V}{(L3+T4)}/L3 = \)
FTAO Calculator: Inputs

Shear Wall Calculation Variables

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Opening 1</th>
<th>Opening 2</th>
<th>Wall Pier Aspect Ratio</th>
<th>Adj. Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>3750 lbf</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L1</td>
<td>4.00 ft</td>
<td>ha1</td>
<td>ha2</td>
<td>P1=ho1/L1=</td>
<td>0.67</td>
</tr>
<tr>
<td>L2</td>
<td>4.00 ft</td>
<td>ho1</td>
<td>ho2</td>
<td>P2=ho2/L2=</td>
<td>0.67</td>
</tr>
<tr>
<td>L3</td>
<td>3.50 ft</td>
<td>hb1</td>
<td>hb2</td>
<td>P3=ho2/L3=</td>
<td>0.76</td>
</tr>
<tr>
<td>hwall</td>
<td>8.00 ft</td>
<td>Lo1</td>
<td>Lo2</td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>Lwall</td>
<td>19.50 ft</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
FTAO Calculator: Inputs

Shear Wall Calculation Variables:

<table>
<thead>
<tr>
<th>V</th>
<th>3750 lbf</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>4.00 ft</td>
</tr>
<tr>
<td>L2</td>
<td>4.00 ft</td>
</tr>
<tr>
<td>L3</td>
<td>3.50 ft</td>
</tr>
<tr>
<td>h_wall</td>
<td>8.00 ft</td>
</tr>
<tr>
<td>L_wall</td>
<td>19.50 ft</td>
</tr>
<tr>
<td>ha1</td>
<td>1.33 ft</td>
</tr>
<tr>
<td>ho1</td>
<td>2.67 ft</td>
</tr>
<tr>
<td>hb1</td>
<td>4.00 ft</td>
</tr>
<tr>
<td>Lo1</td>
<td>6.00 ft</td>
</tr>
<tr>
<td>ha2</td>
<td>1.33 ft</td>
</tr>
<tr>
<td>ho2</td>
<td>2.67 ft</td>
</tr>
<tr>
<td>hb2</td>
<td>4.00 ft</td>
</tr>
<tr>
<td>Lo2</td>
<td>2.00 ft</td>
</tr>
</tbody>
</table>

Wall Pier Aspect Ratio:

<table>
<thead>
<tr>
<th>Wall Pier</th>
<th>Adj. Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1=ho1/L1</td>
<td>0.67</td>
</tr>
<tr>
<td>P2=ho2/L2</td>
<td>0.67</td>
</tr>
<tr>
<td>P3=ho2/L3</td>
<td>0.76</td>
</tr>
<tr>
<td>Step</td>
<td>Formula</td>
</tr>
<tr>
<td>------</td>
<td>---------</td>
</tr>
<tr>
<td>1.</td>
<td>$H = \frac{V_{h_{wall}}}{L_{wall}}$</td>
</tr>
<tr>
<td>2.</td>
<td><strong>Unit shear above + below opening</strong>&lt;br&gt;First opening: $v_{a1} = v_{b1} = \frac{H}{(h_{a1}+h_{b1})}$</td>
</tr>
<tr>
<td></td>
<td>Second opening: $v_{a2} = v_{b2} = \frac{H}{(h_{a2}+h_{b2})}$</td>
</tr>
<tr>
<td>3.</td>
<td><strong>Total boundary force above + below openings</strong>&lt;br&gt;First opening: $O_{1} = v_{a1} \times (L_{o1})$</td>
</tr>
<tr>
<td></td>
<td>Second opening: $O_{2} = v_{a2} \times (L_{o2})$</td>
</tr>
<tr>
<td>4.</td>
<td><strong>Corner forces</strong></td>
</tr>
<tr>
<td></td>
<td>$F_{1} = \frac{O_{1}(L_{1})}{(L_{1}+L_{2})}$</td>
</tr>
<tr>
<td></td>
<td>$F_{2} = \frac{O_{1}(L_{2})}{(L_{1}+L_{2})}$</td>
</tr>
<tr>
<td></td>
<td>$F_{3} = \frac{O_{2}(L_{2})}{(L_{2}+L_{3})}$</td>
</tr>
<tr>
<td></td>
<td>$F_{4} = \frac{O_{2}(L_{3})}{(L_{2}+L_{3})}$</td>
</tr>
<tr>
<td>5.</td>
<td><strong>Tributary length of openings</strong></td>
</tr>
<tr>
<td></td>
<td>$T_{1} = \frac{(L_{1} \times L_{o1})}{(L_{1}+L_{2})}$</td>
</tr>
<tr>
<td></td>
<td>$T_{2} = \frac{(L_{2} \times L_{o1})}{(L_{1}+L_{2})}$</td>
</tr>
<tr>
<td></td>
<td>$T_{3} = \frac{(L_{2} \times L_{o2})}{(L_{2}+L_{3})}$</td>
</tr>
<tr>
<td></td>
<td>$T_{4} = \frac{(L_{3} \times L_{o2})}{(L_{2}+L_{3})}$</td>
</tr>
<tr>
<td>6.</td>
<td><strong>Unit shear beside opening</strong>&lt;br&gt;$V_{1} = \frac{(V/L)(L_{1}+T_{1})}{L_{1}}$</td>
</tr>
<tr>
<td></td>
<td>$V_{2} = \frac{(V/L)(L_{2}+L_{2}+T_{3})}{L_{2}}$</td>
</tr>
<tr>
<td></td>
<td>$V_{3} = \frac{(V/L)(T_{4}+L_{3})}{L_{3}}$</td>
</tr>
<tr>
<td></td>
<td>Check $V_{1} \times L_{1} + V_{2} \times L_{2} + V_{3} \times L_{3} = V$?</td>
</tr>
<tr>
<td>7.</td>
<td><strong>Resistance to corner forces</strong></td>
</tr>
<tr>
<td></td>
<td>$R_{1} = V_{1} \times L_{1}$</td>
</tr>
<tr>
<td></td>
<td>$R_{2} = V_{2} \times L_{2}$</td>
</tr>
<tr>
<td></td>
<td>$R_{3} = V_{3} \times L_{3}$</td>
</tr>
<tr>
<td>8.</td>
<td><strong>Difference corner force + resistance</strong></td>
</tr>
<tr>
<td></td>
<td>$R_{1} - F_{1}$</td>
</tr>
<tr>
<td></td>
<td>$R_{2} - F_{2} - F_{3}$</td>
</tr>
<tr>
<td></td>
<td>$R_{3} - F_{4}$</td>
</tr>
<tr>
<td>9.</td>
<td><strong>Unit shear in corner zones</strong>&lt;br&gt;$v_{c1} = \frac{(R_{1} - F_{1})}{L_{1}}$</td>
</tr>
<tr>
<td></td>
<td>$v_{c2} = \frac{(R_{2} - F_{2} - F_{3})}{L_{2}}$</td>
</tr>
<tr>
<td></td>
<td>$v_{c3} = \frac{(R_{3} - F_{4})}{L_{3}}$</td>
</tr>
</tbody>
</table>
FTAO Calculator: Shear wall analysis

Check Summary of Shear Values for Two Openings

<table>
<thead>
<tr>
<th>Line</th>
<th>V (lb)</th>
<th>H (lb)</th>
<th>1538</th>
<th>641</th>
<th>897</th>
<th>1538 lbf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line 1: vci(ha1+hb1)+V1(ho1)=H?</td>
<td>641</td>
<td>897</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Line 2: va1(ha1+hb1)-vci(ha1+hb1)-V1(ho1)=0?</td>
<td>1538</td>
<td>641</td>
<td>897</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Line 3: vc2(ha1+hb1)+V2(ho1)-va1(ha1+hb1)=0?</td>
<td>504</td>
<td>1034</td>
<td>1538</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Line 4: va2(ha2+hb2)-V2(ho2)-vc2(ha2+hb2)=0?</td>
<td>1538</td>
<td>1034</td>
<td>504</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Line 5: va2(ha2+hb2)-vc3(ha2+hb2)-V3(ho2)=0?</td>
<td>1538</td>
<td>889</td>
<td>650</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Line 6: vc3(ha2+hb2)+V3(ho2)=H?</td>
<td>889</td>
<td>650</td>
<td></td>
<td></td>
<td></td>
<td>1538 lbf</td>
</tr>
</tbody>
</table>

Design Summary

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Value</th>
<th>4-Term Deflection</th>
<th>3-Term Deflection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheathing Capacity</td>
<td>388 plf</td>
<td>0.316 in.</td>
<td>0.335 in.</td>
</tr>
<tr>
<td>Strap Force</td>
<td>865 lbf</td>
<td>0.013 %</td>
<td>0.014 %</td>
</tr>
<tr>
<td>HD Force (H)</td>
<td>1538 lbf</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

See Page 2

See Page 3
Design output:

- Required sheathing capacity
- Required strap force above and below openings
- Required hold-down force
- Maximum deflection

Design Summary:

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Value</th>
<th>4-Term Deflection</th>
<th>4-Term Story Drift %</th>
<th>3-Term Deflection</th>
<th>3-Term Story Drift %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Req. Sheathing Capacity</td>
<td>388 plf</td>
<td></td>
<td>0.316 in.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Req. Strap Force</td>
<td>855 lbf</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Req. HD Force (H)</td>
<td>1538 lbf</td>
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</tr>
</tbody>
</table>

See Page 2

See Page 3
FTAO Calculator

### Shear Wall Deflection Calculation Variables

<table>
<thead>
<tr>
<th>Sheathing:</th>
<th>7/16</th>
<th>APA Rated Sheathing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheathing Material</td>
<td>OSB</td>
<td></td>
</tr>
<tr>
<td>Performance Category</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade</td>
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</table>

<table>
<thead>
<tr>
<th>Wood End Post Values:</th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Species:</td>
<td>Hem-Fir No.2</td>
<td></td>
</tr>
<tr>
<td>E:</td>
<td>1.60E+06 (psi)</td>
<td></td>
</tr>
<tr>
<td>Qty</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stud Size</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dimensions:</td>
<td>2</td>
<td>2x6</td>
</tr>
<tr>
<td>A:</td>
<td>16.5 (in.)</td>
<td>16.5 (in.)</td>
</tr>
<tr>
<td>A Override:</td>
<td>(in.)</td>
<td>(in.)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nail Type:</th>
<th>8d common</th>
<th>(penny weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pier 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pier 3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Four-Term Equation Deflection Check

\[
\Delta = \frac{8vh^3}{EAb} + \frac{vh}{Gl} + 0.75he_a + d_a \frac{h}{b}
\]  
(Equation 23-2)

<table>
<thead>
<tr>
<th>Sheathing:</th>
<th>Pier 1-L</th>
<th>Pier 1-R</th>
<th>Pier 2-L</th>
<th>Pier 2-R</th>
<th>Pier 3-L</th>
<th>Pier 3-R</th>
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<td>7/16</td>
<td>7/16</td>
<td>7/16</td>
<td>7/16</td>
<td>7/16</td>
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<tr>
<td>Nails:</td>
<td>8d common</td>
<td>8d common</td>
<td>8d common</td>
<td>8d common</td>
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<tr>
<td>(V_{siz}^2:</td>
<td>337</td>
<td>337</td>
<td>388</td>
<td>388</td>
<td>244</td>
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<tr>
<td>(V_{strength}:</td>
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<td>481</td>
<td>554</td>
<td>554</td>
<td>348</td>
<td>348</td>
</tr>
<tr>
<td>E:</td>
<td>1.60E+06</td>
<td>1.60E+06</td>
<td>1.60E+06</td>
<td>1.60E+06</td>
<td>1.60E+06</td>
<td>1.60E+06</td>
</tr>
<tr>
<td>h:</td>
<td>8.00</td>
<td>4.00</td>
<td>4.00</td>
<td>4.00</td>
<td>4.00</td>
<td>8.00</td>
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<tr>
<td>A:</td>
<td>16.5</td>
<td>16.5</td>
<td>16.5</td>
<td>16.5</td>
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</tr>
<tr>
<td>Gt:</td>
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<td>83,500</td>
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<td>83,500</td>
</tr>
<tr>
<td>Nail Spacing:</td>
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<td>4</td>
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<tr>
<td>Vn:</td>
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<td>160</td>
<td>185</td>
<td>185</td>
<td>116</td>
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<td>e:</td>
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<td>0.0264</td>
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<td>0.0065</td>
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<tr>
<td>b:</td>
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<td>4.00</td>
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<td>3.50</td>
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<tr>
<td>HD Capacity:</td>
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<td>2145</td>
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<td>2145</td>
</tr>
<tr>
<td>HD Defl:</td>
<td>0.128</td>
<td>0.128</td>
<td>0.128</td>
<td>0.128</td>
<td>0.128</td>
<td>0.128</td>
</tr>
</tbody>
</table>

Deflection calculations assume the applied load is seismic and the designer is using ASD.

The calculator does not check the sheathing selection for the required capacity calculated above.
FTAO Calculator

Three-Term Equation Deflection Check

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

(4.3-1)

Sheathing:  
<table>
<thead>
<tr>
<th></th>
<th>Pier 1-L</th>
<th>Pier 1-R</th>
<th>Pier 2-L</th>
<th>Pier 2-R</th>
<th>Pier 3-L</th>
<th>Pier 3-R</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/16</td>
<td></td>
<td></td>
<td>7/16</td>
<td></td>
<td>7/16</td>
<td></td>
</tr>
</tbody>
</table>

Nail:  
| 8d common | 8d common | 8d common | 8d common | 8d common | 8d common | 8d common |

\[ v_{sd} \]  
|          |          | 337       | 337       | 388       | 388       | 244       |

\[ v_{strength} \]  
|          |          | 481       | 481       | 554       | 554       | 348       |

E:  
| 1.60E+06 | 1.60E+06 | 1.60E+06 | 1.60E+06 | 1.60E+06 | 1.60E+06 |

h:  
| 8.00     | 4.00     | 4.00      | 4.00      | 4.00      | 8.00      |

A:  
| 16.5     | 16.5     | 16.5      | 16.5      | 16.5      | 16.5      |

Ga:  
| 22.0     | 22.0     | 22.0      | 22.0      | 22.0      | 22.0      |

b:  
| 4.00     | 4.00     | 4.00      | 4.00      | 3.50      | 3.50      |

HD Capacity:  
| 2145     | 2145     | 2145      | 2145      | 2145      | 2145      |

HD Defl:  
| 0.128    | 0.128    | 0.128     | 0.128     | 0.128     | 0.128     |

Check Total Deflection of Wall System

<table>
<thead>
<tr>
<th></th>
<th>Pier 1 (left)</th>
<th></th>
<th>Pier 1 (right)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Term 1</td>
<td>Term 2</td>
<td>Term 3</td>
<td>Term 1</td>
<td>Term 2</td>
</tr>
<tr>
<td>Bending</td>
<td>Shear</td>
<td>Fastener</td>
<td>Bending</td>
<td>Shear</td>
</tr>
<tr>
<td>0.019</td>
<td>0.175</td>
<td>0.459</td>
<td>0.002</td>
<td>0.087</td>
</tr>
</tbody>
</table>

Sum       | 0.653         | Sum      | 0.205           |

Pier 2 (left)  
|          | Pier 2 (right) |          |
| Term 1   | Term 2        | Term 3   |
| Bending  | Shear         | Fastener |
| 0.003    | 0.101         | 0.132    |

Sum       | 0.236         |

Total Defl. (in.)  
| 0.335 |

% drift  
| 0.0140 |
Final Design Output

- Summary of input parameters
- FTAO shear wall analysis
- Summary of final design requirements
- Total calculated deflection
- Three-page shear wall design to include in calculation package
  - Print directly from Excel
  - Save as PDF
Force Transfer Around Openings (FTAO)

VERSATILE SHEAR WALL ANALYSIS METHOD LENDS GREATER DESIGN FLEXIBILITY

Wood structural panel sheathed shear walls and diaphragms are the primary lateral-load-resisting elements in wood-frame construction. As wood-frame construction is continuously evolving, designers in many parts of the U.S. are optimizing design solutions that require the understanding of force transfer between elements in the lateral load-resisting system.

The force transfer around openings (FTAO) method of shear wall analysis offers some advantages compared to other methods:

- More versatility, because the FTAO method allows for the use of narrower wall segments while meeting required height-to-width ratios, and
- A high likelihood that fewer hold-downs will be required.

Technical Note: Design for Force Transfer Around Openings

This technical note presents a rational analysis for applying FTAO to walls with asymmetric plans and walls with multiple openings. It is based upon APA modeling and testing and uses methodology that assists the design professional in solving for the required sheathing, nailing, hold-downs, straps, and maximum deflection.

APA Force Transfer Around Openings Calculator

This calculator is an Excel-based tool for professional designers that uses FTAO methodology to calculate maximum hold-down force for uplift resistance, the required horizontal strap force for the tension straps above and below openings, the maximum shear force to determine sheathing attachment, and the maximum deflection of the wall.
Upcoming Webinar

**After the Storm: Building for High Wind Resistance**

*March 30—11:30 a.m. EST, 9:30 a.m. PST*

Join APA Engineered Wood Specialist Mary Uher for *After the Storm*, a webinar focusing on common structural failures observed during storm damage assessments. The presentation will include an overview of high wind forces, the importance of a continuous load path, and how good design and construction practices can improve the storm resistance of buildings.

Mary will also discuss code requirements and present APA’s above-code recommendations for wind-resistant building, as well as how attention to connection details, understanding lateral load concepts, and recognizing common failure modes seen in storm damage assessments can help builders cost-effectively build a safer home and reduce future storm damage. 0.10 ICC CEU credits will be available upon completion of the webinar.

Mary Uher is part of a team of APA engineers who have conducted recent storm damage assessments and provided design recommendations for wind resistance.

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Updated ANSI Standard


ANSI/APA PRG 320-2018, *Standard for Performance-Rated Cross-Laminated Timber (CLT)*, was recently released. The major change in ANSI/APA PRG 320-2018 is the addition of CLT adhesive qualification requirements, adding full-scale compartment fire criteria to the standard based on a new fire test method developed by the ANSI PRG 320 Committee and published in a mandatory annex of the standard.
Questions/ Comments?

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