Design for Combined Shear and Uplift from Wind

1. Basis of the APA System Report

- 2009 and 2006 International Building Code: Sections 104.11 Alternative materials, design and methods of construction and equipment, and Section 1604.4 Analysis
- 2009 and 2006 International Residential Code: Sections R104.11 Alternative materials, design and methods of construction and equipment, and Section R301.1.3 Engineered design
- 2007 Florida Building Code, Building, Section 104.11 Alternative materials, design and methods of construction and equipment and Section 1604.4 Analysis
- 2008 ANSI/AF&PA Special Design Provisions for Wind and Seismic
- APA Test Reports, Combined Shear and Uplift Tests on 7/16-inch Oriented Strand Board Panels, Combined Shear and Wind Uplift Tests with 10d Common Nails, and Development of Anchor Bolt Spacings for Combined Shear and Uplift Applications

2. System Description

Using wood structural panels that are required to resist lateral loads and normal wind load requirements of the IBC (Sections 6.4.2.2 of ASCE-7) or IRC R301.2.1, additional wind uplift resistance from the panel can be achieved by providing additional nails to the shear nailing at the top and bottom of the panel. These additional nails are used to transfer the uplift forces from the top plate to the panel, from panel to panel at splice locations (if present) and from panel to sill plate at the foundation, effectively eliminating the need for uplift straps at these locations. Uplift straps may still be required around window and door openings in exterior walls to transfer the wind uplift loads acting on the header to the foundation below.

3. Methodology

Wood structural panel sheathing or siding shall be permitted to simultaneously resist shear and wind uplift loads provided the following conditions are met:

- Panels shall have a minimum thickness of 7/16 inch and may be installed with the strength axis parallel or perpendicular to the studs,
- Anchor bolt spacing shall be in accordance with Table 1, depending on the magnitude of shear and uplift forces,
- 3- x 3- x 0.229-inch steel plate washers shall be used at anchor bolt locations,
- Nails in any single row shall not be spaced closer than 3 inches on center, and
- Nails in any double rows shall be spaced 1/2 inch between rows.
- Framing anchors and uplift straps that form all parts of the wind uplift resistance system shall be attached to framing on the wood structural panel sheathing side of the exterior walls.
Conditions effectively eliminate the cross-grain bending as a failure mode in the bottom plate, as shown by full-scale test results. Assuming conditions are met, the following steps may be used to design wood structural panel sheathing or siding to simultaneously resist shear and wind uplift loads.

**Step 1 – Design the shear walls**
The first step in designing for combined shear and wind uplift is to design the shear walls for the structure under the applied wind loads. This method may be used for either the conventional segmented shear wall or perforated shear wall methods. When using the segmented method, a table similar to Table 2 of this report can be used to determine the required thickness, nail size, and spacing for the individual shear walls. Note that a minimum 7/16-inch wood structural panel sheathing or siding panel must be used.

When using the perforated shear wall method, an additional step is required in the shear wall design. This is the step where the Shear Resistance Adjustment Factor (C_w) is used to adjust the Table 2 design values for the geometry of the wall penetrations (see AF&PA Special Design Provisions for Wind and Seismic). Once the perforated shear wall design is complete, however, the nailing type and schedule information is used in exactly the same way as discussed in Step 3. Information on the perforated shear wall design method is available in Section 4.3 of the AF&PA Special Design Provisions for Wind and Seismic.

Also note that wind uplift loads must be distributed around the opening and into the structure below. This may require hardware specifically designed for such applications.

**Step 2 – Determine required uplift**
The required wind uplift at the top of the wall can be found prescriptively by using Table 3, which was taken from the AF&PA Wood Frame Construction Manual.

**Step 3 – Determine combined shear and uplift nailing**
Based on the nail size and spacing determined in Step 1, find an uplift capacity larger than or equal to the required wind uplift loads determined in Step 2 using Table 4.

### TABLE 1
**ANCHOR BOLT SPACING (INCHES) FOR COMBINED SHEAR AND WIND UPLIFT (a)**

<table>
<thead>
<tr>
<th>Nail Size</th>
<th>Allowable Design Shear (plf)</th>
<th>Allowable Design Uplift (plf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>G = 0.50</td>
<td>G = 0.42</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>200</td>
<td>184</td>
<td>48</td>
</tr>
<tr>
<td>335</td>
<td>308</td>
<td>48</td>
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<tr>
<td>490</td>
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<td>0</td>
<td>48</td>
</tr>
<tr>
<td>200</td>
<td>184</td>
<td>48</td>
</tr>
<tr>
<td>435</td>
<td>400</td>
<td>48</td>
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</tbody>
</table>
## 4. Design Capacities

<table>
<thead>
<tr>
<th>Sheathing Material</th>
<th>Sheathing Thickness (in.)</th>
<th>Nail Size(d)</th>
<th>Recommended Shear Capacity (plf)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Framing Species G ≥ 0.50</td>
</tr>
<tr>
<td></td>
<td>7/16</td>
<td>8d</td>
<td>355&lt;sup&gt;h&lt;/sup&gt; 550&lt;sup&gt;h&lt;/sup&gt; 705&lt;sup&gt;h&lt;/sup&gt; 935&lt;sup&gt;h&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>15/32</td>
<td>8d</td>
<td>690 770 1020</td>
</tr>
<tr>
<td></td>
<td>10d</td>
<td>475 715 930 1215</td>
<td>455 685 890 1165</td>
</tr>
<tr>
<td></td>
<td>7/16</td>
<td>8d</td>
<td>335&lt;sup&gt;h&lt;/sup&gt; 490&lt;sup&gt;h&lt;/sup&gt; 630&lt;sup&gt;h&lt;/sup&gt; 820&lt;sup&gt;h&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>15/32</td>
<td>8d</td>
<td>690 770 1020</td>
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<td>10d</td>
<td>475 715 930 1215</td>
<td>455 685 890 1165</td>
</tr>
<tr>
<td></td>
<td>19/32</td>
<td>10d</td>
<td>435 645 840 1075</td>
</tr>
</tbody>
</table>

G = Specific gravity of framing members.
(a) Not all nail spacings are appropriate for combined shear and wind uplift applications.
(b) Nails of the same size required for panel edges and shall be placed along all intermediate framing at 12 inches on center.
(c) Where panel edges abut, stud framing shall be a minimum of 3 inches nominal in thickness, and nails in each row shall be staggered.
(d) Common or galvanized box nails. Minimum nail penetration in framing shall be 1-3/8 inches for 8d nails and 1-1/2 inches for 10d nails.
(e) Allowable shear values are permitted to be increased to values shown for 15/32-inch sheathing with the same nailing, provided studs are spaced a maximum of 16 inches on center.
### TABLE 3

UPLIFT CONNECTION LOADS FROM WIND (FOR ROOF-TO-WALL, WALL-TO-WALL, AND WALL-TO-FOUNDATION)  
(Adopted from Table 2.2A of the AF&PA 2001 Wood Frame Construction Manual, Courtesy of American Forest & Paper Association, Washington, D.C.)

<table>
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<tr>
<th>3-Second Gust Wind Speed (mph)</th>
<th>85</th>
<th>90</th>
<th>100</th>
<th>110</th>
<th>120</th>
<th>130</th>
<th>140</th>
<th>150</th>
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<tr>
<td>Roof/Ceiling Assembly Design Dead Load</td>
<td>Roof Span (ft)</td>
<td>Unit Connection Loads (plf)</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>0 psf</td>
<td>12</td>
<td>119</td>
<td>134</td>
<td>165</td>
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<tr>
<td></td>
<td>60</td>
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<td>592</td>
<td>717</td>
<td>853</td>
<td>1001</td>
<td>1161</td>
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<td>525</td>
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<td>–</td>
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<td>45</td>
<td>79</td>
<td>117</td>
<td>159</td>
<td>203</td>
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<tr>
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<td>9</td>
<td>61</td>
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<td>180</td>
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<tr>
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<td>112</td>
<td>237</td>
<td>373</td>
<td>521</td>
<td>681</td>
</tr>
</tbody>
</table>

(a) Tabulated unit uplift connection loads shall be permitted to be multiplied by 0.75 for framing not located within 6 ft of corners for buildings less than 30 ft in width (W), or W/5 for buildings greater than 30 ft in width.

(b) Tabulated uplift loads assume a building located in Exposure B with a mean roof height of 33 ft. For buildings located in other exposures, the tabulated values for 0 psf roof dead load shall be multiplied by the appropriate adjustment factor below (Table 1.1 of the WFCM) and then reduced by the appropriate dead load.

(c) Tabulated uplift loads are specified in pounds per linear ft of wall. To determine connection requirements, multiply the tabulated unit uplift load by the multiplier from the table below corresponding to the spacing of the connectors:

![Spacings Table]

(d) Tabulated uplift loads equal total uplift minus 0.6 of the roof/ceiling assembly design dead load.

(e) Tabulated uplift loads are specified for roof-to-wall connections. When calculating uplift loads for wall-to-wall or wall-to-foundation connections, tabulated uplift loads shall be permitted to be reduced by 60 plf for each wall above.

(f) When calculating uplift loads for ends of headers/girders, multiply the tabulated unit uplift load by 1/2 of the header/girder span (ft). Cripple studs need only be attached per typical uplift requirements.

(g) Tabulated uplift loads for 0 psf design loads are included for interpolation or use with actual roof dead loads.
5. Design Examples

A designer wants to use a conventional segmented shear wall segment for combined shear and uplift in a structure being designed for high wind. The shear on the wall segment is determined to be 420 plf and the uplift along this wall segment is 570 plf. The framing, including bottom plate is southern pine (G = 0.55) with studs at 16 inches on center.

Step 1 – Design the shear walls
From Table 2, using sheathing-grade wood structural panels, a 7/16-inch thickness is selected and attached with 8d nails at 4 inches on center at panel edges and 12 inches on center in the field of the panel. This yields a shear capacity of 490 plf. Note that this value may be increased to 530 plf (see Footnote e to Table 2). 530 > 420, therefore OK.

Step 2 – Determine the required uplift force
The uplift force is given as 570 plf.

Step 3 – Determine combined shear and uplift nailing
From Table 4, based on 8d nails at 4 and 12 inches on center, look for any number that is larger than or equal to 570 plf. There is none. Notice, however, that a double row of nails at 3 inches on center yields a capacity of 540 plf and that Footnote a to Table 4 provides an 8 percent increase for framing with a specific gravity of 0.49 or higher 540 plf x 1.08 = 586 plf. 586 > 570, therefore OK.

The designer should specify a double row of 8d nails at 3 inches on center at top and bottom plates (see Footnote f to Table 4 and Figures 1 through 4), which satisfies the combined shear and uplift requirements for this wall segment. For the shear of 420 plf and uplift of 570 plf, this segment is required to use 5/8-inch anchor bolts spaced at 16 inches on center with 3- x 3- x 0.229-inch square steel plate washers from Table 1 (8d nails and framing G of 0.50).
Note that the designer must still size the hold down for the ends of the segmented shear wall based only on the design shear, as is done in shear walls designed for shear only. Similarly, for the perforated shear wall method, hold downs are required at the ends of the perforated wall and are designed in the same manner as walls without wind uplift. Uplift forces resulting from wind uplift at headers over windows and doors may still have to be resisted by straps or other tie-down devices as when conventionally framed.

### 6. INSTALLATION REQUIREMENTS

The installation of wood structural panel walls for resisting combined shear and wind uplift loads shall be as follows:

a) Multiple rows of nails applied at panel ends and edges shall be installed in accordance with Figure 1. Panel splice occurs across studs or horizontal framing such as rim joists shall be installed in accordance with Figure 2.

b) All horizontal joints shall occur over framing or blocking and shall be attached per Figures 2, 3 and 4.

c) On single-story construction, panels shall be attached to bottom plates and top member of the double top plate. Lowest plate shall be attached to foundation with minimum 5/8-inch bolts at a specified spacing with 3- x 3- x 0.229-inch steel plate washers, and with minimum embedment of 7 inches or by connectors of sufficient capacity to resist the uplift and shear loads developed in the wood structural panel sheathing or siding walls.

d) On two-story construction, upper panels shall be attached to the top member of the upper double top plate and to rim joist at bottom of panel. The panel edges need not fall in the center of the rim joist. Upper attachment of lower panel shall be made to rim joist and lower attachment made to lowest plate at first-floor framing, which shall be attached to foundation with minimum 5/8-inch bolts at a specified spacing with 3- x 3- x 0.229-inch steel plate washers, and minimum embedment of 7 inches or by connectors of sufficient capacity to resist the wind uplift and shear loads developed in the wood structural panel sheathing or siding walls. When a shear and uplift connection is made at a rim joist or with an inter-story splice, the rim joists and/or splice plates must have the ability to withstand the resulting tensile stresses perpendicular to the grain. Since sawn lumber, glulam and most SCL do not have a published allowable tensile stress perpendicular to the grain, the shear and uplift connection can be made by a wood structural panel splice plate that is sandwiched between the wall sheathing/siding and the rim joist or splice plate. This wood structural panel splice plate must be of the same thickness, grade and strength axis orientation as the wall sheathing/siding material. This can be seen in Figures 5 and 6. Note that OSB or plywood rim joists are a suitable material for the shear and uplift splice connections shown in Figures 2 through 6.

If a wood structural panel splice plate is to be used over a lumber rim joist, due to the potential for shrinkage of the lumber as it dries out, the wood structural panel splice plate shall be cut slightly under height (approximately 1/4 inch) to permit room for shrinkage of the rim joist.

e) Where windows and doors interrupt wood structural panel sheathing or siding, framing anchors or connectors shall be used to resist the appropriate wind uplift loads, as required.

f) Roof or upper level uplift connectors shall be installed on the same side of the wall as the sheathing to prevent twisting of the top plate due to eccentric loading. This may be accomplished by installing the roof to wall connectors (hurricane ties) on the outside of the wall beneath the wood structural panel sheathing. It is also possible to install the roof to wall connectors (hurricane ties) on the outside of the wall over the wood structural panel sheathing or to install both the roof to wall connectors (hurricane ties) and top plate to stud connectors on the inside of the wall when the recommendations of connector manufacturers, such as Simpson Strong-Tie, (www.strongtie.com) are followed.
FIGURE 1

PANEL ATTACHMENT FOR SHEAR AND UPLIFT

Nail spacing at intermediate framing 12" o.c.

16 or 24 oc stud spacing

Shear wall design nail spacing per Table 2

Alternate nail spacing per Table 4

NAIL SPACING (S) FOR SINGLE ROW OF NAILS

3/8" 3/4"

S

NAIL SPACING (S) FOR DOUBLE ROW OF NAILS

3/8" 1/2" 1/2"

S
Double top plates

Panels attachment to upper top plate for uplift (see Figure 1)

16 or 24 oc stud spacing

Shear and uplift nailing provided in horizontal framing member (single or double row, see below and Figures 1 and 5)

Panel attachment to bottom plate for uplift (see Figure 1)

Foundation

Rim joist (see Figure 5)

NAIL SPACING (S) FOR SINGLE ROW OF NAILS – Minimum Edge Distance Shown

See Figure 5 for rim joist detail

3/4"

Panel edge

1/2" S

NAIL SPACING (S) FOR DOUBLE ROW OF NAILS – Minimum Edge Distance Shown

See Figure 5 for rim joist detail

1/2" S

Panel edge
FIGURE 3

PANEL ATTACHMENT FOR SHEAR AND UPLIFT—AT INTER-STORY SPLICE PLATE

- Double top plates
- Inter-story splice plate, single or double row, (see below and Figure 6)
- Rim joist (see Figure 5)
- Panel attachment to upper top plate for uplift (see Figure 1)
- 16 or 24 oc stud spacing
- Panel attachment to bottom plate for uplift (see Figure 1)

NAIL SPACING (S) FOR SINGLE ROW OF NAILS – Minimum Edge Distance Shown

- 3/4"
- Panel edge
- See Figure 6 for splice detail

NAIL SPACING (S) FOR DOUBLE ROW OF NAILS – Minimum Edge Distance Shown

- 1/2"
- Panel edge
- See Figure 6 for splice detail
FIGURE 4

**PANEL ATTACHMENT FOR SHEAR AND UPLIFT – AT RAISED WOOD FLOOR**

NAIL SPACING (S) FOR SINGLE ROW OF NAILS – Minimum Edge Distance Shown

NAIL SPACING (S) FOR DOUBLE ROW OF NAILS – Minimum Edge Distance Shown

Concrete Foundation Wall

FIGURE 5

**TENSION SPlice MADE At LVL OR LUMBER RIM JOIST, SHOWING OFFSET RIM JOIST TO PERMIT THE USE OF WOOD STRUCTURAL PANEL TENSION SPlice PLATE**

Tension splice made at lumber or LVL rim joist. Wood structural panel tension splice required.

Leave a minimum 1/2" space between sheathing panels when a lumber rim joist is used to accommodate potential shrinkage of the joist.

Lumber or LVL rim joist offset to allow use of wood structural panel tension splice.

Wood structural panel tension splice plate. Match sheathing construction, thickness, and strength axis orientation.

Maintain gaps at top and bottom of splice plate to accommodate shrinkage of lumber rim joist.

**Note:** Only the uplift nailing at the splice is shown for clarity. A complete load path may include additional nails in the panel tension splice plate’s upper and lower half, additional nails in the wall studs above and below the panel tension splice, and additional nails for shear transfer. Number of nails shown is for example only. Actual number required will depend on design uplift, panel thickness, nail size, dead-load weight of overlying structure and lumber species.

FIGURE 6

**REQUIRED SHEATHING/SIDING SHEAR AND UPLIFT SPlice BETWEEN PLATES**

Inter-story splice plate between studs

Sheathing splice – same thickness and strength axis orientation as wall sheathing is **required** between studs.
Recommendations provided in this report are subject to the following conditions:

a) The structural systems provided in this report shall be designed by a design professional qualified in wood design and installed in accordance with the installation requirements specified in this report.

b) The structural systems shall be constructed with wood structural panels meeting the requirements of DOC PS 1 or PS 2 and trademarked by an approved agency required by the code.

c) The structural systems shall be limited to dry service conditions where the average equilibrium moisture content for solid-sawn lumber is less than 16 percent.

d) This report is subject to review in one year. The latest copy of this report can be downloaded from www.apawood.org/publications.
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