APA System Report
SR-101B JANUARY 2010

Design for Combined Shear and Uplift from Wind

1. BASIS OF THE 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
- 2001 ANSI/AF&PA Wood Frame Construction Manual
- 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.

TABLE 1

ANCHOR BOLT SPACING (INCHES) FOR COMBINED SHEAR AND WIND UPLIFT[a]

Nail Size	Allowable Design Shear (plf)		Allowable Design Uplift (plf)										
	G = 0.50		0	108	216	324	432	540	648	729	864	972	1,080
		G = 0.42	0	100	200	300	400	500	600	675	800	900	1,000
8d (0.131" x 2-1/2")	0	0	48[c]	42	36	36	32	24	24	19.2	16	(b)	(b)
	200	184	48	42	36	36	32	24	24	19.2	16	(b)	(b)
	335	308	36	32	24	24	24	24	19.2	19.2	16	(b)	(b)
	490	451	24	24	19.2	19.2	19.2	16	16	(b)	(b)	(b)	(b)
10d (0.148" x 3")	0	0	48	42	36	36	32	24	24	19.2	16	16	16
	200	184	48	42	36	36	32	24	24	19.2	16	(b)	(b)
	435	400	24	24	24	19.2	19.2	19.2	16	16	(b)	(b)	(b)

G = specific gravity of framing members.

(a) The minimum wall sheathing thickness shall be in accordance with Footnote c to Table 4.

(b) Outside the scope of SDPWS.

(c) This anchor bolt spacing is provided for interpolation purposes.

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_o) 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.

4. DESIGN CAPACITIES

TABLE 2

ALLOWABLE SHEAR CAPACITIES FOR WOOD STRUCTURAL PANEL SHEAR WALLS FOR WIND LOADS (for Allowable Stress Design)[a]

			Framing Species G ≥ 0.50				Framing Species 0.50 > G ≥ 0.46				Framing Species 0.46 > G ≥ 0.42			
			Panel Edge Nail Spacing (in.)[b]											
			6	4	3	2[c]	6	4	3	2[c]	6	4	3	2[c]
Sheathing Material	**Sheathing Thickness (in.)**	**Nail Size[d]**	**Recommended Shear Capacity (plf)**											
Structural I	7/16	8d	355[e]	550[e]	705[e]	935[e]	340[e]	525[e]	675[e]	895[e]	325[e]	505[e]	650[e]	865[e]
	15/32	8d	390	600	770	1020	375	575	740	980	360	555	710	940
		10d	475	715	930	1215	455	685	890	1165	440	660	860	1125
Sheathing Grade, Plywood Siding	7/16	8d	335[e]	490[e]	630[e]	820[e]	320[e]	470[e]	605[e]	785[e]	310[e]	450[e]	580[e]	755[e]
	15/32	8d	365	530	685	895	350	510	655	860	335	490	630	825
		10d	435	645	840	1075	415	620	805	1030	400	595	775	995
	19/32	10d	475	715	930	1215	455	685	890	1165	440	660	860	1125

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.)

3-Second Gust Wind Speed (mph)		85	90	100	110	120	130	140	150
Roof/Ceiling Assembly Design Dead Load	Roof Span (ft)	Unit Connection Loads (plf)[a][b][c][d][e][f]							
0 psf[g]	12	119	134	165	199	237	279	323	371
	24	196	219	271	328	390	458	531	610
	36	273	306	378	457	544	639	741	850
	48	350	393	485	587	698	820	951	1091
	60	428	480	592	717	853	1001	1161	1333
10 psf	12	71	86	117	151	189	231	275	323
	24	112	135	187	244	306	374	447	526
	36	153	186	258	337	424	519	621	730
	48	194	237	329	431	542	664	795	935
	60	236	288	400	525	661	809	969	1141
15 psf	12	47	62	93	127	165	207	251	299
	24	70	93	145	202	264	332	405	484
	36	93	126	198	277	364	458	561	670
	48	116	159	251	353	464	586	717	857
	60	140	192	304	429	565	713	873	1045
20 psf	12	23	38	69	103	141	183	227	275
	24	28	51	103	160	222	290	363	442
	36	33	66	138	217	304	399	501	610
	48	38	81	173	275	386	508	639	779
	60	44	96	208	333	469	617	777	949
25 psf	12	–	14	45	79	117	159	203	251
	24	–	9	61	118	180	248	321	400
	36	–	6	78	157	244	339	441	550
	48	–	3	95	197	308	430	561	701
	60	–	0	112	237	373	521	681	853

(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.

Mean roof height (ft)	0 - 15	20	25	30	33
Exposure C	1.18	1.25	1.31	1.36	1.39
Exposure D	1.43	1.50	1.56	1.61	1.64

(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:

Connection Spacing (in.)	12	16	19.2	24	48
Multiplier	1.00	1.33	1.60	2.00	4.00

(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.

TABLE 4

UPLIFT CAPACITY (ALLOWABLE STRESS DESIGN) OF WOOD STRUCTURAL PANEL SHEATHING OR SIDING WHEN USED TO SIMULTANEOUSLY RESIST SHEAR AND WIND UPLIFT LOADS[a][b]

	Nail Spacing Required for Shear Wall Design[c] – See Table 2											
	6d@6" & 12"			8d@6" & 12"			8d@4" & 12"			10d@6" & 12"		
	Alternate Nail Spacing at Top and Bottom Plate Edges (in.), S[f]											
	6	4	3	6	4	3	6	4	3	6	4	3
	Uplift Capacity (plf)[a]											
NAILS-SINGLE ROW[d]	0	84	168	0	108	216	NP	0	108	0	131	262
NAILS-DOUBLE ROW[e]	168	336	504	216	432	648	108	324	540	262	524	786

(a) The framing species shall have a published specific gravity of 0.42 (spruce-pine-fir) or greater. For framing with a specific gravity of 0.49 or greater, multiply uplift values listed in above table by 1.08.

(b) Anchor bolts shall be installed in accordance with Table 1. Nail dimensions are: 6d – 0.113" x 2", and 8d – 0.131" x 2-1/2", and 10d – 0.148" x 3".

(c) Where nail size is 6d or 8d, the tabulated uplift values are applicable to 7/16" minimum OSB panels or 15/32" minimum plywood with species of plies having a specific gravity of 0.49 or greater. Where nail size is 10d, the tabulated uplift values are applicable to 15/32" minimum OSB or plywood with a species of plies having a specific gravity of 0.49 or greater. For plywood with other species, multiply the tabulated uplift values by 0.90.

(d) Wood structural panels shall overlap the top member of the double top plate and bottom plate by 1-1/2 inches and a single row of fasteners shall be placed 3/4 inch from the panel edge.

(e) Wood structural panels shall overlap the top member of the double top plate and bottom plate by 1-1/2 inches. Rows of fasteners shall be 1/2 inch apart with a minimum edge distance of 1/2 inch. Each row shall have nails at the specified spacing.

(f) Alternate nail spacing (S) is nail spacing that includes both the shear nailing and uplift nailing. See Figures 1 through 4.

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

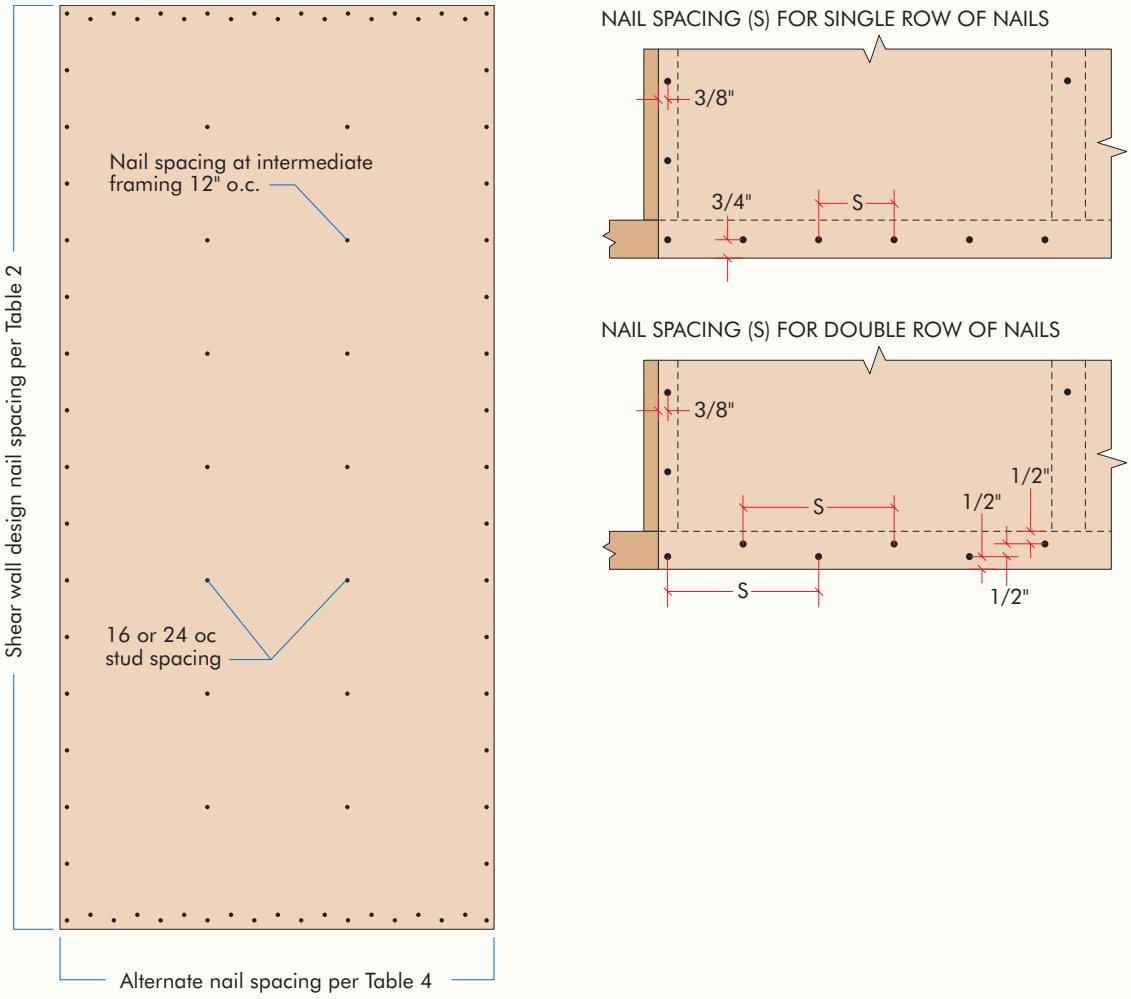
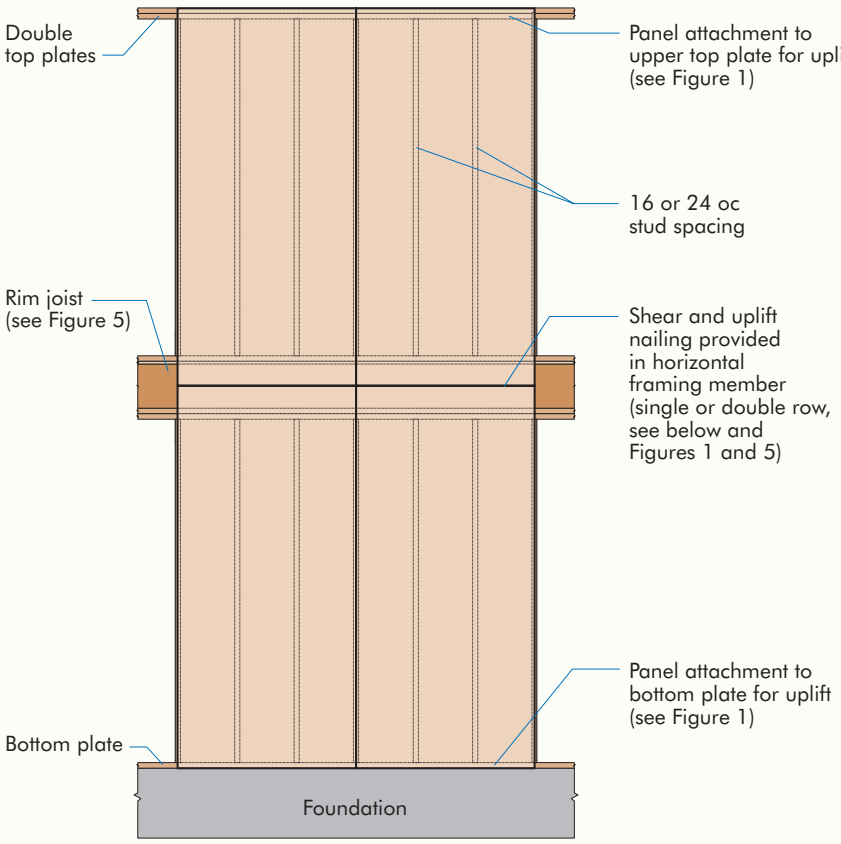
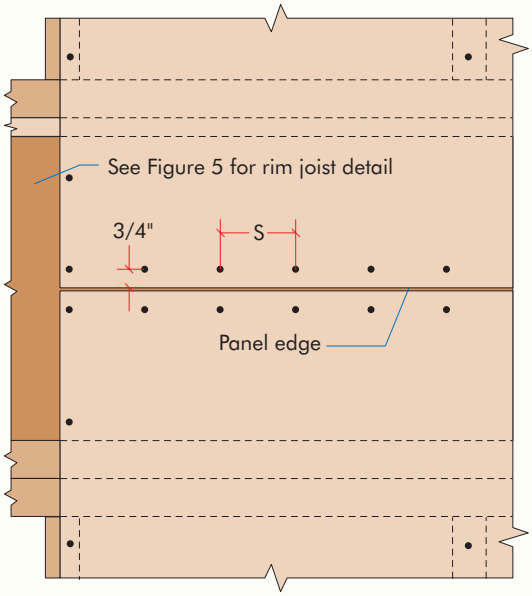


FIGURE 2

PANEL ATTACHMENT FOR SHEAR AND UPLIFT — AT RIM JOIST



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



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

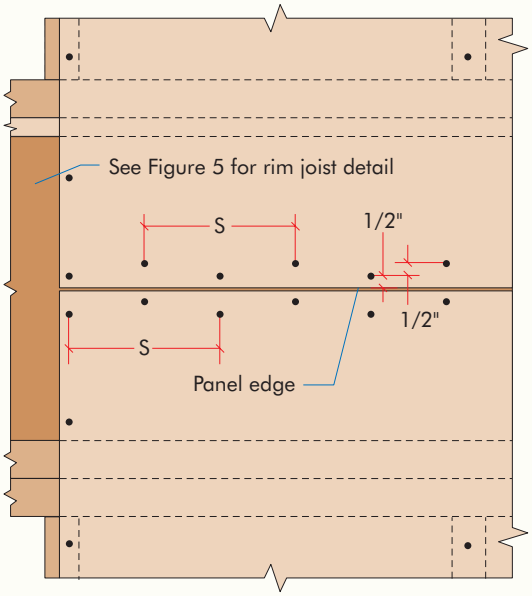
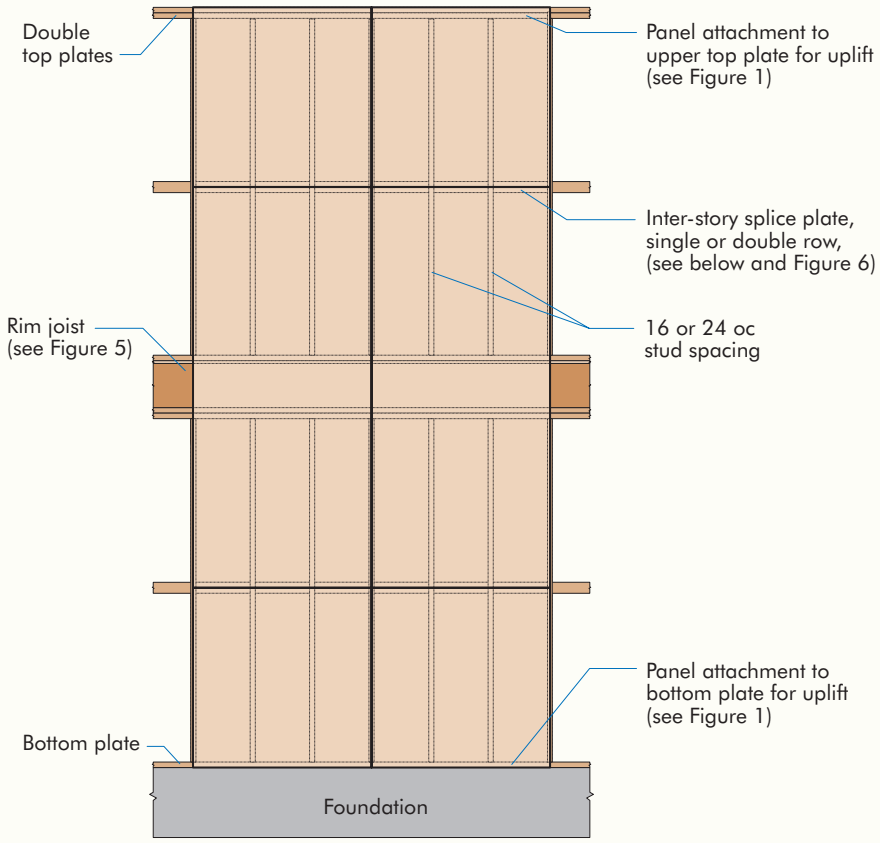
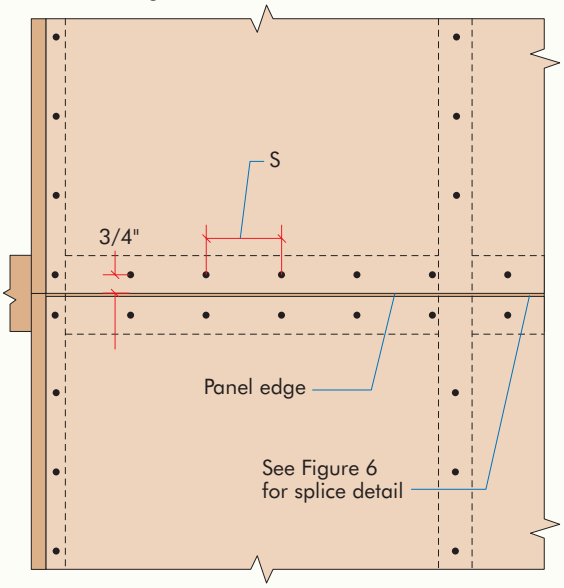


FIGURE 3

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



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



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

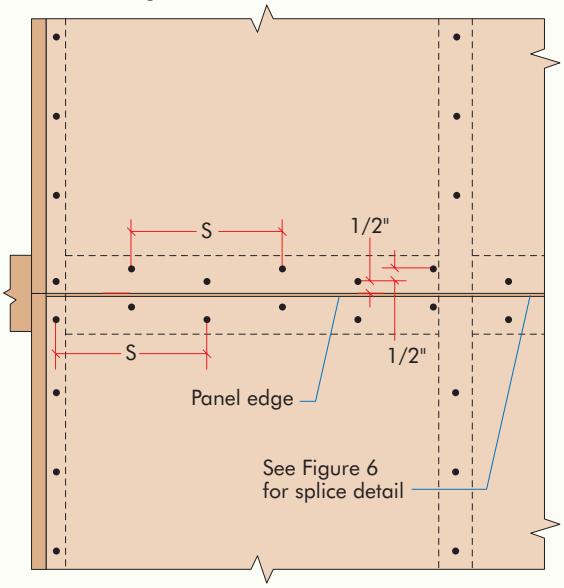


FIGURE 4

PANEL ATTACHMENT FOR SHEAR AND UPLIFT – AT RAISED WOOD FLOOR

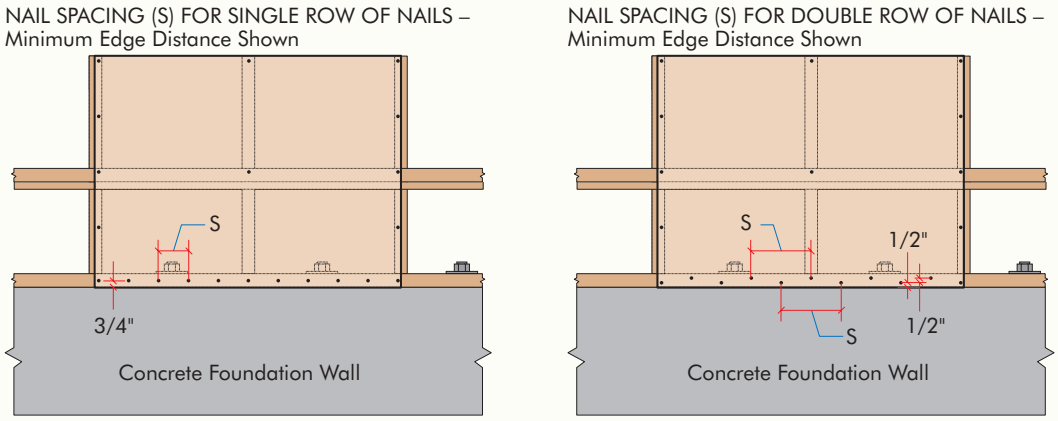
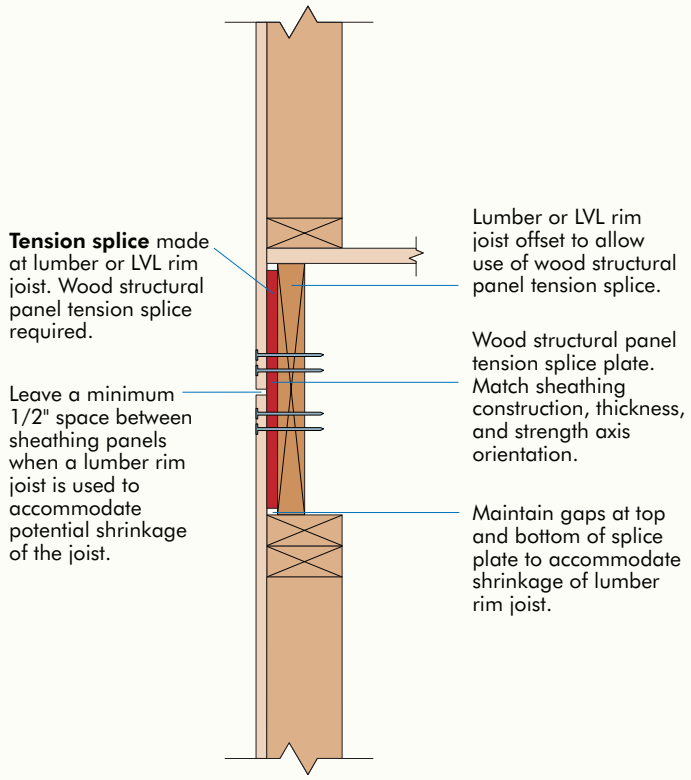


FIGURE 5

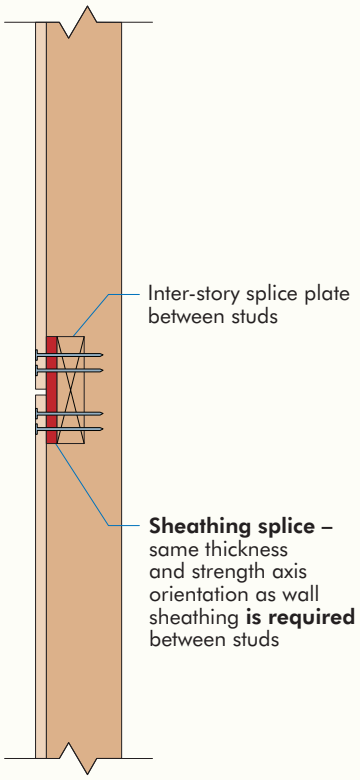
TENSION SPLICE MADE AT LVL OR LUMBER RIM JOIST, SHOWING OFFSET RIM JOIST TO PERMIT THE USE OF WOOD STRUCTURAL PANEL TENSION SPLICE PLATE



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



7. LIMITATIONS

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.

APA – The Engineered Wood Association is an accredited certification body under ISO 65 by Standards Council of Canada (SCC) and an accredited inspection agency by the International Code Council (ICC) International Accreditation Service (IAS) under ISO/IEC 17020. APA is also an accredited testing organization recognized by IAS and SCC under ISO/IEC 17025. APA is a recognized testing laboratory by Miami-Dade County, and a Product Testing Laboratory, Product Quality Assurance Entity, and Product Validation Entity by the Florida Department of Community Affairs (DCA).

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