Use of Wood Structural Panels to Resist Combined Shear and Uplift from Wind

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Introduction

It is well known that wood structural panel shear walls can be constructed to simultaneously resist shear forces and uplift forces due to wind. With publication of the American Wood Council's (AWC) *Special Design Provision for Wind and Seismic* (*SDPWS*) in 2008 (Figure 1), this concept of using nail connections to resist both shear and uplift was codified by the wood design community. Section 4.4 of the *SDPWS* now contains tabulated values for the uplift capacity of certain wood structural panel shear walls, with a list of requirements for installation and illustrations for nailing. The capacities are based on provisions in the 2005 AWC *National Design Specification® for Wood Construction* (*NDS®*) and have been verified by full scale testing.

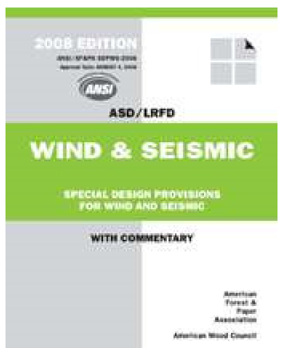

Figure 1. *Special Design Provision for Wind and Seismic* (*SDPWS*), 2008.

The primary characteristic of this method is increased nailing of panels to framing to provide a continuous load path and enabling uplift loads to be transferred to existing wall anchorage at the foundation.

Need for Fewer Tie-downs

A desire to investigate the inherent uplift capacity of nailed wood structural panel shear walls was the impetus for development of this design method.

In the last two decades, as design standards have evolved to address losses associated with high-wind events, designers and home builders have been challenged by the substantially "beefed up" methods and equipment required to resist wind forces. Among the concerns is the number of tie-downs required for shear walls, which can present both cost increases and practical construction challenges. Traditional methods of providing for uplift resistance with additional tie-downs at shear walls can be cumbersome and expensive.

Recent and Current Prescriptive Engineered Design Tools and Standards

Model codes and standards have played a part in the evolution of the methodology and its incorporation into *SDPWS*. In order to address the high costs of wind damage in high wind events, particularly in hurricane-prone regions of the southeast, building officials, the building industry, and the insurance industry have encouraged and supported development of prescriptive design tools and standards for residential construction in high-wind areas. Emphasis has been on the use and substantiation of prescriptive documents that are easily applied by designers and builders, easily enforced by code officials, and are completely consistent with the most current loading criteria in the International Code Council's (ICC) *International Building Code* (IBC), the *International Residential Code* (IRC), and the American Society of Civil Engineer's (ASCE) *Minimum Design Loads for Buildings and Other Structures, ASCE 7*.

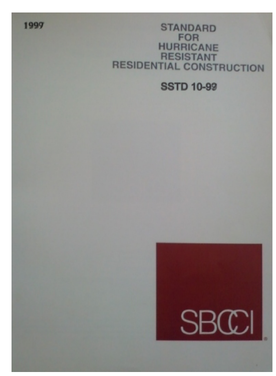

Figure 2. *Standard for Hurricane Resistant Construction*, *SSTD-10* published by the Southern Building Code Congress International.

The progression of prescriptive, yet engineering-based, documents began with publication of the *Standard for Hurricane Resistant Construction, SSTD-10* (Figure 2), by the Southern Building Code Congress International, in 1990. Although comprehensive in regard to materials, the standard contained provisions for resisting wind loads only, and it did not address other design considerations such as earthquake, flood, or gravity loads. An update of that standard was published in 1999.

A comprehensive standard encompassing all structural loadings for buildings in high wind regions was needed. As a result, *SSTD-10* has since been succeeded by the ICC's *Standard for Residential Construction in High-Wind Regions*, *ICC 600* (Figure 3), published in 2008.

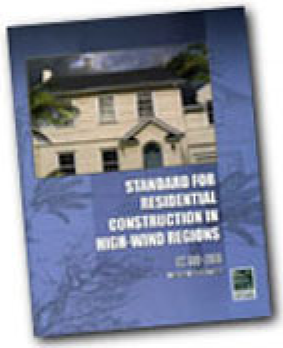

Figure 3. ICC's *Standard for Residential Construction in High-Wind Regions*, *ICC 600*, published in 2008.

Prior to publication of the *ICC 600* standard, the Institute for Business and Home Safety (IBHS) published a version of the *SSTD-10* standard that broadened the application to more coastal areas of the southeast U.S. with higher wind speeds than originally addressed in *SSTD-10*, as a stop-gap for use in the state of Florida, in cooperation with ICC.

The concept of using wood structural panel shear walls to resist uplift forces had been incorporated into the *SSTD-10* standard, and later into *ICC-600* with few changes. Incorporation of these provisions in *SDPWS* completes the codification with some modification to the earlier provisions. This will now serve as the basis for continued development of prescriptive provisions for combined shear/uplift resistance.

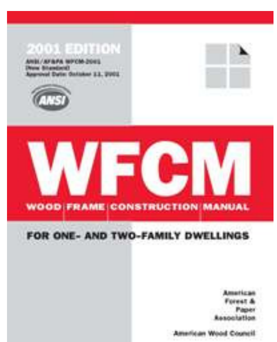

Figure 4. In 2001, AWC published the national version of the *Wood Frame Construction Manual* (*WFCM*) *for One- and Two-Family Dwellings*, based on all gravity, snow, seismic, and wind loads specified by the first edition of the *IBC* (2000).

In 1995, AWC (previously the American Forest & Paper Association) published the first version of the *Wood Frame Construction Manual* (*WFCM-SBC*), a comprehensive, engineered, and prescriptive standard for wood frame construction based on high wind loads specified in the 1994 *Standard Building Code* (*SBC*). In 2001, AWC published the national version of the *Wood Frame Construction Manual* (*WFCM*) *for One- and Two-Family Dwellings* (Figure 4), based on all gravity, snow, seismic, and wind loads specified by the first edition of the *IBC* (2000). Supplying both engineering criteria as well as prescriptive framing tables and diagrams, the *WFCM* complimented prescriptive framing provisions of the *IRC* and was referenced by that code for buildings in high wind regions, and was also adopted by certain states in the south as mandatory for wood frame residential construction in high wind zones.

The 2001 *WFCM* does not contain provisions for walls designed to resist combined shear and uplift; however, *ICC 600* and the *2001 WFCM* are formatted so that shear walls resisting combined uplift and shear can be used in conjunction with the prescribed loads in *WFCM*. Efforts are being made to incorporate prescriptive shear wall designs into the 2012 edition of the *WFCM*, which will contain tables for combined shear and uplift wood structural panel walls for each wind region.

Progression of Provisions

Uplift capacity tables for wood structural panel sheathing or siding when used for both shear and uplift in the *ICC 600* standard are identical to its predecessor, *SSTD-10*. However, the newer *ICC 600* standard directly references prescriptive tables in the *WFCM* for selection of initial shear wall design and the determination of uplift pressures, naming the appropriate *WFCM* tables in the text. In addition, specifications for anchor bolt spacing, and washer dimensions and installation details, are provided in *ICC 600* (and subsequently in the 2008 *SDPWS*) — requirements that became necessary when the results of full-scale testing showed the occurrence of excessive cross-grain bending of the bottom plate under combined loading.

Specific provisions for the transfer of uplift forces across horizontal joints in the sheathing were new in *SDPWS*. Whereas *SSTD-10* and *ICC 600* required horizontal joints to occur over framing members, there was no specific guidance for certain common circumstances, such as joints occurring at mid-story over blocking between studs. Section 4.4.1.7 of *SDPWS* requires that where horizontal joints occur over blocking between studs (as opposed to other horizontal framing members such as a floor band joist), nailing at the studs above and below the joint must be designed to transfer uplift across the joint. Alternatively, use of sheathing tension splices in conjunction with blocking is permitted with certain conditions. See Figures 5a, b, and c on pages 5 and 6.

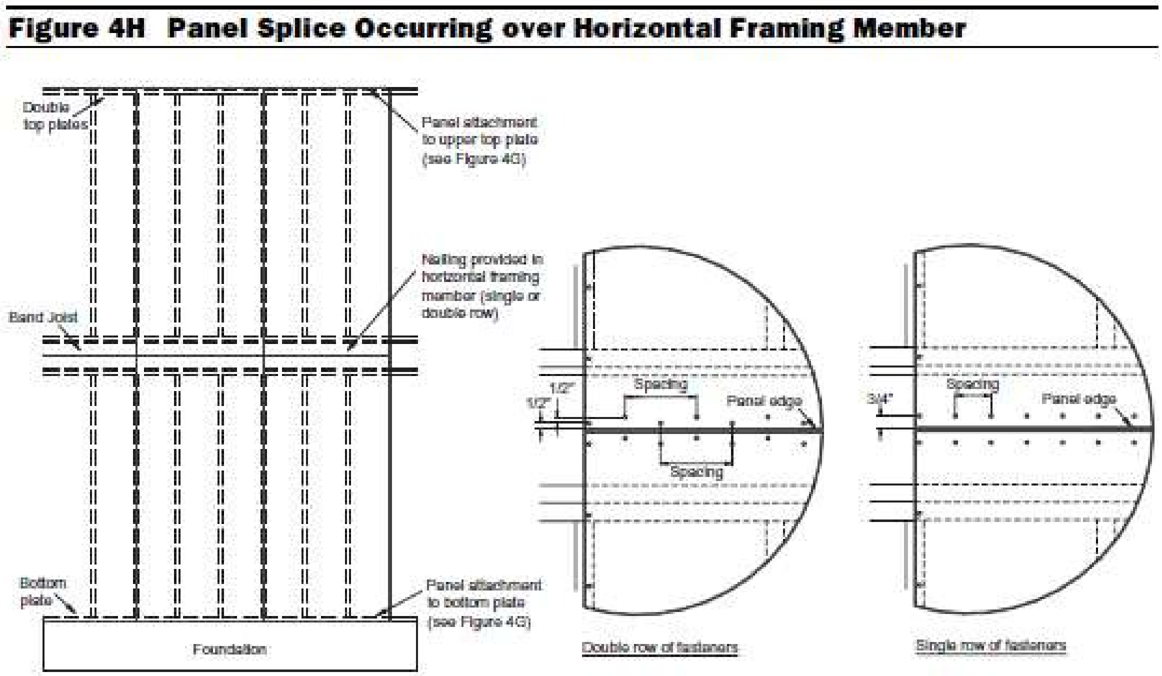

Figure 5A. AWC's *Special Design Provision for Wind and Seismic* (*SDPWS*), 2008 Figure 4H.

Whereas *SSTD-10* and *ICC 600* assume ASD design methods, the uplift capacity table in *SDPWS* (Table 1, page 7) shows nominal values that must be modified by the ASD reduction factor or the LRFD resistance factor. Footnote adjustments to table values accounting for wood species are indicated by ranges of specific gravities in the *SDPWS*, whereas species group designations, defined in accordance with the *NDS*, were used in *SSTD-10* and retained in *ICC 600*.

Testing

Consideration of panel nailing for resisting combined uplift and shear had been used by engineering analysis and appeared in early editions of *SSTD-10* prior to any formal testing. Testing was encouraged by IBHS in order to substantiate retention of the provisions during an update of the standard prior to 2005. One wood structural panel manufacturer, Norbord, had conducted initial testing at the National Association of Homebuilders Research Center, and in 2006, with APA-The Engineered Wood Association, entered jointly into an additional testing program at Clemson University. Testing substantiated the concept and design methodology, but some adjustments were necessary in regard to specifications for anchor bolt installation, in order to provide for resistance of cross-grain bending of bottom plates, as mentioned above.

Overview of combined shear and uplift provisions in the *SDPWS*

Requirements for wood structural panels designed to resist combined shear and uplift from wind include the following (see Section 4.4.1 of the *SDPWS* for complete details):

- wood structural panels must have a minimum thickness of 7/16-inch
- all horizontal joints must occur over framing members or blocking
- sheathing is attached at top plate and bottom or sill plates of walls
- anchor bolts must have a maximum spacing of 16 inches and be designed to resist combined wind shear and uplift; washers are a minimum size of 0.229 x 3 x 3 inches, extending to within ½-inch of the bottom plate edge on the sheathed side
- sheathing splices must occur at designed horizontal members or blocking designed for shear transfer, or a tension splice of the same thickness and grade as the sheathing must be provided
- in general, 3-inch single row spacing or 6-inch double row spacing of fasteners at panel edges is required, with minimum clearances to panel edges
- uplift forces on framing around window and door openings must be addressed by the use

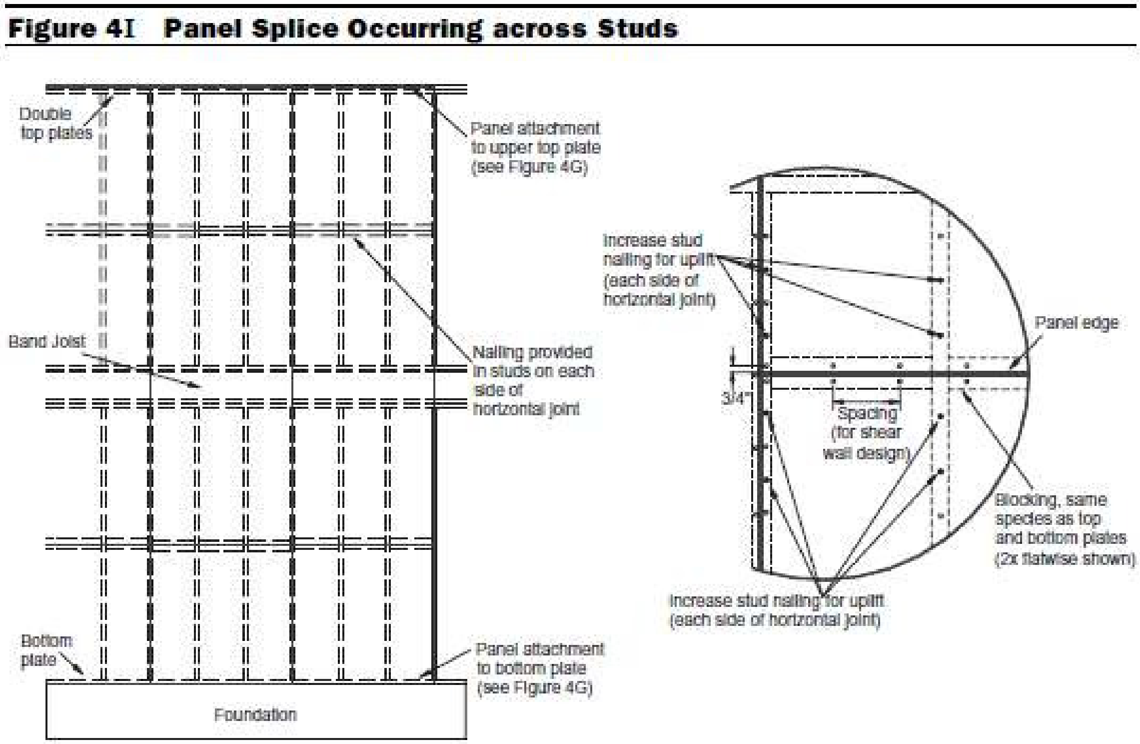

Figure 5B. AWC's *Special Design Provision for Wind and Seismic* (*SDPWS*), 2008 Figure 4I.

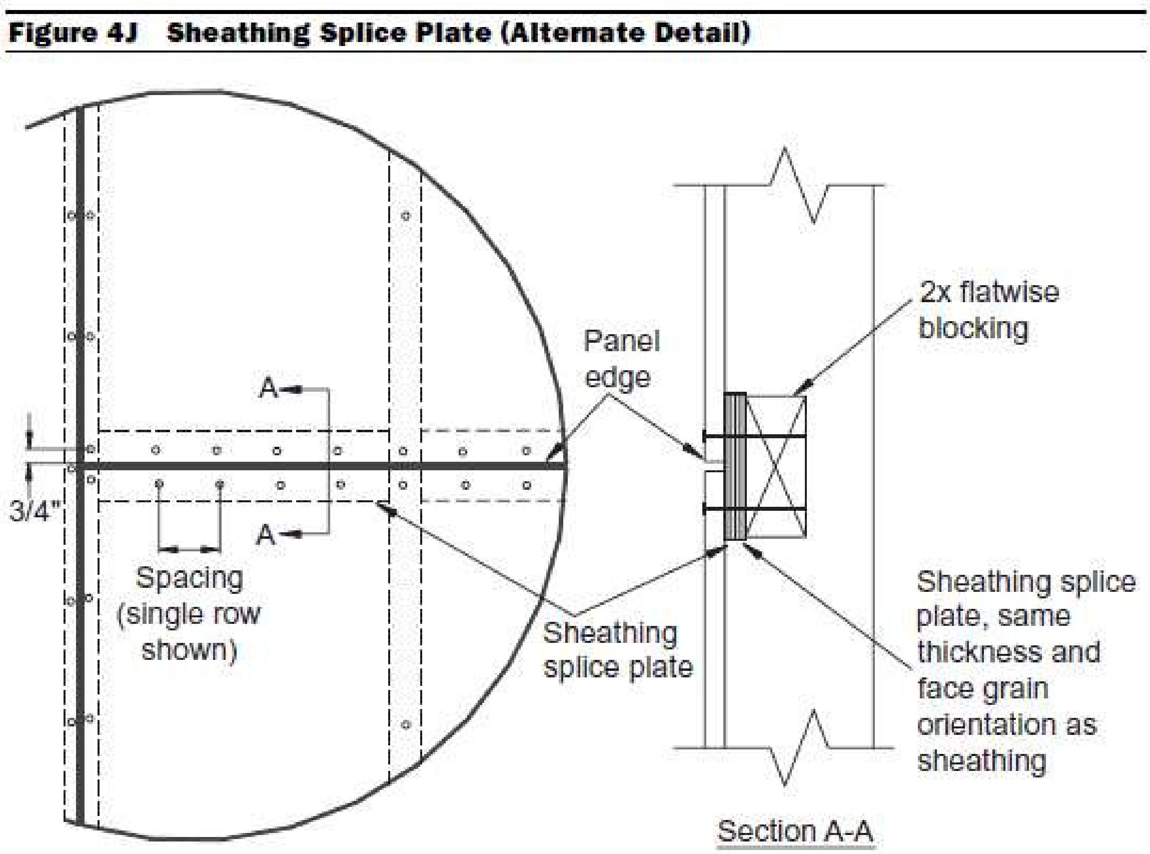

Figure 5C. AWC's *Special Design Provision for Wind and Seismic* (*SDPWS*), 2008 Figure 4J.

Table 4.4.1 Nominal Uplift Capacity of 7/16" Minimum Wood Structural Panel Sheathing or Siding When Used for Both Shear Walls and Wind Uplift Simultaneously over Framing with a Specific Gravity of 0.42 or Greater [1]

	Nail Spacing Required for Shearwall Design											
	6d Common Nail 6" panel edge spacing 12" field spacing			8d Common Nail 6" panel edge spacing 12" field spacing			8d Common Nail 4" panel edge spacing 12" field spacing			10d Common Nail 6" panel edge spacing 12" field spacing		
	Alternate Nail Spacing at Top and Bottom Plate Edges											
	6"	4"	3"	6"	4"	3"	6"	4"	3"	6"	4"	3"
	Uplift Capacity (plf) of Wood Structural Panel Sheathing or Siding [2,3]											
Nails-Single Row [4]	0	168	336	0	216	432	NA	0	216	0	262	524
Nails-Double Row [5]	336	672	1008	432	864	1296	216	648	1080	524	1048	1572

1. Nominal unit uplift capacities shall be adjusted in accordance with 4.4.1 to determine ASD allowable unit uplift capacity and LRFD factored unit resistance. Anchors shall be installed in accordance with this section. See Appendix A for common nail dimensions.
2. Where framing has a specific gravity of 0.49 or greater, uplift values in table 4.4.1 shall be permitted to be multiplied by 1.08.
3. Where nail size is 6d common or 8d common, 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 common, 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.
4. Wood structural panels shall overlap the top member of the double top plate and bottom plate by 1-1/2" and a single row of fasteners shall be placed ¾" from the panel edge.
5. Wood structural panels shall overlap the top member of the double top plate and bottom plate by 1-1/2". Rows of fasteners shall be ½" apart with a minimum edge distance of ½". Each row shall have nails at the specified spacing.

Table 1. AWC's *Special Design Provision for Wind and Seismic* (*SDPWS*), 2008 Table 4.4.1.

Table 4.4.2 Nominal Uplift Capacity of 3/8" Minimum Wood Structural Panel Sheathing or Siding When Used for Wind Uplift Only over Framing with a Specific Gravity of 0.42 or Greater [1]

	6d Common Nail 6" panel edge spacing 12" field spacing			8d Common Nail 6" panel edge spacing 12" field spacing			10d Common Nail 6" panel edge spacing 12" field spacing		
	Alternate Nail Spacing at Top and Bottom Panel Edges								
	6"	4"	3"	6"	4"	3"	6"	4"	3"
	Uplift Capacity (plf) of Wood Structural Panel Sheathing or Siding [2,3]								
Nails-Single Row [4]	320	480	640	416	624	832	500	750	1000
Nails-Double Row [5]	640	960	1280	832	1248	1664	1000	1500	2000

1. Nominal unit uplift capacities shall be adjusted in accordance with 4.4.2 to determine ASD allowable unit uplift capacity and LRFD factored unit resistance. Anchors shall be installed in accordance with this section. See Appendix A for common nail dimensions.
2. Where framing has a specific gravity of 0.49 or greater, uplift values in table 4.4.2 shall be permitted to be multiplied by 1.08.
3. The tabulated uplift values are applicable to 3/8" minimum OSB panels or plywood with 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.
4. Wood structural panels shall overlap the top member of the double top plate and bottom plate by 1-1/2" and a single row of fasteners shall be placed ¾" from the panel edge.
5. Wood structural panels shall overlap the top member of the double top plate and bottom plate by 1-1/2". Rows of fasteners shall be ½" apart with a minimum edge distance of ½". Each row shall have nails at the specified spacing.

Table 2. AWC's *Special Design Provision for Wind and Seismic* (*SDPWS*), 2008 Table 4.4.2.

of conventional uplift anchors at the sides of openings.

Typically, the designer would choose a shear wall design by conventional calculations or table methods for the determined shear, and then determine uplift forces on the wall by calculation or using prescriptive methods from the *WFCM*, based on building geometry. Once the uplift force is known, the designer can enter Table 4.4.1 of the *SDPWS* to find a wall with the needed uplift capacity, verifying that the wall chosen has nailing that exceeds what is required for shear design alone.

Uplift capacities in Table 4.4.1 must be modified by either the ASD reduction factor of 2.0, or the

LRFD resistance factor of 0.65, depending on the design method chosen.

This method also provides for the use of wood structural panel walls designed to resist uplift alone (Section 4.4.2 of the *SDPWS*). A separate table (Table 2, page 7) gives uplift capacities when minimum 3/8-inch thick sheathing or siding is used.

APA-The Engineered Wood Association has published design examples in APA System Report SR-101B *Design for Combined Shear and Uplift from Wind* and Technical Note E510A *Using Wood Structural Panels for Combined Uplift and Shear Resistance*. Derivation of values in *SDPWS* Table 4.4.1 can be found in the commentary material at the back of the *SDPWS* standard.

Broadened Application

Whereas previous standards are limited in scope to residential structures, the incorporation of the combined shear/uplift methodology in *SDPWS* broadens application of this method to other than residential structures. All structures using wood shear walls and diaphragms to resist lateral loads are now required to comply with the *SDPWS*, in accordance with Section 2305.1 of the *IBC*.

Conclusion

AWC's *SDPWS* now contains provisions for wood structural panel shear walls designed to resist shear and uplift simultaneously, and wind uplift alone. These provisions are based primarily on increased perimeter nailing of standard thickness wood structural panels to top and bottom plates, and specific requirements for panel splices. Similar provisions appeared in the *SSTD-10* and the *ICC-600* standards for residential construction. *SDPWS* provisions contain all necessary design criteria to apply this methodology to any wood structure regulated by the ICC codes and designed in accordance with provisions of the *NDS*. Design examples are readily available on industry websites.

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