Walls designed to stand up to wind

Structural wall coverings in wind design and wood structural panel solutions

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Abstract

Winds loads create structural demands on a building on all exterior surfaces and in all three directions (into/out of the wall surface, racking in the plane of the wall, and uplift). Siding and intermittent wall bracing or shear walls cannot always resist each of these wind load effects over the entire wall line, especially the pressures into and out of the wall surfaces. Many sidings actually require a structural "solid" backing capable of resisting all imposed wind pressures. The required design wind pressures on exterior walls can be quite high and can even exceed common floor (40 psf) or roof (30 psf) design pressures. Recent high wind events have shown wall covering failures to occur. Wall covering failures can lead to catastrophic damage due to wind-driven rain intrusion and/or by reducing the structural integrity of the building while at the same time increasing internal pressures. Structural wall coverings provide resistance to wind loads when used on exterior surfaces. In this paper, use of wood structural panel sheathing to resist the required design wind pressures is discussed.

Wind Loads and Minimum Wall Covering Design Wind Pressures

Winds exert pressures (inward or outward) on all exterior building surfaces. Section R301.2.1 of the *2006 International Residential Code (IRC)* requires that "wall coverings" be capable of resisting these wind pressures (called component and cladding loads in the *IRC* and *Minimum Design Loads for Buildings and Other Structures, ASCE7-05*). The design wind pressures act toward (positive) or away (negative) from the exterior surfaces. Pressures acting away have a negative sign and can also be considered a suction pressure. The suction pressures generally have a higher magnitude than the positive pressures. The required minimum net suction pressures on walls are summarized in **Table 1**. Some of these minimum required wall design wind pressures are of similar magnitude to typical roof and floor design pressures.

Wall Covering Failures

Typical wall coverings are siding, sheathing, or a combination of both. Siding and sheathing products, however, vary greatly and some have more structural capabilities than others. High wind events show that failure of air permeable siding placed over non-structural wall coverings is a real problem as shown in **Figures 1 through 7.** The initial failure or breaching of the wall coverings can expose the interior of the building to rain water and frequently dominoes into further structural damage. Once the structural wall envelope is breached, the building begins losing its structural integrity (its strength) and, in addition, is subject to even higher loads due to increased internal pressurization acting along with external wind pressures. The combination of lower strength and higher loads is a recipe for disaster.

Failed Wall Coverings and Wind-Driven Rain Damage

Once the building envelope is breached, as shown in **Figures 1 through 7,** wind-driven rain can cause catastrophic water damage to the furnishings and interior finish as well as subject the building to internal pressurization. In fact, the failure shown in **Figure 3** led to rain water intrusion and subsequent damage more costly than the original house structure.

Figure 8 shows that structural sheathing on the exterior wall can help prevent catastrophic damage.

Limits of Wall Bracing

Wall bracing is commonly thought to be the structural component of the wall, but the primary purpose of wall bracing is to resist load in one dimension–wall racking. For example, a 1 by 4 let-in brace or equivalent metal brace provides no resistance to wind pressures acting on the wall surface and relies on a structurally capable wall covering. If the wall covering cannot

Table 1.—Minimum wind suction loads (psf) on exterior walls per *2006 IRC*.[a]

Wind exposure category	Mean roof height	Wind speed (mph)				
		85	90	100	105	110
	(ft)					
B	30	17	20	24	27	29
C	30	24	27	34	37	41
D	30	29	32	40	44	48

[a] Negative pressures from *IRC* Table R301.2(2) for walls in Zone 5 with effective wind area of 10 $ft.^2$ with exposure adjustments per Table R301.2(3). Note that these *2006 IRC* requirements are derived from *ASCE7-05* Section 6.4.

Figure 1 — Foam and vinyl wall covering failure.

Figure 2 —Foam and vinyl wall covering failure.

Figure 3 — Siding and non-structural sheathing wall covering failure. Rain following the wind event caused massive interior damage to interior finishes and personal property.

Figure 4 — Foam and vinyl wall covering failure. Note the roof damage caused when the breach in the gable-end wall pressurized the attic area.

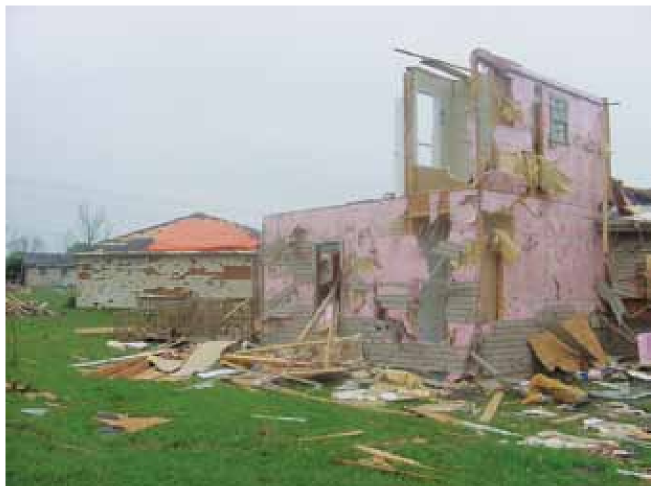

Figure 5 — Foam and vinyl wall sheathed home in foreground, wood structural panel sheathed home in background.

Figure 6 — Difference between structural and non-structural wall sheathing. Wind pressures act on all exterior surfaces, not just the corner bracing.

Figure 7 — Foam and vinyl wall covering failure. Note: the corner bracing was not what failed.

Figure 8 — Homes sheathed with continuous structural sheathing have significantly stronger resistance to the effects of wind pressures.

resist load, then the wall bracing will not receive any load as shown in **Figure 9**.

Even if a wall bracing method is selected that does have resistance to wind pressures or suction loads like a wood structural panel, most bracing is only required to be used intermittently along a given wall line and often not at all at gableends. This can also be seen in **Figures 1 through 7**. This means that the structure's resistance to wind pressure ends where the bracing ends, and the structure is unprotected between bracing panels. Since wind affects all exterior surfaces, it's important to provide resistance on all exterior surfaces, not just some percentage, or in corners only, as is the minimum requirement for wall bracing.

Understanding bracing or shear wall requirements is not necessarily easy, but there is a wide variety of straightforward information on the topic of resisting wall racking. Wall cladding requirements are often overlooked. Information on common product limits for wind pressure resistance is not easy to find, and after many wind events this appears to be a more common problem than wall racking failures.

Limits of Air Permeable Siding and Non-Structural Wall Sheathing

When non-structural wall sheathing is used (e.g., foam sheathing), then the siding must be capable of resisting the loads (both positive and negative). Many sidings, especially air permeable sidings such as vinyl are "rated" assuming that there is a backing capable of resisting all or a portion of the positive and negative wind pressures. At present, all International Code Council (ICC) Evaluation Service (ES) code reports for vinyl

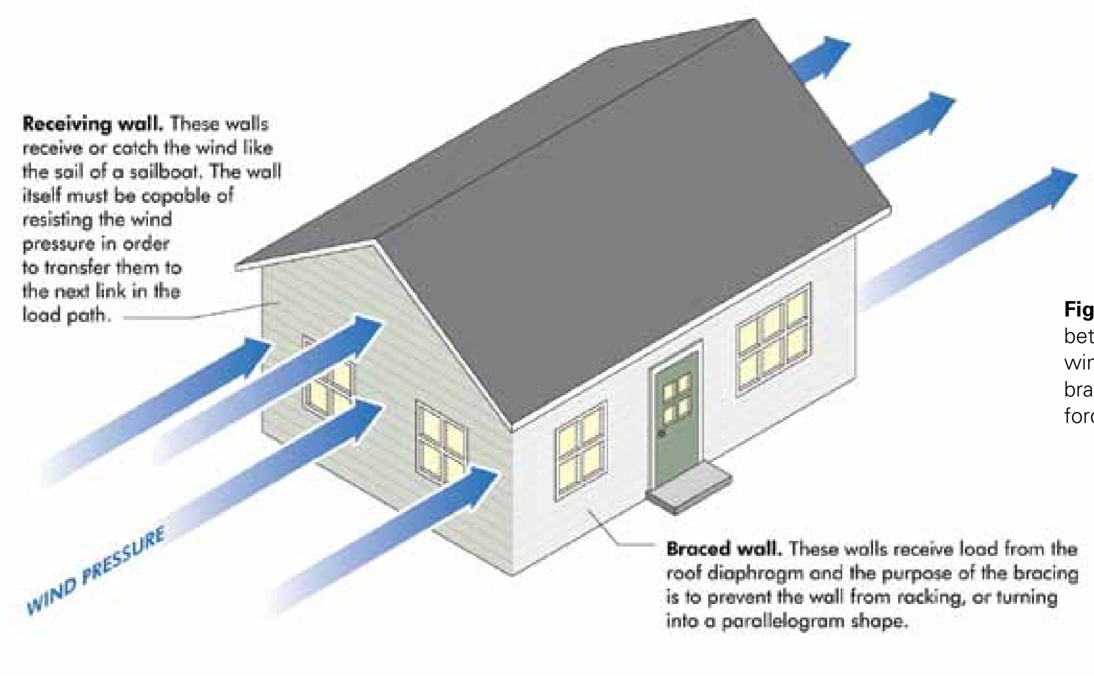

Figure 9 — The difference between the wall receiving wind pressures and the braced wall (wind uplift forces are not shown).

siding require a "solid" backing capable of resisting all imposed wind pressures. Non-structural foam sheathing is typically not considered a solid backing capable of resisting wind pressures since it has no structural design values.

Meeting the Requirements with Wood Structural Panels

Unfortunately, the *IRC* does not have much specific information on the strength limits of wall coverings as they pertain to Section R301.2.1. **Table 2** was created to show the limits of using wood structural panel wall sheathing and siding to meet the wind pressure requirements. Information on how other types of wall sheathing or siding products meet the required wind pressures is beyond the scope of this paper and readers are encouraged to contact the product manufacturer for details.

Wood Structural Panel Design Details

The basic design principles used to create **Table 2** are relatively straightforward. For resisting negative wind pressures, the overall resistance is the lesser of the fastener strength or panel strength. A sample calculation is shown in **Figure 10**. The fastener strength is the lesser of nail head pull through or nail shank withdrawal from the framing determined as follows:

- Nail head pull through values are determined from testing to *ASTM D 1037 Standard Test Methods for Evaluating Properties of Wood-Base Fiber and Particle Panel Materials*. Results of testing can be seen in APA form TT-070A (2007) and work by Chow et al. (1988). Design values were derived from the wet peak strength test values divided by a safety factor of 5 and then multiplied by an additional 0.9. The wet test values and 0.9 factor were used to be conservative.
- Nail shank withdrawal was computed using the 2005 National Design Specification (NDS) for Wood Construction provisions for nail withdrawal in 0.42 (Spruce Pine Fir lumber) specific gravity framing.
- The largest tributary area to a fastener is at the intermediate framing members. This area controls since it is the largest to any single nail. It is assumed that one nail rather than all of the panel nails controls the fastener based strength as shown in the sample calculation in **Figure 10**.
- The fastener design values are increased by a load duration factor of 1.6 for wind design loads per the 2005 NDS.

The wood structural panel strength is the lesser of panel bending, shear, or deflection (limited to L/120) for the worst case panel orientation (strength axis parallel or perpendicular to supports). Each capacity is calculated for a two span condition. All panel design properties and capacity equations were taken from the APA Panel Design Specification (2007).

Since positive pressures are equal to or less than negative pressures and panel properties are the same for positive or negative wind pressures, the table based on negative pressures (**Table 2**) can also conservatively be applied to resist positive pressures.

Summary and Conclusion

Design wall pressures can be as high as roof and floor pressures (**Table 1**). Because of this, it is important to have wall coverings, like floor and roof coverings, capable of resisting the design pressures. When wall coverings cannot resist the wind pressures and fail, rainwater entries are created, the structural integrity is compromised and internal pressures increase. Wall covering failures and the resulting combination of problems can be catastrophic.

Table 2.—Maximum wind speed (mph – 3-second gust) permitted for wood structural panel sheathing used as wall covering to meet *IRC* Table R301.2(2) requirements.[a,b,c]

Minimum nail		Minimum wood structural panel span rating	Minimum nominal panel thickness	Wall stud spacing	Panel nail spacing		Maximum wind speed (mph) Wind exposure category		
Size	Penetration				Edges	Field	B	C	D
	(in.)		- - - - - - (in.)	- - - - - -	- - - - (in. o.c.)	- - - -			
6d (0.113 by 2.0 in.)	1.5	24/0	3/8	16	6	12	110	90	85
						6	110	90	85
		24/16	7/16	16	6	12	110	100	90
						6	150	125	110
8d (0.131 by 2.5 in.)	1.75	24/16	7/16	16	6	12	130	110	105
						6	150	125	110
				24 or less	6	12	110	90	85
						6	110	90	85

[a] Panel strength axis parallel or perpendicular to supports. Three-ply plywood sheathing with studs spaced more than 16 in. o.c. shall be applied with panel strength axis perpendicular to supports.

[b] Table is based on wind pressures acting toward and away from building surfaces per R301.2, lateral bracing requirements shall be in accordance with R602.10.

[c] Wood structural panels with span ratings of Wall-16 or Wall-24 shall be permitted as an alternate to panels with a 24/0 span rating. Plywood siding rated 16 o.c. or 24 o.c. shall be permitted as an alternate to panels with a 24/16 span rating at 16-and 24-in. stud spacing, respectively. Plywood siding rated 16 o.c. shall be permitted with a 24/16 span rating at 24-in. stud spacing when installed with strength axis perpendicular to supports.

Wind Pressure Wall Panel Capacity Sample Calculation

For this example calculation, consider 7/16-in.-thick wood structural panel with studs spaced 24 in. o.c. and nailing at intermediate framing 12 in. o.c.

1. **Uniform load capacity**

   $Panel_{capacity} = 29.3$ psf — Capacity is controlling limit of bending, shear, or deflection calculated in accordance with APA *Panel Design Specification* for panel strength axis parallel to supports.

2. **Nail head pull through capacity**

   $W_{pullthrough} = 37.4$ lbf — Nail head pull through based on qualification APA TT-070A - allowable load determined by dividing average wet test results by 5.

3. **Nail withdrawal capacity from framing**

   $w_{withdrawal} = 21$ lbf/in. — Nail withdrawal per Table 11.2C of the *2005 NDS* for nail shank diameter of 0.131 framing with specific gravity = 0.42

   $P = 2.5 - 0.4375$ in. — Penetration of 8d common nail into framing (nail length – panel thickness)

   $W_{withdrawal} = w_{withdrawal} \cdot P$ — $W_{withdrawal} = 43.3$ lbf

4. **Controlling fastener value**

   $W_{control} = \min(W_{withdrawal}, W_{pullthrough}) \cdot 1.6$ — Multiply controlling fastener value by load duration factor for wind load (1.6) per Table 2.3.2 of the *2005 NDS*

   $W_{control} = 59.8$ lbf

5. **Convert single fastener value to uniform fastener capacity**

   $Stud_{spacing} = 24$ in. — A single field nail has the largest tributary area and will be used to determine the uniform fastener capacity.

   $Fastener_{spacing} = 12$ in.

   $$Tributary_{fastener} = \frac{Stud_{spacing} \cdot Fastener_{spacing}}{144}$$ $Tributary_{fastener} = 2\ ft.^2$

   $$Fastener_{capacity} = \frac{W_{control}}{Tributary_{fastener}}$$ $Fastener_{capacity} = 29.9$ psf

6. **Controlling negative (suction) pressure capacity**

   $Controlling_{capacity} = \min(Fastener_{capacity}, Panel_{capacity})$ — $Controlling_{capacity} = 29.3$ psf

7. **Compare the capacity to the required negative wind pressure per Table 1 and by inspection the calculated panel/fastener capacity exceeds the requirement for:**

   100 mph Exposure B
   90 mph Exposure C
   85 mph Exposure D

Figure 10 — Sample calculation procedure to derive Table 2.

Some people mistakenly think that wall bracing resists wind pressures, but bracing has a limited purpose (to resist wall racking) and is typically required only at corners, every 25 ft. or some percentage of the wall. While understanding bracing or shear wall requirements is not easy, there is a wide variety of straightforward information on the topic of resisting wall racking. Wall cladding requirements are often overlooked, and after observation of many wind events appear to be more of a real problem than wall racking (**Figs. 1 through 7**).

This paper provides tabulated information (**Table 2**)on using wood structural panels as a wall covering to resist the *2006 IRC* and *ASCE 7-05* Section 6.4 component and cladding wind pressures which wall coverings are required to meet. Detailed background on how the table was derived is also provided. Information on how other types of wall sheathing or siding products meet the required wind pressures is beyond the scope of this paper and readers are encouraged to contact the product manufacturer for details. ■

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