Braced Wall Panel Testing Project in SBCRI

Yields Important Market Development Data for Component Manufacturers

by Kirk H. Grundahl, P.E.

Sometimes subjects we don't have much knowledge of seem far more complex than they really are. When this is the case we can be baffled by what was described as being "foggy bottomed" by Professor Lee Crandell in our engineering economics class 32 years ago. Structural engineering principles are not very complex:

- If one knows exactly how load travels, providing resistance to that load is easy.
- Stiffness attracts load; the stiffer the element, the more load it will accumulate.

These concepts are best shown in Figure 1 and the following photos of wall bracing tests in SBCRI.

Figure 1 compares SBCRI data (pink line) and AWC WoodWorks data (blue line) on load paths in braced shear walls. The load cells are shown in green at the bottom of the wall line. The lines in the graph below represent the reactions of the SBCRI test data and the RISA (FEA) engineering analysis output using the same applied load; the pink line shows the SBCRI test data; the blue line is the American Wood Council (AWC) WoodWorks RISA Finite Element Shear Wall engineering program's analysis of this wall.

Photo 1 (below left). A 4'x8' sheet of stiffness was added to this braced wall line and is shown by the major humps in the lines.

Photo 2 (below right). The end view of the 4'x8' sheet of stiffness and its impact on the wall top plate and truss bottom chord.

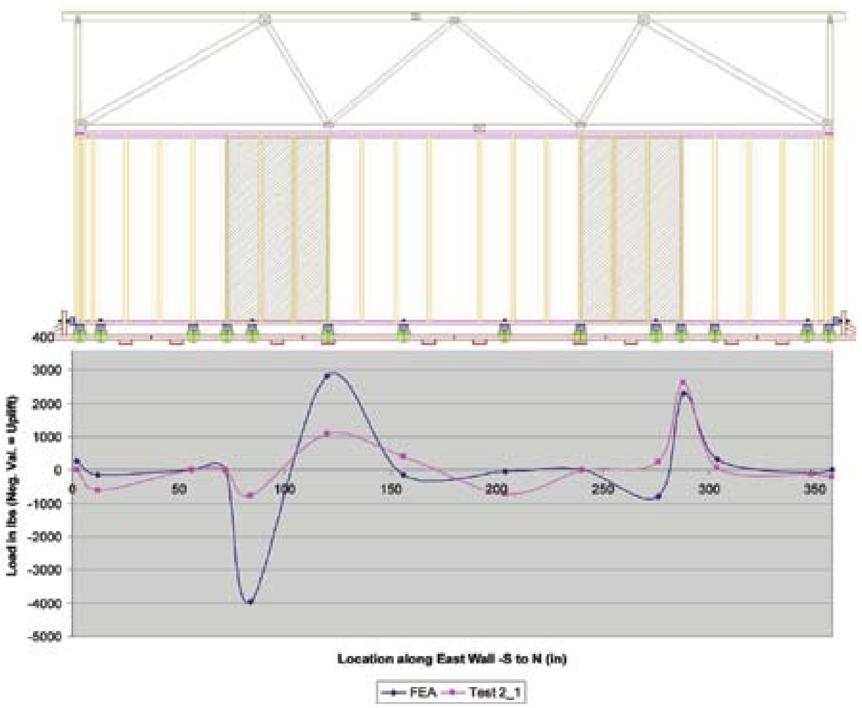

Figure 1 (see caption above). Blue line is WoodWorks FEA. Pink line SBCRI test data.

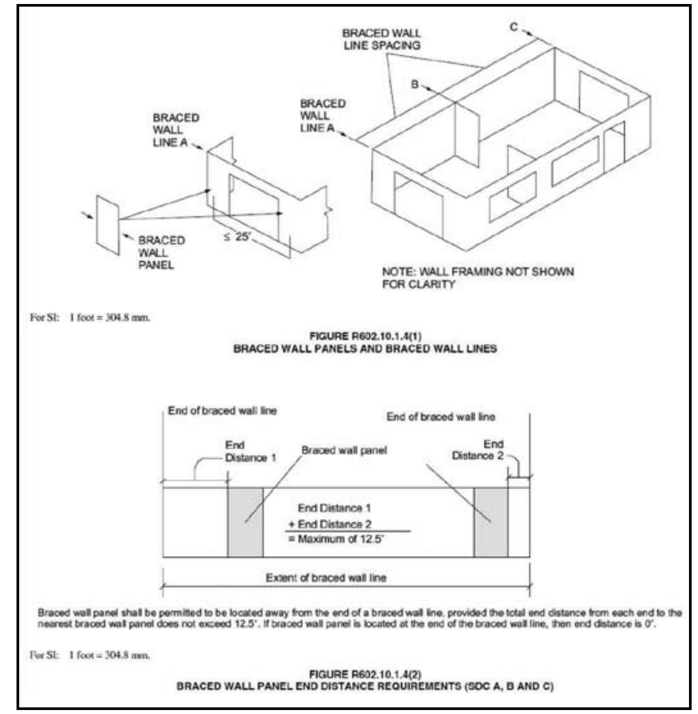

Figure 2. Maximum Braced Wall Panel End Distance Requirements per IRC Figure 602.10.1.4(2)

With this understanding in mind, SBCRI (through funding by Qualtim*) conducted wall bracing tests in 2009 and 2010. Given our strong desire to understand load and resistance accurately, SBCRI constructed a standard comparative equivalency test structure—a 12'x30' single-story building, in this case built in accordance with prescriptive requirements of the IRC. Figure 2 is from the IRC and depicts how a typical braced wall panel can be applied and still comply with the IRC and as built in our test structure.

Photos 3-10 illustrate the dimensions and set-up information for the equivalency structure. Continued on page 16

Photo 3. For SBCRI's 3/8" wood structural panel (WSP) test, the braced wall panel consisted of two 4x8 sheets (8' of bracing) and the braced wall line was 30' long.

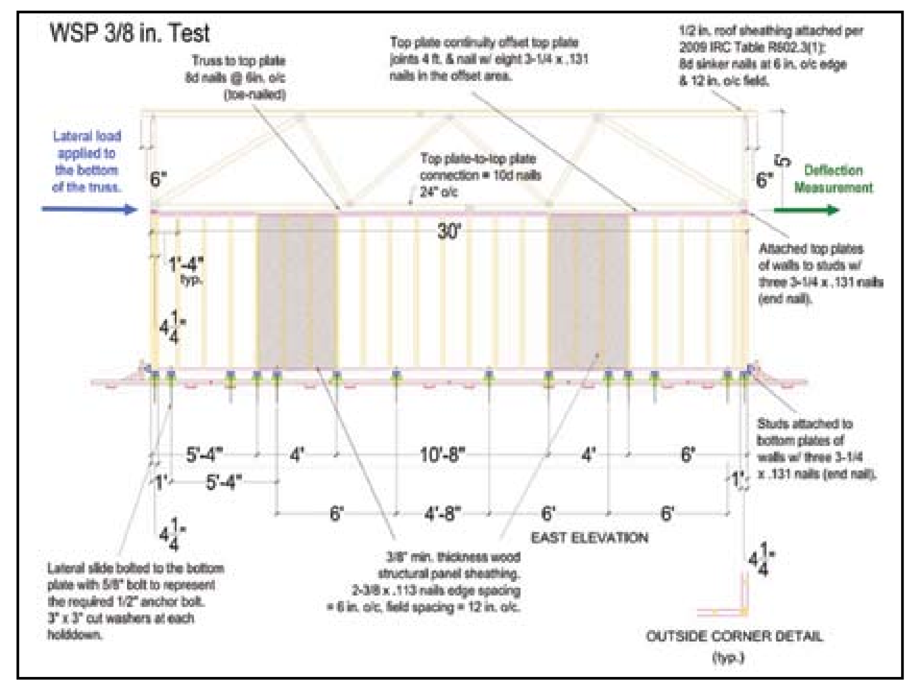

Figure 3: Side construction detail of SBCRI *IRC* conforming 12'x30' test structure, showing locations of applied lateral load, deflection measurements and how the entire structure sits on load cells to accurately measure load path

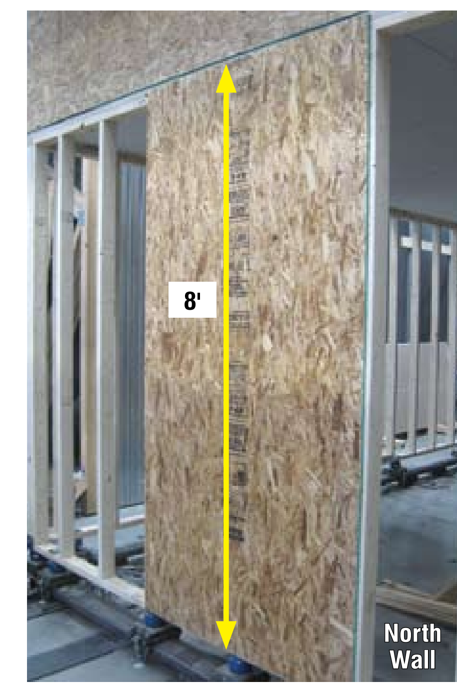

Photo 4: The wall height was 8'.

Editor's Note: As of this writing, we are undertaking IRC/SDPWS (AWC) equivalency testing and will report on our findings as soon as it is completed. We intend for this data to fill in some of the knowledge gaps in Tables 1-4 on pages 18-19. Please visit www.sbcri.info/testresults.php for updates as they are created. Watch SBC Industry News Top Headlines for future updates as well.

*For a more detailed understanding of the relationship between Qualtim and SBCRI, please contact Suzi Grundahl at 608-310-6710 or sgrundahl@qualtim.com.

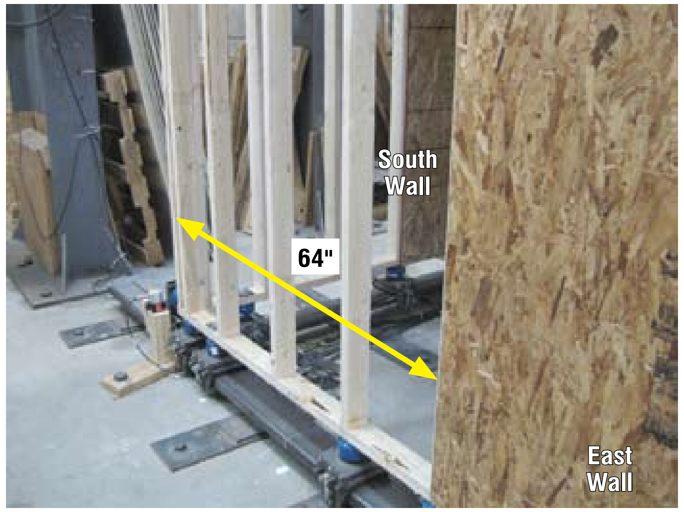

Photo 5. Due to the 16" typical wall panel stud spacing available to SBCRI at the time of this test, the first 3/8" OSB braced wall panel was installed 64" from the south end of the wall. The OSB panel on the north end of this braced wall line was set 72" from the end of the wall.

Photo 6. In the first baseline IRC test, no gypsum was applied on the inside of the 30' wall. This was our approach to replicate the IRC defined 500 plf and AF&PA's SDPWS 515 plf braced wall panel design.

Photo 7. As defined by the IRC, there was no OSB corner return deployed, and the end walls had a single sheet of OSB in the center of the 12' wide wall on both the exterior and interior faces. This was intended to provide end wall bracing support only and did not affect the braced wall line performance.

Braced Wall Panel Testing Project in SBCRI...

Continued from page 15

Test Results

When SBCRI staff analyzed the our test results, they were compared to similar tests conducted by other organizations including AWC, NAHB Research Center, Forest Products Laboratory, APA–The Engineered Wood Association and others.

Photo 8. End wall WSP centered on 12' wall to provide end wall stability only.

Photo 9. Anchor bolts were applied per the IRC. Overturning restraint was provided by sole plate anchor bolts, and by the roof truss assembly built so that the real dead load would be applied to the wall assembly as a real 12x30 building would apply it.

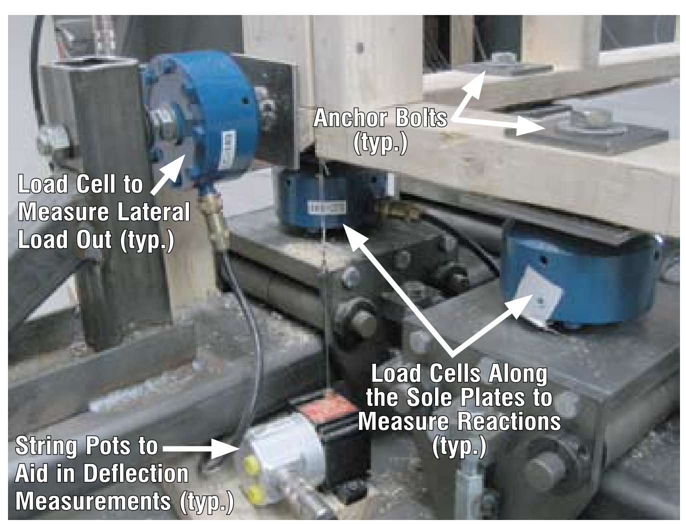

Photo 10. Close-up of Anchor Bolts, String Pots and Load Cells

Figure 1 represents a side-by-side comparison of the SBCRI testing and the RISA-3D 9.0 software program, which accommodates three approaches to shear wall design in wood buildings, which engineers use today to design braced wall lines. This program has been created in concert with the testing and analysis that AWC has available to it and which is incorporated into its Special Design Provisions for Wind and Seismic (SDPWS) design specification. Clearly there is a marked difference between the engineering analysis using the current state-of-the-art engineering judgments and the actual test data. This is the value of SBCRI testing and where opportunity exists for the building components industry through the information that we gain. The axiom that will easily apply is that we'll make much better engineering judgments through more precise knowledge.

AWC prepared a presentation in 2008 called DES130: Lateral Load Resisting Systems for Wood Structures. This is a complimentary eCourse on the AWC website that can be viewed or downloaded from their eCourses page: www.awc.org/helpoutreach/ecourses/index.html. In it, AWC discusses the IRC's prescriptive wall requirements and bracing.

Pages 69-70 of the presentation state that relative shear strength of bracing models is unknown: "We're not sure exactly what resistance to lateral loads are being provided by prescriptive bracing." They've based their modeling approach on the best data that they have available to them and engineering judgment (see Figure 4). Given the uncertainty that exists, the judgments have to be conservative. What is different about SBCRI testing is that we now DO know the resistance that a braced wall panel in a braced wall line provides to an applied load in a real IRC compliant 12x30 building. SBCRI data show us the performance of the wall in a visual manner and the path of the load to the foundation in a very precise manner. This testing work has provided SBCRI significant depth of knowledge of braced wall panel performance.

Wall Bracing Materials & Methods

Bracing Method	Estimated Allowable Shear
1. Let-in diagonal 1x4	0-100 plf?
2. 5/8-in. diagonal boards	300 plf?
3. 3/8-in. WSP	220 plf?
4. 1/2-in. fiberboard	180 plf?
5. 1/2-in. gypsum board	100 plf?
6. 1/2-in. particleboard	140 plf?
7. 7/8-in. PC stucco	180 plf?
8. 7/16-in. hardboard	Unknown?

"In a formal shearwall, design, we can quantify the shear resistance in bracing material; in fact, the code provides those numbers for everything but let-in bracing. But because the overall resistance to racking in conventional construction isn't completely understood, we don't know exactly what shear resistance is being provided by the bracing material itself. Here are some estimates of the shear strength of the 8 allowed bracing materials applied according to the IRC. The widely varying numbers explain why different materials must be provided in different amounts."

Figure 4 (from 2008 AWC presentation, DES130: Lateral Load Resisting Systems for Wood Structures).

What follows on pages 18 and 19 is a summary of the SBCRI testing data that we have and that allows us to make direct comparisons to SDPWS/IRC design values and existing public domain test data.

The data presented in these tables clearly illustrate Dr. A. R. Dykes' engineering philosophy in his 1946 Chairman's Address to the Scottish Branch of the Institution of Structural Engineers (IStructE).

> Structural engineering is the art of modeling materials we do not wholly understand into shapes we cannot precisely analyze so as to withstand forces we cannot properly assess in such a way that the public at large has no reason to suspect the extent of our ignorance.

The USDA Forest Products Laboratory (FPL) further emphasizes in its 1983 report about ASTM E72 and E564 testing the fact that certain wall test approaches are inaccurate:

> ABSTRACT: Standard methods of testing the racking capacity of light-frame walls are inefficient and may give erroneous estimates of shear wall performance. This study is concerned with improving the data base for racking resistance of light frame walls with plywood and gypsum sheathings……

Further, FPL shear wall testing provided additional insight into these concepts:

> **Test Procedures**
>
> The information and design tools available for the evaluation of wall racking performance

Continued on page 18

Key: White = previously tested • Gray = Values used in IRC or SDPWS • Yellow = E72-E564-E2126 (Other test facility data)

TABLE 1

Report #	Test Method	2:1 4' Wide Panels, Studs 16" o/c, No Gyp, No HD	Fastener	Fastener spacing	Stud spacing	Species	Test PLF	Test Ultimate Load SPF Basis	Test Adjusted to SPF PLF
IRC	ICC Ad Hoc Wall Bracing Committee	3/8" OSB, No Gyp, No HD	0.113 x 2" (6d)	6:12	16	SPF	400[2]	3200[1]	400
SBCRI-09-0104.1	E564	WSP 3/8 Test w/o Gyp 6 ft from corner	0.113 x 2-3/8"	6:12	16	SPF	367	2,936	367
SBCRI-09-0104.2 (3 tests)	E564	WSP 7/16 Test w/o Gyp 6 ft from corner	0.131 x 2-1/2"	6:12	16	SPF	415	3,317	415
SBCRI-09-0104.9	E564	WSP 7/16 Test w/o Gyp @ corner	0.131 x 2-1/2"	6:12	16	SPF	426	3,404	426
IRC	ICC Ad Hoc Wall Bracing Committee	7/16" OSB, No Gyp, No HD	0.113 x 2" (6d)	6:12	16	SPF	400[2]	3200[1]	400
HUD/NAHB 2003	E564	WSP 7/16" w/o Gyp, No HD	0.113 (8d) WSP Pneumatic	6:12	16	SPF	160	640	160
WMEL 2002-03	E2126-SPD Hysteresis (seismic)	WSP 7/16" w/o Gyp, No HD	0.131x2.5" (8d) WSP	6:12	16	SPF	175	700	175
HUD/NAHB 2003	E564	WSP 7/16" w/o Gyp, No HD	0.131x2.5" (8d) WSP	6:12	16	SPF	190	750	190

TABLE 2

Report #	Test Method	2:1 4' Wide Panels, Studs 16" o/c, No Gyp, No HD	Fastener	Fastener spacing	Stud spacing	Species	Test/Code Based PLF	Test Ultimate Load SPF Basis	Test Adjusted to SPF PLF
IRC	ICC Ad Hoc Wall Bracing Committee	3/8" OSB, No Gyp, with HD	0.113 x 2" (6d)	6:12	16	SPF	500	4000[1]	500
SDPWS	Wind	WSP 3/8" w/o Gyp, with HD	0.113 x 2" (6d)	6:12	16	DF	560	4120	515
SDPWS	(seismic)	WSP 3/8" w/o Gyp, with HD	0.113 x 2" (6d)	6:12	16	DF	400	2944	368
PEI 2005-911	E72-98	WSP 3/8" w/o Gyp, with HD	0.112 x 2"(6d)	6:12	16	SPF	448	3585	448
PEI 2005-911	E72-98	WSP 3/8" w/o Gyp, with HD	0.112 x 2"(6d)	6:12	16	SPF	490	3922	490
PEI 2005-911	E72-98	WSP 3/8" w/o Gyp, with HD	0.112 x 2"(6d)	6:12	16	SPF	520	4157	520
APA 154	E72	WSP 3/8" w/o Gyp, with HD	16 ga. x 1-3/8" staple	3:6	16	DF	954	7632	878
APA 154	E72	WSP 3/8" w/o Gyp, with HD	16 ga. x 1-3/8" staple	3:6	16	DF	1066	8528	981
APA 154	E72	WSP 3/8" w/o Gyp, with HD	16 ga. x 1-1/2" staple	3:6	16	DF	854	6832	786
APA 154	E72	WSP 3/8" w/o Gyp, with HD	16 ga. x 2" staple	3:6	16	DF	903	7224	831
APA 154	E72	WSP 3/8" w/o Gyp, with HD	15 ga. x 1-1/2" staple	3:6	16	DF	1128	9024	1038
HUD/NAHB 2003	E564	WSP 7/16" w/o Gyp, with HD	0.113 (8d) WSP Pneumatic	6:12	16	SPF	330	1570	330
WMEL 2002-03	E564	WSP 7/16" w/o Gyp, with HD	0.131 x 2.5" (8d)	6:12	16	SPF	628	2510	628
WMEL 2002-03	E2126-SPD Hysteresis	WSP 7/16" w/o Gyp, with HD	0.131x2.5" (8d) WSP	6:12	16	SPF	553	2210	553
IRC	ICC Ad Hoc Wall Bracing Committee	WSP 7/16", No Gyp, with HD	0.113 x 2" (6d)	6:12	16	SPF	500	4000[1]	500
SDPWS	Wind	WSP 7/16", w/o Gyp, with HD	0.131 x 2-1/2" (8d)	6:12	16	DF	730	5368	671
SDPWS	(seismic)	WSP 7/16", w/o Gyp, with HD	0.131 x 2-1/2" (8d)	6:12	16	DF	520	3824	478
HUD/NAHB 2003	E564	WSP 7/16" w/o Gyp, with HD	0.131x2.5" (8d) WSP	6:12	16	SPF	560	2240	560
SBCRI-09-0104.17	E564	WSP 7/16 Test w/o Gyp 6 ft from corner w/ HD	0.131 x 2-1/2" (8d)	6:12	16	SPF	626	5010	626

Braced Wall Panel Testing Project in SBCRI...

Continued from page 17

are of limited value. The majority of available wall racking test data were generated using a standard test procedure published by ASTM (2). This test was established to evaluate the relative performance of sheathing materials. However, additional information is needed regarding effects of other construction variables as well as design limitations.

Construction variables include framing, windbracing, door and window openings, wall length, and wall interaction with floor and ceiling diaphragms....

The test procedure used to evaluate these factors is an important consideration. Currently two ASTM standards describe test procedures for the racking resistance of lightframe walls; ASTM E 72-77 (2) and ASTM E 564-76 (1). Standard E 564 is similar to E 72 except that it was intended for testing walls rather than evaluating panel performance. For this reason, it permits variation of wall frame configuration and boundary conditions to simulate construction practice....

Studies sponsored by gypsum manufacturers and conducted by private testing laboratories have covered a range of 8- by 8-foot wall fastening details. These tests were conducted in accordance with ASTM Standard E 72 (2). Underwriters Laboratory tests of walls with 1/2-inch gypsum, glued both sides of 2 by 3 framing members, spaced 16 inches O.C., indicated a shear capacity of 880 lb/ft (File MH 9733). Similar tests conducted by Pittsburgh Testing Laboratory using 2 by 4 framing showed average ultimate loads of 730 lb/ft (75). Tests of 1/2-inch gypsum, nailed to one side of a 2 by 4 frame, conducted by IIT Research Institute (IITRI) gave an average of 660 lb/ft (9). Assuming that nailing gypsum to both sides of the frame would double the ultimate load, the IITRI results suggest nailed shear wall capacities exceeding 1,300 lb/ft. This exceeds test values obtained for walls with glued gypsum board. Comparison of such test results suggests a weakness in the E 72 test procedure, which makes the comparison of data collected from various laboratories confusing.

Key: White = previously tested • Gray = Values used in IRC or SDPWS • Yellow = E72-E564-E2126 (Other test facility data)

TABLE 3

Report #	Test Method	2:1 4' Wide Panels, Studs 16" o/c, Yes Gyp, No HD	Fastener	Fastener spacing	Stud spacing	Species	Test PLF	Test Ultimate Load SPF Basis	Test Adjusted to SPF PLF
SBCRI-09-0104.6	E564	WSP 7/16 Test w/ Gyp 6' from corner	0.131 x 2-1/2" (8d)	6:12	16	SPF	939	7508	939
SBCRI-09-0104.10	E564	WSP 7/16 Test w/ Gyp @ corner	0.131 x 2-1/2" (8d)	6:12	16	SPF	807	6458	807
IRC	ICC Ad Hoc Wall Bracing Committee	WSP 3/8", Yes Gyp, No HD	WSP-0.113 x 2" (6d) GYP-5d cooler nail, 0.086 diameter, 1-5/8" long, 15/64 head	6:12-WSP 8:16-GYP	16	SPF	560[3]	4480[1]	560
WMEL-2002-03	E2126-SPD Hysteresis (seismic)	WSP 7/16" w/Gyp, No HD	0.131x2.5" (8d) WSP, 0.120x1.5x 3/8 head roofing nail, gyp	6:12 WSP, 7:16 GYP	16	SPF	193	770	193

TABLE 4

Report #	Test Method	2:1 4' Wide Panels, Studs 16" o/c, Yes Gyp, Yes HD	Fastener	Fastener spacing	Stud spacing	Species	Test PLF	Test Ultimate Load SPF Basis	Test Adjusted to SPF
IRC	ICC Ad Hoc Wall Bracing Committee	WSP 3/8", Yes Gyp, Yes HD	WSP-0.113 x 2" (6d), GYP-5d cooler nail, 0.086 diameter, 1-5/8" long, 15/64 head	6:12-WSP 8:16-GYP	16	SPF	700	5600	700
SDPWS	Wind	WSP 3/8", Yes Gyp, Yes HD	WSP-0.113 x 2" (6d), GYP-5d cooler nail, 0.086 diameter, 1-5/8" long, 15/64 head	6:12-WSP 7:7-GYP	16	DF	760	5720	715
SDPWS	(seismic)	WSP 3/8", Yes Gyp, Yes HD	WSP-0.113 x 2" (6d), GYP-5d cooler nail, 0.086 diameter, 1-5/8" long, 15/64 head	6:12-WSP 7:7-GYP	16	DF	600	4544	568
SDPWS	Wind	WSP 7/16" ,Yes Gyp, Yes HD	WSP-0.131 x 2-1/2" (8d), GYP-5d cooler nail, 0.086 diameter, 1-5/8" long, 15/64 head	6:12-WSP 7:7-GYP	16	DF	930	6968	871
SDPWS	(seismic)	WSP 7/16" ,Yes Gyp, Yes HD	WSP-0.131 x 2-1/2" (8d), GYP-5d cooler nail, 0.086 diameter, 1-5/8" long, 15/64 head	6:12-WSP 7:7-GYP	16	DF	720	5424	678
WMEL-2002-03	E564 (seismic)	WSP 7/16" w/Gyp, with HD	0.131x2.5" (8d) WSP, 0.120x1.5x 3/8 head roofing nail, gyp	6:12 WSP, 7:16 GYP	16	SPF	760	3040	760
WMEL-2002-03	E2126-SPD Hysteresis (seismic)	WSP 7/16" w/Gyp, with HD	0.131x2.5" (8d) WSP, 0.120x1.5x 3/8 head roofing nail, gyp	6:12 WSP, 7:16 GYP	16	SPF	693	2770	693

[1] Assumed based on using 8' long specimens [2] 500 plf adjusted for partial restraint [3] 700 plf adjusted for partial restraint

Conclusions regarding the effects of variations in wall configuration should, therefore, not be drawn on the basis of results reported from different testing laboratories until a test procedure is developed which will give consistent results independent of the test location.….

Values derived from this test are not representative of the performance of walls used in actual building construction. This standard does not provide for testing effects of wall length or building component interactions. Tests are confined to one wall frame configuration.*

Tables 1–4 confirm what FPL reports here. Hence SBCRI is committed to testing actual code complying full scale building construction to provide fundamental engineering data because these limitations in regard to testing and design value development constrain the use of structural building components. As such, we cannot as effectively deploy accepted engineering practice.

The value of the SBCRI wall bracing tests is the potential of making wall panels as cost effective and efficient an engineered solution as possible for braced wall line applications. What trusses are to joist and rafter replacement of the 1950s this will be for wall panels. We're embarking on reenacting the 1960s, this time for wall panels using SBCRI knowledge to gain an accurate and safe performance. **SBC**

* *Contribution of Gypsum Wallboard to Racking Resistance of Light-Frame Walls*, Ronald W. Wolfe, United States Department of Agriculture Forest Service Forest Products Laboratory Research Paper, FPL 439, December 1983, Pages 17 & 19.

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