A REVIEW OF LARGE SCALE WOOD STRUCTURAL PANEL BRACING TESTS

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1. OVERVIEW AND PURPOSE

This report summarizes available large scale test data for wood structural panel conventional construction wall bracing. Several 4-ft long wall tests are included, but the majority of test data is taken from tests where wall lengths are at least 12-ft. The purpose of assembling this information is to help evaluate and determine the strength of wood structural panel wall bracing.

2. WALL DESCRIPTIONS AND TEST DATA

The data in this report come from several studies of conventional wood structural panel wall bracing, as summarized in Tables 1a-1c, and Table 2.

There are two types of wall bracing types tested in these studies, continuous and isolated. Continuous bracing is defined in this paper, and in 2006 IRC Section R602.10.5, as bracing where the wood structural panel sheathing continues from one end of the wall to the other, and occurs above and/or below openings in the wall. Isolated bracing is defined in this paper as walls with full height openings and sheathing is not continuous from one end of the wall to the other. Some 3-dimensional tests had a mix where one or more walls was continuous while one or more other walls had isolated bracing. Table 1a provides a sketch of the wall configurations tested.

None of the walls tested in the study used hold down devices except some tests done on a single 4-ft wide segment, where that segment was the “wall”. All wall heights tested were approximately 8-ft.

Testing by Dolan and Heine (1997a,b) examined walls 40-ft long, with gypsum finish, tested both cyclically and monotonically, and tested both continuous and isolated bracing.

Other testing by Dolan and Heine (1997c) examined walls 12-ft long, with gypsum finish, tested cyclically, with continuous bracing, and with 2-ft or 4-ft return corners on both ends.

NAHB (2001) did monotonic testing of continuous wood structural panel braced walls 20-ft long with 2-ft and 4-ft corners, and tested with a bolted bottom plate and a nailed bottom plate. The width of braced wall segments in this study ranged from 2-ft to 4-ft.

APA (2006) cyclically tested continuous wood structural panel braced walls 12-ft long, with and without gypsum finish and tested 1.33-ft wide and 2-ft wide bracing segments.

Simpson Strong Tie (2007a-t) is working on an extensive study of isolated 4-ft bracing and 1.33-ft wide portal frames in both 3D structures and 2D substructures. The 2D testing includes both single 4-ft wide elements, and 20-ft long walls with and without a 2x10 rim joist on top of the wall. Each 2D substructure test is repeated in a 20-ft x 20-ft 3D structure where loads were applied at 0 degrees, 90 degrees, +45 degrees and –45 degree orientations. Preliminary data, available from the Simpson website, is used in this report for comparison purposes.

Table 1a. Summary and description of wall tests.

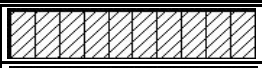
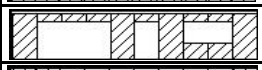
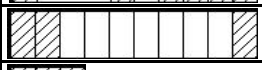
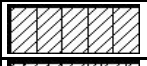
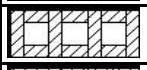
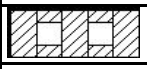
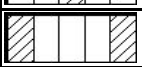
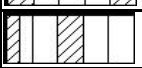
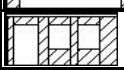
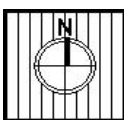
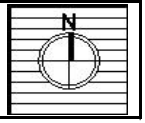
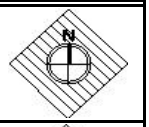
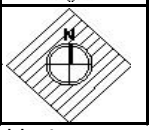
Reference	Test # in Reference	Wall Configuration	Description	Corner Returns	Gypsum
Dolan and Heine, 1997a,b	A		40-ft wall continuous with no openings	None	1/2" GWB. 13g x 1.5" nails at 7"/10" oc edges/field
	D		40-ft wall continuous with openings	None	
	E		40-ft wall isolated bracing segments	None	
Dolan and Heine, 1997c	1,2		12-ft wall continuous with no openings	2-ft and 4-ft	
NAHB, 2001a	2,3,7,8		20-ft wall continuous with no openings	2-ft and 4-ft	None
	4,5,9,10		20-ft wall continuous with openings	2-ft and 4-ft	None
	6,11		20-ft wall continuous with openings	2-ft and 4-ft	None
APA, 2006	7,3		4-ft wall isolated bracing segment	None	None
Simpson, 2007a	718,719,704,705				
APA, 2006	1,2		12-ft wall continuous with openings	None	Tests 2 and 4 had 1/2" GWB. #6 screws 1.625" long at 16" oc. Other tests had none.
	4		12-ft wall portal frame	None	
	9		12-ft wall portal frame	None	
Simpson, 2007b	712,717		20-ft wall "IRC portal frame"	None	None
Simpson, 2007c	702,709,723,724		20-ft wall isolated bracing segment, "IRC Center"	None	None
Simpson, 2007d	713,714,721,722		20-ft wall isolated bracing segments, "Cabo Corner"	None	None
Simpson, 2007e	710,711,726,727		20-ft wall isolated bracing segment, 'IRC Side"	None	None
Paevere, P, et al. 2003	1		20-ft wall continuous with opening	Yes, tested in 3D House	1/2" GWB. #6 screws at 12" oc studs, 16" oc plates
	2		16-ft wall continuous with openings		
	4		36-ft wall continuous with openings		
Fischer et al., 2000	Phase 8		16-ft wall continuous with opening		None

Table 1b. Summary and description of 3-dimensional wall tests by Simpson Strong Tie.

Reference	Test #	Wall Description[1]				Plan View
		West	East	North	South	
Simpson, 2007f	2006716	Cabo Corner	Cabo Corner	Cabo Corner	Cabo Corner	
Simpson, 2007g	2006731	Portal Frame	Cabo Corner	Cabo Corner	Cabo Corner	
Simpson, 2007h	2006695	Portal Frame	IRC Center	IRC Side	IRC Side	
Simpson, 2007i	2007015	Portal Frame	Portal Frame	IRC Side	IRC Side	
Simpson, 2007j	2006703	IRC Center	IRC Center	IRC Center	IRC Center	
Simpson, 2007k	2006700	IRC Center	IRC Center	IRC Center	IRC Center	
Simpson, 2007l	2006715	Cabo Corner	Cabo Corner	Cabo Corner	Cabo Corner	
Simpson, 2007m	2006720	Portal Frame	IRC Center	IRC Side	IRC Side	
Simpson, 2007n	2006725	Portal Frame	Cabo Corner	Cabo Corner	Cabo Corner	

1. Wall descriptions "Cabo Corner", "IRC Center", "IRC Side" and "IRC Portal Frame" can be seen in Table 1a.

Table 1c. Summary and description of 3-dimensional wall tests by Simpson Strong Tie.

Reference	Test #	Wall Description[1] NW	NE	SW	SE	Plan View
Simpson, 2007o	2006744	Cabo Corner	Cabo Corner	Cabo Corner	Cabo Corner	
Simpson, 2007p	2006752	IRC Center	IRC Side	IRC Side	Portal Frame	
Simpson, 2007q	2007008	Cabo Corner	Cabo Corner	Cabo Corner	Portal Frame	
Simpson, 2007r	2007001	IRC Center	IRC Center	IRC Center	IRC Center	
Simpson, 2007s	2006732	Cabo Corner	Cabo Corner	Cabo Corner	Cabo Corner	
Simpson, 2007t	2006753	IRC Center	IRC Side	IRC Side	Portal Frame	

1. Wall descriptions "Cabo Corner", "IRC Center", "IRC Side" and "IRC Portal Frame" can be seen in Table 1a.

Paevere et al (2003) and NAHB (2001b) report on full scale 3D one story house tests conducted at CSIRO in Australia, built following US conventional construction practices. The house was “L” shaped with an approximate overall dimension of 30-ft x 37-ft. Three walls parallel to the load direction were built with continuous wood structural panel bracing and had a gypsum finish. Two of the walls had full height wall bracing segments that were less than 2-ft wide, and the other wall had approximately 4-ft wide bracing segments.

Fischer et al (2000) report on a full scale 3D two story house tests conducted at the UCSD (University of California at San Diego) shake table. The house was rectangular in shape with and overall dimension of 16-ft x 20-ft. One of the tests, phase 8, was built following conventional construction, however this test did not have finishes installed. The house was subjected to five increasing magnitude different shake tests, with the last shake being the largest with a peak ground acceleration (PGA) of 0.5g. The walls were not loaded to their ultimate capacity and so reported values from this test in Table 2 (row 52) are simply the maximum recorded for the maximum shake (PGA = 0.5g).

Table 2 provides a summary of all data examined in this report. The load at 0.5% drift was a value reported in the Simpson and APA reports. It is presented in this report as a measure of stiffness, and as an addtional data point of interest. For the load at 0.5% drift from other than APA or Simpson reports, the values in Table 2 are estimated based on linear interpolation of available reported data.

3. SORTED TEST DATA AND BRACING SPECTRUM

Tables 3-7 sort the data by wood structural panel bracing type (isolated, mixed or continuous) and by whether the wall had gypsum finish or not. Table 3 summarizes the data for isolated wood structural panel bracing without gypsum. Table 4 summarizes the data for mixed (isolated and continuous) wood structural panel bracing without gypsum. Table 5 summarizes the data for continuous wood structural panel bracing without gypsum. Table 6 summarizes the data for isolated wood structural panel bracing with gypsum. Table 7 summarizes the data for continuous wood structural panel bracing with gypsum.

Figure 1 shows graphically the peak load range, in plf, of test data for the different types (isolated, mixed or continuous) with and without gypsum. Also included in Figure 1 are the 4-ft long wall panel tests with and and without hold downs. Since Figure 1 provides the peak load for such a large range of wood structural panel bracing, it’s refered to as the bracing spectrum.

Table 2. Summary of test data.

Row #	Description	Load at 0.5% drift (plf)	Peak Load (plf)	Total Length of Wall (ft)	Total Length of Bracing (ft)	HD[1] --	Gyp --	2D or 3D --	Bracing[2] --	Test Protocol --	W[3] (ft)	Test # in Ref. --	Reference
1	40-ft wall continuous with no openings	*421*	627	40	40.0	No	Yes	2D	Cont.	mono.	4	A	Dolan and Heine, 1997a
2	40-ft wall continuous with openings	*311*	612	40	16.0	No	Yes	2D	Cont.	mono.	4	D	Dolan and Heine, 1997a
3	40-ft wall with isolated bracing	*237*	366	40	12.0	No	Yes	2D	Isolated	mono.	4	E	Dolan and Heine, 1997a
4	40-ft wall continuous with no openings	*474*	668	40	40.0	No	Yes	2D	Cont.	SPD	4	A	Dolan and Heine, 1997b
5	40-ft wall continuous with openings	*373*	631	40	16.0	No	Yes	2D	Cont.	SPD	4	D	Dolan and Heine, 1997b
6	40-ft wall with isolated bracing	*273*	400	40	12.0	No	Yes	2D	Isolated	SPD	4	E	Dolan and Heine, 1997b
7	12-ft wall continuous with no openings w/2' corners	*535*	634	12	12.0	No	Yes	3D	Cont.	SPD	4	1&2	Dolan and Heine, 1997c
8	12-ft wall continuous with no openings w/4' corners	*592*	708	12	12.0	No	Yes	3D	Cont.	SPD	4	1&2	Dolan and Heine, 1997c
9	20-ft wall continuous with no openings w/ 2' corner	*396*	418	20	20.0	No	No	3D	Cont.	mono.	4	2	NAHB, 2001a
10	20-ft wall continuous with no openings w/ 4' corner	*432*	461	20	20.0	No	No	3D	Cont.	mono.	4	3	NAHB, 2001a
11	20-ft wall continuous with openings w/ 2' corner	*593*	900	20	8.0	No	No	3D	Cont.	mono.	2	4	NAHB, 2001a
12	20-ft wall continuous with openings w/ 4' corner	*559*	856	20	8.0	No	No	3D	Cont.	mono.	2	5	NAHB, 2001a
13	20-ft wall continuous with openings w/ 4' corner	*423*	658	20	12.0	No	No	3D	Cont.	mono.	4	6	NAHB, 2001a
14	20-ft wall continuous with no openings w/ 2' corner	*390*	420	20	20.0	No	No	3D	Cont.	mono.	4	7	NAHB, 2001a
15	20-ft wall continuous with no openings w/ 4' corner	*455*	490	20	20.0	No	No	3D	Cont.	mono.	4	8	NAHB, 2001a
16	20-ft wall continuous with openings w/ 2' corner	*400*	824	20	8.0	No	No	3D	Cont.	mono.	2	9	NAHB, 2001a
17	20-ft wall continuous with openings w/ 4' corner	*475*	909	20	8.0	No	No	3D	Cont.	mono.	2	10	NAHB, 2001a
18	20-ft wall continuous with openings w/ 4' corner	*583*	650	20	12.0	No	No	3D	Cont.	mono.	4	11	NAHB, 2001a
19	4-ft wall isolated bracing segment	210	225	4	4.0	No	No	2D	Isolated	SPD	4	7	APA, 2006
20	4-ft wall isolated bracing segment	440	596	4	4.0	Yes	No	2D	Isolated	SPD	4	3	APA, 2006
21	12-ft wall continuous with openings	204	512	12	4.0	No	No	2D	Cont.	SPD	2	1	APA, 2006
22	12-ft wall continuous with openings	306	539	12	4.0	No	Yes	2D	Cont.	SPD	2	2	APA, 2006
23	12-ft wall portal frame	501	855	12	4.0	No	No	2D	Cont.	SPD	1.33	9	APA, 2006
24	12-ft wall portal frame	537	993	12	2.7	No	Yes	2D	Cont.	SPD	1.33	4	APA, 2006
25	4-ft wall isolated bracing segment	131	180	4	4.0	No	No	2D	Isolated	mono.	4	718&719	Simpson, 2007a
26	4-ft wall isolated bracing segment	337	597	4	4.0	Yes	No	2D	Isolated	mono.	4	704&705	Simpson, 2007a
27	20-ft wall portal frame	308	740	20	2.7	No	No	2D	Cont.	mono.	1.33	712&717	Simpson, 2007b
28	20-ft wall isolated bracing, "IRC Center"	115	294	20	4.0	No	No	2D	Isolated	mono.	4	702&709	Simpson, 2007c

Table continues…

Table 2. (continued) Summary of test data.

Row #	Description	Load at 0.5% drift (plf)	Peak Load (plf)	Total Length of Wall (ft)	Total Length of Bracing (ft)	HD[1] --	Gyp --	2D or 3D --	Bracing[2] --	Test Protocol --	W[3] (ft)	Test # in Ref. --	Reference
29	20-ft wall isolated bracing, "IRC Center" with 2x10 rim joist	172	467	20	4.0	No	No	2D	Isolated	mono.	4	723&724	Simpson, 2007c
30	20-ft wall isolated bracing segments, "Cabo"	136	204	20	8.0	No	No	2D	Isolated	mono.	4	713&714	Simpson, 2007d
31	20-ft wall isolated bracing, "Cabo" with 2x10 rim joist	158	238	20	8.0	No	No	2D	Isolated	mono.	4	721&722	Simpson, 2007d
32	20-ft isolated bracing segment "IRC Side"	147	401	20	4.0	No	No	2D	Isolated	mono.	4	710&711	Simpson, 2007e
33	20-ft isolated bracing "IRC Side" with 2x10 rim joist	307	582	20	4.0	No	No	2D	Isolated	mono.	4	726&727	Simpson, 2007e
34	3D - W: Cabo, E: Cabo, N: Cabo, S: Cabo (0)	*281*	469	20	16.0	No	No	3D	Isolated	mono.	4	2006716	Simpson, 2007f
35	3D - W: Portal Frame, E: Cabo, N: Cabo, S: Cabo (0)	*272*	539	20	10.7	No	No	3D	Mix	mono.	1.33	2006731	Simpson, 2007g
36	3D - W: Portal Frame, E: IRC Center, N: IRC Side, S: IRC Side (0)	*330*	736	20	6.7	No	No	3D	Mix	mono.	1.33	2006695	Simpson, 2007h
37	3D - W: Portal Frame, E: Portal Frame, N: IRC Side, S: IRC Side (0)	*395*	883	20	5.3	No	No	3D	Mix	mono.	1.33	2007015	Simpson, 2007i
38	3D - W: IRC Center, E: IRC Center, N: IRC Center, S: IRC Center (0)	*219*	513	20	8.0	No	No	3D	Isolated	mono.	4	2006703	Simpson, 2007j
39	3D - W: IRC Center, E: IRC Center, N: IRC Center, S: IRC Center (90)	*181*	394	20	8.0	No	No	3D	Isolated	mono.	4	2006700	Simpson, 2007k
40	3D - W: Cabo, E: Cabo, N: Cabo, S: Cabo (90)	*222*	363	20	16.0	No	No	3D	Isolated	mono.	4	2006715	Simpson, 2007l
41	3D - W: Portal Frame, E: IRC Center, N: IRC Side, S: IRC Side (90)	*300*	571	20	6.7	No	No	3D	Mix	mono.	1.33	2006720	Simpson, 2007m
42	3D - W: Portal Frame, E: Cabo, N: Cabo, S: Cabo (90)	*244*	492	20	10.7	No	No	3D	Mix	mono.	1.33	2006725	Simpson, 2007n
43	3D - NW: Cabo, NE: Cabo, SW: Cabo, SE: Cabo (+45)	*177*	256	20	32.0	No	No	3D	Isolated	mono.	4	2006744	Simpson, 2007o
44	3D - NW: IRC Center, NE: IRC Side, SW: IRC Side, SE: Portal Frame (+45)	*203*	429	20	14.7	No	No	3D	Mix	mono.	1.33	2006752	Simpson, 2007p
45	3D - NW: Cabo, NE: Cabo, SW: Cabo, SE: Portal Frame (+45)	*204*	355	20	26.7	No	No	3D	Mix	mono.	1.33	2007008	Simpson, 2007q
46	3D - NW: IRC Center, NE: IRC Center, SW: IRC Center, SE: IRC Center (+45)	*177*	420	20	16.0	No	No	3D	Isolated	mono.	4	2007001	Simpson, 2007r
47	3D - NW: Cabo, NE: Cabo, SW: Cabo, SE: Cabo (-45)	*168*	265	20	32.0	No	No	3D	Isolated	mono.	4	2006732	Simpson, 2007s
48	3D - NW: IRC Center, NE: IRC Side, SW: IRC Side, SE: Portal Frame (-45)	*236*	492	20	14.7	No	No	3D	Mix	mono.	1.33	2006753	Simpson, 2007t
49	20-ft wall continuous with opening (CSIRO, W1)	--	707	20.3	3.8	No	Yes	3D	Cont.	cyclic	1.9	1	Paevere, P, et al. 2003.
50	16-ft wall continuous with openings (CSIRO, W2)	--	1072	16.35	6.3	No	Yes	3D	Cont.	cyclic	1.5	2	Paevere, P, et al. 2003.
51	36-ft wall continuous with openings (CSIRO, W4)	--	711	36.4	15.8	No	Yes	3D	Cont.	cyclic	3.93	4	Paevere, P, et al. 2003.
52	16-ft wall continuous with opening (UCSD, PGA 0.5g)	*544*	*874*	16	13.0	No	No	3D	Cont.	Shake	6.5	Phase 8	Fischer et al., 2000.
53	4-ft "IRC Bracing design value"	--	630	--	--	--	--	--	--	--	--	--	Crandell, J, 2006.

1. HD = Hold down device was used
2. Bracing is classifed as either continuous, isolated, or mixed. Continuous means that sheathing is used above and/or below openings. Isolated means that wall has full height openings and sheathing is not continuous. Mixed means that tested wall has a mix of isolated and continuous bracing.
3. W = bracing segment width

Table 3. Summary of test results for isolated wood structural panel wall bracing without gypsum finish.

Row #	Description	Load at 0.5% drift (plf)	Peak Load (plf)	Total Length of Wall (ft)	Total Length of Bracing (ft)	Gyp --	Bracing --	Test Protocol --	Segment Width (ft)	Test # in Ref. --	Reference
25	4-ft wall isolated bracing segment	131	180	4	4	No	Isolated	mono.	4	718&719	Simpson, 2007a
30	20-ft wall isolated bracing segments, "Cabo"	136	204	20	8	No	Isolated	mono.	4	713&714	Simpson, 2007d
19	4-ft wall isolated bracing segment	210	225	4	4	No	Isolated	SPD	4	7	APA, 2006
31	20-ft wall isolated bracing, "Cabo" with 2x10 rim joist	158	238	20	8	No	Isolated	mono.	4	721&722	Simpson, 2007d
43	3D - NW: Cabo, NE: Cabo, SW: Cabo, SE: Cabo (+45)	*177*	256	20	32	No	Isolated	mono.	4	2006744	Simpson, 2007o
47	3D - NW: Cabo, NE: Cabo, SW: Cabo, SE: Cabo (-45)	*168*	265	20	32	No	Isolated	mono.	4	2006732	Simpson, 2007s
28	20-ft wall isolated bracing, "IRC Center"	115	294	20	4	No	Isolated	mono.	4	702&709	Simpson, 2007c
40	3D - W: Cabo, E: Cabo, N: Cabo, S: Cabo (90)	*222*	363	20	16	No	Isolated	mono.	4	2006715	Simpson, 2007l
39	3D - W: IRC Center, E: IRC Center, N: IRC Center, S: IRC Center (90)	*181*	394	20	8	No	Isolated	mono.	4	2006700	Simpson, 2007k
32	20-ft isolated bracing segment "IRC Side"	147	401	20	4	No	Isolated	mono.	4	710&711	Simpson, 2007e
46	3D - NW: IRC Center, NE: IRC Center, SW: IRC Center, SE: IRC Center (+45)	*177*	420	20	16	No	Isolated	mono.	4	2007001	Simpson, 2007r
29	20-ft wall isolated bracing, "IRC Center" with 2x10 rim joist	172	467	20	4	No	Isolated	mono.	4	723&724	Simpson, 2007c
34	3D - W: Cabo, E: Cabo, N: Cabo, S: Cabo (0)	*281*	469	20	16	No	Isolated	mono.	4	2006716	Simpson, 2007f
38	3D - W: IRC Center, E: IRC Center, N: IRC Center, S: IRC Center (0)	*219*	513	20	8	No	Isolated	mono.	4	2006703	Simpson, 2007j
33	20-ft isolated bracing "IRC Side" with 2x10 rim joist	307	582	20	4	No	Isolated	mono.	4	726&727	Simpson, 2007e
	Average =	**187**	**351**								
	Minimum =	**115**	**180**								
	Maximum =	**307**	**582**								

Table 4. Summary of test results for mixed (isolated and continuous) wood structural panel wall bracing without gypsum finish.

Row #	Description	Load at 0.5% drift (plf)	Peak Load (plf)	Total Length of Wall (ft)	Total Length of Bracing (ft)	Gyp --	Bracing --	Test Protocol --	Segment Width (ft)	Test # in Ref. --	Reference
45	3D - NW: Cabo, NE: Cabo, SW: Cabo, SE: Portal Frame (+45)	*204*	355	20	26.66	No	Mix	mono.	1.33	2007008	Simpson, 2007q
44	3D - NW: IRC Center, NE: IRC Side, SW: IRC Side, SE: Portal Frame (+45)	*203*	429	20	14.66	No	Mix	mono.	1.33	2006752	Simpson, 2007p
42	3D - W: Portal Frame, E: Cabo, N: Cabo, S: Cabo (90)	*244*	492	20	10.66	No	Mix	mono.	1.33	2006725	Simpson, 2007n
48	3D - NW: IRC Center, NE: IRC Side, SW: IRC Side, SE: Portal Frame (-45)	*236*	492	20	14.66	No	Mix	mono.	1.33	2006753	Simpson, 2007t
35	3D - W: Portal Frame, E: Cabo, N: Cabo, S: Cabo (0)	*272*	539	20	10.66	No	Mix	mono.	1.33	2006731	Simpson, 2007g
41	3D - W: Portal Frame, E: IRC Center, N: IRC Side, S: IRC Side (90)	*300*	571	20	6.66	No	Mix	mono.	1.33	2006720	Simpson, 2007m
36	3D - W: Portal Frame, E: IRC Center, N: IRC Side, S: IRC Side (0)	*330*	736	20	6.66	No	Mix	mono.	1.33	2006695	Simpson, 2007h
37	3D - W: Portal Frame, E: Portal Frame, N: IRC Side, S: IRC Side (0)	*395*	883	20	5.32	No	Mix	mono.	1.33	2007015	Simpson, 2007i
	Average =	**273**	**562**								
	Minimum =	**203**	**355**								
	Maximum =	**395**	**883**								

Table 5. Summary of test results for continuous wood structural panel wall bracing without gypsum finish.

Row #	Description	Load at 0.5% drift (plf)	Peak Load (plf)	Total Length of Wall (ft)	Total Length of Bracing (ft)	Gyp --	Bracing --	Test Protocol --	Segment Width (ft)	Test # in Ref. --	Reference
9	20-ft wall continuous with no openings w/ 2' corner	*396*	418	20	20	No	Cont.	mono.	4	2	NAHB, 2001a
14	20-ft wall continuous with no openings w/ 2' corner	*390*	420	20	20	No	Cont.	mono.	4	7	NAHB, 2001a
10	20-ft wall continuous with no openings w/ 4' corner	*432*	461	20	20	No	Cont.	mono.	4	3	NAHB, 2001a
15	20-ft wall continuous with no openings w/ 4' corner	*455*	490	20	20	No	Cont.	mono.	4	8	NAHB, 2001a
21	12-ft wall continuous with openings	204	512	12	4	No	Cont.	SPD	2	1	APA, 2006
18	20-ft wall continuous with openings w/ 4' corner	*583*	650	20	12	No	Cont.	mono.	4	11	NAHB, 2001a
13	20-ft wall continuous with openings w/ 4' corner	*423*	658	20	12	No	Cont.	mono.	4	6	NAHB, 2001a
27	20-ft wall portal frame	308	740	20	2.66	No	Cont.	mono.	1.33	712&717	Simpson, 2007b
16	20-ft wall continuous with openings w/ 2' corner	*400*	824	20	8	No	Cont.	mono.	2	9	NAHB, 2001a
23	12-ft wall portal frame	501	855	12	4	No	Cont.	SPD	1.33	9	APA, 2006
12	20-ft wall continuous with openings w/ 4' corner	*559*	856	20	8	No	Cont.	mono.	2	5	NAHB, 2001a
52	16-ft wall continuous with opening (UCSD, PGA 0.5g)	*544*	*874*	16	13	No	Cont.	Shake	6.5	Phase 8	Fischer et al., 2000.
11	20-ft wall continuous with openings w/ 2' corner	*593*	900	20	8	No	Cont.	mono.	2	4	NAHB, 2001a
17	20-ft wall continuous with openings w/ 4' corner	*475*	909	20	8	No	Cont.	mono.	2	10	NAHB, 2001a
	Average =	**447**	**683**								
	Minimum =	**204**	**418**								
	Maximum =	**593**	**909**								

Table 6. Summary of test results for isolated wood structural panel wall bracing with gypsum finish.

Row #	Description	Load at 0.5% drift (plf)	Peak Load (plf)	Total Length of Wall (ft)	Total Length of Bracing (ft)	Gyp --	Bracing --	Test Protocol --	Segment Width (ft)	Test # in Ref. --	Reference
3	40-ft wall with isolated bracing	*237*	366	40	12	Yes	Isolated	mono.	4	E	Dolan and Heine, 1997a
6	40-ft wall with isolated bracing	*273*	400	40	12	Yes	Isolated	SPD	4	E	Dolan and Heine, 1997b
	Average =	**255**	**383**								

Table 7. Summary of test results for continuous wood structural panel wall bracing with gypsum finish.

Row #	Description	Load at 0.5% drift (plf)	Peak Load (plf)	Total Length of Wall (ft)	Total Length of Bracing (ft)	Gyp --	Bracing --	Test Protocol --	Segment Width (ft)	Test # in Ref. --	Reference
22	12-ft wall continuous with openings	306	539	12	4	Yes	Cont.	SPD	2	2	APA, 2006
2	40-ft wall continuous with openings	*311*	612	40	16	Yes	Cont.	mono.	4	D	Dolan and Heine, 1997a
1	40-ft wall continuous with no openings	*421*	627	40	40	Yes	Cont.	mono.	4	A	Dolan and Heine, 1997a
5	40-ft wall continuous with openings	*373*	631	40	16	Yes	Cont.	SPD	4	D	Dolan and Heine, 1997b
7	12-ft wall continuous with no openings w/2' corners	*535*	634	12	12	Yes	Cont.	SPD	4	1&2	Dolan and Heine, 1997c
4	40-ft wall continuous with no openings	*474*	668	40	40	Yes	Cont.	SPD	4	A	Dolan and Heine, 1997b
49	20-ft wall continuous with opening (CSIRO, W1)	--	707	20.3	3.8	Yes	Cont.	cyclic	1.9	1	Paevere, P, et al. 2003.
8	12-ft wall continuous with no openings w/4' corners	*592*	708	12	12	Yes	Cont.	SPD	4	1&2	Dolan and Heine, 1997c
51	36-ft wall continuous with openings (CSIRO, W4)	--	711	36.4	15.75	Yes	Cont.	cyclic	3.93	4	Paevere, P, et al. 2003.
24	12-ft wall portal frame	537	993	12	2.66	Yes	Cont.	SPD	1.33	4	APA, 2006
50	16-ft wall continuous with openings (CSIRO, W2)	--	1072	16.35	6.27	Yes	Cont.	cyclic	1.5	2	Paevere, P, et al. 2003.
	Average =	**444**	**718**								
	Minimum =	**306**	**539**								
	Maximum =	**592**	**1072**								

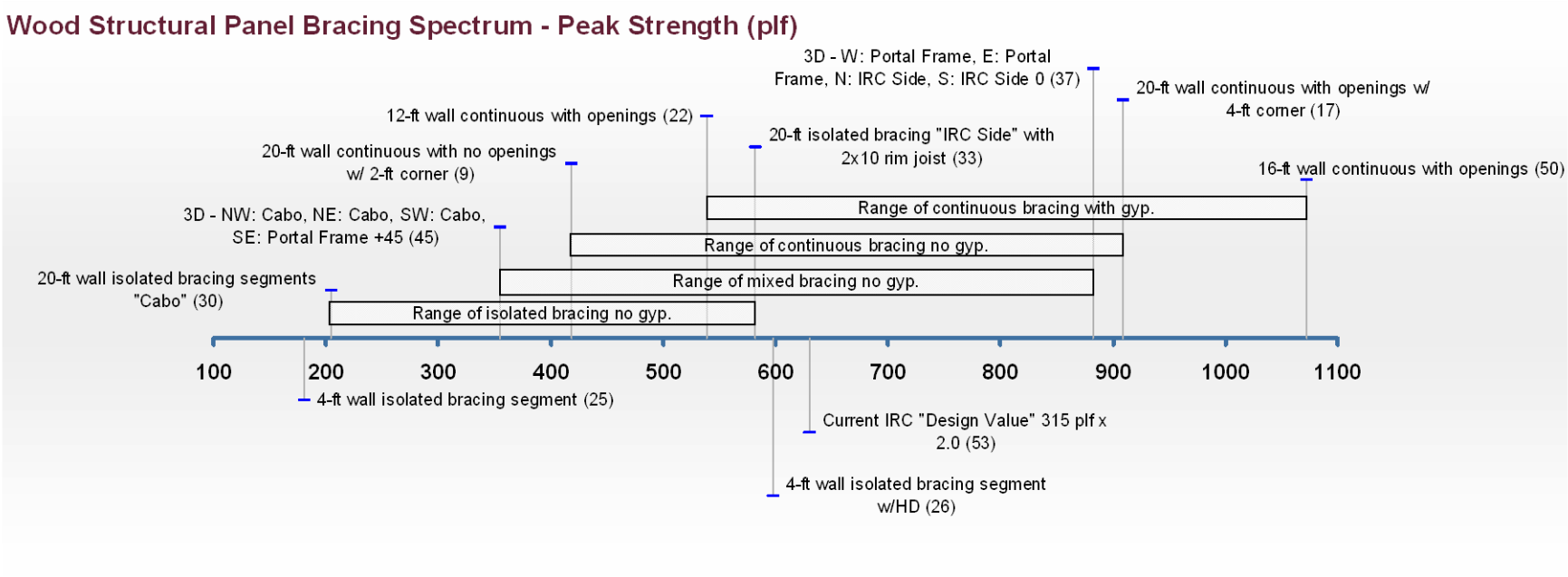


Figure 1. Graphic analysis of data tabulated, using the concept of a bracing spectrum.

In Figure 1, the numbers in parenthesis refer to the test data row number of Table 2. Also, in Figure 1, the values making up the ranges are based on tests with ho hold down devices. Considering only the range of isolated bracing with no gypsum, Figure 1 data shows that “whole house effects” (long walls, and stiff sections (such as a 2x10) above walls), can lead to peak strength test results close to that of a single 4-ft wall isolated bracing segment with a hold down.

Table 8 summarizes the report group average results of Tables 3-7.

Table 8. Summary of average test results from Tables 3-7.

Wood Structural Panel Bracing Type	Number of Tests	Gypsum	Load at 0.5% drift (plf)	Peak Load (plf)
Isolated	15	No	187	351
Mixed	8	No	273	562
Continuous	14	No	447	683
Isolated	2	Yes	255	383
Continuous	11	Yes	444	718

From Table 8 it can be seen that the ratio between the isolated and continuous bracing types is around a factor of 2 for both load at 0.5% drift and peak load.

4. KEY FINDINGS

1) A majority of the large scale wood structural panel bracing tests conducted to date have been with continuous bracing rather than isolated bracing (see Table 2).

2) The testing used to establish the IRC Method 3 (wood structural panel) bracing amounts are reported in row #7 of Table 2 (Crandell, 2006). The IRC Method 3 bracing amounts are based on the peak load (634) divided by 2, to get 315 plf (Crandell, 2006). IRC Method 3 bracing is an isolated bracing type i.e it is required to occur only in isolated locations and no wood structural panels are required elsewhere. The test which established the 634 plf was a continuosly sheathed wall i.e. it was fully sheathed from one end to the other and had continuously sheathed corners. Reported whole house confirmation tests are also based on wood structural panel bracing applied continuously rather than isolated. The current IRC “design value” for isolated wood structural panel bracing (Method 3), is based on, and confirmed by, tests of continuously sheathed braced walls.

3) Continuously sheathed braced walls resist around two times the load at 0.5% drift and peak load compared to isolated bracing (see Figure 7 and Table 8).

4) The only 3-D whole house test of conventional construction with finishes and tested to peak capacity, had continuous wood structural panel bracing and was single story.

5) Many of the highest reported loads at 0.5% drift and peak loads are based on walls with narrow bracing segments (less than 4-ft wide). In many of these cases the highest reported loads are based on bracing segements less than 2-ft wide.

6) The tests where the entire resistance was provided by portal frames (with a 1.33-ft bracing segment width) is shown in rows 23, 24, 27 and 37 of Table 2. The average loads at 0.5% drift was 435 plf, and peak loads was 867 plf. These values exceed the average isolated bracing performance by a factor more than 2. The peak strength value of 867 plf also exceeds the 2006 IRC assumed peak Method 3 value of 634 plf by 37%.

7) Greater separation between continuous bracing and isolated is warranted by the test data. Currently, Section R602.10.5 of the 2006 IRC provides a 20% benefit at most to continuous wood structural panel bracing compared to isolated wood structural panel bracing. The test data reviewed in this report suggests that continuous provides a benefit closer to 100% compared to isolated.

8) Isolated Method 3 bracing without gypsum has an average peak value of 351 plf and with gypsum of 381 plf. These values are 55% to 60% of the assumed Method 3 "design value" of 634 plf.

9) Continuous wood structural panel (Method 3) bracing without gypsum has an average peak value of 683 plf and with gypsum of 718 plf. These values are 108% to 113% of the assumed isolated Method 3 "design value" of 634 plf.

10) Where continuous bracing is mixed with isolated, the results are in between continuous and isolated, as expected.

5. SUGGESTIONS

- Wall bracing researchers should collect data that represents a finished large scale structure that is bracing the first of three stories. This would potentially add stiffness and dead lead along the top of the wall. This data would help calibrate where on the bracing spectrum this boundary condition is represented.

- Within each bracing type (e.g. isolated or continuous) there is a wide range of performance depending on boundary conditions. The effect of exact boundary conditions need to be quantified.

- Once the location along the bracing spectrum is established, a method for assigning design values is needed. It is suggested that the value be the lessor of the load at 0.5% drift or the peak load divided by a safety factor.

- Separate continuous and isolated bracing when examining past test data and in future code provisions. These bracing methods, while using the same wood structural panel sheathing, perform very differently.

6. REFERENCES

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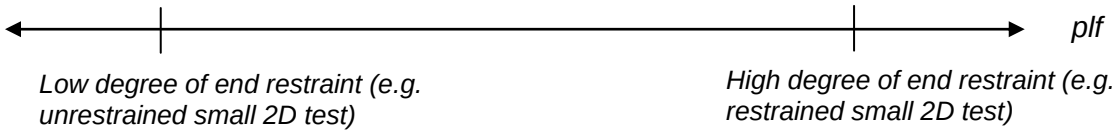
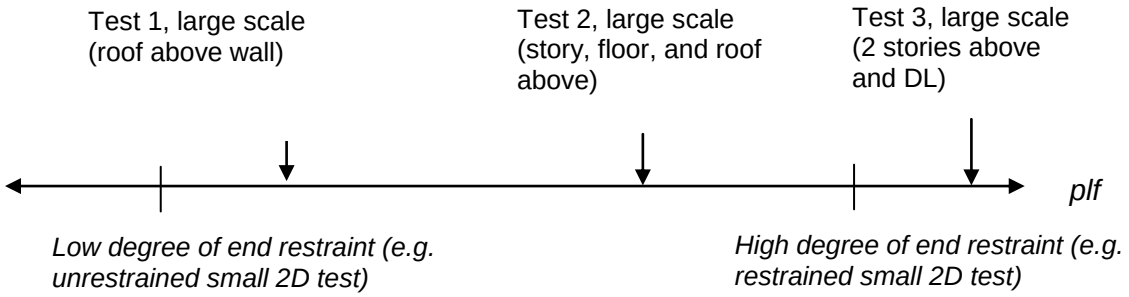
Appendix A. Use of Bracing Spectrum

Purpose: Present complete bracing response spectrum for variety of restraint conditions to facilitate decision making.

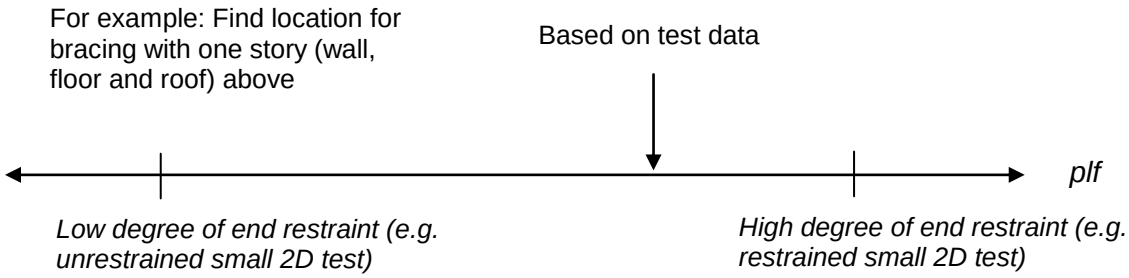
Step 1. Establish spectrum for given bracing type.



Step 2. Plot available large scale test data (2d, 3d and whole house) on the spectrum for different restraint conditions (note: Tests are shown to relay concept, not actual values. Actual relative positions may vary)



Step 3. Knowing test data select appropriate location on bracing spectrum for given condition.



If test data is not available then: 1) make assumption using engineering judgement with consensus approval, or 2) don't use bracing method.

Step 4. Knowing location on bracing spectrum for given condition, a "design" value can be calculated.

> Bracing design value = minimum of: 1) Peak load divided by safety factor (2.0 is proposed) or 2) load at a given displacement (0.5-inch displacement is proposed).

A bracing spectrum can be developed for peak load values, load at a given displacement, or any other values.