SBCRI Reveals Data from Wall Bracing Tests

by SBC Staff

SBCA/TPI Steering Committee Reports

1. SBCRI Industry Steering Committee Cover Letter
2. SBCRI Industry Steering Committee 2008 recap and 2009 plan
3. SBCRI 2009 Joint Industry Testing Program
4. Report - Lateral Walls SBCRI-08-0112
5. Report - Tension Perpendicular to the Grain SBCRI-08-0114 final
6. Report - Gravity Loaded Truss Performance Single vs System SBCRI-08-0113
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8. Report - Intellectual Property - SBCRI-08-0118
9. Report - Buckling Performance of Top Chords- SBCRI-08-0111

at a glance

- The performance of shear walls under lateral loads was recently tested in a full-scale assembly in SBCRI.
- The tests yielded results that are consistent with similar testing done by NAHB RC and APA.
- The test data calls into question prescriptive requirements of braced wall lines in the IRC.

Together with the Truss Plate Institute (TPI), SBCA has an industry testing program underway that is focused on generating fundamental information about structural building component performance. In fact, much of 2007 and all of 2008 were spent performing proprietary and industry testing in SBCRI. Throughout this time, SBCRI staff has gone through a significant growth curve that involved learning the technology in the lab and determining the best way to report new data. These efforts have resulted in the **SBCA/TPI Steering Committee Reports** listed in the sidebar below.

One of the projects, which was done in tandem with a project to develop lateral load application technology, was to collect data on the capacity of shear walls using various braced panel approaches without interior wallboard. The test results have been analyzed in the report, *Evaluation of Shear Wall Performance Under Laterally Applied Loading,* and this article details a portion of its results.

Two-Fold Goals

The first testing goal was to confirm that SBCRI's lateral load system, procedures and assembly would produce results consistent with other testing that exists in the market. In addition to SBCRI, the APA—The Engineered Wood Association[1] has performed testing on lateral loading applied to walls in a fully framed wall structure with floor or roof framing applied to the top of the walls. The NAHB Research Center has performed comparable testing of different bracing, but on a single wall using ASTM E72 test methods.[2] Given the APA and NAHB RC wall bracing data, the main purpose of SBCRI's testing was gather data to compare results and evaluate the performance of SBCRI testing based on the similarities and differences.

The second goal was to get an understanding of the bracing capabilities of different IRC shear wall configurations under laterally applied load conditions using in situ conditions.

One of the clear benefits of SBCRI is its large scale testing capabilities, which allows for in situ testing conditions that represent actual buildings and their resulting performance under various load conditions. This particular set-up is truly representative of a braced wall panel in a braced wall line in a typical residential structure because it consisted of a fully framed structure. Figures 1 and 2 show the wall and roof elements of the SBCRI assembly.

As shown in Figure 1, the big picture goal of this testing is to help the industry understand the flow of applied loads through wall panels, braced in a given manner, to the foundation, where the load cells placed below bottom plates of the walls account for the realistic flow of applied loads. From this engineering models can be more easily checked and calibrated, and new models can be created.

Details of the Test Set-up

The SBCRI test was conducted on a full-scale assembly measuring 30'x12'x 8' as shown in Figure 1. The two test walls measured 30' in length, and the roof was enclosed with 30' roof trusses. The roof was attached to the top plate of the walls using toe-nail connections. 7/16" OSB roof sheathing was applied to the top chord and 1/2" gypsum wall board sheathing was applied to the bottom chord.

[1] APA Report T2007-73 Full-Scale 3D Wall Bracing Tests available at www.apawood.org/level_b.cfm?content=pub_main.

[2] Evaluation of the Lateral Performance Of Let-In Bracing and Mixed Bracing System, EG5736_052908 available at www.foamsheathing.org/images/icc/0805%20let-in%20bracing%20Test%20Report%20EG5736_052908.pdf. NAHB RC tested a single wall using the ASTM E72 standard. The testing by NAHB RC only allowed the wall to deflect in the direction of load application, and uplift was completely prevented. The exception is the NAHB RC-15 designated test which allowed uplift, but still prevented out-of-plane deflections. Such restraints appear to make the walls perform better than if they were allowed to deflect more like they would in an in-situ application. The testing performed by SBCRI and APA are closer simulations to as-built performance with SBCRI applying pure lateral loading and APA applying a lateral load that also induces a torsional component due to load only being applied to one corner of the assembly.

Figure 1. Wall Setup Layout. The blue arrows indicate load application points, red dots represent load cells, and green arrows are deflection measurement locations.

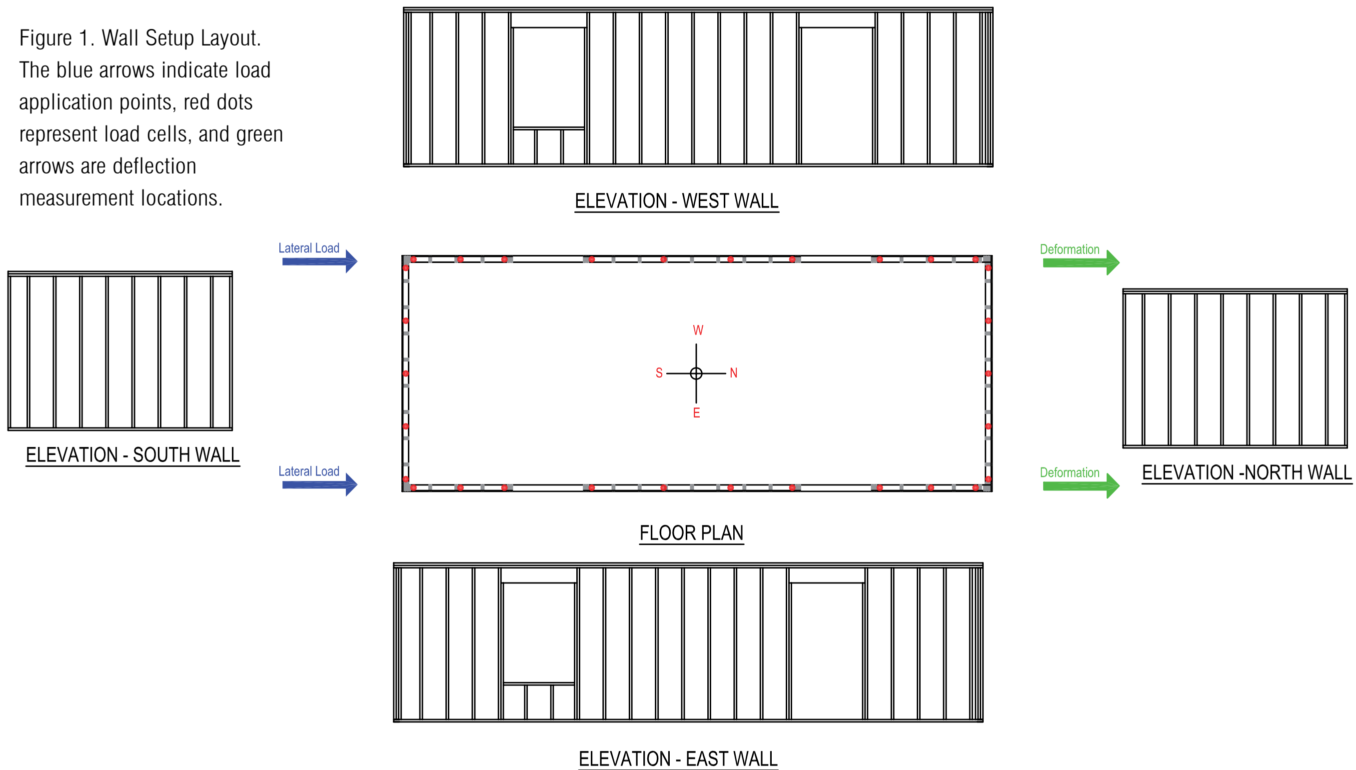
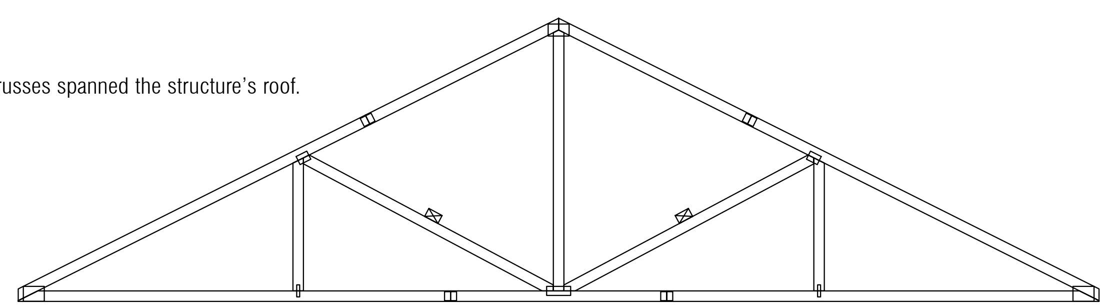


Figure 2. 30-foot roof trusses spanned the structure's roof.



Loads were applied laterally to the 30-foot walls through actuators located the south end of each of the walls. A total of 38 load cells were placed around the perimeter of the structure. Lateral deflections were measured at the top plate of the north end of each 30' wall, as well as at the mid-length of the north end wall.

The types of braced wall line methods examined are listed in Table 1 on page 18. For the tests designated SBC-1 through SBC-6 and test SBC-8, the wall was laterally loaded in 0.10-inch increments, to a total of 0.80". SBC-7 was laterally loaded in 1/8-, 1/4-, 3/8-, 1/2-, and 3/4-inch displacement increments. The solid green color indicates that a

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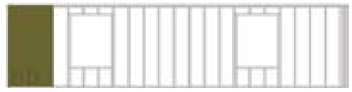
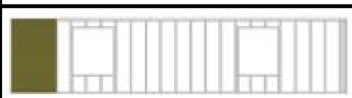
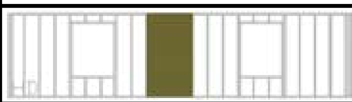
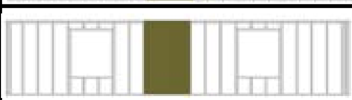
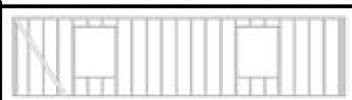
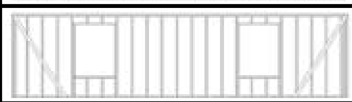
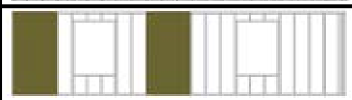
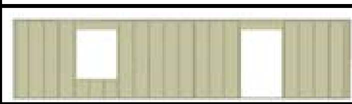
Wall Number	Hold Down	Wall Diagram	Braced Panel Length
SBC-1	Yes		4 ft.
SBC-2	No		4 ft.
SBC-3	Yes		4 ft.
SBC-4	No		4 ft.
SBC-5	No		5 ft.
SBC-6	No		10 ft.
SBC-7	No		8 ft.
SBC-8[1]	No		22.75 ft.

Table 1. SBCRI Wall Bracing Test Matrix. ([1] Test SBC-8 was conducted at a later date and had a setup slightly different than test 1-7.)

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4x8' OSB sheet (7/16-inch) was applied at that location on the 30' wall. SBC-5 and SBC-6 use 1x4-inch bracing at 60 degrees. Similar to the APA testing, the braces were not actually let-in, but applied to the outer edge of the wall studs. NAHB RC let-in bracing was at 45 degrees and was let-in to the studs. The walls shown in Table 1 represent the east wall of the assembly; the west wall mirrored it.

The actuator, seen in Photo 1, recorded the force necessary to displace the top plate of the wall to the predetermined displacement values. The values recorded by the actuator were attached to individual displacement values for each braced panel type and this was used to compare performance. During the tests, the load cells beneath the walls recorded the vertical force that flowed to the foundation due to the applied lateral load, as well.

Test Results

Graph 1 on page 20 provides a summary of the full data from the SBCRI testing. The x-axis of the graph is deflection imparted by the actuator, while the y-axis is the calculated pounds per square foot (PLF) value of each brace type. The length used in determining PLF is the actual length of the brace wall panel along the wall, not including areas of perforations (windows and doors).

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Photo 1. Load Application Device

The SBCRI results are a good representation of actual performance of a braced wall panel in a braced wall line in a typical residential structure.

Line Color Key for Graphs 1 and 2:
Orange = sheathing placed on one end of the loaded wall at the corner
Green = sheathing used in the middle of the wall (roughly 12.5' from applied load)
Purple = let-in bracing
Blue = a fully sheathed wall

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Graph 2 shows the performance of each wall under load in the SBCRI, APA and NAHB RC tests. The purpose of this graph is to provide a foundation for making an assessment of comparative results. The x-axis of the graph is deflection, while the y-axis is the calculated PLF value of each brace type.

Analysis of SBCRI Test Results

1. SBCRI data is consistent with existing test data. These data reveal that the SBCRI testing provided comparable results to existing tests, which was the primary goal of the testing. The analysis of testing by APA and NAHB RC shows that the SBCRI results are a good

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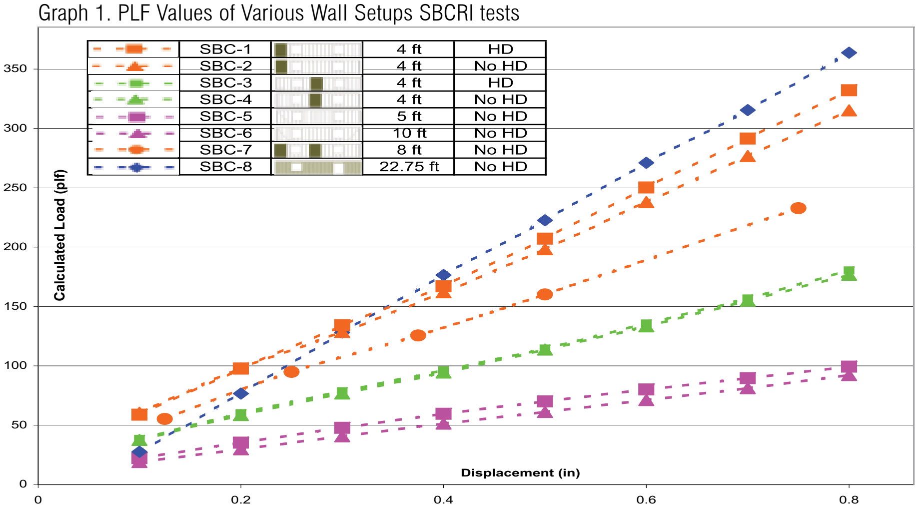
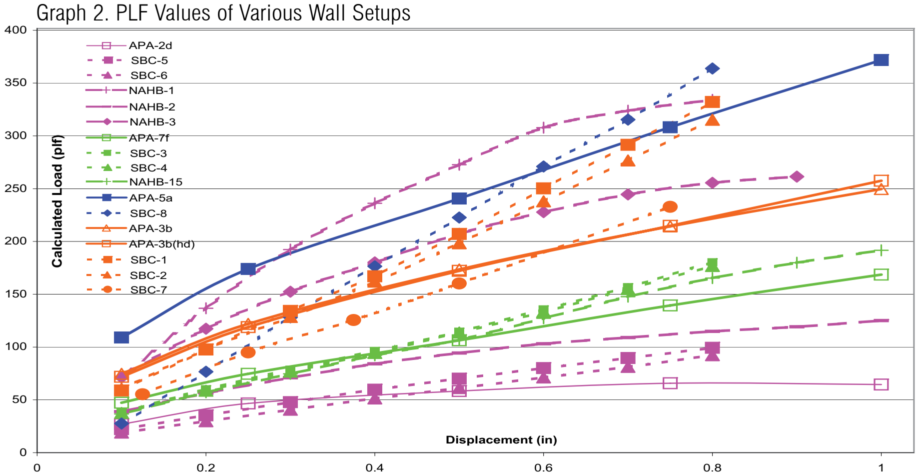
Graph 1. PLF Values of Various Wall Setups SBCRI tests



Graph 2. PLF Values of Various Wall Setups



Applied PLF Load from Test Data at Various Deformations

Line Code	Wall Test	Wall Type	Braced Panel Length	Hold Down	0.1	0.125	0.2	0.25	0.3	0.375	0.4	0.5	0.6	0.7	0.75	0.8
	SBC-8		22.75 ft	No HD	27.6	33.8	76.6	102.4	128.1	164.4	176.5	222.6	271.0	315.4	351.7	363.8
	NAHB-1		8 ft	Tension Rod	70.9	79.2	136.7	164.5	192.3	225.2	236.1	272.7	307.8	323.9	331.5	334.1
	SBC-1		4 ft	HD	58.9	68.6	97.8	116.0	134.3	158.8	167.0	207.1	250.3	291.5	332.0	332.1
	APA-5a		12 ft	No HD	109.1	119.9	152.3	173.9	187.3	207.3	214.0	240.7	267.7	294.7	308.2	320.9
	SBC-2		4 ft	No HD	60.5	69.8	97.8	113.1	128.5	153.6	162.0	198.3	238.0	276.8	305.6	315.3
	NAHB-3		16 ft	Tension Rod	71.3	77.0	117.3	134.9	152.4	173.3	180.2	207.3	227.8	244.6	252.8	255.5
	SBC-7		8 ft	No HD	44.2	55.3	79.1	94.9	107.2	125.6	132.5	160.2	189.2	218.3	232.8	-
	APA-3b(hd)		12 ft	HD	52.3	59.3	80.2	94.1	104.8	121.0	126.3	147.8	165.5	183.2	192.0	198.5
	SBC-3		4 ft	HD	38.5	43.9	60.1	69.4	78.6	91.9	96.4	114.6	135.8	156.8	174.5	180.4
	SBC-4		4 ft	No HD	37.6	42.9	58.6	67.7	76.8	90.0	94.4	113.8	133.3	154.9	171.3	176.8
	APA-3b		12 ft	No HD	48.2	53.9	71.1	82.6	92.3	106.9	111.7	131.2	144.6	158.0	164.8	172.0
	NAHB-15		4 ft	No HD	36.6	39.2	57.1	65.9	74.7	87.8	92.2	106.8	127.3	147.7	160.9	165.3
	APA-7f		8 ft	No HD	47.3	51.8	65.5	74.6	81.0	90.5	93.7	106.4	119.6	132.8	139.4	145.2
	NAHB-2		8 ft	Tension Rod	38.8	41.0	56.3	63.6	70.9	80.8	84.1	94.3	103.1	109.0	113.3	114.8
	SBC-5		5 ft	No HD	22.3	25.6	35.3	41.6	47.8	56.7	59.6	70.1	80.1	89.6	96.9	99.3
	SBC-6		10 ft	No HD	19.0	21.7	29.8	35.2	40.7	48.6	51.3	61.2	71.2	81.2	89.5	92.3
	APA-2d		15 ft	No HD	26.9	30.2	40.0	46.6	48.9	52.5	53.6	58.3	61.3	64.3	65.7	65.5

Table 2 -- Comparative Braced Wall Panel Performance @ 0.75" Deformation

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representation of actual performance of a braced wall panel in a braced wall line in a typical residential structure. This is also confirmed by the fact that the SBCRI results are very linear elastic in nature, which is expected under the reasonably small deformations in the comparison of test results.

2. Braced wall panels with the most and least resistance to load. From the test data analyzed and on a comparative PLF basis, the braced wall type with the most braced wall panel resistance to least braced wall panel resistance at .80" deflection follows:

a. Fully sheathed wall: 364 PLF
b. Sheathing placed at the leading edge (adjacent to the applied lateral load) of the wall at the corner: 332 PLF
c. Sheathing placed 12.5' from the corner of the wall: 180 PLF
d. Let-in bracing: approx. 99 PLF

Clearly, the most economically and structurally efficient braced wall panel application is a 4x8 sheet of OSB placed in the corner of a braced wall line.

3. The impact of differences between APA and SBCRI test setup. The physical setup of APA compared to SBCRI had an impact on the SBCRI data. The APA test data displayed a non-linear load deformation curve at what would assume should be linear elastic deformations. For low braced wall line deformations this appeared to have negligible effect on the outcome of the test result. Additionally, the torsion induced into the APA test assembly by loading a single braced wall line caused a non-linear divergence in load deformation results when compared to loading walls symmetrically as was done in the SBCRI testing.

4. ASTM E72 test criteria do not result in data that reflect true load resistance. Strict adherence to ASTM E72 can easily result in values much greater than what would be expected from normal installation methods. It is reasonable to assume that ASTM E72 test results are dependant on the set-up and vertical restraint conditions that are present for the testing performed. ASTM E72 has great value as a test method when it is used to make direct comparisons of the performance of sheathing materials attached to a wood or steel stud wall or shear wall panel segments where the walls are of consistent size, the set-up is identical and the performance of assembly variations is the focus of the experiment. ASTM E72 appears to have the potential to provide design values for shear walls that are not reflective of in-situ resistance to applied loads, however. So to the extent that E72 tests are used to establish shear wall design values, these values may not be representative of actual in situ shear wall performance.

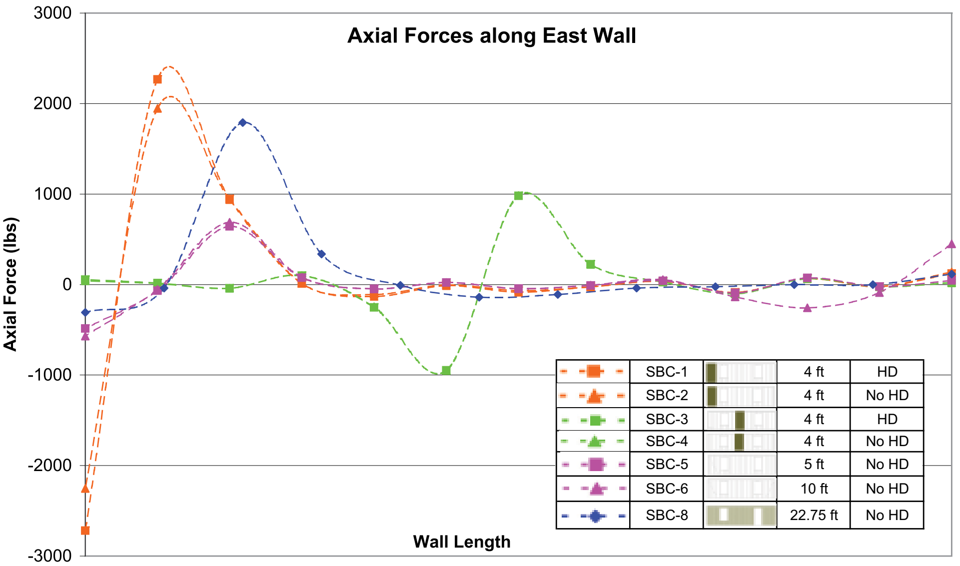
5. At locations where there is no braced wall, a minimal amount of load transfer to the foundation was measured. An important observation can be was made by analyzing vertical loads along the foundation resulting from an applied lateral load to a braced wall line. In general, the flow of load to the foundation accumulates and is output to the foundation along or at the end of the braced wall panel.

Where there is no braced wall panel there is very little lateral load transfer to the foundation. The SBCRI testing showed that the effect of additional 4x8 sheets of OSB as braced wall panels in a braced wall line is not additive, as shown in Graph 3.

6. The final observation from SBCRI data revolves around the IRC, which prescribes the following with respect to braced wall capacity in braced wall lines:

> **R602.10.1 Braced wall lines.** Braced wall lines shall consist of braced wall panel construction in accordance with Section R602.10.3. The amount and location of bracing shall be in accordance with Table R602.10.1 and the amount of bracing shall be the greater of that required by the seismic design category or the design wind speed. Braced wall panel shall begin no more than 12.5 feet (3810 mm) from each end of a braced wall line. Braced wall panels that are counted as part of a braced wall line shall be in line, except that offsets out-of-plane of up to 4 feet (1219 mm) shall be permitted provided that the total out-to-out offset dimension in any braced wall line is not more than 8 feet (2438 mm).

Our testing calls into question the IRC prescriptive requirements, "Braced wall panels shall begin no more than 12.5 feet (3810 mm) from each end of a braced wall line."



Graph 3. Axial Forces due to Lateral Loading at 0.8" of lateral deformation where Negative Indicates Uplifting Forces (green square and triangle overlay)

The results of this testing shows that additional testing should be done to gain a more thorough understanding of braced wall panels, braced wall lines, and the IRC code provisions in the context of the actual flow of forces through braced wall panels in a braced wall line to the foundation.

This testing generated questions that will be addressed as future industry testing is performed. SBCRI has great potential to add solid technical performance insight with respect to in situ building component applications. SBC

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