APA Report T2009P-28

Testing of
Structural Insulated Panels (SIPs) with
New Facer Design Properties
for
The Structural Insulated Panel Association,
Gig Harbor, Washington

by Edward L. Katha, P.E.
Technical Services Division
April 24, 2009

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REPRESENTING THE ENGINEERED WOOD INDUSTRY
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Testing of Structural Insulated Panels (SIPs) with New Facer Design Properties for The Structural Insulated Panel Association, Gig Harbor, Washington

SUMMARY

Subsequent to the publication of the minimum panel properties required for the facers of structural insulated panels (SIPs) in the International Residential Code (IRC) in the 2007 Supplement, it became evident that those facer properties do not reflect the oriented strand board (OSB) facer materials commonly available in the marketplace, which typically have higher properties in the along direction and lower properties in the across direction. Working with Structural Insulated Panel Association (SIPA), APA – The Engineered Wood Association conducted a series of full-scale tests on SIPs manufactured with the commonly available OSB to determine the effect of the new facer materials on the SIPs performance.

Specific SIP panel sizes were selected for this series of testing, which included shear (racking), axial load, and transverse load testing. These tests were conducted in accordance with recognized test methods, such as ASTM E72 and E1803, and ICC-ES Acceptance Criteria AC04. Results of these tests were compared with the ones published in APA Report T2006P-33, which was used to establish the prescriptive SIP section in R614 of the 2007 IRC Supplement. Based on this study, the new facer materials were found to have no impact on the SIP performance.

The properties of the OSB panels, which were matched with the full-scale SIP specimens and closely reflected the current OSB production, were characterized and documented in APA Report T2009P-23.

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This report contains data generated through testing of engineered wood products according to various test methods. Many accepted test methods conducted by APA are accredited or listed by organizations listed above. A list of methods is available upon request. Any test data in this report that is derived from test methods, which deviate from accepted procedure are noted. Accreditation or listing does not constitute endorsement of this report by the accrediting or listing agency or government.

The precision and bias of the test methods given in this report are being established.

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1. INTRODUCTION

In 2003, the Structural Insulated Panel Association (SIPA) made a proposal to the U. S. Department of Housing and Urban Development (HUD), through their Partnership for Advancing Technology in Housing (PATH), to develop a prescriptive method for residential design using structural insulated panels (SIPs). HUD approved the proposal and subsequently signed a contract with the National Association of Home Builders – Research Center (NAHB-RC) to manage the project. The NAHB-RC has worked in conjunction with Building Works, Inc., to develop this method. The result of this effort was the development of a prescriptive method for adoption by the International Residential Code (IRC).

APA – The Engineered Wood Association worked with SIPA and the wood structural panel industry in the development of minimum properties for the oriented strand board (OSB) panel facers (APA Report T2006P-28). Using these industry-developed minimum properties for panels, APA conducted a series of tests on SIPs manufactured to reflect these minimums, including shear (racking), axial load, transverse load, and lintel testing. These tests were conducted in accordance with recognized test methods, such as ASTM E 72 and E 1803, and ICC-ES Acceptance Criteria AC 04. From the results of these tests, design capacities of SIPs were established, reported in APA Report T2006P-33, and used in the development of the SIPA prescriptive method and IRC code change proposal.

Subsequent to the publication of the minimum panel properties required for the facers of SIPs in the 2007 IRC Supplement, it became evident that those facer properties do not reflect the OSB facer materials commonly available in the marketplace, which typically have higher properties in the along direction and lower properties in the across direction. Working with SIPA, APA conducted a series of full-scale tests on SIPs manufactured with the commonly available OSB to determine the effect of the new facer materials on the SIPs performance. Specific SIP panel sizes were selected for this series of testing, which included shear (racking), axial load, and transverse load testing. Results of these tests are documented in this report.

The properties of the OSB panels, which were matched with the full-scale SIP specimens and closely reflected the current OSB production, were characterized and documented in APA Report T2009P-23.

1.1 SIPS Panel Construction

SIP test specimens were manufactured as follows:

1.1.1 Core

The core materials of the SIPs were composed of molded expanded polystyrene (EPS) meeting the requirements of ASTM C 578, Type I, with a minimum density of 0.90 lbm/ft^3.

1.1.2 Facers

Facer materials for structural insulated panels were OSB panels, each having a minimum nominal thickness of 7/16 inch and conforming to DOC PS 2, as manufactured by Ainsworth Engineered, (USA) LLC, Bemidji, Minnesota. The properties of the OSB panels were characterized and documented in APA Report T2009P-23, as given below:

Table 1. Minimum Properties for OSB Facer Material in SIP Walls

Thickness (in.)	Flatwise Stiffness [(a)] (lbf-in.^{2}/ft)		Flatwise Strength [(b)] (lbf-in./ft)		Tension [(b)] (lbf/ft)		Density [(a,c)] (pcf)
	Along	Across	Along	Across	Along	Across	
7/16	55,600	16,500	1,040	460	7,450	5,800	34

[(a)] Mean test value shall be in accordance with Section 7.6 of DOC PS2.
[(b)] Characteristic test value (5 percent with 75 percent confidence).
[(c)] Density based on oven-dry weight and oven-dry volume.

1.1.3 Adhesives

Adhesives used to structurally laminate the EPS insulation core to OSB facers were Type II, Class 2, conforming to ASTM D 2559.

1.1.4 SIP assemblies

All SIP assemblies were fabricated at Premier Building Systems, Fife, Washington, in February 2009 for racking shear and axial load, and in March 2009 for transverse load.

1.1.5 Fasteners

Fasteners used to connect the SIP facer panels to framing were 8d common nails (0.131 x 2-1/2 inches), conforming to ASTM F 1575.

1.1.6 Lumber

Lumber used for the assembly of test specimen was spruce-pine-fir No. 2 or better.

2. TEST METHODS AND TEST ASSEMBLY DESCRIPTIONS

2.1 Racking Shear Test

Tests were conducted to develop racking shear design properties for prescriptive SIP panels.

2.1.1 Test Assemblies

Test assemblies were fabricated from SIP panels as described below:

Table 2. Racking Shear Test Assemblies

SIP Specimen Size (Thickness x width x height)	Number of Assemblies
4-1/2” x 8’ x8’	3

2.1.2 Test Assembly Preparation

Test assemblies were fabricated from the SIP panel sizes listed in Table 2 and prepared in accordance with Figure A1. The adjoining specimen edges of the panel were routed out 1-1/2 inches to accommodate a “box spline” fabricated out of a 3-inch-wide SIP panel with an outside dimension equal to the foam-core thickness (7/16-inch facers). These splines were placed such that the outside OSB faces on the spline were in contact with the inside OSB faces of the two SIP panels being joined. The SIP panel faces were attached on both sides to the spline with 8d common nails (0.131 x 2-1/2 inches) placed at 6 inches on center.

The outside vertical panel edges of the panel were routed out 3 inches to accommodate two No. 2 or better spruce-pine-fir 2x4 members. These members ran the full height of the specimen and were attached to both OSB skins with 8d common (0.131 x 2-1/2 inches) nails placed at 6 inches on center.

The top and bottom edges of the specimen were routed out to 3 inches and 1-1/2 inches, respectively, to accommodate spruce-pine-fir 2x4 members. The bottom plate was attached to the test apparatus prior to attachment to the SIP test specimen to provide access to the anchor bolts. A Simpson HD-8 was lag-screwed to the top plates to facilitate anchoring of the load head. Top and bottom plates were attached to the SPF framing with 8d common nails (0.131 x 2-1/2 inches) placed at 6 inches on center from each side.

2.1.3 Test Method

The shear wall specimens were tested in accordance with ASTM E 72-05, Section 14, and Figure C1. The three steps of loading, per Section 14.4.2, were based on a design load of 315 plf, i.e., 2,520 lbf, 5,040 lbf, and ultimate.

2.2 Axial Load (Compressive) Tests

Tests were conducted to develop axial load (compressive) design properties for prescriptive SIP panels.

2.2.1 Test Specimen

Test specimens were fabricated from SIP panels as described below:

Table 3. Axial Load (Compression) Specimen

SIP Specimen Size (Thickness x width x height)	Number of Specimens
4-1/2" x 4' x 10'	3

2.2.2 Test Specimen Preparation

Test specimens were fabricated from the SIP panel sizes listed in Table 3 and prepared in accordance with Figure A2. All outside ends and edges were routed out 1-1/2 inches. Along the four-foot panel ends, a No. 2 or better spruce-pine-fir 2x member sized to match the foam thickness was placed within this routed area and was attached to both OSB facers with 8d common (0.131 x 2-1/2 inches) nails placed at 6 inches on center.

2.2.3 Test Method

The axial load (compression) specimens were tested in accordance with ASTM E 72-05, Section 9, and Figures B2 – B5. Route-outs for electrical junction boxes were placed on the compression side (on the side of the eccentric load) of the SIP during testing.

2.3 Transverse Load Tests

Tests were conducted to develop transverse load (load perpendicular to the plane) design properties for prescriptive SIP panels.

2.3.1 Test Specimen

Test specimens were fabricated from SIP panels as described below:

Table 4. Transverse Load Specimen

SIP Specimen Size (Thickness x width x height)	Number of Specimen
4-1/2” x 4’ x10’	4[a]

[a] Two specimens were tested with switch box openings and two without.

2.3.2 Test Specimen Preparation

Test specimens were fabricated from the SIP panel sizes listed in Table 4 and prepared in accordance with Figure A3. All outside ends and edges were routed out 1-1/2 inches. Along the four-foot panel ends a No. 2 spruce-pine-fir 2x member sized to match the foam thickness was placed within this routed area and was attached to both OSB facers with 8d common (0.131 x 2-1/2 inches) nails placed at 6 inches on center.

2.3.3 Test Method

The transverse load specimens were tested in accordance with ASTM E 72-05, Section 11, and Figures B6 – B8. Route-outs for electrical junction boxes, when used, were placed on the tension side of the SIP.

3. RESULTS AND DISCUSSION

3.1 Racking Shear Test Results

The results of racking shear tests are shown below. The typical failure mode was the failure of the nailed connections at spline, as shown in Figure C1.

Table 5. Racking shear test results (plf) for 4-1/2-inch x 8-foot SIPs

Test Criteria	Wall 1	Wall 2	Wall 3	Mean
Ultimate (plf)	1,080	1,057	976	1,038
Ult/3.0 (plf)	360	352	325	**346**
Load at 1/8” deflection (plf)	510	610	500	540

3.2 Axial Load Test

The results of axial load tests are shown below. The typical failure modes were the buckling failure on compression face at electrical chase and the shear failure through foam due to eccentric loading, as shown in Figures C2 and C3, respectively.

Table 6. Axial load test results (plf) for 4-1/2-inch x 10-foot SIPs

Test Criteria	Specimen 1	Specimen 2	Specimen 3	Mean
Ultimate (plf)	11,014	9,638	8,845	9,832
Ult/3.0 (plf)	3,671	3,213	2,948	**3,277**
Deflection at Ult/3.0 (in.)	0.044	0.109	0.117	0.090

3.3 Transverse Load Test

The results of transverse load tests are shown below. The typical failure mode was the shear failure of the foam at electrical chase, as shown in Figures C4 and C5. Note that Specimens 1 and 2 were tested with 4-inch x 4-inch switch-box holes routed out and Specimens 3 and 4 without. The existence of the switch-box hole did not appear to have any significant effect on the SIP transverse load performance.

Table 7. Transverse load test results (lbf) for 4-1/2-inch x 10-foot SIPs

Specimen	Height (in.)	Ultimate load (lbf)	Slope (lbf/in./4 ft)	Load at deflection (lbf)			
				L/360	L/240	L/180	L/120
1	120	3,322	2,204	714	1,061	1,395	1,977
2	120	3,466	2,198	743	1,093	1,433	2,061
3	120	3,401	2,582	801	1,165	1,512	2,152
4	120	3,024	2,235	758	1,107	1,434	2,042
Mean		**3,303**	**2,305**	**754**	**1,107**	**1,444**	**2,058**
Calculated allowable load (psf)		28[a]	--	19[b]	28[b]	36[b]	51[b]
Allowable load[c] (psf)		--	--	**19**	**28**	**28**	**28**

[a] Calculated allowable load (psf) is based on the mean ultimate load (lbf) divided by the total SIP panel area (ft^2) and by a factor of 3.0.

[b] Allowable load (psf) is based on the mean load (lbf) at a specific deflection limit and by the total SIP panel area (ft^2).

[c] Allowable load (psf) is tabulated based on the calculated ultimate load or the calculated load at a specific deflection limit, whichever is less.

4. CONCLUSION

From the test results shown above, the allowable design values were established, as shown in Tables 8 through 10. Test values from the previous tests, as documented in APA Report T2006P-33, are shown in parenthesis for comparison.

4.1 Allowable Racking Shear Design Values

Table 8. Allowable racking shear design values (plf) for SIP wall panels[a]

Wall height (in.)	Wall thickness
	4-1/2 in.
	Allowable racking shear (plf)
96	**346** (315)

[a] Applicable to short-term load duration (10 minutes).

4.2 Allowable Axial Load (Compressive) Design Values

Table 9. Allowable axial load design values (plf) for the SIP wall panels[a]

Wall height (in.)	Wall thickness
	4-1/2 in.
	Allowable axial load (plf)
120	**3,277** (3,100)

[a] Applicable to long-term load duration (10 years). As a standard practice recommended by the SIP industry, the tabulated values shall not be adjusted for other load durations.

4.3 Allowable Transverse Load Design Values

Table 10. Allowable transverse load design values (psf) for SIP wall panels[a]

SIP Panel	Height (in.)	Allowable transverse load for deflection limits (psf)			
		L/360	L/240	L/180	L/120
10' high x 4-1/2"	120	**19** (18)	**28** (27)	**28** (27)	**28** (27)

[a] Applicable to long-term load duration (10 years). As a standard practice recommended by the SIP industry, the tabulated values shall not be adjusted for other load durations.

As can be seen from the results provided in Tables 8 -10, the SIP performance with the new facer materials was found to be comparable with the results from previous tests (APA Report T2006P-33) that formed the basis for the prescriptive SIPs section (R614) in the 2007 IRC Supplement. Therefore, the new OSB facer properties characterized in Table 1 can be used to substitute for the OSB facer properties tabulated in the existing IRC Table R614.3.2 without affecting the prescriptive SIP provisions in section R614 of the IRC.

5. REFERENCES

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6. APPENDICES

List of Appendices

Appendix A: Drawings of Test Specimens (3 pages)

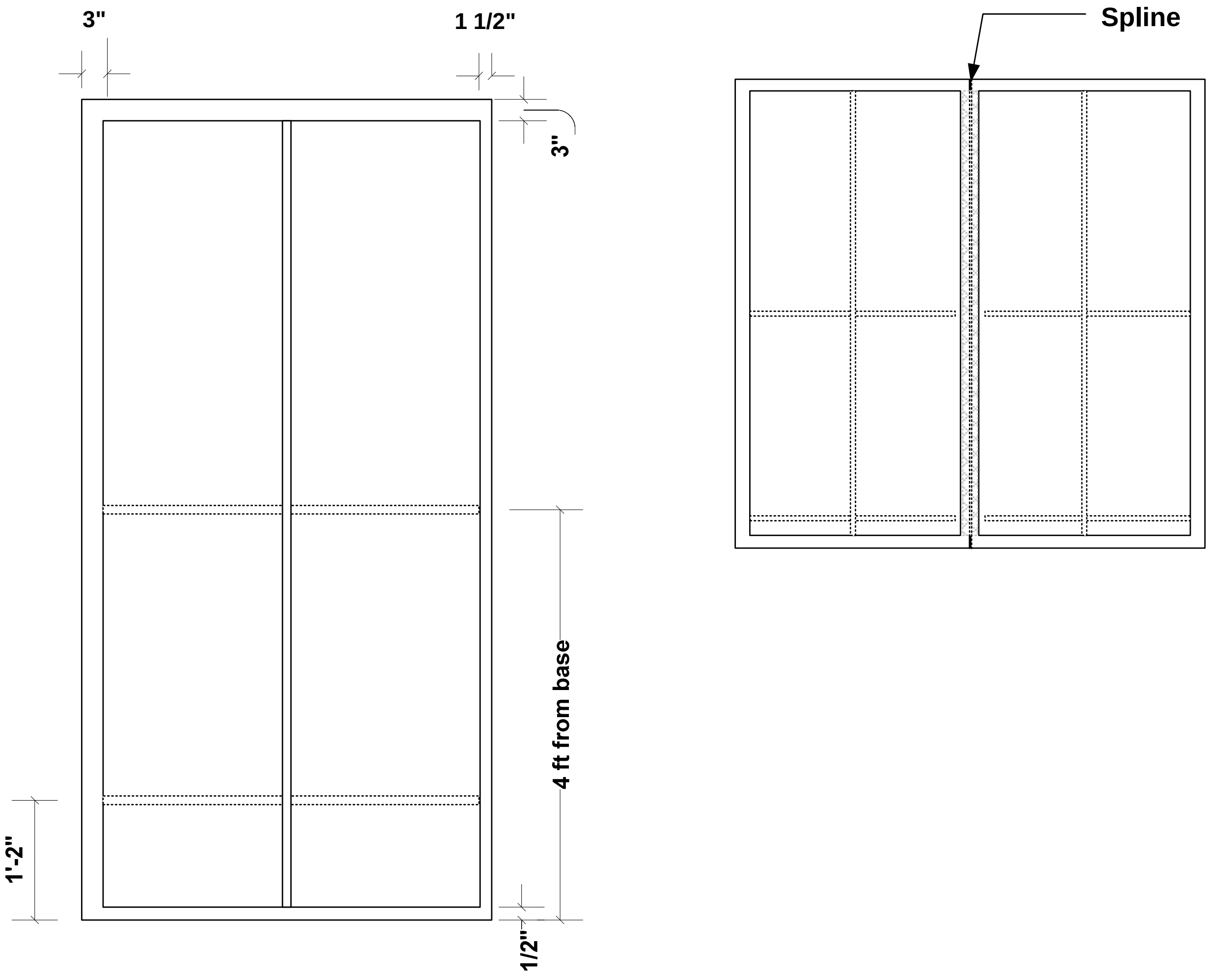

FIGURE A1. RACKING SHEAR TEST SPECIMEN AND ASSEMBLY

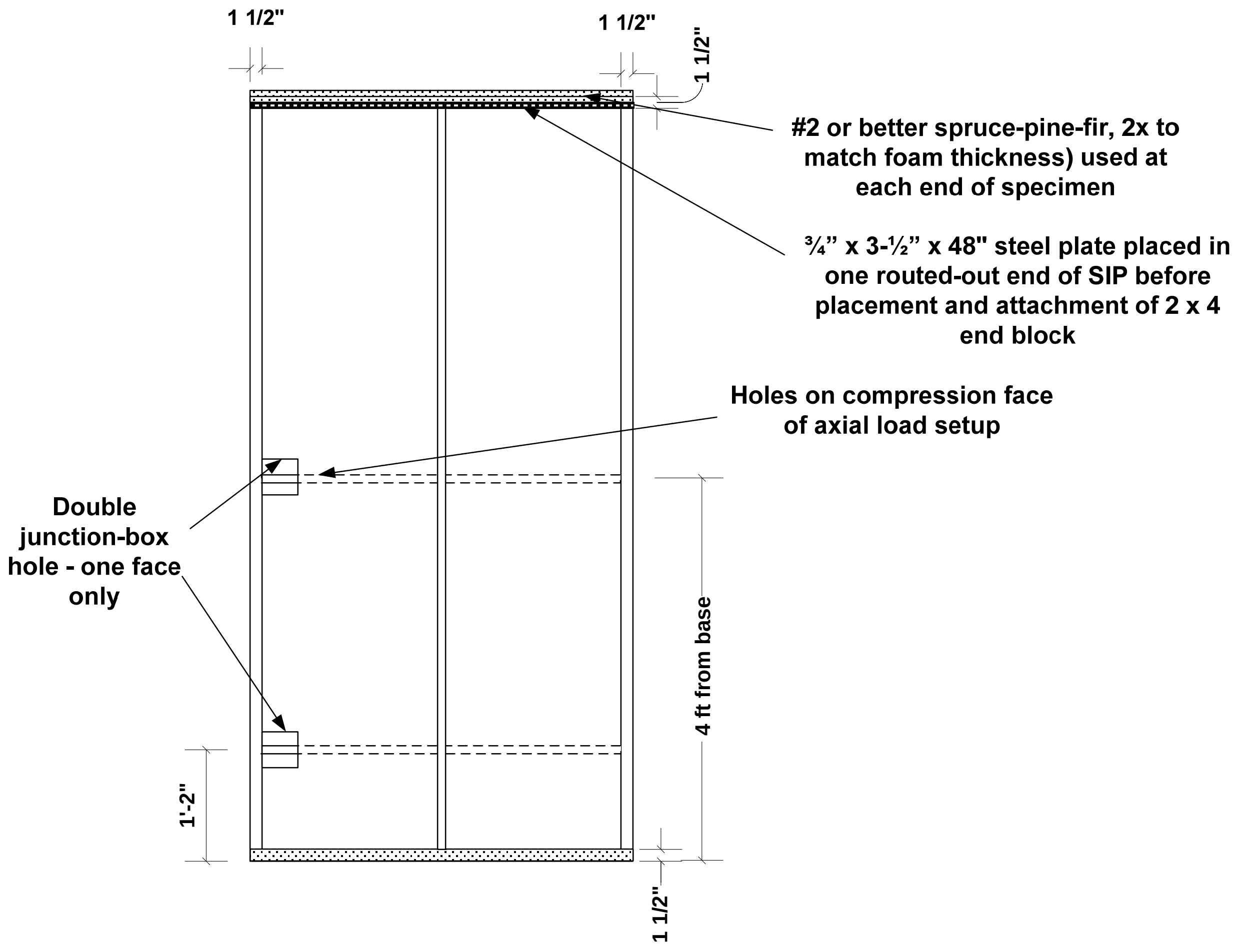

FIGURE A2. AXIAL (COMPRESSION) LOAD TEST SPECIMEN AND ASSEMBLY

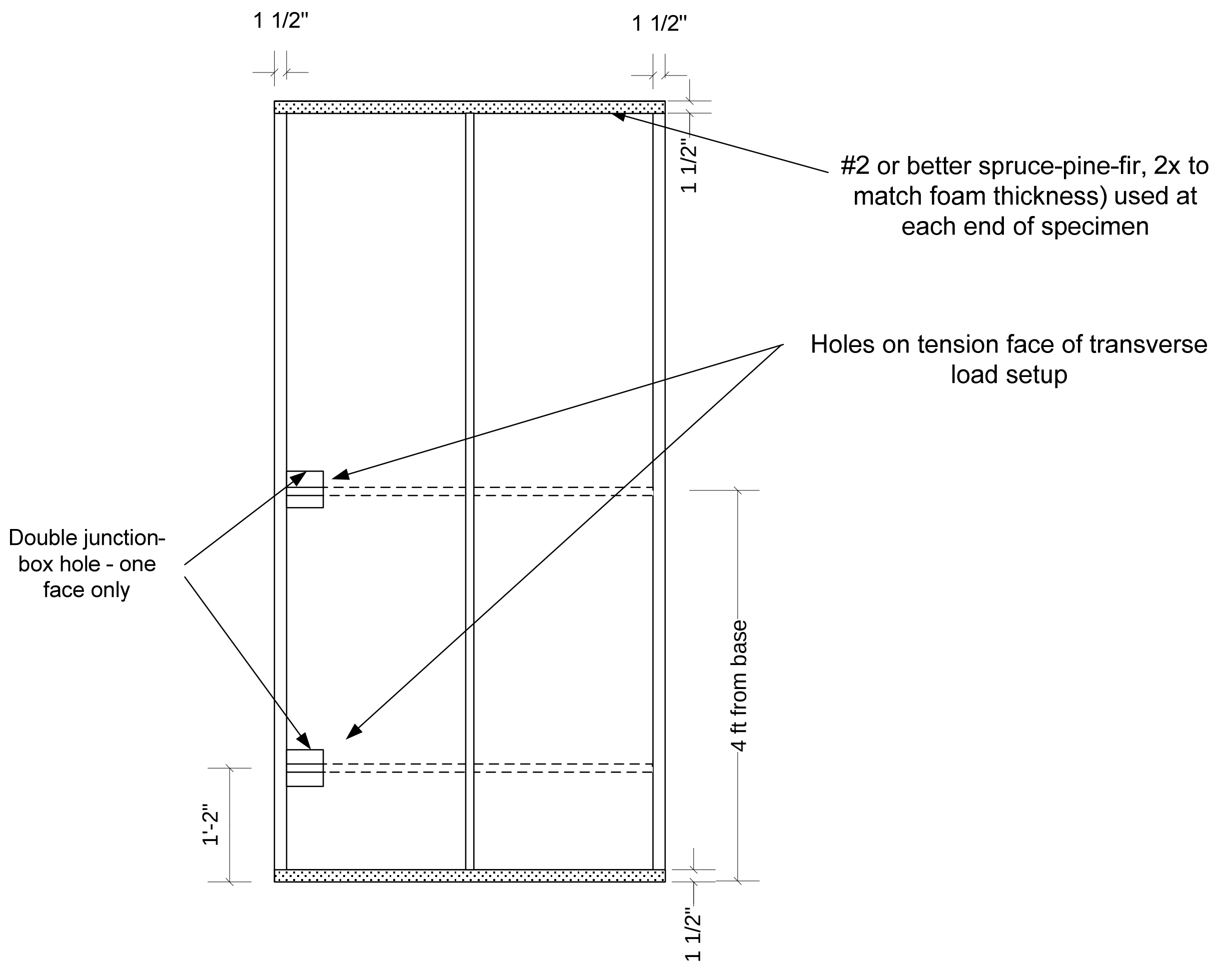

FIGURE A3. TRANSVERSE LOAD TEST SPECIMEN AND ASSEMBLY

Appendix B: Test Assemblies (8 pages)

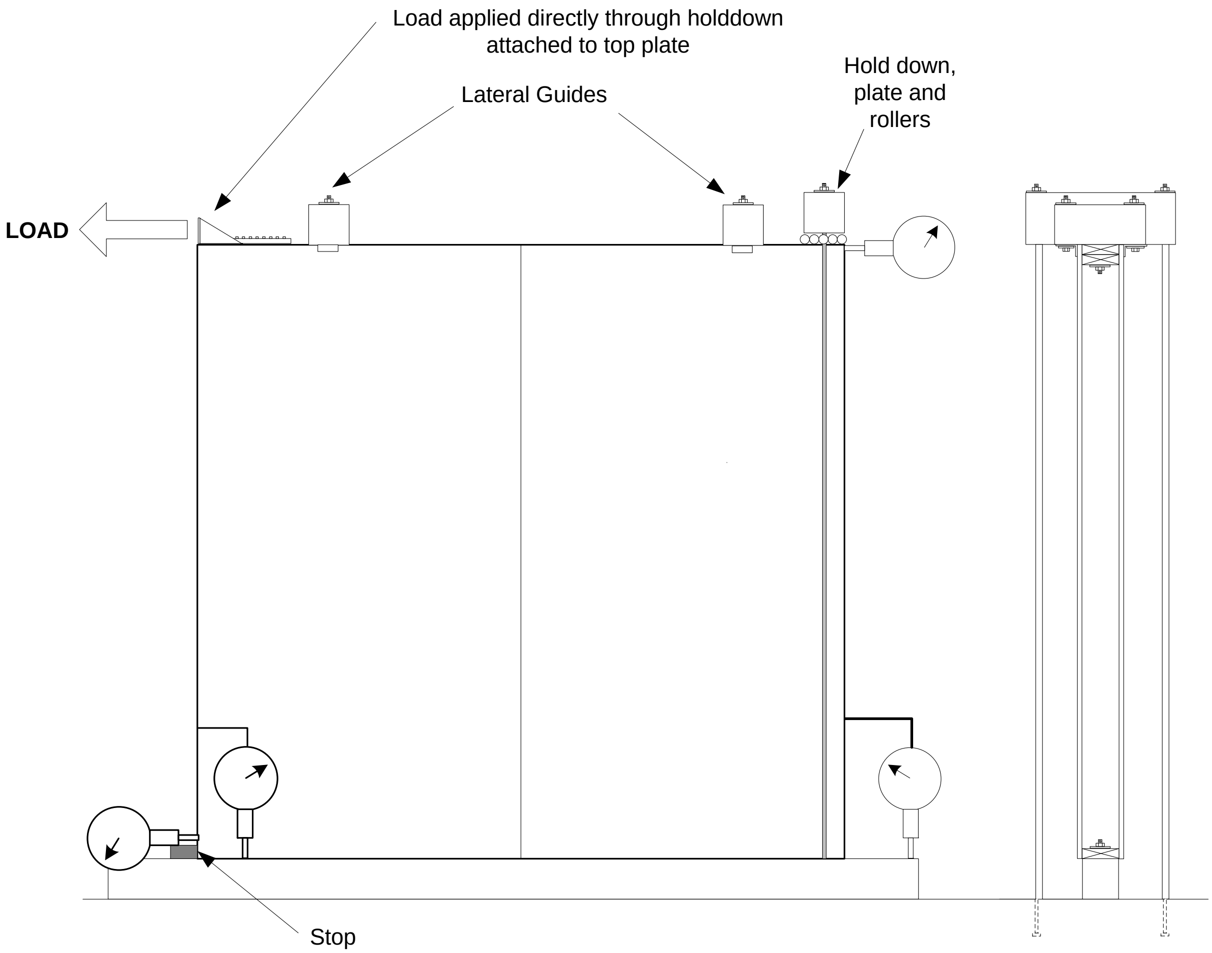

FIGURE B1. RACKING SHEAR TEST ASSEMBLY

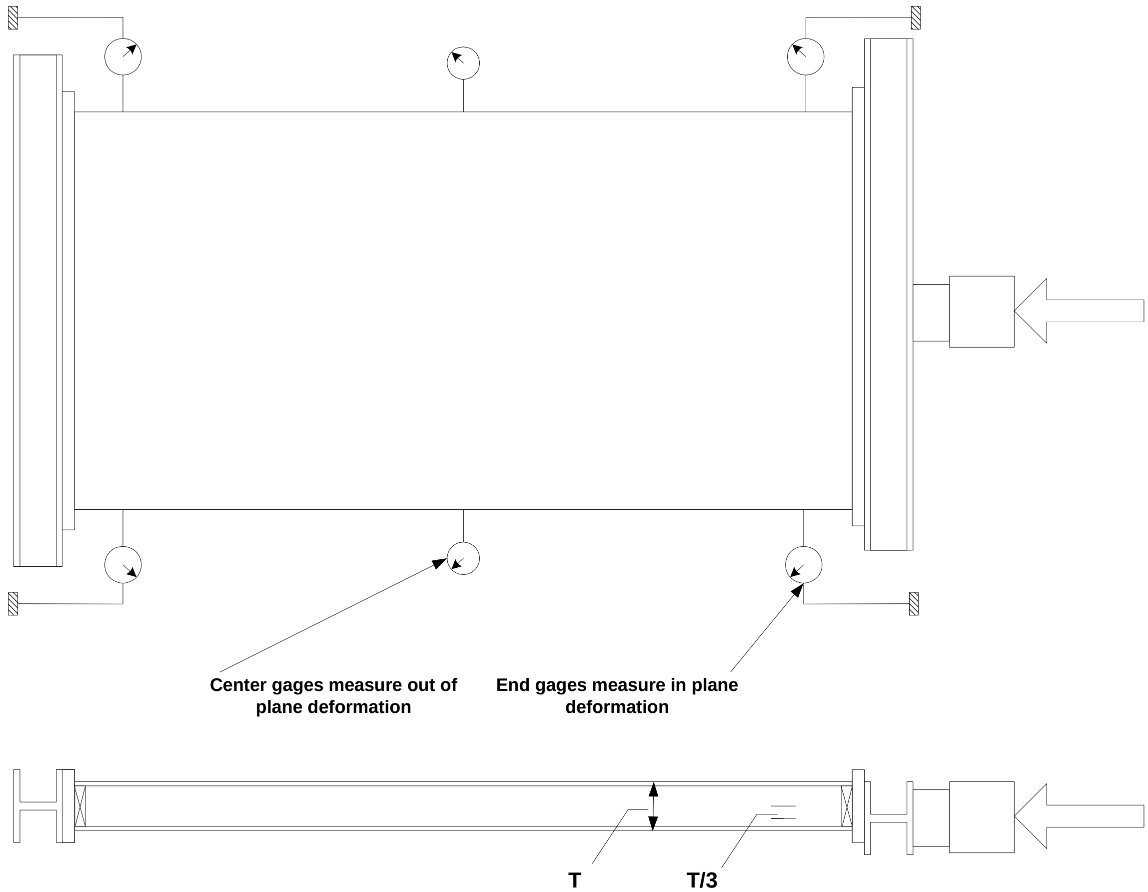

FIGURE B2. AXIAL (COMPRESSION) LOAD TEST ASSEMBLY

FIGURE B3. AXIAL (COMPRESSION) LOAD TEST ASSEMBLY

FIGURE B4. AXIAL (COMPRESSION) LOAD TEST ASSEMBLY – LOAD HEAD WITH INSTRUMENTATION

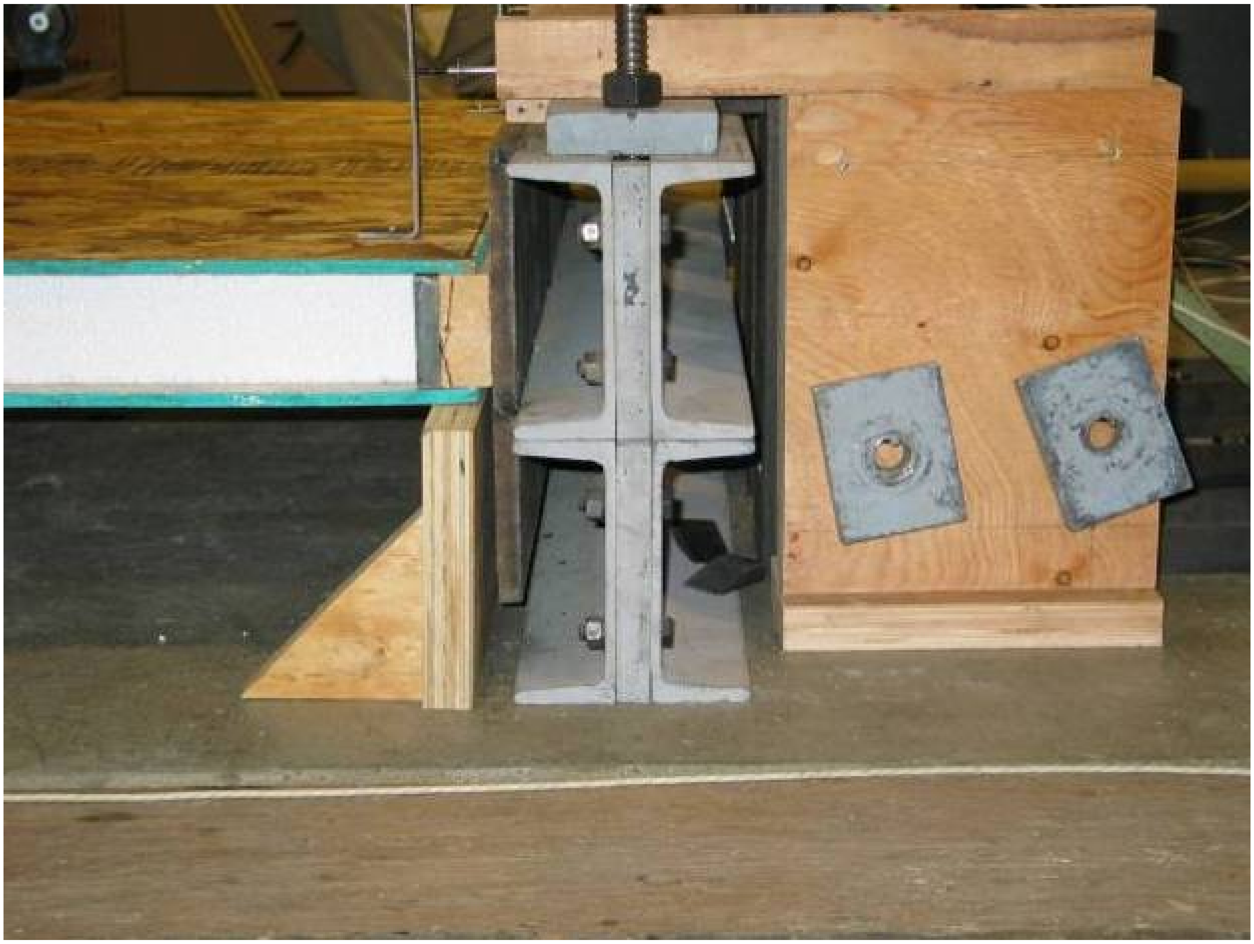

FIGURE B5. AXIAL (COMPRESSION) LOAD TEST ASSEMBLY – REACTION BEAM

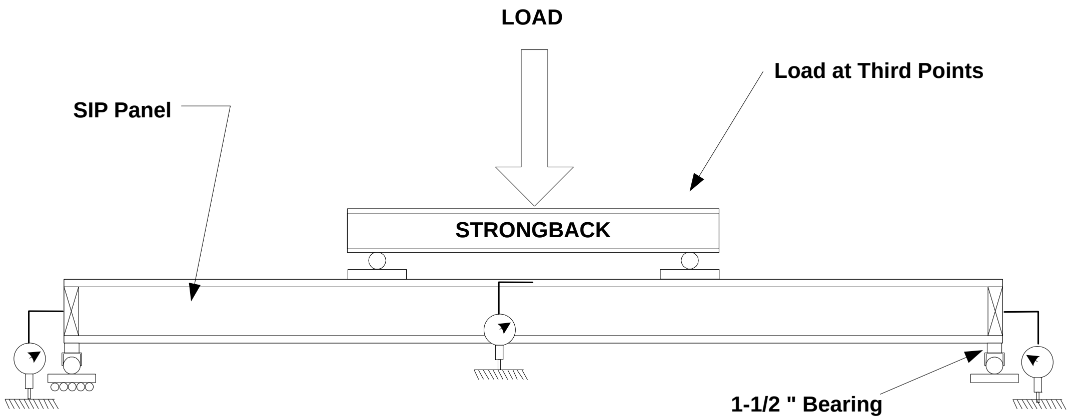

FIGURE B6. TRANSVERSE LOAD TEST ASSEMBLY

FIGURE B7. TRANSVERSE LOAD TEST ASSEMBLY

FIGURE B8. TRANSVERSE LOAD TEST ASSEMBLY –THIRD-POINT LOADING APPARATUS WITH INSTRUMENTATION

Appendix C: Failure Modes of Test Assemblies (5 pages)

FIGURE C1. RACKING SHEAR TEST FAILURE
(Nails tear away from center spline)

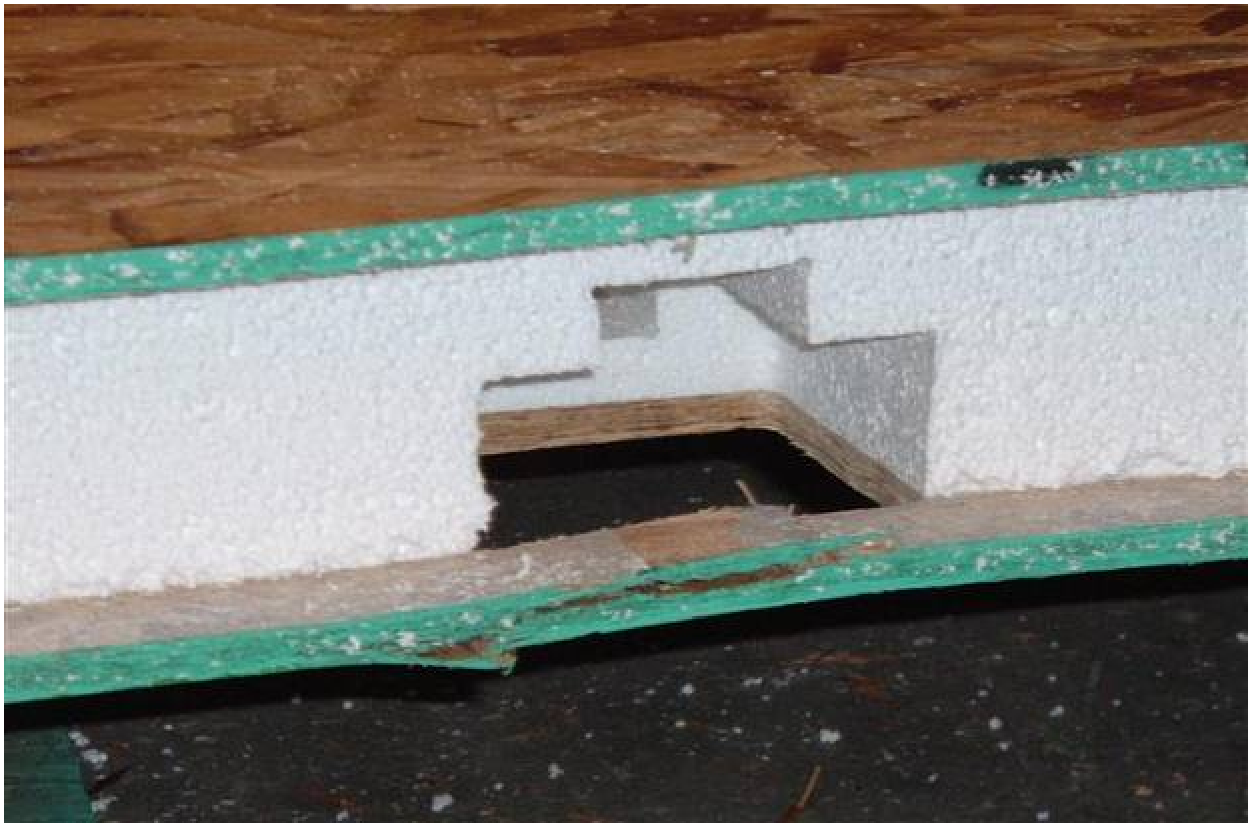

FIGURE C2. AXIAL LOAD (COMPRESSION) TEST
(Initial buckling failure on compression side through electrical chase holes - typical)

FIGURE C3. AXIAL LOAD (COMPRESSION) TEST
(Fully propagated shear failure through foam propagated from horizontal electrical chase at bottom edge of panel - typical)

FIGURE C4. TRANSVERSE LOAD TEST
(Initial failure on tension side at electrical chase holes - typical)

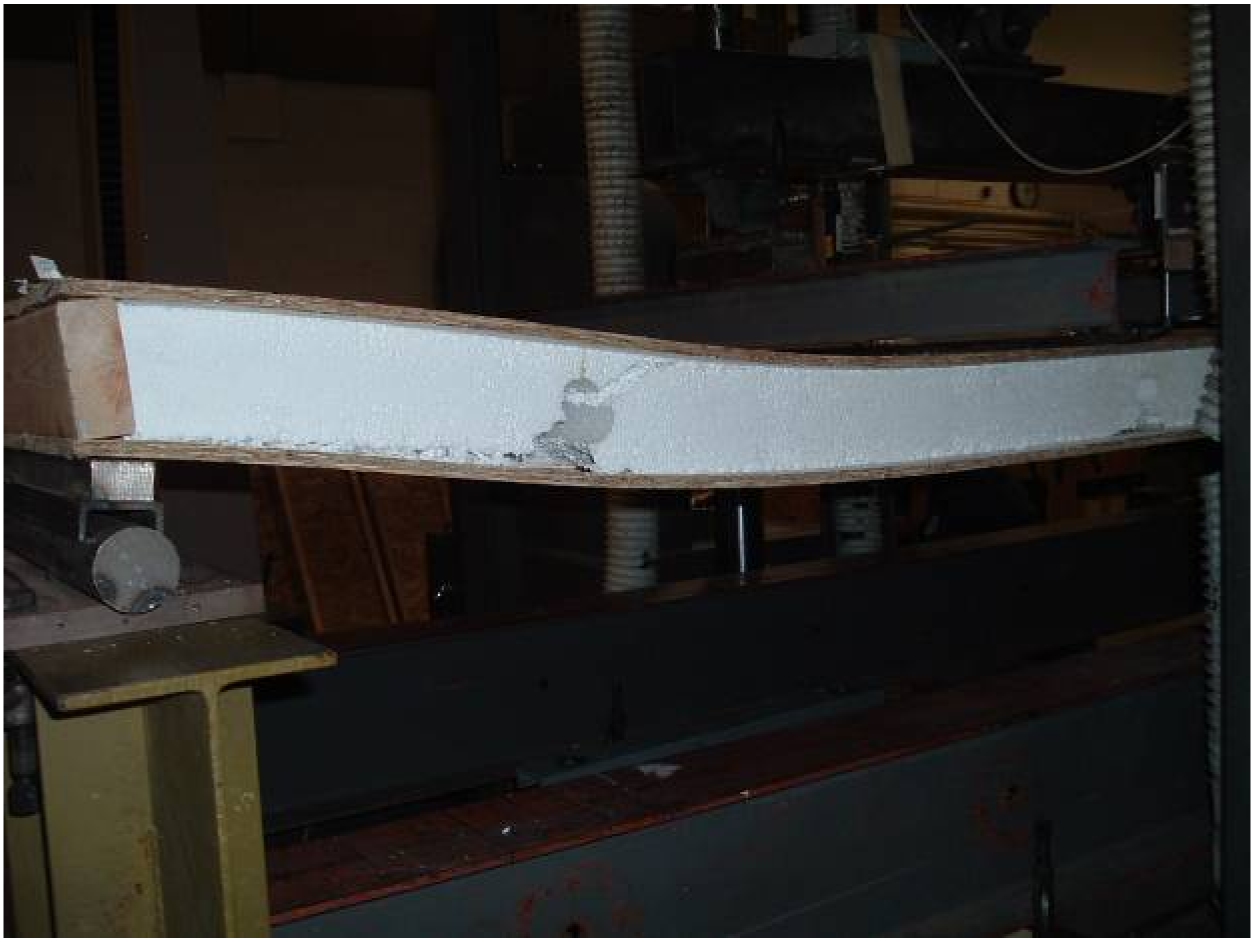

FIGURE C5. TRANSVERSE LOAD TEST
(Fully propagated failure on tension side at electrical chase holes - typical)