Recent Research to Expand the Engineering Knowledge Base for SIPs

2017 TFEC Symposium
Madison, WI

Tom Williamson, P.E., Timber Engineering, LLC
Chair, SIPA Technical Activities Committee
Code Recognition of SIPs

- IRC – Section R613 for SIP Walls
  Limited to 2 story construction, 10 ft walls,
  40 ft. x 60 ft. footprint, seismic categories A, B, C
- IBC – no mention of SIPs
- NDS – no mention of SIPs
- SPDWS – no mention of SIPs
- ICC-ESR – several manufacturers have reports
- NTA Code Report – multiple manufacturers listed
Use of Structural Insulated Panels (SIPs) in Seismic Design Categories

- Section R613 of the 2009 International Residential Code (IRC), Structural Insulated Panel Wall Construction, has limits for the use of SIPs. Section R613.2 Applicability Limits states that SIPs shall be limited to sites subjected to seismic design categories A, B or C.

- In accordance with Section R301.1.3, a building that contains structural elements not conforming to the prescriptive limits of the code is acceptable if designed in accordance with accepted engineering practice. Also, Section R104.11 permits the use of SIP wall construction beyond the applicable limits of Section R613.2.

- ICC-ES publishes evaluation reports in compliance with the ICC ES AC04 Acceptance Criteria for Sandwich Panels. AC04 Appendix A Section 4.5.1 says that structural insulated panels evaluated in accordance with the requirements set forth in Appendix A are permitted to be used as shear walls in all Seismic Design Categories.
Recent SIP Research

- Joint FPL/APA/SIPA creep testing project
- Joint FPL/SIPA creep testing project
- Joint FPL/APA/SIPA testing of SIP shear wall performance
- Joint FPL/SIPA/HIRL aspect ratio and walls with openings testing
- Joint FPL/SIPA aspect ratio and walls with openings testing
- Joint FPL/APA/SIPA diaphragm testing
Creep Testing – APA/FPL/SIPA Pilot Study

Results published as FPL Research Note FPL–RN–0332

No significant strength loss (Pmax) was observed after 90 days of creep loading and 30 days of unloading.
Specimens tested under both shear critical (APA) and moment critical loading (FPL) configurations using 3 load levels as shown.

Recovered approximately 95% of the creep deflection after 30 days relaxation.

Results led to Phase II test program.
# Phase II - 2015/2016 Joint FPL/SIPA Creep Testing of SIPs

## Test Matrix

<table>
<thead>
<tr>
<th>Test #</th>
<th>Sample Depths</th>
<th>Sample Width(a)</th>
<th>Span(a)</th>
<th>Load Level</th>
<th># of Samples</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6-1/2 in.</td>
<td>12 in.</td>
<td>118.5&quot;</td>
<td>To failure</td>
<td>28</td>
<td>1 min.</td>
</tr>
<tr>
<td>1a</td>
<td>6-1/2 in.</td>
<td>12 in.</td>
<td>118.5&quot;</td>
<td>350 lbs.</td>
<td>28</td>
<td>90 days</td>
</tr>
<tr>
<td>2</td>
<td>12-1/4 in.</td>
<td>12 in.</td>
<td>226.5&quot;</td>
<td>To failure</td>
<td>28</td>
<td>1 min.</td>
</tr>
<tr>
<td>2a</td>
<td>12-1/4 in.</td>
<td>12 in.</td>
<td>226.5&quot;</td>
<td>350 lbs.</td>
<td>28</td>
<td>90 days</td>
</tr>
</tbody>
</table>

FPL $100,000  SIPA Test Panels
2015/2016 FPL Creep Testing of SIPs
Short Term Bending Tests

Short term bending testing of twenty-eight 12-1/4” deep specimens and twenty-eight 6-1/2” deep specimens completed to determine test loads for creep testing
2015/2016 FPL Creep Testing of SIPs
Short Term Bending Tests

Typical Static Bending Failure (12-1/4”)

Typical Static Bending Failure (6-1/2”)

SIPA Structural Insulated Panel Association
## 2015/2016 FPL Creep Testing of SIPs

### Short Term Bending Tests – Control Specimens

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Quantity</th>
<th>PMax (lbf)</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>5% PE = mean - 1.645 * std. dev.</th>
<th>5% PTL with 75% confidence = mean – 1.878 * std. dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-1/2”</td>
<td>28</td>
<td></td>
<td>1031.8</td>
<td>85.9</td>
<td>901.5</td>
<td>870.5</td>
</tr>
<tr>
<td>12-1/4”</td>
<td>28</td>
<td>1013.6</td>
<td>68.2</td>
<td>901.5</td>
<td>885.6</td>
<td></td>
</tr>
</tbody>
</table>

Creep Test Load = PMax/3 ~ 350 lbs
2015/2016 FPL Creep Testing of SIPs

90 day testing of twenty-eight 12-1/4” deep specimens and twenty-eight 6-1/2” deep specimens under creep load completed + 30 days with load removed
2015/2016 FPL Creep Testing of SIPs Creep Deflection Curves

CREEP DEFLECTION OVER TIME, 12-1/4" DEEP SPECIMENS

12-1/4" Specimens
2015/2016 FPL Creep Testing of SIPs
Creep Deflection Recovery Curves

DEFLECTION RECOVERY AFTER REMOVAL OF LOAD,
12-1/4" DEEP SPECIMENS

12-1/4” Specimens
2015/2016 FPL Creep Testing of SIPs
Creep Deflection Curves

CREEP DEFLECTION OVER TIME,
6-1/2" DEEP SPECIMENS

DEFLECTION, INCHES

TEST TIME, DAYS

6-1/2” Specimens
2015/2016 FPL Creep Testing of SIPs
Creep Deflection Recovery Curves

DEFLECTION RECOVERY AFTER REMOVAL OF LOAD,
6-1/2” DEEP SPECIMENS

6-1/2” Specimens
## 2015/2016 FPL Creep Testing of SIPs Results

<table>
<thead>
<tr>
<th>Static failure load of control specimens, lbs</th>
<th>12-1/4&quot; Deep Specimens</th>
<th>6-1/2&quot; Deep Specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deflection of control specimens at failure, in</td>
<td>1.251</td>
<td>1.031</td>
</tr>
<tr>
<td>Initial elastic deflection at start of creep test, in</td>
<td>0.469</td>
<td>0.400</td>
</tr>
<tr>
<td>Additional deflection due to creep behavior, in</td>
<td>0.190</td>
<td>0.116</td>
</tr>
<tr>
<td>Total deflection, in</td>
<td>0.659</td>
<td>0.516</td>
</tr>
<tr>
<td>Initial elastic recovery at removal of long-term load, in</td>
<td>-0.439</td>
<td>-0.397</td>
</tr>
<tr>
<td>Additional recovery due to creep behavior, in</td>
<td>-0.094</td>
<td>-0.077</td>
</tr>
<tr>
<td>Total deflection recovered, in</td>
<td>-0.533</td>
<td>-0.474</td>
</tr>
<tr>
<td>Static failure load of post creep-tested specimens, lbs</td>
<td>916.8</td>
<td>1043.3</td>
</tr>
<tr>
<td>Deflection of post creep-tested specimens at break , in</td>
<td>1.048</td>
<td>1.140</td>
</tr>
</tbody>
</table>
## 2015/2016 FPL Creep Testing of SIPs Results

<table>
<thead>
<tr>
<th></th>
<th>12-1/4&quot; Deep Specimens</th>
<th>6-1/2&quot; Deep Specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creep deflection, as a percentage of initial elastic deflection</td>
<td>40%</td>
<td>29%</td>
</tr>
<tr>
<td>Creep deflection, as a percentage of break deflection</td>
<td>15%</td>
<td>11%</td>
</tr>
<tr>
<td>Total deflection recovery, as a percentage of total creep test deflection</td>
<td>81%</td>
<td>91%</td>
</tr>
<tr>
<td>Static bending strength of post-creep tested specimens as a percentage of control specimen strength</td>
<td>90%</td>
<td>101%</td>
</tr>
<tr>
<td>Static deflection of post-creep tested specimens as a percentage of control specimen deflection</td>
<td>84%</td>
<td>111%</td>
</tr>
</tbody>
</table>
Modeling of Creep Behavior of SIPs

Creep behavior for structural insulated panels (SIP) under flexural loading with respect to time was modeled by Taylor, et al. (1997 ASCE Journal of Structural Engineering)

Taylor examined four distinct models for creep behavior: a three, four, and five element visco-elastic model, and a power model.

\[ \Delta(t) = \Delta_0 + A_1 t^{A_2} \]
Modeling of Creep Behaviour of SIPs

Solid line is test data from 12-1/4” deep specimen.

Dotted line is power model which matches well.

But numerous questions remain to be resolved prior to final report.
SIPA/ FPL/APA test program on effects of boundary conditions on SIP shear wall performance

Project co-funded by:
- FPL ($40,000)
- APA ($8,000)
- SIPA ($5,000)

Cyclic testing of twenty-six 8x8 wall assemblies and monotonic testing of three 8x8 wall assemblies completed in July, 2016
SIP/ FPL/APA test program on effects of boundary conditions on SIP shear wall performance

Test Variables

• Test protocol (monotonic and cyclic)
• Nail size for panel connection (8d Box vs. 8d Common)
• Nail spacing (6 inches, 4 inches, and 3 inches)
• Wall bearing type (wood vs. steel bearing)
• Spline type (block spline vs. 2-2x lumber spline)
• Number of panel joints (no joint, 1 joints, 2 joints, and 3 joints)
• SIP thickness (4-1/2 inches vs. 6-1/2 inches)
• Orientation of OSB facers (strength axis horizontal vs. vertical)
• Bottom plate washer geometry (square, large round, and small round)
SIPA/ FPL/APA test program on effects of boundary conditions on SIP shear wall performance

<table>
<thead>
<tr>
<th>Test Series</th>
<th>Purpose (Compared to Basic Wall)</th>
<th>Test Assembly Size</th>
<th>Test Protocol</th>
<th>Replicates</th>
<th>SIP Segment</th>
<th>Deviation from Basic Wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Effect of test protocol</td>
<td>8' x 8'</td>
<td>ASTM E72</td>
<td>3</td>
<td></td>
<td>Monotonic test protocol</td>
</tr>
<tr>
<td>2</td>
<td>Basic wall</td>
<td></td>
<td></td>
<td>3</td>
<td></td>
<td>Basic wall configuration</td>
</tr>
<tr>
<td>3</td>
<td>Effect of nail size</td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td>8d Common (0.131” X 2-1/2”)</td>
</tr>
<tr>
<td>4a</td>
<td>Effect of nail spacing</td>
<td></td>
<td></td>
<td>2</td>
<td>4’ x 8’</td>
<td>3” nail spacing</td>
</tr>
<tr>
<td>4b</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>4” nail spacing</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Effect of spline nailing</td>
<td>8' x 8'</td>
<td>ASTM E2126</td>
<td>2</td>
<td></td>
<td>Modified basic wall configuration (12” nail spacing at spline)</td>
</tr>
<tr>
<td>6</td>
<td>Effect of spline type</td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td>(2) 2x Lumber spline</td>
</tr>
<tr>
<td>7a</td>
<td>Effect of number of panel joints</td>
<td></td>
<td></td>
<td>2</td>
<td>8’ x 8’</td>
<td>1 SIP segment (no panel joints)</td>
</tr>
<tr>
<td>7b</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>32” x 8’</td>
<td>3 SIP segments (2 panel joints)</td>
</tr>
<tr>
<td>7c</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>24” x 8’</td>
<td>4 SIP segments (3 panel joints)</td>
</tr>
<tr>
<td>8</td>
<td>Effect of SIP thickness</td>
<td></td>
<td></td>
<td>2</td>
<td>4’ x 8’</td>
<td>6-1/2” SIP thickness</td>
</tr>
<tr>
<td>9</td>
<td>Effect of sheathing orientation</td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td>Modified basic wall configuration with horizontal sheathing</td>
</tr>
</tbody>
</table>

Total number of tests 26

*Monotonic Test to be conducted using ASTM E72 and ASTM E564*
Basic Wall Test Setup

- Load Head
  - >10 x SDS Screws evenly spaced
- 4x Block Spline (provided)
- 6” o.c. nail spacing
  - (3/8” from edge)
  - Both Sides
  - 8d Box nails
- 2x6 Untreated SPF Cap Plate
  - (No.2 or Better)
- 6” o.c. nail spacing
  - (3/8” from edge)
  - Both Sides
  - 8d Box nails
- 6” o.c. nail spacing
  - (3/8” from edge)
  - Both Sides
  - 8d Box nails
- Two 2x4 end-post
  - 12 x SDS Screws
  - ~6.5” spacing staggered in both directions
- HDQ-8 Hold-down
  - 12 x SDS Screws evenly spaced
- 3/4” Bolt
  - bore 1” deep hole in foam
- 2x6 Treated SPF (or equiv.) Sill Plate (No.2 or Better)
- 3/4” Bolt
  - bore 1” deep hole in foam
- 3/4” Bolt
  - bore 1” deep hole in foam

- TEST #2
  - Cyclic Loading
  - 3 Replicates

SIPA
Structural Insulated Panel Association
Basic wall, 2 panels, 0.113-inch-diameter (8d box) nails spaced at 6 inches on center on wall perimeter.
Wall fabricated with four SIP pieces, 24 inches wide per piece. Perimeter nails of 0.113-inch-diameter nails spaced at 6 inches on center.
Example Cyclic Data

Backbone curves comparing 8d Box nails (Wall 2a) with 8d Common nails (Wall 3a).
Backbone curves comparing 8d Box nails spaced at 6 inches (Wall 2a), 3 inches (Wall 4a), and 4 inches (Wall 4b) on center.
Example Cyclic Data

Backbone curves comparing walls with 1 joint (Wall 2a), zero joints (Wall 7a), 2 joints (Wall 7b), and 3 joints (Wall 7c).
SIPA/ FPL/APA test program on effects of boundary conditions on SIP shear wall performance

Test Results

• Test protocol (monotonic and cyclic): Testing based on ASTM E72 and ASTM E2126 resulted in similar ultimate loads. Testing based on ASTM E564 and ASTM E2126 resulted in similar deflection profiles, but the ultimate load from monotonic (ASTM E564) tests was approximately 12% lower than the cyclic (ASTM E2126) tests. There is not enough evidence to conclude that ASTM E564 will result in a significantly lower ultimate load than the other test methods.

• Nail size for panel connection (8d Box and 8d Common): Data showed that there was no practical difference in the ultimate load between SIP walls constructed with these two nail sizes.

• Nail spacing (6 inches, 4 inches, and 3 inches): Data showed that a decrease in nail spacing from 6 to 4 inches and from 6 to 3 inches on center resulted in an ultimate load increase of 27% and 58%, respectively.
Test Results

• Wall bearing type (wood and rigid steel bearing): Data showed that when SIPs bear on steel, as compared to SPF bottom plates, the ultimate load was reduced by approximately 15%. However, the effect of bearing plate types on cyclic performance parameters was not significant.

• Spline type (Block spline and 2-2x lumber spline): Data showed that the difference in the ultimate load is insignificant (less than 5%).

• Number of panel joints (no joint, 1 joint, 2 joints, and 3 joints): Data showed that the number of panel joints and the aspect ratio of the individual SIP segments clearly had an effect on the cyclic performance. The more number of joints, the higher the ductility capacity of the SIP walls. As compared to 1 panel joint, zero joint resulted in an increase of around 10% in ultimate load, while 2 and 3 joints resulted in a reduction of ultimate load of 11% and 17% respectively.
Test Results

• SIP thickness (4-1/2 inches and 6-1/2 inches): Data showed that the ultimate load is similar between SIP wall thicknesses of 4-1/2 and 6-1/2 inches (less than 7%).

• Orientation of OSB facers (strength axis horizontal and vertical): Data showed that cross-oriented (horizontally oriented) facers resulted in a marginal (approximately 10%) reduction in the ultimate load, as compared to vertically oriented OSB facers.

• Bottom plate washer geometry (square and round): Data showed no difference between large and standard round washers. However, the squared washers showed a 13% higher ultimate load. However, since the failure modes were often associated with the top plate, but virtually never associated with the bottom plate, the difference in the ultimate load between squared and round washers is recommended to be further studied.
SIP Shear Walls: Cyclic Performance of High Aspect Ratio Segments and Perforated Walls

Forest Product Laboratory Forest Service U.S. Department of Agriculture Madison, Wisconsin $100,000

Structural Insulated Panel Association Gig Harbor, Washington SIP Test Panels

October 1, 2013 Report 3339_10012013
Wall Aspect Ratios for SIPs

Prescriptive Braced Wall Segments

Section R613.5.3 of the 2012 IRC states that SIP walls shall be considered as “continuous wood structural panel sheathing” (CS-WSP method) for purposes of computing required wall bracing. Therefore, a SIP wall following the prescriptive requirements of the 2012 IRC can have a braced length as narrow as 24 in. or an aspect ratio of 4:1 under certain circumstances such as garage doors in low SDCs or applications next to windows up to and including 64 in. in height, or an aspect ratio of 3:1 adjacent to full height door openings up to 80 in. without limit.

Engineered Shear Walls

There is no specific mention of SIPs as a wall sheathing type in Table 4.3.4 and an interpretation whether the SIP can be considered as a blocked wood structural panel system is necessary.
HIRL/FPL/SIPA Test Program
Aspect Ratios

<table>
<thead>
<tr>
<th>Size</th>
<th>Aspect Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 x 8</td>
<td>AR = 1:1</td>
</tr>
<tr>
<td>4 x 8</td>
<td>AR = 2:1</td>
</tr>
<tr>
<td>2.67 x 8</td>
<td>AR = 3:1</td>
</tr>
<tr>
<td>2 x 8</td>
<td>AR = 4:1</td>
</tr>
</tbody>
</table>
HIRL/FPL/SIPA Test Program
Aspect Ratios

![Aspect Ratio Graph]

- Config 1
- Config 2
- Config 3
- Config 4

**Unit Shear (lb/ft)**

**Aspect Ratio**
HIRL/FPL/SIPA Test Program
Aspect Ratios

![Unit Stiffness vs Aspect Ratio Graph]

- **Unit Stiffness (lb/ln/ft)**
- **Aspect Ratio:** 1:1, 1:2, 1:3, 1:4
- **Configurations:**
  - Config 9
  - Config 3SP-C
  - Config 2
  - Config 1
  - Config 4

Graph showing the decrease in unit stiffness as the aspect ratio increases.
HIRL/FPL/SIPA Test Program
Walls with Openings
HIRL/FPL/SIPA Test Program
Walls with Openings

Shear Strength Ratio (Config 1_{SPL-C} Baseline)

Shear Strength Ratio

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

r, Sheathing Area Ratio

Config 6
Config 8
Config 7
Config 5

r

3-2r
HIRL/FPL/SIPA Test Program
Walls with Openings

Shear Stiffness Ratio (Config 1_{SPL-C Baseline})

- Config 6
- Config 5
- Config 7
- Config 8

Shear Stiffness Ratio vs. $r$, Sheathing Area Ratio

$3 - 2r$
1. The measured unit shear capacity for fully-anchored SIP shear wall segments ranged from 1,400 lb/ft to over 2,100 lb/ft depending on the segment’s aspect ratio.

2. The unit shear wall capacity and stiffness of SIP shear wall segments decreased with an increased number of panels jointed with a spline connection. A 25 percent decrease in unit shear was observed for a 20-foot wall with four spline joints compared to an 8-foot wall with one spline joint.

3. The unit shear wall capacity of SIP shear wall segments decreases with an increased segment’s aspect ratio with a 16 percent decrease for a 2-foot segment as compared to a 4-foot segment.

4. The test results indicate that perforated SIP shear walls closely follow the overall PSW method trend for both strength and stiffness.
FPL/SIPA Aspect Ratio and Walls with Opening Testing

- Extension of HIRL Study in 2013: *SIP Shear Walls: Cyclic Performance of High Aspect Ratio Segments and Perforated Walls*

- HIRL study demonstrated that a SIP perforated shear wall performs like a traditional perforated shear wall but more testing needed.

- FPL staff and SIPA member representatives developed study plan to incorporate testing of 54 SIP wall assemblies

- FPL $200,000  SIPA provided all SIP test panels

- Testing completed April 2017
# FPL/SIPA Aspect Ratio and Walls with Opening Testing

## Test Plan

### Summary of Structural Insulated Panel Lateral Wall Tests

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Item Description</th>
<th>No of Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aspect Ratio Tests With Anchor Bolts Only</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SP128A</td>
<td>2 by 8 SIP Panel Wall Test - Anchor Bolts Only</td>
<td>3</td>
</tr>
<tr>
<td>SP138A</td>
<td>2 ½ by 8 SIP Panel Wall Test - Anchor Bolts Only</td>
<td>3</td>
</tr>
<tr>
<td>SP148A</td>
<td>4 by 8 SIP Panel Wall Test - Anchor Bolts Only</td>
<td>3</td>
</tr>
<tr>
<td>SP188A</td>
<td>8 by 8 SIP Panel Wall Test - Anchor Bolts Only</td>
<td>3</td>
</tr>
<tr>
<td><strong>Aspect Ratio Tests With Hold Downs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SP128H</td>
<td>2 by 8 SIP Panel Wall Test - Hold downs</td>
<td>3</td>
</tr>
<tr>
<td>SP138H</td>
<td>2 ½ by 8 SIP Panel Wall Test - Hold downs</td>
<td>3</td>
</tr>
<tr>
<td>SP148H</td>
<td>4 by 8 SIP Panel Wall Test - Hold downs</td>
<td>3</td>
</tr>
<tr>
<td>SP188H</td>
<td>8 by 8 SIP Panel Wall Test - Hold downs</td>
<td>3</td>
</tr>
<tr>
<td><strong>Multiple SIP Panel Wall Tests Without Openings</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SP248A</td>
<td>8 by 8 SIP Wall constructed with 2 - 4 by 8 Panels (Anchored)</td>
<td>3</td>
</tr>
<tr>
<td>SP348A</td>
<td>8 by 12 SIP Wall constructed with 3 - 4 by 8 Panels (Anchored)</td>
<td>3</td>
</tr>
<tr>
<td>SP548A</td>
<td>8 by 20 SIP Wall constructed with 2 - 4 by 8 Panels (Anchored)</td>
<td>3</td>
</tr>
<tr>
<td><strong>Multiple SIP Panel Wall Tests With Various Openings Sizes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SP5201</td>
<td>8 by 20 SIP Wall with openings - Configuration 1</td>
<td>3</td>
</tr>
<tr>
<td>SP5202</td>
<td>8 by 20 SIP Wall with openings - Configuration 2</td>
<td>3</td>
</tr>
<tr>
<td>SP5203</td>
<td>8 by 20 SIP Wall with openings - Configuration 2</td>
<td>3</td>
</tr>
<tr>
<td>SP5204</td>
<td>8 by 20 SIP Wall with openings - Configuration 4</td>
<td>3</td>
</tr>
<tr>
<td>SP5205</td>
<td>8 by 20 SIP Wall with openings - Configuration 5</td>
<td>3</td>
</tr>
<tr>
<td>SP5206</td>
<td>8 by 20 SIP Wall with openings - Configuration 6</td>
<td>3</td>
</tr>
<tr>
<td>SP5207</td>
<td>8 by 20 SIP Wall with openings - Configuration 7</td>
<td>3</td>
</tr>
</tbody>
</table>

**Maximum Number of Lateral Shear Wall Tests:** 54
FPL/SIPA Aspect Ratio Testing

General Notes:
- Wall Heights: 8'
- Wall Thickness: 6 1/2 in.
- 8d box nails (0.113-in by 2 1/2 in.)
- All framing No. 2 or better SPF
  - 2 - 2 by 6 End Studs
  - 2 by 6 Top and Bottom Plates
  - 2 by 8 Cap Plate (Trimmed)
  - 2 by 8 Sill Plate (Trimmed)
- 1/4-inch anchor bolts with round washers attached only to sill plate
- 8d common nail (0.131-in by 2 1/2 in) fasten sill and bottom plate
- Simpson strong-tie hold downs sized for test

Detail of SIP Wall Test Fabrication
FPL/SIPA Aspect Ratio Testing

General Notes:
- Wall Heights: 8'
- Wall Thickness: 6 1/2 in.
- 8d box nails (0.113-in by 2 1/2 in.)
- All framing No. 2 or better SPF
  - 2 by 2 by 6 End Studs
  - 2 by 6 Top and Bottom Plates
  - 2 by 8 Cap Plate (Trimmed)
  - 2 by 8 Sill Plate (Trimmed)
- 3/4" diameter anchor bolts with round washers attached only to sill plate
- 8d common nails (0.131-in by 2 1/2 in) fasten sill and bottom plate
- Simpson strong-tie hold downs sized for test

4 by 8 SIP Wall Test

8 by 8 SIP Wall Test

Detail of SIP Wall Test Fabrication
FPL/SIPA Aspect Ratio Testing

8x8 wall test with hold downs

8x8 wall test with anchor bolts
Comparison of APA and FPL tests for 8x8 walls
Comparison of use of hold downs vs. anchor bolts only for 8x8 walls
FPL/SIPA Walls with Openings Testing

General Notes:
- Wall Heights: 8'
- Wall Thickness: 6 1/2 in.
- 1/4-in. nails (0.133-in by 2 1/2 in.)
- All framing No. 2 or better SPF
- 2 - 2 by 8 End Studs
- 2 by 6 Top and Bottom Plates
- 2 by 8 Top Plate (Trimmed)
- 2 by 8 Sill Plate (Trimmed)
- 3/4-inch anchor bolts with round washers attached only to sill plate
- 1/4-inch common nail (0.133-in by 2 1/2 in) fastens sill and bottom plate
- Simpson strong tie hold downs sized for test
- Box spline with #8 box nails or 6-in. nails

Detail of SIP Wall Block Spline

5 - 4 by 8 SIP Blocked Spline Wall Test

Detail of SIP Wall Test Fabrication

SIPA - Structural Insulated Panel Association
FPL/SIPA Walls with Openings Testing

General Notes:
- Wall Heights: 8'
- Wall Thickness: 6 1/2 in.
- 8d box nails (0.56-in by 2 in.)
- All framing No. 2 or better SPF
- 2 - 2 by 6 End Studs
- 2 by 6 Top and Bottom Plates
- 2 by 6 Cap Plate (Trimmed)
- 2 by 8 Stud Plate (Trimmed)
- 5/8" diameter anchor bolts with round washers attached only to sill plate
- 1d common nail (0.138-in by 2 1/2 in.) fastens sill and bottom plate
- Surface-stripping tie held downs sized for test
- Box spline with 8d box nails at 6 in. cc

5 - 4 by 8 SIP Multiple Opening Shear Wall Test - Configuration 1

5 - 4 by 8 SIP Multiple Opening Shear Wall Test - Configuration 2

Framing Detail Above Opening

Structural Insulated Panel Association
FPL/SIPA Walls with Openings Testing

8x20 wall with five 4x8 panels
FPL/SIPA Walls with Openings Testing

8x20 wall with single opening
FPL/SIPA Walls with Openings Testing

8x20 wall with two openings
SIPA/ FPL/APA test program on SIP diaphragm performance

FPL $40,000, APA $8,000  SIPA $4,000

12 full-size SIP diaphragms of various configurations that will cover a range of variables as follows:

1. Effect of longitudinal SIP joint (no joint vs. 1 joint)
2. Effect of transverse SIP joint (no joint, 1 joint vs. 2 joints)
3. Inclusion of framing connections (with and without SIP screws)
4. SIP screw spacing (6” o.c. vs. 3” o.c.) between and within Series 1A and 5A
SIPA/ FPL/APA test program on SIP diaphragm performance

Test Variables

Part I: SIP diaphragms without framing

Objective: The purpose of this part is to evaluate the SIP diaphragm capacities without SIP screw connections to framing.

- Commonality for all test series in Part I:
- Assembly size: 8’ x 24’
- SIP thickness: 8-1/4”
- Fastener spacing to SIP plates: 8d cooler (2-5/16” x 0.113”) nails at 6” o.c.
- Test protocol: ASTM E455 (Monotonic)
SIPA/ FPL/APA test program on SIP diaphragm performance

Test Variables

Part I: SIP diaphragms without framing
Series 1 (Base configuration)
1) SIP segment size: 8’ x 24’
2) Spline type: None
3) Number of tests: 1
SIPA/ FPL/APA test program on SIP diaphragm performance

Test Variables

Part I: SIP diaphragms without framing

Series 5

• SIP segment size: 4’ x 8’
• Spline type: Block spline for SIP joints
• Number of tests: 1

![Diagram of SIP segments and joints]

- Longitudinal SIP joint
- Transverse SIP joint
- Series 5
SIPA/ FPL/APA test program on SIP diaphragm performance

Test Variables

Part II: SIP diaphragms with framing

Objective: The purpose of this part is to evaluate the SIP diaphragm capacities with framing and framing screws.

Commonality for all test series in Part II

1. Assembly size: 8’ x 24’
2. SIP thickness: 8-1/4”
3. Fastener spacing to SIP plates: 8d cooler (2-5/16” x 0.113”) nails at 6” o.c.
4. Framing materials: 4x6 No. 2 or Better SPF
5. SIP screws: 6” o.c. (brand and size will be selected later) except for Series 1A and 5A
6. Test protocol: ASTM E455 (Monotonic)
SIPA/ FPL/APA test program on SIP diaphragm performance

Test Variables

Part II: SIP diaphragms with framing

Series 1A (Base configuration)

- SIP segment size: 8’ x 24’
- Spline type: None
- SIP screws: 6” o.c. and 3” o.c. (1 test each)
- Number of tests: 2
Test Variables

Part II: SIP diaphragms with framing

Series 5A

- SIP segment size: 4’ x 8’
- Spline type: Block spline for SIP joints
- SIP screws: 6” o.c. and 3” o.c. (1 test each)
- Number of tests: 2
The completed ASTM Standard on SIPs will provide a single test standard for which SIPs can be evaluated. Draft document in process at ASTM D07.02.08 Section Committee level. Numerous ballots completed. After Section Committee level approval the standard will be balloted at the ASTM D07.02 Subcommittee level. Once it passes the D07.02 Subcommittee it will be submitted to the main ASTM D07 committee for balloting.
SIPA Design Guide Development on schedule with NTA

4 year project which also includes developing software for the design of SIPs

TAC Task Group reviewed Design Guide

Members of SIPA invited to provide input to NTA
CLT Plies and Layers

Alternate plies and layers

Transverse Planks

Longitudinal Planks
CLT Cross Section

- Perpendicular Layer
- Parallel Layer

Strength Axis of CLT
Examples of CLT Configurations

- 3-ply 3-layer
- 5-ply 3-layer
- 5-ply 5-layer
- 7-ply 5-layer
- 6-ply 5-layer
- 8-ply 5-layer
- 9-ply 9-layer
- 9-ply 7-layer
Typical CLT Dimensions

- **Length:** 8 ft up to 40 ft or more (> 20‘ is common)
- **Width:** 4 ft up to 12 ft (8 ft is common)
- **Thickness:** 2 inches up to 20 inches (multiples of 1-3/8“ laminations are typical)

Approved by ANSI in December 2011

Current version is PRG 320-2012

Download at www.apawood.org
2015 Building Code
Multi-Story CLT Buildings in the U.S.

4 Story CLT Hotel at US Army Redstone Arsenal

4 Story Albina Yard Office Building Portland, OR
Tall CLT Buildings - U.S.

Framework Project
Portland, OR
12 stories - 130 ft.

2 stories of retail
5 stories of offices
5 stories of residential

All glulam and CLT framing with CLT exposed at all levels
Framework Project - Portland, OR
Recent Research to Expand the Engineering Knowledge Base for SIPs

Questions ??

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Finn Hill Jr. High School
Finn Hill Jr. High School