WIND PRESSURE TESTING OF WALL ASSEMBLIES WITH FOAM SHEATHING AND VINYL SIDING PRODUCTS

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Purpose and Scope

The purpose of this test program is to provide data on the wind pressure resistance of wall assemblies using foam sheathing and vinyl siding. In addition, the data is intended to help develop and verify a performance-based design methodology for the application of vinyl siding with foam sheathing. The testing procedure and results are intended to be used for the purpose of evaluating existing building code requirements as well as potential product development and code evaluation purposes.

The scope of this work includes the following:

- Positive pressure tests of various foam sheathed 2x4 wall panels using a modified version of ASTM Test Method D 5206-06a Procedure B to obtain ultimate positive test pressure and deflection
- Negative pressure tests of vinyl clad wall panels and foam-vinyl clad panels using a modified version of ASTM Test Method D 5206-06a, Procedure B to obtain ultimate negative test pressure and deflection
- Flexural testing of foam sheathing samples using ASTM Test Method C203-05a, Method 1, Procedure D, to obtain flexural properties of the foam products

The basic test plan detailing the specific types of materials and combinations for testing was provided by the Foam Sheathing Coalition.

Methods and Materials

All sheathing and siding materials were sampled either directly from production at the manufacturing facility by an NAHB Research Center representative, or from purchasing through a local supplier. Lumber and hardware used for this testing was purchased through local suppliers. All lumber used was number 2 grade spruce-pine-fir (SPF) 2x4s.

For this testing program, 8 different brands of foam sheathing were sampled and tested in accordance with the test plan shown in Table 1. These varieties were divided into three types of foam and thicknesses. They were as follows:

- *½" Foil-Faced, Preformed, Rigid Cellular Polyisocyanurate* (ISO) complying with ASTM C1289-06 (Type 1, Class 1)
    - Atlas – ½" Energy Shield with foil facers
    - Rmax – ½" R-Matte Plus-3 with foil facers
    - Dow – ½" Super Tuff-R with foil facers
- *3/8" Expanded Polystyrene* (EPS) complying with ASTM C578-07 (one Type VIII with density of 1.29 pcf and one Type IX with density of 2.05 pcf)
    - Premier – 3/8" R-Tech insulating sheathing with nominal 1.2mil polymeric facers
    - Atlas/Falcon Foam – 3/8" Falcon insulating sheathing with nominal 1.2mil polymeric facers
- 1/2*" Extruded Polystyrene* (XPS) complying with ASTM C578-07 (Type X, 1.3 pcf density)

- Pactiv – ½" GreenGuard® Insulative Sheathing (nominal 1.2mil polymeric facers)
- Owens Corning – ½" FOAMULAR® Insulating Sheathing (IS) (nominal 1.2mil polymeric facers)
- Dow – ½" Styrofoam® Residential Sheathing (nominal 1.2mil polymeric facers)

All foam sheathing was in sheets of 48" x 96" dimensions.

Two different vinyl siding types (a double lap and triple lap horizontal siding product) were used for the negative pressure testing portion of the program as shown in Table 1. They were classified based on their reported pressure resistance rating in accordance with ASTM D3679. They were categorized as lower (Product A) and higher (Product B) pressure rated siding representing a typical upper and lower bound of rated siding available on the market.

Table 1. Study Matrix for Negative and Positive Pressure Testing

Specimen Configurations		Test Repetitions		Comments
Foam Sheathing Product Type	**Vinyl Siding Type**	**Neg. Pressure[2]**	**Pos. Pressure[2]**	
None	Product A	3	0	These tests confirm a baseline performance of siding without foam sheathing per ASTM D5206 and ASTM D3679 with OSB backer
	Product B	3	0	
½" ISO	None	0	2	The test results are grouped for a total of 3 reps for each siding type in negative pressure tests and 6 reps in positive pressure tests comprising all sampled ISO sheathing brands
	Product A	1	0	
	Product B	1	0	
½" ISO	None	0	2	
	Product A	1	0	
	Product B	1	0	
½" ISO	None	0	2	
	Product A	1	0	
	Product B	1	0	
3/8" EPS	None	0	3	The test results are grouped for a total of 4 reps for each siding type in negative pressure tests and 6 reps in positive pressure tests comprising all sampled EPS sheathing brands
	Product A	2	0	
	Product B	2	0	
3/8" EPS	None	0	3	
	Product A	2	0	
	Product B	2	0	
½" XPS	None	0	2	The test results are grouped for a total of 3 reps for each siding type in negative pressure tests and 6 reps in positive pressure tests comprising all sampled XPS sheathing brands
	Product A	1	0	
	Product B	1	0	
½" XPS	None	0	2	
	Product A	1	0	
	Product B	1	0	
½" XPS	None	0	2	
	Product A	1	0	
	Product B	1	0	

Test Equipment

Pressure Chamber

The apparatus used to perform positive and negative pressure testing on the wall assemblies consists of a sealed box made from dimensional lumber and sheathing, and conforms to ASTM D5206-06a protocol. The box can be modified to have an opening that varies with the dimensions of the test sample. The test samples lie horizontally over the opening, supported by two ledges inside the box. The samples are sealed to the test chamber box with a plastic membrane. A hose links the interior of the chamber with a single speed blower that can pressurize or depressurize the chamber. For this test program, the chamber was depressurized for both positive and negative pressure testing. Pressure in the chamber is controlled through use of variable valves that adjust the flow from the box. These valves are in turn adjusted electronically through use of a computer based data acquisition and control software program. This software monitors the pressure in the box though a pressure transducer and controls valve adjustments, also serving as the primary recording center for test data. Additionally, to record deflection of test samples, linear displacement sensors were mounted to a rack above each stud and outside stud bays of each test sample. The data acquisition software also controls and records the output of the linear displacement sensors.

Figure 1. Pressure Chamber used for pressure testing. The blower is located in the upper right of the photo, with the linear displacement sensor rack and DAQ control computer in the upper center of the figure

Flexural Testing Apparatus

To perform the flexural testing of the foam sheathing, a Tinius Olsen H50KT Universal Testing Machine (UTM) and data acquisition and control unit were utilized. The supports and loading head were designed to ASTM C203-05a protocol, being 1-1/4” in diameter.

Test Methods

Positive Pressure Testing

For the positive pressure testing segment, test frames were assembled in the following manner. A 49.5"x 96" 2x4 wall was constructed with studs at 16" O.C. The bottom and top plates were fastened to the studs using 2-16d 3-1/2" long, 0.131" shank nails at each stud. Double top and bottom plates were used, with top plate-to-top plate being fastened with 2-10d 3" long, 0.148" shank common nails at 16" O.C., and bottom plate-to-bottom plate being fastened with a single 16d 3-1/2" long, 0.131" shank nail at 16" O.C. The frame was fabricated using a pneumatic nail gun. Foam sheathing was then laid over the frame, with marked side facing away from studs, and fastened with 1-1/4" long, 7/16" head, 0.120" shank, galvanized roofing nails at 12" O.C. on all framing members. An edge gap of 3/8" was used for the side studs and an edge gap of ¾" was used for the bottom and top plates. The sheathing was hand nailed to the frame. The sample would then be placed in the chamber in positive pressure orientation with sheathing facing away from the chamber (meaning that as the chamber is depressurized, sheathing is forced into the studs). 2 mil clear plastic sheeting was then layered over the sample as prescribed in ASTM D5206-06a and sealed using a compression frame with vice grips. The linear displacement sensor rack was then placed midway over the frame to obtain mid-span deflection of the studs and outside two stud bays.

Figure 2. Foam sheathing prepared for positive pressure test

When setup was complete, the testing procedure was initiated. Per the test method, pressure was ramped to 5 psf and held for 30 seconds before returning to zero for 1 minute. At this point all linear displacement sensors were zeroed and then pressure is increased in increments of 5 psf, holding for 30 seconds at each pressure increment before increasing again. This continued until ultimate failure of sheathing, which would manifest as permanent buckling of the sheathing or sheathing pull off from fasteners.

This process was repeated for each brand of foam sheathing, in order to obtain two positive pressure results for each brand of ISO and XPS sheathing and three positive pressure results for each brand of EPS sheathing.

Negative Pressure Testing

- ***Baseline Tests***

Baseline tests were performed in order to verify the negative pressure resistance of the siding sampled. This was done as prescribed in ASTM D5206-06a. Frames were made to measure 49.5” x 50”, and nailed in the same fashion as the positive pressure test frames. 7/16” OSB sheathing was laid over the frame and nailed to it using 8d, 2-1/2” long 0.99” shank common nails, 6” O.C. on the border and 12” O.C. in the field. 2” holes were drilled into the OSB in the center of each stud bay as per the test method. Clear plastic sheeting was then laid over the OSB per the test method. A starter strip (located to leave at least 1-1/2” of bearing support area at the bottom of the frame) and four siding panels were installed over the plastic, nailing with galvanized roofing nails at the framing members. An OSB filler panel was then used to cover the plastic between the top of the siding and top of the test frame, nailed at 6” O.C. with the same nails used to attach the sheathing to the frame. The frame was then loaded into the test chamber with the siding facing the inside of the chamber to cause the siding to pull away from the framing and OSB sheathing. The plastic was clamped in the same manner as for the positive pressure tests and the displacement sensors aligned. The test was then run as in the positive pressure test until ultimate failure (which would manifest as a siding-nail disengagement).

Figure 3. Negative baseline test sample after assembly and set in chamber for testing

Different nails and plastic sheets were used for the two different rated siding products, to ensure that nail withdrawal from sheathing and studs did not occur, and so that a high enough pressure to cause siding-fastener disengagement could be reached. For the lower rated siding, 2 mil plastic sheeting and 1-1/2” long, 3/8” head, 0.120” shank, galvanized roofing nails were used. For the higher rated siding, 4 mil plastic sheeting and 2” long, 3/8” head, 0.120” shank galvanized roofing nails were used.

Each type of siding underwent at least 3 baseline tests.

- ***Negative Foam-Vinyl System Tests***

Frames for the Negative Pressure testing of the foam-vinyl system were constructed in the exact same manner that they were for positive pressure testing, in the same dimensions of 49.5” x 96”. Plastic sheeting was then laid per the test method over the stud frame. Three inches of material was removed from the foam sheathing in the

longitudinal direction, making the sheet dimensions 48” x 93”, in order to allow the outside top and bottom plate to rest directly on the chamber bearing edge. The foam was then nailed over the plastic using the same nailing schedule and nails as in the positive pressure test (in the negative pressure test, fasteners were driven into the interior top and bottom plates). A starter strip was then applied to the bottom of the panel, and siding product was then applied, nailing at all framing members. At the top of the wall panel, a j-channel was applied and the last siding panel was the cut short in order to be tucked into the j-channel. The sample was then placed into the test chamber with the siding facing the interior of the chamber. The plastic sheeting was then sealed and the sensor rack aligned to begin the test process. The test process was the same as for the positive pressure and baseline tests. Testing continued until ultimate failure, which would manifest as a siding failure such as the baseline or sheathing failure (pull off from fastener).

Figure 4. Negative pressure foam-vinyl test sample after assembly and loaded in chamber for testing

The plastic sheeting and fasteners used were different depending on the siding. For the lower rated siding, 2 mil plastic and 2” roofing nails were used. For the higher rated siding, 4 mil plastic and 2-1/2” nails were used. The longer nails were used to prevent nail withdrawal as a failure mode. The thicker plastic sheeting was used to mitigate tearing of the plastic sheeting around the nail penetrations to enable the pressure to reach a point where the sample could reach ultimate failure.

Each ISO and XPS brand of sheathing was tested once with each type of vinyl siding. Each EPS brand of sheathing was tested twice with each type of vinyl siding.

Flexural Testing

Flexural Testing utilized the test method ASTM C203-05a in order to determine flexural properties of the foam sheathing. Three samples from each brand of foam sheathing were cut, each from a separate sheet. Samples were cut to fit within the guidelines of the test method. Sheathing of ½” nominal thickness was cut into a 10”x8” sample and sheathing of 3/8” nominal thickness was cut into an 8”x6” sample. The longer dimension corresponded to how the sheathing would span across the studs of a framed wall. The sample was then placed in the test apparatus, centered and leveled, with the exterior side of the sheathing (if applicable) facing the loading head. The span utilized was 6”

and 8" for the nominal thickness 3/8" and ½" sheathing, respectively. The test method protocol was then followed, with a constant load head traversing rate of 0.625 in/min. The test ended when either a 50% load drop off was detected or the deflection reached 1/5th of the span, which was 1.2" and 1.6" for the 3/8" and ½" foam, respectively. The Tinius Olsen control and DAQ software recorded load and deflection information.

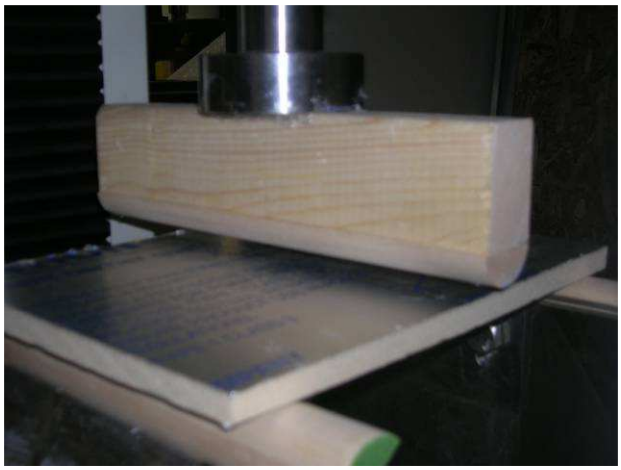

Figure 5. Flexural test sample placed on supports before testing

Table 2 below summarizes the parameters used in all the testing.

Table 2. Pressure Test Specimen Details

Test Type	Positive Pressure	Negative Pressure baseline	Negative pressure System
Framing	49.5"x96" 2x4 at 16"OC, double top and bottom plates	49.5"x50" 2x4 at 16"OC, double top and bottom plates	49.5"x96" 2x4 at 16"OC, double top and bottom plates
Frame Fasteners	Stud to plates 2-16d 3-1/2" 0.131" shank, bottom plate-to-plate 1-16d 3-1/2" 0.131" shank @16"OC, top plate-plate 2-10d 3" 0.148" shank @16"OC	Stud to plates 2-16d 3-1/2" 0.131" shank, bottom plate-to-plate 1-16d 3-1/2" 0.131" shank @16"OC, top plate-plate 2-10d 3" 0.148" shank @16"OC	Stud to plates 2-16d 3-1/2" 0.131" shank, bottom plate-to-plate 1-16d 3-1/2" 0.131" shank @16"OC, top plate-plate 2-10d 3" 0.148" shank @16"OC
Sheathing	Foam	OSB	Foam
Sheathing Fastener	1-1/4", 3/8" head, 0.120" shank electro galvanized roofing nails at 12"OC on all framing member	8d 2-1/2" 0.99" shank @6"OC around border and 12"OC in field	1-1/4", 3/8" head, 0.120" shank electro galvanized roofing nails at 12"OC on all framing member
Plastic Sheeting	2 mil over foam and frame	lower siding: 2 mil, higher siding: 4 mil, between OSB and siding	lower siding: 2 mil, higher siding: 4 mil, between frame and sheathing
Siding Fastener	N/A	lower: 1-1/2" higher: 2", 3/8" head 0.120" shank galvanized roofing nails at every stud	lower: 2" higher: 2-1/2", 3/8" head 0.120" shank galvanized roofing nails at every stud

Results

The results for each type of testing have been summarized to provide an overview of product performance for each type of foam sheathing tested.

Table 3. Summary of Positive Pressure Test Results for Foam Sheathing

	EPS	ISO	XPS
Avg Peak Press (psf)	**14.77**	**44.88**	**48.03**
Std-dev (psf)	3.30	0.72	9.68
COV	0.22	0.02	0.20
AvgDefl at 50%Peak(in)	**0.75**	**0.31**	**1.27**
Std-dev (in)	0.09	0.26	0.26
COV	0.12	0.84	0.20
Avg Defl. At Peak (in)	**1.50**	**1.31**	**2.09**
Std-dev (in)	0.17	0.66	0.36
COV	0.12	0.51	0.17

EPS - two products (3 reps each), 3/8 thick
ISO - three products (2 reps each), 1/2" thick
XPS – three products (2 reps each), ½" thick
- Average deflection is based on deflection of foam at center of span between studs at end stud bays and mid-height of 4x8 wall specimens

Table 4. Summary of Negative Pressure Test Results

Vinyl Siding ID	Test Statistic	Baseline Tests (psf)	Siding + 3/8" EPS (psf)	Siding + 1/2" ISO (psf)	Siding + 1/2" XPS (psf)
A (lower pressure rating)	Avg_Ult (psf)	**22.73**	**29.13**	**41.11**	**41.63**
	Std-dev (psf)	1.36	3.59	6.44	2.80
	COV	0.06	0.12	0.16	0.07
	AvgDefl_Ult (in)	n/a	**0.69**	**0.53**	**0.84**
	Std-dev (in)	n/a	0.16	0.22	0.09
	COV	n/a	0.23	0.43	0.10
	AvgDefl_50%Ult (in)	n/a	**0.37**	**0.20**	**0.40**
	Std-dev (in)	n/a	0.08	0.08	0.04
	COV	n/a	0.21	0.39	0.10
B (higher pressure rating)	Avg_Ult (psf)	**81.85**	**77.02**	**86.13**	**89.45**
	Std-dev (in)	10.82	n/a *	6.86	13.45
	COV	0.13	n/a *	0.08	0.15
	AvgDefl_50%Ult (in)	n/a	**0.60**	**0.37**	**0.56**
	Std-dev (in)	n/a	0.10	0.04	0.05
	COV	n/a	0.17	0.11	0.09

Notes:
* Includes only one EPS type for two tests; other type used 2" nails which resulted in some instance of nail withdrawal failures.
- Deflections are based on deflection of foam at center of span between studs at end stud bays and mid-height of 4x8 wall specimens.
- Data based on testing of two EPS types (2 reps each), three ISO types (one rep each) and three XPS types (one rep each).
-Baseline tests are average from 3 tests each for both Siding A and Siding B.

Table 5. Summary of Small Specimen Bending Results (Averaged by Foam Sheathing Type)

	Thickness (in)	Span (in)	Width (in)	Max Load (lbs)	Max Stress (psi)
EPS (2 products, 3 reps each)					
average	0.370	6	6	5.52	**5.5**
stdev	0.006	n/a	n/a	2.16	2.2
COV	0.017	n/a	n/a	0.39	0.39
ISO (3 products, 3 reps each)					
average	0.499	8	8	17.67	**17.7**
stdev	0.040	n/a	n/a	5.01	5.0
COV	0.080	n/a	n/a	0.28	0.28
XPS (3 products, 3 reps each)					
average	0.540	8	8	11.79	**11.8**
stdev	0.029	n/a	n/a	1.16	1.2
COV	0.053	n/a	n/a	0.10	0.10

TABLE NOTES:

Temperature of ~75deg F

-Max load recorded for load head deflections up to 1.2 inches for EPS and 1.6 inches for ISO and XPS (~mid-span specimen deflection)

-Some products had clear yield or failure points others had a moderate knee in load-deflection curves, others had a smooth non-linear curve which had no defined yield or failure point

Table 3 summarizes the positive pressure test results. Deflections are given as the average of the deflection of the foam over the outside two stud bays, with each bay deflection relative to the average deflection of the two bordering stud bays. The deflections were measured in the center of the bay at midpoint of the walls' height. Failure for positive pressure tests was typically realized when the sheathing pulled off one or more fasteners. However, in most of the ISO products, buckling of the sheathing mid-span over an exterior stud bay would be the initial failure, and this would usually result in the foam pulling off the fasteners on the side studs. In most failure cases, pressure dropped suddenly and significantly when the plastic sheeting was torn by the fasteners. Typical Sheathing pull off from fasteners can be seen in Figure 6.

Figure 6. Failure in positive pressure test where foam pulled off fasteners on right end stud

Table 4 summarizes ultimate pressure and deflections for baseline vinyl negative pressure tests and foam-vinyl system negative pressure tests. EPS foam tested with siding B does not have a statistical comparison because one type of EPS was not considered due to fastener withdrawal[1]. Typical failure for negative pressure tests occurred when siding pulled off fasteners. In some cases both siding and sheathing failed, but in others, only the siding failed. In some tests, only partial disengagement of the siding from a fastener occurred. In these tests, a peak pressure was reached without having a failure because the seal on the sample could not be maintained due to tearing of the plastic film. Anytime a disengagement of any type occurred, a distinct popping sound would be heard.

Figure 7. Baseline test failures (described from left): Nail hem tear, Siding disengagement from fastener, and partial disengagement from fastener

Figure 8. Negative system test failures (described from left): Siding tear from fastener, Siding disengagement from fastener, and siding partial disengagement from fastener

Figure 9. Negative system failure where sheathing failed after siding failed

[1] This was due to initially using shorter fasteners. Due to time sensitivity, a retest with longer fasteners was not possible.

Table 5 summarizes the flexural specimen results. Most samples reached a maximum deflection before failure could occur. Therefore, the modulus of rupture could not be reported. However, a maximum load was achieved for the samples, and this allowed a maximum stress to be obtained.

Figure 10. ISO sample undergoing flexural test

The testing was conducted at the NAHB Research Center's laboratory between September 2007 and January 2008.

Discussion and Conclusions

The major conclusions from the test results of this project include:

1. Inclusion of foam sheathing behind vinyl siding did not result in reductions in the vinyl sidings' negative pressure resistance relative to installation over OSB sheathing (baseline tests) provided adequate siding fastener penetration into framing is maintained (see Table 4).
2. For the lower pressure-rated siding (Product A) as shown in Table 4, the negative pressure resistance of the vinyl siding and XPS or ISO foam sheathing system was improved relative to the baseline vinyl siding tests.
3. In positive pressure tests and small specimen flexural tests, differences in foam sheathing resistance (strength and stiffness) were observed (refer to Tables 3 and 5); however, the XPS and ISO products performed with similar peak positive pressure resistance. Differences in performance can be associated with differences in foam sheathing thickness as well as facer and foam material properties.

References

ASTM International. ASTM Standard C203-05a "Standard Test Methods for Breaking Load and Flexural Properties of Block-Type Thermal Insulation".

ASTM International. ASTM Standard C578-07 "Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation".

ASTM International. ASTM Standard D1289-07 “Standard Specification for Faced Rigid Polyisocyanurate Thermal Insulation Board”.

ASTM International. ASTM Standard D3679-06a “Standard Specification for Rigid Poly (Vinyl Chloride) (PVC) Siding”.

ASTM International. ASTM Standard D5206-06a “Standard Test Method for Windload Resistance of Rigid Plastic Siding”.

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