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BUILDING TECHNOLOGIES OFFICE

Expert Meeting Report: Cladding Attachment Over Exterior Insulation

P. Baker
Building Science Corporation

October 2013

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Expert Meeting Report: Cladding Attachment Over Exterior Insulation

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Definitions

ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
BSC	Building Science Corporation
CFD	Computational fluid dynamics
DOE	U.S. Department of Energy
EPS	Expanded polystyrene
FEM	Finite element modeling
IBC	International Building Code
IBHS	Institute for Business and Home Safety
IECC	International Energy Conservation Code
IRC	International Residential Code
lb/ft^2	Pounds per square foot
LVDT	Linear voltage displacement transducer
NAHBRC	National Association of Home Builders Research Center
NYS	New York State
NYSERDA	New York State Energy Research and Development Authority
ORNL	Oak Ridge National Laboratory
OSB	Oriented strand board
PEF	Pressure equalization factor
XPS	Extruded polystyrene

Executive Summary

Building Science Corporation (BSC) held an expert meeting on Cladding Attachment Over Exterior Insulation on Saturday, July 28, 2012 at the Westford Regency Hotel in Westford, Massachusetts. Featured speakers included Jay Crandell of ARES Consulting, Peter Baker of BSC, Gary Parsons of DOW Chemical Company, Vladimir Kochkin of the National Association of Home Builders Research Center, Randy Van Straaten of BSC, and Dawn Cole of James Hardie Building Products (presented on her behalf by Jay Crandell). This was followed by an open question-and-answer discussion period.

The Building America expert meeting focused directly on supporting the Building America Standing Technical Committee identified Critical Milestone #1:

> By end of 2015, have adopted code language defining the requirements for attaching cladding over typical thicknesses of insulating sheathing (i.e., 1", 1.5", 2" and 4") for both 16" and 24" o.c. framing.

The meeting focused on issues surrounding cladding attachment and performance of walls with exterior insulating sheathing. The topics of discussion were split into two[1] separate categories:

1. Gravity load resistance
2. Wind load resistance.

The presentations explored these topics from the perspectives of engineering design, laboratory testing, field monitoring, and practical construction. Key results of this meeting were:

Gravity Load Resistance

There was general agreement that the proposed deflection limits (1/16 in. for board/panel sidings, and 1/64 in. for brittle claddings) were reasonable given the current state of knowledge. Most comments from attendees were that, in reality, these limits are still conservative, and that greater movements in both cladding types could very likely be tolerated.

The current engineering cladding attachment design approach has many limitations, as it is largely based on fitting research to past datasets and does not account for other aspects that may contribute to the development of capacity (friction and compression of insulation). This is being weighed against a critical industry need for code guidance on attachment over exterior insulation. Long-term plans are to work with the America Wood Council to develop the design method to enable engineers to calculate solutions.

Creep is currently accounted for in design with safety factors applied to the design values for cladding attachment. Current research looking at exposed long-term deflection movement of

[1] Seismic load resistance should also be acknowledged here, but no work in this area is currently known and it was not discussed at the meeting.

cladding assemblies over exterior insulation will help to determine if these safety factors are appropriate.

Wind Load Resistance

Research has demonstrated that pressure moderation across the wall assemblies does occur. Recent full-scale wall tests showed no damage to exposed (no cladding installed) exterior foam insulation when tested to extremely high wind loads. This is an encouraging result, as most cladding systems will reduce the pressure equalization factor on the insulation and will help clamp the insulation in place. Additional testing across a wider range of insulation types with various water resistive barriers is recommended.

The newly available full-scale testing provides differing results about the pressure equalization factor of the siding. Further refinement to test methodologies and development of new methodologies could help to further refine the design requirements for wall layers.

Research is underway to approximate full-scale test methods using small-scale component testing or predictive modeling. The method proposed is to construct a small-scale idealized cladding test rig and compare the results to existing 3D flow models. If needed, a new 3D flow model will be developed and validated using data from full-scale wall assembly tests.

1 Introduction

Adding insulation to building exteriors effectively increases the thermal resistance of wood-framed walls and mass masonry wall assemblies. The location of the insulation to the exterior of the structure has many direct benefits, including better effective R-value from reduced thermal bridging, better condensation resistance, reduced thermal stress, and other commonly associated improvements such as increased airtightness and improved water management (Hutcheon 1964; Lstiburek 2007).

There is significant resistance to the widespread implementation of this approach, because research and understanding about the performance of cladding systems installed either directly over the exterior insulation or to a cladding support system installed over the exterior insulation is lacking. Performance questions have arisen about the gravity load resistance and the wind load resistance of these wall assemblies.

The expert meeting supported the Building America Standing Technical Committee Critical Milestone #1:

> By end of 2015, have adopted code language defining the requirements for attaching cladding over typical thicknesses of insulating sheathing (i.e., 1", 1.5", 2" and 4") for both 16" and 24" o.c. framing.

The intent of the meeting was to review the current state of industry knowledge about cladding attachment over exterior insulation with a specific focus on:

1. Gravity load resistance
2. Wind load resistance.

The presentations explore these topics from the perspectives of engineering design, laboratory testing, field monitoring, and practical construction. By bringing various groups together (who have conducted research or have experience in this area), a more holistic review of the design limits and current code language proposals can be completed and additional gaps identified. The results will help inform design standards and criteria.

2 Logistics

Building Science Corporation (BSC) held an expert meeting on Cladding Attachment over Exterior Insulation on Saturday July 28, 2012 at the Westford Regency Hotel and Conference Center in Westford, Massachusetts. Thirty-three people (Table 1), including the six invited speakers, attended. Presentations and discussion topics included code development, laboratory testing, field testing, in-situ monitoring, and manufacturers' recommendations. The presentations were followed by an open discussion period with all attendees.

Table 1. Expert Meeting Participants

	Name	Organization	Email Address
1	Arne Anderson	DOW	aganderson@dow.com
2	Peter Baker	BSC	pbaker@buildingscience.com
3	Gary Bergeron	Synergy	gary@synergy-companies.com
4	Katie Boucher	BSC	katie@buildingscience.com
5	Rockford Boyer	Roxul Inc.	rockford.boyer@roxul.com
6	Anne Cope	IBHS[a]	acope@ibhs.org
7	Jay Crandell	ARES	jcrandell@aresconsulting.biz
8	Ken Eklund	Washington State University	eklundk@energy.wsu.edu
9	Paul Eldrenkamp	Byggmeister	paul@byggmeister.com
10	Ali Fallahi	Fraunhofer CSE	afallahi@fraunhofer.org
11	Doug Fast	Product Testing Laboratories	doug.fast@jm.com
12	Marquam George	U. Alaska Southeast	marquam.george@uas.alaska.edu
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14	Anthony Grisolia	IBACOS	agrisolia@ibacos.com
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20	Phil Kaluza	Alsaska	pkaluza@gmail.com
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31	Kohta Ueno	BSC	kohta@buildingscience.com
32	Randy Van Straaten	BSC	randy@buildingscience.com
33	Eric Werling	DOE	eric.werling@ee.doe.gov

[a] Institute for Building Home Safety
[b] National Renewable Energy Laboratory
[c] Oak Ridge National Laboratory
[d] National Association of Home Builders Research Center
[e] U.S. Department of Energy

3 Research Questions

The objective of this session was to examine the current state of the industry of cladding attachment over exterior insulation. The Standing Technical Committee Critical Milestone #1 is intended to support the adoption of code language by the end of 2015 that will allow cladding systems to be attached over exterior insulation for a range of thicknesses. BSC identified several key questions that needed to be reviewed to inform this process.

3.1 Gravity Load Resistance

What should be the in-service vertical deflection limits? There is a current understanding as to the "expected" performance of many of these assemblies (based on research completed to date); however, it is important that this information is not confused with "acceptable" performance. Setting a reasonable acceptable performance metric is key to ensure limitations are not placed on emerging or alternate design approaches.

Is the current engineering cladding attachment design approach appropriate? The research and design methodology completed to date was built off past research and accepted limit state designs of wood-to-wood connections. Much of this past work was completed with the intent to remove several factors (such as friction and compression resistance of insulation) from the design. Current understanding of the mechanics of these assemblies suggests that these factors may be more significant, and possibly dominant, in the development of the system capacity and should possibly be included in the design methodology.

How should creep be accounted for in design? A large unknown is still the potential for long-term creep in the assembly. This has traditionally been accounted for by the application of safety factors to the design, which may result in overly conservative design values.

3.2 Wind Load Resistance

Are cladding systems and underlying building elements at risk of damage under high wind loads? A very conservative assumption is that the cladding elements are loaded to 100% of the incident wind load. In reality, the load is shared over many enclosure elements because of pressure moderation. This can place underlying components, such as taped joints in exterior insulation, at risk of being damaged.

Do current test methods properly account for pressure moderation and load sharing across enclosure assemblies? The amount of pressure moderation across the assemblies is not necessarily well understood. Different testing programs have yielded significantly different results. There is still some question about whether the current test protocols accurately capture the load distribution.

Can full-scale testing of assemblies be replicated or approximated with smaller laboratory testing of assemblies? Full-scale building test facilities can examine the performance of cladding systems in a full-scale test scenario. Given the scale, the cost of testing would likely be prohibitive if large sample sets of various scenarios need to be studied. The intent is to examine means of repeating or approximating full-scale test results and data using smaller test protocols.

4 Objectives

The expert meeting was designed to bring in experts to discuss issues relating to vertical load deflection issues and wind loading issues. The primary objectives were to:

1. Review the current code proposals for issues of approach, results, and potential impacts on future work or code adoption.
2. Review gaps in the current knowledge of load resistance mechanisms that are important to the development of system capacity.
3. Review the issues around creep in the enclosure assemblies and its impacts on long-term performance.
4. Review research into wind load resistance of cladding assemblies attached over exterior insulation.

5 Agenda

Table 2 includes the agenda that was followed for the expert meeting.

Table 2. Expert Meeting Agenda

Time	Speaker	Topic
8:30 to 9:00		Mingling and refreshments
9:00 to 9:15	Dr. Joseph Lstiburek BSC	Introduction
9:15 to 10:15	Jay Crandell ARES Consulting	Cladding Attachments of Exterior Insulation: History, Principles, and Codes
10:15 to 10:30		Break
10:30 to 11:15	Peter Baker BSC	Exterior Cladding Attachment Research
11:15 to 12:00	Gary Parsons DOW Building Solutions R&D	Structural Field Monitoring and Modeling of Thick Continuously Insulated Wall Assemblies
12:00 to 1:00		Lunch
1:00 to 1:45	Vladimir Kochkin NAHBRC	Wind Performance Testing of Walls with Exterior Rigid Foam
1:45 to 2:30	Randy Van Straaten BSC	Recent Wind Loading Research
2:30 to 2:45	Break	
2:45 to 3:30	Dawn Cole (presented on her behalf by Jay Crandell) James Hardie Building Products	Installing James Hardie Siding over Exterior Rigid Foam
3:30 to 4:15		Open discussion
4:15 to 4:30	Peter Baker BSC	Final remarks

6 Presentation Summaries

Six main presentations described history, research, and current practice in the area of cladding attachment over exterior insulation.

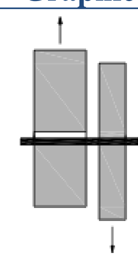
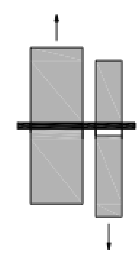
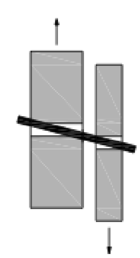
6.1 Cladding Attachments of Exterior Insulation: History, Principles, and Codes

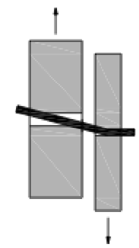
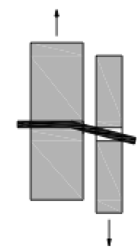
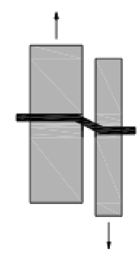
(Jay Crandell – ARES Consulting)

Mr. Crandell provided an overview of the wood connection design. He said that in the United States much wood connection design (withdrawal as well as shear) was based on equations fit to large sets of empirical data. However, much unexplained variability appeared in the data, resulting in the use of large safety factors to account for the variability.

In the 1940s the European Yield Theory was first conceived. This approach is based on an equilibrium of forces caused by rotation of fasteners in wood members and predicts performance of the connection at the point where yielding of materials (wood or fastener) has developed. The equations predict performance of a multitude of failure modes, with the governing mode being the one with the lowest capacity. A visual representation of the potential failure modes (AFPA 1999) is included in Table 3.

Table 3. Yield Modes From American Forest and Paper Association TR-12

Yield Mode	Description	Graphic
Im	Main member bearing failure	
Is	Side member bearing	
II	Side and main member bearing	

IIIm	Main member bearing and dowel yielding in the side member	
IIIs	Side member bearing and dowel yielding in the main member	
IV	Dowel yielding in the side and main members	

The yield equations do predict reasonably well the joint yield strength based on the yield strength of wood in bearing and a fastener in bending. He stated that it can also be used with joints having gaps that are filled with ½–1 in. of Type II expanded polystyrene (EPS) insulation. The equations do not, however, predict deflection, nor do they take into account other effects such as friction, tension-compression strut (fastener tension to insulation compression), or head effects of the fastener (head diameter providing additional rotational resistance).

The European yield equations were calibrated back to old U.S. empirical-based shear design values at a rough prediction of performance at 0.015 in. joint slip, by dividing the values by 2.2.

In theory, cladding or furring attachment over continuous insulation was an extension of the yield equations. Several studies have examined the capacity of system to resist vertical displacement:

FPL RP 469 "Lateral Load-Bearing Capacity of Nailed Joints Based on the Yield Theory" (Aune and Patton-Mallory 1986a)

FPL RP47"Lateral Load-Bearing Capacity of Nailed Joints Based on the Yield Theory Experimental Verification" (Aune and Patton-Mallory 1986b)

"Fastening Systems for Continuous Insulation" (Bowles 2010)

"External Insulation of Masonry Walls and Wood Framed Walls" (Baker 2013)

The intent of the NYSERDA testing was to test a representative range of conditions to verify and calibrate the application of the yield equations, and based on this testing derive easy-to-use and reliable connection requirements for use by the building industry for common conditions. The scope of the testing followed ASTM Test Method D1761 (Figure 1 and Figure 2) and examined:

- Side member (furring/cladding)
- ¾-in. and ⅜-in. pine
- 33 mil (20 g) steel hat channel
- Main member (studs/substrate)
- 2x studs (spruce pine fir worst-case density)
- 33 mil (20 g) and 54 mil (16 g) studs
- 7/16-in. and ¾-in. oriented strand board (OSB)
- Fasteners
- Nails
- Wood screws
- Lag screws
- Self-drilling/tapping screws (steel connections).

Figure 1. Typical ASTM D1761 test setup

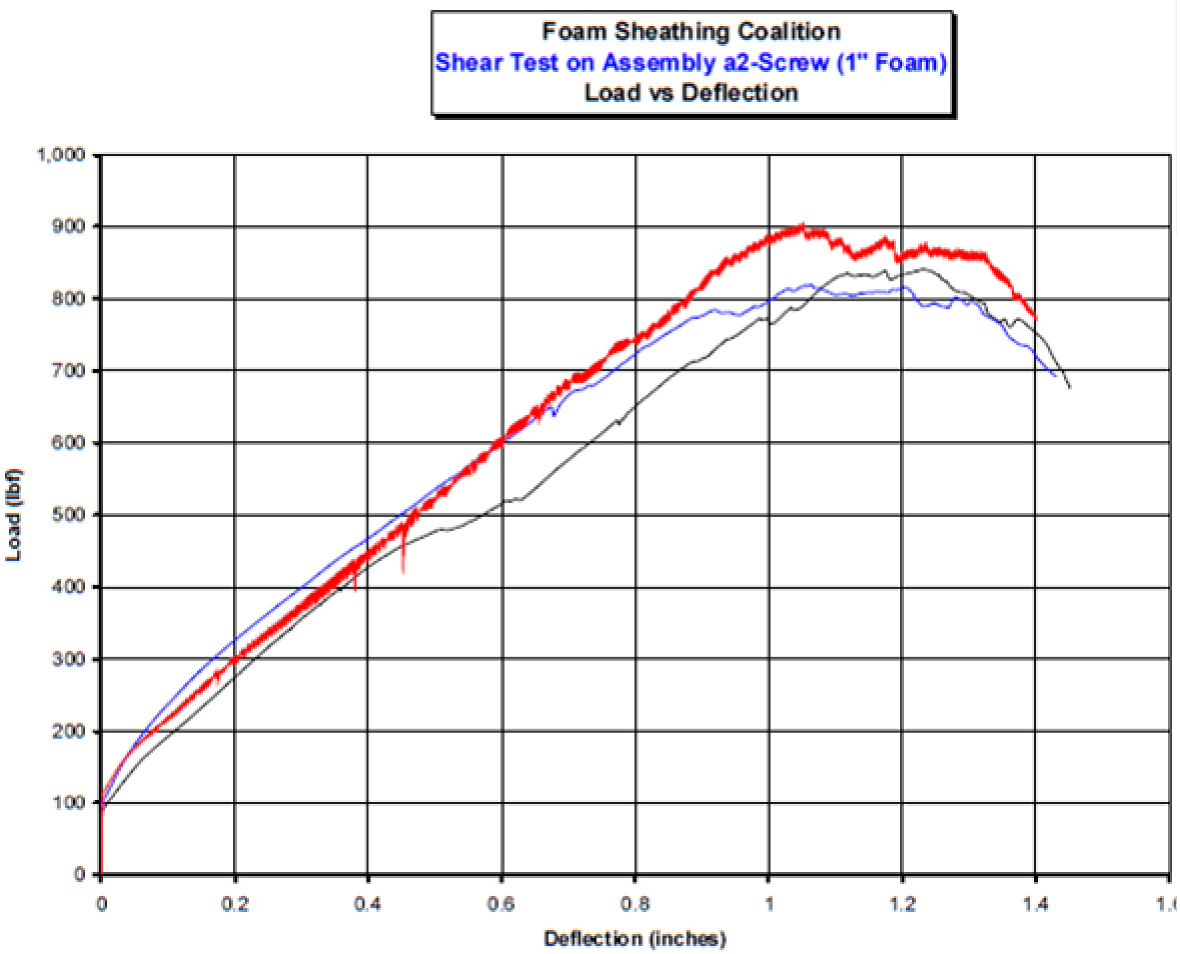


Figure 2. Example of measured load versus deflection

The measured data were compared to the predicted performance of the yield equations (based on actual properties of the materials used in the testing). The yield equations predicted tested joint load at about 0.015 in. deflection. Based on this result the following design approach was developed:

Step 1: Calculate using National Design Specification for Wood Construction yield equations

Step 2: Divide calculate results by 1.5

Step 3: Use calculated per fastener shear strength, cladding weight, and insulation thickness to determine fastener spacing

The procedure provided reliable and "workable" solutions and established a framework for future improvements.

This work was packaged into several code proposals. The first was submitted to the New York State (NYS) building code council and was approved and adopted in the current NYS Energy

Code. It was also submitted for the 2012 International Energy Conservation Code (IECC), and 2015 International Building Code (IBC), though the proposals did not pass. Future work will include public comments, the 2015 International Residential Code (IRC), and the International Conservation Code (ICC) 600.

Long-term plans are to work with the America Wood Council (to develop the design method to enable engineers to calculate solutions:

- Use the design method to calculate pre-engineered (prescriptive solutions).
- Get the methodology into design standards first, then into codes.
- Alternatively, develop a code compliance report (technical evaluation report).

6.1.1 Questions and Discussion

Validation of the European Yield Equations:

Peter Baker (BSC) question: Were the European yield equations fit for the data?

Jay Crandell (ARES) answer: Yes, the equations came from testing/verification.

Joe Lstiburek (BSC) comment: If you do all the tests with no foam, it is predictable. This is not useful for systems with foam.

Jay Crandell (ARES) comment: We're taking baby steps; things go slowly, especially in code hearings.

Peter Baker (BSC) question: If they tested with ½ in. to 1 in. of foam insulation, how did they "discount" the effect of friction and foam compression?

Jay Crandell (ARES) answer: Basically the test is designed to avoid friction effects. Thin shims were used in wood-to-wood connections to avoid friction. The same was likely true for the foam insulation tests.[2]

Peter Baker (BSC) question: If you gap everything, why do they say that it was tested with foam? This effectively decoupled it.

Jay Crandell (ARES) answer: Agreed. They wanted a generalized equation to allow for shrinkage of wood members.

---

[2] After the expert meeting the yield equation validation testing was further reviewed. The test setups that included ½-in. to 1-in. EPS insulation between the wood members were not shimmed to discount the friction and compression effects of the insulation. The test setups also used very large 40d nails (0.225-in. shank diameter). Large shank diameter fasteners would have significantly higher bending resistance than more common smaller shank diameter fasteners. The fasteners heads were also not driven flush with the wood furring (to avoid head fixity issues). With the head being held away, the furring would be able to slide along the shank reducing the potential for friction and compression forces on the insulation to be developed in the system. The theory is that the combination of the gap width, the fastener size, and the fastener not being driven flush, would help to reduce the impacts of friction and foam compression on the measured capacity of the system and allow for closer alignment with the predictions from the yield equations.

Jay Crandell (ARES) comment: For foam to reach the plastic limit, you need 14 degrees of fastener deflection. We need to get a model to explain it, to help the design. To increase joint stiffness/strength, you can increase fastener stiffness/diameter, or increase wood density. Dividing the yield equation results by 2.2 takes us back to about the same answer as in previous codes. This method gives more "intelligence"; for example, you can design a seismic joint that has good ductility.

6.1.2 Current Code Proposals

Jay Crandell (ARES) comment: The wood industry has been concerned with the practicality of solutions derived by relying on the testing and the yield equations. There has been some resistance to a prescriptive table without some type of engineering to ensure that hidden conditions will be met.

Jay Crandell (ARES) comment: At the code hearings the wood industry wanted to modify the table from 4 in. to 2 in. thickness for the smallest diameter fastener. The industry felt having the table approved was a worthwhile and practical move.

Joe Lstiburek (BSC) comment: I agree with the approach for the code; it is the only way to pass through this code cycle. However, it's the wrong approach. Experience in the field and larger scale testing show we are conservative. But that won't matter in the code process. This is a political process. I am worried that once it is in the code, it will never come out. If we built a basement according to structural codes, we would be far overbuilt compared to an 8 in. wall conventional basement. Are we headed down this road?

6.2 Exterior Cladding Attachment Research

Peter Baker (BSC) briefly reviewed the benefits of exterior insulation on the thermal performance and condensation resistance benefit of framed wall assemblies. The means of attaching the cladding system over the exterior insulation has been a stumbling block for many practitioners.

There is a practical limit of installation methods based on the thickness of exterior insulation:

For insulation ≤ 1½ in., attaching the cladding directly through the insulation back to the structure is often practical.

For insulation > 1½ in. a secondary cladding support system is often needed.

Historically, the secondary cladding support system was poorly executed. A common means was through the use of a single ZZ-furring that extended completely through the insulation (Figure 3). This single Z furring functions in essence like a steel stud, thereby eliminating much of the benefit of the exterior insulation. Other means were though the use of a double Z furring (Figure 4); however, this was also often poorly done as the first Z furring extended through the insulation layer and the second Z furring formed a gap between the cladding and the insulation. For a double Z furring system to be at all effective, it must be coupled with at least two layers of insulation and the first Z furring completely must be covered by the second layer of insulation.

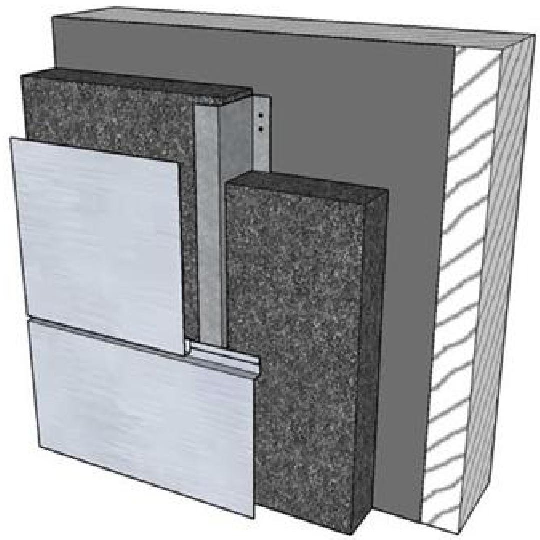


Figure 3. Example of a single Z furring installation

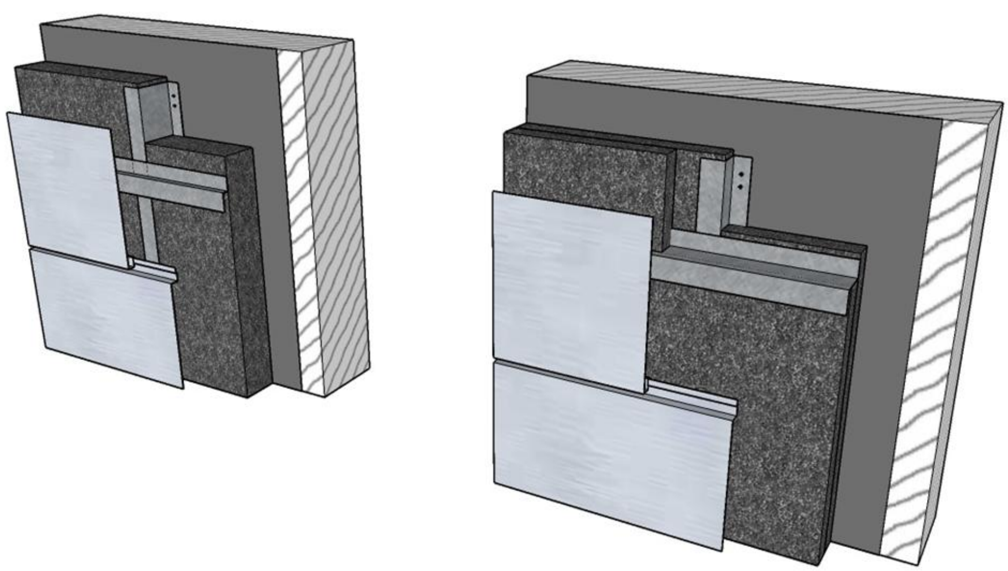


Figure 4. Examples of double Z furring installations (the one on the left has the same performance as a single furring, the one on the right improves performance by covering the first Z furring layer with insulation)

A further improvement is through the use of a clip and Z furring or hat channel approach (Figure 5). This approach reduces the thermal bridging to small clips (metal or fiberglass) that penetrate the insulation layer. The concerns with this approach have been the resistance by structural engineers to design the system without defaulting to larger steel support brackets, or higher system costs associated with pre-engineered proprietary systems.

To help reduce costs and simplify installation, a method of directly attaching the furring strip through the insulation back to the structure has also been used (Figure 6).

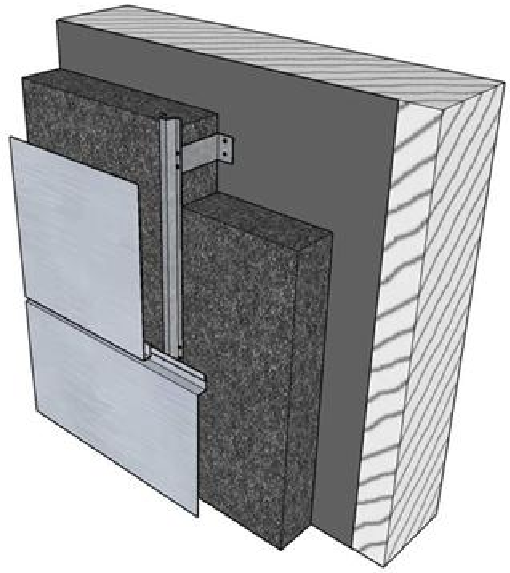


Figure 5. Example of a clip and furring cladding attachment system

This approach has been met with significant resistance from the industry, which lacks confidence that the connection will provide adequate structural resistance to the gravity loads imposed on the furring from the weight of the cladding. In reality, this approach has been used for several decades on numerous projects, and has demonstrated very good performance. Unfortunately, without engineering data, wide acceptance of the approach in industry has been limited.

One of the most common concerns is that the insulation provides no capacity for the system. A simple test conducted by a BSC staff member on his own home demonstrated that the insulation provides significant capacity and is critical to the assembly performance.

Two test iterations were conducted. The first test loaded two furring strips, gapped 4 in. from the backup wall, with succession weight increments up to approximately 4.5 lb/ft^2 (Figure 7). The second test followed the same protocol; however, 4 in. of rigid mineral fiber insulation was installed between the furring strips and the backup wall (Figure 8).

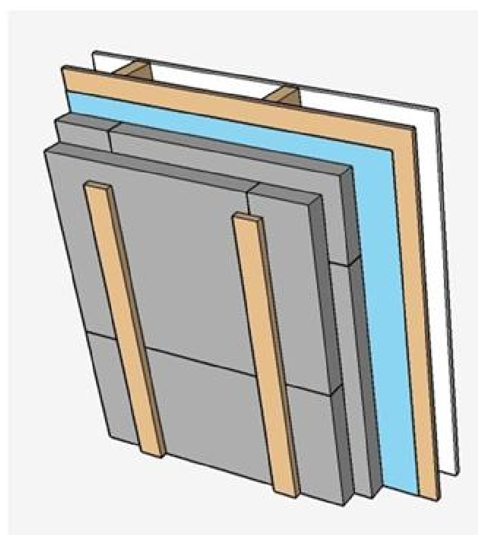


Figure 6. Example of a furring strip attached directly back through the insulation to the structure

Figure 7. BSC staff test setup (4-in. gap)

Figure 8. BSC staff test setup (4-in. mineral fiber insulation)

The test results (Figure 9) clearly demonstrate the additional capacity the insulation layer provided to the system, as considerable deflection was noted without the insulation, and almost none with the insulation in place.

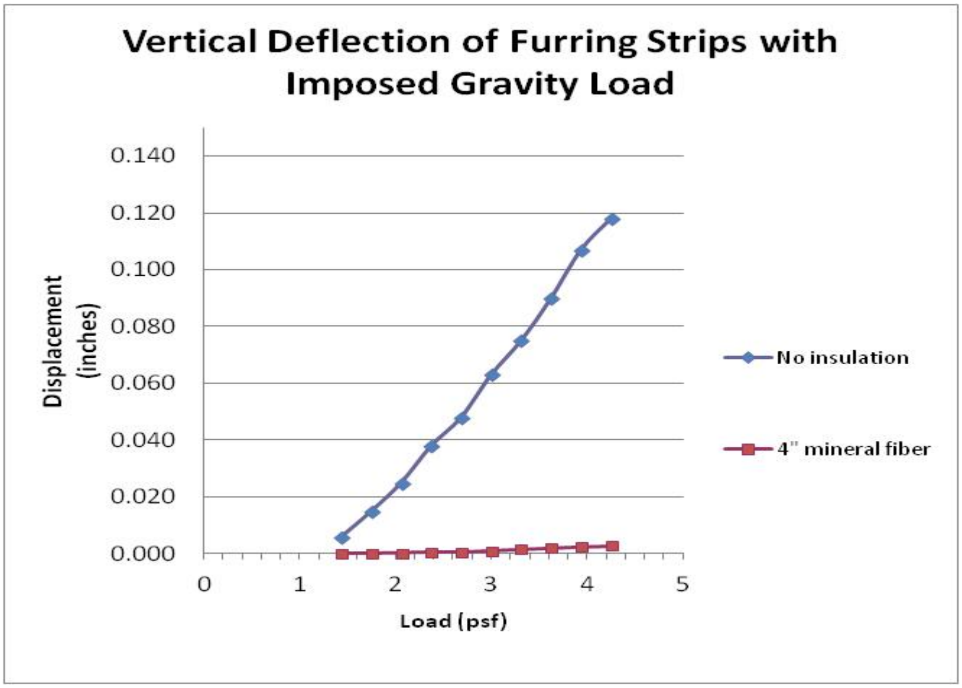


Figure 9. Load versus deflection (4-in. gap and 4 in. of insulation)

Because the insulation is a significant factor in system capacity development, concerns are often raised about its structural capacity. Often it is stated that the insulation will crush under load. This statement is true; however, the context is wrong. Loading the system until failure (500–1000 lb or more per screw fastener) will crush most rigid insulation materials. This type of loading is at least an order of magnitude greater than the expected in-service loads (Table 4 and Table 5) of even the heaviest of cladding materials. Under expected in-service loads, the insulation materials have adequate capacity.

Table 4. Common Cladding Weights (lb/ft^2)

	Low	High
Vinyl	0.6	1.0
Wood	1.0	1.5
Fiber Cement	3.0	5.0
Stucco	10.0	12.0
Adhered Stone Veneers	17.0	25.0

Table 5. Cladding Weight per Fastener (lb)

Fastener Spacing (in.)	16 × 16	16 × 24	24 × 24
Area/Fastener (ft^2)	**1.78**	**2.67**	**4.00**
Vinyl	1.8	2.7	4.0
Wood	2.7	4.0	6.0
Fiber Cement	8.9	13.3	20.0
Stucco	21.3	32.0	48.0
Adhered Stone Veneers	44.4	66.7	100.0

The design of the cladding attachment system is governed by acceptable deflection and not ultimate capacity. A proposed definition of acceptable deflection follows:

> Movement a cladding system can accommodate without causing physical damage or exceeding aesthetic tolerances.

With this some limits were proposed:

- Lap sidings and panel cladding ~ 1/16 in.
- Brittle claddings ~ 1/64 in. (after initial deflection).

For lap siding and panel cladding BSC felt that minor deflection would not have the potential for physical damage to the siding, so the tolerance should be based on the expected aesthetic limit. Given normal construction tolerances, most contractors would not be expected to achieve anything more precise than 1/16 in. (or even ⅛ in.) for a cladding installation.

For brittle claddings (such as stucco and cultured stone), the tolerance was set to a lower threshold, as BSC felt that movement could lead to cracking. This is likely a conservative limit, which was chosen based on a lack of information about how much movement stucco claddings are subjected to in a normal installation.

BSC has researched this cladding attachment approach for several years. In 2011, research conducted under the Building America program examined short- and long-term loading of wall assemblies using furring strips fastened back through the insulation as the primary cladding support structure (Baker 2012). The testing covered multiple insulation types:

- EPS
- Extruded polystyrene (XPS)
- Foil faced polyisocyanurate
- Rigid mineral fiber.

The short-term load testing was conducted on full 4-ft × 8-ft wall panels with two 1 × 3 wood furring strips spaced 24 in. o.c. (Figure 10). The furring strips were attached with #10 wood screws spaced 16 in. o.c. vertically. Tests were conducted at 4 in. thickness of insulation (Figure 11) and at 8 in. thickness (Figure 12).

Figure 10. Short-term gravity load response test setup

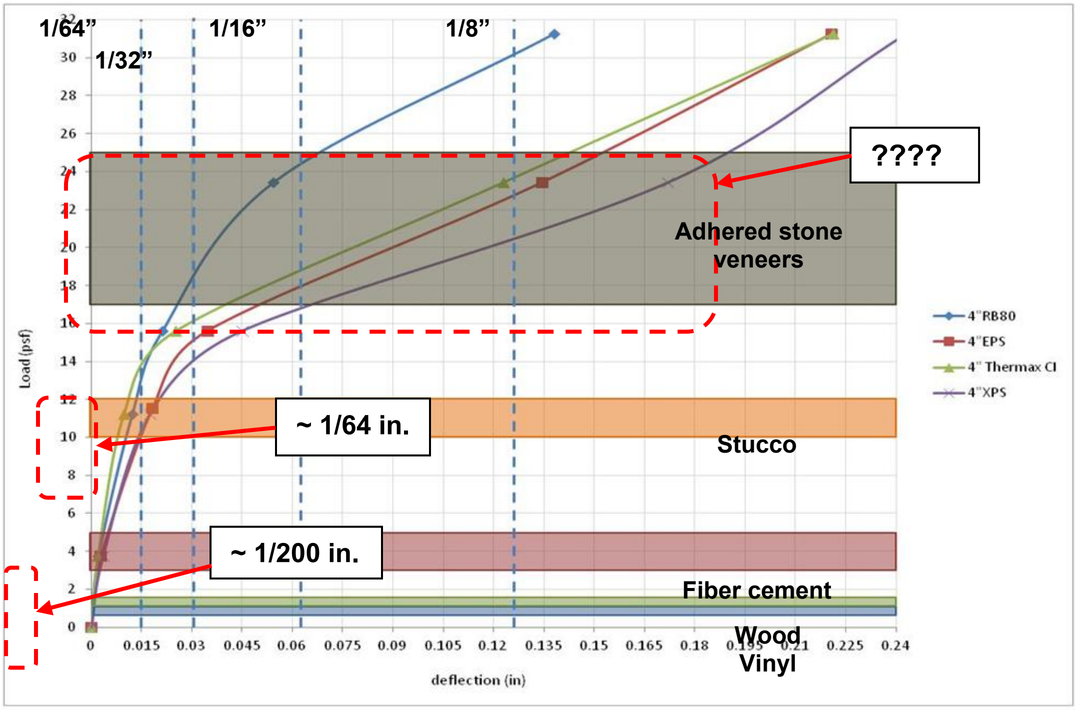


Figure 11. Short-term load versus deflection for assemblies with 4 in. of exterior insulation

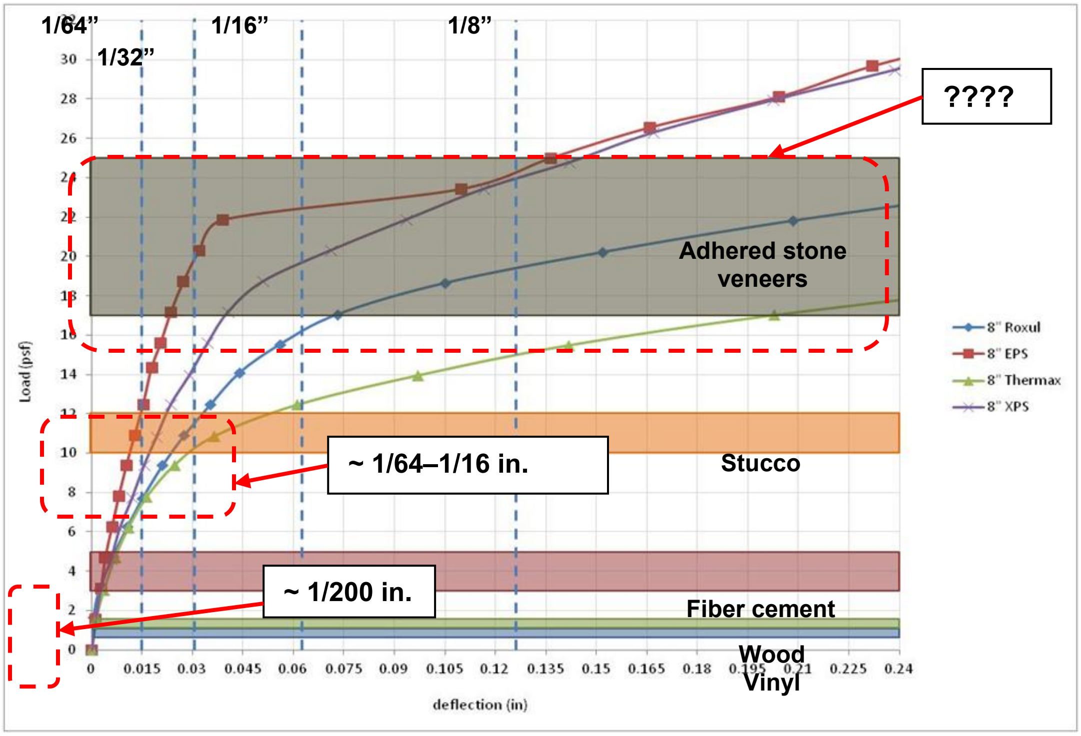


Figure 12. Short-term load versus deflection for assemblies with 8 in. of exterior insulation

The long-term load testing was conducted on 2-ft × 8-ft wall panels with a single 1 × 3 wood furring (Figure 13). The furring strip was attached with #10 wood screws spaced 16 in. o.c. vertically. Tests were conducted at 4 in. thickness of insulation only. The test panels were loaded to the following levels:

- 13 lb/ft^2 (if furring is spaced at 24 in. o.c.)
- 20 lb/ft^2 (if furring is spaced at 16 in. o.c.)
- 30 lb/fastener.

A fifth test panel was constructed with XPS as the insulation material; however, this panel was loaded to only 5 lb/ft^2 (based on furring spaced 16 in. o.c.).

Figure 13. Long-term gravity load response test setup

The test results (Figure 14) indicate that lightweight claddings (vinyl, wood, and fiber cement) have very little movement under either initial or long-term loading (~1/200 in.). The deflection for these claddings does not even approach the proposed limit (1/16 in.). The results were in line with a long history of performance of buildings constructed with this assembly.

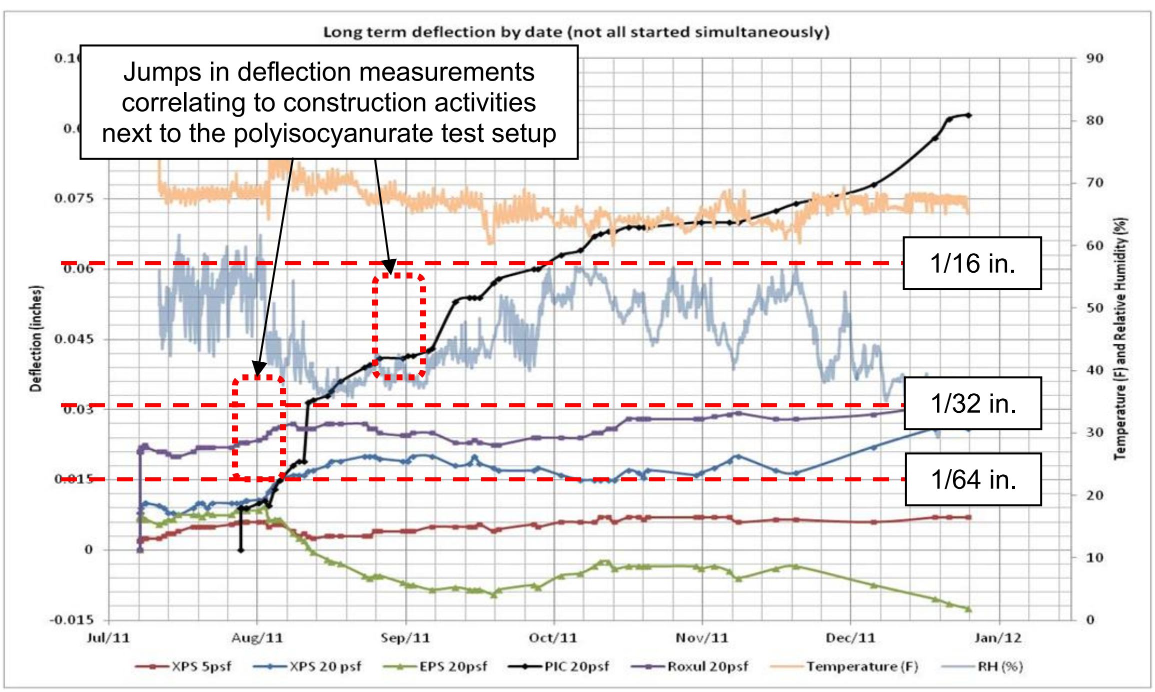


Figure 14. Long-term load versus deflection for assemblies with 4 in. of exterior insulation

For heavier brittle claddings (stucco and adhered stone veneers), initial deflection is less important than long-term deflection. For stucco claddings (10 lb/ft^2), long-term deflection after initial deflection is within the proposed limit under stable environmental conditions. For adhered stone veneer (17–25 lb/ft^2), there is a wide range of deflection potential; however, the capacity could be increased with increased fastener spacing.

The assemblies in the laboratory seemed to react to even slight temperature and relative humidity changes. This could indicate a greater sensitivity to environmental factors than to gravity loading. The EPS assembly seemed to have the inverse reaction compared to the other assemblies. It moves upward based on changing environmental conditions when other assemblies recorded downward movements. The research team could not explain these movements.

During the testing, work being conducted next to the test assemblies resulted in small (< 1/64 in.) but notable movement of the polyisocyanurate test setup (as indicated by the dashed red boxes on Figure 14). The first jump noted in the test data coincided with construction of a short-term wall setup test. During the construction an impact driver was being used; its vibration may have disturbed the assembly. The second noted jump occurred when a furring strip moved onto the test assembly. This raised questions about the "set in" potential caused by construction activities.

The completion of the 2011 testing raised more questions and highlighted gaps that needed additional research. Fundamental to this was the issue of system creep, which was still not well understood or quantified, because it is affected by multiple factors:

- Expansion and contraction of wood
- Expansion and contraction of insulation
- Relaxation of wood fibers
- Plastic deformation of insulation.

Many of these are affected by temperature and relative humidity, so the performance of these systems needs to be examined in exposed environments.

The exact mechanisms of the load deflection resistance were also not well quantified. Discrete load components (such as fastener bending/bearing, insulation compression, and friction forces between layers) may have impacted the system capacity, but had not been measured. BSC felt that understanding the factors that affect the development of system capacity would be important to examine means to engineer the attachment systems.

The Building America research continued into 2012. It focused on testing of the discrete system load components and on conduct long-term deflection testing of the assemblies in an exposed (outdoor) environment. As in 2011, the testing examined multiple insulation types.

- EPS
- XPS
- Foil faced polyisocyanurate
- Rigid mineral fiber.

For the discrete load component testing a series of tests was being completed to measure material properties (such as coefficients of friction and the compression modulus of the insulation materials), as well as the discrete load components (Figure 15):

- Fastener bending/bearing
- Insulation compression
- Friction forces between layers.

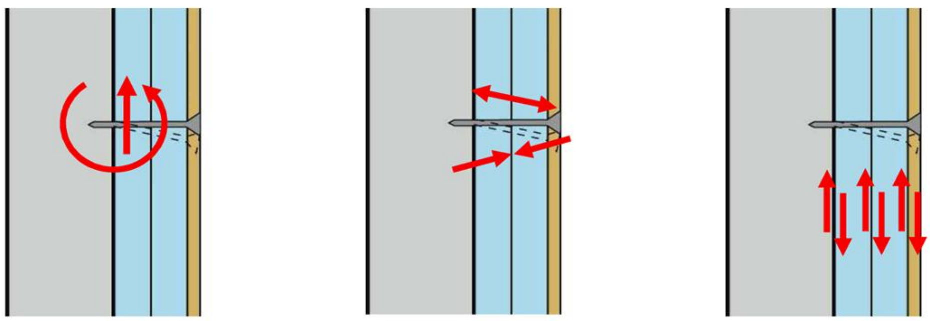


Figure 15. Discrete load components

Another aspect of the assembly that needed to be considered and examined was the pre-compression (clamping forces) imposed on the system from driving the wood screw into the structural framing member (Figure 16). Previous testing showed that the failure mechanism for this assembly with a common wood screw was from the head pull of the fastener through the furring and not from deformed insulation. Testing the system until the fastener head became overdriven would help to define the upper limit of pre-compression forces in the system. A small bench top test was completed that placed a load cell between a 2 × 4 wood stud and a 1 × 3 wood furring strip.

Figure 16. Pre-compression force test setup

The two were fastened together using a #10 wood screw and the load was measured. Preliminary results indicated consistent force magnitudes:

- ~150 lb per fastener with the screw head flush with the furring surface
- ~180 lb per fastener with the screw overdriven.

Further testing is planned to examine the relaxation in the load over time.

A custom-built test apparatus is being used for the small-scale discrete load component tests to evaluate the individual force resistance components (Figure 17).

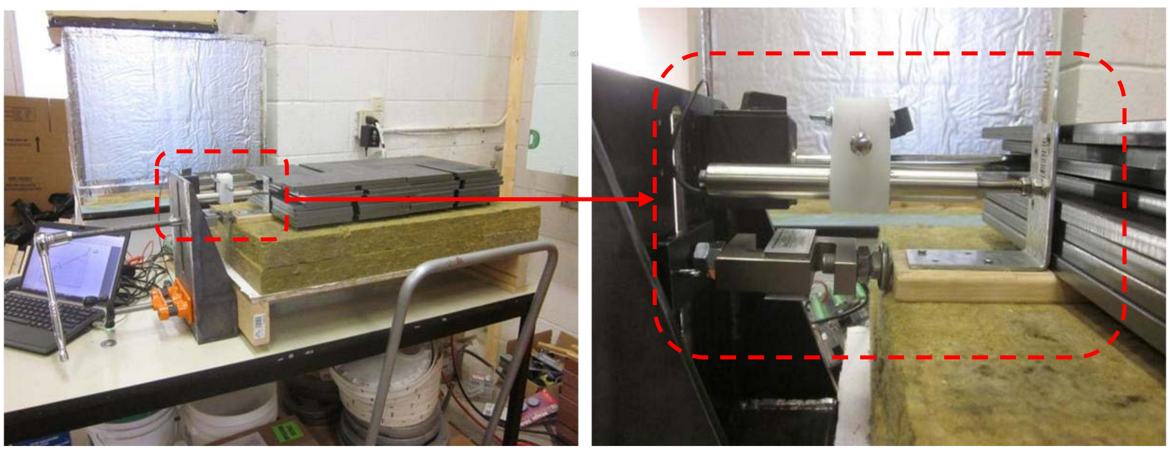


Figure 17. Example of friction component test setup
(weights placed on top of the furring replicate pre-compression clamping forces)

The climate exposure testing is being completed using full-scale wall assemblies loaded to three representative cladding weights (Figure 18 through Figure 20):

- Fiber cement
- Stucco
- Cultured stone.

The assemblies are instrumented to measure temperature and relative humidity in the space created by the furring strip. The intent is to measure deflection of the assemblies for an entire year and compare the measurements to fluctuations in the environmental conditions (Figure 21 and Figure 22). On a few discrete days, the daily fluctuations will also be captured and compared.

Figure 18. Exposed wall assemblies before the furring strips are loaded

Figure 19. Exposed wall assemblies loaded to representative cladding weights

Figure 20. Exposed wall assemblies covered with a corrugated metal cladding panel

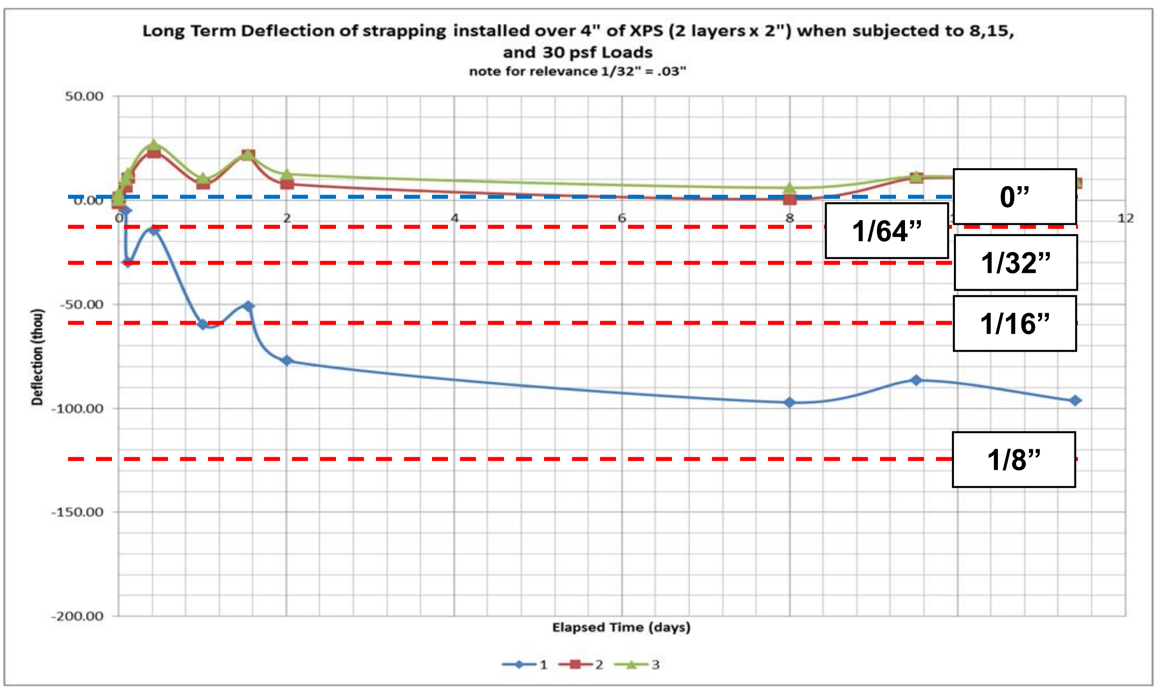


Figure 21. Preliminary deflection over time of 4 in. of XPS insulation loaded to 8, 15, and 30 lb/ft^2

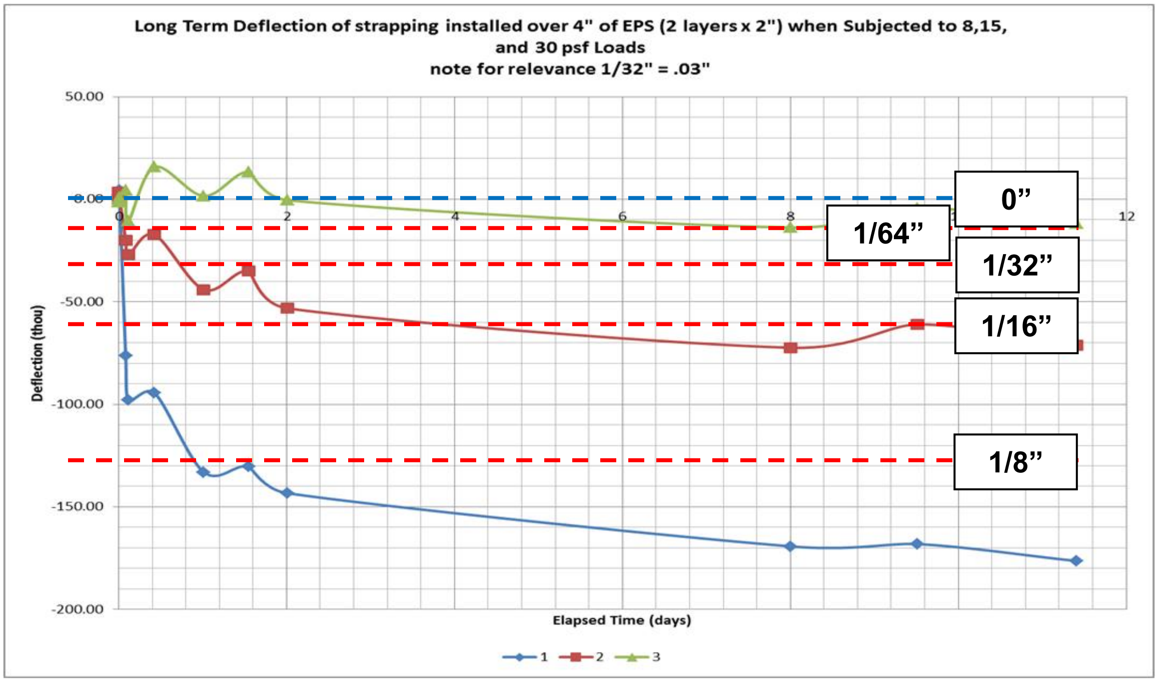


Figure 22. Preliminary deflection over time of 4 in. of EPS insulation loaded to 8, 15, and 30 lb/ft^2

Testing is currently underway, and the results have not been fully analyzed.

6.2.1 Questions and Discussion

Creep of assemblies:
Joe Lstiburek (BSC) comment: This long-term creep will be irrelevant compared to the movement caused by seasonal changes. But we need to go through this exercise to demonstrate that point.

System alternates:
Arne Anderson (DOW) question: Wouldn’t there be a benefit for using other types of cladding attachment (e.g., Z girts or ripped plywood)?

Peter Baker (BSC) answer: Sure, but there was a limitation on what we could look at within our budget. Perhaps we should just say that if we don’t have a concern, we don’t need to worry about other options.

Test program:
Eric Werling (DOE): I am a bit worried about the sequence of testing. Shouldn’t we go for more extreme testing, temperature, wind, etc.?

Joe Lstiburek (BSC) answer: We need to do this as baby steps, to fundamentally understand.

Peter Baker (BSC) answer: We have a pretty extreme climate. The testing is done in a very cold climate zone, with south-facing solar exposure. Also, thick insulation is most appropriate for colder climates, so Waterloo is a good representative location.

Jay Crandell (ARES) comment: Temperature can have a big effect, on creep especially. This type of test gives us basic but important insight. Big temperature swings in foam material itself.

Vladimir Kochkin (NAHB) question: You used screws in all these tests; how did you control tightness?

Peter Baker (BSC) answer: We tried to mimic construction practice; drive screw heads to flush. Tension is in the fastener. Measured force on the load cell was 150 lb—the area of distribution was not identified.

6.2.2 Proposed Deflection Limits and Potential Deflection

Pat Huelman (University of Minnesota) comment: These are really conservative deflection limits, compared to what we see in buildings in reality (e.g., band joist in a stucco building with wood lumber framing). Goes well beyond the deflections that we're seeing in the testing.

Jay Crandell (ARES) comment: We're looking at all the negatives, but there are positives to being able to move. It isolates the movement of the building from the cladding. It's like resilient channels with drywall. The insurance industry pays a lot for stucco and plaster cracks after earthquakes, but not for failed buildings.

6.3 Structural Field Monitoring and Modeling of Thick Continuously Insulated Wall Assemblies

(Gary Parsons – DOW Building Solutions R&D)

Mr. Parsons began his presentation with a brief overview of finite element modeling (FEM), and how the model was validated through testing of discrete components, small-scale system tests up to full-scale wall tests (Figure 23) (Parsons et al. 2009).

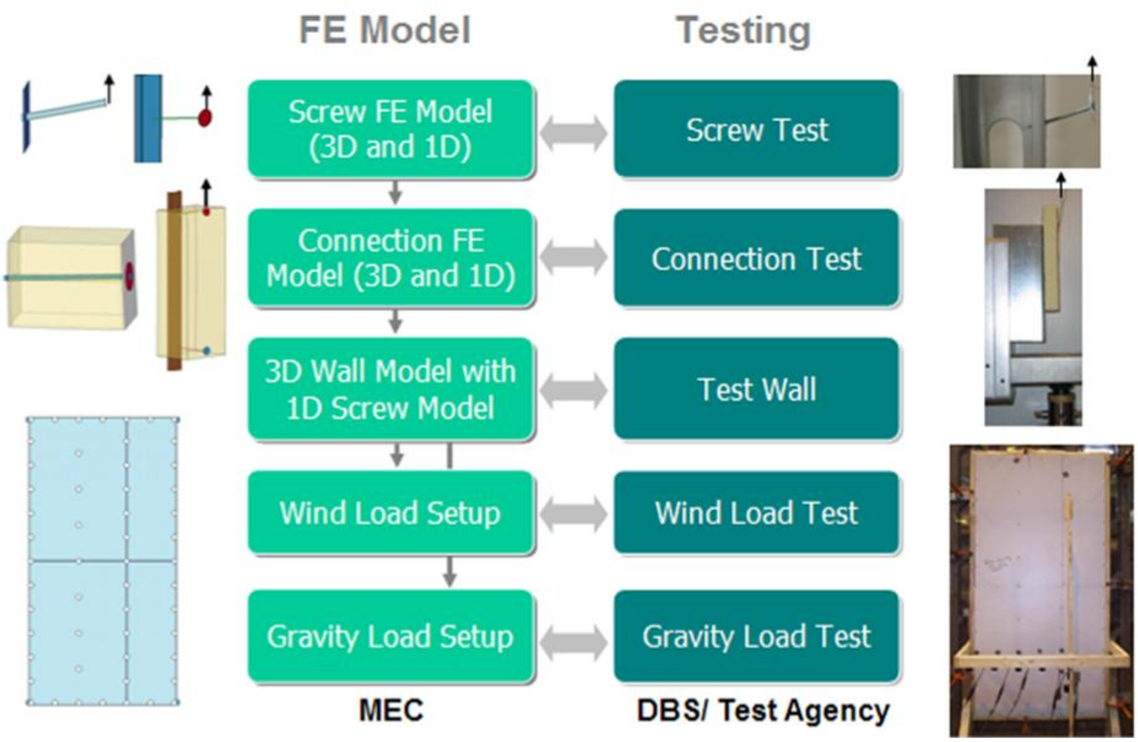


Figure 23. Graphical representation of FEM

Initial modeling focused on the performance of a single fastener. The modeling and testing results were then used as inputs for a simple 1D beam element model (Figure 24 and Figure 25). These connections were modeled in two configurations; one using a washer at the screw head (washer contact model) and one using a rigid sheet connecting the fasteners (direct connection model).

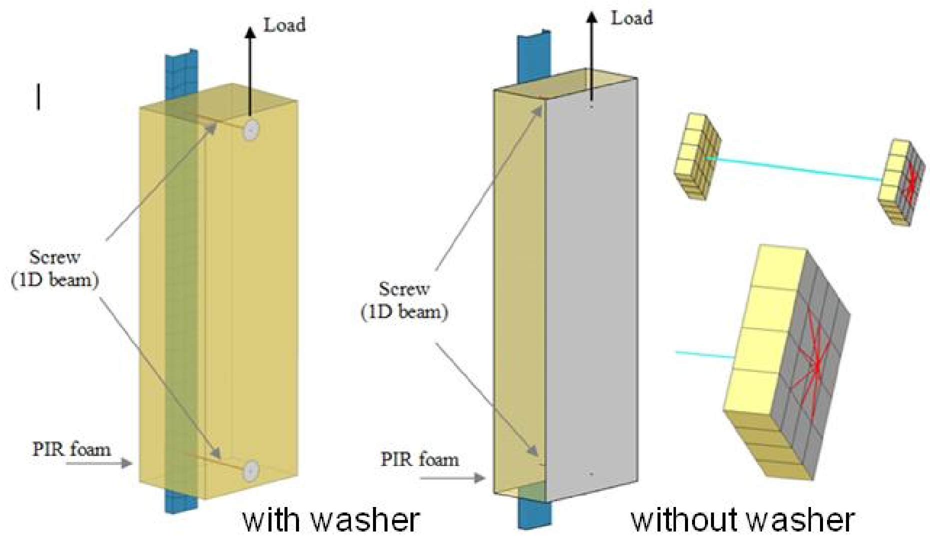


Figure 24. Example of 1D beam element modeling approaches

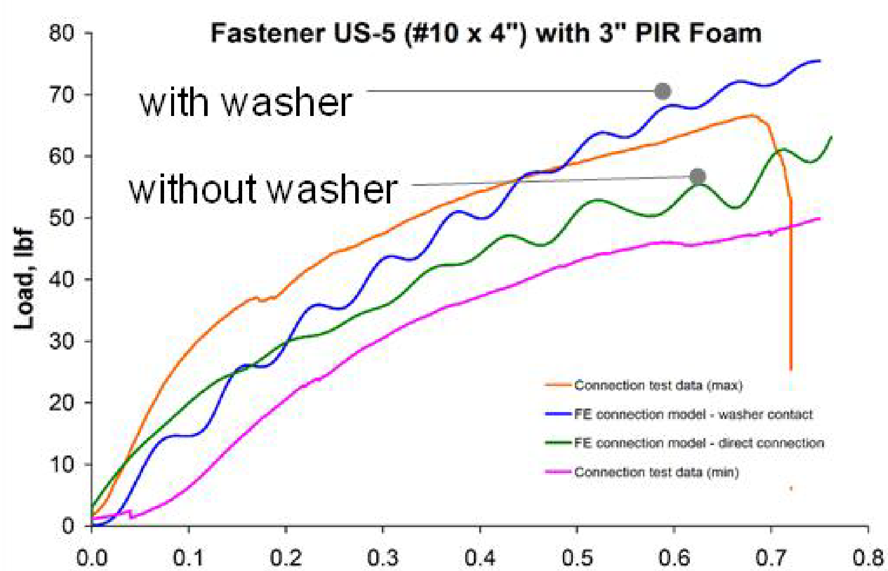


Figure 25. Results of 1D beam element modeling and system testing

Expanding from this, full-scale wall assemblies were then modeled (3D finite element analysis) and tested. The testing examined wind pressure resistance and gravity load resistance.

For the wind load resistance, the pressure drops when air leakage begins; however, it would be complex to model such failure criteria in an FEM. Based on test results, a maximum displacement of about 1 in. anywhere in the panel approximately corresponds to failure (air leakage). This criterion is used in FEM to predict the pressure at failure (Figure 26 and Figure 27).

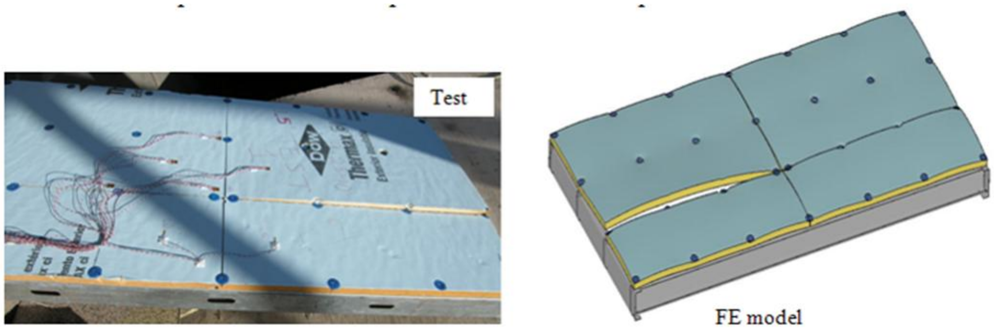


Figure 26. Actual test panel (after testing and elastic recovery) and FEM (showing displacement under load)

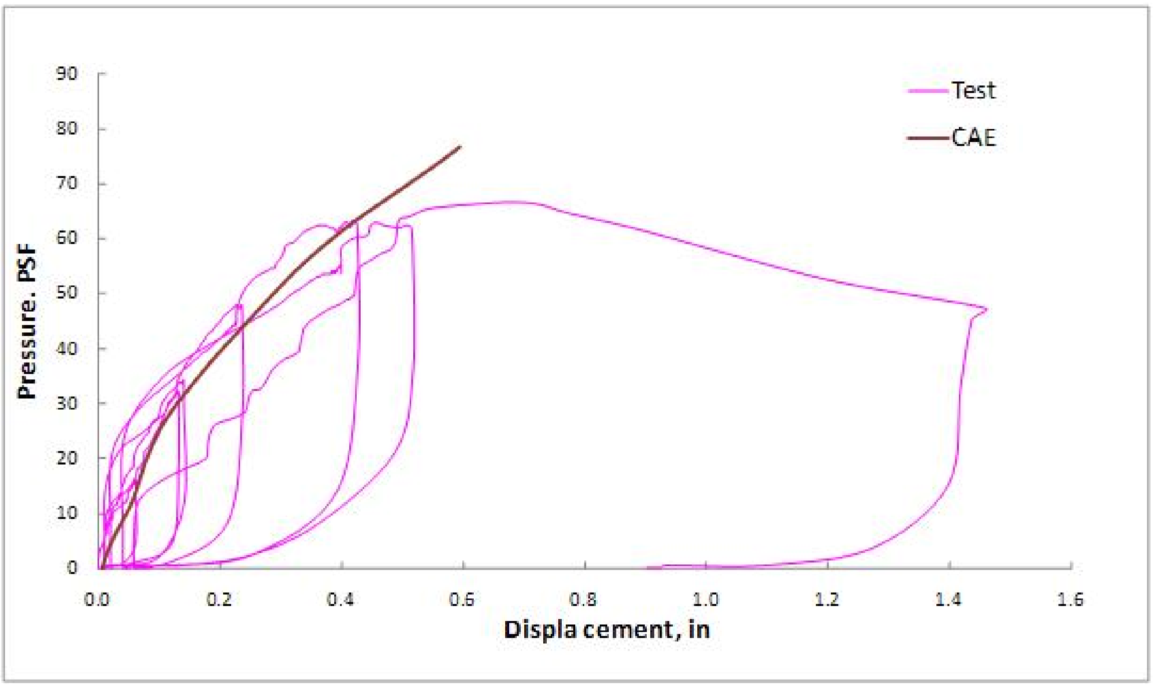


Figure 27. Load versus deflection plot of actual test and FEM prediction

A stucco clad wall assembly was used for the gravity load resistance analysis. Finite element analyses were completed using both the washer contact model and direct connection 1D beam models with various edge and field spacings of the stucco lath attachment. A 4-ft × 8-ft full-scale wall assembly was also constructed and instrumented with linear voltage displacement transducers (LVDTs) to measure the gravity-induced creep over time (Figure 28).

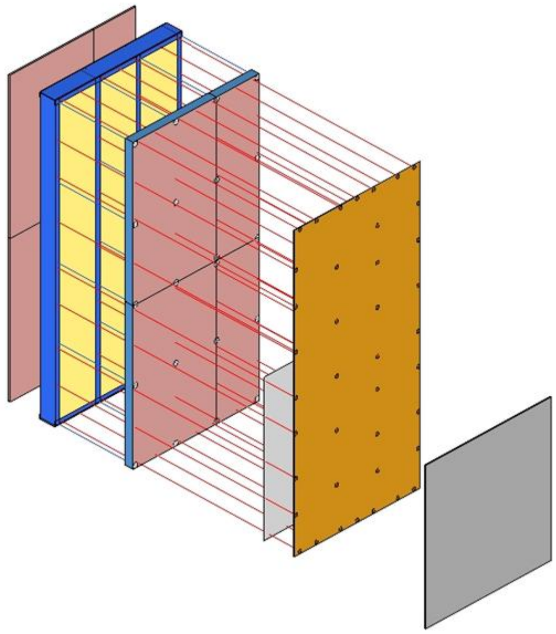


Figure 28. Graphical representation of the full-scale wall assembly with stucco cladding

The FEM results had the following maximum vertical displacement values:

- Washer contact model = 2.25 mm
- Direct connection model = 0.5 mm.

The maximum stress in the foam insulation was indicated to be 0.05 MPa, which is one third the foam yield stress (one third maximum allowable stress ~ safety factor of 3).

By comparison, the magnitude of creep displacement of the stucco with respect to foam is about 0.04 mm after about two months, when the displacement appears to level off (Figure 29). The magnitude of the displacement confirms that the fastener layout based on FEM prediction of gravity loading is on the conservative side.

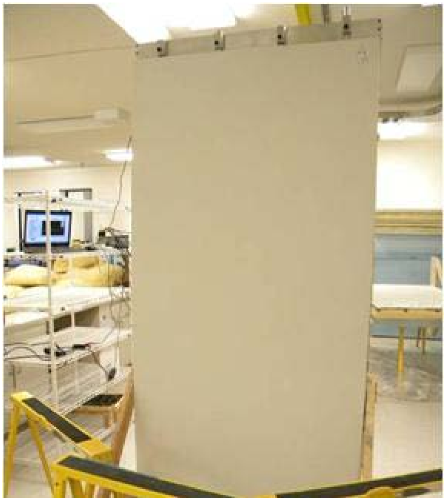
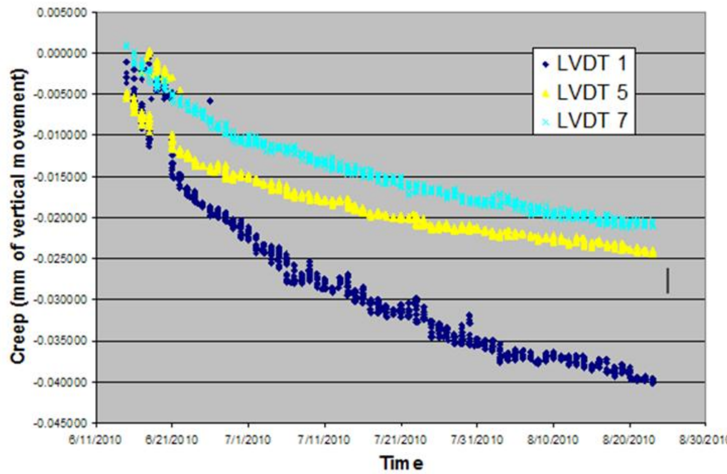
 

Figure 29. Full-scale wall test assembly (left) and deflection over time (right)

Mr. Parsons then discussed a case study of a residential building retrofit that was constructed in Vancouver, BC in Canada, where the movement of the cladding was monitored over time (Parsons et al. 2012).

The original building was construction with the following wall assembly:

- Cement stucco with wire lath
- Semi-rigid fiberglass insulation (~ 1 in. thick)
- 3½-in. steel studs with fiberglass batt insulation infill
- Polyethylene air/vapor barrier
- ½-in. interior drywall.

The retrofitted wall assembly was constructed as follows (Figure 30):

- ⅞-in. acrylic stucco on paper backed lath
- ⅞-in. Z-girts at 16 in. o.c. fastened with self-tapping screw fasteners at 6 in. o.c.
- 3-in. Type 4 rigid insulation (R-15) with peel and stick flashing at joints
- Self-adhered membrane
- ½-in. fiberglass faced exterior gypsum sheathing
- Existing 3½-in. steel studs
- Existing ½-in. interior drywall.

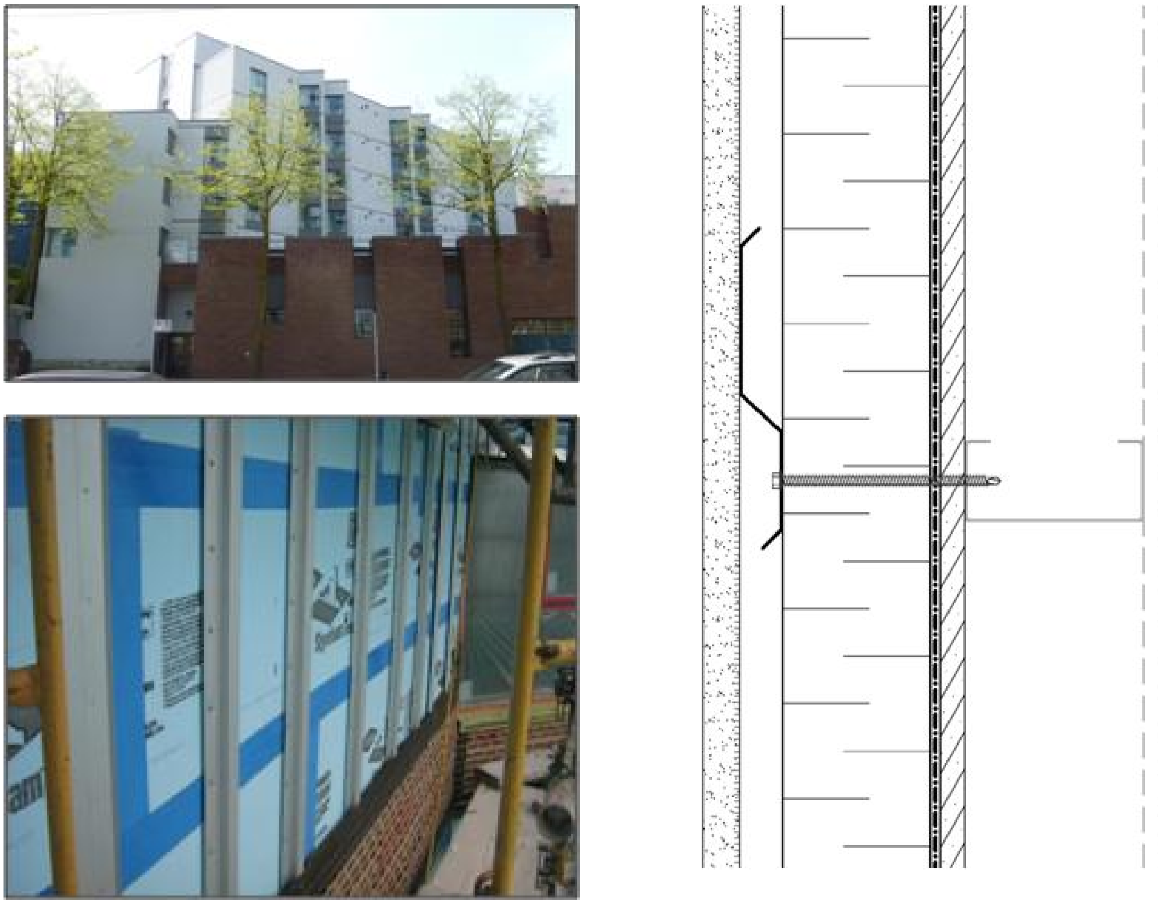


Figure 30. Exterior retrofit wall assembly

The structural design of the cladding attachment functioned based on the following elements:

Wind and gravity loads are transferred through the exterior vertical Z girts to the insulation and backup wall.

The rigid girt spreads gravity and wind load onto rigid insulation.

The gravity load puts a tension load on the fastener because rotation is constrained by insulation (the fastener cannot rotate unless the foam compresses) and a shear load.

Wind and gravity put a compression load on the rigid insulation or tension load on fastener (Figure 31).

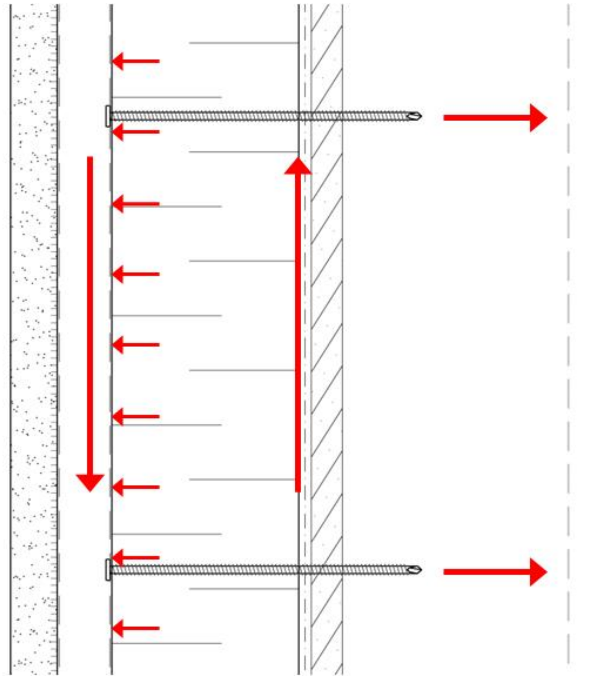


Figure 31. Wind and gravity load transfer through the wall assembly

LVDTs with an accuracy of 0.085 mm ± 5% were used to measure displacement. The LVDTs were placed in six locations in a test block of insulation. The sensors were placed to measure movement in the vertical y direction (three sensors at the bottom of the panel), in the lateral or x direction (two sensors in either edge of the panel), and in the out-of-plane or z direction (one sensor placed near the middle of the panel). These test panels were placed at multiple floor heights on various elevations.

Displacement data were collected for more than one year (Figure 32). The results indicated stable performance and evidenced no creep over time.

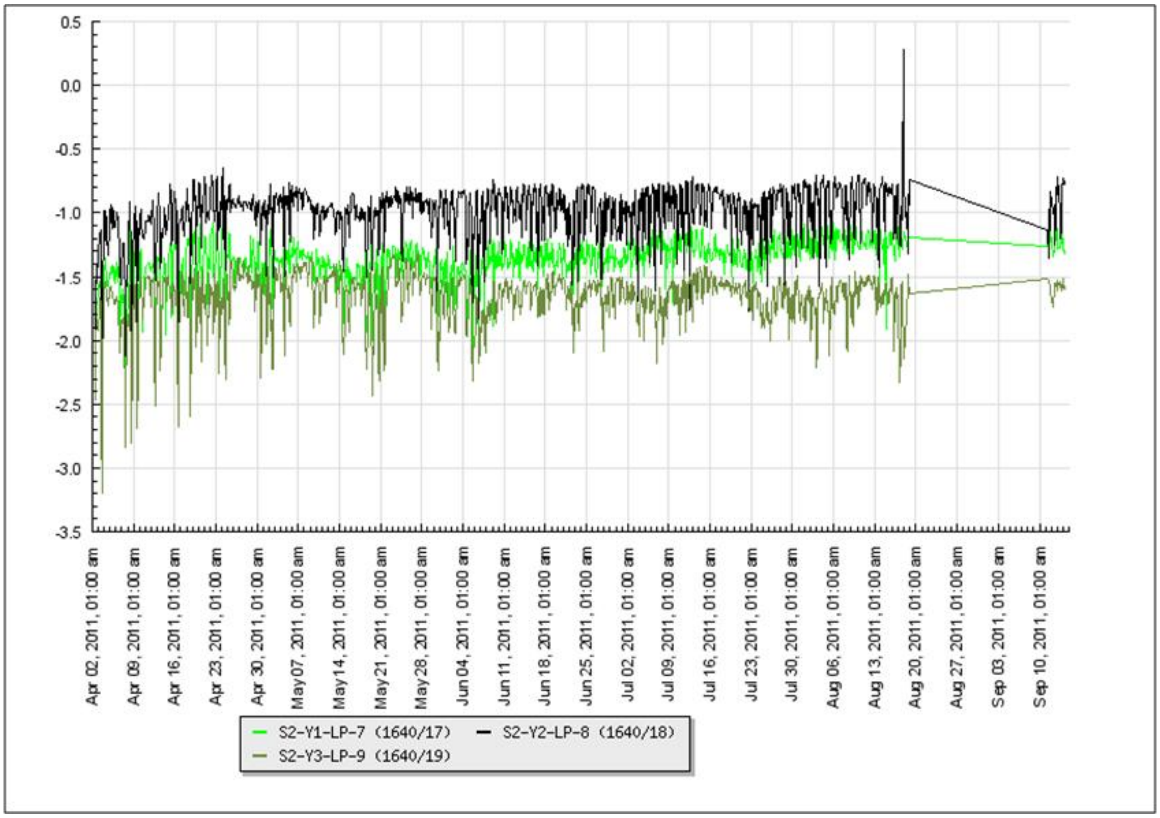


Figure 32. Vertical displacement data (2nd floor, south), mm

The data were also analyzed to examine the thermal expansion and contraction correlation to the measured displacement (Figure 33). No correlation could be seen in the data collected.

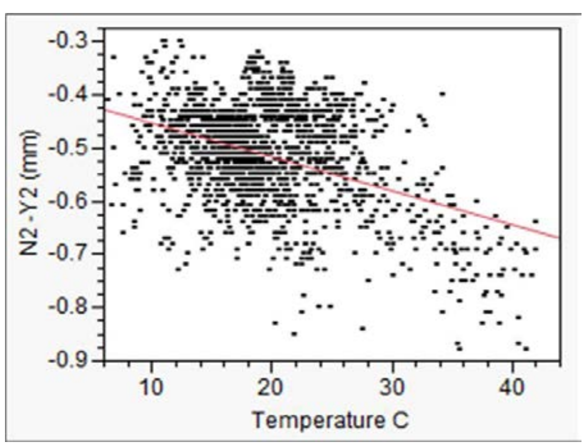


Figure 33. Example of a displacement versus temperature plot

The results of the Vancouver monitoring project showed that displacement ranges (x, y, and z directions) are negligible and do not depend on measurement location. Also, there was a poor correlation between the temperature and displacement measurements. Overall the building performs well; no stucco performance problems have been reported to date.

It was also demonstrated that the FEM correlates reasonably well to connection scale tests; however, FEM generally overpredicts movement of full-scale test assemblies.

6.3.1 Questions and Discussion

Finite element analysis:

Mike Gestwick (NREL) question: if finite element analysis consistently overpredicts, that should suggest something is wrong with the model, right?

Gary Parsons (DOW) answer: Part of the mismatch may be the complexity of the building (corners, windows, etc.).

Mike Gestwick (NREL) comment: But you see the same thing on the 4 × 8 sections.

Modeling compared to case study:

Arne Anderson (DOW) question: What were the differences between the modeling and the test site?

Gary Parsons (DOW) answer: There was no Z-furring in the model and effectively fewer fasteners at the test site. We did not create more models to do this actual wall system.

6.3.2 Case Study Monitoring Setup:

Vladimir Kochkin (NAHB) question: Could you describe the y deflection—what was being measured relative to what?

Gary Parsons (DOW) answer: Sensors were placed as outboard as possible in the foam so as not interfere with stucco install, but still within the foam. Measurements were taken relative to brackets, through the DensGlass sheathing, attached to steel. The intent was to find a reference that will not move—ideally a post in the ground—but that won't happen.

Anthony Grisolia (IBACOS) question: Any movement at the control joints?

Gary Parsons (DOW) answer: Not sure.

Anthony Grisolia (IBACOS) question: With the three-coat stucco, are there any data on each applied layer creeping?

Gary Parsons (DOW) answer: Sensors were on the building when stucco was being applied, but I don't think the measurement could have made out the deflection from installers applying stucco on the building.

Anthony Grisolia (IBACOS) question: How much total data?

Gary Parsons (DOW) answer: Probably will run another three years.

6.4 Wind Performance Testing of Walls with Exterior Rigid Foam

Vladimir Kochkin (NAHBRC) began his presentation by reviewing the issues surrounding wind pressure resistance of walls with exterior rigid foam insulation. Its importance is related to market implications, as the 2012 IECC will require exterior rigid insulation for walls in climate zones 3 and higher.

Exterior wall systems are loaded by positive wind pressure forces and leeward suction forces. A simple model would assume that 100% of the pressure is registered across the exterior sheathing layer only. In reality, the pressure is distributed across all the wall layers (Figure 34).

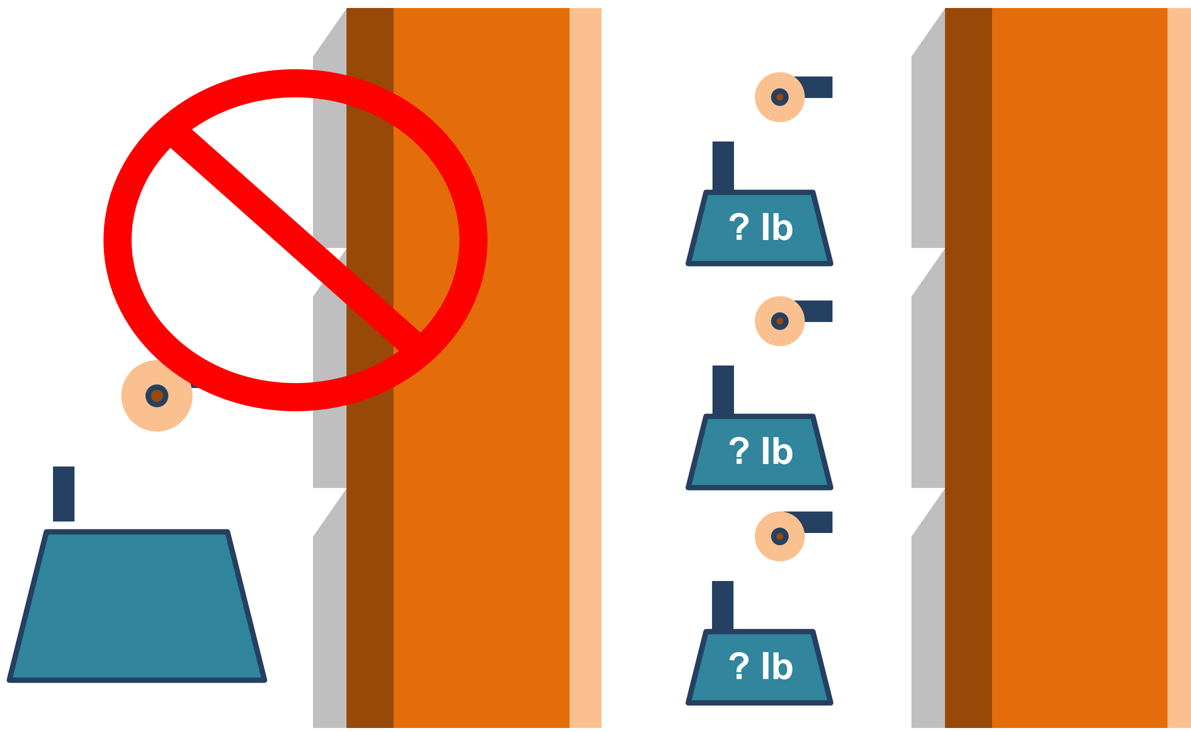


Figure 34. Schematic of pressure distribution across wall assemblies

The pressure distribution can be described by determining the pressure equalization factors (PEFs) for each layer of the wall assembly. The PEFs are evaluated based on the following equation:

$$PEF_{layer} = \Delta P_{layer} / \Delta P_{total\ assembly}$$

Understanding the pressure distributions is key to optimizing assembly designs to properly manage wind loads.

Two test programs that looked at these issues:

- High-R Walls for New Construction Structural Performance: Wind Pressure Testing (DeRenzis and Kochkin 2013)
- Wind Loads on Components of Multi-Layer Wall Systems with Air-Permeable Exterior Cladding (Cope et al. 2012).

The results from these test programs were used in the development of ANSI/SBCA FS100 – 2012 *Standard Requirements for Wind Pressure Resistance of Foam Plastic Insulating Sheathing Used in Exterior Wall Covering Assemblies* (SBCA 2012).

The NAHBRC testing used nominal wall specimens that were 4–9 ft tall and 4–12 ft long. The wall assemblies were instrumented with pressure sensors and deformation sensors. The loads were applied using pressure load actuators that can deliver a very quick response to modulate pressure loads on the test samples (Figure 35).

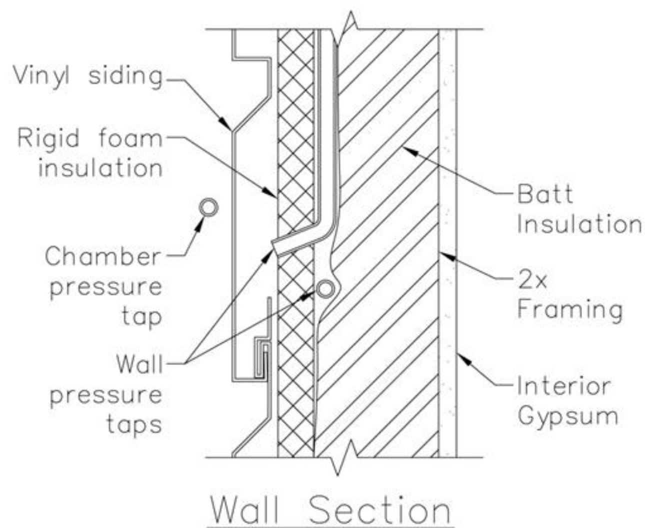


Figure 35. Example pressure load actuator test setup

Several types of wall assemblies were tested, including:

- Group 1 (exterior foam only)
- Group 2 (exterior foam + interior gypsum board) untaped
- Group 2 (exterior foam + interior gypsum board) taped
- Group 3 (vinyl siding, exterior foam + interior gypsum board)
- Group 4 (vinyl siding + exterior foam).

The assemblies were tested to failure with the peak pressures recorded. Vinyl siding effectively acts as a plate washer for the foam sheathing. PEF measurements, however, indicated vinyl siding does not pick up a significant load (< 0.1). The PEF was split roughly 50/50 foam versus gypsum (Figure 36).

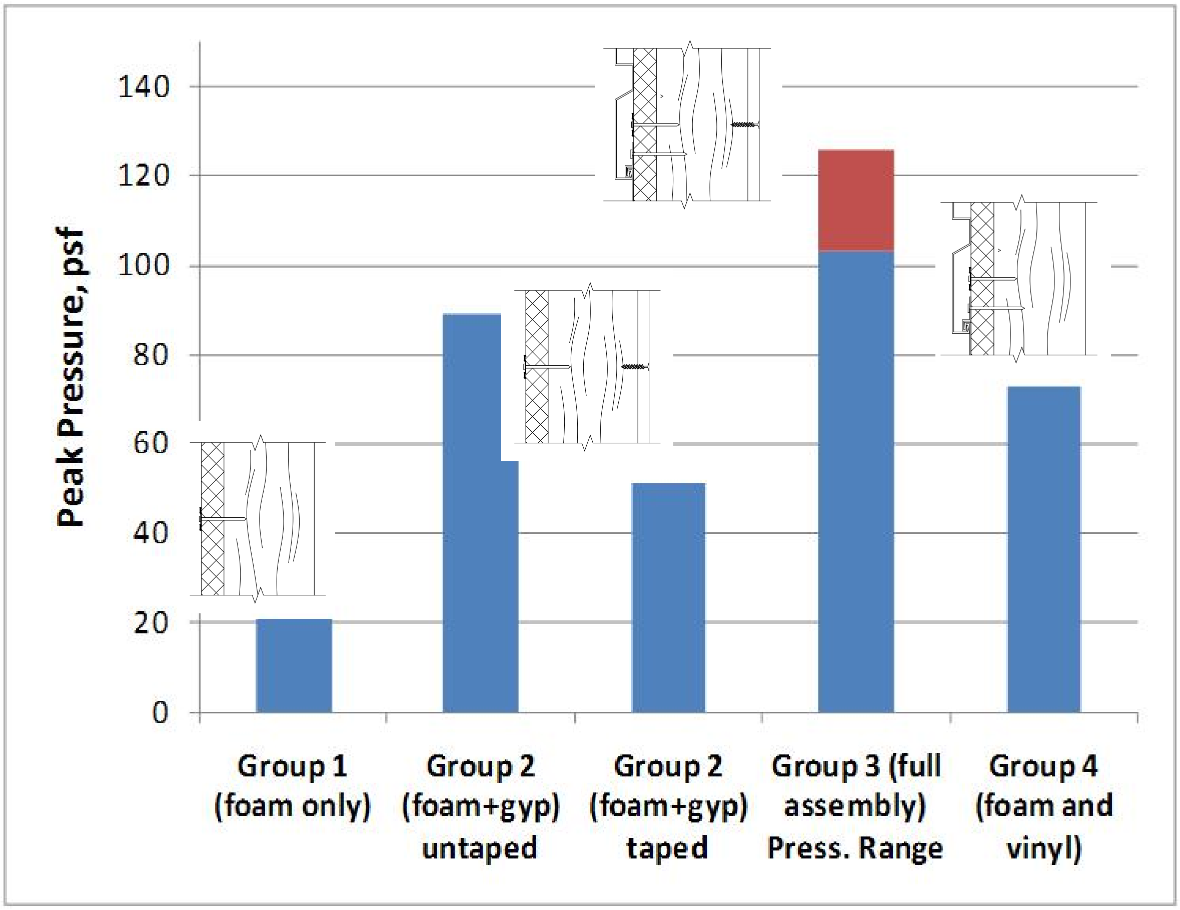


Figure 36. Results of wind testing on walls with rigid foam plastic insulation

The second series of test was conducted at the IBHS full-scale testing facility (Figure 37). This testing was conducted through a large project team, including:

- IBHS
- Foam Sheathing Coalition
- NAHBRC
- Vinyl Siding Institute
- American Chemistry Council
- ORNL/DOE

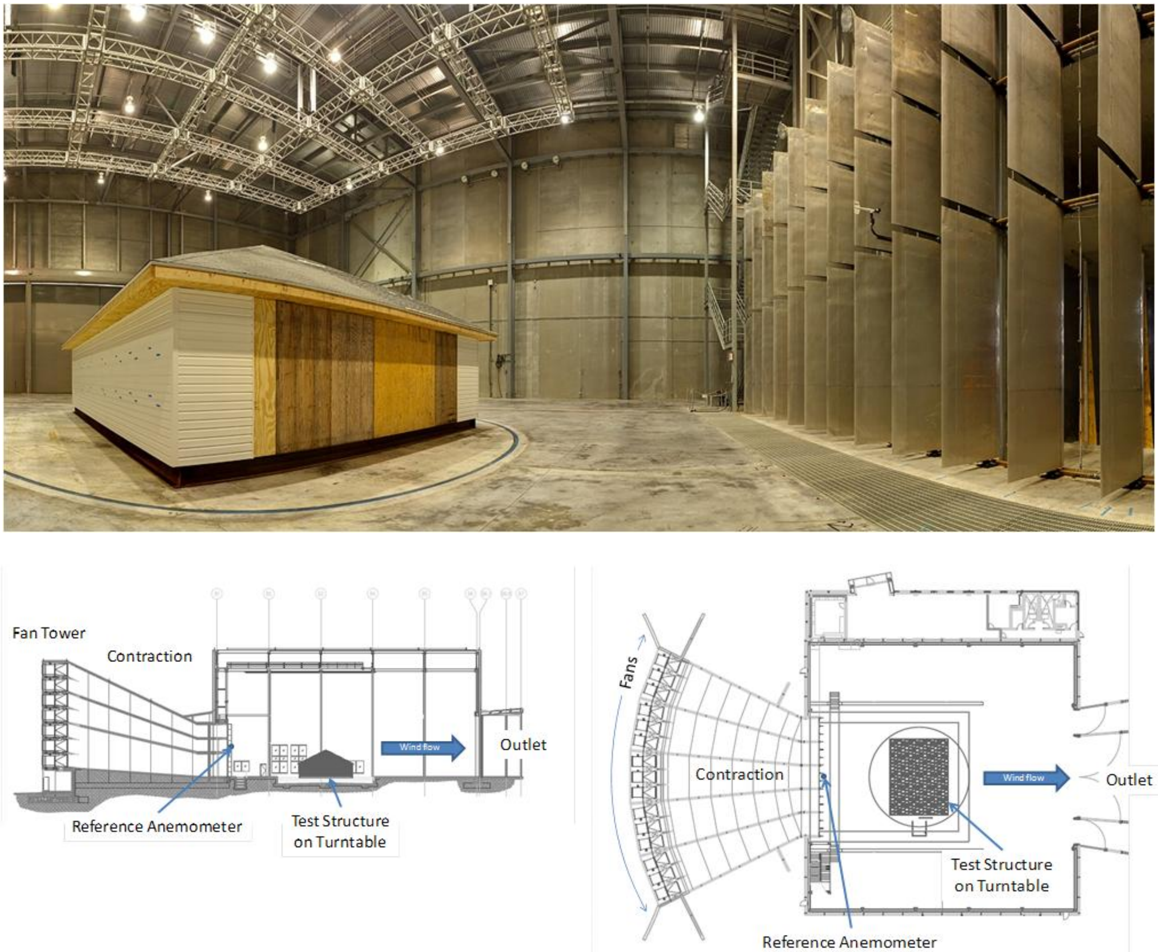


Figure 37. IBHS full-scale test facility

Testing was completed on two 2 × 4 wall systems with interior gypsum finish.

1. Vinyl siding over 1 in. of XPS
2. Vinyl siding over 7/16 in. of OSB.

Measurements were taken via 32 pressure tap locations on each test wall. The objectives were to measure the PEFs, measure the ultimate capacity of the wall assemblies, and observe the failure modes (Table 6).

Table 6. Observed Failure Based on Test Wind Speed and Wall Configuration

Test Seq. #	Siding	Wind Speed (mph at 16 ft)	Pressure (lb/ft^2)	Angles	Failure
1	Vinyl	43–46	< 10	360° at every 10°	No damage
2	Vinyl	58–79	< 25	10 different orientations	No damage
3	Vinyl	87–103	< 30	0° and 180°	Damage to vinyl (both XPS and OSB)
4	No siding	105–107	< 35	0°	No damage to foam

The results indicate that the vinyl siding resists as much as 75%–80% of the exterior negative design pressures. These results were greater than the results from the NAHBRC air box tests. The differences between the pressure box and wind tunnel test are probably due to differences in uniform pressure compared to pressure gradients. Air can move behind vinyl siding, so that the pressure profile of the exterior is different than pressure profile behind vinyl siding. With increased pressures, more layers pick up the load. In runs with no vinyl siding, the load is mostly on the foam, and little is on the gypsum.

As long as the siding remains in place, the sheathing experiences 55%–60% of the peak negative and positive pressure acting on the wall system. The peak pressures across the gypsum wall board were generally 50%–60% of the pressure across the wall system. The vinyl siding products tested still had very good performance (failed at 120 mph, 33-ft elevation). A question was raised about whether the siding component should be considered when designing the foam sheathing. The PEF for foam was greater without the siding.

Further research is needed to understand the actual force (rather than pressure at a single infinitely small location) on the vinyl siding fasteners. Other issues that need to be considered are the impacts on capacity of vinyl attached to OSB only (not stud penetration), or vinyl siding over thicker foam attached to vertical 1x framing (gap between siding and sheathing).

6.3.1 Questions and Discussion

Rating of vinyl siding:

Question: What was the siding rated for in terms of mph?

David Johnson (Vinyl Siding Institute) answer: It is not a direct relationship, but ASTM D5206 testing provided values in the same ballpark of pressures where it failed. The point where it failed was comparable to where you would expect this siding to fail.

6.4 Recent Wind Loading Research

Randy Van Straaten (BSC/University of Western Ontario) began his presentation by reviewing some basics of wind testing. Unlike the IBHS full-scale testing laboratory, most wind testing needs to be completed using either scale models or pressure boxes installed over specific areas of a building or enclosure assembly.

With scale models, pressure relationships between areas and volumes are not directly scalable (Figure 38). Certain adjustments need to be made to compensate for the differences.

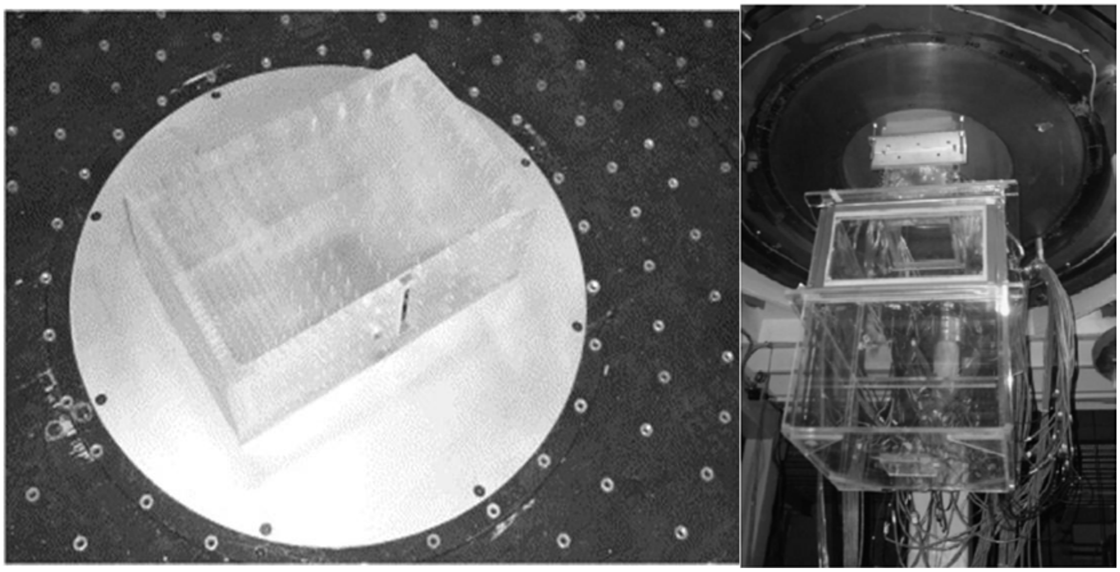


Figure 38. Example of scale test house with an air cavity connected to the inside (under the wind tunnel) to deal with scaling problems

The National Institute of Standards and Technology hired the University of Western Ontario to put together time series of pressures on the outsides of residential-scale buildings. The work provided a database of pressure coefficients around the building areas (see Figure 39).

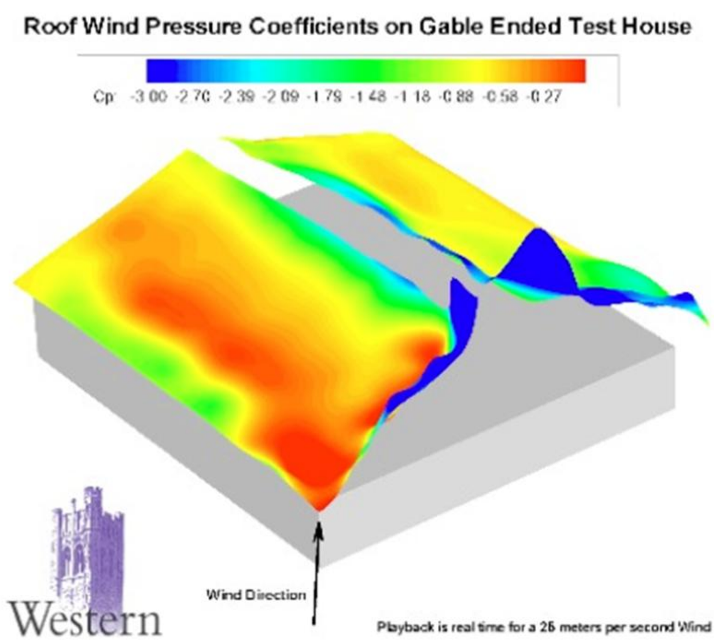


Figure 39. Example of roof wind pressure coefficients on a gable ended test house

Another example of testing looked to evaluate the pull off/pull through of fasteners attaching wood sheathing to roof framing. For this testing, an array of air boxes was attached to a roof in a grid to achieve spatial variation of pressure (Figure 40). This testing compared fluctuating loading versus ramp loading. The results indicated most nail fasteners demonstrated similar performance, while staples demonstrated only 50% capacity compared to the nails Hurriquake nails have the highest resistance. Staples do, however, have some benefits, in that installers typically use many to increase resistance.

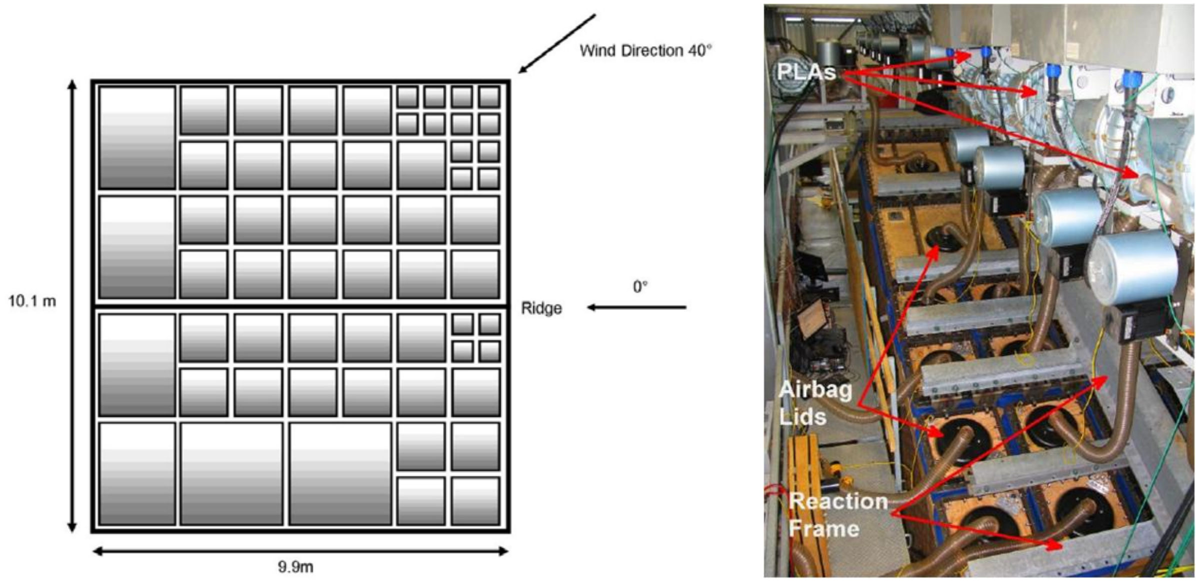


Figure 40. Example of air box test setup and grid pattern on a roof assembly

Testing wall claddings presents more difficult problems. Wall claddings are typically leaky (air porous), which requires more fan power. It is also difficult to attach an array of air boxes to flexible cladding systems without restricting movement.

There is some question about the significance of pressure moderation. Historically there have been numerous failures of wall sheathing at gable end walls (Figure 41). Dr. Kopp studied gable end failures and determined that they could not be explained solely by pressure differences, aerodynamics (more wind hitting it), or spacing of studs. He determined that drywall must take a significant portion of the pressure drop.

Figure 41. Example of a building with sheathing failure at the gable end wall of the attic space

The challenge is developing a method to predict the PEF. Several options are available; each has advantages and disadvantages.

1. Empirical model from IBHS testing.
    a. Cumbersome and expensive
2. Wind tunnel testing
    a. Scale issues (small-scale siding)
    b. Reynolds number effects (e.g. for flow through vinyl siding gaps)
    c. Having only a full scale section in wind tunnel would not capture the bluff body aerodynamic of the overall house structure
3. Computational fluid dynamics (CFD)
    a. A wide range of length and time scales that need to be considered and could make CFD modeling difficult
    b. Difficulties with modeling flow separation and turbulence
4. Apply/adapt an available model
5. Develop full-scale component testing.

Currently, the most viable options appear to be apply/adapt an existing model, or assembly-level testing (which includes spatial and temporal variations).

Earlier flow network models examined the aerodynamic performance of roof pavers. There are two models to look to: the Sun and Bienkiewicz Model and the Gerhardt Model about the roof pavers. Some insights that can be gleaned from examining these models are that pressure moderation improves as the ratio of opening size to cavity depth increases, and greater flow resistance underneath. Also increasing the permeability of the pavers increases the pressure equalization (Figure 42).

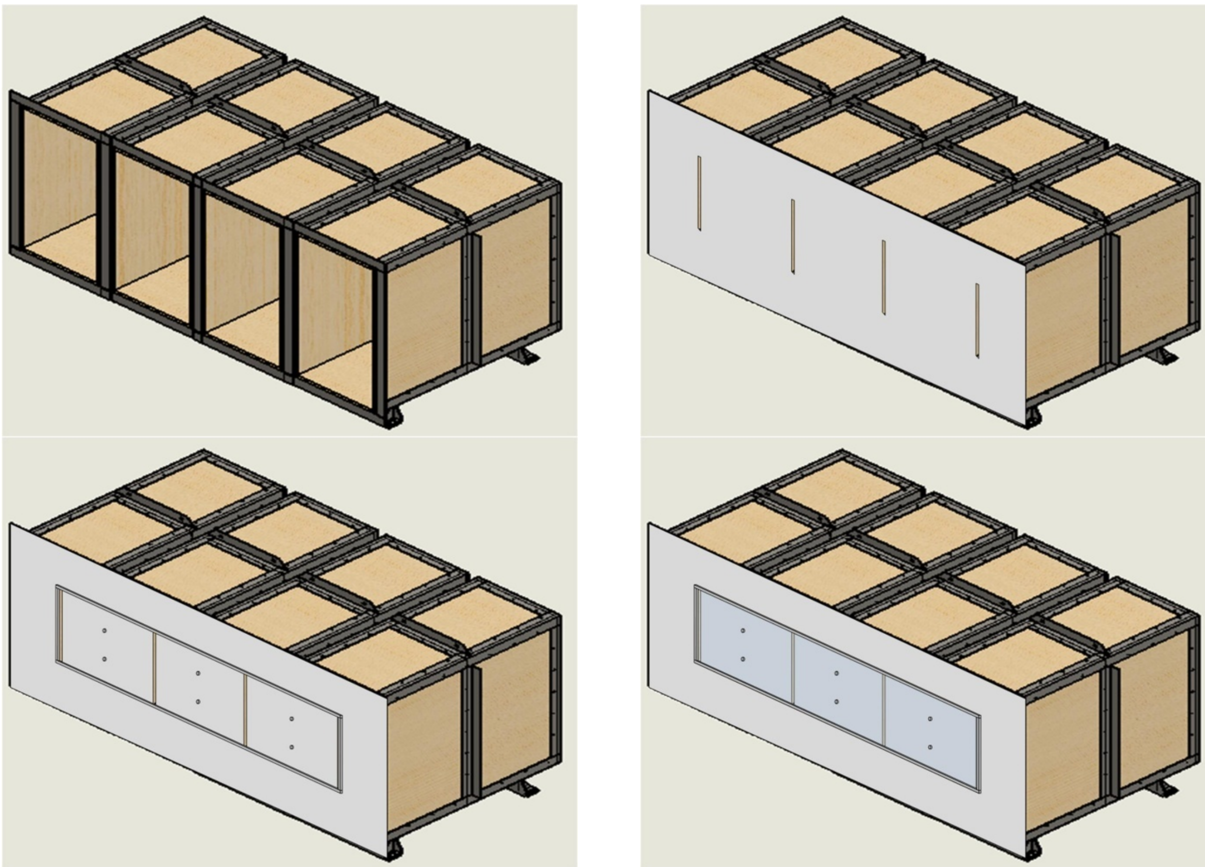


Figure 42. Schematic of pressure moderation test rig with idealized cladding

Flow network models:

- 3D models
- Apply Darcy's law for flow through openings—dominated by wall friction losses
- Apply Darcy's law for cavity flow—assuming laminar flow (no Reynolds effects)
- Quasi steady state assumptions—no inertial or compressibility effects.

The current research plan is to:

- Analyze IBHS data.
- Build a test rig—start with idealized claddings.

- Compare to existing models.
- Develop an adequate model.
- Test the model with IBHS data.

The intent is to develop a means to test cladding systems using small-scale component tests that will provide results that can be reasonably correlated with full-scale test results. This will allow a wider range of cladding types to be tested in shorter periods and at much lower cost than full-scale building tests.

6.4.1 Questions and Discussion

None.

6.5 Installing James Hardie Siding Over Exterior Rigid Foam

(Dawn Cole – James Hardie Building Products, Inc.)

This presentation was given by Jay Crandell on behalf of Ms. Cole.

The current James Hardie installation requirements allow fiber cement siding to be installed directly over foam insulation up to 1½ in. thick. This is a change from past literature that limited the thickness to 1 in. For foam sheathing thicker than 1½ in., and up to 4 in., the fiber cement siding can be installed to the furring/strapping installed atop the insulation.

Wood furring:

- Shall have a specific gravity consistent with fastener holding capacity (typically 0.36 or greater).
- Shall be nominally 4 in. wide and thick enough for full engagement with fastener.
- James Hardie cautions the use of pressure-treated lumber and stainless steel fasteners.

Steel strapping:

20 gauge thickness minimum fastened with pins.

For wind load resistance, the fastener must have a solid connection of siding to a nailable substrate with a minimum 1¼ in. of fastener penetration into framing or full net penetration of furring connected to the framing. The shank diameter must also remain consistent for the required wind load.

James Hardie is concerned about the cantilevering effect, but has not seen a catastrophic response. Some issues in siding applications are nail shine (diversion of the fastener to miss the framing) and in rare circumstances, water migration has followed the fastener, through the foam, and into the framing.

Dimpling of siding has been noted, caused by the compressible nature of the foam insulation. Field inspection of these occurrences revealed poor quality practices of the siding installation.

ASTM E330 *Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference* evaluations identified the following minimum limits:

- Type II (EPS)
- Type X (XPS) per ASTM C578 (2012)
- Type 1 (polyisocyanurate) per ASTM C1289 (2013).
- The recommendations are summarized in James Hardie Building Products Technical Bulletin 19.

6.5.1 Questions and Discussion

None.

6.6 Open Discussion Period

At the end of the presentations an open discussion period was held. A summary of the discussions follows.

Attachment of wood furring over exterior insulation:

Anthony Grisolia (IBACOS) question: Does this research apply to retrofits, in addition to new construction? Particularly attaching to brick?

Peter Baker (BSC) answer: Assuming that the baseline is wood frame construction, going back to wood frame makes sense. Overclad of masonry is a similar concept. Use 2 × 4 wood members attached to the masonry with insulation between the wood studs as the base layer, with the furring strips attached back through subsequent insulation layers into the wood studs.

Pat Huelman (University of Minnesota) comment: Fastening a furring strip to the building or substrate has been addressed. Nailing through foam can cause blowouts or problems; but I have not seen it with screws. All fasteners are not the same in terms of interactions (as opposed to structural requirements).

Jay Crandell (ARES) comment: I have not seen blowout, but have seen head pull-through, which is predictable. But many washers are available to improve pull-through resistance. Remember, Vladimir's work at 100 lb/ft^2 exceeds Florida's wind code requirements.

Use of spray polyurethane foam:

Anthony Grisolia (IBACOS) question: We are doing nine homes with NYSERDA on retrofits. Does anyone know anything about applying spray foam to exterior walls? (General reference back to John Straube's work.)

Anthony Grisolia (IBACOS) comment: On the retrofit side, one problem is old siding with lead paint, as it is expensive to remove the lead paint. Going over the existing siding with spray polyurethane foam encapsulates the lead paint.

Acceptable cladding movement and deflection limits:

Peter Baker (BSC) question: In regards to the proposed acceptable deflection limits for cladding products, are we in the right range, or should we reconsider?

Brian Lieburn (DOW) comment: In terms of lightweight claddings, the 1/16 in. limit makes perfect sense. There is considerably more variation in practice. But if the entire wall surface deflects/sags uniformly, there is no real problem from a consumer acceptance standpoint. Uneven settlement (lap siding) results in uneven instead of straight lines in laps; this could be a problem. A surprisingly small tolerance there, but I can't put a number on it. It might take some consumer focus groups.

Peter Baker (BSC) comment: I think the main concern is at window and door openings as they are rigidly attached to the structure, and the differential movement between the cladding and the fenestration can result in problems. We have solutions to these problems by providing a movement joint at the interface (such as a sealant joint between the window and the stucco J-bead).

Published work:

Vladimir Kochkin (NAHB) question: Is BSC's and DOW's work published?

Gary Parsons (DOW) answer: Mostly.

Peter Baker (BSC) answer: 2011 research has a final technical report that has been published.

Builder experience:
Dave Joyce (Synergy Construction) comment: We have done 30 buildings with 4 in. of foam, and have not seen any creep yet.

Kohta Ueno (BSC) question: Does anyone have any good solutions to shingles on the outsides of foam walls? Paul Eldrenkamp with Byggmeister built a house in the 1980s (?) with horizontal strapping, 6 in. of exposure. Ended up being a huge amount of strapping, and thus cost. Didn't bother kerfing the back of the strapping for drainage, but it is still on its original coat of paint and looks fine (coated six sides). In later cases, he used the prefabricated shingle panel products.

Peter Baker (BSC) answer: Use a second layer of wood sheathing and building wrap over the furring as a nail base for the shingles.

7 Answers to Research Questions

7.1 Gravity Load Resistance

What should be the in-service vertical deflection limits?

There was general agreement that the proposed deflection limits (1/16 in. for board/panel sidings, and 1/64 in. for brittle claddings) were reasonable given the current state of knowledge. Most of the comments from attendees were that in reality these limits are still conservative, and that greater movements in both cladding types could very likely be tolerated.

Is the current engineering cladding attachment design approach appropriate?

The current design approach has many limitations, as it is based to a great degree on fitting research to past datasets and does not account for other aspects that may contribute to the development of capacity (friction and compression of insulation). This is being weighed against a current critical industry need for code guidance on attachment over exterior insulation. Long term plans are to work with the AWC to develop the design method to enable engineers to calculate solutions.

How should creep be accounted for in design?

Creep is currently accounted for with safety factors applied to the design values for cladding attachment. Current research looking at exposed long-term deflection movement of cladding assemblies over exterior insulation will help to determine if these safety factors are appropriate.

7.2 Wind Load Resistance

Are cladding systems and underlying building elements at risk of damage under high wind loads?

Research has demonstrated that pressure moderation across the wall assemblies does occur. Recent full-scale wall tests showed no damage to exposed (no cladding installed) exterior foam insulation when tested to extremely high wind loads. This is an encouraging result, as most cladding systems reduce the PEF on the insulation and help clamp the insulation in place. Additional testing across a wider range of insulation types with various water resistive barriers is recommended.

Do current test methods properly account for pressure moderation and load sharing across enclosure assemblies?

The newly available full-scale testing provides differing results about the PEF of the siding. Further refinement to test methodologies, and development of new methodologies, could help to further refine the design requirements for wall layers.

Can full-scale testing of assemblies be replicated or approximated with smaller laboratory testing?

Research is underway to try to approximate full-scale test methods using small-scale component testing or predictive modeling. The method proposed is to construct a small-scale idealized cladding test rig and compare the results to existing 3D flow models. If needed, a new 3D flow model will be developed and validated using data from full-scale wall assembly tests.

8 Action Items

Draft code language has been developed; SNY has already adopted it. Proposals submitted to the IBC code hearings, however, failed to be adopted. The language is to be further reviewed and modified based on responses from the IBC code hearings, and results of this meeting to refine the proposals for the IRC hearings in January 2013. Jay Crandell of ARES Consulting has been leading this effort.

BSC is to continue conducting research in the area of gravity load resistance. The focus is on trying to better understand and quantify the potential impacts of long-term creep on the vertical displacement of cladding systems.

The University of Western Ontario will continue to research the pressure moderation effects and wind resistance of wall cladding systems. The intent is to help develop test methods and analysis tools to allow for cost-effective wind resistance analysis of a wide range of cladding materials.

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