MULTI-YEAR ADVANCED RESIDENTIAL BUILDING SYSTEMS RESEARCH

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Summary of Code Barriers:
Summary of Code and Standard Barriers to the Implementation of High Performance Home Systems Designs

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INTRODUCTION

Building codes serve to ensure minimum requirements for safety, durability, and energy efficiency of homes. To enable innovation and to support continual improvement, building codes are updated on a 2-3 year basis to (1) include new methods of and/or materials for construction and (2), where needed, revise the current methods of construction to better meet the intent of the code.

In serving their regulatory role, building codes can present barriers to the use of new construction technologies that are not listed in the provisions of the code. In order to obtain acceptance of a national model building code, technical substantiation of performance validated by testing, analysis, successful practice, or other means is required. The process of amending the building code is time and resource consuming as it may involve development of new testing methods, design approaches, performance criteria, performance evaluation, etc. On the other hand, the building code development process can be used to eliminate or limit the use of existing technologies where there is a real or perceived lack of sufficient technical substantiation for demonstrating their ability to meet the intent of the code.

Building codes also allow alternative compliance through the use of materials, designs, and methods of construction that are not specifically listed in the building code, but are shown to meet the intent of the performance or prescriptive requirements. This option is typically implemented through designated entities (e.g., the ICC Evaluation Service) accredited to evaluate code compliance of alternative construction practices. Code officials can also accept other types of substantiating information for approval of alternative compliance.

In recent years, energy efficiency has been one of the primary drivers for innovation in construction. The pursuit of high performance homes continues to prompt the development of new technologies as well as refinements to the existing methods of construction. In addition, as these developments continue to work through the code development process, some of the historically accepted building practices and building code requirements have been scrutinized and re-assessed, for example with regard to wall bracing and wind pressure performance. Significant changes have occurred over previous code cycles, particularly with regard to wall bracing requirements. However, code changes have been more difficult with respect to wind pressure requirements due to complexities and lack of knowledge regarding the distribution of wind pressure between various components in a multi-layered wall assembly.

This document discusses issues of wind pressure resistance in walls with exterior rigid foam sheathing installed directly over framing members.

USE OF FOAM PLASTIC INSULATION AS THE PRIMARY WALL SHEATHING MATERIAL

Issue Statement

Wall systems with exterior rigid foam insulation are among the most cost-effective and practical approaches to achieving substantial thermal performance improvements of the building enclosure. It has been common residential construction practice in many parts of the country to attach foam sheathing directly to wall studs. This practice is permitted by the 2009 IRC prescriptive provisions of Chapter 7 Wall Covering. Wall bracing in such systems is typically provided by let-in bracing or by wood structural panels installed at building corners and every 25 feet. The direct wind pressure applied to the wall's surface is shared between multiple layers of the wall assembly with the foam sheathing resisting a substantial part of the total wind pressure. Because of the lack of an accepted design procedure and an approved test methodology for evaluation and determination of objective limitations for such systems, the use of rigid foam to resist wind pressures has been questioned in recent code development forums. Building code debates are expected to continue with unpredictable outcome until more design and performance information is available to define proper use of wall systems with rigid foam attached directly to studs.

BACKGROUND

2009 International Residential Code (IRC)

Section R602.3 of Chapter 6 Wall Construction of 2009 IRC states "Exterior wall coverings shall be capable of resisting the wind pressures listed in Table R301.2(2)". The range of negative wind pressures required by the IRC for wall design with studs 16 or 24 inches on center is summarized in Table 1 below.

Table 1. Design negative wind pressure (psf)[1]

Wind Exposure	Zone	Wind Speed (3 second gust), mph				
		90	100	110	120	130
B	4 feet within corner (Zone 5)	18.1	22.4	27.1	32.3	37.8
B	Away from corner (Zone 4)	15.1	18.7	22.5	26.8	31.5
C[2]	4 feet within corner (Zone 5)	25.3	31.4	37.9	45.2	52.9
C[2]	Away from corner (Zone 4)	21.1	26.2	31.5	37.5	44.1

1. Wind pressures for walls with 16" or 24" on center stud spacing based on an effective tributary area of 21.3 feet^2 determined as the height of the stud times wind area width calculated as (1/3) the stud length.
2. Calculated using an adjustment coefficient of 1.40 from 2009 IRC Table R301.2(3).

For wood structural panels, Section R602.3 of Chapter 6 provides a prescriptive method for compliance with the wind pressure requirements – Table R602.3(3) "Requirements for Wood Structural Panel Wall Sheathing Used to Resist Wind Pressures". A similar table was proposed for rigid foam sheathing for inclusion in 2009 IRC, but was not accepted at the International Code Council (ICC) final action hearings. A new proposal was submitted on behalf of the Foam Sheathing Coalition for the 2012 IRC. Whether the new proposal is or is not accepted in the 2012 IRC, the use of exterior rigid foam sheathing as the primary exterior sheathing is likely to continue to be questioned until a standard test method and an accepted design methodology are developed through a recognized standards development process such as ICC, ASTM, ANSI, and/or ICC-ES.

The practice of attaching rigid foam sheathing directly to studs is allowed in 2009 IRC in Table R703.4 "Weather-Resistant Siding Attachment and Minimum Thickness" and the provisions of Section R703.11 "Vinyl Siding". It is interpreted that these prescriptive provisions meet the intent of the new requirements of Section R602.3 for wind pressure resistance. However, there is no accepted engineering calculation methodology to demonstrate this equivalency.

Performance of Wall Enclosures - General

Wall enclosures perform multiple functions including:
1) control bulk water intrusion from the outside to the inside
2) control water vapor drive from both the inside and outside
3) control heat transfer through the wall
4) control air movement from the inside to the outside and from the outside to the inside
5) structurally resist wind pressure
6) resist shear forces from wind and seismic event transferred to walls through roof and floor diaphragms

   (***<u>Note</u>***: *Gravity forces are not included as part of this discussion.)*

In light-frame construction, these functions are typically performed by different layers or combinations of layers of the wall system. The performance of the overall enclosure system is dependent on the performance of and interactions between the individual components. With respect to wind pressure resistance, the response of a wall to a wind pulse depends on the characteristics of the wall that affect the airflow between and within the layers, including:
1) location of air pressure boundaries
2) air leakage between the layers
3) stiffness of layers as it affects air volume

Performance of Wall Enclosures - Bulk Moisture Control

From the bulk moisture control standpoint, there are three primary types of wall enclosure systems including: (1) pressure equalized rainscreen (PER) systems, (2) drained/back-ventilated (DBV) systems, and (3) face-sealed systems.

The **<u>PER systems</u>** are not common at this time in residential construction and discussed here only for background purposes and to emphasize differences and similarities in design performance characteristics between different wall systems. However, PER systems have been used successfully in commercial applications and the design principles associated with the pressure equalization effects have been studied and accepted by the design and construction industry.

A PER system consists of a rainscreen, an enclosed air space, perforations in the rainscreen for controlled air entry, and an air barrier system. Figure 1 shows the primary design elements of a PER system. The main objective of a PER system is to control the wind pressure-driven bulk water intrusion into the wall by reducing the wind pressure gradient across the rainscreen such that:

$$\Delta P\ rscrn << \Delta P\ wall$$

Where:

$\Delta P\ rscrn$ = *pressure gradient across rainscreen*

$\Delta P\ wall$ = *pressure gradient across the entire wall system, i.e., total pressure*

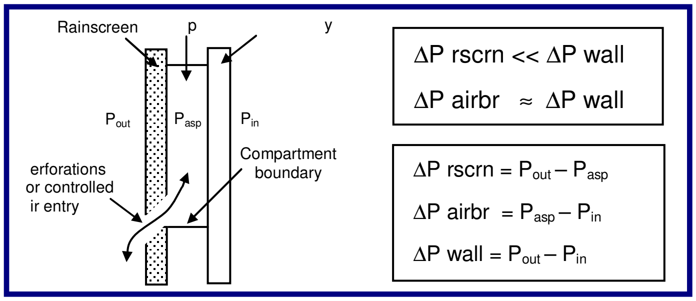

Figure 1 – Primary Design Elements of a PER Wall System

The designated air pathways in the rainscreen allows air entry and exit such that the pressure in the enclosed air space approaches the outside pressure. The enclosed air space pressure counterbalances the outside pressure imposed on the rainscreen resulting in **pressure equalization** across the rainscreen. The size and the number of air pathways is designed using principles of physics. The degree of pressure equalization is often expressed in terms of pressure equalization factors (PEF) defined as follows:

$$PEF = \frac{pressure\ gradient\ across\ layer}{total\ \ pressure\ gradient} = \frac{pressure\ at\ \ face\ 1 - pressure\ at\ \ face\ 2}{total\ \ pressure\ gradient}$$

$$0 \leq PEF \leq 1.0$$

The air space between the rainscreen and the air barrier is compartmentalized to prevent lateral air movement behind the rainscreen. The compartmentalization is necessary because the outside wind pressure varies along the exterior wall surface with the highest pressures experienced at the building edges. Therefore, maximal pressure equalization can only be achieved over a finite surface area.

In a PER system, the rainscreen is designed for a reduced wind pressure and the air barrier system is designed for the full wind pressure.

> ***Note:*** *For the purposes of this report, the term air barrier system refers to the wall's components/layers that (1) control air movement between the exterior and the interior and (2) perform the structural function of resisting wind pressure.*

Similar to the PER system, a typical drained/back-ventilated (**DBV) system** includes a cladding material, an air space, and an air barrier system. Figure 2 shows the primary design elements of a DBV system. DBV systems are common in residential construction and examples include stud walls with lap siding or brick veneer. The primary difference is that the rainscreen (i.e., cladding system) is not specifically designed to provide pressure equalization and wind-driven bulk moisture is expected, by design, to penetrate behind the cladding. Therefore, the cladding's primary function is to minimize bulk water penetration driven by gravity and capillary action, and to provide only the first line of defense against wind-driven rain. A second water control layer is installed on the interior plane of the air space to manage the water by drainage and ventilation. However, it is important to note that even though not specifically designed, pressure equalization occurs over the cladding as well as other layers of the wall as discussed in more detail later in this document. This pressure equalization affects the mechanism by which the wall system provides resistance to wind pressure from a structural standpoint.

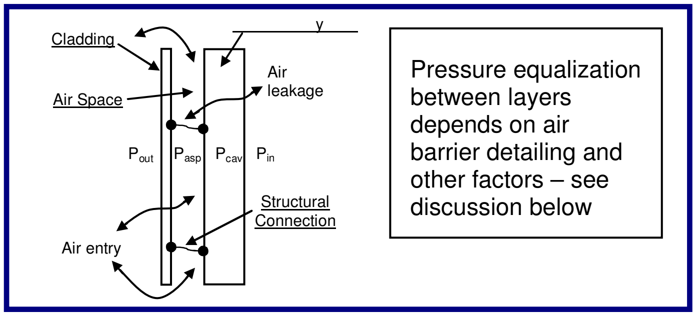

Figure 2 – Primary Design Elements of a DBV Wall System

In a **face-sealed system**, the rain penetration is prevented by sealing the joints, openings, and perforations in the exterior cladding. An example of this type of wall system is the unvented Exterior Insulated Finishing System that is designed to prohibit any moisture penetration into the wall through the exterior covering. These systems are outside of scope of this document. Some pressure equalization may still occur across the sealed cladding system due to air leakage through unintended perforations.

Wind Pressure Resistance of Wall Enclosures - Light-Frame DBV Systems

Two typical light-frame system designs incorporating exterior foam sheathing are discussed below to describe the difference in their response to wind pressures: exterior rigid foam attached to wood structural panels (Table 2) and exterior rigid foam attached to studs (Table 3).

Table 2 - Exterior Rigid Foam Attached to Wood Structural Panels

Layer	Enclosure Function	Pressure Resistance	Discussion
Siding	Bulk water control	Designed to resist partial wind pressure	Because the air flows through the joints and behind the siding, pressure equalization occurs across the siding such that the siding pressure is less than the total pressure gradient across the wall. Previous testing conducted by Architectural Testing, Inc (ATI) measured the maximum pressure equalization factor of 0.18 for vinyl siding[1].
WRB[a]	Bulk water control and air control	Flexible membrane with no resistance to pressure	
Rigid Foam	Thermal transfer control and air control	Pressure primarily resisted by the wood structural panel	
Wood structural panel (WSP)	Air barrier and secondary moisture control through storage and release	Designed as the primary wind pressure resisting element	Previous testing conducted by ATI measured the pressure equalization factor ranging from 0.2 to 0.75[2] for exterior plywood sheathing (walls tested without exterior foam).
Framing	N/A	N/A	Provides support for WSP sheathing and attachment for fasteners.
Interior gypsum panels	Air barrier	Resists a portion of the overall wind pressure	The amount of pressure on the interior gypsum depends of the air leakage into the wall cavity. The WSP is designed as the primary wind pressure resisting element, but testing indicates that the interior gypsum resists significant pressure in walls with WSP sheathing. Previous testing conducted by ATI measured the pressure equalization factor ranging from 0.2 to 0.8[b] for interior gypsum sheathing (walls tested without exterior foam).

a. If rigid foam is taped, it is common practice not to install a separate WRB layer. The WRB function is provided by the system of rigid foam panels and tape.
b. Pressure equalization factors (PEF) for exterior and interior sheathings were determined based on visual analysis of plots provided in the ATI report. Therefore, the pressure equalization factors provided in this study for exterior and interior sheathings represent estimates rounded to the closest 0.05, not the actual measured data. The ATI report provides calculated values only for PEFs for vinyl siding.

Where rigid foam sheathing is installed in direct contact over wood structural panels (e.g., OSB), the wind pressure is assumed to be primarily resisted by the wood structural panel. Because the stiffness of the wood structural panel is substantially higher than that of the rigid foam, the foam does not resist substantial loads in these types of assemblies. If an air gap were introduced between the rigid foam and the wood structural panel, the load sharing mechanism would change and the force exerted on the foam sheathing could increase.

There is always some air leakage into the wall cavity (i.e., system porosity) that results in some degree of pressure equalization across the wood structural panel. However, it is typical design practice to assume that the wood structural panels resist the full wind pressure, because the capacity of commonly used wood structural wall panels (i.e., 3/8 inch or 7/16 inch thickness) typically exceeds the wind pressure loads.

Siding is a part of the wall system and it has to be able to resist forces resulting from wind pressure. Because air can penetrate through the joints of lap siding, the pressure gradient across lap siding is

[1] Pressure Equalization Factor Project, Report No. 01-40776.01, Research Project Report rendered to Vinyl Siding Institute, September 5, 2002, Architectural Testing, Inc., York, PA.

substantially lower than the total wind pressure gradient across the wall. The magnitude of the wind pressure resisted by the siding depends on the stiffness of the siding, the air gap between the siding and the adjacent air barrier, stiffness of the air barrier, and air leakage through the air barrier. All of these factors affect air pressure because they affect the airflow characteristics. The laboratory testing conducted by Architectural Testing, Inc. (ATI) on walls with vinyl siding indicated the maximum pressure equalization factor of 0.18[2], i.e., vinyl siding experiences only 18% or less of the total wind pressure. The significantly lower pressure is the result of airflow behind the siding that equalizes the pressure exerted by the airflow over the siding's exterior surface. Therefore, even though it is not designed as a PER system, the pressure profile across rainscreen (vinyl siding in this case) has pressure equalization characteristics. Similar testing would be of value for systems with brick veneer cladding and other types of siding and installation, to better understand the behavior of such wall systems.

A study conducted by the Forest Product Laboratory[3] measured pressures across the wall in two single-story wood-frame buildings located in southern Florida. The wind speeds observed at the test sites ranged below 18 mph. Both buildings used wood lap siding. The study concluded that wood lap siding experienced substantial air pressure equalization. The study also indicated that due to leakage of air into the cavity, the pressure drop across interior drywall was of similar magnitude as pressure drop across sheathing and siding. While these observations were made at low wind pressures, the above-mentioned ATI testing suggests that the pressure equalization profile is maintained for a wide range of pressures for a given wall system.

[2] Pressure Equalization Factor Project, Report No. 01-40776.01, Research Project Report rendered to Vinyl Siding Institute, September 5, 2002, Architectural Testing, Inc., York, PA.

[3] Air Pressures in Wood Frame Walls, Anton TenWolde, Charles G. Carll, Vyto Malinauskas, Forest Product Laboratory, USDA Forest Service, Madison, WI. Published in Conference Proceedings, Buildings VII, December 6-10, 1998, Clearwater Beach, FL. (http://www.fpl.fs.fed.us/documnts/pdf1998/tenwo98a.pdf)

Table 3 - Exterior Rigid Foam Attached Directly to Framing

Layer	Enclosure Function	Pressure Resistance	Discussion
Siding	Bulk water control	Designed to resist partial wind pressure	Because the air flows through the joints and behind the siding, pressure equalization occurs across the siding such that the siding pressure is less than the total pressure gradient across the wall. Previous testing conducted by Architectural Testing, Inc (ATI) measured the maximum pressure equalization factor of 0.18.
WRB[a]	Bulk water control and air control	Flexible membrane with no resistance to pressure	May or may not be included in system.
Rigid Foam	Thermal transfer control and air control	Resist a significant amount of wind pressure	Without WSP, the rigid foam becomes the primary exterior air barrier and wind pressure resisting component. Previous testing conducted by ATI measured the pressure equalization factor ranging from 0.17 to 0.5[b] for ½-inch exterior rigid foam sheathing[c].
Framing	N/A	N/A	Provides reaction for panels and attachment for sheathing and siding fasteners.
Interior gypsum panels	Air barrier	Resists a portion of the overall pressure	The amount of pressure on the interior gypsum depends of the air leakage into the wall cavity. Previous testing conducted by ATI measured the pressure equalization factor ranging from 0.5 to 0.85[b] for interior gypsum sheathing.

a. If rigid foam is taped, it is common practice not to install a separate WRB layer. The WRB function is provided by the system of rigid foam panels and tape.
b. Pressure equalization factors (PEF) for exterior and interior sheathings were determined based on visual analysis of plots provided in the ATI report. Therefore, the pressure equalization factors provided in this study for exterior and interior sheathings represent estimates, not the actual measured data. The ATI report provides calculated values only for PEFs for vinyl siding.
c. Where the rigid foam might rely on the siding attachments to secure the foam sheathing, these attachments must be designed to resist the combined pressure differential across the siding and foam sheathing layer (i.e., 0.18 + 0.5 = 0.68 as a worst case combination of PEF factors determined for the individual siding and sheathing layers per ATI testing).

Where the rigid foam is the primary exterior sheathing (without wood structural panel backing), it resists substantial portion of the pressure exerted by the airflow. Because the wall system has a certain degree of leakage (i.e., system porosity), the wall cavity will in turn be pressurized/depressurized, leading to some level of pressure equalization across the rigid foam. The degree of pressure equalization depends on the air leakage into the wall cavity, as well as the stiffness of air barriers and the cavity volume. The wall cavity pressure leads to pressure exerted on the interior air barrier covering, typically gypsum wallboard. Therefore, the pressure is “shared” between the interior and exterior air barriers. However, the fraction of the pressure resisted by each layer may vary in time such that different layers may experience their peak pressures at different times. The degree of pressure sharing between the rigid foam and the gypsum is difficult to accurately predict using available engineering methods. Laboratory and/or field testing are the only options available for accurate evaluation of pressure equalization across multiple air barrier systems.

The wall system variables that affect the pressure equalization characteristics include:

- Stiffness of rigid foam insulation
  - XPS, EPS, ISO
  - Thickness
  - Facings
- Air permeability of the exterior air barrier (i.e., air barrier system porosity)
  - Taped joints vs. untapped joints
  - Air sealing details at top and bottom plates, rim joists, adjacent studs, etc
  - Penetrations from installation of fasteners into the framing
  - Penetrations at mechanical and plumbing entries, and air sealing at such locations
  - Permeability of insulation material
  - Permeability of the facing materials
- Cladding material, its stiffness, attachments, and air permeability
  - Lap siding
  - Insulation-backed vinyl siding
  - Brick veneer
  - Stucco
  - Other
- Gap between the cladding and the exterior air barrier
- Connections of the cladding to backing/framing
- Wall cavity material
  - Spray foam
  - Blown-in insulation
  - Batt insulation
  - Other types of insulation
- Permeability of the interior air barrier
  - Fastening schedule of gypsum (gypsum often not attached at top and bottom plates for crack control)
  - Air sealing at top and bottom plates
  - Penetrations at mechanical and plumbing entries, and air sealing at such locations
- Direction of loading
  - positive or negative pressure

The degree at which these variables affect pressure equalization needs to be better quantified and explained based on an enhanced physical analysis of the entire wall system. In general, the stiffer and the less permeable the exterior air barrier the lower the pressure equalization across the rigid foam sheathing (i.e., higher design pressure). A typical practice in energy-efficient construction is to air-seal the house to reduce air leakage. Different strategies are possible to achieve this goal with layers on both sides of the wall cavity acting as an air barrier. Therefore, test specimens should have air-sealing characteristics typical of the wall construction in the field. In addition, testing a broader range of air-sealing options can be beneficial in understanding the impact of air-sealing practices on pressure equalization effects in light-frame construction.

DESIGN AND TESTING CONSIDERATIONS

The wind design provisions of ASCE 7-05 "Minimum Design Loads for Buildings and Other Structures" allow for reduced loads for air-permeable cladding based on approved test data or recognized literature (ASCE 7-05 Section 6.4.3). However, ASCE 7 does not provide a design method or a test procedure for implementing the provision.

Claddings in PER systems, common in commercial applications, are typically designed for reduced pressure due to pressure equalization. The design pressures are established based on analysis, laboratory testing, and data accumulated from monitoring the performance of existing buildings.

In residential construction, however, wind pressure design methods for DBV systems are not well developed. Available design and testing procedures are narrowly limited in scope to specific materials and configurations. The only accepted and code-referenced design method based on pressure equalization is discussed below – design method for vinyl siding. The prescriptive IRC solutions for installation of rigid foam are, in part, based on historical practice and traditional framing techniques.

The design method for vinyl siding covered under ICC-ES AC37 "Acceptance Criteria for Vinyl Siding"[4] is limited to wall configurations with vinyl siding installed over solid sheathing (i.e., wood structural panel), with the solid sheathing resisting the full positive and negative design wind pressures. The AC37 test procedure requires the specimen to be constructed with oriented strand board (OSB) sheathing. The allowable design pressures for vinyl siding are determined in accordance with a design procedure Annex A1 of ASTM D 3679-09 "Standard Specification for Rigid Poly (Vinyl Chloride) (PVC) Siding" as follows:

$$P_{D-VS} = \frac{P_{Test\,D5206}}{(0.36)(1.5)}$$

Where:

P_{D-VS}	- Allowable design pressure for vinyl siding for direct comparison with wind pressures in Table 1 (i.e., IRC Table R301.2(2))
$P_{Test\,D5206}$	- Direct test pressure applied to vinyl siding measured in accordance with ASTM D5206 (without pressure equalization)
(0.36)	- Pressure equalization factor
(1.5)	- Allowable stress design (ASD) safety factor for vinyl siding

The pressure equalization factor in ASTM D3679 is a product of two inputs:

(0.18)	- Maximum pressure equalization factor measured through testing for vinyl siding installed over wood structural panel or rigid foam sheathing (ATI Report No. 01-40776.01, September 5, 2009)
(2.0)	- Safety factor on the pressure equalization effect recommended by ATI and included in ASTM D3679

[4] Acceptance Criteria for Vinyl Siding, AC37, July 1, 2009, ICC Evaluation Service, Whittier, CA.

The ATI report suggested a safety factor of 2.0 with the maximum measured pressure equalization factor for use in design of vinyl siding. The basis for this safety factor is unclear and it is likely an interim measure put in place at the time to facilitate the adoption of the approach. When combined with the ASD safety factor of 1.5, the total safety factor for the system is 3.0. Such practice of using a separate safety factor for one of the physical characteristics of the assembly is not common in engineering design. A more appropriate method is to establish a pressure equalization property based on statistical analysis of data and apply a single safety factor for the design of an entire assembly or its layers. Therefore, the basis for the current ASTM D3679 approach should be reassessed and re-aligned with the accepted engineering design practices.

The pressure equalization factor (PEF) of 0.18 represents the highest value measured by ATI in a testing program that included a total of 24 wall configurations and three incremental levels of pressure. The test variables are summarized in Table 4. Three repetitions of all 72 unique combinations of test variables were tested for a total of 216 tests. The specimens were tested in a chamber designed to simulate a wind pulse by creating a sudden pressure drop on the exterior side of the specimen. The pressure equalization factors for vinyl siding ranged between 0.03 to 0.18. At the highest pressure drop level (105 psf[5]), the pressure equalization factors ranged between 0.03 and 0.12. For specimens with foam sheathing, the PEF ranged between 0.05 and 0.18. For specimens with plywood sheathing, the PEF ranged between 0.03 and 0.16, indicating no detectable difference in the siding pressure between the two sheathing materials.

Table 4 – Test Variables (ATI testing program for pressure equalization factors)

Test Variable	Range
Vinyl siding	0.048" thick, double 3 0.048" thick, double 4 0.048" thick, double 5 0.038" thick, double 3 0.038" thick, double 4 0.038" thick, double 5
Sheathing	½ plywood or ½ polystyrene sheathing
Water Resistive Barrier	Installed (*note: the test report does not specify whether it was taped*) Not Installed
Vacuum Chamber Pressure	Level 1: 50 psf (low pressure) Level 2: 75 psf (medium pressure) Level 3: 105 psf (high pressure)

Because the purpose of the ATI report was to measure pressure equalization across vinyl siding, the ATI report does not provide the PEFs for the interior and exterior sheathing layers. Using the reported wall cavity pressure, the ranges of PEFs for the exterior sheathing are summarized in Table 5. There is a wide range of PEFs for both plywood and ½-inch polystyrene sheathing. The highest PEF observed for plywood is 0.76, whereas the highest PEF for ½-inch polystyrene sheathing is 0.44. In both walls with plywood sheathing and ½-inch polystyrene sheathing substantial pressure was imposed on the gypsum wallboard.

The ATI report includes limited analysis of results and does not attempt to explain the reason for such a significant dispersion within configurations (approaching a factor of 3 for plywood without water

[5] The reference pressure drop represents the pressure generated in an auxiliary chamber of the test apparatus. The pressure experienced by the specimen is typically 2 to 5 times lower due to an increase in the total air volume after the auxiliary chamber is open to the test chamber in order to generate a pressure drop across the specimen.

resistive barrier). Under each of the four configurations summarized below, six different types of vinyl siding were tested. However, analysis of the results as part of this review did not reveal a correlation or a trend between the exterior sheathing PEF and vinyl siding PEF. Therefore, the difference in vinyl siding by itself does not suggest an explanation for the observed ranges in the sheathing PEFs. Other reasons may include air leakage into the wall cavity. It is interesting to note that the variability between the three replicas tested under each of the 24 unique wall configurations was substantially less than the variability between the configurations. This observation suggests that the observed wide range of PEFs may not be all due to random variability.

Table 5 – PEFs for Plywood and ½-inch Rigid Foam Insulation based on ATI Testing

Group	Exterior Sheathing and WRB	PEF Range Across Exterior Sheathing[a]
1	½" Plywood w/o WRB	0.2 – 0.75
2	½" Polystyrene foam sheathing w/o WRB	0.15 – 0.35
3	½" Plywood with WRB	0.45 – 0.75
4	½" Polystyrene foam sheathing with WRB	0.2 – 0.45

a. Pressure equalization factors (PEF) for exterior sheathings were determined based on visual analysis of plots provided in the ATI report. Therefore, the pressure equalization factors provided in this study for exterior and interior sheathings represent estimates rounded to the nearest 0.05, not the actual measured data. The ATI report provides calculated values only for PEFs for vinyl siding.

At this time, there are no codified and even generally accepted engineering methodologies for design of exterior foam sheathing or other types of sheathing for reduced pressures due to pressure equalization. A design of foam sheathing for the full pressure would not be representative of the system's response and would result in uneconomical solutions for the rigid foam products available on the market today.

A comprehensive design methodology acceptable for application under the IRC and other building codes needs to include:

1) A standardized and appropriately calibrated testing procedure for measuring PEFs for a variety of wall systems
2) A design procedure for wall sheathing layers using PEFs that is coordinated with application of results from the standardized PEF test method and standardized methods for determining static wind pressure resistance of the sheathing and/or siding
3) Performance criteria (strength and deformation) and safety factors for the sheathing materials and the system overall
4) For IRC applications, prescriptive solutions for typical wall systems.

To enable consistent and replicable results, a testing procedure should cover the testing apparatus geometry, the mechanism to create the air pressure pulse, the test pressure levels, the geometry and detailing of the specimen, attachment requirements for the interior finish, air sealing details, etc. An effort to develop an ASTM test standard has recently been initiated by the Vinyl Siding Institute under the ASTM D20.24 subcommittee on Plastic Building Products[6]. The outcome of this effort has the

[6] An NAHB Research Center representative is on the ASTM task group charged with development of the test method. The first conference call for the effort is scheduled for December 22, 2009.

potential to have significant implications on the testing procedures and design methods for exterior rigid foam sheathing, and ultimately on the use of this technology in residential construction.

SUMMARY

The practice of using rigid foam insulation attached directly to studs has been successfully used to improve energy efficiency of walls in many parts of the country. Although the prescriptive provisions of 2009 IRC Chapter 7 Wall Covering continue to allow this practice, debate in the code development forums is expected to continue with regard to limitations of such wall systems to resist wind pressure. If accurate and objective performance information and necessary analytical tools are not available for building code officials, designers, and builders, there is a potential that overly restrictive limitations may be imposed on the foam sheathing technology.

The key to understanding the performance of rigid foam wall systems is the pressure profile across all wall layers. Limited testing available to date on such systems with the previous studies focusing primarily on the performance of vinyl siding. The existing data suggests a wide range of pressure equalization profiles across the exterior and interior sheathing panels. Additional laboratory testing is needed to better understand the performance of walls with exterior rigid foam sheathing and to attempt to rationalize the observed range of the responses.

A design method with appropriate performance criteria and a standardized testing methodology are ultimately needed to enable a broad acceptance of the technical justification for the wind pressure resistance profiles. In addition, a long-term research agenda should include validation of laboratory test results through wind tunnel testing and full-size field monitoring studies.

As part of its 2010 Building America work plan, the NAHB Research Center proposed a research and testing program designed to better understand the wind pressure resistance characteristics of systems with exterior foam sheathing. The proposed effort is intended to provide performance data as well as establish the basis for the development of a design procedure for such wall systems.