6175 Riverside Drive, SW
Atlanta, Georgia 30331
Phone: (404) 346-3666
Fax: (404) 346-7422
www.stocorp.com

Sto Technical Report 01-07.3

StoGuard™: Testing for International Building Code Compliance and Comparison to Sheet Water-Resistive Barrier Products

Introduction

In 2000 Sto Corp. introduced StoGuard ™, an innovative moisture protection product for exterior walls. Generically, StoGuard™ is considered a water-resistive barrier (WRB) coating by the International Code Council Evaluation Service (ICC-ES). ICC-ES is responsible for verifying compliance of alternate materials and means of construction to the requirements of the model building codes in the United States. Sto Corp. was the first manufacturer to develop a WRB coating system for use as an alternate to code-recognized building paper or felt over framed and sheathed wall construction.

StoGuard™ received recognition in the Southeastern US under the Standard Building Code in 2001 based on comparison testing of several physical properties to those of building paper. Both materials were tested before and after weathering and accelerated aging protocols. However, the adoption of the International Building Code (IBC) and International Residential Code (IRC) required StoGuard™ to be re-evaluated by the new code evaluation service, ICC-ES. ICC has a formal process for developing product requirements which involves public hearings and input from the engineering staff of ICC-ES. The resulting documents are called "Acceptance Criteria" and establish the test methods and levels of performance required for a product or system to receive recognition as complying with the IBC and/or IRC. Sto Corp. was a leading participant in this process to develop acceptance criteria for WRB coating products.

Input regarding performance requirements was provided by interested industry representatives, code officials, the evaluation service staff and testing laboratories. The actual requirements are published as ICC-ES AC 212, "Acceptance Criteria for Water-resistive Coatings used as Water-Resistive Barriers Over Exterior Sheathing"[1], which is available at www.icc-es.org.

The testing required for code recognition primarily produces either a passing or failing result. If a product passes a test, no further testing is required to measure the ultimate performance of the product. Therefore, code compliance testing is not very helpful in differentiating between products or systems. Sto Corp. has undertaken several testing programs to demonstrate differences in performance and to identify the advantages of StoGuard™ compared to building paper/felt and sheet-installed building wrap products.

This report presents information about the code compliance testing performed on StoGuard™, test results, and comparative data that Sto Corp. has produced by testing other types of water-resistive barrier systems.

Code Compliance Testing

ICC-ES AC 212 contains testing protocols to address several performance aspects of StoGuard™ and similar products. The properties for which tests are required include:

- Waterproofing performance
- Adhesion to substrates and bonded coverings (EIFS)
- Resistance to aging (durability before and after cladding installation)
- Live load, racking and environmental cycling WRB resistance.
- Water vapor permeance

Waterproofing Performance

The basic purpose for which StoGuard™ was originally developed is to prevent water ingress into the wall framing and sheathing assembly. Water penetration resistance is evaluated using a modification of AATCC 127,"Water Resistance: Hydrostatic Pressure Test,"[2]. A water column with a 21.7 inch (550 mm) head is placed on the specimen, and the coating is required to maintain the head for 5 hours (Figure 1). This head pressure equates to approximately 210 mph (337.5 km/hr) wind pressure. There are two modifications from the test standard: a nominal 4-inch (102 mm) diameter tube is used versus the standard 4.5 inch (114 mm) size, and the AC 212 test is run at one pressure for a specified duration, whereas the standard AATCC 127 method increases pressure at a specified rate until leakage is produced.

Sheathing joint treatments are included in the evaluation. Specimens are prepared with a ¼-inch (6.4 mm) wide joint and the water column is placed directly over the joint to apply the full head pressure to the joint treatment.

AC 212 also requires performing this test after an accelerated aging and weathering regime. Specimens are placed in a UV chamber for 210 hours, and then subjected to 25 cycles of wetting and oven drying. Additional information about the conditioning is presented in the "Aging Resistance" section of this report.

StoGuard™ passed both sets of tests (weathered and unweathered), and internal testing was performed by leaving the water column full for approximately 1 year. No leaks occurred in the 1 year period of exposure under a full 21.7 inch (550 mm) head of water.

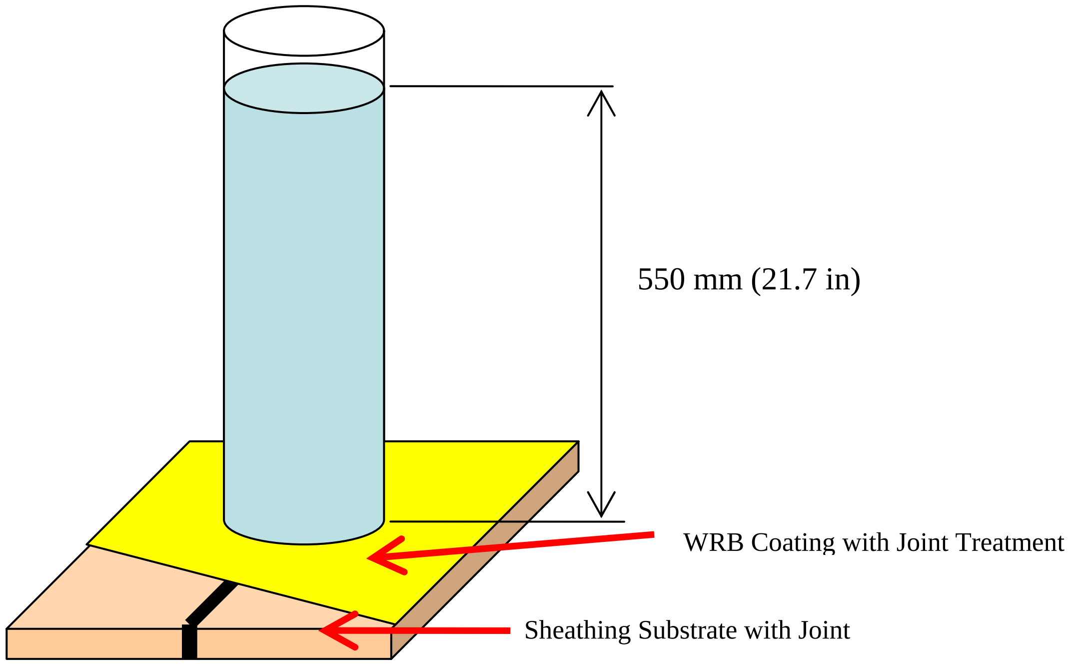

Figure 1. American Association of Textile Chemists and Colorists (AATCC) 127 test set-up for water-resistive barrier coatings.

Adhesion

Adhesion, or bond strength, of the coating is important because the coatings are relatively thin and require structural support to remain durable in-place. Most would innately expect the coating to be bonded to the substrate, at least while wet, but it is important that the coating remain bonded after drying and during service. An unsupported fluid-applied coating would be susceptible to damage from air movements, wind pressures and incidental damage during construction. The required bond strength for the coating system was established to be 15 psi (103 kPa). The requirement is based on the required bond strength for exterior insulation and finish systems (EIFS) claddings, which is governed primarily by the cohesive strength of the expanded polystyrene (EPS) insulation board. The requirement may seem low for coatings which generally have much higher potential bond strengths, but 15 psi (103 kPa) translates to a wind pressure in excess of 900 mph (1450 km/hr), much greater than any design wind speed in North America. Adhesion testing is required by ICC-ES for each type of substrate material proposed for use.

If EIFS is to be adhesively fastened to the water-resistive barrier coating, the bond strength of the EIFS adhesive to the coating must also be evaluated. The bond strength of the assembly, including substrate, WRB coating, adhesive and EPS, is also required to be minimum 15 psi (103 kPa).

Testing of StoGuard™ products has shown that the bond strength exceeds the cohesive (or internal) strength of plywood, OSB and gypsum based sheathing (Figure 2). Similarly, the bond strength of EIFS adhesives to Sto Gold Coat® exceeds the cohesive strength of the EPS insulation board.

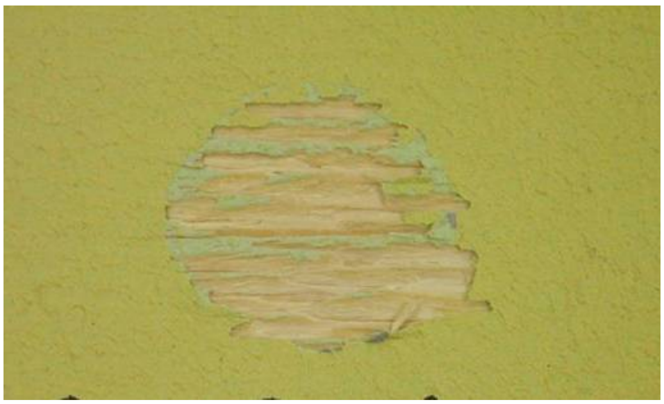

Figure 2. Adhesion test specimen of StoGuard™ applied to plywood showing cohesive failure of plywood substrate.

<u>Aging Resistance</u>

There are two primary considerations for the aging resistance of the WRB coating. First, the coating must maintain its protective and functional properties during the period of direct exposure before the cladding is installed. Secondly, the WRB coating must continue to maintain these properties after cladding installation for the expected service life of the structure. The long-term durability is very important because once the cladding is in place there will not be an opportunity to observe the condition of the WRB or repair it. Of course this is true for any WRB material including building paper, felt and synthetic building wrap products.

Manufacturers provide construction exposure limitations for their products based on their knowledge of the raw materials used and exposure testing that is performed during product development. However, simple exposure tests cannot always address the question of how well the coating maintains its properties over an extended period of service.

Unfortunately, any weathering or aging test is applicable only to the conditions under which it is run, and correlation of results to real-world project conditions is not always possible. Nevertheless, a standard lab testing procedure is desirable to provide evidence of the durability of the WRB. Two sets of conditioning and testing procedures were included in the building code evaluation process.

The effects of weathering and aging on the waterproofing characteristics of the WRB are evaluated by subjecting specimens (prepared as for the waterproofing tests) to 210 hours of UV light exposure (10 hours per day for 21 days). The UV source is a 275 W bulb having 5.0 W/m^2 irradiance at a wavelength of 315 to 400 nm (irradiance measured 1 meter [3.28 feet] from the bulb). For this procedure the bulbs are placed 2 ft (610 mm) above the specimens.

After the UV exposure, the same specimens are subjected to 25 cycles of wetting and drying. The exposure cycle consists of three hours oven-drying at 120˚F (49˚C); three hours immersion; and 18 hours of air drying at 75˚F ± 5˚F (23.8˚C ± 2.8˚C) and 50 % relative humidity.

After completion of the UV and wetting/drying exposures, the samples are tested using the AATCC 127 water column as described above in the "Waterproof Performance" section of this paper. The WRB must meet the same criteria (55 cm head for 5 hours with no leakage) as an unconditioned specimen. StoGuard met these requirements.

Live Load Resistance, Environmental Conditioning and Water Resistance

The WRB coating must be able to accommodate structural movements due to wind loading (perpendicular to the face of the wall [Figure 3]) and racking loads (parallel to the face of the wall [Figure 4]) as well as environmental stresses produced by heating and cooling. ICC-ES AC 212 includes a conditioning and testing protocol to evaluate the coating behavior under these stresses.

An 8-ft x 8 ft (2438 mm x 2438 mm) panel is constructed with horizontal and vertical sheathing joints. The joints are 1/8-inch (3.2 mm) wide. The panel is subjected to 10 cycles of positive transverse loading in accordance with ASTM E 1233, "Test Method for Structural Performance of Exterior Windows, Doors, Skylights, and Curtain Walls by Cyclic Air Pressure Differential"[3]. The load is that which is necessary to produce a given deflection. The target deflection is selected by the proponent of the test such that it meets the criteria of Table 1604.3 of the IBC[4] for the wall cladding type that is anticipated to be used. For brittle wall coverings, such as stucco or brick, the deflection would be 1/240th of the span, or 0.4 in. (10.2 mm); for flexible wall coverings the deflection is 1/180th of the span, or 0.53 in. (13.5 mm).

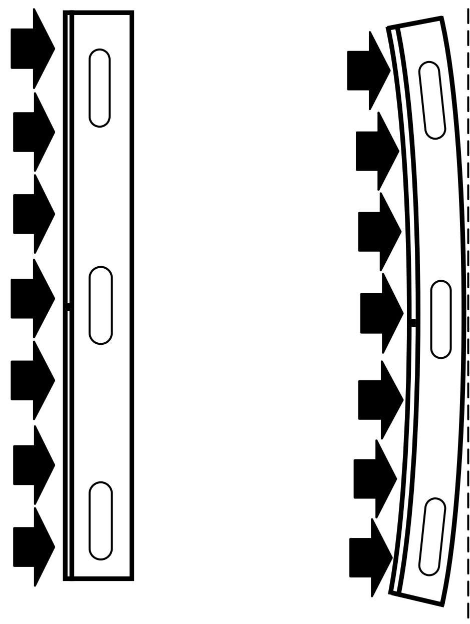

Figure 3. Schematic of uniformly distributed positive (wind) load application.

After completing the 10 transverse load cycles, the panel is subjected to racking in accordance with ASTM E 72, "Test Methods of Conducting Strength Tests of Panels for Building Construction"[4]. Racking provides shear stresses along the sheathing joints to test the strength of the WRB joint treatment.

The racking test consists of mounting the test panel in a load frame and pushing on one corner horizontally to deform the panel (Figures 4 and 5). The requirement to pass this test is that the coating must remain undamaged when the panel is subjected to the racking force and resulting displacement. The test can be run either with or without "hold-downs," which serve to keep the panel from rotating as a unit during the test. The required displacement if hold-downs are not used is 1-inch (25 mm). The required displacement if hold-downs are used is 1/8-inch (3.2 mm) due to the increased efficiency of the test. StoGuard™ was tested using hold-downs. Both joint treatments, Sto Gold Fill® with StoGuard™ Mesh and StoGuard™ Fabric embedded in Sto EmeraldCoat™ met the ICC-ES requirements.

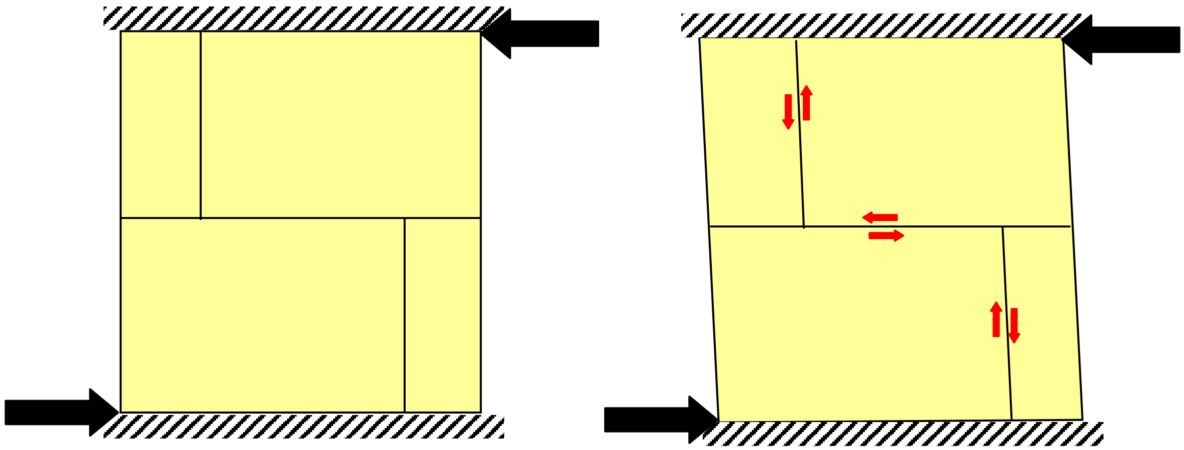

Figure 4. Schematic of racking loads and stress effects along sheathing joints.

Sto Guard panels passed the 1/8-inch (3 mm) displacement test required for code recognition. A second test was run to investigate the ultimate limit of the StoGuard™ Fabric joint treatment. The joint treatment withstood a full 1" (25 mm) displacement, with hold downs, or 8 times the minimum requirement, without tearing or breaking loose from the substrate and without cracking.

Figure 5. Racking test set-up in laboratory.

Figure 6. Wrinkles in joint treatment due to racking load. Joint treatment is StoGuard™ Fabric. Racking displacement is greater than ¾-inch (19 mm) when photo was taken.

The racking test is followed by a series of five environmental conditioning cycles performed on the same panel as was previously uniformly loaded and racked. Each cycle includes 24 hour constant water spray followed by 24 hours of radiant heat exposure. The radiant heat produces a uniform surface temperature of 120˚F ± 5˚F (49˚C ± 2.8˚C). Throughout the environmental conditioning the panel is inspected for cracks or leaks which would indicate failure of the WRB.

After completing the environmental conditioning, the same panel that has completed the uniformly distributed load cycles, the racking displacement, and the environmental cycling is subjected to a water penetration test in accordance with ASTM E 331,"Test Method for Water Penetration of Exterior Windows, Curtain Walls, and Doors by Uniform Static Air Pressure Difference"[5] at a differential pressure of 2.86 psf (137 Pa) for 15 minutes. This is an added requirement for WRB materials that are intended for use behind all claddings. A manufacturer can choose not to run this final ASTM E 331 test, but if the test is not run, the WRB is only recognized for use behind claddings that meet the water resistance criteria (such as EIFS and siding) and cannot be used behind water-permeable claddings like masonry. StoGuard™ was tested in this manner and met the supplemental requirements of AC 212 for use behind any cladding.

Water Vapor Transmission

AC 212 requires reporting of the water vapor transmission rate for the WRB coating and the permeance, or "perm rating." Water vapor transmission rate and permeance are measured using ASTM E 96, "Test Method for Water Vapor Permeability of Materials"[6]. The test method is relatively simple, but the properties of vapor movement through materials are complex. More information about the testing and use of ASTM E 96 data are available in Sto Tech Hotlines No.

307 BSc, “Vapor Permeable vs. Waterproof”,[7] and No. 806 BSc, “Vapor Barriers: Frequently Asked Questions”.[8]

The permeance value itself does not have a pass-fail requirement, but the value is needed by a designer to assess the potential for condensation to form in the wall assembly. StoGuard™ is vapor permeable and allows water vapor to move through it without condensation occurring in most instances. A static or dynamic water vapor transmission analysis using material properties and thicknesses of the entire wall assembly and the climatic conditions of the construction locale are tools that should be use to verify that condensation is not an issue for any particular project.

StoGuard™ Compared to Sheet Installed WRB Products

As previously discussed, the testing required for building code recognition does not provide data that can be used to differentiate between the performance of different products or systems. Sto Corp. modified some code compliance test methods and used other standard test methods to help define the capabilities of StoGuard™ and compare the water penetration and air leakage resistance of StoGuard™ products and systems to building paper/felt and polymeric building wraps.

<u>Water Column Testing</u>
The basic AATCC 127 water column test determines whether a WRB system will resist a 21.7-inch head of water for 5 hours, but it does not determine the ultimate resistance of the product to water penetration. Sto Corp. devised a modified version of AATCC 127 to measure higher head pressures and compared StoGuard™ to four polymeric building wrap products and code prescribed No. 15, Grade D asphalt impregnated kraft building paper (Figure 7).

Figure 7. AATCC 127 water column specimens on plywood substrates prior to testing.

The test method was modified by fitting a rubber gasket and cap with an air inlet valve onto the top of the water column (Figure 8). Air pressure was then increased within the sealed column until either water leakage was produced through the WRB or until the gasket failed. One of the key functions of the gasket was as a safety mechanism to prevent the PVC water column tube from breaking.

Figure 8. Modified AATCC 127 water column testing in-progress.

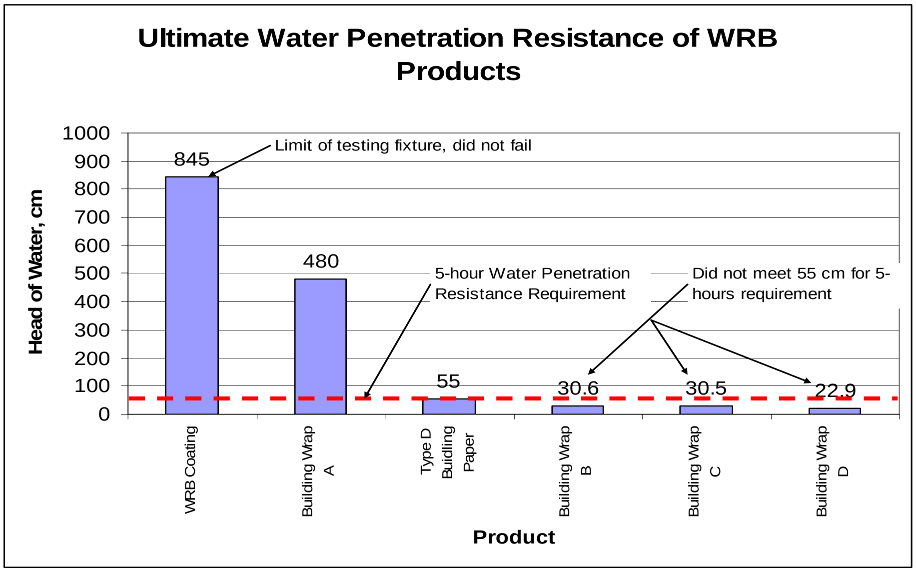

Figure 9. Modified AATCC 127 water column test results[9]

Figure 9 presents the test results for the modified AATCC 127 testing. StoGuard™ exceeded the capabilities of the test apparatus and withstood more than 15 times the minimum head pressure or about 27.8 feet (845 cm) of water. This compares favorably to the nonwoven, spun bonded polyolefin building wrap which leaked at a head pressure of 15.7 feet (480 cm).

Several of the woven WRB products leaked at less than the minimum head pressure, and did not meet the basic requirements for water penetration resistance. The No.15, Grade D paper met the minimum head pressure requirement, but failed within one minute of applying additional pressure.

Installed Product Resistance to Air Leakage and Water Penetration[6]

While both StoGuard™ and "Building Wrap A" both substantially exceeded the minimum head pressure requirement used in the AATCC 127 testing, the test does not incorporate fasteners or seams that would be present in sheet-installed systems. To investigate the effect of basic fastening details on the performance of the different systems, Sto Corp. performed a series of ASTM air leakage and water penetration tests.

Four panels were tested in this program: StoGuard™; No. 15, Type D building paper fastened with roofing nails; "Building Wrap A" with seams taped (fastened with cap fasteners); and "Building Wrap A" with seams taped (fastened with staples). All panels were nominal 2"x4" (50mm x 100mm) wood framing with 5/8-inch (16mm) exterior grade plywood sheathing. The "Building Wrap A" fastened with cap fasteners represents installation in accordance with the manufacturer's published instructions. The "Building Wrap A" fastened with staples and the building paper fastened with roofing nails both represent common practice observed in the field for installation of these products.

All four panels were tested individually. Each panel was subjected to 10 cycles of positive and negative loading at a differential air pressure of 6.24 psf (300 Pa) or approximately 49.4 mph (79.5 km/hr) wind pressure. StoGuard™ exhibited no visible changes caused by the pressure cycling. "Building Wrap A" with cap fasteners exhibited movement of the WRB between the fasteners in reaction to the changes in pressure (Figures 10 and 11). "Building Wrap A" fastened with staples also moved in response to the pressure cycling and several staples either pulled out of the sheathing or pulled through the WRB (Figure 12). The nail fasteners pulled through and tore the building paper during the first negative load cycle.

Figure 10. "Building Wrap A" specimen under negative wind loading conditions.

Figure 11. "Building Wrap A" specimen under positive wind loading conditions.

Figure 12. Staple withdrawn from the building wrap specimen by negative wind load cycles.

After completing the initial cycles, the four panels were tested in accordance with ASTM E 283, "Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls , and Doors Under Specified Pressure Differences Across the Specimen"[10], at 1.57 psf (75 Pa) or approximately 24.8 mph (39.9 km/hr) wind pressure. Air leakage was measured under both positive and negative pressure conditions, with the results being shown in Table 1.

Table 1. ASTM E 283 Test Results

	Air leakage, CFM*	
Specimen	+75 Pa (1.57 psf)	- 75 Pa (-1.57 psf)
StoGuard™	0.00	0.00
Tyvek® with cap fasteners	0.00	1.74
Tyvek® with staples	0.00	1.57
No.15, Grade D building paper	4.75	62.63

Measured at 70˚F and 29.92 in. Hg (759.9 mm Hg). Test results are measured over 32 ft^2 (2.97 m^2) test area.
1 CFM = 2.83 L/min

After completing the air leakage testing, the panels were water spray tested in accordance with ASTM E 331.. The air pressure difference used for this testing was roughly equivalent to a 49.4 mph (79.5 km/hr) wind-driven rain. The water spray rate is standard for ASTM E 331: 5.0 gallons per square foot (204 L/m^2) per hour. The test was run for 75 minutes, and a tracer dye was added to the water spray to help document the locations and extent of leaks. Observations of water leakage were made from inside the test chamber during the test. There was no water leakage through the StoGuard™ specimen, while the building paper and building wrap leaked (figures 13, 14, 15).

Figure 13. Building paper panel after ASTM E 331 water spray testing. Dye stains indicate source points and extent of leakage.

Figure 14. Water leakage in "Building Wrap A" panel during ASTM E 331 water spray testing.

Figure 15. "Building Wrap A" with staples panel after ASTM E 331 water spray testing.

Figure 16. Indication of water leakage around cap fasteners in "Building Wrap A" specimen.

Air Barrier Performance

The air leakage tests performed above (ASTM E 283) provide data which demonstrate that the fasteners used to install building paper/felt and building wraps result in air leakage through the sheet-applied WRB materials. StoGuard does not require fastening, therefore does not inherently leak air (or water) simply as a result of its application method.

While the ASTM E 283 air leakage data is helpful, a different test is used to classify materials as "air-barrier" materials: ASTM E 2178, "Air Permeance of Building Materials"[11]. The tests are similar, but ASTM E 2178 sets a defined protocol for pressurizing and measuring the air leakage. ASTM E 2178 is limited to testing only the material. If a product, such as a building wrap, requires fasteners or field laps those features are not included in the test, and thus ASTM E 2178 does not tell the whole story for sheet-good products.

StoGuard™ has been tested in accordance with ASTM E 2178. The results, shown in Table 3, comply with requirements for air barrier materials listed in the International Energy Conservation Code, the Canadian National Building Code, and the Massachusetts Commercial Energy Code.

Table 3. ASTM E 2178 Air Leakage Test Results

Product/Substrate	Air Leakage Rate, cfm/ft^2 (L/s.m^2) @ 0.3 inches H_2O (75 Pa)	Requirement, cfm/ft^2 (L/s.m^2) @ 0.3 inches H_2O (75 Pa)
Gold Coat®/CMU	0.00	0.004 (0.02)
Gold Fill®/CMU	0.00	
Gold Fill®/needle felt	0.0002 (0.0014)	

Conclusions

StoGuard™ has clearly demonstrated excellent performance as a waterproof air barrier material through completion of required code compliance testing and additional WRB comparative testing. StoGuard™ has several advantages when compared to sheet-applied WRB products:

- Waterproof – StoGuard™ resists water penetration under much higher head pressures than code-recognized building paper and felt, which are only water-resistive. StoGuard also resists higher head pressures than polymeric building wrap products.
- Structural and seamless -- StoGuard™ is advantageous compared to sheet good WRB products since it is fully bonded to the substrate (i.e. structural); it does not require fastener penetrations; and it provides seamless transitions to flashings and mechanical penetrations.
- Tear proof and durable – StoGuard™ does not tear and will not be damaged by wind loads placed on it during and after construction and can resist UV damage for up to 6 months before cladding is installed.
- Multi-purpose – StoGuard™ provides durable protection against water and air leakage. As the test data indicates, not all house wraps are good barriers against water penetration, air leakage resistance of house wraps is compromised by fastening methods, and a code prescribed paper WRB is not an air barrier.

Combining all of these advantages, StoGuard™ is a superior waterproofing and air barrier product for above grade wall construction.

References

1 AC 212, “Acceptance Criteria for Water-Resistive Coatings Used as Water Resistive Barriers Over Sheathing,” ICC-ES Evaluation Service, Inc., February 2005.
2 AATCC T127-2003, “Water Resistance: Hydrostatic Pressure Test,” American Association of Textile Chemists and Colorists, Research Triangle Park, NC
3 ASTM E 1233-06, “Test Method for Structural Performance of Exterior Windows, Doors, Skylights, and Curtain Walls by Cyclic Air Pressure Differential”
4 ASTM E 72-05 “Test Methods of Conducting Strength Tests of Panels for Building Construction”
5 ASTM E 331-00, “Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference”
6 ASTM E 96-05, “Test Method for Water Vapor Permeability of Materials”
7 Sto Tech Hotline 307-BSc, “Vapor Permeable vs. Waterproof”, 2007.
8 Sto Tech Hotline 806-BSc, “Vapor Barriers: Frequently Asked Questions”, 2006.
9 Test Reports 22188-1 through 22188-4, Cerny & Ivey Engineers, performed for Sto Corp., October 2005
10 ASTM E 283, “Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls , and Doors Under Specified Pressure Differences Across the Specimen”
.11 ASTM E 2178, “Air Permeance of Building Materials”.