POSITION DOCUMENT:

An Examination of Wind Loads Across Various Standards and the Use of Pull-Off Adhesion Testing to ASTM D4541 and ABAA T0002 to Meet a Desired Wind Load Target

July 2024

Document Scope

The scope of this white paper is three-fold, first, a review of the wind load requirements set forth in ASCE 7-22 and the IBC 2021, and other related wind speed information; second, the math used to translate mph and psf to a value measurable at the lab or small scale level; and finally, the use of pull-off adhesion testing in conjunction with gypsum-based sheathing products and the air and water barrier coatings applied to them.

Wind Loads

Structures built around the world are subjected to various directional wind loads depending on their geographic location. As such, various codes and standards have been developed to ensure that the structures and the materials used to build these structures are suitable for the anticipated wind loads in a given geographic location.

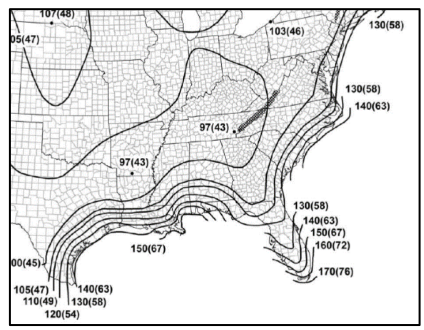


Figure 1 - Excerpted from ASCE 7-22

ASCE 7-22, Chapter 26, discusses methods for calculation of wind load minimums and provides figures with various minimum wind load requirements based on psf (pounds per square foot). A partial example of one of those tables is shown in the figure to the right. The peak value for the United States is southern Florida with a requirement of 200 mph. Including a safety factor of 1.5 would raise this value to 300 mph.

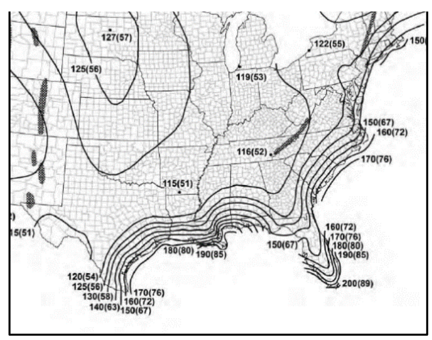


Figure 3 - Excerpted from IBC 2021

IBC 2021, Chapter 16, references the ASCE 7 standard and includes the same tables for various risk categories. The most severe of these is risk category II and in the accompanying table (Figure 1609.3(3)) found to the right, the highest peak value for the United States is again southern Florida with a requirement of 200 mph Including a safety factor of 1.5 would raise this value to 300 mph.

National Hurricane Center and Central Pacific Hurricane Center, describes and defines the Saffir-Simpson Hurricane Wind Scale as the various mph of different hurricane categories. This scale is described as “a 1 to 5 rating based only on a hurricane's maximum sustained wind speed.” The scale has a corresponding range for wind speeds and can be seen in the table seen here to the right. Category 5 has a maximum sustained wind speed of 157 mph, and when including a safety factor of 1.5, would mean designing to 235 mph.

Hurricane Wind Scale
Category 1- 75 to 95 mph winds
Category 2- 96 to 110 mph winds
Category 3- 111 to 129 mph winds
Category 4- 130 to 156 mph winds
Category 5- 157 or higher mph winds

Figure 2 - Saffir-Simpson Scale

As a final reference, the highest recorded wind speed in the world occurred in Barrow Island, Australia in 1996 and registered at 250 mph. If a safety factor of 1.5 is included, that would yield a wind speed of 375 mph.

Calculations

In order to more easily test or measure the performance of a building material or component used in an exterior envelope, it has been necessary to translate the value from wind load/speed on a psf basis down to psi basis to allow for small scale or lab size testing. The primary formula used for this calculation is a two-step conversion. First, mph is converted into psf using the equation,

$$P=0.00256*V^2=(x)psf$$

Where:

P= wind pressure, psf

V = wind velocity, mph

and then the psf value is converted using the equation,

$$psf/144=(x)psi$$

As an example, we will use the Barrow, Australia highest recorded speed, including the 1.5 safety factor of 375 mph.

$$P = 0.00256 * 375^2 \text{ mph} = 360 \text{ psf}$$

$$psi = 360 \text{ psf} / 144 \text{ in}^2 = 2.5 \text{ psi}$$

Using this combination of equations, the highest recorded wind speed, including a safety factor of 1.5, would equate to 2.5 psi of sustained wind pressure on a given structure. This value of 2.5 psi is important to keep in mind while reviewing some of the current product testing standards and how those standards are being used today.

ASTM D4541 and ABAA T0002

The purpose of ASTM D4541 *Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers* and ABAA T0002 *Standard Test Method for Pull-Off Strength of Adhered Air and Water Resistive Barriers Using an Adhesion Tester* is to determine the adhesion or pull-off tensile strength of a coating such as an air and water barrier applied to a substrate. These tests attempt to determine if the air and water barrier material have sufficient bond to prevent failure in the system. With this goal in mind, both standards are intended to be a product test rather than a system test as evidenced by the language and requirements used in each standard. What is stated in the scope is the following: ASTM D4541, "for evaluating the pull-off strength (commonly referred to as adhesion) of a coating system from metal substrates." ABAA T0002 is not quite as specific stating, "for evaluating the pull-off (adhesion) strength (may also be considered tensile stress) of adhered air and water resistive barriers on rigid substrates." Both standards were developed to test the performance of the air and water barrier material and its ability to bond to a substrate, not to test an exterior envelope assembly.

ASTM D4541 or ABAA T0002 Testing When Using a Homogenous Substrate Such as Metal Versus a Composite Material Such as a Paper or Glass Mat Gypsum Sheathing Panel.

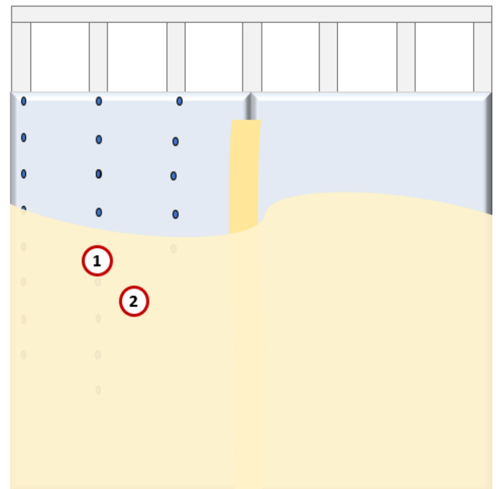
Both standards describe the testing substrate to be **rigid**. ASTM D4541 states that the testing substrate is to be metal, or optionally plastic or wood while ABAA T0002 relies on the tester to determine what constitutes a rigid substrate. To ensure consistent and accurate results, the substrate should be **smooth**, as described in ASTM D4541, Section 1.1 (Note 2), "The procedure in this standard was developed for use on flat surfaces. The results could have greater variability with lower values and averages for surfaces other than flat." Additionally, the air and water barrier samples are to be **scored** through the coating material to the substrate. These standards included this step as they were originally only intended for thick-film materials over rigid surfaces; However, today it is regularly used with thin-film materials over a range of substrates, both in the lab and in the field, even though this is beyond the original scope and intent of the product test standards, introducing the very variability they warn against.

Metal- Homogenous material, very hard & rigid

Glass Mat Gypsum Sheathing- Composite material that includes a gypsum core and glass-mat facers

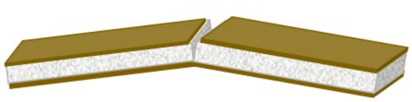
This is an important factor when considering the make-up of a substrate used in many of these systems. As an example, glass mat gypsum sheathing panels, such as those meeting ASTM C1177, *Standard Specification for Glass Mat Gypsum Substrate for Use as Sheathing*, are often the substrate choice for exterior envelope assemblies that include an air and water barrier material. These ASTM C1177 products have a long history of excellent performance both as an exterior sheathing panel and as a substrate for thin and thick liquid-applied air and water barriers, peel and stick membranes and other materials and facades. Importantly, glass mat gypsum panels are composite panels made up of a gypsum core with glass mat facers surrounding the gypsum core. As a result of this composite make-up, glass mat gypsum panels behave very differently when compared to a homogenous material such as metal or plastic particularly when used for testing materials such as those addressed in ASTM D4541 and ABAA T0002.

With the above in mind, it's important to take a closer look at why the type of substrate used becomes critical to the ability of the tester to achieve consistent test results when performing ASTM D4541 or ABAA T0002

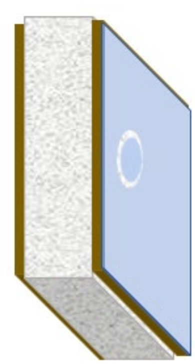


Rigidity is identified as a factor in the consistency and repeatability of these tests. Substrates such as metal, plastic, or wood can have a considerably higher rigidity than gypsum sheathing panels. ASTM D4541 states that even different thicknesses of metal substrates can affect the tests, “For example, steel substrate of less than 3.2 mm (1⁄8 in.) thickness usually reduces test results compared to 6.4 mm (1⁄4 in.) thick steel substrates.” In contrast, gypsum sheathing panels often are sufficiently flexible enough to be used in radius wall applications [1], albeit gradual ones. The rigidity increases when the panels are installed over a framed wall, but this creates an additional variable as both standards have requirements for where testing samples should be taken that may not factor in the effects of a flexible material applied to a framed (stiffer) wall. As an example, if the first test in a series is located over a stud location and in-line with the fasteners securing the gypsum panel substrate to the framing, the tester will get different results than a second test that is located horizontally in between standard 16” framing and vertically between fastener locations, where the gypsum panel may flex.

Smoothness is also identified as a factor that can affect testing results. Most would agree that metal, plastic, and wood are all relatively flat and smooth and some might state that glass mat gypsum panels are as well. However, glass mat gypsum panels do not have a smooth surface and in fact have a rather rough surface. This roughness is a benefit in the field as more surface area and texture in a surface often means better bonding between materials. As a result of this lack of smoothness, the application of a liquid applied air and water barrier over such a surface creates a series of peaks and valleys which follow the surface of the substrate. Why does this matter if ultimately there is a good bond? Ironically, this potential for improved bond cannot then be tested accurately using these standards and the tools they reference.



Scoring the sample now becomes an issue as both testing standards direct the tester to separate or delineate the test material from the surrounding material area. To do so, both standards include instructions for scoring around the perimeter of the testing “puck”. Section 5.7, ASTM D4541 states, “Scoring tool, circular hole cutter, or similar tool to score the coating to the substrate around the loading fixture.” ABAA T0002 alternatively states in Section 5.9, “Utility Knife or Circular Hole Cutter, device used to cut through the material being tested to the substrate around the disc.” When scoring the air and water barrier through to the substrate, the rigidity and homogenous nature of the metal substrate limits the scoring depth, i.e. the substrate is not damaged in the process. However, as stated, glass mat gypsum panels are not homogenous, instead they are a composite material. As anyone who has installed gypsum panels can attest, scoring through the facer of the material makes it easy to snap with minimal force. This creates a situation where scoring through the air and water barrier and not damaging the glass mat gypsum panel is very difficult and can yield



inconsistent results. It is simply not possible to score only through the material to be tested and not through the facer material. *It should be noted again that ASTM D4541 recommends only scoring thick-film materials, "Scoring should not be considered for coatings less than 20 mils." However, nearly all field testing incorporates the scoring or cutting practice.* When the facer is scored, the test may be evaluating the bond between the facer and core, rather than the adhesion between the air and water barrier and substrate as intended.

Field Testing Versus Laboratory Conditions.

Testing per ASTM D4541 in laboratory conditions is required for repeatability. The challenge with using a lab test for field testing is the wide range of conditions that exist in nature and by man created during the "under construction" process. These can include:

- Temperature,
- Humidity,
- Cure time of coating due to climatic conditions,
- Winter application challenges,
- Rain,
- Technician's ability to consistently hold the testing apparatus and apply load evenly,
- The use of make-shift "pucks", the adhesive selection and proper set of the adhesive.

All of these factors will influence results negatively and/or provide inconsistent results.

Interpretation of Results

The main objective for in-situ testing is to demonstrate, on a small scale, the coatings' ability to maintain bond at pressures that were required in full-scale system testing according to IIC-ES AC235 and other code requirements. These values can range from 90 mph up to 200 mph (0.14 to 0.71 psi) depending on desired safety factor, risk category, etc.

Conclusions When Using ASTM D4541 or ABAA T0002 for Field Testing of AWB Materials over Glass Mat Gypsum Panels

To this point, this paper has been focused on what ASTM D4541 and ABAA T0002 test and how that testing is to be performed and what that means when attempting to perform the test when a coating is applied to a glass mat gypsum panel substrate. As previously mentioned, this is a product test used to determine the potential for an air and water barrier to remain bonded to a substrate under conditions where it would encounter forces sufficient to break the bond, potentially putting the assembly components outbound of the air and water barrier at risk of pulling off of the structure. Even as this document is intended to help readers recognize that issues with using ASTM D4541 or ABAA T0002 as written for testing air and water barriers over a glass mat gypsum panel substrate, it is equally important to note that in all likelihood, these tests will continue to be used. As such, it is important to offer guidance as to what level of performance is to be expected when testing an air and water barrier used in conjunction with a glass mat gypsum sheathing panel.

Environmental conditions play a critical role as to when the testing should and should not be performed. Firstly, the air and water barrier material must be fully cured, factoring in potential delays for rain, cold weather, or humidity. Secondly, the adhesive used to bond the test puck to the air and water barrier material must also be fully cured, factoring in potential delays for the same list of environmental conditions. Thirdly, if the glass mat gypsum sheathing has become saturated from moisture or rain, it should be allowed time to fully dry and reach equilibrium prior to testing. Any shortcuts taken in the above will lead to inaccurate test results.

Testing locations should be standardized so that locations with similar structure are used (all located over framing or none over framing, consistent distance from board edges or ends, etc.). This ties back to the environmental conditions as well as different faces of the structure can yield different results due to exposure to sun, wind, or other weather factors.

Expected values when using a non-rigid, composite substrate in the lab instead of the prescribed material are not definable, more importantly they are even less definable when attempted in the field. However, it's reasonable to consider 2.5 psi or greater as a value that would exceed the highest recorded wind, including a 1.5 safety factor, as demonstrating sufficient bond between the glass mat gypsum substrate and the air and water barrier coating.

While it is critical that the products and assemblies used in exterior envelopes perform as needed and expected, it's also critically important to understand what is able to be tested in the lab versus the field and whether that performance testing adequately meets the code requirements for safety and resilience.

Appendix

1- GA-226 *Application of Gypsum Board to Form Curved Surfaces.*

2- ASTM D4541-22- "1.1 This test method covers a procedure for evaluating the pull-off strength (commonly referred to as adhesion) of a coating system from metal substrates."

3- ASTM D4541-22- "NOTE 1—The procedure in this standard was developed for metal substrates but may be appropriate for other rigid substrates such as plastic and wood. Factors such as loading rate and flexibility of the substrate must be addressed by the user/specifier."

4- ASTM D4541-22- "NOTE 2—The procedure in this standard was developed for use on flat surfaces. The results could have greater variability with lower values and averages for surfaces other than flat."

5- ASTM D4541-22- "4.2 Variations in results with the same coating are likely when any parameter of the test is changed. This includes change in glue, load fixture size, substrate coating cure time, pull rate, environmental conditions, if the coating is scored, or using a different device."

6- ASTM D4541-09- "6.6 Based on the glue manufacturer's recommendations and the anticipated environmental conditions, allow enough time for the glue to cure."

7- Maximum recorded speed- https://www.wunderground.com/cat6/the-highest-anemometer-measured-wind-speeds-on-earth

8- American Society of Engineers ASCE 7-22, Chapter 26- Figures 26.5 1A-1D- available for purchase here, ASCE Bookstore

9- International Code Council, International Building Code, 2021 edition- https://codes.iccsafe.org/content/IBC2021P1/chapter-16-structural-design