Currently, the International Building Code, the International Residential Code, and the Building Construction and Safety Code NFPA 5000 require asphalt shingles to meet ASTM D-3462. One of the provisions of D-3462 is the testing of asphalt shingles using ASTM D-3161. This test measures the reliability of the sealant strip of shingles to resist a 2-hour exposure to winds that can be experienced by shingled roofs. These codes also require that asphalt shingled roofs installed in areas of the country where the design wind speed as defined by local authority or ASCE 7 equals 110 mph or greater be tested using ASTM D-3161 at 110 mph. Other wind speeds have in fact been recently added to ASTM D-3161.

ASTM D-3161 at 60 and 110 mph is a good test of the reliability of the sealant strip and provides data that supports the nailing patterns recommended by the manufacturer. This results in most shingles meeting the requirements of ASTM D-3161 using four nails, as has been prescribed by the building codes for years. The Florida Building Code and some other jurisdictions require six nails as additional securement. Additional nails do not have a major impact on the wind speed that a shingle will resist.

ASTM D-3161 has provided valid data about the performance of shingles for years, but it did not give the code official or designer comfort that the shingle being installed would resist the actual wind loads that would be encountered. The traditional tests for low slope roofing wind loads use either a pressure or vacuum device to apply a load to a solid roofing system. The resistance of the system is measured as the loads are increased and the system is brought to failure. This type of test will not work for shingles, because they are air permeable, which means that air can move freely through the shingle matrix as the vacuum or pressure is applied. Therefore, very little load is measured. Yet we know that loads do develop on the shingle in high winds. We also know that the loads are less than those that would be expected if no air could move through the matrix. Because of these factors, the Asphalt Roofing Manufacturers Association (ARMA) has extensively researched the subject of wind loads and, working with Underwriters Laboratories (UL), has developed a new process for the classification of Shingle Wind Loads. This classification uses the uplift coefficient of the shingle and the resistance to vertical load to determine the wind load that a shingle is designed to resist.

**Historical Background**

Since the mid-1960s, UL has been evaluating listed “wind-resistant” asphalt shingles with self-sealing adhesive in accordance with the standard for “Wind Resistance of Prepared Roof Covering Materials,” UL997 (ASTM D-3161). This test method was
based on recommendations included in research published in 1960 by the National Institute for Standards and Technology (NIST – formerly the National Bureau of Standards). A fan-driven wind speed of 60 mph for a 2-hr. duration is specified in UL997. This corresponds to the wind speed used by NIST due to the limits of the fan used in the original research. The finding reported was that "...an effective method for preventing wind damage is to secure the shingle tabs to the course below." The UL997 wind resistance evaluations are an integral component of UL’s Listing and Follow-Up Service Program. Shingles exhibiting the UL label are selected from production runs on a quarterly basis by field representatives and forwarded for UL997 evaluations at UL’s Northbrook test facility. This element of UL's Listing and Follow-Up Service Program for self-sealing asphalt shingles will continue.

Roof cladding, which includes asphalt shingles, is required to be designed to resist wind loads within the various wind speed regions of the U.S. as defined in the “Minimum Design Loads for Buildings and Other Structures,” ASCE 7, as published by the American Society of Civil Engineers. However, earlier building code provisions included an exception for asphalt shingles based on prescriptive attachment specifications and compliance with UL997 (ASTM D-3161).

As a result of hurricane events, as well as concerns expressed by model code organizations by insurance authorities and local building official jurisdictions such as Dade County, Fla., the exception for asphalt shingles was removed from the building codes. In addition, some local jurisdictions and the current International Residential Code have imposed a requirement for high wind speed regions that asphalt shingles comply with UL997 conducted at an increased wind speed of 110 mph.

**ARMA-Sponsored Research**

Asphalt shingles are designed for steep-slope applications whereby rain is shed naturally as a result of flow down the slope of the roof. There is an inherent air permeability associated with asphalt shingle products. As such, uplift loads attributed to wind movement over, around, and about the building structure are significantly reduced as air pressures rapidly equalize beneath the shingles. Provisions in ASCE 7 permit assessment of reduced loading for air permeable cladding based on approved test data.

To address this issue, ARMA contracted Dr. Jon Peterka and CPP Wind Engineering Consultants, Fort Collins, Colorado, to develop data with respect to the wind resistance performance of asphalt shingles. This research involved data developed in the CPP boundary layer wind tunnel (see Figure 1) and on an actual test building built on a turntable so it could be rotated into the desired wind direction. The focus of this work was to identify the uplift mechanism acting on the shingle due to local wind flow across the shingle surface and from that to derive methodology for measuring the critical uplift properties that relate to the impact of wind on shingles.

**New UL Standard Published**

The publication of ANSI/UL2390 Test Method for Wind Resistant Asphalt Shingles with Sealed Tabs, in May 2003, represents the culmination of efforts begun by ARMA in 1990 with Dr. Peterka and the more recent efforts by UL’s Standards Development staff. Under this new evaluation procedure, a wind uplift coefficient is determined based on air flow perpendicular to and across the shingle surface. The wind uplift coefficient is calculated by measuring pressures above and below the shingle surface at the windward and leeward sides of the sealant. The uplift force (lbf) acting on the sealant is then calculated to correspond to the wind speed.

**Classification.** Once this force (lbf) is identified, the next step is to determine the resistance force (lbf) capability of the tab sealant as measured by a mechanical test. This test is described in the “Standard Test Method for Measurement of Asphalt Shingle Tab Mechanical Uplift Resistance,” ASTM D-6381.

When these tests are combined, the load developed by the wind at any given wind speed can be determined and the inherent resistance of the sealed shingle as measured can be used to determine...
Figure 3. Wind test set up at Underwriters Laboratories. The grid creates a gusty wind. The wind speed is measured with the pitot tube, and the shingles are pressure tapped.

the classification for the shingle. (See Figure 6 for information on the shingle classification process.)

**Test Method Derivation**

In order for a shingle to be classified, four things need to be known. They are: 1) the area of the shingle in front of and behind the sealant; 2) the strength of the sealant; 3) the uplift coefficient in front of and behind the sealant; and 4) the stiffness or flexural modulus of the shingle. UL2390 measures the stiffness of the shingle, the area of the shingle, and the uplift coefficient of the shingle.

ASTM D-6381 measures the resistance of the sealed shingle to an applied force, which simulates the force that is applied by the wind. (See Figure 2).

Breaking UL2390 into its parts, a manufacturer can have a shingle tested for stiffness using a procedure in UL2390, which applies a load on the product and determines how much it bends. In the development of the standard, a variety of shingles were evaluated. These varied from the most flexible products (such as standard, lightweight, three-tab shingles) to heavy, multi-layered laminates. The most flexible of the shingles tested – a standard three-tab – had an average flexural modulus (EI) of 5.0. The developers chose to use a value just outside two standard deviations below this value, or EI=2.5 as the standard flexural modulus for most evaluations. The test provides for measurement of the actual modulus if desired by the manufacturer.

Flexural modulus is a powerful factor in determining the wind resistance of the shingle. The uplift coefficient is increased by 20% when the EI is reduced from 5.0 to 2.5 on a typical shingle. Increasing the EI above 10.0 can further reduce the uplift coefficient to such an extent that shingles lay almost flat at 150 mph (0.02 inch lift). Multi-layered laminates can exhibit a flexural modulus of 20 or more. When considering the wind performance of a shingle, increasing the stiffness (higher modulus with all other factors being equal) results in more wind resistance. The net result of using a flexural modulus of 2.5 is that a significant reserve capacity (safety factor) is added to standard calculations.

In order to complete the test, shingles are arrayed on a deck as in ASTM D-3161, and selected shingles are pressure tapped prior to the prescribed 135 to 140°F heat conditioning for 16 hours. After conditioning, the shingled and pressure-tapped decks are placed in front of the standard wind machine, which has a special grid attached to the ori-

Figure 4. Data points representing the wind speedup (wind gusts) just above the shingles versus the ambient approach wind. This shows that the maximum wind speed just above the shingles was less than 2.5 times the mean approach wind speed.
The taps are connected to a system of tubes that links them to a sequential timer that connects to a pressure transducer. Taps are located in both the underlying shingle and the exposed shingle. The taps are connected through a sleeve in the lower shingle so that the top shingle is free to move when the wind force applies a load and the shingle is distorted or lifted.

During the test, the wind machine is set at 35 mph, and a computer connected to the transducer measures the coefficient of uplift pressure. In order to simulate the distortion effect of wind lifting the tabs as the wind speed increases, the tabs in front of some of the shingles are raised with small blocks or shims. The standard condition for the test is the simulation of a 150 mph, 3-second gust. Using the stiffness and the area of the tab, the load expected to be applied by this wind is calculated, and a projected distortion is determined. This dictates the initial thickness of the shim. The coefficient is determined in this test, and this is iterated through the process to more accurately select the shim thickness. The test is repeated until the shim thickness provides appropriate distortion and the final coefficient is determined. Uplift coefficients in front of the sealant typically range from 0.4 to 0.8; whereas behind the sealant, the range is typically 0.05 to 0.30. This is significantly less than the coefficient of 1.0 or more for clad systems. The uplift coefficients in front of and behind the sealant strip are multiplied by the area and the resultant uplift force on the shingle is determined.

Uplift coefficients are independent of wind speed but dependent on the shape and thickness of the shingle. Shingles with a thick leading edge will have a higher uplift coefficient in front of the sealant than shingles with a thin leading edge. The coefficients for a given type, style, and thickness do not change from shingle to shingle.

The calculation for the force on the shingle uses the failure strength derivation from ASCE 7 and the enveloping maximum wind speed at any point on the roof from the ARMA research, which results in a final load on the shingle sealant equivalent to a 312 mph wind. The strength design is 60% greater than the 50-year return design. This, in combination with the conservative flexural stiffness measurement, provides a large reserve capacity (safety factor) for shingle sealant loads. In terms we are more familiar with, a shingle in a 150 mph gust would experience a sustained wind of 245 mph. The sustained wind is found by using the Durst curve to establish the mean wind speed (150/1.53) and multiplying the mean wind speed by the factor of 2.5, representing the maximum wind speed up factor (150/1.53x2.5=245). The 245 mph sustained wind represents the 50-year return wind for the shingle. ASCE 7 uses a strength design factor (safety factor) of 1.63 x V or 1.63 x 245 = 312 mph. See Figure 4.

During research on shingle uplift coefficients and the development of the UL2390 Standard, a parallel research and development project was carried out through ASTM. This resulted in ASTM D-6381, “Standard Test Method for Measurement of Asphalt Shingle Mechanical Uplift Resistance,” which measures the resistance of the sealed shingle to an uplift force. Initially the most common shingles were three-tab products having relatively long distances from the leading edge of the sealant to the leading edge of the shingle (3/4" to 1.5") and a total exposed length of 5 inches. This resulted in most of the uplift force being applied to the front of the tab. Therefore, ASTM D-6381 initially only had a single test design, and that was the application of the load in a peel fashion from the lead-
PREPARED ROOF COVERING MATERIALS - ASPHALT SHINGLE WIND RESISTANCE (TGAH)

General
This category covers the evaluation of asphalt shingles surfaced with mineral granules that are designed to resist wind forces by affixing the shingle above to the surface of the shingle below with a sealant (factory or field-applied) applied in a pattern aligned parallel to the windward edge of the shingle. The evaluation process involves three steps: 1) the determination by test of a wind uplift coefficient, 2) the calculation of the potential uplift force (lbf) acting on the tab sealant utilizing the wind uplift coefficient and specific wind speed selected for the evaluation; and 3) the determination of resistance force (lbf) capability of the tab sealant as determined by mechanical test.

Wind Uplift Force Requirements
A wind uplift coefficient is determined based on air flow perpendicular to and across the shingle surface. The wind uplift coefficient is calculated by measuring pressures above and below the shingle surface at the windward and leeward sides of the sealant. The uplift force (lbf) acting on the sealant is then calculated to correspond to the wind speed classifications as tabulated below.
- Class D - 90 mph
- Class G - 120 mph
- Class H - 150 mph

The wind uplift coefficient is to be determined, and the corresponding uplift force (lbf) is to be calculated in accordance with the standard Test Method for Wind Resistant Asphalt Shingles with Sealed Tabs, UL2390.

Tab Sealant Uplift Resistance Requirements
The uplift resistance (lbf) capability is to be determined by the Standard Test Method for Measurement of Asphalt Shingle Tab Mechanical Uplift Resistance, ASTM D-6381. The uplift resistance force determined from this mechanical test method shall be equal to or greater than the calculated uplift force for the corresponding wind speed classification.

Related Products
For fire rating of roof covering materials, see Prepared Roof Covering Materials (TFWZ).

UL Mark
The classification mark of Underwriters Laboratories Inc. on the product or package of products is the only method provided by UL to identify roof-covering materials, which have been produced under its Classification and Follow-Up Service. The classification mark includes the UL symbol, the word CLASSIFIED above the UL symbol (as illustrated in the Introduction of this Directory), and the following additional information:

Prepared Roof Covering Materials - Asphalt Shingle Wind Resistance
Class _+_+

+ - Class D, G or H

How to Use the Classification when Specifying Asphalt Shingled Roofs
Most shingles will be installed on roofs that are less than 60 feet in height and in ground roughness exposure categories B or C. The specifier will call out a shingle that is acceptable for the appropriate wind speed found on the ASCE 7 wind map or the wind speed specified in that jurisdiction by the code official. For most of the United States, the basic 3-second gust speed is 90 mph. Therefore, all roofs in ground roughness exposure category B or C on buildings 60 foot high or less with an importance factor of 1 should be a minimum UL Wind Force Class D. If, instead the roof were in a 150 mph, 3-second basic wind speed zone in ground roughness B or C, the specified shingle would be a wind uplift force Class H. (See UL Guide, Figure 6 for description of the wind speed designations.)

Currently, there are no guidelines for roofs that fall outside of

UL2390, either Part A (peel) or Part B (T-pull) or a combination of both is selected as the classification criteria for the resistance of the sealant to wind loads.

Figure 6. UL Guide finalized in May 2004.
these requirements, such as roofs on taller buildings or in ground roughness exposure D. For these situations, the consultant will need to work directly with the supplier to determine the appropriate classification of the shingle to be used. The load values and resistances can be calculated from test data, but generally this will be proprietary information.

For about 98% of the roofs, specifying a shingle with code-required wind resistance will be a simple process. Just select the wind speed from the ASCE 7 wind map and choose the appropriate classification category to match that design wind speed. For the fewer than 2% of the roofs that do not meet the criteria, a phone call to the supplier will likely get the verifiable data that will allow appropriate calculation.

**Observation to Ensure Compliance with the New Classification**

The primary elements of the roof observation are verification that the right product is being installed and that the product is being installed to the manufacturer’s instructions. The package of shingles should have a label indicating its UL wind classification. This should meet or exceed the required classification for the ground roughness exposure category and three-second gust basic wind speed for the location where the product is being installed. Next, the manufacturer’s instructions for installation, either on the label or in product literature, must be followed. This involves both the number of nails per shingle and the placement of nails in the shingle. No nails should be placed in the sealant strip, as they can have a blocking effect and keep the sealant from attaching. There are no current industry-wide tolerances for nail placement because the nail placement tolerance varies with individual products.

The most important factor in achieving a wind-stable roof is having the sealant strip attach the shingles together. Without the sealant strip bond, the exposed area of the shingle will be lifted in very high winds, transferring the loads entirely to the nails. Therefore, shingles should be hand tabbed when

*Figure 5. ASTM D-6381 Procedure B. The load is applied perpendicular to the sealant strip.*
being installed in very cold weather or when adverse dust and dirt conditions exist in accordance with the manufacturer’s recommendations. For more information about proper installation of asphalt shingles, consult Good Application Makes a Good Roof Better, available from ARMA, or the Residential Asphalt Roofing Manual, also available from ARMA.

**Benefits of the New Classification for Consultants and Owners**

Asphalt shingle products have already changed in response to the ARMA research. Understanding the fundamentals of performance has allowed manufacturers to design products with more wind resistance. ASTM D-6381 is a quality assurance test that can be performed in the factory. Since the shape of the shingle and the stiffness are such major contributors, as long as these factors remain constant and the wind load remains constant, the manufacturer need only to determine the sealant resistance. A wind machine to run the test is not required. ASTM D-6381 tests can be conducted as frequently as required to assure the manufacturer that appropriate product is leaving the plant.

The building owner gets a better product because the manufacturer has access to test methodology and results that make field performance more predictable for new products, and the consultant has a more reliable guide for the type of shingle that should be installed. ANSI and ASTM have accepted the tests as consensus tests through accredited processes. Any laboratory having the correct equipment can perform them.

A caveat is necessary. These tests and this classification process are for as-manufactured products. As shingles age, they become stiffer. The increased flexural modulus will improve the wind resistance. The bond strength will also change with age and contaminated bonds will weaken. Upon a forensic investigation, these tests, therefore, are not likely to provide representative data of the product characteristics when installed.

The International Code Council incorporated UL2390 and ASTM D-6381 into the International Building Code in May 2004. These test methods will be included in the 2004 supplement to the International Building Code. This action now provides a code-accepted set of tools to determine the uplift force on an asphalt shingle and the corresponding resistance to wind loads.

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