Experimental Research Plan #2: System-Level Wind Resistance of Asphalt Shingle Roofs

SERRI Proj. No. 90100: Residential Roof Covering Investigation of Wind Resistance of Asphalt Shingles

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1. Summary

The Windstorm Simulator (henceforth Simulator) at the Institute for Business & Home Safety (IBHS) Research Center is the principal experiment tool for this research, which seeks to:

1. Identify regions of the roof that are more susceptible to shingle uplift [IBHS led]
2. Quantify the flow characteristics near the roof surface [UF led; see Exp. Research Plan #3]
3. Evaluate the system-level wind resistance of asphalt shingle roofs [UF led; the focus herein]

IBHS will lead the Objective 1 effort to identify the areas on the roof surface more likely to experience shingle uplift. Once the "hotspots" are identified, UF will instrument these locations with an array of turbulence probes to characterize the profile near the roof plane to address Objective 2 (forthcoming in Experimental Research Plan #3). For Objective 3, UF will construct half-roof mockups outside of the Research Center to expose them to 1 yr of natural aging, followed by testing in the Simulator. Eighteen (9 hip and 9 gable) asphalt shingle roofs with plan dimensions of 6.1 m x 9.1 m (20 ft x 30 ft) will be constructed. Test variables are two architectural (dimensional) and one three-tab ASTM D 7158 (2008) Class H shingle products, three wind speed intensity levels and three wind azimuths. IBHS will provide a one story base structure with plan dimensions of 12.2 m x 9.1 m (40 ft x 30 ft) to accommodate the half roof mockups. The other half of the roof structure will be a permanent gable ended roof structure. Mean velocity and turbulence profiles will correspond to Exposure C conditions described in ASCE 7-10 (2010). A forensic assessment will be carried out following each test.

2. Test Structures

The two components of the subject building are a base structure (Figure 1) and a half-roof mockup (Figure 2) that form a 12.2 m x 9.1 m (40 ft by 30 ft) one-story regular building. The base structure will remain in the test chamber for the entire sequence of tests. The half-roof mockups are the test specimens, which will be interchanged between tests.

2.1. Base Structure

The base structure is a 9.1 m W x 12.2 m L x 2.4 m H (30 ft W x 40 ft L x 7 ft 10 in H steel frame sheathed with plywood panels (Figure 1). The permanent half of the structure is a 6:12 gable roof with 1 ft eave overhangs constructed from fan-type wood trusses spaced at 0.6 m (2 ft) o.c. and 12 mm x 1.2 m x 2.4 m (15/32 in x 4 ft x 8 ft) four-ply plywood roof and gable end sheathing fastened with 60 mm (2 3/8 in) 8d ring shank nails spaced at 6 in in the field and edge regions. The roof structure will be secured to a 2x4 wood double top plate.

2.2. Half-Roof Mockups (Test Specimens)

The "half-roof" test specimens will consist of 9 hip and 9 gable 6:12 roof structures. Standard wood residential construction will be used for the test sections (Figure 2). Each section will be constructed with fan-type wood trusses at 0.6 m (2 ft) o.c. and 0.3 m (1ft) eave overhang (both sides gable, all sides hip). To install each section on the base structure for testing, the section will be hoisted by a telehandler on the section's underside. To prevent racking of the test section during installation, the gable ends and bottom truss chord will be fully sheathed along with the roof decking. The 12 mm x 1.2 m x 2.4 m (15/32 in x 4 ft x 8 ft) four-ply plywood sheathing will be fastened according to Florida Building Code Section R803.2.3.1 (2008). The asphalt shingles and roofing felt will be installed according to manufacturer's specification by a professional roofing contractor. A door on the mockups's interior gable end (as installed on the base structure) will provide access into the section's attic space during conditioning and testing.

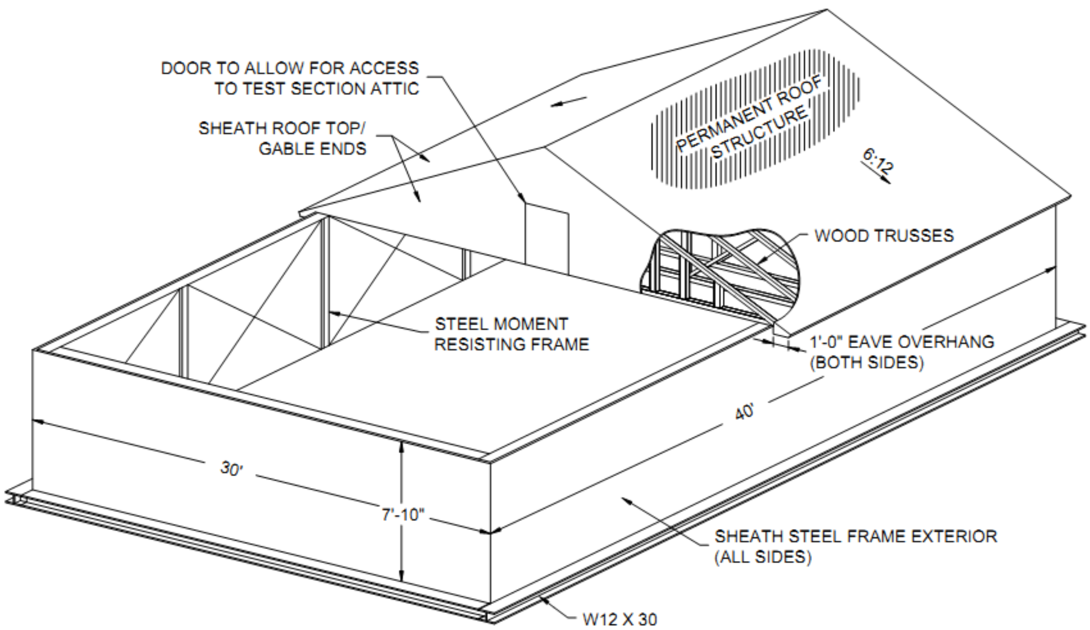


Figure 1. Base structure construction plan.

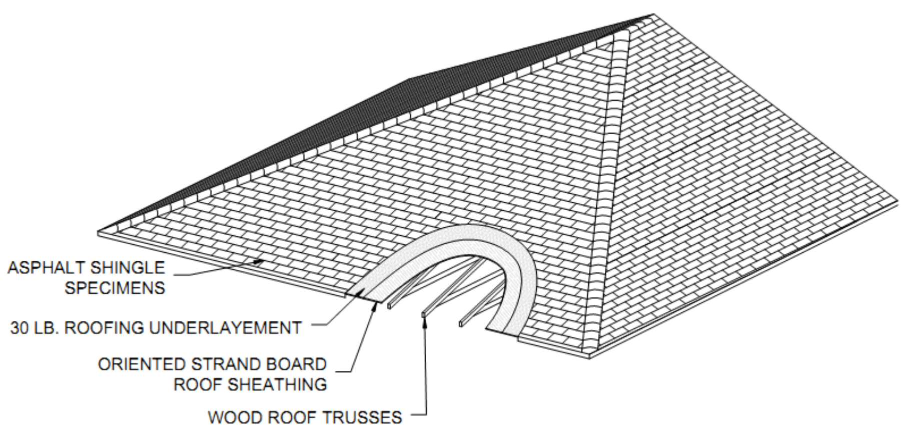


Figure 2. Test section construction detail (hip roof shown; gable-end roof also to be used)

The specimens will be constructed in an open field at the IBHS Research Center. The bottom chords will bear on 0.3 m (1 ft) tall wood blocking to elevate the roof structure above the ground. The open side of the truss assembly will be sheathed to enclose the attic space. The specimens will be oriented such that one side of the gable ended mockups faces south for maximum UV and heat cycling exposure. The hip roofs will be correspondingly aligned.

2.3. Asphalt Shingle System

Three asphalt shingle products will be purchased by UF from contractor supply stores for each roof type/shingle product combination. ASTM D7158 Class H (ASTM, 2008d) shingle products will be used; Classes D and F are no longer commonly available according to the manufacturers we contacted. Both three-tab (1 product) and architectural shingles (2 products) will be tested (Table 1). Shingles will be installed in accordance with the manufacturer's instruction for 6:12 pitch buildings located in the High Velocity Hurricane Zone. Generally, this requires six fasteners per shingle and a 150 mm (6 in.) starter strip along the eave edge. Installation of asphalt shingle underlayment will conform to Florida Building Code Section R905.2.7 (2008). Metal drip edge flashing will be installed along all eaves and gable ends.

Table 1. Asphalt shingle test matrix.

Asphalt Shingle Product	Hip Roofs to be Constructed	Gable Roofs to be Constructed
Architectural Shingle #1	3	3
Architectural Shingle #2	3	3
Three-tab Fiberglass Shingle	3	3
Total	**9**	**9**

3. Conditioning

Construction of test sections will begin in late May 2011 at the IBHS Research Center. Each section will be conditioned outdoors for a period of one year and elevated above the ground with wood blocking on each span end. UF will monitor onsite ambient temperature, solar radiation, wind speed, and rainfall.

4. Installation/Removal of Test Specimens

This section outlines the pre-test installation and post-test removal of a single test specimen. All sections will be installed/removed following this procedure.

4.1. Installation

A Lull 944E-42 Telehandler (available for rental nearby) or an equivalent piece of equipment will transport the test specimen from the staging area to the base structure. Prior to moving the test section, two 76 mm x 180 mm x 10 mm X 6 m (3 in x 7 in x 3/8 in X 20 ft) long rectangular steel sections will be installed on the bottom chord truss sheathing to provide additional lifting stiffness on the underside of the test section. The base structure will be located on the Simulator turntable. The Telehandler will hoist and place the section on the base structure with the test section bearing on the lengthwise wood double top plate (Figure 3). The Simpson Strong-Tie H10 truss/double plate connector, pre-installed on each truss, will then be fastened to the double top plate to secure the test section to the base structure. Figure 4 shows each roof configuration assembled for testing.

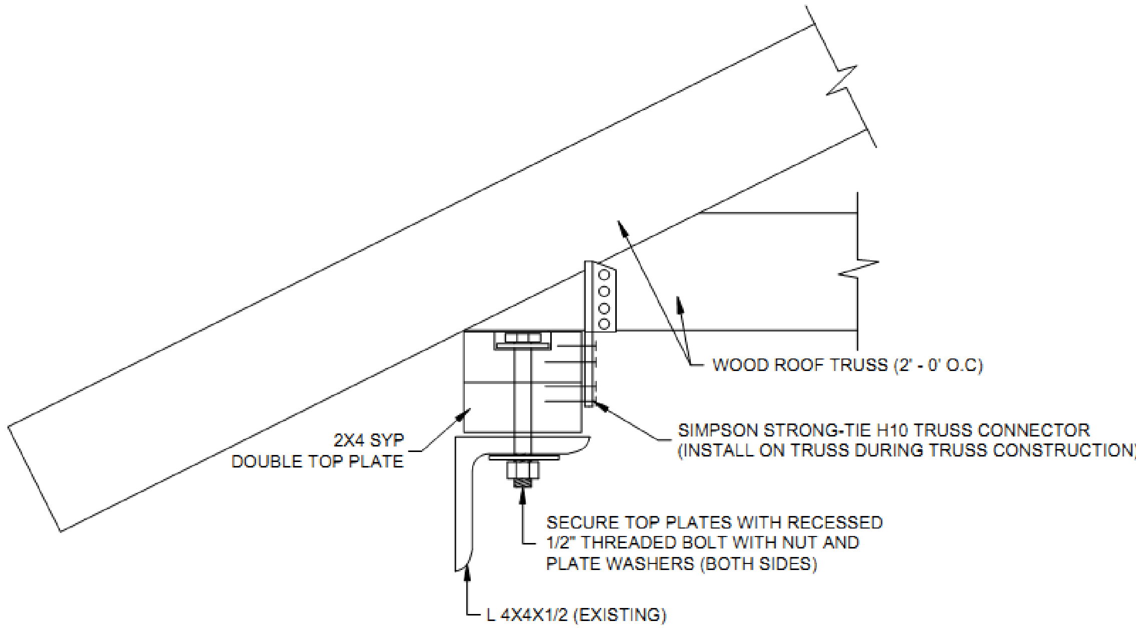
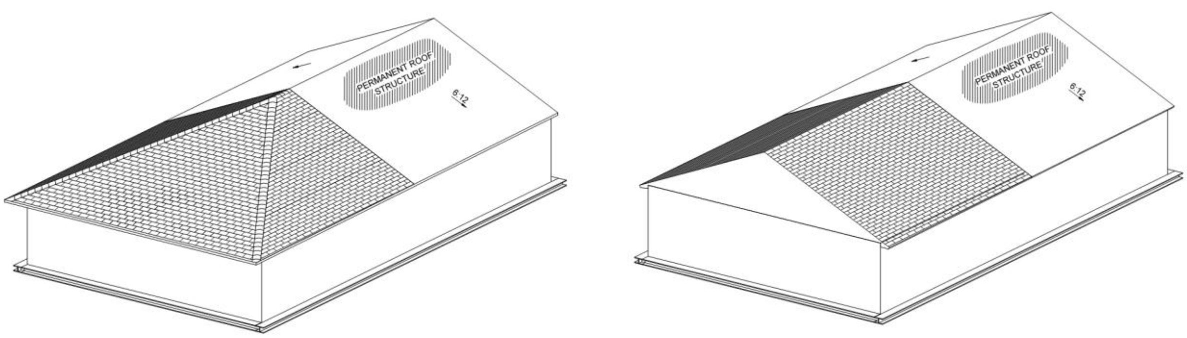


Figure 3. Test section connection detail.



(a) (b)

Figure 4. Roof sections installed on base structure (a) hip (b) gable

4.2. Removal

After testing (Section 5), the top plate will be detached from the trusses, and the mockup will be removed from the base structure using the Telehandler. The section will be placed back onto its conditioning location and the bottom steel tubing will be removed for use on the next section.

4.3. Additional Aging

The Simulator can produce wind speeds not exceeding 60 m/s (134 miles per hour) measured at 10 m (33 ft), which is below the rated wind speed threshold for a Class H Shingle. Therefore, all specimens that do not sustain damage (i.e. unadhered shingle tabs, shingle tearing, shingle blow off, etc.) will be placed outdoors for additional conditioning and tested at IBHS at a later date.

5. Wind Load Testing

NOTE: Experimental plans are tentative until the IBHS Research Board gives final approval.

5.1. IBHS Research Center

The newly commissioned open circuit wind tunnel of the IBHS Research Center is located in Chester County, South Carolina. An array of actively controlled 105 electric vaneaxial fans creates along-wind gusts and lateral flow variation to subject full-scale test specimens to extreme wind effects (Figure 5). Test buildings are attached to a 17 m (55 ft) diameter turntable capable of supporting distributed loads up to 1300 kN (300 kips).

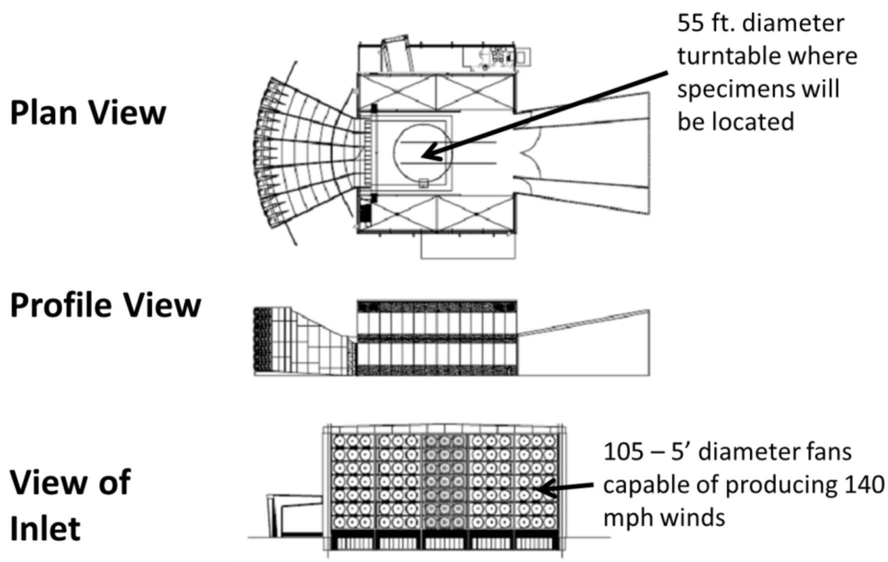


Figure 5. Conceptual renderings of the IBHS Research Center

5.2. Experimentation

Each test specimen will be subjected to three 30 min segments of wind loading from one wind direction. Segments will differ by intensity; the first segment being the least intense and the third segment being the most intense. IBHS is currently commissioning the facility, so a final determination on wind speeds has not been made. We are anticipating that peak gusts for the three tests will be on the order of 40 m/s (90 mph), 50 m/s (110 mph) and 60 m/s (134 mph) at 10 m. Three different wind directions will be utilized, but any one test specimen will be subjected to only one wind direction. The three directions are illustrated in Figure 6, where 0° is parallel to the ridgeline and 90° is perpendicular to the ridgeline.

5.3. Approach Flow Conditions

Approach flow conditions (mean velocity profile, longitudinal turbulence intensities, integral length scales, and power spectral densities) will conform to flat, open country conditions, otherwise known as Exposure C in ASCE 7-10.

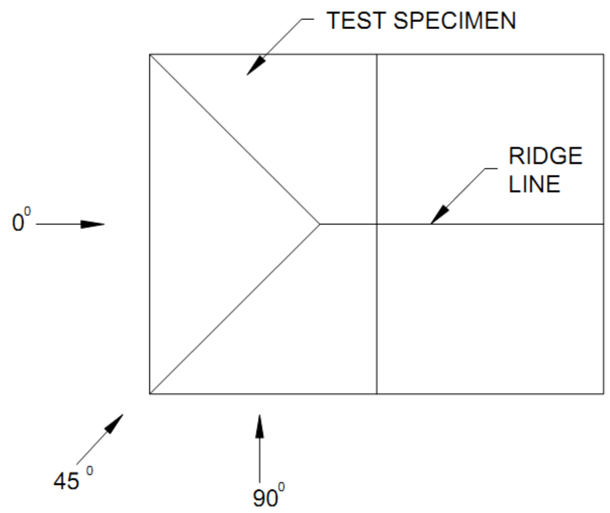


Figure 6. Approach flow directions.

5.4. Test Sequence

The test sequence is depicted in Figure 7. The test building (test roof section of interest + base structure) will be installed on the IBHS wind tunnel turntable and the test will begin at the first wind speed threshold. The test will continue for 30 minutes and upon completion the roof test section will be physically inspected using the damage rating system method described in Section 5.3. The test will begin again at the second wind threshold and will follow the same inspection and testing procedure until the third threshold.

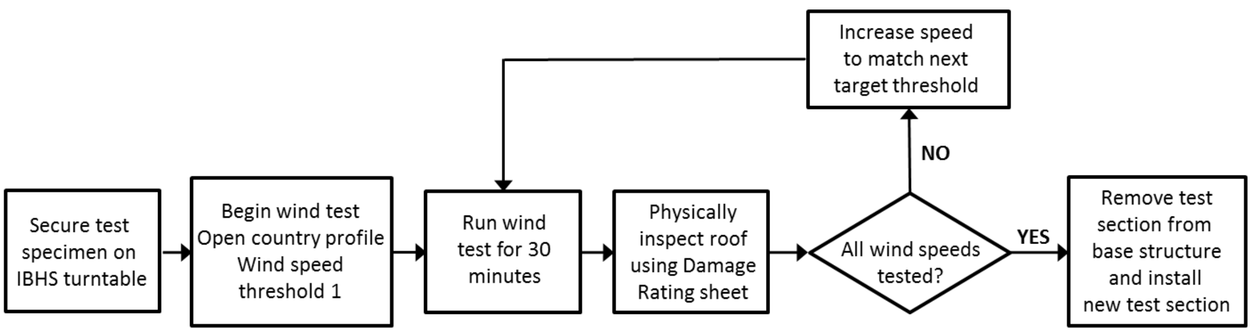


Figure 7. Test sequence flowchart. (Note: Exposure C wind profile for all wind tests)

5.5. Evaluation Methods

Two methods will be employed to document the performance of the shingle roof systems. First, high definition video cameras will be used to record the shingles behavior during testing. A camera will be located on all sides of the test section roof (2 cameras for the gable section, 3 for the hip). The location of the cameras will be selected to maximize visual results while minimizing flow distortion on the test section. The video will be monitored during testing to highlight damaged areas in need of investigation using the second method describe below. The second method will be a physical inspection of the test section after each 30 minute test run. Lamb and Noe (1989) successfully used a "damage rating system" to quantify the performance of unsealed asphalt shingles during wind tunnel testing conducted in the 1980s. This investigation will use this grading rubric; modified to conform to this test's wind speed levels and fastener types. Along with the grading system, photographic evidence of the assessed damage will be taken. This method will provide a quantifiable comparison of different asphalt shingle systems and will be instrumental in results reporting.

6. References

ASCE 7-10 (2010). Minimum design loads for buildings and other structures, American Society of Civil Engineers/Structural Engineering Institute, Reston, VA.

ASTM D 7158 (2008). "Standard Test Method for Wind Resistance of Asphalt Shingles (Uplift Force/Uplift Resistance Method)." ASTM International, West Conshohocken, PA.

FBC (2008). Florida Building Code, Tallahassee, Fla. Available at www.floridabuilding.org.

Lamb, G. D., and Noe, J. S. (1989). "Wind performance of asphalt roofing shingles." Proceedings of the 1989 Structures Congress, pp 528-535.