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Wind Uplift of Asphalt Shingles: Sensitivity to Roof Slope and Installation Temperature

Heather E. Estes

Jason T. Smith, Ph.D.

Tanya M. Brown-Giammanco, Ph.D.

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IBHS wind testing of asphalt shingle products has demonstrated that the most important factor affecting high-wind performance for self-sealing asphalt shingles is the strength of the seal between shingles. Self-sealing asphalt shingles contain a temperature-activated adhesive strip applied during the manufacturing process, which is used to adhere the lower-edge bottom-surface of the exposed top shingle to the top surface of the shingle below. Improvements in sealants applied to these products over the past 15 years[1] have resulted in dramatic increases in the wind ratings of self-sealed asphalt shingles from 60 mph in the 1990s to 150 mph today. Nevertheless, asphalt shingle manufacturers typically indicate that hand-sealing of these shingles is required when shingles are installed on steep-slope surfaces or during extended periods of cold weather (defined by some manufacturers as below 40°F). The Asphalt Shingle Manufacturers Association (ARMA) recommends hand-sealing for slopes greater than 12:12 (45 degrees)[2] or when shingles are installed during very cold weather[3], although no specific temperature is given. Despite these recommendations, hand-sealing of self-sealing asphalt shingles is not common practice for winter or steep-slope installations.

IBHS conducted an exploratory research program during 2015 and 2016 to determine whether wind uplift resistance for newer products could be significantly affected by installation when temperatures were below 40°F or by slope for more common roof slopes, i.e., between 2:12 and 12:12. This exploratory research program used four different self-sealing asphalt shingles, two 3-tab and two architectural shingles, each produced by a different manufacturer. One set of shingles was installed in the summer of 2015 and a second set during the winter of 2016. Panels were exposed to natural conditions at the IBHS Research Center site for extended periods of time before being subjected to wind uplift testing. Panels were installed at five different slopes (2:12, 4:12, 6:12, 8:12 and 12:12) with one panel facing north and its pair facing south. A total of 80 panels were constructed and tested during this research program (4 products; 5 slopes; 2 exposures; 2 installation times). Shingles were installed following manufacturer recommendations for normal (not cold and not steep slope) installations. Shingles were installed on standard 50-inch by 66-inch panels meeting the geometry and structural requirements for ASTM wind testing of self-sealing asphalt shingles. The exposure setup of the asphalt shingle panels is shown in Figure 1.

Currently two different methods, ASTM D3161 and ASTM D7158, are used to rate the wind uplift resistance of self-sealing asphalt shingles. The ASTM D3161 test standard is

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[1] Dutton, Eileen, Advances in Asphalt Shingle technology, Facilities Maintenance Decisions. Milwaukee, WI, 6 pp, <www.asphaltroofing.org/sites/default/files/press/Advances%20in%20Asphalt%20Shingle%20Technology.pdf>.

[2] Asphalt Roofing Manufacturers Association: Recommendations for Application of Asphalt Shingles on Steep Slopes and Mansard Construction. Washington DC, 2 pp, <www.asphaltroofing.org/sites/default/files/tech-bulletin/Recommendations%20for%20Application%20of%20Asphalt%20Shingles%20on%20Steep%20Slopes%20and%20Mansard%20Construction_0.pdf>.

[3] Asphalt Roofing Manufacturers Association, 2015: Recommendations for Installation of Asphalt Roofing Shingles in Cold Weather, Technical Bulletin. Washington DC, 2 pp, <www.asphaltroofing.org/sites/default/files/tech-bulletin/Recommendations%20for%20Installation%20of%20Asphalt%20Roofing%20Shingles%20in%20Cold.pdf>.

based on blowing wind over a panel of properly installed shingles sealed by exposing them to 135°–140°F temperatures in an oven for 16 hours. Receiving an ASTM D3161 “F” rating (highest available using this standard) means that shingles on the panel survived the application of constant 110 mph winds for two hours. ASTM D7158 produces a rating based on two tests. In one test, uplift pressure coefficients for shingles are measured and used to calculate uplift forces for various design wind speeds. Uplift resistance is obtained from a second test where a universal testing machine is used to determine the amount of force needed to break the sealant bond on a shingle section. The highest rating currently available is an “H” rating (150 mph). IBHS research indicates that the ASTM D3161 test, with its two-hour application of a wind load on a viscoelastic material, is a more severe test. From a practical standpoint, virtually any shingle that achieves an “F” rating from ASTM D3161 also achieves an “H” rating using ASTM D7158.

Figure 1. Forty panels (20 pairs) installed at 2:12, 4:12, 6:12, 8:12 and 12:12 pitches.

Test Methods

The panels were tested using an ASTM D3161 test apparatus, shown in Figure 2, with two deviations from the standard test procedures. The first deviation involved conditioning of shingles. ASTM D3161 requires that asphalt shingle test panels have their shingles installed at a 2:12 slope, be conditioned in a controlled environment at a 2:12 slope, and be tested at a 2:12 slope. Although tested at 2:12 slope, as noted above, the shingles were conditioned at various slopes using the natural environmental conditions experienced at the IBHS Research Center.

The second deviation involved testing panels at increasing wind speeds until failure occurred using the following sequence:

1. 10-minute check at 60 mph (Class A rating wind speed)
2. 10-minute check at 90 mph (Class D rating wind speed)
3. Two hours at 110 mph (Class F rating wind speed)
4. Wind speed increased by 10 mph increments and panel tested for two hours (up to a speed of 170 mph)

The two 60 mph and 90 mph intervals were used because IBHS had experienced numerous tests where shingles failed immediately when exposed to 110 mph winds, and this did not provide any insight into how the shingles performed at the lower classes.

All installed shingles were labelled with a Class F wind rating under ASTM D3161, and were selected because they had performed well in previous IBHS testing of multiple panels. The two 3-tab shingles selected, Owens Corning Supreme (OC) and Malarkey Alaskan (MAL), had previously exhibited the ability to survive two hours of 130 mph winds using the ASTM D3161 test apparatus and setup. Similarly, the selected architectural shingles, CertainTeed Landmark (CT) and GAF Timberline HD (GAF), had previously exhibited the ability to resist 140 mph winds for two hours using this same test apparatus and setup. The ASTM D3161 test apparatus is shown in Figure 2. The Malarkey Alaskan shingle uses polymer-modified asphalt in the shingle while the other three shingles use oxidized asphalt.

Figure 2. IBHS Component Materials Evaluation Tester (COMET). This is a single-fan test apparatus that can test the wind performance of materials up to 170 mph. Panels are tested at 2:12 pitch and exposed to a steady speed wind for two-hour increments if they pass 60 mph and 90 mph 10-minute-long tests. Tests were performed when the temperature was 75°F +/- 10°.

All products were installed within six months of being manufactured. Products used for summer and winter installations came from different batches of shingles. For three of the manufacturers, summer- and winter-installed batches came from the same factory. Only the GAF batches of summer- and winter-installed shingles came from different factories. Summer-installed shingle panels were mounted on their support racks in July 2015, when the outdoor temperatures were 75°–85°F. These 40 panels were conditioned outside from July to October 2015 and the average of the maximum temperatures for the southern exposure panels reached about 190°F, while the average of the maximum temperatures for the northern exposure panels reached about 160°F. These temperatures were measured by thermocouples installed on a subset of the panels. Winter-installed shingle panels were mounted on their support racks during January 2016 when outdoor temperatures were 30°–40°F. These 40 panels were conditioned outside from January to June 2016 and the average of the maximum temperatures for both southern and northern exposure panels reached about 160°F. Biweekly observations were made to document when seals between shingles became tacky and shingles began to seal. This was accomplished by gently lifting on bottom edges of the shingles. The sealant became tacky for summer-installed shingles when the temperature of the shingles exceeded 140°F (the temperature normally used to set seals in a kiln or oven), about one day after they were mounted on the support racks. Sixteen of the winter-installed panels were tacky and sealed at the two-week mark (predominantly the Owens Corning Supreme and the GAF Timberline shingles); but, it took about 12 weeks before the sealant became tacky on all winter-installed shingle panels (CertainTeed Landmark took the longest to fully seal).

Results and Observations

Results obtained from the wind uplift tests of the 80 panels are listed in Table 1. The <60 values indicate that the panel failed before it could complete 10 minutes of 60 mph winds. A value of 60 mph indicates that it survived 10 minutes of 60 mph winds but failed before it could complete 10 minutes of 90 mph winds. Similarly, a value of 90 mph indicates that the panel survived 10 minutes of 90 mph winds but failed before it survived two hours of 110 mph winds. Values of 110 through 170 indicate that the panel survived two hours of winds at the indicated speed plus two hours of wind at every 10 mph increment between 110 mph and the indicated maximum value. Uplift wind speeds achieved for various panels are also presented graphically in Figure 3.

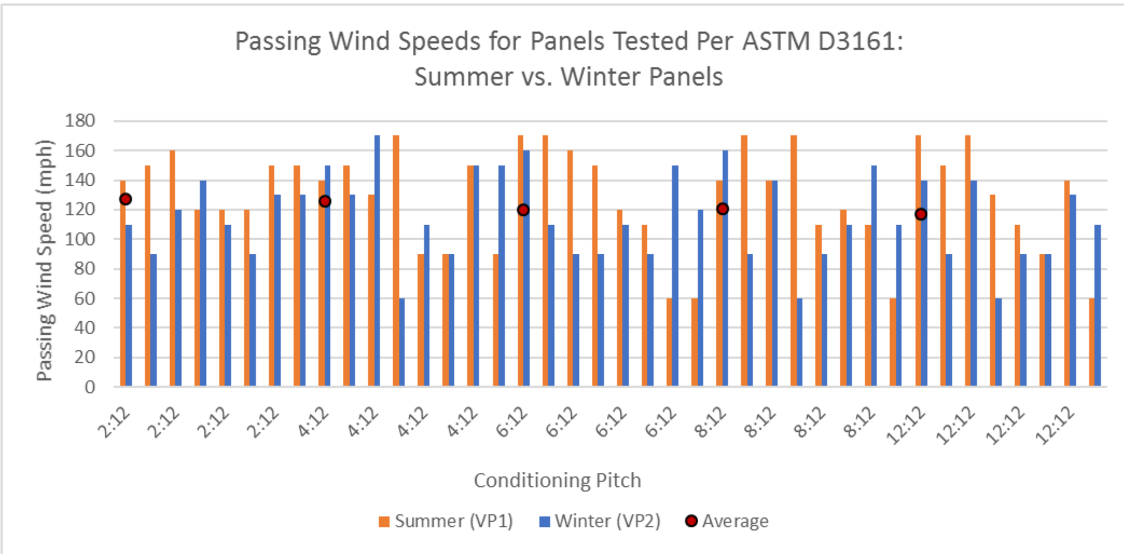

Figure 3. Comparison of passing wind speeds for all manufacturers for the summer-installed panels (orange) and the winter-installed panels (blue) by pitch. The red dots compare the averages for all panels conditioned at each pitch. The order of products for each slope is Owens Corning, Malarkey, CertainTeed, and GAF. Average values for all panels for each roof slope are: 2:12 – 127 mph; 4:12 – 126 mph; 6:12 – 120 mph; 8:12 – 121 mph; 12:12 – 117 mph.

Table 1. Maximum Wind Speeds Passed by the Indicated Product for the Indicated Slope, North or South Exposure, and Summer or Winter Installation

Manufacturer	Owens Corning	Malarkey	CertainTeed	GAF
Product Line	Supreme	Alaskan	Landmark	Timberline HD
Shingle Type	3-tab	3-tab	Architectural	Architectural
ASTM D3161 Wind Speed Achieved Without Shingle Failure (mph)				
Original IBHS ASTM D3161 Test Results	130	130	140	140

Summer Installation								
Panel Slope	South Face	North Face	South Face	North Face	South Face	North Face	South Face	North Face
2:12	140	150	160	120	120	120	150	150
4:12	140	150	130	170	90	90	150	90
6:12	170	170	160	150	120	110	<60	60
8:12	140	170	140	170	110	120	110	<60
12:12	170	150	170	130	110	90	140	<60
Average	152	158	152	148	110	106	<122	<84
Std. Deviation	16	11	16	23	12	15	>38	>39

Winter Installation								
Panel Slope	South Face	North Face	South Face	North Face	South Face	North Face	South Face	North Face
2:12	110	90	120	140	110	90	130	130
4:12	150	130	170	<60	110	90	150	150
6:12	160	110	90	90	110	90	150	120
8:12	160	90	140	60	90	110	150	110
12:12	140	90	140	<60	90	90	130	110
Average	144	102	132	<82	102	94	142	124
Std. Deviation	21	18	29	>35	11	9	11	17

Effect of Installation Slope

It is clear these limited results do not signal a dependence of wind performance on installation roof slope for the range of roof slopes selected. The difference in the average passing wind speed only varied from 127 mph at 2:12 slope to 117 mph at 12:12 slope, for a total difference of 10 mph, as indicated in Figure 3. The maximum variation in average passing wind speed from one slope to the next was only 6 mph, between the 4:12 and 6:12 slopes. As noted above, all panels were tested at 2:12 slope, so this finding is only relevant to the installation slope and additional testing would be needed to understand the effects of testing slope.

Effect of Installation Temperature and Exposure

From the limited results presented here, there is a signal suggesting a dependence on temperature at the time of installation and in the weeks and months following the installation, particularly for north-facing shingles. As noted earlier, shingles on south-facing summer-installed panels reached an average maximum temperature of about 190°F. In contrast, summer-installed north-facing shingles and both south- and north-facing winter-installed shingles reached an average maximum temperature of about 160°F. However, the amount of time these shingles experienced temperatures above 140°F was significantly different.

Maximum temperatures measured on the instrumented panels are shown in Figure 4 and duration of time when temperatures were above 140°F are presented in Figures 5 and 6. Variations in solar angle, panel angle, and shingle solar absorption characteristics contribute to the variability in maximum temperatures and durations measured. However, it is also clear that positioning and possible shifting of sensors also contributed to variability in results which were magnified in the duration calculations. Duration of temperature estimates for CT 2:12 N and MAL 12:12 S panels exhibit significant anomalies that are likely due to sensor positioning differences. South-facing summer-installed shingle panels experienced an average of 228 hours where shingle temperatures exceeded 140°F and the length of exposure was reasonably consistent regardless of slope. North-facing summer-installed shingle panels experienced an average of only 73 hours where temperatures exceeded 140°F and the length of time the shingles were exposed to these temperatures decreased to near zero with increasing roof slope. South-facing winter-installed shingle panels experienced an average of 165 hours where temperatures exceeded 140°F and the peak duration occurred for roof slopes between 6:12 and 12:12. North-facing winter-installed shingle panels experienced considerably less time at these temperatures with an average of only 37 hours where temperatures exceeded 140°F and numbers of hours decreased to near zero with increasing slope. Whether the winter-installed north-facing shingles would eventually achieve similar uplift resistance to the summer-installed north-facing shingles or even the winter-installed south-facing shingles remains unclear. Further research could be conducted to investigate this.

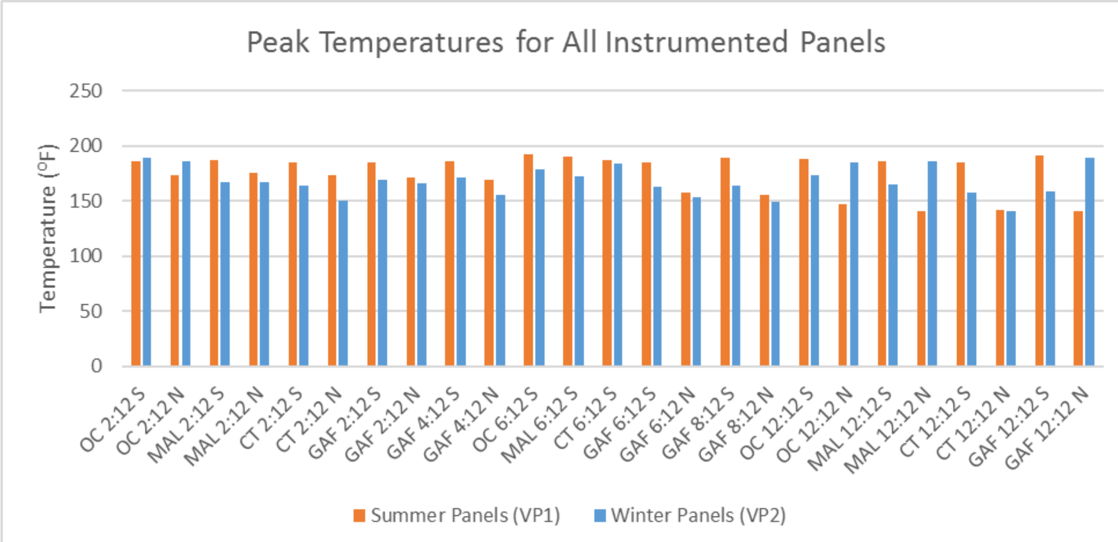

Figure 4. Maximum temperatures of summer and winter-installed south- and north-facing shingles. Labels on the X-axis indicate the manufacturer, slope and direction the panel was facing.

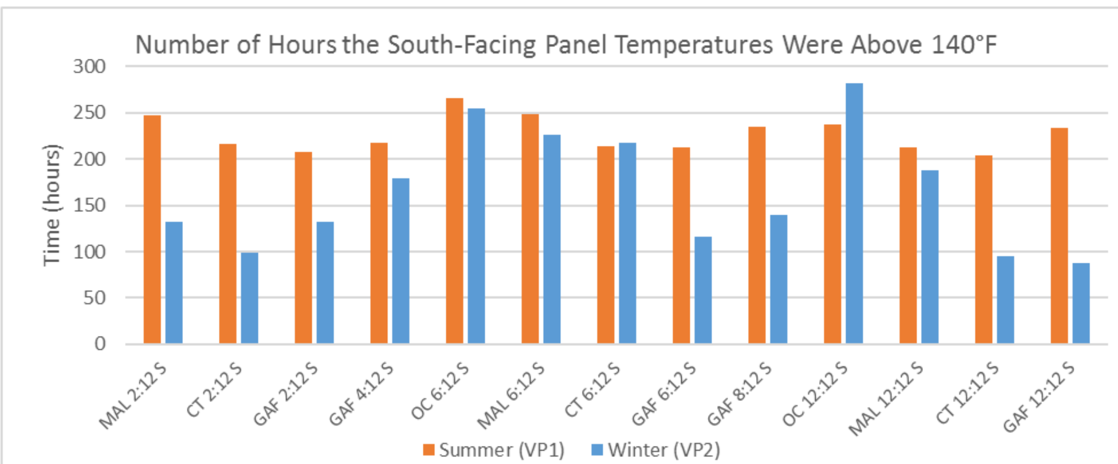

Figure 5. Time (hours) that the indicated south-facing instrumented panels experienced temperatures exceeding 140°F. Labels on the X-axis indicate the manufacturer, slope and direction the panel was facing. Sensors for OC 2:12 S panel malfunctioned and did not give accurate readings for this graph, and thus are not included.

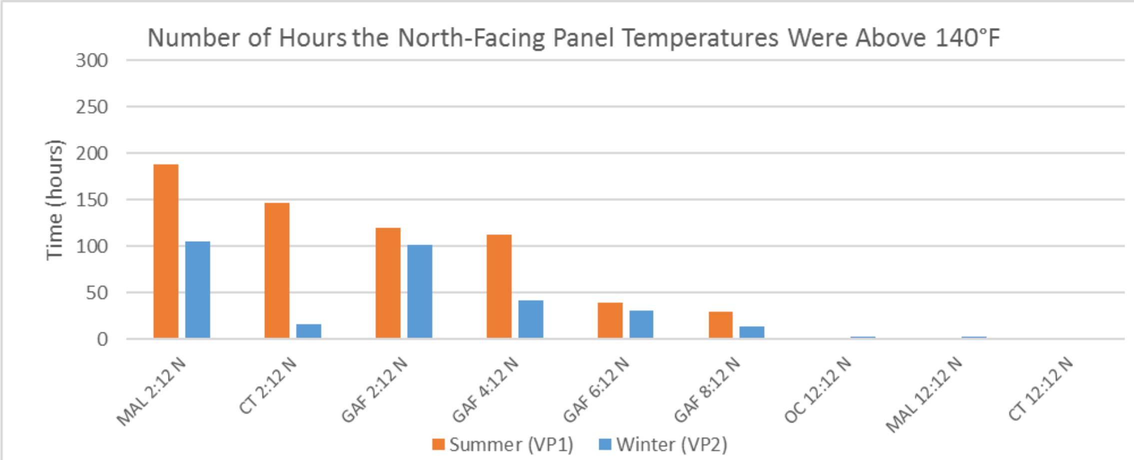

Figure 6. Time (hours) that the indicated north-facing instrumented panels experienced temperatures exceeding 140°F. Labels on the X-axis indicate the manufacturer, slope and direction the panel was facing. Sensors for OC 2:12 N and GAF 12:12 N panels malfunctioned and did not give accurate readings for this graph, and thus are not included.

Summary of Results by Shingle

It must be emphasized that even though 80 panels were tested, this exploratory investigation represents a very limited data set, with just a single replication of each condition and a limited number of batches of shingles and manufacturers. With that caveat in mind, the limited data available tend to support the following observations:

- Best summer installation performance was provided by the Owens Corning Supreme and Malarkey Alaskan 3-tab shingle panels. Average shingle uplift failure wind speeds were around 150 mph for both north- and south-facing panels. Scatter in results appears to be random and does not suggest a dependence on slope for the range of slopes tested.
- South-facing winter-installed Owens Corning Supreme shingles performed well with an average uplift failure wind speed over 140 mph. With one exception, the south-facing winter-installed Malarkey Alaskan shingle panels also performed well with an average uplift failure wind speed over 130 mph.
- North-facing winter-installed Owens Corning Supreme and Malarkey Alaskan shingles performed poorly with only three panels out of 10 achieving a failure wind speed of 110 mph or higher.
- Poorest overall performance was provided by the CertainTeed Landmark architectural shingles. Nine of 20 panels failed to pass the ASTM D3161 test with 110 mph winds blowing for two hours.
- GAF Timberline HD shingles exhibited poor summer installation results with four of 10 panels failing in either 60 mph or 90 mph 10-minute preliminary tests. In contrast, winter-installed panels performed quite well with all panels, north or south exposure, passing ASTM D3161 at 110 mph. This suggests that consistency between manufacturing plants may be a significant issue.

Results for this small sample of products should not be used as an indication that 3-tab shingles perform better than architectural shingles in wind tests. Earlier tests of naturally aged roofs indicated that the architectural shingles performed better than 3-tab shingles. These differences are yet another reminder that there is considerable variability in products from manufacturer to manufacturer, product line to product line, factory to factory, and batch to batch.

Conclusions

This pilot study with its limited number of samples, manufacturers, batches, and factory sources of products suggests the following:

- **Installation Slope:** The installation slope of the roof within the range 2:12 to 12:12 did not appear to influence the uplift resistance of the shingles (i.e., the strength of the seal did not change with respect to the slope of the installation).
- **Season and Exposure:** Shingles on winter-installed panels consistently exhibited lower wind uplift resistance than shingles on summer-installed panels. Winter-installed panels with a north-facing exposure exhibited the poorest overall wind uplift resistance. It is not clear whether the uplift resistance of the shingles on the winter-installed panels would have improved if these shingles had been allowed to experience a full summer of heating, and this is an area of potential future research. When shingles do not seal soon after installation, windborne debris and dust may significantly inhibit their ability to ultimately seal.
- **Factory-to-Factory and Batch-to-Batch Variability:** The largest difference in shingle panel performance, and one that was opposite of the trends exhibited by all other products, was exhibited by the GAF Timberline HD shingles. Summer- and winter-installed GAF shingles came from two different factories and winter-installed shingles performed much better than summer-installed shingles. Summer-installed shingles from the other three manufacturers all exhibited better wind uplift performance than the corresponding winter-installed shingles. Furthermore, the Owens Corning and Malarkey summer-installed shingles performed better on average than the original IBHS panel test results, while the CertainTeed and GAF summer-installed shingles performed much worse than expected based on original testing.
- **Implications for Real-World Roofing Practice:** The variability in observed results reinforces the importance of sealing the roof deck to help prevent interior damage when shingles are lost in a wind event.

Actionable Results and Next Steps

1. **Roof Slope:** While tools are being developed by various vendors that will be able to extract roof shape and slope, the data from this exploratory study do not suggest that roof slope will be a good indicator of relative wind performance of shingles. Unless the industry has loss data that indicates otherwise, IBHS should not pursue slope effects on shingle sealing any further.
2. **Installation Season:** It is highly unlikely that the insurance industry will be able to capture reliable data about when during the year asphalt shingles are installed unless permit data becomes much more uniformly required and recorded by local building departments. If there is an interest in more data on seasonal

performance, IBHS could conduct additional studies to determine whether longer exposure to high temperatures would close the gap between summer and winter installation performance. Dust and other environmental conditions that might further prevent sealing of products that do not begin to seal within a few days would be another potential issue to investigate.

3. **Product Variability:** These limited preliminary results suggest that considerable variability exists in performance of products; but, they also suggest that some products and factories may exhibit greater quality control (less variability) than others. This inherent variability will strongly influence real-world performance, and would have to be controlled or otherwise accounted for in any rating or modeling of shingle products.