IBHS Roof Aging Program

Data and Condition Summary for 2015

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Executive Summary

In 2013, the Insurance Institute for Business & Home Safety (IBHS) began a long-term roof aging program. This measurement and testing program seeks to understand and report how the wind, impact, and fire performance of various roof cover materials change with age and exposure to the natural environment.

This document provides:

- A brief description of the program, which currently includes asphalt shingle products at three project sites.
- Summary tables of maximum and minimum shingle temperatures experienced by roof specimens in 2015.
- Summary of the accumulated time spent above specific temperature thresholds during 2015.
- Examination of rapid temperature change events experienced by the roof specimens in 2015.
- Summary of visual inspections of all specimens.

1. Program Description

The IBHS roof aging program collects data on the conditions asphalt shingles experience in the natural environment and seeks to relate that data to product performance. An initial set of roof specimens was constructed at the IBHS Research Center in 2013, and will be subjected to testing at 5-year intervals beginning in early 2019. Additional specimens were added in 2014 and 2015, and testing on them is expected to begin in early 2020 and 2021, respectively. In addition, two smaller, remote sites were constructed in 2014 in Madison, Wisconsin, and Amelia, Ohio, using some of the same products as those installed at IBHS. These sites will become available for testing in late 2019. This long-term research program will allow IBHS to investigate the effect of different climate zones on material aging and performance. Along with roof temperature data, meteorological data, such as the environmental temperature, humidity, precipitation, and solar radiation, are being collected. Each roof is also being visually evaluated on an annual basis to determine if there are any changes in appearance or condition.

Within this project, test specimens were constructed as a "set," where each set included four separate roof specimens to be tested at different time intervals, up to 20 years in length. Individual test panels from each roof specimen will all be removed for testing at the same time, while the remaining roofs within the set will continue aging until their exposure interval is reached. All specimens at each of the three sites are oriented with roof surfaces facing north and south to examine differences resulting from incident solar radiation due to location (i.e., latitude) and weather-related factors. All products are of similar color to reduce influences due to material reflectance properties. Each specimen has the following characteristics:

Figure 1-1. Diagram of a roof specimen showing temperature probe measurement locations. Note that for specimens at the Madison (Wisconsin) and Amelia (Ohio) sites, temperature probes are located on the center panel of each roof face only.

- Each specimen structure (Figure 1-1) is a gable roof, 6/12 slope, with code-required ventilation, and is nominally 15 ft x 15 ft. The roof is enclosed on the sides and bottom to create an enclosed ventilated "attic."
- Roof products were selected based on type, manufacturer, market prevalence, and published standard test ratings.
- Each specimen features six removable panels—three north-facing panels and three south-facing panels:
    - Two each: 55- x 66-in. panels for use in ASTM D3161 and ASTM D7158 high wind tests, and FM 4473 and IBHS impact tests.
    - One each: 36- x 36-in. panel for use in UL 2218 impact tests.
    - Excess shingles around the panels will be used for materials testing.

Table 1-1 lists the product types deployed at the IBHS site. Table 1-2 provides product types for the Madison and Amelia sites.

The specimens at the IBHS Research Center are instrumented with multiple temperature sensors (Type K thermocouples) on each roof face. For each embedded test panel, temperature sensors are located in the center of the panel between shingle courses to measure the shingle temperature, and between the underlayment and roof deck (2013 specimens also have sensors located between the shingles and the underlayment). In addition to the test panel temperature sensors, the 20-year IBHS specimens have an array of sensors across the entire roof face. Temperature and relative humidity measurements are made in the attic space of select IBHS specimens. At the Amelia and Madison sites, shingle and roof deck temperature measurements are made on the center panel of each roof face. For more detailed information on the specimen design and instrumentation, please see the detailed technical report completed in 2015 at DisasterSafety.org/wp-content/uploads/2015/12/aging-farm-climate-summary-2015_ibhs.pdf.

Table 1-1. Types of products currently deployed on the IBHS roof aging farm site.

Specimen Identification	Product Class
2013-IBHS-A	Architectural
2013-IBHS-B	Polymer-Modified Impact-Resistant Architectural
2013-IBHS-C	Architectural
2013-IBHS-D	Architectural
2013-IBHS-E	3-Tab
2013-IBHS-F	3-Tab
2014-IBHS-A	Polymer-Modified Impact-Resistant Architectural
2014-IBHS-B	Traditional Impact-Resistant Architectural
2014-IBHS-C	Traditional Impact-Resistant Architectural
2015-IBHS-A	Architectural
2015-IBHS-B	Architectural
2015-IBHS-C	Traditional Impact-Resistant Architectural
2015-IBHS-D	3-Tab
2015-IBHS-E	Traditional Impact-Resistant Architectural
2015-IBHS-F	Polymer-Modified Impact-Resistant Architectural

Table 1-2. Types of products currently deployed on the Madison and Amelia roof aging farm sites. The matching specimens on the IBHS farm are the A-D products installed in 2013.

Specimen Identification	IBHS Match	Product Class
2014-AmFam-A	2013-A	Architectural
2014-AmFam-B	2013-B	Polymer-Modified Impact-Resistant Architectural
2014-AmFam-C	2013-C	Architectural
2014-AmMod-D	2013-D	Architectural

2. Data Summary

The data collected on the 20-year specimens from each of the three roof aging farm sites were used to produce summary statistics for yearly maximum and minimum temperature for each roof face; total hours above specified temperature thresholds; and number of temperature fluctuation events experienced during the year. For maximum and minimum temperatures, the values represent the observation from the center panel shingle thermocouple sensor on the north and south roof faces for all three sites. A spatial average over each roof face was used for the IBHS specimens for the accumulated hours above different temperature thresholds, to show approximately how long the entire roof face was above the specified thresholds. During 2015, the Amelia site suffered a data interruption that resulted in partial data loss from April–June.

2.1 Maximum and minimum shingle temperatures in 2015

The absolute maximum shingle temperatures during the course of a year are primarily driven by the amount of incoming solar radiation reaching and being absorbed by the roof specimens. Differences in peak roof temperatures are also related to the color of individual products and its influence on radiative absorption. Roofs at different slopes, different orientations, and of different color variations than those in the aging farms would exhibit differences compared to the observations presented here. Included in the long term goals of the study are pilot projects to quantify the effects of some of these differences, but the results to date include those for 6/12 roofs with similar color shingles facing north or south.

Observations of peak shingle temperatures are summarized in Table (2-1). It is possible that the maximum temperature at the Amelia site may have occurred in June when the data acquisition system was inoperable. The following observations of peak temperatures were found in the data collected in 2015:

- North-facing roof slopes:
    - Maximum shingle temperatures of 180°–190°F for the IBHS site. Maximum shingle temperatures were lower at the Madison and Amelia locations owing to their higher latitude.
    - Maximum temperatures at the IBHS site occurred in June. Maximum shingle temperatures occurred in July at the higher latitude sites in Amelia and Madison (Table 2-1A).
- South-facing roof slopes:
    - Maximum temperatures exceeded 200°F for four out of nine IBHS 20-year specimens and all 20-year Madison specimens. The Amelia specimens did not reach 200°F (possible this may have occurred during May and/or June when data were not available).
    - Maximum shingle temperatures occurred in September for IBHS specimens. Maximum shingle temperatures occurred in August for the Amelia and Madison specimens.

Some general observations included:

- In general, daily minimum shingle temperatures converge toward the overnight low environmental temperature.
- The absolute minimum temperatures for 2015 generally occurred in either December or January at the IBHS site.
- More recently installed products at the IBHS site retained slightly higher minimum temperatures.
- Only one 20-year specimen experienced its minimum temperature in November and February (Table 2-1).
- The Amelia and Madison sites experienced their minimum temperatures in January.

Table 2-1. (A) North face and (B) south face maximum and minimum shingle temperatures at the center panel shingle-mounted thermocouple probe for 20-year specimens during 2015.

A.

Specimen	Location	Roof Face Orientation	Max Temp (°F)	Max Temp Month	Min Temp (°F)	Min Temp Month
2013-A-IBHS	Richburg, SC	North	183.7	June	16.2	January
2013-B-IBHS	Richburg, SC	North	180.2	June	18.7	January
2013-C-IBHS	Richburg, SC	North	183.3	June	17.1	December
2013-D-IBHS	Richburg, SC	North	177.9	June	17.8	December
2013-E-IBHS	Richburg, SC	North	184.4	June	17.8	December
2013-F-IBHS	Richburg, SC	North	170.4	June	19.2	December
2014-A-IBHS	Richburg, SC	North	190.7	June	22.8	January
2014-B-IBHS	Richburg, SC	North	185.7	June	21.6	January
2014-C-IBHS	Richburg, SC	North	183.0	June	25.5	January
2014-A-AmFam	Madison, WI	North	129.4	July	8.5	January
2014-B-AmFam	Madison, WI	North	125.7	July	8.7	January
2014-C-AmFam	Madison, WI	North	134.4	July	8.2	January
*2014-D-AmMod	Amelia, OH	North	139.8	July	15.4	January

B.

Specimen	Location	Roof Face Orientation	Max Temp (°F)	Max Temp Month	Min Temp (°F)	Min Temp Month
2013-A-IBHS	Richburg, SC	South	193.4	September	17.2	December
2013-B-IBHS	Richburg, SC	South	191.7	September	19.3	November
2013-C-IBHS	Richburg, SC	South	200.8	September	17.6	December
2013-D-IBHS	Richburg, SC	South	194.4	September	18.3	December
2013-E-IBHS	Richburg, SC	South	204.8	September	12.2	February
2013-F-IBHS	Richburg, SC	South	189.7	September	19.4	December
2014-A-IBHS	Richburg, SC	South	211.0	September	21.5	January
2014-B-IBHS	Richburg, SC	South	206.2	September	21.0	January
2014-C-IBHS	Richburg, SC	South	198.3	September	24.2	January
2014-A-AmFam	Madison, WI	South	200.8	August	7.8	January
2014-B-AmFam	Madison, WI	South	202.4	August	8.2	January
2014-C-AmFam	Madison, WI	South	208.6	August	8.0	January
*2014-D-AmMod	Amelia, OH	South	179.2	August	15.1	January

**Partial data for April and June; missing data for May*

2.2 Temperature thresholds

Shingle temperatures at the three sites were compared to different thresholds to examine the accumulated time the roof faces spent above these values. Five high temperature thresholds were selected to guide research efforts focused on simulating and accelerating the effects of natural weathering on roofing products: 100°, 120°, 140°, 160° and 180°F. The accumulated time the north and south faces of each 20-year specimen spent above these values is shown in Table 2-2. The following observations were made:

- The IBHS specimens accumulated more time above each temperature threshold than the higher latitude sites.
- North-facing roof slopes at the Madison and Amelia sites struggled to reach 140°F.
- South-facing roof slopes readily exceeded 140°F during much of the year and exceeded 180°F at times.

Table 2-2. (A) North face and (B) south face total duration above the specified temperatures in 2015. For IBHS specimens, duration was determined using a spatial average of temperatures from all thermocouple probes on each roof face. Durations are rounded to the nearest hour.

A.

Specimen	Location	Roof Face Orientation	> 100°F (hrs)	> 120°F (hrs)	> 140°F (hrs)	> 160°F (hrs)	> 180°F (hrs)
2013-A-IBHS	Richburg, SC	North	1835	1212	665	221	5
2013-B-IBHS	Richburg, SC	North	1797	1158	609	168	1
2013-C-IBHS	Richburg, SC	North	1893	1234	677	221	5
2013-D-IBHS	Richburg, SC	North	1842	1159	601	157	0
2013-E-IBHS	Richburg, SC	North	2058	1318	772	271	8
2013-F-IBHS	Richburg, SC	North	1612	946	421	61	0
2014-A-IBHS	Richburg, SC	North	2340	1536	939	414	23
2014-B-IBHS	Richburg, SC	North	2241	1444	843	318	21
2014-C-IBHS	Richburg, SC	North	2043	1314	728	236	7
2014-A-AmFam	Madison, WI	North	625	144	12	1	0
2014-B-AmFam	Madison, WI	North	596	127	3	0	0
2014-C-AmFam	Madison, WI	North	816	180	20	2	0
*2014-D-AmMod	Amelia, OH	North	581	269	34	0	0

B.

Specimen	Location	Roof Face Orientation	> 100°F (hrs)	> 120°F (hrs)	> 140°F (hrs)	> 160°F (hrs)	> 180°F (hrs)
2013-A-IBHS	Richburg, SC	South	2261	1598	995	459	81
2013-B-IBHS	Richburg, SC	South	2194	1515	909	375	46
2013-C-IBHS	Richburg, SC	South	2306	1640	1049	518	130
2013-D-IBHS	Richburg, SC	South	2219	1568	970	437	69
2013-E-IBHS	Richburg, SC	South	2635	1848	1196	627	172
2013-F-IBHS	Richburg, SC	South	2026	1385	801	285	16
2014-A-IBHS	Richburg, SC	South	2746	1991	1365	802	301
2014-B-IBHS	Richburg, SC	South	2656	1906	1263	694	219
2014-C-IBHS	Richburg, SC	South	2458	1734	1080	539	131
2014-A-AmFam	Madison, WI	South	1971	1120	418	118	3
2014-B-AmFam	Madison, WI	South	1483	781	152	24	0
2014-C-AmFam	Madison, WI	South	2208	1231	185	59	1
*2014-D-AmMod	Amelia, OH	South	1023	663	351	91	0

**Partial data for April and June; missing data for May*

The amount of time specimens spent at sub-freezing temperatures was also examined (Table 2-3).

- The Madison specimens spent nearly 500 more hours below freezing than the Amelia or IBHS specimens.
- Differences in number of hours below freezing between north and south roof faces were typically between 100–200 hours for IBHS specimens but not as large for the Madison and Amelia roofs.

Table 2-3. (A) North face and (B) south face total hours at or below 32°F in 2015. Durations are rounded to the nearest hour.

A.

Specimen	Location	Roof Face Orientation	T ≤ 32°F (hrs)
2013-A-IBHS	Richburg, SC	North	540
2013-B-IBHS	Richburg, SC	North	486
2013-C-IBHS	Richburg, SC	North	451
2013-D-IBHS	Richburg, SC	North	426
2013-E-IBHS	Richburg, SC	North	585
2013-F-IBHS	Richburg, SC	North	434
2014-A-IBHS	Richburg, SC	North	360
2014-B-IBHS	Richburg, SC	North	388
2014-C-IBHS	Richburg, SC	North	324
2014-A-AmFam	Madison, WI	North	986
2014-B-AmFam	Madison, WI	North	1019
2014-C-AmFam	Madison, WI	North	946
*2014-D-AmMod	Amelia, OH	North	539

B.

Specimen	Location	Roof Face Orientation	T ≤ 32°F (hrs)
2013-A-IBHS	Richburg, SC	South	396
2013-B-IBHS	Richburg, SC	South	368
2013-C-IBHS	Richburg, SC	South	302
2013-D-IBHS	Richburg, SC	South	303
2013-E-IBHS	Richburg, SC	South	292
2013-F-IBHS	Richburg, SC	South	281
2014-A-IBHS	Richburg, SC	South	219
2014-B-IBHS	Richburg, SC	South	203
2014-C-IBHS	Richburg, SC	South	207
2014-A-AmFam	Madison, WI	South	953
2014-B-AmFam	Madison, WI	South	992
2014-C-AmFam	Madison, WI	South	906
*2014-D-AmMod	Amelia, OH	South	489

**Partial data for April and June; missing data for May*

2.3 Temperature fluctuations and shock events

Data collected from the IBHS aging specimens in 2014 revealed that shingle material temperatures can fluctuate by 10°–20°F between two 5-minute observation periods as a result of passing cloud cover. Precipitation, especially during the warm season (April–September), was found to produce larger temperature variations. In the most extreme cases, the shingle temperature fell more than 50°F between consecutive 5-minute observations. The specimen temperature data were used to evaluate the occurrence of these rapid temperature decreases using thresholds of 10°, 25°, 45° and 60°F temperature decreases between two 5-minute observations. For IBHS specimens, a spatial average across each roof face was calculated for each 5-minute observation. Thus more localized temperature departures may have exceeded the thresholds used here. Table 2-4 provides the total number of large fluctuation events observed during 2015 and the results from data showed:

- Most temperature decreases of 10°F or greater (approximately 90%) were not associated with any measureable precipitation (≥ 0.01 in.).
- Temperature decreases of more than 45°F between 5-minute observations were approximately 2% of identified events. Precipitation was recorded within 10 minutes of each of these cases.
- For decreases more than 60°F, precipitation occurred within five minutes of the event.
- Events with a temperature decrease of 60°F or larger were only found in April–September.
- The south-facing roof slopes experienced a slightly larger number of temperature decreases that exceeded 45°F, likely due to their higher initial temperatures.
- Rapid increases have also been observed if precipitation and/or cloud cover did not persist.

Table 2-4. (A) North face and (B) south face total number of identified temperature fluctuation events in 2015. Events are defined as a temperature decrease of 10°, 25°, 45°, or 60°F between two consecutive 5-minute observations. For IBHS specimens, the temperature decrease is determined from the spatial average across each roof face for each 5-minute observation.

A.

Specimen	Location	Roof Face Orientation	ΔT > 10°F	ΔT > 25°F	ΔT > 45°F	ΔT > 60°F
2013-A-IBHS	Richburg, SC	North	1424	314	13	1
2013-B-IBHS	Richburg, SC	North	1010	136	8	1
2013-C-IBHS	Richburg, SC	North	1366	288	23	5
2013-D-IBHS	Richburg, SC	North	838	88	15	2
2013-E-IBHS	Richburg, SC	North	1328	84	19	9
2013-F-IBHS	Richburg, SC	North	1153	149	11	1
2014-A-IBHS	Richburg, SC	North	845	72	13	1
2014-B-IBHS	Richburg, SC	North	913	105	26	4
2014-C-IBHS	Richburg, SC	North	806	92	20	1
2014-A-AmFam	Madison, WI	North	1153	149	11	1
2014-B-AmFam	Madison, WI	North	913	105	26	4
2014-C-AmFam	Madison, WI	North	806	92	20	1
*2014-D-AmMod	Amelia, OH	North	1055	121	8	1

B.

Specimen	Location	Roof Face Orientation	ΔT > 10°F	ΔT > 25°F	ΔT > 45°F	ΔT > 60°F
2013-A-IBHS	Richburg, SC	South	1635	321	17	4
2013-B-IBHS	Richburg, SC	South	1419	232	8	3
2013-C-IBHS	Richburg, SC	South	2092	490	29	9
2013-D-IBHS	Richburg, SC	South	2062	483	21	4
2013-E-IBHS	Richburg, SC	South	1941	429	32	9
2013-F-IBHS	Richburg, SC	South	1804	322	14	3
2014-A-IBHS	Richburg, SC	South	1180	190	21	4
2014-B-IBHS	Richburg, SC	South	1622	276	35	13
2014-C-IBHS	Richburg, SC	South	1982	521	26	7
2014-A-AmFam	Madison, WI	South	1424	307	13	5
2014-B-AmFam	Madison, WI	South	1366	287	23	5
2014-C-AmFam	Madison, WI	South	1310	146	31	7
*2014-D-AmMod	Amelia, OH	South	1208	135	11	1

**Partial data for April and June; missing data for May*

3. Roof Condition Inspections

Visual inspections of each roof at the IBHS site were conducted in October 2015; inspections were conducted in Amelia in late November and in Madison in early December. Both the north and south faces of the four specimens in each product set were visually examined and locations of unsealing, nail pops or exposed fasteners, granule loss, blistering, foot traffic scuffs, uneven substrates, and other types of vulnerabilities were documented and will be monitored each year. These conditions may have been widespread across entire roof faces, or limited to small areas on an individual roof face. New areas of interest will be added to the database each year as they appear and trends will be monitored. Some general patterns observed on the IBHS site, by product, are listed in Table 3-1. General patterns, by product, as observed in Madison and Amelia are list in Table 3-2.

Table 3-1. Roof condition visual evaluation patterns. Observations modes are identified by color codes to allow for quick comparisons between products. These represent common patterns and other conditions may be present on individual roof faces.

Roof Set	Condition Description	North Faces Affected	South Faces Affected
2013-A-IBHS	Loss of granules exposing mat	4/4	2/4
2013-B-IBHS	Loss of granules generally around edges of shingles		2/4
	Loss of granules exposing mat	2/4	1/4
2013-C-IBHS	Loss of granules exposing mat	2/4	2/4
	Loss of granules due to blistering	2/4	2/4
	Lumps and unevenness of shingles	2/4	4/4
2013-D-IBHS	Loss of granules generally around edges of shingles	4/4	3/4
	Lumps and unevenness of shingles	1/4	2/4
	Fasteners beginning to back out	2/4	1/4
2013-E-IBHS	Loss of granules generally around edges of shingles	2/4	4/4
	Loss of granules exposing mat	4/4	4/4
	Fasteners beginning to back out		3/4
2013-F-IBHS	Loss of granules generally around edges of shingles	1/4	4/4
	Fasteners beginning to back out	2/4	1/4
2014-A-IBHS	Loss of granules generally around edges of shingles		2/4
	Lumps and unevenness of shingles	3/4	3/4
2014-B-IBHS	Loss of granules exposing mat	4/4	4/4
2014-C-IBHS	Loss of granules generally around edges of shingles	2/4	4/4
	Loss of granules exposing mat	1/4	3/4
	Loss of granules due to blistering	3/4	
	Lumps and unevenness of shingles	1/4	2/4

Table 3-2. Roof condition visual evaluation patterns. Observations modes are identified by color codes to allow for quick comparisons between products. These represent common patterns and other conditions may be present on individual roof faces.

Roof Set	Condition Description	North Faces Affected	South Faces Affected
2014-A-AmFam	Loss of granules generally around edges of shingles	2/4	3/4
	Loss of granules exposing mat		2/4
	Loss of granules due to blistering	2/4	1/4
	Grease, solvent drippings		2/4
2014-B-AmFam	Loss of granules generally around edges of shingles	4/4	3/4
	Lumps and unevenness of shingles		2/4
	Holes in shingles that do not extend to underlayment	2/4	2/4
	Fasteners beginning to back out		3/4
2014-C-AmFam	Loss of granules exposing mat	2/4	2/4
	Lumps and unevenness of shingles	3/4	3/4
	Unsealed shingles	3/4	3/4
	Fasteners beginning to back out	2/4	2/4
2014-D-AmMod	Loss of granules generally around edges of shingles	2/4	4/4
	Loss of granules due to blistering	3/4	
	Fasteners beginning to back out	1/4	2/4
	Grease, solvent drippings	1/4	2/4

Based on these observations, granule loss patterns will be important to monitor over the long-term life of the project to determine if shingle manufacturer, color, location, and/or roof direction have a larger role. Some initial trends indicate that some shingle brands may have more widespread granule loss and an increased likelihood of lumps and unevenness in the shingles.

4. Summary

The in-situ instrumentation deployed on specimens at the three roof aging sites have enabled a detailed look into conditions experienced by the asphalt shingles. This information will help guide ongoing IBHS research into simulating these conditions in a lab environment. The data will also provide guidance in developing best practices to help mitigate potential vulnerabilities associated with installation. Data summaries will be compiled each year, providing an overview of the conditions experienced by the roof specimens. A more detailed analysis study will be conducted when the first group of specimens are ready for testing, and will examine the annual variability in the conditions experienced over the previous exposure time period. The data and visual inspection information will be compared to performance test results to determine trends.