

Hail Damage to Shingles

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INTRODUCTION

The following article is the first in a series of three addressing hail damage to shingles. The article provides an overview of the history of shingle system testing and is a preface to the second and third articles, which address actual hail data and the future of shingle hail testing. The Roof Consultants Institute has sponsored the second phase of testing. A technical paper will be delivered in Dallas at the 1998 RCI Convention and Symposium addressing the test protocol and results.

THE TWO MOST COMMON CAUSES OF weather damage to asphalt composition shingles are wind and hail. Research and development work first carried out in the 1950s addressed the former with the development and implementation of the sealing strip, a heat activated adhesive strip placed adjacent to the nail line that bonds the overlapping shingle to the base shingle layer close to the point of mechanical attachment. Shingle manufacturers quickly adopted this advance in wind-resistant shingle design and, in turn, the number of wind-damaged shingle installations was reduced.

In the late 1960s, a wind resistance test was developed to document the performance of asphalt shingles with an adhesive strip. The test subjects a "conditioned" shingle assembly to forced air blown at 60 miles per hour (97 kph) from a 36" x 12" opening for a period of two hours or until failure. The American Society of Testing and Materials (ASTM) adopted the test protocol in 1972 under the designation D 3161¹. Thereafter, Underwriters Laboratories adopted the test protocol, under the designation UL 997², as part of the requirements for shingle system classification. Shingles are typically warranted to resist wind gusts of up to 60 miles per hour (97 kph).

Development of more wind resistant shingles has been ongoing. Very few shingles tested under the ASTM protocol have passed at wind speeds in excess of 60 miles per hour. Testing to elevated wind speeds, as discussed below, has resulted in further UL classifications under the Prepared Roof Covering Materials (TFWZ) section in the 1997 UL Roofing Materials and Systems Guide.³

After Hurricane Andrew, which struck South Florida in

1992, the South Florida Building Code established two new wind related requirements for asphalt shingle systems.

Metro-Dade County Protocol PA 100⁴ subjects a large (10 ft. x 10 ft.) shingle assembly to wind forces in combination with simulated wind-driven rain. Forced air is blown at the test specimen at incrementally increased wind speeds during a simulated rainstorm.

Metro-Dade County Roofing Protocol PA 107⁵ subjects a "conditioned" shingle assembly to a maximum wind speed of 110 miles per hour (180 kph) for a period of two hours or until failure. The protocol is based on ASTM D 3161 / UL 997, with an elevated wind speed requirement. As a result, the 1997 UL Roofing Materials and Systems Directory includes six shingle systems classified to wind speeds in excess of 60 miles per hour (97 kph). Wind speed classifications range from 90 to 110 miles per hour (145 to 180 kph).

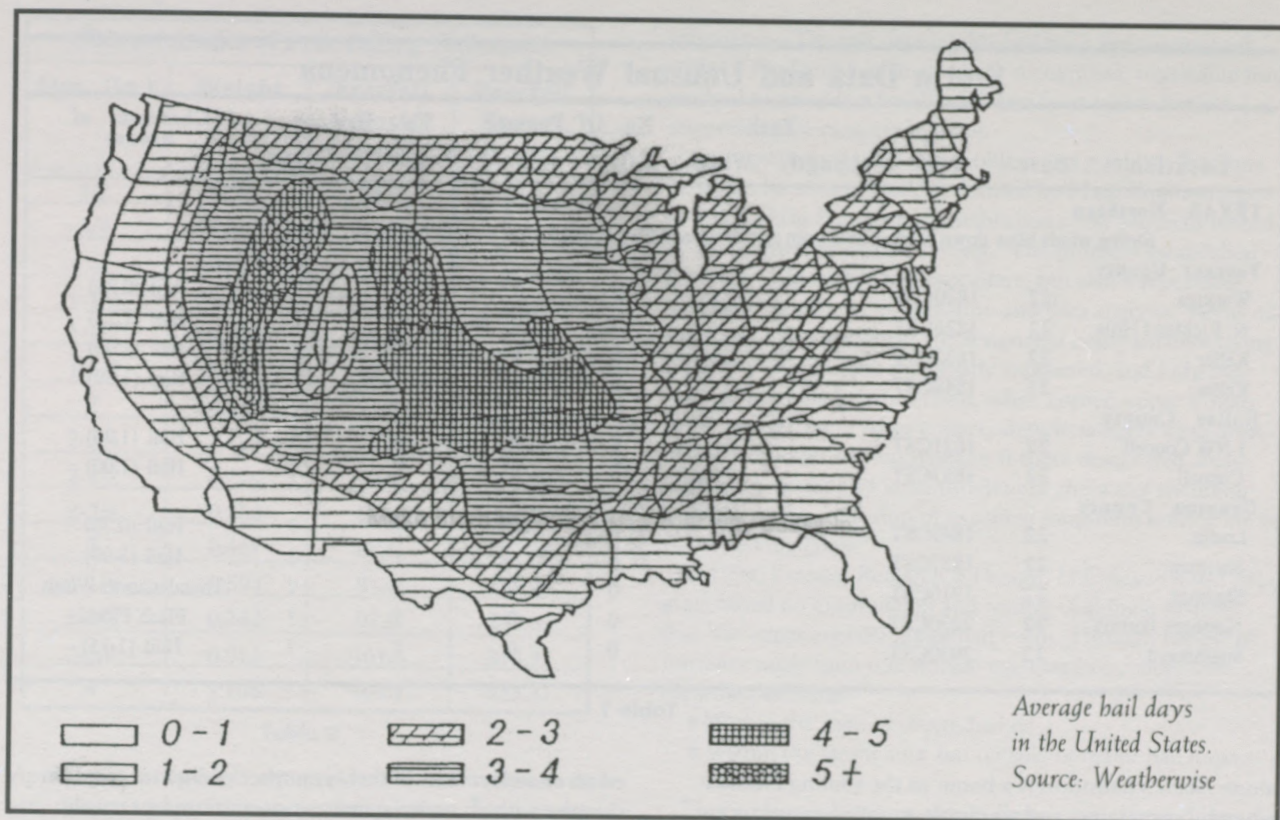
The South Florida Building Code also requires that shingles marketed within the Metro-Dade jurisdiction comply with the physical property requirements of ASTM D 3462⁶. As a result, some manufacturers have increased mat weights to meet these requirements.

Initially, only shingles that successfully passed at elevated wind speeds were submitted for physical property testing. Within one year of the test requirement, most shingle manufacturers reformulated/redesigned their shingles to meet the new requirements; however, the manufacturers' wind warranties have remained at 60 miles per hour for the great majority of asphalt composition shingles.

Research on both shingle products and associated test methods is ongoing today. The most prominent is a multi-year project sponsored by the Asphalt Roofing Manufacturers Association (ARMA) at the University of Colorado.⁷ The project is multi-phased, first addressing the effects of wind on shingle assemblies, and eventually, addressing a new test criteria for wind resistance of discontinuous roof assemblies.

Prior to 1992, the only shingle offering a 100 mile per hour (161 kph) wind warranty was Herbert Malarkey Roofing Company's modified bitumen "Hurricane" shingle. While today there are six shingle systems that are UL classified to wind speeds in excess of 60 miles per hour (97 kph), only two of the six offer a wind warranty in excess thereof. Shingle damage resulting from wind speeds in excess of 60 miles per hour has been, and continues to be, considered an insurable event.

In contrast to the industry-wide research and development



dedicated to wind resistance, hail resistance in shingles has, until the early part of this decade, received far less attention. While limited hail testing of steep slope products has been carried out over the last four decades, testing has followed no common procedure. Therefore, data from one program cannot be compared to that from another. Moreover, no test standard for hail or impact resistance has been developed or adopted by United States building code agencies or ASTM.

Hail has been considered an act of nature and, therefore, an insurable event, regardless of storm intensity. Consequently, the cost to insurers for hail-related damage has been significant. This has resulted in the insurance industry taking a leading role in the development and implementation of a hail test standard. In recent months, the Texas State Insurance Commission has petitioned for the adoption of a new hail test and mandatory homeowner credits for the use of sloped roofing products that have been tested to be "hail resistant."

Hail is a weather event that occurs most frequently and at its highest severity within a small area of the United States: east of the Rockies and west of the Mississippi River. The most severe hail areas cover approximately 8% of the United States. A larger, moderate hail area includes approximately 80% of the United States, with 90% of the United States experiencing some sort of hail event annually (See map, above.)

Hailstones form when moisture in a thunderstorm is held in the upper atmosphere between currents of rising air (updrafts) and currents of descending air (downdrafts). Hailstones vary in size, dependent on the magnitude of the

updraft versus that of the downdraft. Larger hailstones form if held in the atmosphere for a longer period of time. Moreover, because hailstones are composed of frozen water and encapsulated air, the density and shape of hailstones will vary.

Hailstorms are generally contained within a relatively small area, moving quickly within a confined path, making it difficult to detect, follow and quantify the severity of a storm. While new radar systems are capable of detecting and quantifying hail events, the technology is relatively new and human observation, with its inherent limitations, remains the primary source of data gathering. Hail data are gathered and reported to the Severe Storm Center of the National Weather Service. Data are recorded after each observation in monthly tallies. See *Table 1*.

Hail damage is not limited to roof damage. Damage to automobiles, livestock and crops contributes to the billions of insurance dollars paid each year to compensate for hail damage. Hail has also been a cause of loss of human life in rare instances. The extent and magnitude of damage caused by a hailstorm are dependent, in part, on the size and density of hailstones dropped by the storm. Larger and/or more dense hailstones incur greater impact energy on the object(s) being struck (See *Table 2*).

Moreover, the population density, storm intensity and storm duration have a significant impact on the extent and magnitude of damage incurred.

While hailstorms have been primarily viewed as an unusual, insurable weather event, a major hail event in an urban area can result in hundreds of millions of dollars in roof damage

Storm Data and Unusual Weather Phenomena

Location	Date	Time	Path		No. Of Persons		Est. Damage		Character of Storm
			Length	Width	Killed	Injured	Property	Crops	
TEXAS, Northern									
Strong winds blew down several trees onto power lines at Center and 1 mile west of Center.									
Tarrant County									
Watauga	22	1820CST			0	0	?	?	Hail (0.88)
N. Richland Hills	22	1826CST			0	0	?	?	Hail (1.25)
Keller	22	1832CST			0	0	?	?	Hail (1.00)
Keller	22	1848CST			0	0	?	?	Hail (1.50)
Dallas County									
1 NW Coppell	22	1831CST			0	0	?	?	Hail (1.75)
Coppell	22	1837CST			0	0	?	?	Hail (1.00)
Grayson County									
Luella	22	1849CST			0	0	?	?	Hail (0.75)
Sherman	22	1857CST			0	0	?	?	Hail (3.00)
Sherman	22	1910CST			0	0	?	?	Thunderstorm Winds
Northern Portion	22	2230CST			0	0	?	?	Flash Flood
Southmayd	22	2030CST			0	0	?	?	Hail (1.75)

Table 1

alone. Such a hailstorm is a boom to the roofing industry, whereby contractors and wholesale suppliers travel to a stricken area to participate in the insurance-financed reroofing bonanza. Product shortages due to the resultant surge in demand increase prices within a wide region. Inexperienced installers and insurance defrauders add to the overall costs and the difficulty in providing quality roof replacements.

In short, hail events provide localized demand for new steep sloped roofs, increasing the sale of products and installation labor. The cost of the reroofing is primarily borne by the insurance industry. There is little incentive within the roofing industry to reduce the demand for its products and services. In contrast, there is a great incentive on the part of the insurance industry to reduce damage during a hail event.

Comprehensive hail studies began in the 1960s when Sidney H. Greenfeld published findings of a hail test program intended to replicate damage incurred on a shingle assembly when installed over various substrates. The test program, which was sponsored by the United States Department of Commerce, simulated hail impact through the use of a "hail gun" that shot ice pellets at test specimens at a predetermined velocity. After impact, the shingle was visually examined and categorized as severe or superficial damage, as noted below.

- ▼ Superficial: Damage with no loss of weather-proofing capabilities
- ▼ Severe: Penetration of the shingle

The Greenfeld test program examined a variety of substrates, including shingles installed over 3/8 inch and 1/2 inch thick plywood and 1 inch x 6 inch tongue-and-groove decking, with and without an underlayment.

Data from the Greenfeld test program indicated that a shingle's hail resistance decreased when the assembly includ-

ed an underlayment. In theory, impact energy incurred on shingles with an underlayment was transferred to tensile loading within the shingle, which the organic mat shingles of the time were not able to absorb. To that end, comparative testing of organic shingles versus "new" fiberglass mat shingles provided data indicating those with a fiberglass mat had greater hail resistance. Lastly, testing of shingles and built-up roofing assemblies performed better on a more rigid substrate than on lighter, less rigid substrates.

In 1978, ASTM published Test Method D 3746⁹ in which steel missiles are fired at test specimens to simulate the impact energy incurred by a falling hail stone. The method has been used to test a variety of roof covers for impact resistance.

During the 1970s, the majority of shingles produced were of a fiberglass mat. In 1983, ASTM published Test Specification D 3462. The ASTM specification established minimum physical properties for fiberglass mat shingles; however, the document makes no reference to minimum hail resistance criteria. Moreover, system designers and industry members have made little to no change to the underlayments and decking materials over which shingles are installed, a variable clearly established as critical in the Greenfeld report.

In contrast to what appeared to be a blind eye view of hail resistance for steep slope roofing products, hail test standards and minimum requirements were developed and instituted for low slope roof systems. In 1986, Factory Mutual Research Corporation (FMRC) amended its Test Standard 4470¹⁰ to include a hail resistance test requirement for FM Approved Class 1 roof covers. The test standard was revised in 1992 to include moderate and severe hail designations (Class 1-MH and Class 1-SH, respectively). The hail test prescribes the use of a steel ball dropped onto various locations of the test specimen from a predetermined height. For a moderate hail

Characteristics of Free-falling Hailstones			
Size (in.)	Weight (lbs.)	Freefall Velocity (mph)	Freefall Energy (ft.-lbs.)
1/2	0.002	34.7	0.09
3/4	0.007	42.3	0.44
1	0.017	49.8	1.43
1-1/4	0.034	55.9	3.53
1-1/2	0.058	61.4	7.35
1-3/4	0.093	66.2	13.56
2	0.138	71.6	23.71
2-1/4	0.197	75.7	37.73
2-1/2	0.270	79.8	57.48
2-3/4	0.360	84.6	85.95
3	0.467	88.6	122.66
3-1/4	0.594	93.4	173.21
3-1/2	0.742	97.5	235.67
3-3/4	0.913	101.6	314.71
4	1.108	105.7	413.31

Table 2

Approval (Class 1-MH), the steel ball is 1-3/4 inches in diameter dropped from 5 feet above the specimen. For a severe hail Approval (Class 1-SH) the steel ball is 2 inches in diameter dropped from 17 feet 9-1/2 inches. Testing is performed on both "as received" and UV-conditioned samples.

In contrast to the irregular ice pellets shot from a "hail gun," the FMRC 4470 hail test incurs a specific, repeatable impact energy onto the test specimen surface. The repeatability inherent in the test method allows for data from one system to be compared to that from another.

In 1996, Underwriters Laboratories published UL 2218¹¹. Similar in concept to the FMRC 4470 hail test, this UL impact test subjects a conditioned test specimen to the impact energy incurred by dropping steel balls of various diameters from various heights at predetermined increments. When a series of impacts is complete, the specimen is examined for failure, through a magnified visual examination, or through subjecting the specimen to a flexibility test, or a combination thereof. While UL 2218 is a repeatable test method, it is designated as an impact resistance test, not to be mistaken for a hail resistance test.

In Switzerland (a country affected by severe hailstorms), a test procedure using a 40 mm diameter plastic sphere to simulate hail impact was developed. The test method is slightly more complex than the aforementioned methods in that data gathered are not limited to "pass" or "fail" at a predetermined impact energy. The data generated include the impact velocity, backing and boundary conditions, and kinetic energy at which the specimen incurs damage. The method also categorizes "failures" based on type, form, extent and behavior.

While the shingle manufacturers have stated their commitment to studying the effects of hail on steep slope roofing products, research data have been kept, for the most part,

proprietary. The test data established have been generated without the benefit of an industry-recognized, repeatable test method to provide a baseline of data from which further research and testing could draw.

An attempt to resolve this problem and establish "baseline data" can be seen in work performed by Haag Engineering. In 1993, Haag Engineering established a test protocol intended for "controlled impact testing." The protocol established not only a repeatable test procedure, but also a repeatable method of specimen examination and data analysis. Areas on the shingle test specimen are designated based on underlying support (unsupported, marginally supported, and fully supported) and area location (field, edge, corner, upper trough, lower trough, etc.). After impact, shingle samples were desaturated and examined for damage at these designated areas. Damage is defined as "diminishment of the water shedding capacity or the reduction of expected long-term service life of the tested materials."

In 1994, Exterior Research & Design, LLC began a test program based on examination and testing of shingle systems that had experienced a major hail event. Through review of warranty cards from one shingle manufacturer, roofs were identified as being:

- ▼ Within the path of severe hail or
- ▼ Within the storm area, but outside of major hail impact areas.

Thirty-five applications of two shingle weights and ten applications of a third shingle weight were identified. Shingle systems that endured the hailstorm with no subsequent repair were examined and samples were extracted from both sides of the roof ridge, approximately eight to ten courses up from the eave. In addition, neighboring homeowners were interviewed to determine whether their respective shingle systems had withstood the hailstorm with no repair work. If the appropriate answers were given and the shingles could be positively identified, samples were taken from the same roof areas. Sampling also included shingles taken from roofs installed in Seattle, WA during the same roofing season. The Seattle shingles had not experienced a major hail event, but had been in place for an equal period of time.

The subject shingle applications were visually examined for damage. Damage location (if any), underlayment and substrate data were recorded. Shingle samples were packaged and returned to the laboratory for further testing. Shingles taken from roofs outside the path of the storm were viewed and sampled in a similar manner.

Sampled shingles and new shingles of an identical type were conditioned in the laboratory, installed on test panels and tested for simulated hail resistance following the FMRC 4470 severe hail test standard. Variables examined included roof pitch, underlayment type, deck type and impact location. After impact, shingle impact areas were examined for damage under 30x magnification and desaturated for a view of the fiberglass mat condition.

Test procedure development and observations of weathered samples subjected to a major hail event will be covered in Part II of this article. Comprehensive test data and conclusions will be covered in Part III.

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About The Author

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of roof systems, materials analysis, laboratory testing and long-term analysis of in-place roof systems. The firm is based in Seattle, WA. Colin joined RCI in 1986 and became an RRC in 1993. He is currently the Director of Region VII. In 1996, he was honored with the Richard Horowitz Award for excellence in technical writing for Interface.

ASCE's EdAC Clarifies Resolution Condemning ASTM Consensus Documents

A recent press release from the Professional Firms Practicing in the Geosciences (ASFE) announcing that the American Society of Civil Engineers' Educational Activities Committee (ASCE EdAC) had endorsed a resolution opposing the American Society for Testing Materials' (ASTM's) "promulgation of consensus documents that are labeled as Standard Practices or Standard Guides" has been characterized as "factually incorrect" by ASCE.

According to a release signed by James E. Davis, ASCE Executive Director, the Midwest Civil Engineering Department Heads had prepared the said resolution, which was later endorsed by the Society's Department Heads Council. The council then forwarded the resolution to ASCE's board-level Educational Activities Committee for consideration, but no action has been taken to date on the issue.

"ASCE has a long history of working cooperatively with ASTM," Davis wrote. "Following further review of this issue, ASCE will work collaboratively to resolve any concerns the Society may have with ASTM."

Both ASFE and the Geo Institute have argued that the materials involved should be called something other than "standards," claiming that the guides presuppose a standard client with standard risk management objectives for a standard project at a standard site—conditions impossible to match in the "real world."

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