Hail Damage to Shingles

Part II

By Colin Murphy, RRC, Robert Mills and Remo Capolino

THE FOLLOWING ARTICLE IS THE SECOND IN A SERIES OF THREE ADDRESSING HAIL DAMAGE to shingles. The first (published in the January issue of *Interface*) provided an overview of the history of general shingle testing. This second article covers the history of shingle hail resistance testing and the development of a repeatable test procedure. The third will cover test data generated and conclusions drawn from the actual test program.

The performance of shingles and shingle assemblies has been examined and documented in many facets, including wind resistance and physical properties; however, hail resistance has not received comparable attention. While some shingle hail resistance studies have been performed and published, commonality from one study to the next is minimal. This is due to lack of a standardized, repeatable test method at the time the studies took place. With the 1996 publication of UL 2218 came a repeatable test standard for shingles; however, establishment of baseline data, minimum performance criteria and code requirements remain. Lack of a standardized test method and minimum performance criteria over the years is due, in part, to industry perception of a hail event.

Hail events have been primarily viewed as unusual, insurable weather events, regardless of the fact that 90% of the United States experiences some sort of hail event annually, with severe hail areas covering 8% of the United States.[1] This perception has resulted in hundreds of millions of dollars in hailstorm claims borne by insurance companies throughout North America. It is no surprise that these insurance companies have an increasing incentive to reduce damage incurred during a hail event. Meeting this objective calls for the establishment of minimum performance criteria.

Establishment and implementation of any performance criteria is based initially on development of a repeatable test standard to generate comparable baseline data. The concept is not new for hail resistance of low slope roof assemblies. For example, in 1986, Factory Mutual Research Corporation (FMRC) established a hail resistance test for low slope roof assemblies as part of its requirements for FM Class 1 Approval.[2] The standard was amended in 1992 to include a "severe" hail category. In Europe, hail resistance testing of low slope roof assemblies has been incorporated into regional and national test requirements. The Swiss Hail Test, forming a part of Test Standard SIA 280[3], utilizes a plastic sphere of a specified diameter and mass launched from a specially developed propulsion device.[4] These test standards are further discussed later in this paper.

A REVIEW OF STUDIES AND PROCEDURES

As noted above, there are few published shingle hail resistance studies available for review. In addition, a number of the primary studies are more than 30 years old, and they document testing of products no longer available on the market.

In 1960, the National Building Research Institute of South Africa published C. S. I. R. Research Report Number 176[5], authored by J. A. P. Laurie. The study, titled "Hail and Its Effects on Buildings," utilized terminal velocity formulae, established in 1937 by Messrs. Bilham and Relf, to correlate the diameter of a hailstone to its maximum kinetic energy based on an assumed specific gravity. This correlation allowed Laurie to produce artificial hailstones of a specific diameter, which were launched at various roofing specimens using a rifle grenade thrower. Hailstone velocities were measured and impact energies calculated. The lack of control inherent to the method of launching often required a large number of tests to maintain a statistically viable data set. The study documents the impact energies required to damage a variety of South African roofing products. The test sampling did not include asphalt shingles.

In 1969, the U.S. Department of Commerce published a study titled "Hail Resistance of Roofing Products,"[6] authored by Sidney H. Greenfeld. Referencing the Laurie study, Greenfeld produced artificial hailstones, which were launched at roofing specimens using a compressed air gun. The study includes a variety of asphalt shingles installed over 3/8" and

Overview of shingle test assembly

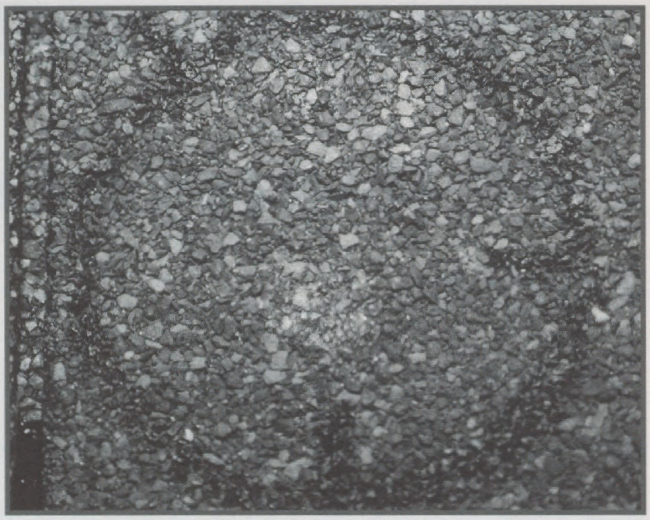
1/2" plywood, and 1" x 6" tongue-and-groove decking with and without a 15# organic felt underlayment. The conclusions designate three areas of vulnerability: tab edges, unsupported areas and triple coverage areas. Impact areas were visually examined for damage and indentation depths measured after each hailstone launch.

Greenfeld designated two damage categories: 1) severe damage, which leads to penetration; and 2) superficial damage, which affects only appearance. Defining the former as "failure," Greenfeld reported the smallest hailstone size to produce a "failed" condition, termed a "threshold of failure."

The Greenfeld study qualitatively documented:

- Three distinct areas of vulnerability;
- Increased hail resistance with increased substrate rigidity;
- Increased hail resistance with increased substrate hardness;
- Increased hail resistance with increased shingle weight (thickness of reinforcing mat and asphalt mass);
- Increased hail resistance with use of fiberglass mats in lieu of organic mats;
- Increased hail resistance with increased ambient temperature; and,
- Decreased hail resistance with shingle weathering/exposure.

The Greenfeld study quantitatively documented a hailstone size range ("threshold for failure") of 1-1/4" to 2" diameter for organic mat reinforced shingles relating to an impact energy range of 4 to 22 ft-lbf (5.42 to 29.8 Joules). Inorganic (fiberglass) mat reinforced shingles recorded a threshold as high as 2-3/4" diameter relating to 81 ft-lbf (109.8 Joules). As a comparison, the FMRC hail test specifies impact energies of 8 ft-lbf (11 Joules) for moderate hail and 14 ft-lbf (19 Joules) for severe hail on low slope roof assemblies.



View of impact location

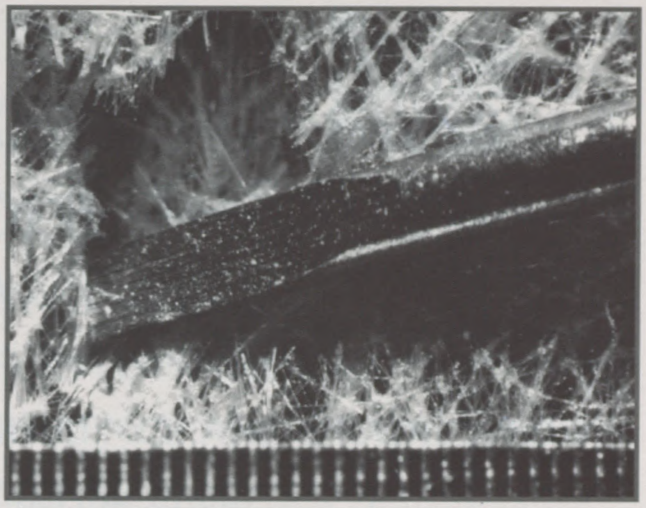
While methods utilized and data generated by Laurie and Greenfeld are certainly of value, both studies required the development of a new test protocol instead of following a standardized test method. Therefore, data generated are useful only when viewed within the context of the study. Moreover, repeatability of the test methods is inherently difficult due to use of artificial hailstones made of ice using various fabrication methods. While the nature of hail formation results in hailstones of various size, shape and specific gravity, the intent of a standardized test method is to reduce variables associated therewith to a minimum. Repeatability is also affected by the use of various hailstone launch methods intended to incur an impact energy based on simulating a hailstone's terminal velocity. Minor variations in velocity resulting from a minimal degree of control led to large variations in impact energy incurred on the specimen target area. In addition, the Greenfeld definition of "failure" was inherently subjective as all observations for damage were made at a macro level.

As noted earlier, these test programs date back to the 1960s. North American roofing products for steep slope roof applications have changed significantly over the past 30 years.

In 1993, Haag Engineering Company published a paper titled "Hail and Composition Shingles,"[7] authored by Scott J. Morrison, P.E. The paper includes a test protocol similar to those used by Laurie and Greenfeld; however, damage analysis includes the desaturation of impacted areas and examination of the reinforcing mat condition. With this advance, Morrison further expounded the failure definition to include mat rupture or strain (permanent deformation) in excess of 1/4" diameter.

The Laurie, Greenfeld and Haag methods are each based on impacting the target area with a projected artificial hailstone and calculating its maximum kinetic energy just prior to impact. The intent is to simulate the terminal velocity of an actual hailstone and the associated impact energy incurred on roofing materials. While control over the projectile velocity has increased over time, resulting in a more repeatable

View of steel ball at impact location



Microscopic view of mat rupture. Failure, Category 3.

method, variations associated with hailstone fabrication remain.

In 1988, the Swiss Federal Laboratories for Materials Testing and Research (EMPA) published a paper titled "The Hail Resistance of Plastic Components of the Building Shell,"[8] authored by Peter Flueler and Fritz Rupp. The paper includes a test protocol in which a 1.6 inch (40 mm) sphere is fired at a plastic roofing specimen using compressed air. Similar to the Laurie and Greenfeld studies, the terminal velocity is measured and impact energy calculated. Using failure values recorded for clay tiles and fibrated concrete panels as a datum point, the authors proposed a minimum velocity test criteria for damage resulting in leaks and damage relating to façade appearance.

Factory Mutual Research Corporation and Underwriters Laboratories, Incorporated have published test methods that limit hailstone variations through the use of steel balls and limit velocity variations through dropping rather than launching.

As noted above, the Factory Mutual hail test method was first published in 1986 as an amendment to its Test Standard 4470. The method specifies use of fixed sizes and weights of steel balls dropped from fixed heights to incur a specific impact energy on the target area. The impact energies, based on the steel ball's potential energy prior to the drop, are set at 8 ft-lbf (11 Joules) for moderate hail and 14 ft-lbf (19 Joules) for severe hail. The test standard requires testing of an assembly including the insulation layer and fasteners (if any). The point of impact is viewed for 1) membrane damage and 2) loss of adhesion to the underlying layer when the assembly is fully adhered. Roof assemblies are tested for "severe hail" when use of the assembly is anticipated within an area designed for severe hail in the Factory Mutual Loss Prevention Data Sheet 1-47S.1[9]. The hail test, which includes testing of both new and weathered samples, is set forth as one of several performance tests required for FM Approved, Class 1 Roof Covers, a category in which asphalt shingle systems do not apply.

The Underwriters Laboratories test method, titled "UL 2218—Standard for Impact Resistance of Prepared Roof Covering Materials,"[10] was published in 1996. Similar to the Factory Mutual test, UL 2218 simulates impact energies of 3.4 ft-lbf (4.5 Joules), 7.2 ft-lbf (9.8 Joules), 13.5 ft-lbf (18.3 Joules), and 23.0 ft-lbf (31.2 Joules) through the dropping of steel balls. The impact test does not include testing of weathered samples nor does it include desaturation of impact areas as part of damage analysis. Since its publication, UL 2218 has been the subject of a petition filed by The Texas Department of Insurance to establish mandatory credits for roof coverings meeting the test criteria.

In 1994, Exterior Research & Design, LLC. (ERD) began an asphalt shingle hail resistance program with the objective of documenting changes in hail resistance performance based solely on changes in specimen construction, configuration and condition. Using the FMRC severe hail test method as its primary basis, ERD utilized a fixed impact energy of 14 ft-lbf (19 Joules) to examine the following specimen associated variables.

- Substrate rigidity/hardness (15/32" plywood vs. 1" thick T&G) nailed at 24" centers;
- Substrate hardness [no underlayment vs. one layer of ASTM D 226, type II (30# organic) felt];
- Asphalt type forming the shingle (oxidized vs. modified bitumen having various weights);
- Shingle type (strips and dimensional);
- Shingle condition (new vs. field weathered samples in the path of a hailstorm vs. field weathered samples not in the path of a hailstorm);
- Impact angle/roof pitch (2:12 vs. 4:12);
- Impact location [shingle tab (at non-adhered areas), shingle overlap (double and triple coverage)]

In addition to minimizing method-based variables, a fixed impact energy of 14 ft-lbf (19 Joules) was selected based on review of data generated in aforementioned studies. While differing methods were used, an impact energy datum point was selected to ensure a cross-section of damage was achieved.

Damage assessment includes a macroscopic and microscopic (5X) examination of impact areas as well as removal and desaturation for microscopic viewing of the mat condition. These assessment methods are used to categorize damage as: 1) none to minor damage, 2) moderate damage, or 3) severe damage (rupture or tear of the reinforcing mat).

The ERD test program began as a field analysis of shingle applications installed over a two-year period in one city. A portion of the city was struck by a severe hailstorm three and four years after installation, resulting in significant roofing losses. Based on warranty data provided at time of installation, shingle applications were examined and sampled both within and outside of the track of the hailstorm. In addition, shingles installed at neighboring houses were examined and sampled where the specific type and age of the product could be identified and confirmed.

The field sampled shingles were visually and microscopically examined for hail damage. The samples were subsequently used in conjunction with new shingles to construct hail test specimens for examining the aforementioned assembly-related variables. All test panels were conditioned under heat lamps for a period of 72 hours prior to testing to activate the "hold-down" tabs and to allow the shingle components to conform to underlying shingles and substrate components.

The project was extended, (partially funded by the Roof Consultants Institute), to include a broader examination of new shingles available in the United States market. Testing commenced in 1994 and was completed in the fourth quarter of 1997.

Test results are expressed in a numeric value based on a visual examination of the top and bottom surfaces of the impact areas and a desaturation of the impact areas for a microscopic examination of the reinforcing mat. No damage to minimal damage has a numeric reference of "1." Damage was noted as moderate, having a numeric reference of "2," when the top, asphalt surface exhibited cracking or exposure, and/or the reinforcing mat exhibited permanent deformation or individual fiber breakage. Damage was noted as severe, having a numeric reference of "3," when the shingle underside exhibited spalling or the reinforcing mat exhibited complete rupture or tearing. The aforementioned testing and damage analysis were performed three times for each combination of assembly variables resulting in an average numeric damage value.

The third article in this series reviews the test results and proposals for additional testing. It will be published in Interface *following RCI's International Convention and Trade Show. Colin Murphy will present results of the testing as part of the proceedings of that convention.*

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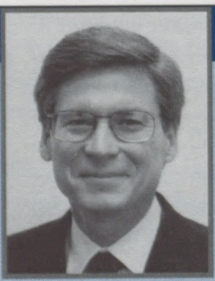
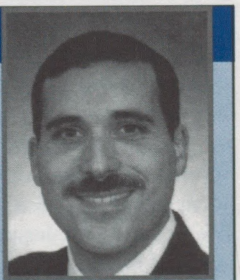
EDITORS NOTE: We regret that co-authors Remo Capolino and Robert Mills did not receive bylines or credit on the first of this series of three articles.

About The Authors



Colin Murphy



Remo Capolino

Colin Murphy, RRO, RRC, *founded Trinity Group Fastening Systems in 1981. In 1986, he established Trinity Engineering, focusing primarily on forensic analysis of roof systems, materials analysis, laboratory testing and long-term analysis of in-place roof systems. The firm, formally known as Exterior Research & Design, LLC, Trinity Engineering, 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.

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Remo Capolino *received his B.S. in civil engineering in 1991 from the University of Connecticut. Between 1989 and 1996, Remo served as Treasurer and President of the Association of General Contractors' (AGC) Student Chapter and Northeast Roofing Contractors Association's Advisory Committee. Prior to his employment with Exterior Research and Design, LLC, Trinity Engineering, in July 1997, Capolino served on the Board of Directors for the NRCA and Northeast Roofing Contractors Association, where he assisted in updating the NRCA Roofing and Waterproofing Manual, 4th Edition. Remo was profiled by* Professional Roofing *in July 1997.*