Hail Damage To Shingles Part III

BY COLIN MURPHY, RRC, ROBERT MILLS AND STEVE BUNN

INTRODUCTION

THE FOLLOWING ARTICLE IS THE THIRD IN A SERIES OF THREE ADDRESSING SIMULATED HAIL testing and hail (impact) damage to shingles. The first (published in the January issue of *Interface*) provided an overview of the history of general shingle testing. The second (published in the February issue of *Interface*) provided an overview of the history of shingle hail resistance testing and the development of repeatable test procedures. This article summarizes the test data and conclusions generated from a recently completed, five-year test program conducted by Exterior Research & Design, LLC.

A comprehensive testing program to simulate hail damage to shingles is not new. Test protocols were developed over 30 years ago, indicating there are system design, product manufacturing and installation issues to reduce hail-induced damage to shingles. Unfortunately, past testing and test method development have not led to a method recognized by the roofing and insurance industries or building code authorities.

The primary burden of repair and replacement of hail damaged shingles has fallen to the insurance carriers, and therefore, ultimately to those who pay the premiums. The roofing industry—both manufacturers and installers—has benefitted from these natural events. The roofing industry has had no financial incentive to develop products and promote building standards that would reduce the effects of hail damage. Insurance carriers have recently responded to this major loss category by cooperating with and encouraging testing agencies to develop a recognized test standard for impact damage. In addition to the efforts of the insurance carriers, state government agencies have been active in promoting legislation or executive order directives to insurance carriers to offer premium discounts to policy holders who install shingle roof systems proven to be more resistant to hail damage.

Some carriers are not waiting for government executive orders or legislation, and instead are offering discounts to promote the use of more impact-resistant installations. Discounts in some states range from 17 to 21% of a homeowner's premium, providing the shingle and its application meet the requirements of the insurance carrier. For example, some discounts are promised by removal of the original roof system in re-roof applications. In addition, some carriers are developing their own test facilities to gain first-hand knowledge of shingle performance.

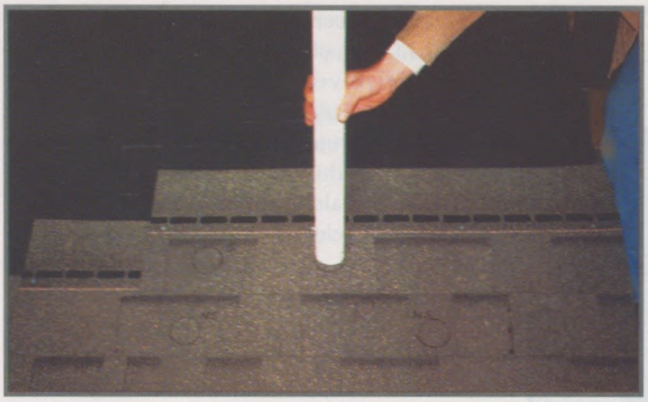
The testing procedures for determining the effects of impact to shingles have been in development since the 1960s. Sidney H. Greenfeld, working under the sponsorship of the U.S. Department of Commerce, was an early researcher in this field of research, publishing findings of a simulated hail laboratory study. The study examined impact resistance of organic and fiberglass-reinforced shingles, as well as various built-up roof assemblies. The study, titled "Hail Resistance of Roofing Products,"[1] was published in 1969. The Greenfeld test method included the production of artificial hailstones from ice balls, which were launched at roofing specimens using a compressed air gun. Greenfeld conducted the testing over various substrates, including 3/8" plywood, 1/2" plywood and 1" x 6" tongue and groove decking. Substrates were further varied by altering the underlayment layer.

Greenfeld published a series of conclusions based upon his test program. He concluded that:

- There are three distinct areas where shingles are vulnerable to simulated hail damage. These occur at overlaps, tabs and edges.
- Impact resistance increases with substrate rigidity and hardness.
- There is increased impact resistance with increased shingle weight.
- Fiberglass mats offer increased impact resistance to comparable organic mats.
- Shingle aging decreases impact resistance.

The American Society for Testing and Materials (ASTM) published Test Method D 3746[2] in 1978. This test protocol utilizes steel missiles, which are fired at test specimens to simulate hailstone impact.

In 1986, the Factory Mutual Research Corporation



Modified FM 4470 testing procedure.

(FMRC) amended its Test Method 4470[3] to incorporate a requirement for hail testing. The protocol called for specifically-sized and weighted steel balls to be dropped from established heights. In 1992, the resultant impact energies were given two classifications: "Moderate Hail" classification when an impact energy of 8 ft-lbf (11 Joules) is utilized, and "Severe Hail" when an impact energy of 14 ft-lbf (19 Joules) is utilized. While the test protocol does not address all variables that could affect hail performance, the method is easily repeatable in the study of hail resistance. The 4470 test procedure was developed primarily for low-slope roofing products and does not specifically address testing of shingle assemblies.

The Swiss Federal Laboratories for Materials Testing and Research (EMPA) published an article titled, "The Hail Resistance of Plastic Components of the Building Shell,"[4] in 1988. The paper included a test procedure for determining impact resistance utilizing plastic balls launched from a compressed air gun at different velocities. The plastic balls are fired at close range to reduce variables, which could alter the

Hailstones manufactured for Haag Engineering testing.

impact energy.

In 1993, Haag Engineering developed a further test protocol utilizing frozen ice balls to simulate hailstones fired from a compressed air gun, as described in an article titled, "Hail and Composition Shingles."[5] The author, Scott J. Morrison, P.E., further refined the analysis of impact damage by desaturating the test specimens for observation of the shingle mat, rather than simply examining the shingle surface under magnification. The Haag protocol introduced a newly defined mode of shingle failure, rupture of the shingle mat.

Most recently, in 1996, Underwriters Laboratories, Inc. published Test Standard UL 2218[6], an impact resistance test utilizing different sized steel balls to simulate varying levels of impact. This protocol utilizes steel balls dropped from various heights, developing different categories or ratings of impact resistance. Most notably, some members of the insurance industry and government bodies have begun to classify roofing materials for impact resistance by adopting the UL protocol and criteria. Test Standard 2218 appears to have been adopted as the insurance standard providing the shingle producers with a clear performance requirement. The test protocol creates scaled performance for production of product to meet various geographic needs. Insurance carriers in Texas, Kansas, and Oklahoma are offering insurance premium discounts to policy holders who install roofing materials based upon the results of UL 2218 testing and application of those materials in compliance with a specified installation guideline.

With the various impact methods utilized, there is a lively discussion as to whether simulated impact test methods produce repeatable results and which method(s) most accurately simulate actual hail impact. Researchers who have used both ice balls and/or steel or plastic missiles have offered conflicting conclusions regarding repeatability.

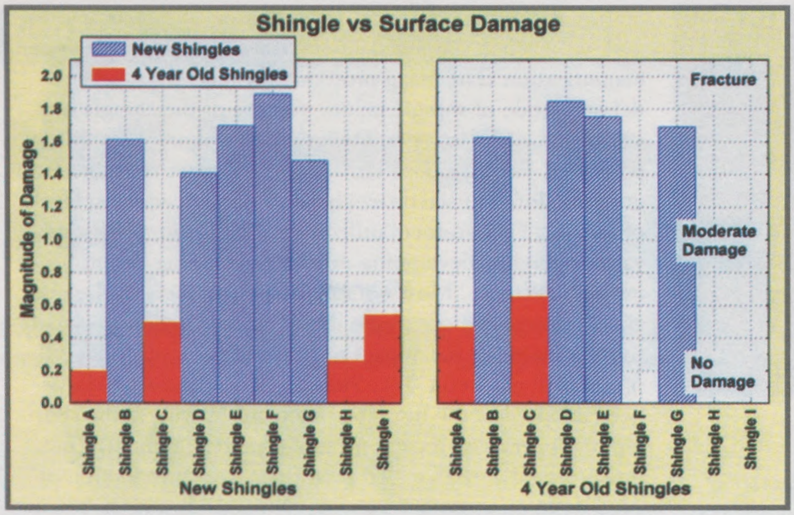
Exterior Research & Design, LLC (ERD) Test Program

In 1994, Exterior Research & Design (ERD) began a test program to determine impact hail resistance of shingles based upon changes in specimen construction, configuration, age, and condition. The test program was comprised of two facets, field analysis of shingle products impacted by hail in one major hail event, and laboratory testing of a series of shingle products manufactured in the United States.

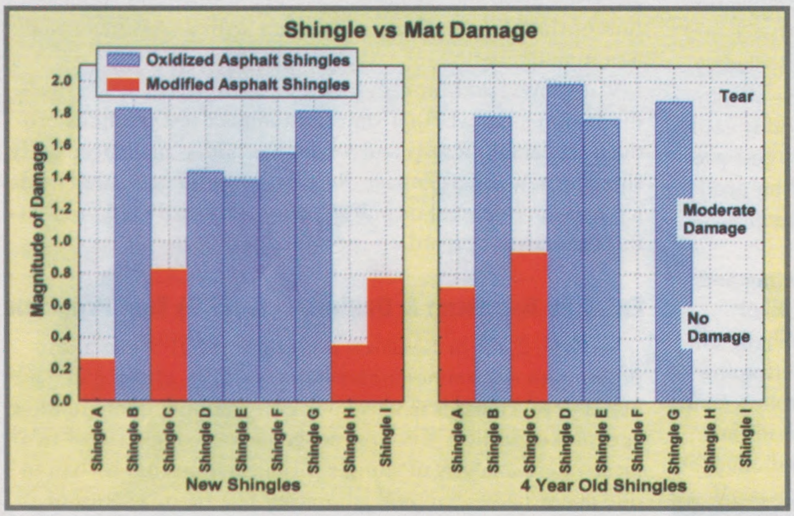
Field Analysis:

On September 7, 1991, a major hailstorm hit Calgary, Alberta, resulting in extensive damage to roofing. The warranty cards from one shingle manufacturer were reviewed to locate specific projects that were potentially within the path of severe hail. Field staff first identified the materials, constructions and locations of the projects provided from the warranty cards. File warranty data and field installations did not necessarily match, resulting in the need for field inspection for confirmation. The team then tracked the path of the storm by reviewing weather service data, as well as interviewing building owners and their neighbors to determine the intensity and path of the storm. Confirmation of this data was obtained by proof of actual damage such as photographs of car or building damage or photographs of actual hail.

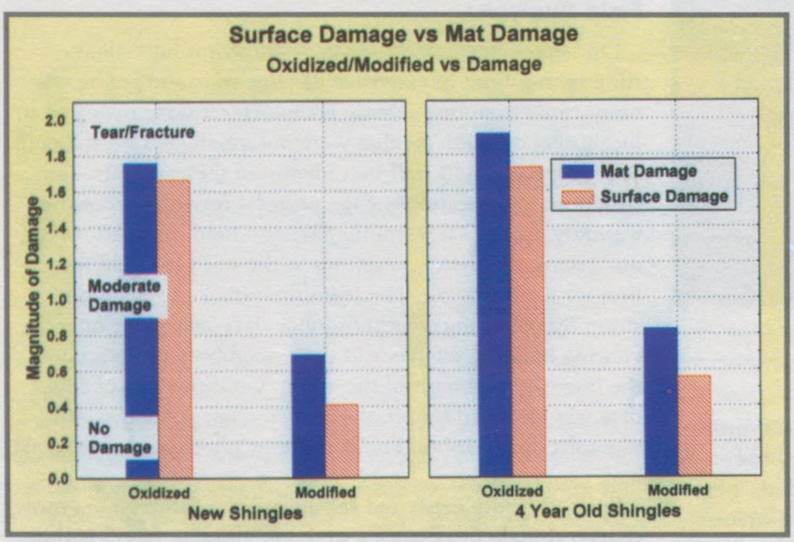
From warranty cards and replacements of thirty-nine roofs, sixteen shingle installations were identified as being within,



SBS modified shingles were more reesistant to surface damage.



SBS modified shingles were less resistant to impact damage.



Surface damage is less indicative of mat damage for modified shingles.

or directly adjacent to, the path of the most severe hail. Five of the sixteen projects were roofed with 20-year strip shingles, manufactured from fiberglass mats and oxidized asphalt. Of these five projects, one could not be confirmed to be within the path of the most severe hail. This roof, along with a large number of the thirty-nine clearly outside the area of the most severe hail, were replaced by an insurance carrier as a total loss due to the hail event. The remaining four 20-year strip shingle projects were confirmed to be within the path of the most severe hail, and were replaced as the result of an insurance loss. In all cases, the new shingle applications were re-roofs over the damaged shingle assemblies.

Nine of the sixteen projects were roofed with Styrene Butadiene Styrene (SBS) modified asphalt shingles manufactured with 2-lb. fiberglass reinforcement. Of these nine projects, two could not be confirmed to be within the direct path of the storm. Of the remaining seven projects, only one was replaced by an insurance carrier as a direct result of the hail event. The one replaced roof was installed over an existing 20-year strip shingle roof installed over an underlayment and a plywood substrate. The remaining six projects remained in service after the hailstorm. Further investigation revealed that these six projects had nominal 1″ tongue-and-groove deck substrate and slope of 4″:12″ or greater.

Laboratory Testing:

The laboratory testing included both new shingle samples and four-year-old field-weathered shingle samples. The field samples were obtained from sites within the Seattle Metropolitan Area. The Seattle area was chosen due to the lack of hailstorms within the locality. The shingle samples were taken from four-year-old projects because the shingles of this age were easily identified by warranty cards on file. Older projects had insufficient documentation to confirm the precise installation dates. Each project was sampled in a consistent manner. Samples were taken from the east and west elevations, visually inspected to be free from surface damage, and were carefully removed to prevent damage during extraction. A total of nine brand name shingles were sampled. In all cases, the samples were identified by warranty cards, and an interview was held with the roofing installer as a cross check of the warranty card data.

The same nine brand name shingles were purchased new from local distributors for comparison with weathered product. The nine different shingles included:

- Three strip shingles, SBS modified asphalt, mat weight 2 lb.;
- One strip shingle, oxidized asphalt, mat weight 1.54 lb.;
- One strip shingle, oxidized asphalt, mat weight 1.93 lb.;
- One dimensional shingle, oxidized asphalt, mat weight 1.61 lb.;
- One dimensional shingle, oxidized asphalt, mat weight 1.58 lb.;
- One dimensional shingle, oxidized asphalt, mat weight 1.86 lb.; and
- One dimensional shingle, SBS modified asphalt, mat weight 2 lb.

The FMRC Test Standard 4470 was chosen for the laboratory testing for consistency in the impact energy created by the steel ball dropped from the same height. Moreover, when testing began in 1994, the UL Test Method 2218 had not yet been published. Specifically, the severe hail requirement from 4470 was chosen because the impact energy of 14 ft-lbf (19 Joules) equated to hailstones sized 1-1/2" to 2" in diameter, a size known to consistently damage shingle roof systems. Tests were conducted to examine a number of variables:

- New shingles and four-year-old "aged" shingles;
- Strip and dimensional shingles (laminated versus non-laminated);
- Oxidized asphalt and SBS modified asphalt shingles to compare the different types of impregnating asphalt;
- Substrate slope comparing 2":12" to "1":12" (additional testing, after completion of the primary test program, also included slopes of 6":12" and 9":12");
- Use of 15# underlayment felt comparing constructions with and without the use of an underlayment;
- Decks constructed from 15/32" plywood and 1" nominal tongue and groove, both attached at 24" centers;
- Simulated impact locations (shingle tabs versus overlaps) with impact at center span;
- Dimensional vs. non-dimensional shingles and damage within top and bottom plies of the dimensional shingles.

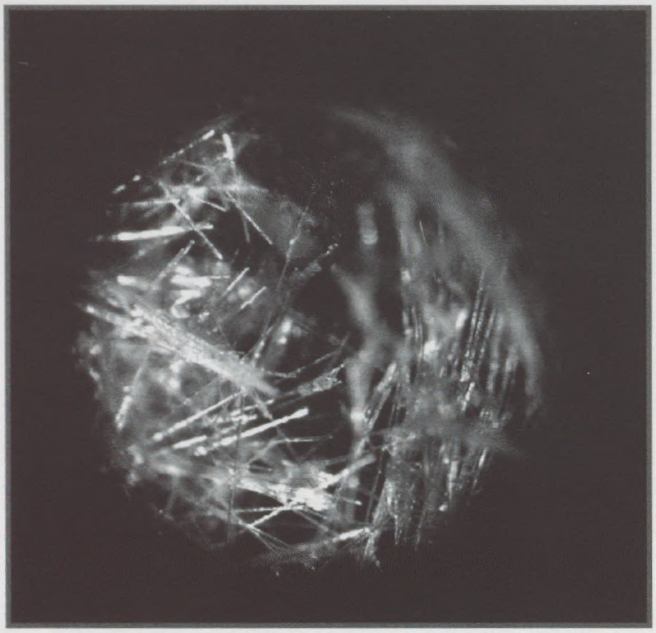
All test specimens, new and aged, were "conditioned" in accordance with the protocol published in ASTM D 3161[7] after installation to the test decks. The impact test consisted of dropping a 2" diameter steel ball through a plastic tube from a height of 17' 9-1/2". Sixteen tests were performed for each variable under examination. The simulated hail impact locations were marked on the test specimen.

Upon completion of the testing, the impacted area was removed and examined through 5x magnification. Three ananalysts qualitatively evaluated the damage on a three-point scale of 0 to 2. A recording of "0" indicated no damage, "1" indicated moderate damage and "2" indicated a surface fracture or other pre-defined severe damage. During the analysis, there was complete agreement between the three parties for approximately 85% of the samples. When there were differences in opinion, the group of three met to arrive at a mutual consensus on the numeric value. After the surface damage had been numerically recorded, the area of impact was desaturated to expose the fiberglass mat. The damage to the fiberglass mat was qualitatively evaluated in the same manner. For the mat damage, recordings of "0" indicated no damage, "1" indicated moderate damage and "2" indicated a tearing or rupture of the mat.

All of the relevant test data were input into a spreadsheet. The data were then imported into a statistical analysis program to determine the correlation of the different variables to the observed damage. The statistical analysis yielded the following results:

- Surface damage and mat damage are nearly proportional for oxidized asphalt shingles, with slightly greater damage to the mat than visually observed on the surface;
- Surface damage and mat damage for SBS modified asphalt shingles are in general agreement; however, the visual observation of mat damage is greater than visual observations of surface damage;
- SBS modified asphalt shingles exhibited less damage to both the surface and the mat when compared to all oxidized asphalt shingles tested within the series;
- Weathered shingles always exhibited greater surface and mat damage when compared with new samples of the same product;
- The top mat layer of dimensional shingles exhibited significantly greater mat damage than the bottom layer where two layers are bonded together;
- Simulated hail impact at shingle overlaps recorded higher level damage than impact over shingle tabs;
- Shingles installed over 15/32" plywood recorded marginally greater damage than those installed over 1" tongue and groove decking with identical support and underlayment.
- Shingles installed over 15 lb. felt recorded marginally greater damage than those installed without an underlayment. In further testing, shingles installed over a double layer of 30 lb. felt recorded significantly greater damage than those installed without underlayment.
- Shingles installed at a slope of 2":12" recorded marginally greater damage than those installed at a slope of 4":12"; however, preliminary testing at slopes of 6":12" and "9":12" indicated a greater reduction in both surface and mat damage;
- Mat damage to lighter weight shingles (210-249 lb/100 ft^2) was marginally greater than heavier weight shingles (250-275 lb/100 ft^2).
- There was no apparent correlation between shingle weight and surface damage.
- There was no apparent correlation between mat weight and mat or surface damage.

Almost without exception, the ERD test results agree with the conclusions published by Sidney H. Greenfeld nearly 30 years ago. The ERD testing supports the conclusions that particular zones of a shingle are more sensitive to impact than others, shingles installed over harder or more rigid substrates show increased impact resistance, and weathering decreases impact resistance. The only exception to the ERD and Greenfeld correlation was the relation that increased mat weight correlated to increased impact resistance. Shing-



Severe hail: surface fracture damage.

Severe hail: surface fracture damage.

les tested by Greenfeld were primarily organic shingles, not fiberglass. This is likely a factor in the lack of correlation. The manufacture of shingles has also changed, resulting in many more variables than existed thirty years ago. These factors may also play a role in this lack of correlation.

Additional conclusions drawn from the ERD test program are as follows:

- While the surface damage to oxidized asphalt shingles is a good indicator of mat damage, determination of mat damage in SBS modified asphalt shingles solely from visual observation of surface damage is difficult. As a result, to properly document damage to SBS modified asphalt shingles, the shingle must be desaturated to better identify the full extent of the damage. This issue becomes relevant as more SBS modified asphalt shingles enter the market and more insurance authorities turn to the UL 2218 procedure as a basis of premium reduction. The new UL 2218 test procedure requires a visual examination of the shingle surface; however, it does not require shingle desaturation for examination of the mat. The UL 2218 may not provide the most accurate measure of impact damage when testing SBS modified asphalt shingles.
- The tested SBS modified asphalt shingles exhibited greater impact resistance than the tested oxidized asphalt shingles. SBS modified asphalt shingles better conform to the underlying substrate than oxidized asphalt shingles, thereby reducing bridging and contributing to their increased performance, especially at overlaps.
- The top plies of dimensional shingles exhibited greater damage than single and bottom layers even on harder substrate materials. On softer substrates, particularly in re-roofs over existing shingles, damage to the bottom layer can be significant.
- There is a minimal improvement in impact resistance when installing shingles over slope increases from 2":12" to 4":12". However, preliminary testing indicates significant improvement at slopes of 6":12" and greater.
- Regardless of shingle weight, type, mat weight and impact location, re-roofing over existing shingle roofs decreases the impact resistance of the new shingle roof assembly.

The primary mode of shingle failure caused by impact is a failure of the fiberglass mat in tension. When impact occurs, the resultant deformation of the shingle stretches (elongates) the fibers of the mat. When the ultimate elongation of the fibers is exceeded, the mat ruptures. Any factor that increases the magnitude of shingle deformation also contributes to an increased fiber elongation and greater potential for mat rupture. These factors include soft substrates, flexible substrates, soft underlayments, multiple shingle plies, and tab and overlaps.

As of this date, not all variables have been sufficiently addressed. Additional testing is required to examine impact resistance when shingles are greater than four years old, installed at slopes of 6":12" and greater, and installed over other substrates. Preliminary testing in the second round has already indicated reduced impact resistance of eight-year-old shingles when compared to the four-year-old samples. Even though more testing is required, the first round of testing has provided a number of considerations for increasing the impact resistance of shingles:

- Substrates should be well supported, hard and rigid;
- Thin, hard underlayment layers should be considered. Thin, durable "permeable" membranes are available on the market, reducing underlayment thickness to 10-20 mils, as compared to the common 27 mils for 15# and 58 mils for 30#;
- Shingles should be installed with as little bridging as possible;

- Shingles should lie as flat against the substrate as possible; and
- Existing roof systems should be removed in re-roof applications to enhance impact resistance of the new shingle installation.

Methods for reducing hail-related damage have been known for the last 30 years. The roofing industry, however, has been slow to develop new building materials and alter methods of application. Slow development has been fueled by the classification of hail damage as an insurable event, resulting in increased sales of product and installation paid for by insurance premium dollars. This has provided little incentive to invest in the development of a more hail resistant shingle roof assembly. However, until recently, there has not been a published test standard recognized by all parties. State officials and insurance companies are now fostering change by offering insurance premium discounts to homeowners who install roofs with more impact-resistant products over specified substrates. As a result of this intervention and the adoption of a new standard, shingle manufacturers are beginning to develop more impact-resistant products. Further testing and study will help create specific guidelines for building products and the construction of more hail-resistant roof assemblies, which, in turn, will help divert significant dollars expended on hail-related reroofing to more pressing issues, relieve overburdened landfills and promote roofing manufacturers to increase the structural life of roof installations.

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About The Authors

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Colin Murphy, RRO, RRC, *founded Trinity Group Fastening Systems, a company that developed fastening systems for use in roofing assemblies, 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 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. *This spring, he was granted the prestigious Herbert Busching Jr. Award by RCI for "significant contribution to the general betterment of the roof consulting industry."*

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