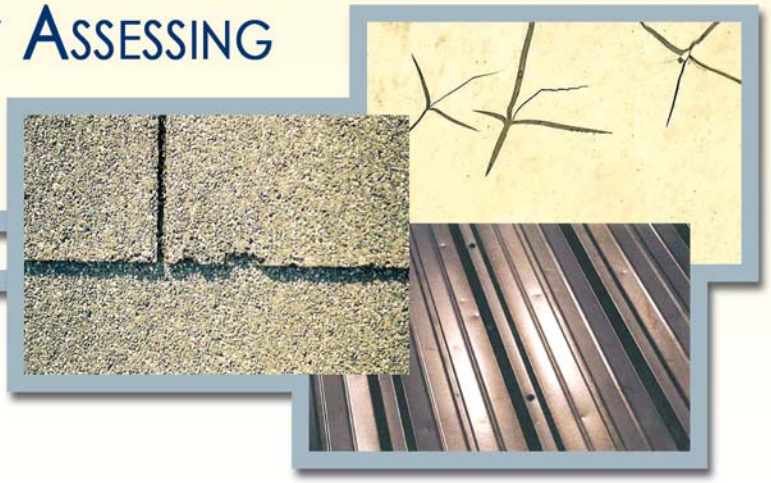
A Proposal for Uniformly Assessing Hail Damage to Roofs



By Lyle D. Hogan, FRCI, PE

Figure 1 – Hailstone pockmarking is the loss of ceramic granules and the asphalt top coating. Where this has occurred, the shingle has been compromised, especially if the glass reinforcement is exposed.

Abstract

This article is offered as a proposal for uniformity in the assessment of what actually constitutes hailstorm compromise to various roof types. The discussion reviews the author's experience from hail events of all magnitudes. Roof types explored herein are not all-inclusive but are instead representative of the author's frequency of experience.

Seldom is there a "bright-line distinction" regarding the extent of damage sustained from hailstorms. That is, the occurrence of a hailstorm may be recognized, but assessment of actual damage can be highly subjective and controversial.

Discussion is also given to the "physics of ice." Because of varying particle density, there can be substantial damage to roofs subjected to comparatively small hailstones. On the other hand, much larger stones can sometimes induce very little damage if the particle density is comparatively low.

ASPHALT SHINGLES

It is generally recognized that pockmarking involving loss of both ceramic granules and the asphalt top coating constitutes damage by falling hailstones (*Figure 1*). Where this characteristic signature has occurred, the shingle has been compromised, especially if the glass reinforcement is exposed. Inspection should then focus on how many "hits" per square are evident across the roof. That is, a square of roofing is demarcated, and individual hits are counted within that area. Several such areas should be quantified to determine a representative average, as exposure can vary among slopes of the same structure, especially when there is a directional attitude of the storm approach.

As with wind loss determination, some products perform admirably during hail exposure while others (sometimes immediately adjacent) experience considerable damage. The author has witnessed side-by-side homes, owned by brothers, where hail damage was obvious on one and completely absent on the other. Such observation would appear to highlight the wide variation in product quality or exposure level.

Hail damage should not be confused with heat blisters, observed on occasion with lightweight, "utility-grade" shingles. This condition, also known as "rash blistering," is particularly likely with substandard attic ventilation (*Figure 2*). The small blisters can rupture under even very light contact, leaving the appearance of small pockmarks. This occurrence is often non-uni-

Figure 2 – "Rash blistering" is particularly likely when substandard attic ventilation is afforded. The tiny blisters can rupture under even very light contact, leaving the appearance of small pockmarks.

Figure 3 – Lot-to-lot variation in a shingle product.

Figure 4 – "Bruising" of the protective granules but no loss of the coating asphalt. Surface temperature at the time of hail has considerable influence on damage susceptibility.

form across a roof, severe in areas and moderate in others (*Figure 3*) because of lot-to-lot variation in the shingle product or differences in ventilation effectiveness. However, rash blistering and weathering variations are completely unrelated to unusual weather events, as both can occur in the complete absence of hail.

There can be a condition known as "bruising" (*Figure 4*) where there is removal of the protective granules but no loss of the coating asphalt. This condition may result from particles having less density than hard-frozen hailstones, a matter discussed further below. Prevailing surface temperature at the time of hail has considerable influence on actual susceptibility of a roof to sustain damage. None of these surface appearances should be confused with "scuffing," which can stem from several sources, including periodic trafficking.

Shingles that overhang rake lines can be a good indicator of hail exposure. Absence of impact damage along these vulnerable locations is indicative of moderate hail intensity, small particle diameter, or both. But to complicate the matter, there can also be chipping of shingles along edges only (*Figure 5*). More than once, we have recorded hail hits that produced chipped edges but did not generate ordinary pockmarks anywhere. Water-shedding effectiveness was not compromised (because of the two-ply construction and headlap of properly installed shingles), but there was, nonetheless, some reduction of expected service life. This office associates such behavior with products that also weather in the same pattern, losing granules first along edges (*Figure 6*).

Erosion of ceramic granules must be discussed. A liberal accumulation of granules in gutters (cited by some as bona fide evidence of damage) can result from several influences without any exposure to hail. While aggressive contact can indeed loosen granules, it is irresponsible to make this leap without first examining other factors described above.

Figure 5 – Chipping of shingles edges (only) with no evidence whatsoever of ordinary pockmarking.

Finally, for the hapless individual who, like the author, has been tasked to evaluate vandalism, there is also some distinction. On occasion, a diagnostician may be asked to consider hail exposure that is, in fact, hammer damage inflicted by an owner. "Hammer tracks" will pulverize (reduce to powder) the ceramic granules, while hail particles of diameter equivalent to a hammer head will not. A hand-held 10x magnifying glass will easily expose this condition.

METAL ASSEMBLIES

Metal roofing enjoys favorable status in terms of service life expectancy. Yet, hail events often prompt consideration of damage sustained. Soft metals such as copper, lead, and light-gauge galvanized steel are likely to have indentations confirming hail exposure. Curiously, 26-gauge galvanized (*Figure 7*), although in vogue in several locales, is siding material, inappropriate for roof construction. Such a covering is unrated and unlisted with loss prevention agencies and approval guides. The user who specifies or accepts this form of covering may expect surface indentions from even minor hail events – that is, assuming the product can even be installed without crimping or creasing. The property insurance carrier who underwrites such construction can expect trouble.

Copper, depending upon its tempering, can be vulnerable to indentations. Lambert - St. Louis Airport, the first municipally-owned airport in the country, was constructed in the mid 1950s. Its beautiful domed design was the model for John F. Kennedy Airport in New York and Charles DeGualle Airport in Paris. Though the curved copper roof bears silent witness to many hail events, as the riddled surface can easily be seen through the mature patina, such exposure has apparently not merited replacement. Note that the stainless steel cladding of the Gateway Arch a few miles away is inherently more resistant to hail (even if it were the same gauge) because of metallurgical properties. If eventual indentations on a copper roof will be considered analogous to indentations on the

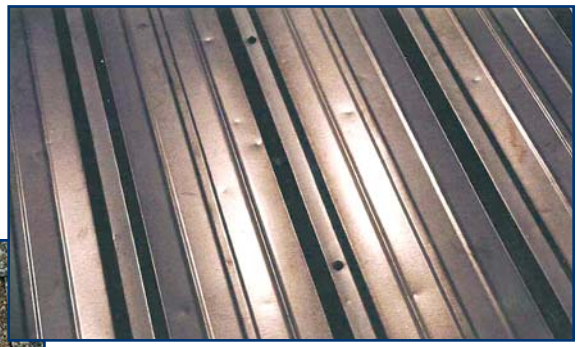


Figure 7 (above) – 26-gauge galvanized, although in vogue in several locales, is siding material, inappropriate for roof construction.

Figure 6 – Certain products weather by losing edge granules first. This is a product attribute, completely unrelated to hail activity.

fender of an automobile, perhaps alternative claddings should be used. Otherwise, copper can perform admirably, as it has for centuries.

THERMOPLASTIC MEMBRANES

This portion deals principally with PVC and co-polymerized alloys of the same. Some first generation membranes did not have internal reinforcement and routinely experienced loss of chemical plasticizers. Such weathering (rapid in many instances) left these one-ply membranes brittle and vulnerable to rupture under abrupt or concentrated loads. Star-type breaches (*Figure 8*) were a customary response when these products were subjected to hail.

Strong fabric reinforcements were incorporated into later products. As a result, service life vastly improved for many products, but changes in plasticizer chemistry did not always spell success. Hail damage could still result for some membranes, although the reinforcing scrim limited the size and shape of the breach from impact (*Figure 9*). Both images represent fully compromised roofs. However, the latter example, being a modern formulation on a good scrim, should not have occurred and represents a substandard product; it was stiff and boardy (even at moderate temperature) and had clearly lost plasticizer. Although many commercial warranties exclude coverage for hail, quality thermoplastic membranes can withstand fairly aggressive exposure and are tested and rated for the same.

As with shingles, there can be astonishing lot-to-lot variation in PVC products, even on the same roof. Our experience on a large distribution center in Kentucky is noteworthy. One phase (roughly half of the building) received a new roof covering in 1988; the adjacent half was re-roofed in 1989 using the same vendor's product. A 1992 hailstorm ravaged the newer portion (*Figure 10*) while the older part was virtually unaffected. This illustrates the continually changing formulation chemistry -- some of it good, some not.

Figure 8 – Star-type breaches resulted when first-generation PVC membranes were subjected to hail.

THERMOSETTING MEMBRANES

In contrast to plastic sheets described above, this is the family of rubber membranes. Fully vulcanized elastomers (EPDM is the best example) do not become rigid and "boardy"

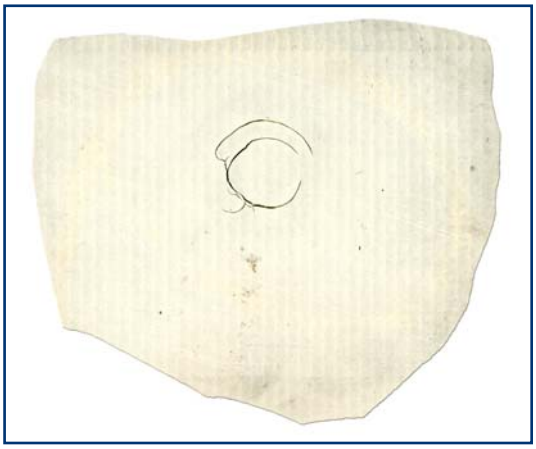


Figure 9 – Internal reinforcing fabric limits the size and shape of the breach from hail impact.

when cold, nor do they experience leaching of crucial ingredients. Again, the use of rubber membranes in the domestic marketplace has been rife with experimentation, but this family of products enjoys outstanding hail resistance (although many such roofs have stone topping). Recognizing this attribute, one leading manufacturer now extends warranty coverage for hail particles up to and including two inches in diameter. This is for a smooth-surfaced configuration, having no stone ballast or other topping.

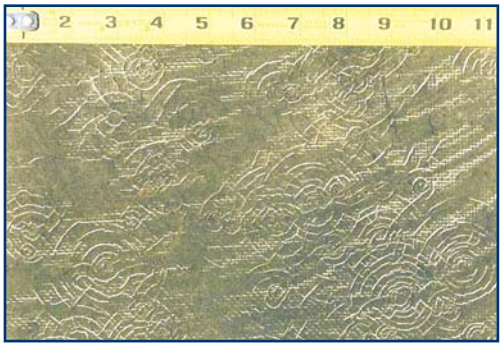


Figure 10 – a hailstorm ravaged this 1989 membrane while the older 1988 phase (same membrane vendor) was virtually unaffected. The loss should not have occurred and represents substandard product.

Even though characterized by 300-400% elongation, EPDM can still be breached by hail. Investigation of a major storm in Tennessee revealed small holes in a smooth-surfaced sheet having internal reinforcement. This occurred because, while reinforcing fabric imparts tensile strength, it limits the ultimate elongation. Vertical deformation at the more pronounced hail hits exceeded the breaking strain of the product. However, as with reinforced thermoplastics, tearing was contained and limited at each rupture.

It should be noted that indentations in the insulation may result even if membrane compromise is not recorded. Broken insulation facers, wetting at individual punctures, and distorted stress plates (for fasteners) must all be considered during a hail claim investigation.

BITUMINOUS MEMBRANES

All forms of bituminous roofing should have a UV shield of some type in order to achieve service life expectancy. This protection comes in the form of ceramic granules, gravel surfacing, insulating paver tiles, aluminum coatings, latex paint, high-albedo coatings, clay emulsion, etc. Loss of protective coating leads to rapid degradation of the bitumen. Modern, smooth-surfaced, built-up roofs have fibrous glass felts, providing a sturdy, finished membrane. However, the coating can be compromised by hail exposure, even when the felt plies remain intact (*Figure 11*). Most such occurrences can be restored by application of new coating, observing all the appropriate (and recognized) surface preparation parameters.

When there is uncertainty about whether felt plies have been damaged, a laboratory procedure can yield good insight. With careful sampling directly over a hail hit, bitumen can be removed from the felt by solvent extraction to permit microscopic examination of reinforcement. *Figure 12* depicts magnification of fibrous glass in the immediate region of minor impact. Glass fibers are actually hollow, as can be seen at this level of magnification; note that individual filaments were not ruptured from this particular hail event.

The granule-surfaced modified bitumen depicted in *Figure 13* was on a major upscale facility of notoriety and was the focus of a recent dispute. The surface markings shown were claimed as hail compromise when, in fact, they are the attempts after installation to rework scarred regions with a torch and additional granules (for cosmetic purposes). Hailstorms do not produce rectangular or linear pockmarks, even with highly angular approach directions. Some theories about hail damage, enthusiastically communicated to this writer, seem impervious to contamination with fact.

Figure 13 – Granule-surfaced modified bitumen has been reworked with a hot trowel and loose granules for cosmetic purposes. The markings are not from hail.

Figure 11 – Roof coating can be compromised by hail exposure, even when the felt plies remain intact.

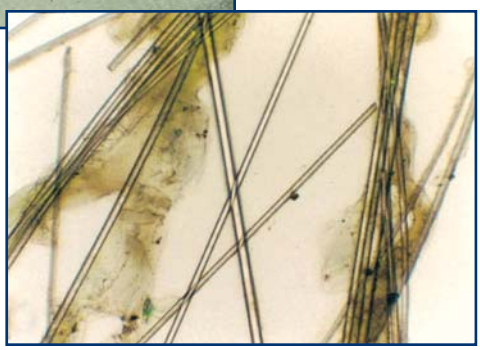


Figure 12 – Magnification of fibrous glass in the immediate region of minor impact. Individual filaments were not ruptured from this particular hail event.

PERIPHERAL OBSERVATIONS

Deformed cooling fins on HVAC units are the sure signature of hail exposure (*Figure 14*). The condition can be moderate, corrected by a tradesman "combing" the fins; it can also be severe, rendering such attempts futile.

Examination of accessory metals such as gutters or light-gauge flashings (*Figure 15*) can also be helpful in evaluating the severity of hail exposure. Particle diameter can often be estimated, and directional ori-

Figure 14 – Deformed cooling fins on HVAC units are the sure signature of hail exposure.

entation of a storm can sometimes be gleaned from the "splatter" marks left on equipment hoods. Splatter marks (removal of the oxidized surface of aluminum and some types of paint) will be comparatively shiny and can corroborate hail exposure when contrasted with adjacent dull surfaces. From this aspect, metal mansard and connecting canopies can yield good information for damage assessment as well.

THE PHYSICS OF ICE

Vulnerability to hail damage depends on many factors such as roof slope, presence of underlayment, nearby tree cover, reinforcement type, deck span, and directional orientation of the storm. Even the density of hail particles is considered, as we know that hail can indeed have varying properties.

Motorists (storm-chasers) have reported that golfball-sized stones did not break windshield glass. Both hardness of the stones and angle of impact factor heavily into all instances of property damage. Soft stones result when temperatures aloft are warmer than those known to generate very hard particles. Beyond this, hailstones are seldom perfectly spherical. Many have a cluster of spikes, likely caused by spinning while aloft (*Figure 16*).

Some hailstones are cloudy throughout, while others are virtually clear. When cut in half, hail may have distinct layers of clear ice separated by layers of cloudy ice, similar to the rings observed on cut trees. So hail has its spectrum of properties, ranging from "freezer-hard" to slushy.

In evaluating roof resistance to hail, the problem is defining what is ice? Or more to

Figure 15 – Light-gauge metal flashings can be helpful in evaluating the severity of hail exposure.

Figure 16 – Large, highly angular, spiked hailstone (image from www.ucar.edu/research/storms/hail.shtml).

the point, what is hail? Testing agencies have struggled with this notion, and Underwriters Laboratories concerns itself with the matter. UL 2218 is a test procedure using steel balls to arrive at rankings (classes 1 through 4) depending on severity of exposure. Class 4 is best, using ball diameter of two inches. As with any form of consensus testing, it's quite helpful in comparing products. Whether or not it truly simulates hail is another argument, so the procedure is aptly termed "impact resistance" testing.

SUMMARY COMMENTS

Experts are presumably retained because there is a need to evaluate behaviors of different materials and systems. The diagnostician's first task is to determine whether hail has even been experienced. Hopefully, the foregoing discussion will yield some clues in that determination. Secondly, the task is to evaluate whether there is, in fact, roof compromise. Remember that most roof types, in order to be code-compliant, have endured at least some hail simulation in order to be listed in various directories. Then, if compromise has been sustained, quantifying the density of hits is necessary, along with an estimate of particle diameter if possible.

Several Web-based search programs monitor and report hail activity, sorting the accumulated results by location, date, particle size, and other parameters. Newspaper accounts, sometimes relying on witness description, have proven unreliable in several of our investigations. There is often a range of diameters received, and there is seldom incentive to report the "average"; it seems the larger size makes better copy. We have direct experience working a "4-inch storm" when in fact there was clear evidence on the roof of 1-1/8-inch particles.

It should be noted that much of the hail (a majority by some accounts) received in the U.S. has a diameter of 3/8 inch or less. Particles of this size should not compromise any type of functional covering. Highly weathered roofs will obviously be more vulnerable to damage than newer or better-maintained assemblies. All damage encountered should be viewed in the backdrop of roof condition, underscoring the need for expert assessment.

And so it seems that 1) roofs change (weathering during service life), 2) product formulations change, and 3) hail has variable properties. The reader may begin to appreciate the absence of "bright-line distinction" in what constitutes damage to roof coverings. Nonetheless, there should be better congruency by unbiased experts in determining storm compromise. While there are inescapable variables, there are also some very reliable constants.

Lyle Hogan

Lyle Hogan is owner of Fincastle Engineering, Inc. He is a registered engineer in six states, a Registered Roof Consultant, a fellow of RCI, senior editor of *Interface*, and an ICC structural masonry inspector. Mr. Hogan has executed roofing projects in half of the United States using a variety of systems. His technical articles have appeared in numerous technical publications.