PROTOCOL FOR ASSESSMENT OF HAIL-DAMAGED ROOFING

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A protocol has been developed for assessing hail-impact damage to steep-slope roof systems. The protocol includes a definition of hail-caused damage to roofing, a detailed field inspection procedure, and a calculation method for determining repair or replacement of hail-damaged roofing materials based on economics. This paper limits its discussion to asphalt shingles and wood shingles and shakes, although the general principles can be applied to other steep-slope roof systems. Hail damage is quantified by examining test areas on directional roof slopes to determine the number of damaged shingles/shakes per roofing square. The difficulty in making roof repairs is incorporated via a repair difficulty factor. Finally, the decision to repair or replace hail-damaged roofing is made on an economical basis by comparing expected costs to remove damaged shingles/shakes versus costs to replace roofing on entire slopes.

KEYWORDS

Hail, Hail Damage, Test Areas, Asphalt Shingles, Wood Shingles, Wood Shakes.

PURPOSE

The purpose of this paper is to present a protocol for assessing of hail-impacted roofing that has been developed by the authors' firm. This methodology evolved in the early 1960s for use in field inspections and was incorporated formally in *Hail Damage to Wood Shingle and Shake Roofs: Assessment Criteria* [1]. This protocol has been taught in numerous short courses and seminars and adopted by architects, engineers, consultants, roofing contractors, insurance adjusters and other parties interested in assessment of hail damage to steep-slope roof systems (Property Loss Research Bureau, 1994). Recent papers by Cullen and Murphy have addressed hail damage to roof systems but have not provided a procedure for evaluating whether a roof should be repaired or replaced [3, 4, 5, 6].

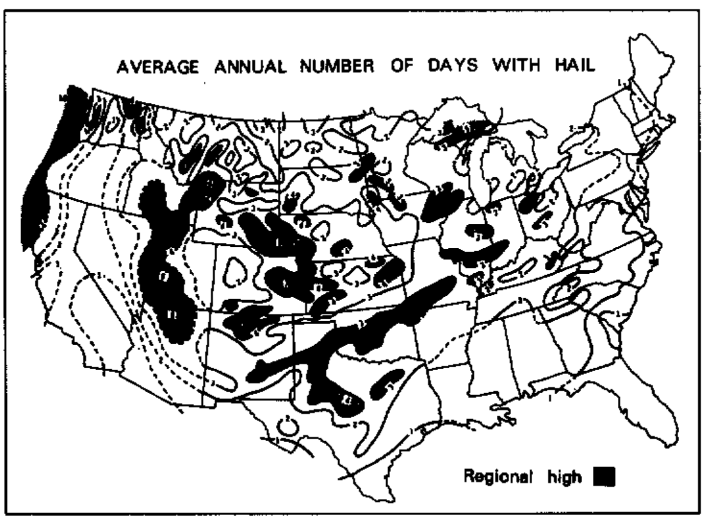

Figure 1. (Changnon, 1996) [2].

A protocol is necessary to promote an accurate and repeatable method for evaluating roof damage caused by hail. Without such, the determination can bring disagreement among involved parties, such as owners, contractors, insurance, adjusters, consultants and roofing material manufacturers. The need for a protocol is widespread with more than 75 percent of the cities in the continental United States sustaining one or more hailstorms per year (Figure 1). Huge annual insurance losses for hail-damaged roof systems have inspired standards to classify the hail resistance of roofing products [7, 8, 9]. Presently, standards evaluate only new roofing materials for impact resistance. Nonetheless, the size of hail required to damage most roof systems depends on each roof system's product type, age, condition, and other factors [10].

Asphalt shingles and wood shingles and shakes are some of the most common roofing materials applied to steep-slope roofs in the geographical areas of the United States that experience the most damaging hailstorms [11]. This region extends east/west from near the Mississippi River to the leeward side of the Rocky Mountains and north/south from North Dakota to Texas (Figure 2).

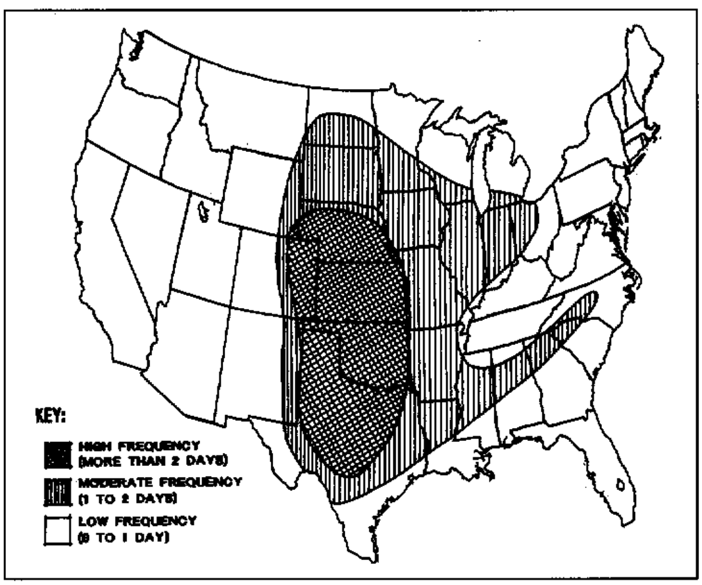

Figure 2. Point frequency of hailstones 1- to 2-inch diameter in a 20-year period.

The authors' firm has performed impact tests of many roofing materials since 1963. The first study involved the effects of hail damage to wood shingles and shakes. At the conclusion of the 10-year study, a summary of test results was published [12]. In 1983, the study was expanded to include the effects of hail on asphalt shingles, fire-retardant-treated wood shingles and shakes, fiberboard panels, and aluminum panels. Meteorologists at the author's firm have conducted storm surveys of major hailstorms and developed software programs that search historical data bases for hail-fall records and analyze the risk of damaging hail in the continental United States.

ASSESSMENT PROCEDURE

The assessment procedure is based on determining whether there is hail-caused damage and if so, quantifying the amount of damage on each roof slope. It also involves determining whether repair of individual shingles or shakes or roof system replacement on an entire slope (or roof) is the economical choice. The first step is to inspect the roof system and differentiate hail damage from non-hail damage. Functional damage to roofing materials from hail has been defined as the diminution of water-shedding capability or reduction of the expected service life of the roofing material [13]. The second step is to quantify the damage on each directional slope by examining test areas. The third step is to determine through a repair cost formula whether repair or replacement of the roofing material is appropriate.

IDENTIFICATION OF HAIL-CAUSED DAMAGE

Asphalt Shingles

Hail-caused damage to an asphalt shingle in roofing is rupture of the reinforcing mat or displacement of granules sufficient to expose underlying bitumen [14]. The former is a penetration of the shingle that, in effect, removes a ply of roofing and has the potential for water to reach the fasteners or butted joints in the underlying shingle. The latter represents a potential loss of expected service life of the shingle. However, we are not aware of any studies to date that have demonstrated a quantifiable loss of shingle life where the bitumen is exposed to the weather.

Rupture of the reinforcing mat involves either bruising, which can be felt as a soft spot on the shingle (much like an apple bruise), or puncturing where there is a hole in the mat. Bruises are soft areas large enough to be detected by finger pressure and generally are accompanied by a sufficient loss of granules within the impact area to expose the underlying bitumen (Figure 3). Bruises in field shingles often occur in the less-supported areas of the shingles, such as along ridges, valleys, and overhanging roof edges or above the tops of shingle head laps, (about 2 inches [52 mm]) from shingle butt edges). Our field experience and laboratory testing have shown that punctures or bruises in asphalt shingles rarely occur with hailstones less than 1 inch (25 mm) in diameter, unless the shingle is poorly supported and deteriorated. Generally, we find hard ice balls that impact perpendicularly can damage weathered asphalt shingles when they are 1¼ inches (32 mm) in diameter and new shingles when 1½ inches (38 mm) in diameter [15]. Similarly, Greenfeld and Koontz have found that impact-caused fractures in new shingles occur with ice spheres in a range from 1¼ inches (32 mm) to 2¼ inches (58 mm) in diameter depending on shingle product and support conditions [16, 17]. Large hailstones produce mat fractures or bruises close to the diameter of the hailstone especially where the shingle has less underlying support.

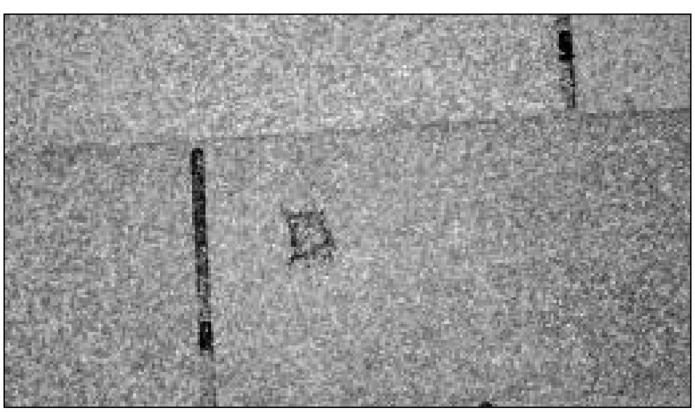

Figure 3. Bruise in a fiber glass composition shingle from hail impact.

In some instances, granules are dislodged from the shingles to expose bitumen without shingle mat rupture. Minor granule loss caused by a hailstone impact that does not result in the exposure of the shingle bitumen has not been found to cause any measurable loss of service life for the impacted shingle [15]. Chipped shingle edges do not shorten shingle service life and, hence, generally are not included in the shingle damage count.

Areas of shingles that have bitumen or mat exposed must be examined to determine whether the damage was caused by hail or any other factors. Mechanically caused marring of shingles during shipping, handling and installation can disturb the granule surfacing enough to displace and expose bitumen. This is true particularly for warm fiber glass shingles subject to foot traffic on the roof. Marring results in a ridge of bitumen and granules at the perimeter of the mark that is not found in hail-caused damage (Figure 4). Patterns of weathering or manufacturing deficiencies can result in areas of little to no granule coverage on the shingles. Bundle variations should be relatively easy to detect because the affected shingles would be arranged in diagonal or straight-up columns. In contrast, exposed areas of asphalt caused by hailstone impact would be roughly circular in shape and randomly distributed in the shingles. Blistering may appear as small bubblelike features in the granule crust whose tops weather away to leave pits in the shingles; the pits have steep sides and often extend to the mat. Granule flaking from old organic shingles can appear as areas of exposed bitumen that have a weathered gray color (Figure 5). Therefore, the overall condition of the shingles on the roof must be evaluated to differentiate between hail-caused damage and other types of damage.

A number of findings have been documented in our laboratory studies and confirmed in our field inspections of how impact-caused fractures in the mats weather [15]. The bitumen exposed in a recently caused hail impact will have a shiny black color. The bitumen weathers through photo-oxidation from a black to light-gray color over time. Impact-caused fractures in shingles initially have sharp edges that, over time, weather to rounded forms. The overall size of the damaged area does not increase measurably even after years of exposure. In fractured organic mat shingles, the shingle mat will shrink and curl back from the fractured area over a period of years. With fiber glass-reinforced shingles, fractures widen but do not propagate visibly.

The author's firm conducted a study on asphalt shingles that delineated hail-caused impacts from ball-peen hammer impacts intended to simulate hail damage [18]. Hammer impacts usually involved crushing or breaking of the granule surfacing on the shingles whereas hailstone impacts do not. Also, hammer impacts leave marks that are roughly the same size and shape regardless of roof slope, whereas hail-caused impacts are of various sizes, shapes and impact angles. Furthermore, people tend to cluster hammer impacts in the middle portion of the shingles or roof, whereas hail impacts are distributed randomly on the shingles or roof.

Wooden Shingles and Shakes

Hail-caused damage to wood shingles and shakes is defined as a split or puncture in the wood caused by hailstone impact [12]. Hail impacts in wood leave recognizable impact marks where some of the gray-colored oxidation and/or organic surface growths have been cleaned away. A hail-caused split in the wood is indicated by an impact mark coincident with a fresh split in the wood (Figure 6). Wood splits from hail impact occur at the moment of impact, and impacts that do not split the wood (e.g., spots, dents, gouges) are not considered damaged. Long-term natural weathering studies following impacts with simulated hailstones have confirmed that impact marks without initial splitting do not create a potential for future splitting [19]. A hail-caused split in a wood roof system does not mean that a leak will occur at that split because there are additional layers of wood protection (and interlacing felt on a shake roof system); however, the potential for split alignments with other splits or joints between shingles or shakes and loss of pieces of the shingle or shake justify classifying the split as damage requiring remedial work. A hail impact sufficient to puncture the wood, most commonly found in thin areas of shakes, also is damage because it involves the loss of one layer of roofing. Impacts by hailstones do not affect the fire or moisture resistance of pressure-treated wood or promote fungus or lichen growths or algae staining.

There are several characteristics that distinguish splits caused by hail impact from those due to natural weathering. A split due to hail impact will expose a bright, unoxidized color on the entire fracture surface in contrast to the gray color of a weathered shingle or shake surface. The edge of the fracture will be sharp, and the split will be coincident with a significant hail-caused impact mark. The sharp-edged split can be "pieced back together," and no shrinkage will be evident between the sides of the fracture. On occasion, a split can occur from hail impact that is not coincident with the impact mark, mainly when the significant impact occurs at the edge of a cupped shingle or shake or the shingle or shake is supported unevenly by the underlying course. Our laboratory testing has indicated that hard ice balls must be approximately 1¼ inches (32 mm) in diameter or larger to split a wood shingle in good condition and approximately 1½ inches (38 mm) in diameter or larger to split a wooden shake in good condition [10]. Similar test results were generated by others [20, 17]. Shingles or shakes adversely affected by erosion, rot, cupping or curling may be vulnerable to impacts from smaller hailstones.

Most splits observed in cedar shingles or shakes are due to grain patterns of the wood and repeated shrink/swell cycles induced by changes in moisture content, referred to generically as "natural weathering." Long-term net shrinkage is greatest tangential to the growth rings of the wood that initiates and extends splits that develop in the wood. Natural

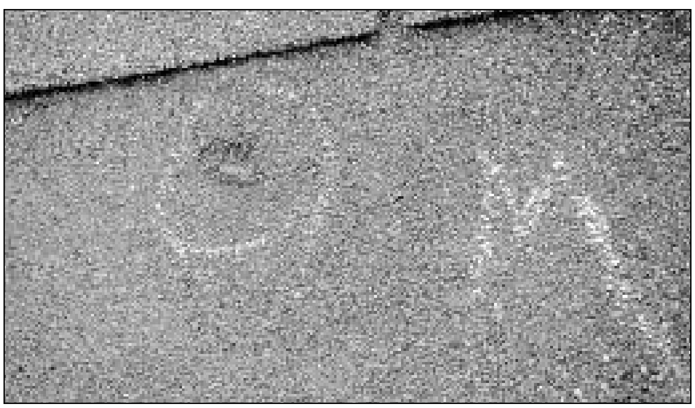

Figure 4. *Marring of a composition shingle surface from mechanical abuse.*

Figure 5. *Delamination and flaking of the tack coat and granules because of material deficiencies.*

Figure 6. *Hail-caused split in a cedar shake with the impact mark circled.*

weathering splits are distinguishable from hail-caused splits by their color, shape and pattern. Splitting of wood caused by natural weathering will be more common in shingles or shakes with flatgrain-cut wood as opposed to edgegrain-cut wood. Field studies have found that flatgrain-cut wood shingles or shakes are approximately twice as likely to split, and the most common area of splitting is along the heart center of the flatgrain, the line where the greatest shrinkage strains occur [12] (Figure 7). Splits that have developed from natural weathering will grow in a tapered fashion typically from the butt edge of the shingle or shake toward the head. The edges of the split tend to be rounded from being smoothed by water erosion. The two sides of the split cannot be "pieced together" because of the net shrinkage of the wood and erosion of material. Splits from weathering also tend to be V-shaped in cross-section, because the top surface of the wood dries more quickly and shrinks more than the bottom surface. Surfaces of the split are exposed and gray from weathering. The depth of the gray color on the split interior will vary with the relative shape and width of the split.

The other type of split that must be distinguished from hail-caused damage is a split caused by footfall. After a hailstorm, an owner may have had inspections made by several contractors or adjusters who walk on and break some shingles or shakes. A recent split caused by footfall will resemble the hail-caused split in its having sharp edges and bright color on the fracture surfaces, but it will not have the coincident initiating impact mark. In many hailstorms, each shingle or shake will exhibit numerous impact marks of varying sizes, and the skill of the inspector must determine whether a split was caused by impact or footfall. Shingles or shakes that have cupped, curled or worn thin are most susceptible to footfall damage, and foot traffic generally is heaviest near valleys and ridge areas.

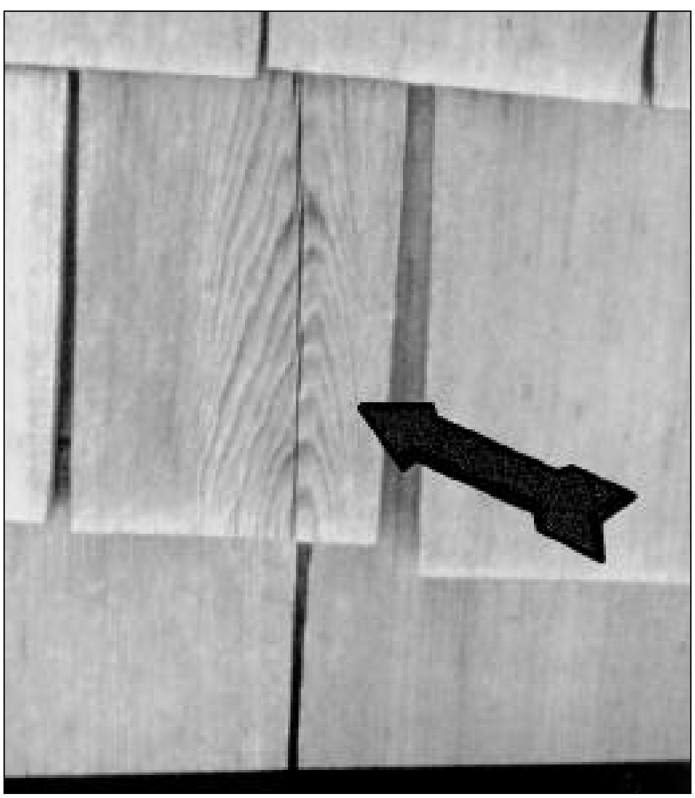

Figure 7. Split in a flatgrain-cut shake due to natural weathering.

Hail-caused punctures in a wood shingle or shake are discernible because sharp-edged openings expose unweathered wood of the underlying shingle or shake. Additionally, there still may be pieces of wood broken away by impact along the edges of the opening. Openings due to long-term water erosion, on the other hand, are contrasted by having smooth edges and thin wood around the opening. The eroded openings most commonly form just below the overlying butt of a shingle or shake or in the upper portion of the joint between shingles or shakes (Figure 8). The wood exposed on the underlying shingle or shake will be a weathered gray similar to other exposed areas of the wood. It can take approximately six to 12 months of exposure to weather, or oxidize, cedar from orange to gray. Areas that have an eroded opening often will have a comblike appearance, where the denser winter wood remains and the less dense summer wood has eroded.

Other possibilities exist for hail-caused damage to wood shingles and shakes. When hailstone impacts chip or break off pieces of wood from shingle or shake edges sufficient to expose interlayment or underlayment felt or fasteners (that had been covered previously), functional damage has occurred. Edges and butts of wood shingles or shakes chipped where the wood already has rotted would not be considered functional damage.

FIELD INSPECTION TECHNIQUES

Equipment

The proper equipment is essential in quantifying the amount of hail damage to the roof system. Access the roof with ladders, man-lifts or other means to provide up-close examination of the roof system and document the roof inspection with photographs, as well as written or recorded notes. In most instances, it will be necessary to diagram and measure the roof with a measuring tape. Lumber crayons or chalk can be used to mark test areas and identify specific conditions on the roof. Yellow crayon or white chalk provides good contrast with the darker colored roof surfaces, and marks made by crayon or chalk are temporary and will wash away during subsequent rains. Use of a magnifying glass can be helpful to closely examine the roofing material. Safety is paramount in all inspections and

Figure 8. Eroded opening in a cedar shake.

especially critical on steep-slope roofs. For steeper slopes, consider safety harnesses and ropes. Wear soft-soled shoes during the roof system inspection, not only for safety but also to protect the roofing materials; care should be taken to avoid stepping on fragile, cupped or curled shingles or shakes.

Initial General Observations

After measuring and diagraming the roof, make an overview of the roof to assess its general condition. Many roof conditions often are confused with hail-caused damage. Roof deficiencies, including installation and weathering problems, should be noted. Flashings and other areas where problems with water infiltration are likely to occur should be examined. Inspect various metal roof appurtenances, such as plumbing vents, metal vent caps, etc., for evidence of hail fall; then, determine the relative size of the hail plus the direction of the hail fall. Generally, "skid" or "spatter" marks in oxidation on surfaces of materials leave a record of impacting hailstone size and direction [21]. Spatter marks are similar to bug smears on a vehicle's windshield. Spatter marks are formed as hail impacts a surface and cleans some of the oxidation away; such spatter marks fade with time and the spot usually re-oxidizes in about one to two years. Spatter marks are narrower at the point of impact and widen and fan out to indicate the hail fall direction. The width of the mark near its narrower end is close to the diameter of the hailstone. Spatter marks are particularly distinct on painted metal surfaces with substantial oxidation—for instance, air-conditioning units and electrical transformers. Areas where algae, microorganisms or grime is cleaned away by impacting hailstones also can be good indicators of hailstone attributes.

Soft metals, such as lead and aluminum, are susceptible to indenting even from small hailstones that have insufficient energy to damage the roof covering. In general, dents in the softer metals are close to the diameter of the hailstone. Because dents in metals do not weather away, the metal becomes a record of all previous storms. In some instances, old roof vents are not replaced when a building is reroofed. Therefore, care needs to be taken to determine which dents are from previous hailstorms and which are from the most recent.

Roof coverings must be examined on each directional slope. Hail fall normally is wind-driven and directional; hence, hail damage likely will be more severe or concentrated on windward roof slopes relative to the leeward slopes. Further, steeper roof slopes usually exhibit less hail damage than shallow slopes as hail impacts typically will be less perpendicular to their target roof coverings. The angle of hailstone impact on the roof covering is one of the important factors in determining whether the roof material will be damaged [17].

A wood roof system should be inspected relatively soon after the hailstorm. In our experience and testing, we have found that hail-caused damage becomes less visible with time on wood roofs as the spatter marks and dents associated with hail-caused splits begin to fade or weather away, respectively. Spatter marks on wood generally remain visible for about one year after impact by hailstones until the wood surface reoxidizes. The spatter marks fade more quickly with smaller/softer hailstones, and marks remain visible a longer time if the impacts have removed organic surface growths (e.g., fungus or lichens). Dents in the wood surface will remain detectable until the wood fibers recover or the surrounding wood is eroded away. In general, dents in the wood are about one-half the diameter of the hailstone whereas spatter marks are closer to the diameter of the hailstone. Hail-caused bruises on an asphalt shingle roof system generally become more visible, especially after the first few rains which wash loose granules away from impact areas.

A wood roof system should be inspected while in a surface-dry condition. First, wood roof systems are more slippery when they are wet. Second, wood colors are darker when wet, making it more difficult to identify the impact marks. Third, when wet, wood swells, and fine hail-caused splits tend to close and become more difficult to see.

A general roof inspection for hail damage begins with examining areas where the roof covering has less underlying support. These areas are damaged more easily by hailstone impact than areas where the roof covering is supported solidly. Shingles that extend over the roof edge at eaves or rakes are susceptible to being broken by hailstone impact. Areas where shingles have air pockets beneath them (i.e., areas of ridges or valley troughs) are also more vulnerable to impact damage than well-supported adjacent areas.

TEST AREAS FOR INSPECTION

The authors' firm developed the concept of the test area to quantify the amount of hail damage across a roof slope [1]. Test areas measuring 100 square feet (9.3 m²), or one roofing square, are examined on each directional roof slope. Each shingle or shake within the test area is examined closely (Figure 9). The examination of one square is a

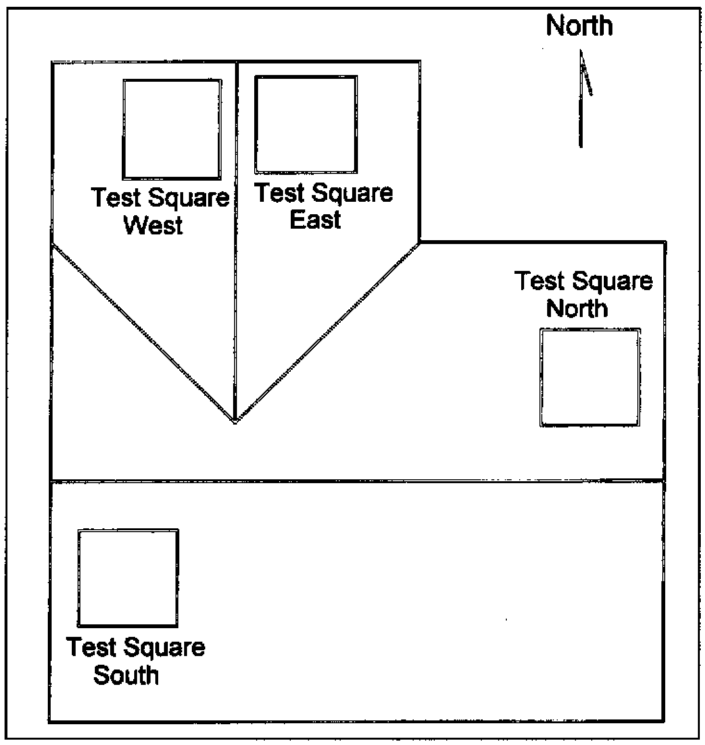

Figure 9.

large enough expanse represented the entire directional slope on most residential roof systems and conveniently facilitates the repair cost calculation. Close examination involves hand-manipulating the wood shingles or shakes by pressing the bottom corners downward to check for hail-caused splits. Similarly, examination for hail damage in asphalt shingles involves pressing downward on shingle surfaces with fingers or thumbs to detect soft spots, which indicate hail-caused bruises. Hail-caused damage can be found at the weathering surface. For this reason, laboratory tests are not required to determine whether the product has been hail damaged.

Test areas should be located away from overhanging tree limbs or structures, which offer protection to the roof, and in areas with little foot traffic. Test areas should be examined on each directional slope in order to account for the variations of hail damage due to different angles of hailstones impacts and varying roof system conditions. Identify the hail-damaged shingles or shakes within test areas with the letter X and circle the impact mark. Other conditions that may be marked include foot traffic damage identified by the letter F and weathering by the letter W.

Additional test areas should be outlined on the same slope when a different type or age of roof covering is encountered. Also, if a roof is quite large, additional test areas should be examined for each 50 squares of roof-slope area.

REPAIR COST FORMULA

The repair cost formula provides a method to determine whether it is more economical to repair individual shingles or shakes or replace the hail-damaged roof covering on the entire slope. The formula is expressed as follows:

$$RC = D \times U \times R \times A$$

RC = the cost to repair the entire slope (in dollars)
D = the number of damaged shingles or shakes per roofing square
U = the unit cost to repair a shingle or shake (in dollars)
R = the repair difficulty factor
A = the actual area of the slope (in roofing squares)

The repair cost of a roof slope is based on the number of hail-damaged units per square multiplied by the unit cost of the repair and the area of the slope in squares. Unit repair costs vary by type of roof covering and other factors. Currently, the cost to repair an asphalt shingle, wood shingle or shake varies from about $5 to $10 per unit in the United States on single-story buildings with a slope less than 8:12. These repair costs have been obtained through discussions with roofing contractors throughout the United States, and prices vary depending on local material, and labor costs, type of repair and demand. The repair difficulty factor is based on the age and condition of the roofing and is assigned values ranging from 1 to 2. Roof coverings in good, fair, or poor condition can be assigned repair difficulty factors 1, 1.5 and 2, respectively, which effectively adjusts the unit cost of repair. The repair difficulty factor considers that roof coverings become brittle with age and are broken more easily during the repair process; therefore, difficulty factors of 1.5 or 2 account for the additional breakage that may occur or extra care needed in the repair process. The repair difficulty factor is a subjective determination based on the inspector's experience in assessing and/or repairing roofs.

There are many types of repairs that can be done on asphalt shingle roofs that have limited hail damage. One option is to remove and replace the damaged shingle. Shingles sealed down with an adhesive strip will have to be unbonded before the fasteners are removed in the damaged shingle, as well as in the overlying shingle. When new shingles are installed, dabs of asphalt plastic cement can be used to seal the new shingles to the original shingles and cover the old nail holes. If the shingle color cannot be matched or the damaged shingle adequately removed, a surface repair can be made with asphalt plastic roof cement and shingle granules [22].

On wood shingles and shakes, removal of the damaged unit will involve splitting the wood around the fasteners using the blade end of the roofing hammer or cutting the fasteners with a slate bar. The pieces of the damaged unit are removed and a new shingle or shake split to the appropriate width and inserted. To avoid "face-nailing," the new shingle or shake is "toe-nailed" prior to driving the unit flush with the course line. Another repair option is to insert a metal shim beneath the damaged shingle or shake. The corners of the shim should be bent downward prior to inserting it in order to hold the shim in place. [12]

The actual area of each directional roof slope is used in calculating the repair cost. In cases where a building's roof area and number of hail-damaged shingles or shakes per roof square are similar for each slope, the number of hail-damaged shingles or shakes per square can be averaged over the entire roof. For example, if there is an average of 10 hail-damaged shingles per square on a 30-square roof in good condition and the unit repair cost is $10 per shingle, the repair cost calculates to $3,000. If the slope areas and/or number of hail-damaged shingles per square are not similar, then the repair cost should be computed on a per-slope basis.

Additional costs are incurred for repair or application of roofing materials on slopes that are very steep, buildings that are more than one story, or roofs with difficult access. These costs can be incorporated into the unit cost of repairs or itemized separately. After the repair cost of the roof slopes has been computed, it can be compared with the replacement cost (which includes tear-off) of the existing roof covering. When computing the replacement cost for a slope (or roof), the actual area is increased by a factor which typically ranges from 10 to 20 percent depending on the configuration of the roof, which accounts for waste and extra use of roofing materials. When calculating replacement costs of individual slopes, waste and extra use factors would be incorporated to tie-in adjoining valleys, ridges or hips. Then, sum the costs to repair or replace the roof on a slope-by-slope basis and compare it with the cost of entire roof replacement. When the roof has multiple layers, the replacement cost may be increased if local insurance regulations and/or building codes require the removal of all layers down to the roof deck. If the cost to repair the individual hail-damaged roofing shingles or shakes is less than the cost to replace the roof covering on the entire slope/roof, the economical choice is made to repair the slope/roof. If the repair cost equals or exceeds the replacement cost of the roofing on the entire slope/roof, then the economical choice is to replace the entire slope/roof. Many insurance carriers have determined that the economical comparison of repair be made against 80 percent of the cost for slope or roof replacement, a conservative approach that favors replacement.

When repair is the economical alternative, other issues may arise involving aesthetic concerns or the remaining service life of the roof covering. Aesthetic concerns, such as color matching, are not included in the damage repair formula because this is subjective and cannot be quantified. If the roof covering is approaching the end of its useful life, building owners will have to decide whether roof repairs should be performed or repair monies should be applied to the replacement of the entire roof covering.

It is important to assess each slope of each roof individually, regardless of other roofs in the vicinity. There are significant variations in types of roofing products, roof ventilation, roof pitch, roof orientation, weathering effects, etc., which can make some roof slopes more susceptible to damage than those adjacent roof slope or roofs on other neighboring buildings.

SUMMARY

A protocol has been developed to assess hail-caused damage to the most common steep roofing materials. The procedures of this protocol involve differentiating hail-caused damage from damage from other sources, examining the roof system up close in test areas to determine the extent of damage, and computing and comparing the costs of repairing vs. replacing roofing materials on a slope by slope basis. These procedures have been used successfully in field inspections for more than 30 years, and we hope this protocol will aid others in their assessments of hail-caused damage to steep-slope roofing.

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