The Roofing Industry Committee on Weather Issues Inc. (RICOWI) has completed its second Hailstorm Investigation Program (HIP). Seven inspection teams examined more than 100 roof systems during a four-day period to evaluate the effects of a significant hailstorm that passed through portions of the Dallas/Fort Worth metropolitan area on May 24, 2011. The purpose of the project was to document the effects of hail impact on a variety of roofing products and describe roof assembly performance and modes of damage for substantiated hailstone sizes. The Dallas/Fort Worth metropolitan area had been targeted because of its concentration of impact-resistant, steep-slope roofing products.

METEOROLOGICAL INFO

On May 24, 2011, three rounds of thunderstorms containing large hail and tornadoes passed through portions of north Texas, including the Dallas/Fort Worth metropolitan area. Several of the thunderstorms were super-cell variety containing very large hail. The National Climatic Data Center publication Storm Data listed 32 reports of hail in Tarrant County (nine reports stated hail sizes of 2-in. diameter or larger) and ten reports of hail in Dallas County (three reports of 2-in. diameter or larger). See Figure 1.

Dallas and Tarrant County are the most populous counties in the Dallas/Fort Worth area, and most of RICOWI’s inspections were made in these counties. Extremely large hail greater than 4 inches in diameter was reported in a portion of northern Tarrant County (cities of Avondale and Keller) and at a separate location in western Dallas County (city of Irving). The hailstorms damaged planes at DFW Airport and Love Field, Dallas. There were large areas of the two counties where hailstones from 1 to 2 inches in diameter were reported (Photo 1).

Figure 1 – HailTrax report showed inspection locations along a portion of the storm path with radar-estimated hailstone sizes provided by Weather Decisions Technologies, Inc. (WDT). The area shown covers portions of the cities of Irving, Coppell, Dallas, and Carrollton, where the greatest concentration of inspections was made.
INVESTIGATION

A data form was developed to record pertinent information from each site. Data included location, roof construction details, generic roof material descriptions, roof pitch, estimated maximum hailstone size at the site, and the type(s) and severity of hailstone impact damage to the roofing product. Impact effects were listed on a scale of 0 to 5:

0 — No apparent damage
1 — Surface impact marks without fractures or punctures
2 — Minimal damage (low severity and low quantity)
3 — Moderate amount of fractures, punctures, or spalling
4 — Moderate/severe denting of metal roofing
5 — Severe damage resulting in potential leakage

Inspection teams consisted of three members with a balance of manufacturer representatives, trade group representatives, engineers, roof consultants, roofing contractors, and insurance professionals. One team member would record the site data, one would photograph and log captions for the photographs, and one would inspect the property and mark items of interest.

The selection of inspection sites was targeted toward areas with moderate-to-large hail sizes and to include a variety of roof system types. Sites primarily were obtained through contacts of HIP or RICOWI member organizations and through local roofing contractors and government agencies. Typical inspections consisted of a complete visual survey of the roof surface, followed by randomly selecting sites where the hail hits were counted and the hail size was estimated. On each roof, several random test areas were selected for counting the locations that exhibited hailstone impact effects. Other building or surrounding elements were also used to establish the size of the hail at the specific site being investigated.

FIELD RESULTS
LOW-SLOPE SYSTEMS

The focus of the 2011 HIP investigation was the performance of impact-resistant roofing products as compared to those materials that were not rated for impact resistance. Although the testing for impact resistance applies to low- and steep-slope roof systems, it was difficult to determine if the low-slope roofing systems were rated. Limited low-slope roofing was inspected; however, roof membranes that were solidly supported and/or protected with gravel or stone ballast performed well.

Built-Up Roofing (BUR)

BUR roofs appeared to perform well. Five of the six roofs inspected were impacted by hail of 2¼ in. or larger, and one roof was impacted with 1¾-in. hail. All were rated with damage levels 1 or 2. Observations included scuffing and some gravel displacement by hail impact.

Modified Bitumen

A total of seven modified-bitumen membrane roofs were inspected in the study.
They were impacted by hail from 1¼ to 5 inches in diameter, with four of the seven being rated at damage level 5. One roof exposed to 2-in. hail had no damage.

**Single-Ply Sheet Membranes**

Three low-slope single-ply membrane roofs were inspected. One roof that was impacted by 1¾-in. hail was rated to have damage level 5; this roof had multiple temporary repairs over the reported fractures in the membrane, so the actual damaged areas could not be observed. Another roof was rated damage level 3 after being exposed to 2½-in. hail. One single-ply roof did not have any visible damage (level 0) when exposed to 2-in. hail.

**STEEP-SLOPE SYSTEMS**

**Asphalt Shingles**

A total of 63 asphalt or modified-bitumen shingle roofs were inspected during the survey, with 40 showing some form of damage (categories 2 or higher) and 28 having moderate (3) or greater damage reported. Maximum hail sizes on the asphalt shingle roofs inspected ranged from about ¼ to 3¼ inches in diameter.

Most of the asphalt shingles inspected (51) were standard fiberglass mat three-tab or laminated asphalt shingles, with 12 roofs having UL 2218 impact-resistance-rated modified-bitumen shingles. It is possible that some of the shingles listed as standard could have been impact-resistance-rated, but if this could not be confirmed, it was not listed as such. Substrates included primarily solid OSB or plywood decking where it could be determined.

Damage modes were primarily fracturing or rupturing of the shingle mats or broken shingle edges (*Photo 2*). Areas with fractured mats generally displayed loss of granules sufficient to expose asphalt, and the recently exposed asphalt was dark in color with limited oxidation. The 16 standard shingle roofs without visible damage (damage categories 0 and 1) had been struck with hail sizes from ¼ to 1¾ inches in diameter. Roofs with damage category 2 or higher had been struck with hailstones 1 in. or larger. Of the 25 standard asphalt shingle roofs rated with damage categories 3 or higher, 92% had been struck with hailstones 1¼ inches in diameter or larger.

Shingles with an impact-resistance rating performed better on average than the standard asphalt shingles. The average standard asphalt shingle damage rat-
Hail-impact damage was most concentrated on the windward roof slopes. Ridge and valley shingles with unsupported areas were noted as being damaged more severely than field shingles. In areas where hail sizes were less than 1 inch in diameter, there were no areas with noted significant or severe general granule loss, even in areas with 20 or more hail impacts per sq. ft.

Known or estimated ages of the roofs ranged from less than three to older than 15 years. Asphalt shingles that appeared (or were known to be) older than nine years and showed signs of embrittlement or deterioration were more susceptible to damage, and often the damage was more severe. The shingles that were nine years and newer...
or had unknown ages but were judged to be in good or excellent condition had an average damage rating of 2.1, while the shingles older than nine years had an average damage rating of 4.2.

**Tile**

One clay-tile (Photo 3) and four concrete-tile roofs were inspected during the survey, with all having some tile fractures from hail impact. Maximum hail sizes on the tile roofs inspected ranged from about 2 to 4 inches in diameter. The profiles included flat, mission, and roll style. Substrates, when they could be determined, were solid decking. Inspections occurred only in the areas where some of the largest hail fell.

*Photo 3 – Clay tiles fractured by hail impact.*
The damage mode was fracturing of the tile field or edge when struck with relatively large hailstones. Fracture surfaces from the recent hail displayed unweathered surfaces, while older fractures (from foot traffic or other previous damage) observed on the roofs often had grime or mildew darkening the surface. A preexisting crack pattern on one roof revealed single fractures near the lower right corner of interlocking tiles. In contrast, hail-caused fractures typically resulted in multiple fractures (shattering) from a single large impact.

When tiles had fractures caused by impact, the hail sizes were greater than 2 inches in diameter. Even in these cases, only a small percentage of tiles had been fractured. In some cases, hailstone spatter marks exceeding 2 inches in diameter were visible on the tile surface without fractures in the tile. Hail-caused damage was most concentrated on the windward roof slopes having the most direct hail impacts. Tiles were older than 12 years in all cases, yet all were considered to be in good condition. The age of tiles did not appear to have an appreciable effect on hail impact resistance. Large amounts of smaller hail had no adverse effect on the tiles where the impact marks were apparent.

**Cedar Shakes/Shingles**

Five cedar-shake or shingle roofs were inspected during the survey, with four showing some form of damage (Photo 4). All roofs had surface marks from impacting hailstones, but impact-caused splits or punctures were considered to be detrimental to the service life of the roof, while surface marks would be a temporary cosmetic condition. Maximum hail sizes on the cedar roofs inspected ranged from about 1 to 2½ inches in diameter. Two roofs were medium-thickness cedar shake, and the
remaining were cedar shingles.

Damage modes were primarily fracturing or puncturing of the wood when struck with relatively large hail. The hail-caused splits were coincident with, or closely associated with, bright-colored indentations in the wood from hail impact; and the wood fracture surfaces were bright-colored. Bright hail-caused splits could be contrasted with gray-colored interior surfaces of splits caused by natural weathering. Often, surface marks from hail impact and indentations in the wood did not result in splitting of the wood. Punctures occurred in areas of the wood that were thinner than average and where relatively large hail fell; fresh color in the underlying wood and broken wood pieces confirmed the impact damage. The very large hail at one inspection site penetrated through to the attic space on a few occasions between the spaced lattice. Hail-caused splitting or puncturing of the wood generally was found when hailstones exceeded 1½-in. diameter, although the sample size of wood roofs was fairly small.

Known or estimated ages of the wood roofs ranged from less than three to greater than 15 years. Roofs older than ten years with surface erosion from weathering displayed reduced hail resistance. Large quantities of smaller hail (¾-in. diameter or less) had no effect other than surface marks that will fade with further weathering.

Metal

Sixteen metal roofs were inspected, including raised-rib metal panels, standing-seam metal panels, and metal shingle panels. In all cases, the roof pitch was 3:12 or steeper. The painted and Galvalume-coated raised-rib panels were on commercial buildings or schools. Other materials included standing-seam copper on two locations (Photo 5), galvanized steel, and standing-seam painted steel. Four roofs had stone-coated steel panels that had UL 2218 Class-4 impact-resistance ratings.

Most of the metal inspection sites were in Irving, where some of the largest hail fell. Maximum hailstone sizes were listed as 1½ to 4 inches in diameter. Nine sites were listed as damage categories 0 or 1. Some of the stone-coated panels on steep slopes (12:12 pitch) sustained hailstones up to 2½ in. without visible dents or spalling of the granule surfacing. Otherwise, the sites were listed as damage category 4 (moderate/severe denting).
No fractures or punctures occurred in the metal panels, and no evidence of leakage was found or reported below the metal roofing at these sites. One site with severely dented metal shingles from 2½-in. hail had some distorted side laps. Raised-rib panels had denting of rib and pan areas, but no open seams were noted. No fracturing or spalling of painted coatings was found at hail impact marks. One of the stone-coated steel panels struck with 2½-in. hail had spalling of the stone coating at a few locations.

RESULTS
In reviewing the overall results, the following findings emerged:

- Hailstone size (and resultant impact energy) was more critical than hailstone quantity in determining if the roofing was damaged. Areas with large quantities of hail did not sustain roofing damage if the maximum hailstone size at that site did not exceed the necessary threshold of damage for that material. Almost no damage was found in areas where the maximum hailstone size was less than 1 inch in diameter, with the exception of badly deteriorated and unsupported material. When maximum hailstone size was between 1 and 2 inches in diameter, the level of damage ranged from none to considerable, depending on material, age/condition, roof slope, and support conditions. When maximum hailstone size was greater than 2 inches in diameter, most roofing materials sustained damage or denting of metal.

- The impact-resistance-rated asphalt shingle products performed better than standard asphalt shingles. The average damage category rating for standard asphalt shingles was 2.5; for impact-resistance-rated asphalt shingles, it was 1.3.

- The teams observed the threshold for roof damage from hailstone impact to most materials was between 1¼ and 2 inches, which correlates with the size ranges used in most standard impact-resistance tests used to simulate the effects of hail impact, including UL 2218, FM 4473, and FM 4470.

- Some materials displayed reduced hail impact resistance with respect to age and deterioration, particularly those more than ten years old. Categories included asphaltic products (including modified bitumen) and cedar shingles and shakes.

- Hail effects on metal roof systems were seen as largely cosmetic rather than functional [Photo 6]. Indentations occurred with larger hailstones, but painted coatings had not been visibly compromised by the denting. Most of the metal roof systems inspected had greater-than-maximum hailstone size of 2½ inches in diameter, and no leakage was observed or reported—even with the moderate-to-severe denting. With extremely large hail, there were a few instances of distorted seams or spalled granule surfacing, but this was rare. Metal roofing products with Class-4 rating performed as designed with no fractures or open seams found with 2-in. diameter or smaller hail.

For more information or to read the full report, visit www.ricowi.com/docs/reports/RICOWI_DFW_Hail_Report.pdf.