LONG-TERM EFFECTS OF HAIL IMPACT ON ASPHALT SHINGLES—AN INTERIM REPORT

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A laboratory study was begun in 1983 to determine the long-term effects of hail on asphalt shingles. Simulated hailstones were launched at speeds of same-sized natural hailstones perpendicular to roofing panels constructed to replicate standard applications. Impacts were made on new fiber glass-reinforced three-tab, organic-reinforced three-tab and fiber glass-reinforced laminated shingles at the beginning of the study and after approximately 11 years of natural weathering exposure. The study confirmed that dents in asphalt shingles caused by impacts that did not initiate fractures did not change measurably over time and, hence, were not functional damage. Additionally, it was demonstrated that hail-damaged areas in shingles do not increase measurably in size with increased time of exposure. This has been found to be true whether the impact damage occurred to new shingles or to weathered shingles. It is important that functional damage to shingles caused by impacts was immediate and identifiable. This interim report is issued after 15 years of testing, which is a typical service life for many shingles in the southern United States. The study is continuing, and further reports may be issued after additional years of exposure.

KEY WORDS

Asphalt Shingles, Granule Loss, Hail, Hail-caused Damage, Hail Damage, Hailstones, Ice Balls, Weathering.

PURPOSE

The purpose of this study is to assess the effects of weathering on asphalt shingles impacted with simulated hailstones on new and weathered shingles. Shingle types tested included 20-year-warranty, three-tab shingles with organic reinforcements; 25-year-warranty, three-tab shingles with fiber glass reinforcements and 30-year-warranty, laminated shingles with fiber glass reinforcements. Findings and methods derived from observations throughout this study include the following:

- Identification of the characteristics of impact-caused damage to shingles.
- Documentation of the attributes of impact-caused fractures initially and after prolonged exposure to natural weathering.
- Evaluation of granule loss at impact locations to determine the effect of granule loss on expected shingle life.

Originally, the study was anticipated to have been completed after 20 years, with impacts to be made on roofing at years 0, 7 and 14. Initial impacts were made on new roofing shingles in Year 0; all shingles then were allowed to weather naturally. At 7 years, the impacting schedule was re-evaluated and modified based on observations of the extent of weathering of the shingles and re-assessment of the study goals. It was decided that more useful data would be generated with impacts made on roofing shingles nearing the end of their expected service lives; hence, impacting on shingles was postponed from Year 7 until Year 11. The impacting regime originally slated for Year 14 similarly has been postponed based on the extent of weathering of the shingles and re-evaluation of study goals.

Functional damage to any roof covering is defined by Haag Engineering Co. as a diminution of water-shedding capability or reduction in the expected long-term service

Photo 1. Naturally occurring hail.

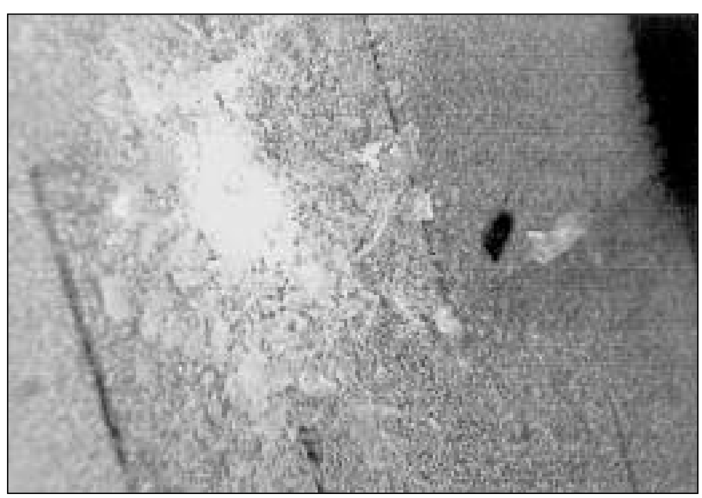

Photo 2. Shingle impacted by a simulated hailstone.

life of the material. More specifically, applied to asphalt shingles, impact-caused damage is rupture of the reinforcement or displacement of granules sufficient to expose underlying bitumen. The former is a penetration of the roofing shingles that, in effect, removes a layer of the shingles; the latter reduces the expected service life of the material. (Haag has further refined the definition of functional damage—for laboratory analyses of asphalt shingles in which reinforcements are solvent-extracted for examination—to include strain [permanent deformation] in the reinforcement over an area greater than ¼ inch [6 mm] in diameter. This is a rare circumstance detectable only in extracted reinforcements.)

ASPHALT SHINGLES USED FOR TESTING

Three types of asphalt shingles were tested: both fiber glass three-tab shingles, organic-reinforced three-tab shingles and fiber glass-reinforced, laminated shingles. Specifics about the shingles are listed in Table 1.

The three selected shingle types were produced by major manufacturers and purchased through local material suppliers. Selection of the three shingle types was intended to represent prevalent types of products in the roofing market. The three shingle products are without known durability problems.

TEST PROCEDURES

In 1983, six panel frames were constructed of steel angles and clad on top sides with ¾-inch- (19-mm-) thick plywood decking treated with a sealer. The 4-foot by 6-foot (1,219 mm by 1,829 mm) decking was covered with No. 15 asphalt-saturated felt. New shingles were applied over underlayment in strict accordance with manufacturers' requirements. Finally, guards for natural hail (steel frames covered with hardware cloth) were secured approximately 5-½ inches (140 mm) above the test assembly. The frame design placed all panels on a 4:12 slope. See Photo 3.

Two test panels were covered with three-tab fiber glass-reinforced shingles; two with three-tab, organic-reinforced shingles; and two with laminated fiber glass-reinforced shingles. Halves of each test panel were designated with anticipated schedules for impacting. For each shingle type, a single half-panel was designated as control; this half-panel would not be impacted but would be exposed only to natural weathering. Other half-panel designations included *0*, *7* and *14*, indicating anticipated *original* schedules for impacting shingles at Years 0, 7 or 14 in addition to natural weathering. Half-panel designations are listed and explained in Table 2.

Following construction of the test panels and application of the shingles, acetate sheets were trimmed to test-panel dimensions, and the shingles were outlined on the acetate sheets. Individual shingle tabs or segments of upper or lower laminates of laminated shingles were designated beginning at the upper left corner of the test panel (references reflect a viewer looking upslope at installed roofing shingles) with alphabetic rows and numeric columns. Conditions of shingles were recorded on the acetate overlays to form a permanent record. Additionally, conditions were notated and photographed. The various conditions included effects of weathering and/or manufacturing and damage caused inadvertently in handling or during storms. See Photo 4.

Year 0 impacts on the shingles were made with freezer

Photo 3. *View of test panel CO-FS-D7/14.*

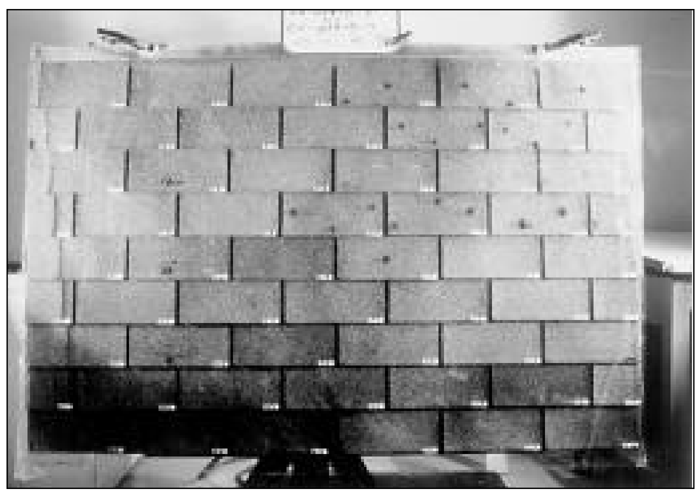

Photo 4. *Test panel CO-WFB-D-7/14 with acetate overlay in laboratory during inspection. Half-panel designations CO-WFB-D-7 and CO-WFB-D-14 refer to right and left portions of the panel, respectively.*

Shingle type	Reinforcement	Warranty	Color	Dimensions in x in (mm x mm)	Weight lb/sq (kg/m²)
Three-tab	Fiber glass	25 years	Brown	13-¼ x 39-⅜) (337 x 1,000)	225 (11.0)
Three-tab	Organic	20 years	Brown	12 x 36 (305 x 914)	216 (10.6)
Laminated	Fiber glass	30 years	Gray	12 x 36 (305 x 914)	320 (15.6)

Table 1. *Asphalt shingles.*

Half-panel designation	Shingle type	Reinforcement	Original schedule for impacting
CO-FS-C-NA	Three-tab	Fiber glass	Control; natural weathering only
CO-FS-D-0	Three-tab	Fiber glass	Natural weathering plus impact dry at 0 years exposure
CO-FS-D-7	Three-tab	Fiber glass	Natural weathering plus impact dry at 7 years exposure
CO-FS-D-14	Three-tab	Fiber glass	Natural weathering plus impact dry at 14 years exposure
CO-WFB-C-NA	Three-tab	Organic	Control; natural weathering only
CO-WFB-D-0	Three-tab	Organic	Natural weathering plus impact dry at 0 years exposure
CO-WFB-D-7	Three-tab	Organic	Natural weathering plus impact dry at 7 years exposure
CO-WFB-D-14	Three-tab	Organic	Natural weathering plus impact dry at 14 years exposure
CO-TS-C-NA	Laminated	Fiber glass	Control; natural weathering only
CO-TS-D-0	Laminated	Fiber glass	Natural weathering plus impact dry at 0 years exposure
CO-TS-D-7	Laminated	Fiber glass	Natural weathering plus impact dry at 7 years exposure
CO-TS-D-14	Laminated	Fiber glass	Natural weathering plus impact dry at 14 years exposure

***Table 2.** Half-panel designations and explanations.*

ice, initially either 1-inch- (25-mm-) diameter ice balls at 49.8 mph (22.3 m/s) or 1⅓-inch (34-mm) crescent shapes (crescent shapes whose masses were equivalent to 1⅓-inch [34 mm] spheres), propelled at 57.5 mph (25.7 m/s), the free-fall speed of 1⅓-inch- (34-mm-) diameter spherical hailstones. Shingles were not sealed prior to Year 0 impacting; nonetheless, shingles were sealed shortly after exposure. Planned impacts with crescent shapes were discontinued because of targeting difficulty. The subsequent impacts in Year 11 were made with 1-inch- (25-mm-), 1¼-inch- (32-mm-) and 1½-inch- (38-mm-) diameter ice balls propelled at no less than free-fall speeds of same-sized spherical hailstones. Projectile speeds and weights were measured, and impact energies were calculated. Impact energies fell within a range of minus zero or plus 10 percent of target energies. Target speeds and kinetic energies are listed in Table 3.

The projectiles were launched perpendicular to dry test panels. Fields of tabs or upper or lower laminates (areas more than one projectile diameter from edges) were targeted for impacts. Immediately after a simulated hailstone had struck a composition shingle surface, the impact area was marked. Marks later were traced onto the acetate sheet overlays to form a permanent record. Impacted areas were scrutinized visually on top surfaces and at coincident locations on bottom surfaces aided by a mirror as slight pressure was applied at impact sites. Effects of impacts also were notated and photographed.

Test panels were weathered naturally at our main office location in Addison, Texas, from January 1984 through June 1987 and since July 1987 at our present location in Carrollton, Texas. The former location is approximately 12.2 miles (19.6 km) northeast of Dallas/Fort Worth (DFW) International Airport; the latter, 6.2 miles (10.0 km) east northeast. DFW International Airport is an official station of the National Weather Service for measurement and collection of weather data. Records from this station were incorporated, as these reasonably reflect conditions for exposure of the test panels. Test panels faced south at the Addison location and face west at Carrollton. Summaries of pertinent weather information are listed in Table 4. A description of the DFW Metroplex climate can be obtained from *Local Climatological Data* by the National Oceanic and Atmospheric Administration (NOAA).

	Freezer ice projectiles			
Year	Shape	Size in (mm)	Speed mph (m/s)	Kinetic energy ft-lbf (joules)
0	Ice ball	1 (25)	49.8 (22.3)	1.43 (1.94)
0	Crescent shape	1-⅓ (34)	57.5 (25.7)	4.82 (6.54)
11	Ice ball	1 (25)	49.8 (22.3)	1.43 (1.94)
11	Ice ball	1-¼ (32)	55.9 (25.0)	3.53 (4.79)
11	Ice ball	1-½ (38)	61.4 (27.4)	7.35 (9.97)

***Table 3.** Target speeds and kinetic energies of freezer ice projectiles.*

OBSERVATIONS AND RESULTS

Panels designated for impacts with freezer ice were constructed at the beginning of the study, and weathering exposure for the panels commenced January 24, 1984. Fractures with sharp edges exposing black-colored asphalt in single-line, curved-line or multi-line patterns were detected in bottom sides of shingles at three of 94 impact locations. Regardless of fractures in shingles, slight dents were detected at some impact sites. Although a few surface granules were displaced from areas impacted by freezer

	Minimum (year)	Maximum (year)
Temperature		
High	100°F (38°C) (1992)	107°F (39°C) (1988)
Low	-1°F (-18°C) (1989)	23°F (-5°C) (1991, 1993)
Average	64.5°F (18.1°C) (1989, 1997)	66.8°F (19.3°C) (1990)
Total precipitation	25 inches (636 mm) (1988)	53.5 inches (1,360 mm) (1991)
Degree days		
Cooling	2,415 (1992)	2,801 (1985)
Heating	1,980 (1992)	2,656 (1985)

***Table 4.** Summary of weather data collected at the DFW International Airport Weather Station from 1984 through 1997.*

ice, there were no instances where granules were displaced sufficiently to expose asphalt. Results of impacting are listed in Table 5. Only overall photographs of roofing panels were taken at Year 0.

Some of the panels were inspected and photographed after approximately nine years exposure time (Year 9). There were fine weathering-caused cracks in some shingles. Asphalt was visible along shingle edges where granules had been shed. Some tabs had begun to curl. There were no identifiable changes in granule coverage at those sites that had been impacted with freezer ice but that did not fracture at the initiation of the study. Fractures caused by impacts at Year 0 had not extended measurably but evinced more exposed and weathered asphalt where granules had been shed.

All panels were inspected at approximately 11 years exposure time (Year 11). Additionally, those panels designated originally for impacting at Year 7 were impacted and inspected. Generally, weathering-caused cracks meandered across shingles, with many cracks nearly parallel to butts and some parallel to ends. Some granules had been shed from ends, especially from butts of shingles; some tabs had curled. Examination at sites which were impacted at the initiation of the study but did not fracture at that time showed no identifiable changes in granule coverage. Examination at impact sites with fractures and comparison with photographs taken at 0- and 9-year exposure times showed no visible changes in fracture lengths but did show, in some instances, wider cracks and substantial loss of granules along fracture edges. Here, exposed asphalt was of weathered gray colors, and fracture edges were rounded and tapered. Table 6 lists results of impact testing. See Photos 5, 6 and 7.

This report is based on work completed after approximately 15 years of exposure time. Observations made at this time parallel those made at a time exposure of approximately 11 years with few exceptions. Asphalt exposed on tabs exhibited more weathered gray colors; edges at cracks were more rounded and tapered. Additionally, dark-colored asphalt was visible at several locations in the laminated shingles impacted previously. With the blade of a penknife, these areas were probed and scraped carefully. A continuous bed of granules was detected immersed fully in asphalt. The frequency of fractures caused by impacts of 1-inch- (25-mm-) diameter freezer ice balls for all types of shingles tested in this study is presented in Table 7. Typical observations of an impact site with fractures are depicted at 10 years 6 months and 14 years 11 months in Photos 8 and 9, respectively. Photo 10 depicts asphalt underlaid with granules.

Fractures were detected at two Year 0 impact locations in three-tab fiber glass-reinforced shingles: two from 1-inch- (25-mm-) diameter freezer ice balls. Year 11 impacts with 1-inch- (25-mm-) diameter ice balls, however, resulted in no fractures in fiber glass-reinforced shingles. The latter was expected, based on our laboratory experience; the former was not. Fractures in new three-tab shingles with fiber glass reinforcement were attributed to tabs not having been sealed prior to impacting. Fractures caused by 1-inch- (25-mm-) diameter ice ball impacts in three-tab shingles with organic reinforcement—none at Year 0 and nine at

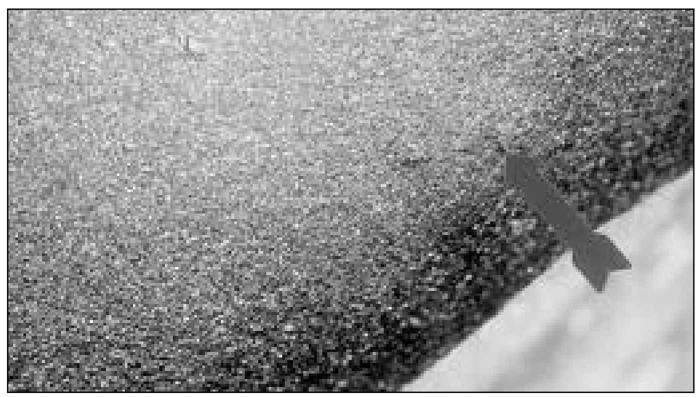

Photo 5. Close-up on bottom side of D-7 of half-panel designation CO-TS-D-7 at impact site. Note single- line fracture pattern weathered 4 years 4 months.

Half-panel designation	Exposure time (years-months)	Freezer ice projectiles					
		1 inch (25 mm) Ice ball		1⅓ inch (34 mm) Crescent shape		Total	
		Impacts	Fractures	Impacts	Fractures	Impacts	Fractures
CO-FS-D-0	0 - 0	12	2	12	1	24	3
CO-WFB-D-0	0 - 0	16	0	14	0	30	0
CO-TS-D-0	0 - 0	20	0	20	0	40	0

***Table 5.** Summary of impacts and impact-caused fractures for panels at Year 0.*

Half-panel designation	Exposure time (years-months)	Freezer ice balls							
		1 inch (25 mm)		1¼ inch (32 mm)		1½ inch (38 mm)		Total	
		Impacts	Fractures	Impacts	Fractures	Impacts	Fractures	Impacts	Fractures
CO-FS-D-7	11-2	10	0	10	6	10	9	30	15
CO-WFB-D-7	11-0	10	9	10	5	10	10	30	24
CO-TS-D-7	10-11	10	0	10	0	10	6	30	6

***Table 6.** Summary of impacts and impact-caused fractures for panels after approximately 11 years weathering exposure.*

Photo 6. *Close-up on bottom side of Tab D-4 of half-panel designation CO-FS-D-7 at impact site. Note curved-line fracture pattern weathered 4 years 4 months.*

Photo 7. *Close-up on bottom side of Tab A-5 of half-panel designation CO-WFB-D-7 at impact site. Note multi-line fractures radiating from common point.*

Photo 8. *Close-up of Tab G-3, half-panel designation CO-FS-D-0 at 10 years 6 months weathering exposure. Note impact-caused fracture.*

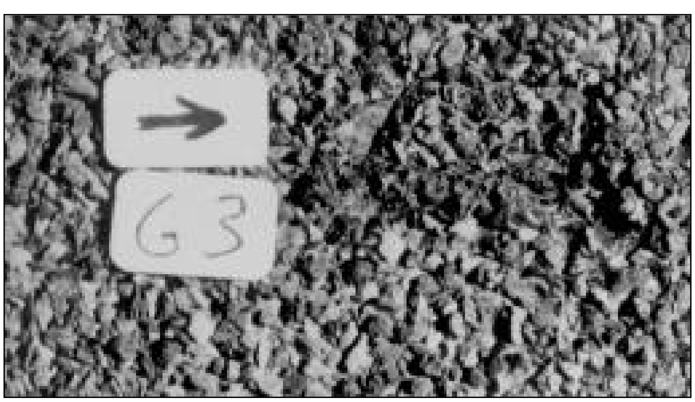

Photo 9. *Close-up of Tab G-3, half-panel designation CO-FS-D-0 at 14 years 11 months weathering exposure. Note impact-caused fracture.*

Panel designation	Year 0		Year 11	
	Impacts	Fractures	Impacts	Fractures
CO-FS-D-0/7	12	2	10	0
CO-WFB-D-0/7	16	0	10	9
C0-TS-D-0/7	20	0	10	0

Table 7. *Summary of impact testing results with 1-inch- (25-mm-) diameter freezer ice balls at Year 0 and Year 11.*

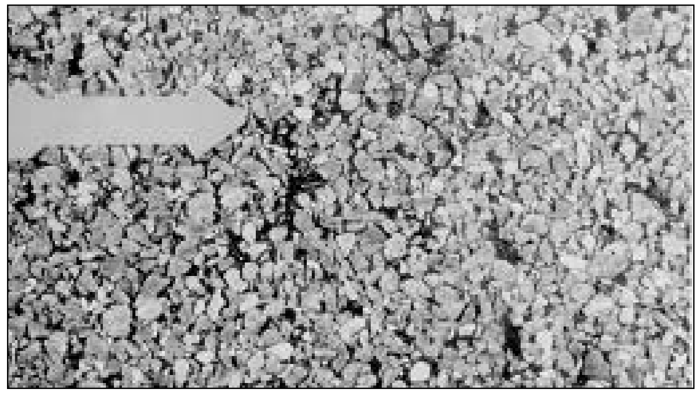

Photo 10. *Close-up of D-2 of half-panel designation CO-TS-D-0 at 14 years 11 months weathering exposure. Note that granules were detected below the asphalt in vicinity of arrow.*

Year 11—were expected because these shingles became extremely brittle with exposure and, hence, more sensitive to impact-caused fractures. The absence of fractures caused by impacts of 1-inch- (25-mm-) diameter ice balls in laminated shingles with fiber glass reinforcement was anticipated based on other impact testing experiences.

The test history of individual shingle tabs or segments is chronicled in Appendices A, B, C and D. Each series comprises photographs from Year 0 through Year 15.

STUDY FINDINGS

Following are findings of this study:

- Dents in asphalt shingles caused by impacts that did not cause initial fractures did not change measurably during the study and, hence, were not functional damage.
- For the three-tab shingles tested, impacts that dislodged granules did not expose asphalt nor affect the service life of the material and, therefore, were not functional damage.
- Some impacts made with freezer ice on laminated shingles dislodged granules from exposures without exposing asphalt. Granules subsequently were shed at impact locations over time with natural weathering. Careful examination at these locations revealed a continuous bed of granules immersed in the asphalt. There was no reduction in the expected service life of the shingles as granules on the shingles continued to protect the underlying asphalt and reinforcement. The condition was not functional damage but merely a cosmetic condition.
- Fractures in shingles caused by impacts from simulated hailstones widened but did not propagate visibly during the study.
- Fractures caused by impacts in shingles ranged from

nearly straight lines to curved lines or multiple lines radiating from the point of impact.

- Impact-caused fractures in shingles exposed to natural weathering exhibited progressively more rounded/tapered edges and more oxidized gray colors of asphalt as exposure time increased.
- New asphalt shingles with organic or fiber glass reinforcements exhibited similar impact resistance.
- Weathered asphalt shingles with organic reinforcements were sensitive to impact damage whereas those with fiber glass reinforcement were not.
- Functional damage to shingles caused by impacts was immediate and identifiable.

APPENDIX A

Appendix A consists of photographs of Tab G-3 on Test Panel CO-FS-D-0 taken at Year 0, 10 years 6 months, and 14 years 11 months. Shingles on this panel are three tab and glass fiber reinforced. The tab was fractured by a 1⅓-inch (¾-mm) crescent-shaped simulated hailstone impact at Year 0.

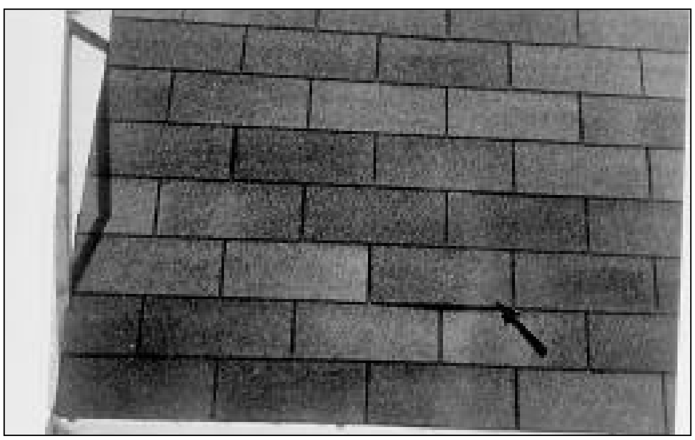

Photo A1. *View of test panel at Year 0 before impacting. Note Tab G-3 at arrow.*

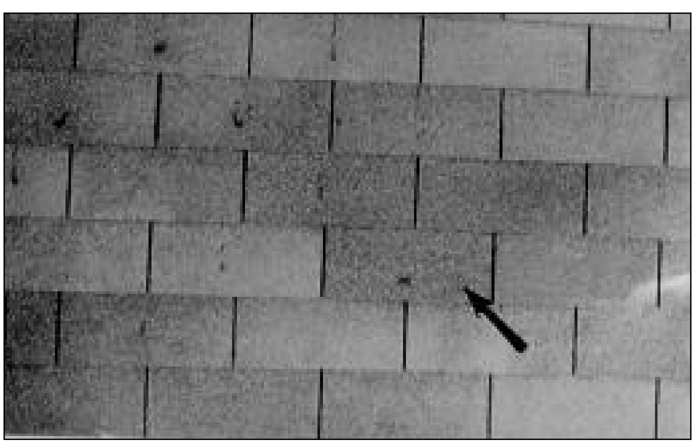

Photo A2. *View of test panel at Year 0 after impacting. Note fracture in Tab G-3.*

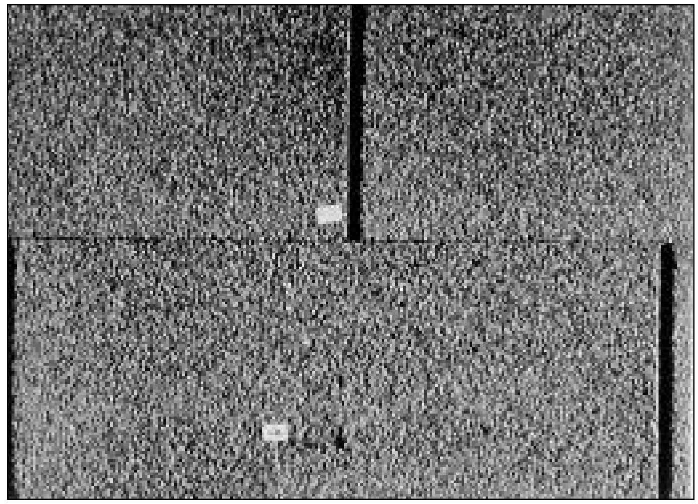

Photo A3. *Close-up at Tab G-3 at 10 years 6 months weathering exposure. Note fracture.*

Photo A4. *Close-up at fracture in Photo A3.*

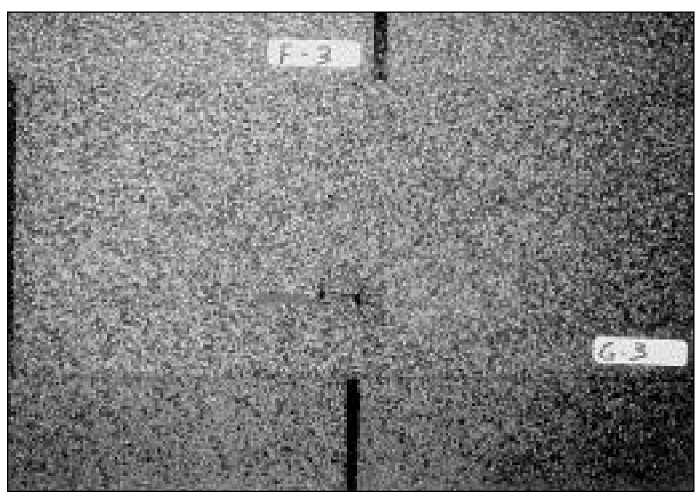

Photo A5. *Close-up of Tab G-3 at 14 years 11 months weathering exposure. Note impact-caused fracture.*

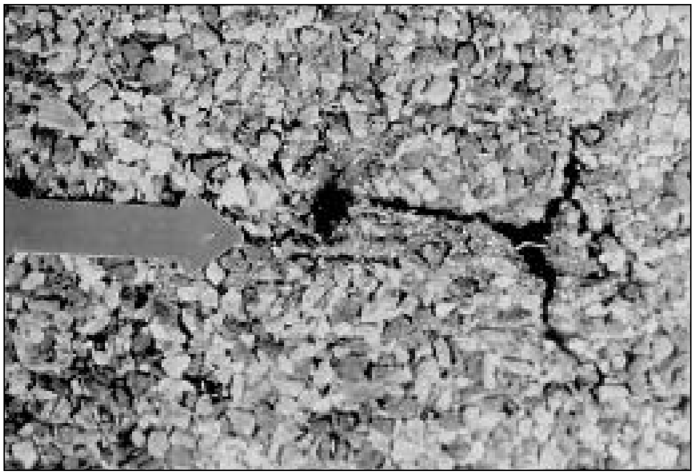

Photo A6. *Close-up of Photo A5.*

Photo A7. *Close-up on bottom side of Tab G-3 at area depicted in Photo A6.*

APPENDIX B

Appendix B consists of photographs of Tab A-4 on Test Panel CO-FS-D-7 taken at Year 0, 10 years 6 months and 14 years 10 months. Shingles on this panel are three tab and fiber glass reinforced. The tab was impacted by a 1-inch- (25-mm-) diameter simulated hailstone after 10 years 6 months exposure.

Photo B1. *View of test panel at Year 0. Note Tab A-4 at arrow.*

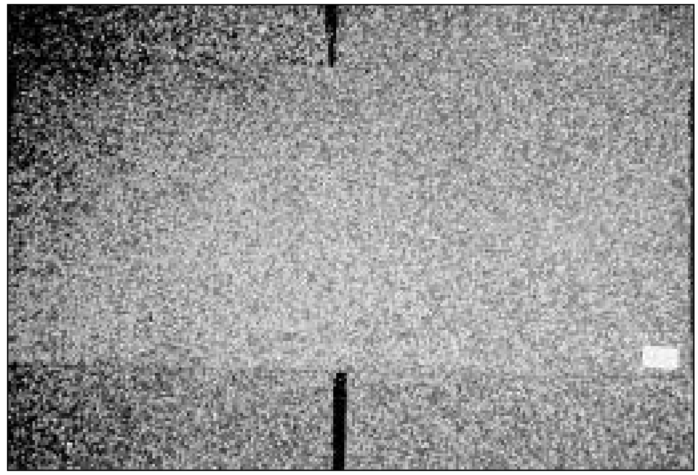

Photo B2. *Close-up of Tab A-4 before impacting at 10 years 6 months weathering exposure.*

Photo B3. *Close-up of Tab A-4 after three impacts at 10 years 6 months weathering exposure.*

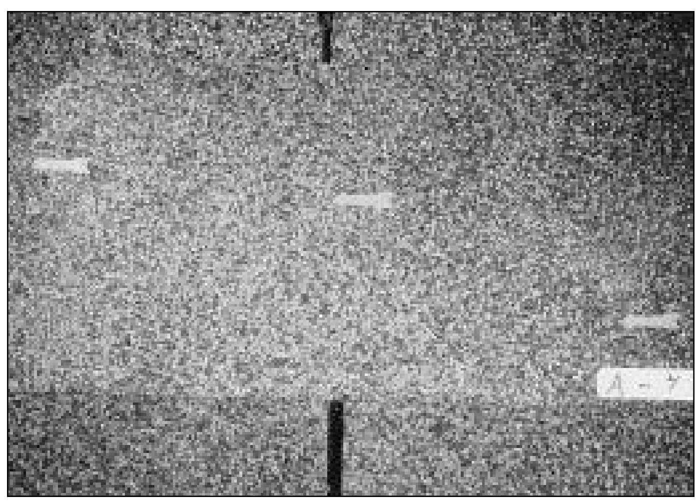

Photo B4. *Close-up of Tab A-4 at weathering exposure 14 years 10 months (4 years 4 months since impacting).*

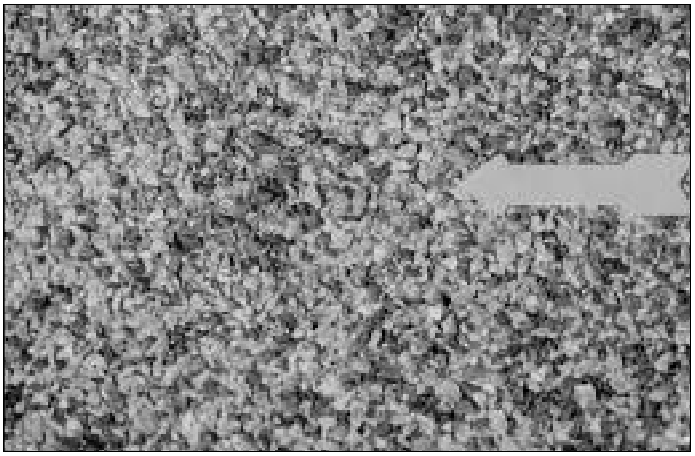

Photo B5. *Close-up of middle-arrow area in Photo B4.*

APPENDIX C

Appendix C consists of photographs taken of Tab C-5 on Test Panel CO-WFB-D-7 at Year 0, 10 years 5 months, and 14 years 11 months. Shingles on this panel are three tab and organic reinforced. The tab was impacted by a 1¼-inch- (32-mm-) diameter simulated hailstone after 10 years 5 months exposure.

Photo C1. *View of test panel at Year 0. Note Tab C-5 at arrow.*

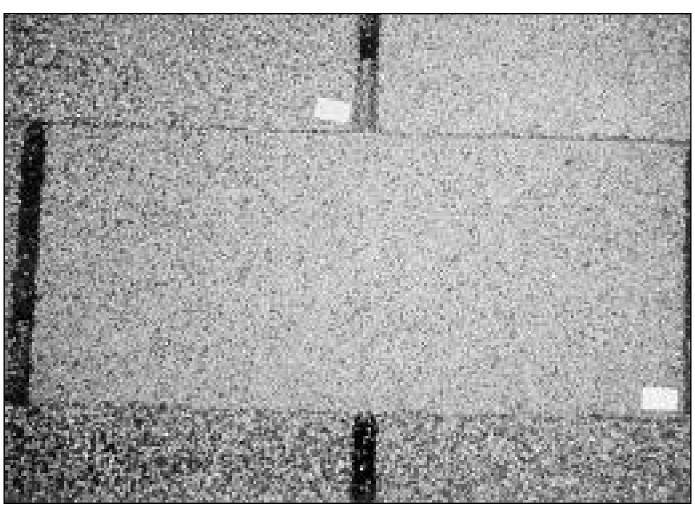

Photo C2. *Close-up of Tab C-5 before impacting at 10 years 5 months weathering exposure.*

Photo C3. *Close-up of Tab C-5 after three impacts at 10 years 5 months weathering exposure.*

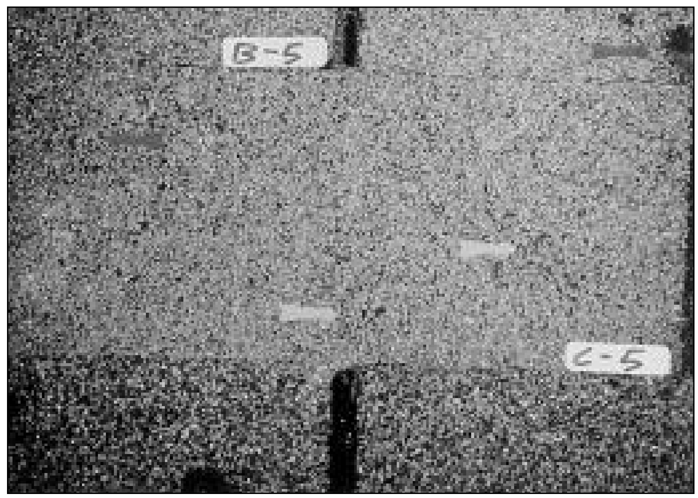

Photo C4. *Close-up of Tab C-5 at 14 years 11 months weathering exposure (4 years t months since impacting).*

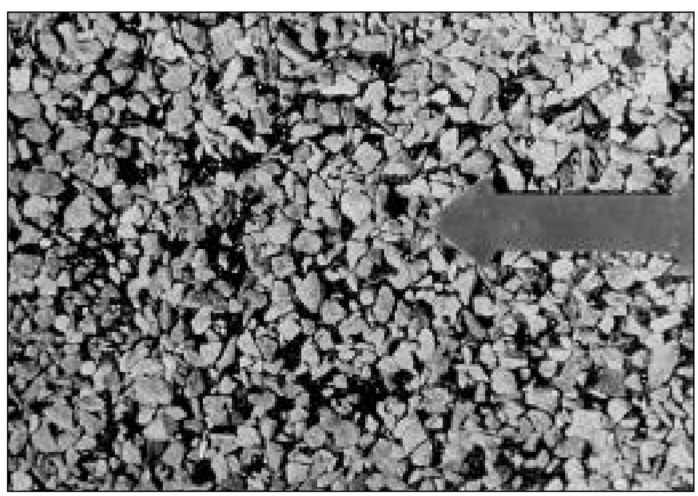

Photo C5. *Close-up of left-arrow area of Tab C-5 in Photo C4.*

Photo C6. *Close-up on bottom side of Tab C-5 at area depicted in Photo C5. Note fracture.*

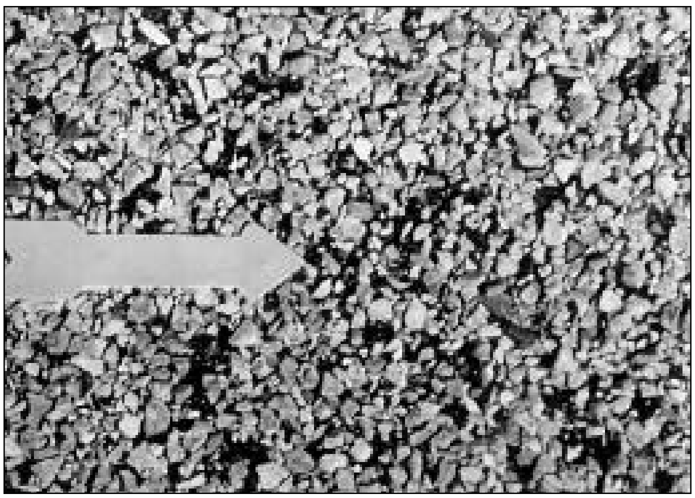

Photo C7. *Close-up of Photo D4 at arrow on right of Tab C-5.*

APPENDIX D

Appendix D consists of photographs of D-10 on Test Panel CO-TS-D-7 taken at Year 0, 10 years 6 months, and 14 years 10 months. Shingles on this panel are laminated and fiber glass reinforced. The laminate was fractured by a 1½-inch- (38-mm-) diameter simulated hailstone impact after 10 years 6 months exposure.

Photo D1. *View of test panel at Year 0. Note D-10 at arrow.*

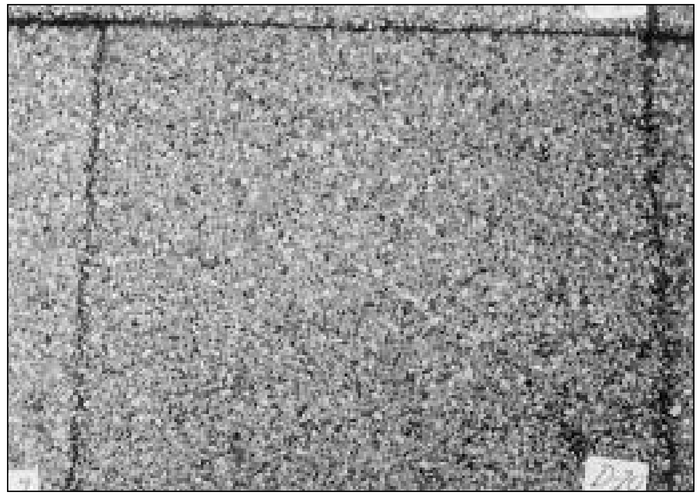

Photo D2. *Close-up of D-10 before impacting at 10 years 6 months weathering exposure.*

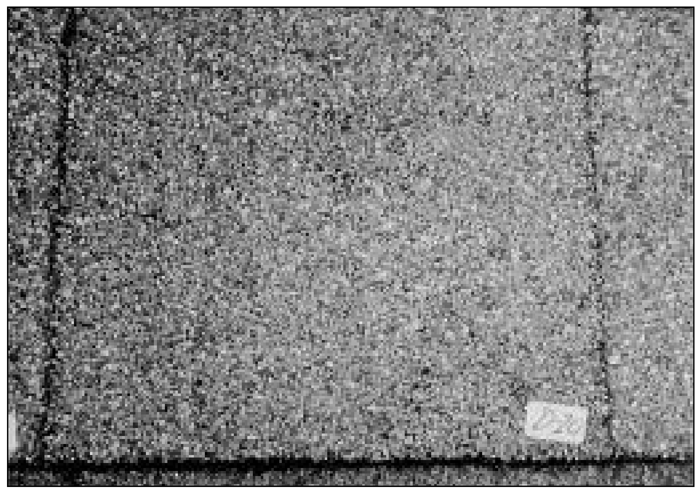

Photo D3. *Close-up of D-10 after impacting at weathering exposure 10 years 6 months.*

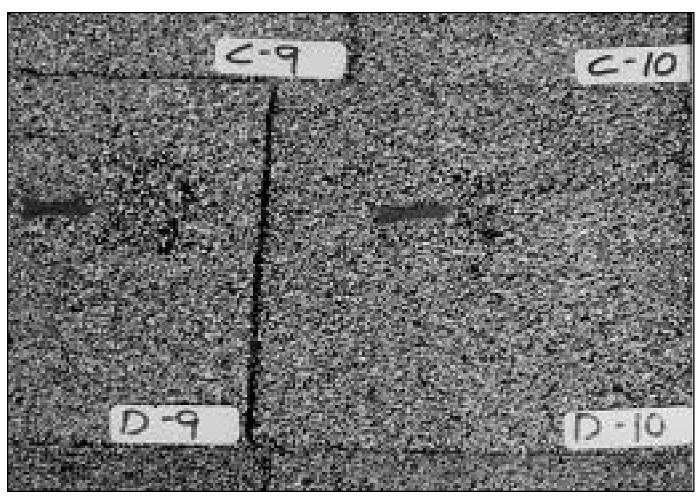

Photo D4. *Close-up of D-10 at 14 years 10 months weathering exposure (4 years 4 months after impacting).*

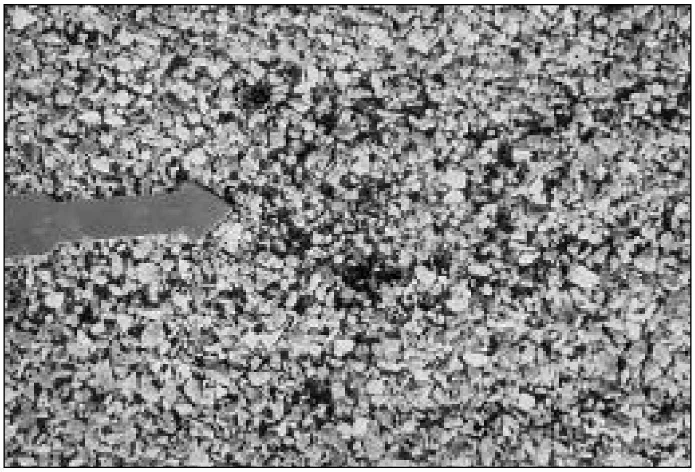

Photo D5. *Close-up of Photo D4 at arrow on D-10.*

Photo D6. *Close-up on bottom side of D-10 at location depicted in Photo D5. Note fracture.*