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# Impact of Hail

## on Rubber & Plastic Roofing Systems

Photo of Staples building in Glastonbury, Connecticut courtesy Carlisle SynTec Inc.

by Ric Vitiello

Selecting the most appropriate roofing system for a particular structure must always be approached carefully, but when the structure is located in the hail belt of the United States, additional considerations regarding how a roof system responds to hail impact could be very important.

Hail is produced when small ice granules make repeated cycles from the high tops of thunderstorms to lower elevations, allowing forming hailstones to thaw, before

being swept back upwards where they accumulate additional granules and re-freeze. This repetitive process creates hailstones comprising layers similar to those of an onion, with individual stones varying greatly in size and density—even within the same storm.

The mass of a hailstone as determined by its density can be just as important as its size. These variations can change within very small areas of hail fall, even a few feet. Other conditions, like wind speed and angle of impact, also affect the potential for damage.

In some cases, the temperature of the surface the hailstones fall upon can play an important role in determining whether any roof damage occurs. In some areas of the country, the initial falling hail from a storm is not always accompanied by rain. In this scenario, the surface of a roof is warmer and more flexible when the first hailstones fall. This flexibility can allow the roof to absorb impact energy more readily. Subsequent hailstones can actually carry less potential for damage because the initial layer of hail on the roof disperses their impact energy. Unfortunately, hail is generally accompanied by rain, which cools roof surfaces immediately. This is obviously detrimental to roofs that lose flexibility as membrane temperatures falls.

While the entire make-up of system components directly affects a roof's ability to survive a hailstorm, a major part of the survival rate is decided by the waterproofing membrane.

#### **Building the roof from the bottom up**

EPDM (ethylene propylene diene monomer) synthetic rubber and PVC (polyvinyl chloride) plastic are two popular single-ply roof systems, and for a number of good reasons, like speed of installation, low life-cycle cost, adaptability to many types of building configurations, and proven service life.

Before looking at specific cases to determine how 'hail-friendly' these two roofing systems are, one must first examine their components and how pertaining variables can affect their resistance to impact damage.

A roof system's ability to combat hail damage often begins below the membrane. The structural stability of the insulation layer can be important, as some types of

insulation (i.e. polyisocyanurate foam) can be compressed under large or dense hailstones. Other types, such as a layer of glass mat gypsum roofboard or a composite insulation with a laminated layer of oriented strandboard (OSB) directly under the membrane, provide additional structural stability to allow less structural deflection.

The compression of the insulation layer is not a concern when it comes to maintaining "R"-values because the loss is so minute. However, it can be a concern when the membrane does not successfully flex at the same rate as the insulation. In other words, when the membrane is subject to fracture from hailstones, then a more structurally sound insulation should be specified to aid in preventing this situation from occurring.

#### **Knowing the options**

##### *EPDM membrane*

An EPDM rubber roof is installed in one of three basic ways. The least expensive method is to simply lay the membrane loose over the insulation substrate and cover it with ballast. The second is to mechanically attach the membrane at set intervals along the roof, then cover the fasteners with EPDM strip-in material or overlapping seams. The most expensive method involves fully adhering the membrane to the substrate material. The mechanically attached and fully adhered methods leave the membrane exposed, making damage easier to find and simplifying the repair process.

While available as a reinforced sheet, EPDM is most popular as a non-reinforced membrane (reinforcement is not required for hail protection). In fact, when specific system requirements are met, EPDM rubber



*The Rosecliff Mansion was originally built in 1902 as a summer residence for Tessie and Herman Oelrich. The house changed ownership a couple of times until 1971, when the Preservation Society of Newport County was given the house. It boasts an EPDM roof for protection against the elements.*

roof systems are available with warranties of 30 years including hail damage.

The ingredients in EPDM sheets are considered pretty much standard across the industry these days. The membrane remains elastic throughout its service life, and does not become brittle over the loss of plasticizers (as do some membranes) simply because none are used in its manufacture. The membrane is produced in an uncured state, then coated with mica powder and rolled. The rolls of uncured membrane are vulcanized in an oven where the mica powder serves its sole purpose of preventing the membrane from sticking to itself.

#### *PVC membrane*

PVC roofing systems are also installed as ballasted, fully adhered, or mechanically attached systems, with the latter being the most popular method. Although the ingredients vary between membranes (particularly with regards to plasticizers), PVC-based

roof membranes are traditionally divided into two main categories: reinforced and non-reinforced.

The difference is simply the reinforced membrane contains a weft or scrim—typically of polyester fabric laminated between a top and bottom layer of PVC—to provide additional strength during times of stress, such as cold weather, which cause stiffening. Many PVC membranes employ liquid plasticizers. As the membrane shrinks from loss of these plasticizers as it ages, the weft helps maintain structural stability to counteract the embrittlement or rigidity that occurs as a result, and returns the membrane to its natural rigid state. In both cases, the scrim helps protect the membrane from splitting or fracturing.

#### **Case studies**

##### *Case study No. 1 (EPDM)*

A large automobile sub-assembly manufacturing facility has a 22-Ga. metal roof deck covered with 64-mm (2.5-in.) of mechanically attached

isocyanurate insulation board. The roof membrane is 0.045 fire-rated EPDM fully adhered to the insulation. No type of protective substrate (i.e. OSB or fibered gypsum board) is installed directly under the membrane to provide additional hail protection, and the roof warranty makes no special stipulation for covering hail-related damage.

A storm producing large, dense hail passed over the area and damaged many residential and commercial roofs of varying types. The subject roof was covered with spots where hailstones had cleaned away the factory-applied powdered mica from the surface. While the mica serves no functional purpose after the roof is installed, the clean spots in it do provide an absolute indication of exactly where the hailstones hit, the direction of their approach (indicating windblown or straight falls), and the size, shape, and density of their formation.

In the case of the impact shown in Photo 1, the size of the hailstone

**Photo 1**



*Hail impact on EPDM membrane roof produced no damage.*

**Photo 2**



*Indentation in insulation below membrane.*

**Photo 3**



*EPDM test sample. 13-mm (0.5-in.) re-cover board is fractured.*

**Photo 4**



*EPDM test sample. Although 13-mm (0.5-in.) re-cover board is fractured, no damage was done to the EPDM membrane.*

**Photo 5**



*Hail impact over metal insulation fastener plate caused no damage to the EPDM membrane.*

appears to have been approximately 51 mm (2 in.) in diameter. Photo 2 shows the hailstones dented the isocyanurate insulation below the roof membrane. Although the hail created a cavity in the insulation approximately 25-mm (1-in.) deep and as large as the surface clean spot, no damage to the EPDM roof membrane was indicated. It simply repelled the hail and returned to its original shape.

#### *Case Study No. 2 (EPDM)*

A turn-of-the-century, multi-wythe, brick bank building with a wood roof deck standing three-stories tall was in need of a roof retrofit. The original, smooth-surfaced built-up roof (BUR) had worn out, so it was re-covered with a 13-mm (0.5-in.) re-cover board, which was mechanically attached through the BUR into the wood deck. The whole assembly was then covered with a fully adhered EPDM rubber roof.

A storm producing dense hailstones the size of baseballs recently passed over the building, leaving in its wake large impressions in the surface and a fracture in the re-cover board (Photo 3). However, the EPDM membrane over the fractured board showed no signs of damage (Photo 4). Other possible locations for damage were explored, such as where the membrane may have been compressed between insulation board fasteners and other metal components, or the embedded drip edge, but no damage was found to the roof covering membrane.

#### *Case Study No. 3 (EPDM)*

A structure consisting of concrete block and wood framing with a barrel-shaped roof covered with an EPDM membrane fully adhered over 13-mm (0.5-in.) re-cover board. Having been recently hit by hailstones as large as 51 mm (2 in.) in diameter, depressions were found in the re-cover board, though no damage was found to the EPDM membrane.

Photo 5 shows the impressions of a metal insulation fastener plate, visible on the surface because foot traffic scuffed the mica coating. A clean spot produced by hail impact is visible at the lower left edge of the fastener impression. When hail makes an impact at this edge of the metal plate, the compression can result in the membrane being cut from below. Although this potential exists and should be closely inspected

for, I have yet to find a case where this has occurred. If such a cut over a metal plate were to be found, the appropriate remedy would be simple spot repair.

*Case Study No. 4  
(reinforced PVC membrane)*

A multi-level aircraft engine manufacturing facility had sections of its roof replaced and/or re-covered over a period of approximately 17 years. All of the roofs studied were of PVC material and had recently been hit by large hailstones. Three sections of the roof—seven, 12, and over 15 years old, respectively—were covered by reinforced membrane over plastic foam insulation. All these sections were severely damaged by the hailstones, determined to have been as large as 51 mm (2 in.) in diameter, although many of the fractures indicated impact by smaller hailstones (25-mm [1-in.] in diameter (See Photos 6 and 7).

On another section of the roof, fibered gypsum board served as the substrate for the PVC membrane. Although the membrane over this section was non-reinforced, there was very little apparent damage. This demonstrates PVC's ability to withstand hail impact can be somewhat improved by increasing the substrate's structural stability. With the exception of the roof section where the fibered gypsum substrate was installed, the roof was damaged to an extent where replacement was required.

*Case study No. 5  
(non-reinforced PVC membrane)*

A one-story aluminum products manufacturing facility has a raised level through the center, which provided shielding from hail impact on one side. A clear delineation of hail impact was noted



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**Photo 6**



*Hail impact fracture to reinforced PVC membrane.*

**Photo 7**



*Hail impact fracture to reinforced PVC membrane.*

**Photo 8**



*(Small) hail impact fracture to reinforced PVC membrane.*

**Photo 9**



*(Small) hail impact fracture to reinforced PVC membrane.*

**Photo 10**



*(Small) hail impact fracture to reinforced PVC membrane.*

where the raised portion offered protection, indicating the windblown approach of the hail fall. Although the hailstones hitting the roof were not particularly large (approximately 25 mm [1 in.] in diameter or less), the large amount of damage was somewhat surprising.

The PVC material was not scrim reinforced and was installed over compressible insulation, so the roof sheet had less protection against the sudden impact of hail. Membrane fractures were also found in larger quantities where there was evidence of historic ponding on the roof. This ponding can accelerate the loss of liquid plasticizers in PVC membranes, causing these areas to become more brittle than adjacent surfaces and more susceptible to fractures. The small size of the fractures shown in Photos 8 through 10 indicate only relatively small hailstones were required to cause severe damage. Had the roof been designed with a structurally sound insulation substrate and reinforced membrane, results may have been somewhat better.

#### *Case Study No. 6 (reinforced PVC membrane)*

The roof on this surgical office building was installed within the last five years. Since the passing of a hailstorm two years ago, roof leaks have repeatedly occurred because of a membrane fracture. Photo 11 shows patched spot repairs completed by a number of competent contractors, but none of them have been able to prevent the reoccurrence of leaks. Although study revealed previous repairs were completed properly, stresses within the membrane due to thermal cycling were causing additional fractures to open.

The fractures causing immediate leaks had been repaired, but the hailstorm had also caused fractures that did not extend completely through both laminates of the membrane. Over time, the repeated expansion and contraction of the membrane caused the fractures to tear through the bottom laminate below the scrim sheet, which caused additional leaks to appear. Photos 12 and 13 show the fractured upper laminate of a membrane sample and its underside, with a fracture that has not completely split to match the top (although there is some leakage). Since the roof could no longer be considered dependable, particularly since it is covering a surgical facility, replacement was recommended.

## Photo 11



*Overview of previous repairs performed after the hail storm.*

## Photo 12



*Test sample. Hail impact fracture to reinforced PVC membrane.*

## Photo 13



*Test sample. Underside of membrane indicates complete fracture allowing leaks.*

## Conclusion

Both PVC and EPDM systems are easily repaired when an isolated cut or fracture is caused by hail impact. However, PVC membranes are more likely to be extensively damaged by hail impact, making the probability for total roof replacement much more likely. While not warranted against hail damage, PVC systems can still be installed in such a way they will be less susceptible to hail damage. The use of a structurally sound substrate, such as fibered gypsum board or even OSB, can improve its performance.

EPDM systems are much more hail-resistant, even without special treatment (i.e. rigid substrate or extra-thick membranes). However, when additional precautions are implemented, the system can be installed with up to a 30-year warranty, including certain coverage against hail damage.

PVC and EPDM single-ply membrane roofs both have proven track records as high-quality systems. Both have their specific advantages and disadvantages under normal conditions, but in the context of surviving hailstone impact, EPDM clearly has the edge over PVC by virtue of its inherent elasticity. When specifying a roof system, then, the specifier should definitely consider the probability of hailstorms when making the final selection. ■

## Additional Information

### Author

Ric Vitiello is a professional member of the Roof Consultants Institute (RCI) and the senior roof consultant with Donan Engineering Co., a forensic engineering company. Since 1989 he has conducted field research, and evaluated hail damage

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### MasterFormat No.

07530—Elastomeric Membrane Roofing  
07540—Thermoplastic Membrane Roofing

### UniFormat No.

B3010—Membrane Roofing

### Key words

Division 7  
EPDM roofing  
Hail damage  
PVC roofing

### Abstract

This article compares the effects of hailstone impact on two popular types of commercial single-ply roof systems: PVC and EPDM rubber membranes. After researching numerous roofs in the hail belt of the United States, the

author concludes unaltered EPDM membranes offer better protection from hailstorms because of their inherent elasticity, while their unaltered PVC counterparts can suffer severe damage requiring a complete re-roof in many cases.