Hail and SPF Roofing

SPF (spray polyurethane foam) roofing systems have exceptional characteristics. They offer great insulation, are resistant to high winds, protect the substrate against damage from hail and wind driven missiles, and can be recoated to extend its life. Frequently, however, some in the roof industry have poor perceptions of how SPF roofing systems perform in hail events. For many years the conventional roofing market perceived SPF roofing as soft and easily damaged calling the system PUF.

In the words of renowned roof expert Richard Fricklas, former director of the Roofing Industry's Educational Institute (RIEI), "SPF has an excellent story to tell when it comes to the wind and hail resistance." The typical hail damage repair procedure for most other roofing systems is tear-off and replacement. According to Fricklas, "There seems to be a mindset among some roofing contractors as well as building owners and designers that foam roofs are not suitable for hail regions at all. … (however,) The NRF (National Roofing Foundation) report on SPF roofing systems by Dr. Rene Dupuis confirmed where (SPF) roofs had experienced hail damage the damage was localized to the upper surface of the foam and most roofs were repaired rather than replaced. "With the continued trends toward "sustainable construction", it is within the best interests of the roofing industry to repair rather than replace whenever possible and practical."

Dr. Dupuis NRF research indicated the damage caused by wind driven missiles typically does not cause the roof to leak. "…the unique aspect of SPF roofs with respect to mechanical damage is that they are not in imminent danger of leaking, provided the penetration does not extend all of the way through the foam."

Wind damage may be isolated to small areas of the roof or cover large areas. Substrate damage and structural damage may or may not occur, however, Thomas Smith noted in his observations of SPF roofs that were struck by Hurricane Andrew, "…It appears a thickness of 2 inches (50mm) (of foam) is sufficient to prevent penetration of most missiles." The type of repairs required will depend on the size and severity of the damage.

How does SPF minimize damage from hail and how can you design a SPF roofing system to specifically resist the damage?

First consider the physical characteristics of the SPF roofing system. The most common system begins with a layer of at least 1 inch and more often 2-3 inches of a high-density spray polyurethane foam covered with a minimum of 25-30 mils of a protective coating of either acrylic, silicone or polyurethane.

SPF used in roofing ranges in density from 2.5 to 3.2 pounds per cubic foot (pcf) with compressive strength from 40 psi to over 60 psi. The compressive strength of the foam combined with the thousands of tiny cells tends to act as shock absorbers against impact. The top of the foam can get crushed but the foam below remains intact. The coatings used over the foam add additional strength to the system depending on their tensile strength, flexibility and thickness. This basic system can usually withstand hail impact of a ½" to 1" size hail stone leaving only a small depression 1/8" to 1/4 " deep in the foam and no cracks in the coating. In fact more than a dozen SPF roofing systems passed Factory Mutual Global's Class I Roofing Covering severe hail test using this basic system.

As hails stones increase in size the depressions in the foam also get larger and cracks in the coating become more frequent. But even the more severe hail damage can frequently be repaired. So long as repairs are performed within in a reasonably time frame, SPF roofing systems can typically be repaired rather than removed and replaced. This is an important factor since most other roofing systems require a tear off and replacement.

Why can we repair and not replace SPF roofs? In most other roofing systems the exterior membrane is the waterproofing or water shedding medium. When hail or other missile impact cracks or bruises a roof system such as single ply, shingles, BUR, etc. leaks are apt to follow. But the damage to SPF roofing systems is typically a cracked coating and an indentation to the foam itself. The damage typically occurs in the top 1/8 inch to 3/4 inches of the foam depending on the size of the hail and the physical properties of the SPF and coating. Since the foam below the dent is closed cell, it continues to provide water resistance so that leaks do not occur. This allows a SPF roof to be repaired in the areas of damage rather than having to remove and replace the whole system.

As reported in RICOWI's (Roofing Industry Committee on Weather Issues) Hail Storm Investigations in Oklahoma City in 2004,"Immediate leaks into the buildings would not be expected from the hail-caused fractures in the coating as the foam is closed-cell and would not allow liquid water to pass through." Five SPF roofs were inspected with 3 of the roofs (all with hail reported ranging in size from over 1 inch to 2 inches having hail-caused fractures in the coating. "The 2 roofs without hail-caused fractures in the coating had been struck with hail stones sizes of 0.5 to 1.0 inch in diameter."

Other Roofing Systems Hail Resistance:

How do some of the other roof systems perform in hailstorms? Evaluating the results of RICOWI's 2004 Oklahoma investigation with their subsequent investigation after a hailstorm in Dallas/Ft Worth, TX in 2011, it is apparent that some roofing systems perform better than others.

Asphalt Shingles: In the Dallas/Ft Worth storm, a total of 63 asphalt and modified bitumen shingle roofs were inspected. "40 showed some form of damage (categories 2 or higher) and 28 having moderate (3 or higher) or greater damage reported. Maximum hail sizes on the asphalt shingle roofs inspected ranged from 0.25 inch to 3.25 inches in diameter…. Roofs with damage category 2 or higher had been struck with hailstones 1.0 inch of larger. Of the 25 asphalt single roofs rated with damage categories 3 or higher (moderate to severe) 92% had been struck with hailstones 1.25-inch diameter or larger. … Shingles judged to be 9 years and newer …had an average damage rating of 2.1 while the shingles older than 9 years had an average damage rating of 4.2."

BUR: Aggregate covered BUR roofing systems appeared to perform well in the Dallas/Ft Worth storm. "Five of the six roofs inspected were impacted by hail of 2.25 inch or larger and one roof was impacted with 1.75 inch hail. All were rated with damage levels 1 or 2, indicating little observable damage and general good performance." In the Oklahoma investigation thirteen BUR roofs were investigated. Some aggregate covered BUR performed well enduring "hail impacts of 1.5 to 2.0 inches without apparent damage in the field of the roof. " However damage was found in the field (and flashings) of five roofs with hail size ranging from 1.0 to 2.5 inches in diameter.

Single Ply Membrane: Six single ply roofs were inspected in the Oklahoma study, three EPDM, two PCV and one TPO. Both ballasted and fully adhered EPDM roofs sustained 2.0-inch hail impacts without apparent damage. However, insulation under the fully adhered membrane was dented. The PVC and TPO membranes showed hail impact marks but not visible fractures. (Note: Destructive sampling was not performed to determine if fractures occurred to the underside of the membrane.) In the Dallas/Ft Worth study, three low slope single ply membranes were inspected. "One roof was rated to have damage level 5 that was impacted by 1.75 inch hail;.... Another roof was rated damage level 3 (moderate amount of fractures or punctures) when exposed to 2.5-inch hail. One single ply roof did not have any visible damage when exposed to 2-inch hail. Note: The report did not list the type of membrane of each single ply system. The Oklahoma study noted, "While performance was generally good on examined roofs with single ply sheet membranes, there were not sufficient sample sizes to identify conclusions regarding hail impact resistance."

Metal Roof Systems: The Oklahoma study reported; "Hail effects on metal roof systems were seen largely as cosmetic, rather than functional. … With the extremely large hail there were a few instances of distorted seams or spalled granule surface, but even this was rare. "

The Dallas/Fort RICOWI investigation concluded. "Almost no damage was found in areas where the maximum hailstone size was less than 1.0 inch in diameter with the exception of badly deteriorated and unsupported material. When maximum hailstone size was between 1.0 and 2.0 inches in diameter, the level of damage ranged from none to considerable depending on the material, age/condition, roof slope and support conditions. When maximum hailstone size was greater than 2.0 inches in diameter, most roofing material sustained damage or denting of metal.

Regardless of the conclusions from RICOWI's hail investigations, with the exception of metal roofing, even light to moderate hail damage to other roofing systems such as single ply membranes, shingles, BUR and others can lead to roof leaks. Consequently, tear off and replacement are the most common recommendations by roof consultants for hail damaged roofs in category 2 and above.

Increasing the hail impact resistance of the Typical SPF roof

While the basic SPF roof system described above has good hail impact resistance, additional design elements can be used to significantly increase its hail resistance. The following design elements can be used to develop a SPF roof that can resistant cracks and dents from fairly large hail in the 1.5-2 inch category.

1. Use higher density foam. As reported above, SPF roofing foam ranges in density from 2.5 pcf to over 3 pcf. As the density increases so does the compressive strength of the foam and its resistance to impact. In order to provide the best hail impact protections use a SPF that has a density over 3.0 pcf (under 4.0 pcf)* and a compressive strength of 60 psi or more.

2. Add a 3rd layer of coating. Most SPF roofing systems consist of 2 layers of 10-15 mils each of coating. Adding another layer of coating thereby increasing the thickness of the coating significantly increases its tensile strength providing greater hail impact resistance.

3. Combine tensile strength with high flexibility. Impact resistance of a coating system is a combination of both tensile strength and flexibility. For example, a coating system with 400-psi tensile strength and 400% elongation is less likely to crack from hail impact than a coating system with 1500 tensile strength and 75% elongation. A combination of high tensile strength and high long-term flexibility provides the greatest protection.

4. Top coating system with granules or crushed aggregate. Field studies show that adding granules or crushed aggregate help reduce hail impact damage more than just coating alone.

5. Check out the weathering characteristic and field history of the coating. It does little good to use a coating that starts with great tensile strength and flexibility, which after a few years loses its flexibility. It is important to use a coating that has demonstrated good impact resistance in the field over time, particularly against moderate to heavy hail.

Repairing SPF Roofing Damaged by Hail

When a SPF roof sustains damage from wind driven missiles or hail how does one determine what procedures are required to maintain the roofs long-term performance? Under what conditions can the roof be renewed? When must it be scarified, recoated or torn-off? This article will discuss the type of damage likely to occur during windstorms and hail events, the affect on the SPF roofing system's performance and industry guidelines developed by the Spray Polyurethane Foam Alliance (SPFA) for inspecting, evaluating and recommending repairs.

Damage from Wind Driven Missiles:

Hailstorms are frequently accompanied with high winds that create airborne debris which can impact and produce damage to the coating and SPF. The type of repairs required from this damage depends on the size and severity of the damage.

Missile damage refers to cuts, gouges, dents, and abrasion to coating and SPF caused by materials such as tree branches, signs, parts of other buildings (shingles, metal panels, flashing, doors, windows, etc.), and many other non-secured items hitting the roof during a windstorm. I've even seen a sailboat end up on a roof. Consequently, damage from wind driven missiles is likely to be quite varied depending on the items that strike the roof.

Small cuts, gouges, etc. (less than 3" in diameter) in the SPF can be repaired by caulking the holes after the damaged SPF is removed. Repair larger damaged areas by removing damaged SPF and applying new SPF and coating to the void.

Hail Damage:

Damage most likely to occur to SPF roofing systems during a hail event consists of cracks, punctures and dents to the surface of the roof. Both the protective covering/coating and the SPF can be damaged. When hail strikes a SPF roof, cracks shaped like a crows foot or semi-circles may appear on the coating surface.

The diameter of the cracks can be used to determine the hail stone size. The SPF, depending on the size, weight and shape of the hail, may be dented as well. The depression typically ranges from 1/8" to 3/4" in depth. Hail damage can be isolated to small areas or cover the whole roof. Determining short term and long-term repairs to hail damage depends on identifying the severity of the damage. It is important to note both the size and quantity of hail dents and cracks. For example, fifteen 3" diameter hail dents on a 1000 sq. ft. roof may be less problematic than hundreds of 3/4" diameter hail dents.

Sometimes, mechanical damage is not discovered for months or even years after the damage occurred. In these circumstances, repair procedures differ depending on the extent of UV degradation of exposed foam and moisture absorption of the roof. Any UV-degraded or moisture-laden SPF in the cuts, cracks/dents should be removed and caulked. If the cuts, cracks/dents are too numerous to remove and caulk, the affected areas should be scarified, refoamed and coated.

Inspection Procedures;

The first step in making an evaluation and repair recommendation of a damaged SPF roofing systems begins with an inspection that includes visual observations and destructive sampling and testing. The following inspection procedures (listed in SPFA's technical Document AY 122) of an existing roofing system can helpful.

Visual Inspection:

- Look for blisters or delaminated areas
- Check the condition of the roofing system at all flashing and termination points
- Look for splits or cracks in the SPF
- Look for damage from impact
- Check for pinholes in the SPF or coating
- Check for exposed SPF and areas of eroded coating
- Check for areas of ponded water
- Check for obvious substrate or structural damage

Physical Inspection:

- Perform a non-destructive moisture survey. Follow-up suspected moisture laden areas with a moisture probe or core samples
- Probe to determine SPF thickness
- Take slit samples of the existing coating (at least 1 per 2500 square feet)
- Take SPF samples (at least 1 per 10,000 square feet)
- Take random slit samples of damaged areas

Analyze Inspection:
Core and slit samples should be examined for the following characteristics:

- UV degradation
- Presence of moisture saturation
- Adhesion of SPF to substrate
- Adhesion of base coat to SPF
- Adhesion of top coat to base coats
- Type and condition of protective coating
- Thickness of protective coating
- Condition of SPF
- Depth of damaged SPF

Indicate on a roof sketch the following:

- Location of core and slit sample
- Type and location of coating deficiencies
- SPF or coating blisters
- Mechanical damage
- Poor drainage
- Repairs required for foamstops, parapet walls, gutters, flashing, scuppers, edge terminations, expansion joints, and other perimeter items.
- Repairs required to soil and vent pipes, drains, roof hatches, equipment curbs, or supports, guy wires, hot stacks, skylights, mechanical units, walkways, sleeper, pitch-pans, and other penetrations.
- Water-saturated sub-roofs, insulation or SPF
- Sub-roof damage or deterioration
- Areas of special consideration

Repair Recommendations

After you obtained information from the roof inspection, repair recommendations can be developed specific to the damage sustained. As we discussed earlier, repairs will vary depending on the severity and the frequency of the damage.

The following chart obtained from SPFA's technical document AY 139 can help classify the mechanical damage and provide repair recommendations. Note: As reported in SPFA AY 139 "Damage extent in this chart is categorized as less than 10 or more than 20 defect per 100 ft^2. Recommended repairs for damage extents between 10 and 20 defects per 100ft^2 will require judgment based on manufacturer's recommendations." Other factors affecting repair recommendations include, age and condition of SPF & coating, service life expected of the roof system, cost of repair, amount covered by insurance and more.

Type of Damage	Size & severity	Extent per 100 ft^2	Recommended repair
Light	1/2"diameter or less less than 1/8" deep	Less than 10 cracks, cuts and/or dents	Coat and/or caulk dent, cuts and cracks *Note: Re-coat should be considered based on remaining service life of coating*
		More than 20 cracks, cuts or dents	Re-coat as required to fill in cracks *Note: Some caulking may be required to seal deeper cracks*
Moderate	1/2" – 3/4" diameter less than 1/4" deep	Less than 10 cracks/dents	Coat/caulk cracks:
		More than 20 cracks, cuts or dents	Recoat as required to seal cracks *Note: Some caulking may be required to seal deeper cracks*
Heavy	3/4" to 1-1/2" 1/4" to 1/2" deep	Less than 10 cracks/dents	Remove damaged SPF: Caulk holes and recoat as required
		More than 20 cracks/dents	Scarf 1/2" of roof surface: Refoam and coat
Severe	1-1/2" or larger 1/2" or deeper	Less than 10 crack/dents	Remove damaged SPF: Caulk holes: Recoat as required
		More than 20 cracks/dents	Scarf 3/4" of roof surface: Refoam and coat

Other Factors to Consider

The recommendations listed above are not specific to regions or varying climates. While the recommendations remain consistent in varying climates, consequences of untreated wind and hail damage to SPF roofs vary in different climates.

Hot Arid Climates:

Climates such as Phoenix or Las Vegas are more forgiving in regards to light to moderate hail damage. However, cracks in the coating can allow UV degradation over time. This degradation may take months to occur. However, this degradation typically does not affect the roof's water resistant characteristics since the low humidity and exceptional drying characteristics of the climate does not allow the SPF to saturate over time. The main concern of light to moderate hail damage in this climate is to maintain the coating's capacity for recoat/renewal. Eventually, UV degradation of the SPF under the coating will affect the adhesion of the coating to the foam. It is recommended that the damaged areas be removed and caulked or re-foamed. It should be noted there are cases of lightly hail damaged roofs in these areas being

successfully recoated years after hail damage without any specific hail damage repairs occurring. Still it is prudent to make hail damage repairs as soon as practically possible.

Hot Humid Climates

Climates such as South Texas and Florida have more complex factors affecting hail damaged SPF roofs. High temperatures tend to dry out the moisture that has seeped into the cracks and crushed foam cells very quickly. On the other hand, the high humidity creates a higher potential for SPF saturation particularly during cooler times of the year. Lower perm rated coatings/coverings also increase the potential for moisture saturation of the hail damaged roofs because they do not allow drying to occur as efficiently as higher perm rated products. As in the hot arid climates, UV degradation that can affect coating adhesion typically occurs within a few months.

Cool Climates:

In cooler temperatures the greater concern of hail damaged roofs is moisture saturating into the SPF. There may be long periods of time where drying conditions do not occur. In many areas snow may stay on the roof for extended periods increasing the possibility of moisture saturation. It is important to repair crushed foam and coating cracks as soon as possible to prevent moisture saturation of the damaged areas.

Conclusions:

SPF roofing systems have unique characteristics that allow the repair rather than the replacement of the system after hail and wind damage. Hail and wind damage repairs to SPF roofing systems vary according to size, severity of damage and the length of time after the damage. It is important to inspect and evaluate the damage in order to make the correct repair recommendations. However, with the correct repair, SPF roofing systems can perform for many years after a significant wind or hail event.

REFERENCES:

Dupuis, Rene. “A Field & Laboratory Assessment of Spray Polyurethane Foam-Based Roof Systems.” Conducted for the National Roofing Foundation, 1998.

Fricklas, Richard. “An Update on Hail and Wind Considerations.” Presented at Spray Foam 2000, Reno, NV

Smith, Thomas. “”How did PUF roofs perform during Hurricane Andrew?” Professional Roofing, January 1993.

SPFD Guideline AY122. “The Renewal of Spray Polyurethane Foam and Coating Roof Systems.” 1994

SPFA Guideline AY 139. “Recommendations for Repair of Spray Polyurethane foam (SPF) Roof Systems Due to Hail and Wind Driven Damage.”

RICOWI Hail Storm Investigation, Oklahoma City, OK April 21, 2005

RICOWI Hail Storm Investigation, Dallas/Fort Worth, TX May 24, 2011

Photos:

Photo 1, Dents on HVAC equipment signal that a hail inspection should be conducted

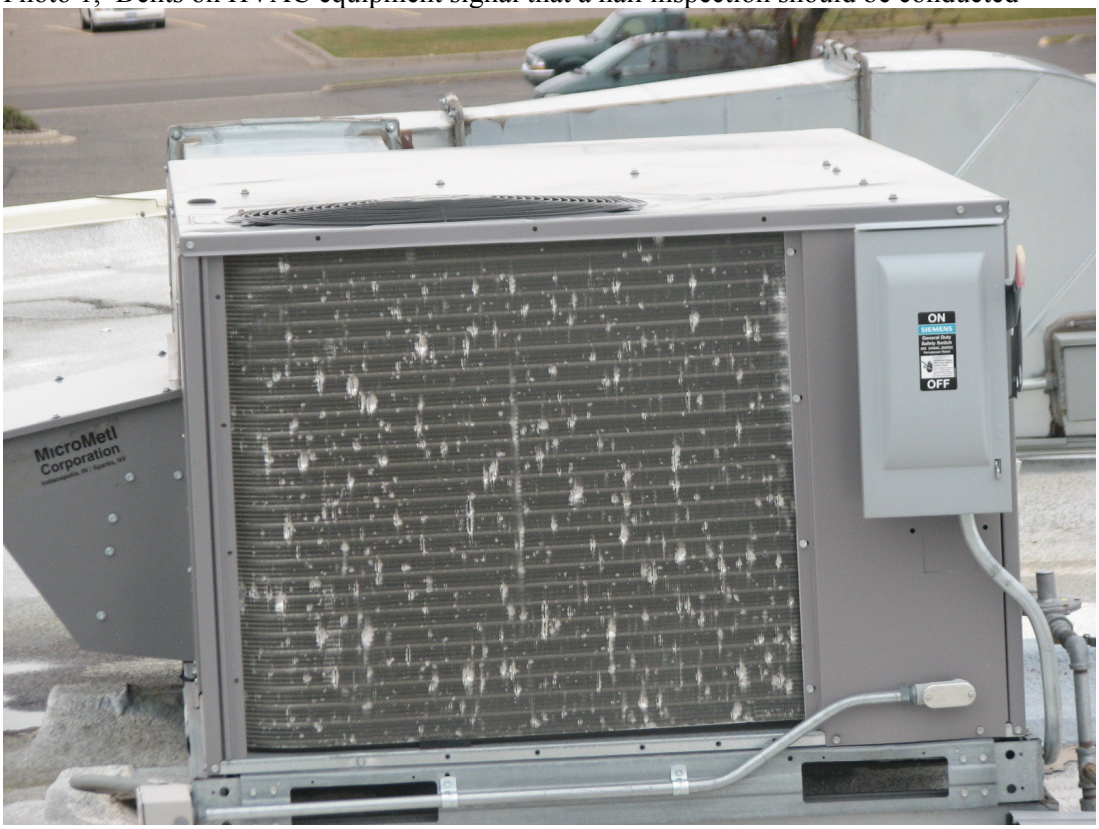

Photo 2 Slit samples can show the severity of damage from hail impact. The crack in this sample is less than ¼ inch indicating light damage

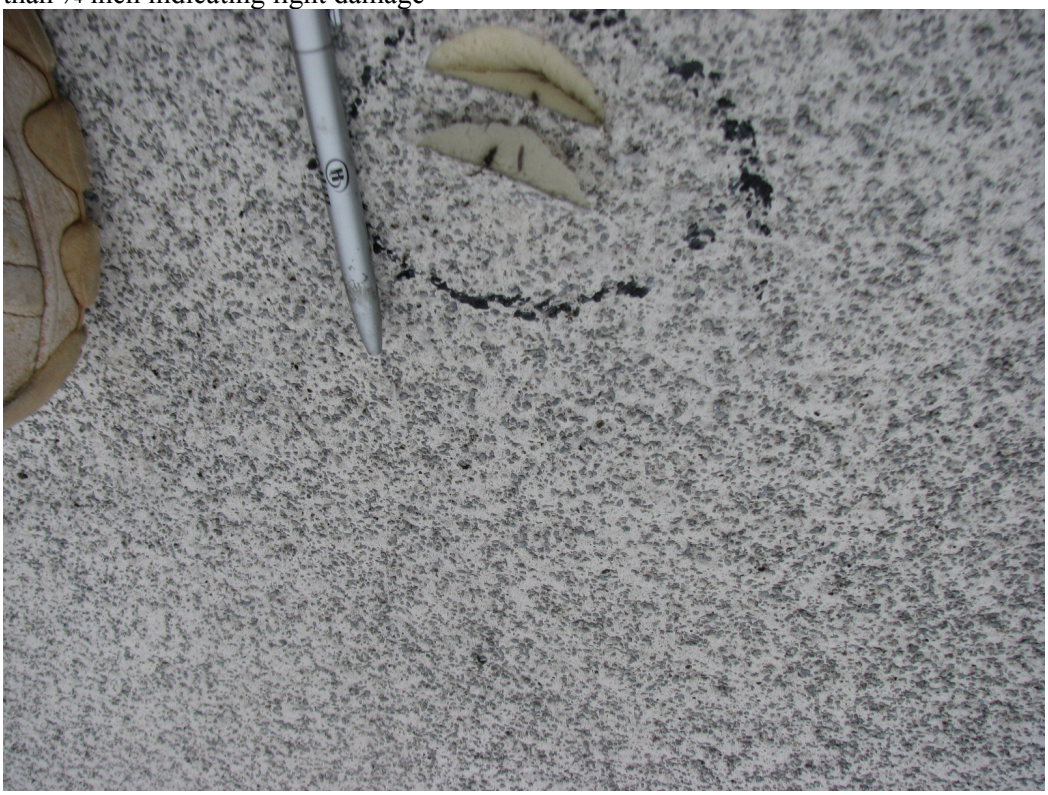

Photo 3 This crack extends 3/4 inch into the foam and showing the hail damage is more severe

Photos 4 & 5 Granules can help reduce hail damage, but can also hide cracks unless investigated more closely

Photo 6 Frequency of the hail dents/cracks is typically more important than the degree of damage. This photo shows more than 20 cracks/dents per 100 ft^2 and would require caulking and a recoat

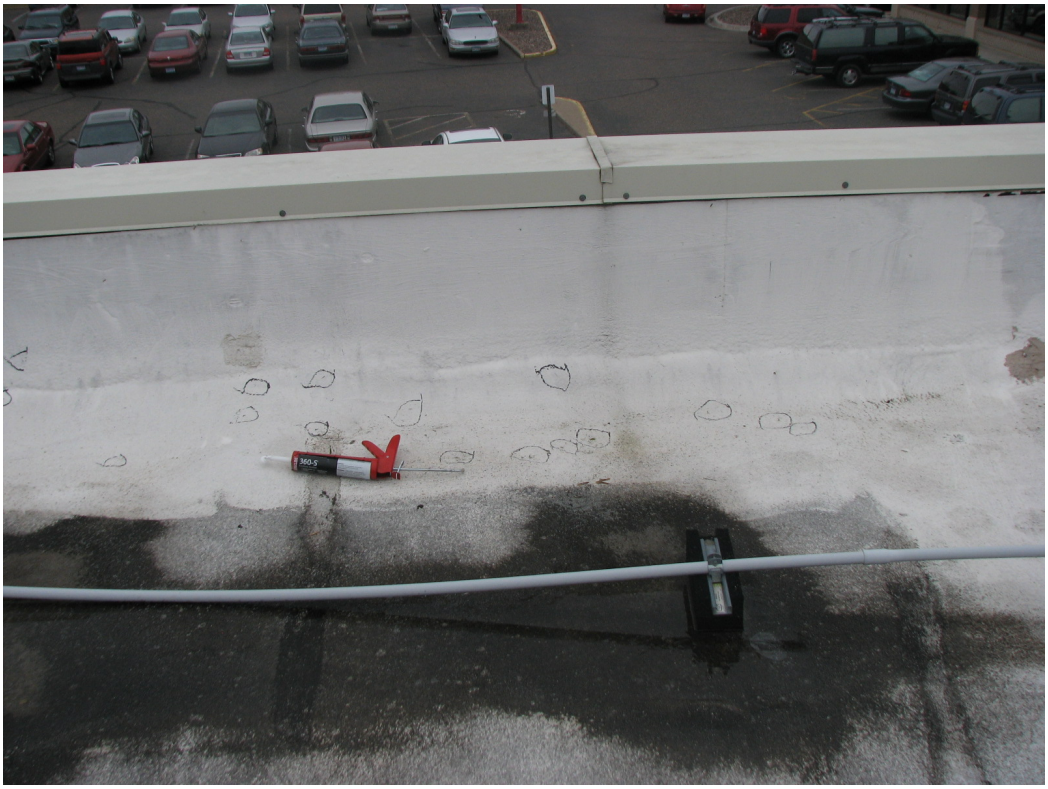

Photo 7 This SPF roof in the northern Midwest was damaged by hail and not recoated for several years. Consequently the roof became saturated.

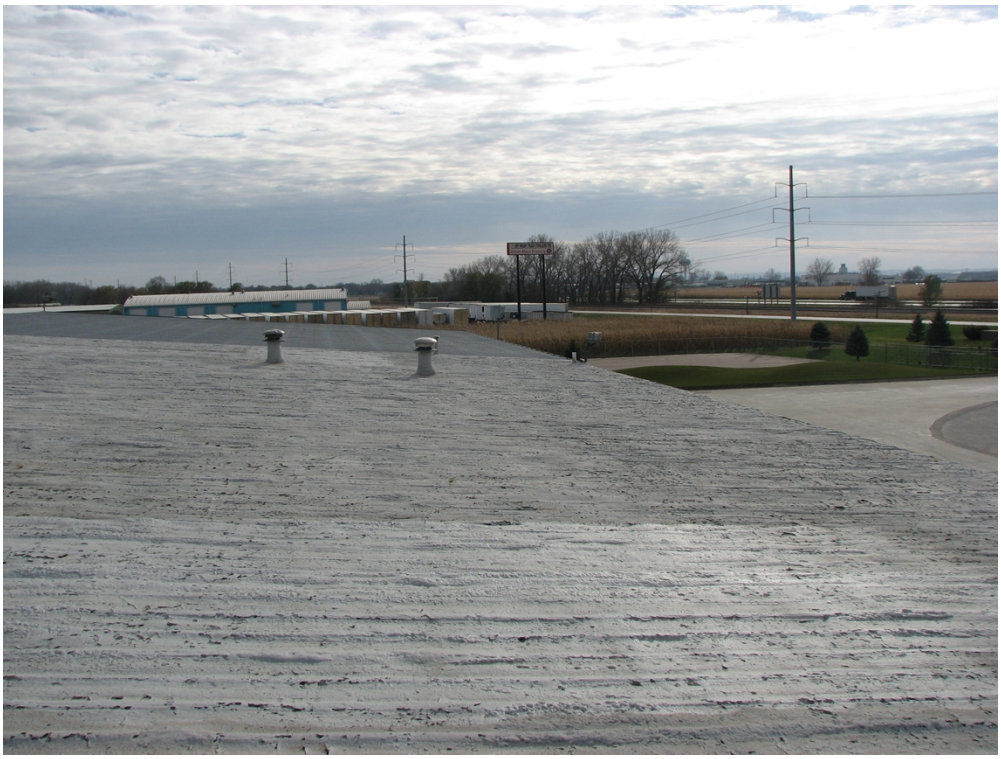

Photo 8 If you observe plants growing in the roof, it is too late to perform repairs in that section