How Modified Asphalt Tackles Extreme Weather Challenges

By Traci Shaw and Greg Malarkey

Of the challenges a roof faces, hail is, in many ways, the most devastating. Storms bring in cold rains that thermally shock the roof; then, in this heightened state of stress, hail slams into the shingles. Each year, the National Weather Service's (NWS's) Annual Severe Weather Report records locations of hail with a diameter of one inch or greater. Preliminary reports from the NWS show 7,065 instances of large hail throughout the United States in 2013 (*Figure 1*), with preliminary reports for 2014 showing a similar story.[1] It is no surprise that property damage due to hail reaches an estimated $1.25 billion annually.[2] The stress imparted by hail can devastate roof coverings. For asphalt shingles, there are three primary modes of failure: fracturing of the shingle, bruising of asphalt, and removal of surface granules.

The impact energy of hail imparts stress on the shingle, causing it to flex downward. The top surface is subjected to vertical compression while the bottom is subjected to horizontal tension. To absorb the impact, the bottom of the shingle will expand. This expansion can lead to cracking, which is referred to as fracturing. If the fracture does not extend through the entire shingle, it is considered a bruise. Bruising is still considered functional damage because it leaves a soft spot in the shingle that is vulnerable to further damage. The impact to the shingle may also dislodge granules from the asphalt, leaving the asphalt exposed to the aging effects of ultraviolet (UV) rays.[3]

When the Texas Department of Insurance created the impact test that has evolved into UL 2218, the focus was on the fracturing of the shingle. For this reason, failure in the UL 2218 test is defined by the Acceptance Criteria (7.2), which reads: "For asphalt shingles, a visible crack of the asphalt on the back of the shingle shall be determined to be a failure." The current testing method accounts for functional damage due to cracking on the bottom of a shingle, but does not address the issue of dislodged granules, asphalt compression, or openings visible only on the top of the shingle, all of which lead to premature degradation of the asphalt material.[4]

The Insurance Institute for Business & Home Safety (IBHS) found that homes with roof coverings classified as impact-resistant were 40% less likely to have claims—and even less likely to have claims resulting in insurance payments—than those without.[5] While many asphalt shingles pass UL 2218 Class 4 impact resistance testing, they do not all perform equally. Independent testing by IBHS has also shown that even among UL-rated, impact-resistant shingles, polymer-modified, impact-resistant shingles performed 20% to 50% better than traditional oxidized impact-resistant shingles for all four steel ball impact classes.[6]

Figure 1 – National Weather Service preliminary severe weather report of large hail events in 2013.

MODIFICATION OF ASPHALT

All roof coverings are comprised of systems of components that work together to create a protective barrier, and shingles themselves are no different. Asphalt shingles are a system built primarily of mat, asphalt, filler, and granules. Each component serves a function and is critical to the

Photo 1 – A roof with Legacy® SBS polymer-modified shingles after a hailstorm in El Dora, Iowa, in August of 2008. The only shingle damage was to the ridge vents, due to the unsupported ridge area.

success of the product. In the search for innovation, modified asphalts are ushering in a new era of more resilient asphalt products.

The asphalt used in traditional manufacturing of shingles is known as coating asphalt. Raw asphalt, also known as flux, is the base stock for roof coating asphalt and has a softening point around 80°F to 120°F (27°C to 49°C). Asphalt shingle roofs have been measured at temperatures exceeding 180°F (82°C). To function as roof coating asphalt, flux must be altered to stiffen the asphalt to withstand the normal operational temperatures experienced on a roof. The traditional process, known as the oxidative aging of asphalt, or oxidation, involves bubbling air through liquid asphalt flux at 500°F (260°C) for one to 10 hours.[7] Once flux has been oxidized, the common softening point is raised to temperatures between 200°F and 225°F (93°C and 107°C).

The natural aging process of asphalt is affected by three components: heat, oxygen, and UV rays. The process of oxidizing asphalt artificially expedites the natural aging effects through heat and oxygen exposure. This chemically alters the asphalt from low-molecular-weight compounds (aromatics, resins, and saturates) in the flux, forming it into longer chain asphaltenes and hardening the asphalt. As a result, the oxidized asphalt is limited in its ability to respond to strain. To resist strain energy, traditional asphalt shingles must have enough mass to resist damage from the impact energy imparted by hailstones.[8]

An alternative method to adjust the asphalt's physical characteristics is by polymer modification. Asphalts have physical properties similar to polymers, but they differ dramatically at the molecular level. A simple polymeric material is composed of large molecules of similar chemical composition that do not change in molecular weight with environmental temperature changes. Unlike polymeric materials, asphalt is composed of a complex mixture of smaller molecules whose bonding forces are highly dependent upon temperature.[9] Blending polymers with the asphalt stabilizes the bonds, making the mixture flow less temperature-dependent than what is normally observed in flux and oxidized asphalt.

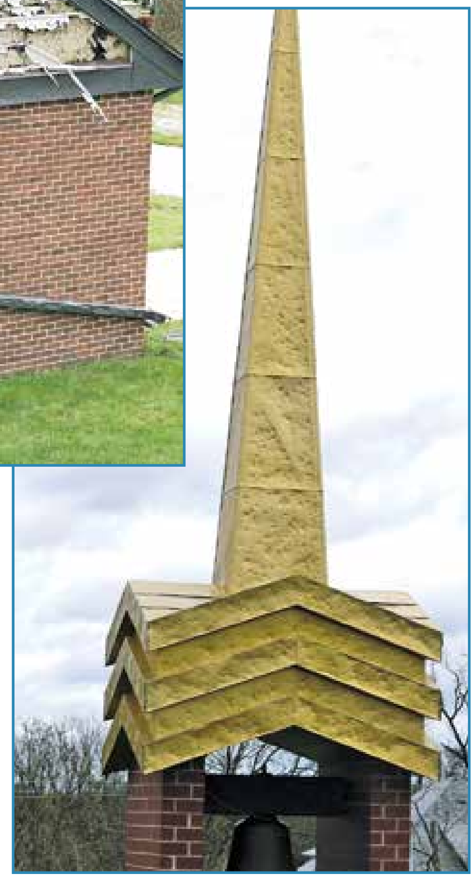
The process of polymer modification allows control of the softening point, while adding benefits such as improved adhesive qualities. The addition of styrene-butadiene-styrene (SBS) polymers to asphalt increases the softening point without changing the chemical makeup of the asphalt and better maintains the flexibility that would be lost during oxidation.[10] By using this alternative to the oxidation process, manufacturers are able to engineer strain-response properties in the asphalt. This creates asphalts able to function under substantially greater strain energy, such as the energy imparted from a hailstone striking the shingle.

The incorporation and application of polymer modification during the manufacturing process will also influence the durability of the shingle. There are three common methods for incorporating polymer-modified asphalts into the production of shingles. The first method is to fully impregnate the mat base with polymer-modified asphalt. This method may slow production due to the added viscosity of the polymer-modified asphalt requiring more time to fully saturate the mat. Shingles that are fully impregnated with SBS polymer-modified asphalt ensure that the SBS flexibility and strain resistance are fully incorporated. The second common method impregnates the mat with oxidized asphalt and then adds a layer of polymer-modified asphalt on top. This allows manufacturing to maintain faster production due to the lower viscosity of oxidized asphalt but loses some of the flexibility and associated benefits seen in the fully incorporated method. The third method adds a polymer oil mixture, or a rosin or resin additive, to the oxidized asphalt. This method slightly softens the oxidized asphalt, but does not provide the full range of polymer characteristics due to incorporation with the artificially aged, oxidized asphalt rather than the raw asphalt.

INTRODUCTION OF POLYMER-MODIFIED SHINGLES

The first SBS polymer-modified commercial base sheet was introduced to North America by Malarkey Roofing Products in

Photos 2 and 3 – Alternate views show destruction of siding and a bronze steeple on the same building during the same hail event.



1977. Building upon this technology, the company introduced the first SBS polymer-modified shingle in 1986. The SBS shingles were developed to allow for low-temperature installation in Alaska, which effectively extended the roofing season and reduced cracking seen from the oxidized shingles in cold-weather application. Upon installation, observations in the field showed polymer-modified asphalt had another unexpected trait: wind resistance.

In 1992, further testing began for resistance to strain energy generated by wind. The test was performed in a testing lab by applying the SBS polymer-modified shingles to a deck, ensuring they were fully sealed, and subjecting them to 110-mph winds for two hours. After passing the initial test, a second test was run with unsealed shingles, again blown at 110 mph for two hours. In the second test, the shingles curled up in the wind, and then lay down to their original position when the test ended. Neither deck experienced shingle blow-off.

Asphalt shingles rely primarily on the effectiveness of the top shingles sealing to the shingles below to prevent blow-offs during high-wind conditions. SBS polymer-modified shingles provide an added level of protection through their ability to flex in the wind and then return to a flat position on the roof, reducing the likelihood of blow-offs and complete roof failure. In concurring 2014 testing, IBHS has seen indications through its research that the increased toughness and flexibility of polymer-modified shingles may allow the shingle to survive a storm, even if the seal is broken.[11] During the aftermath of Hurricane Andrew in 1993, Miami-Dade County amended the building code and instituted the 110-mph requirement for roofing materials. The SBS polymer-modified shingle was shipped to Florida and became the first code-approved shingle in Miami-Dade County.

Throughout the late 1990s, increased installations in elevated wind areas, such as the Midwest, brought with them the strain of hail. Again, the polymer-modified shingles were observed to resist the strain energy imparted on them from the impacts seen in these storms. In 1996, UL introduced UL 2218, the first standard test developed to assess the impact resistance of flexible roof covers.[12] In 1997, the SBS polymer-modified shingle passed the UL 2218 impact resistance test at a Class 4 rating. Since that time, SBS polymer-modified shingles have gained traction throughout the Midwest as the preferred shingle for impact resistance.[13]

Shingle performance is about more than resistance to impacts; it is also about recovery. In ASTM D412, asphalt is tested to withstand tensile forces.[14] During this test, oxidized asphalt may elongate up to 50% of its original size, but will not recover to the original size. In the same test, SBS polymer-modified asphalt may elongate 300% or more, then recover substantially to its original size. The elastic recovery of SBS polymer-modified asphalt allows for better strain response. Elastic recovery also contributes to improved granule adhesion. Granules naturally swell and contract as they heat and cool with the weather. The ability of the SBS polymer-modified asphalt to expand and recover allows the asphalt to maintain better granule adhesion, which, in turn, protects the asphalt from UV degradation.

A FORTIFIED SYSTEM

We cannot change the weather, but we can fortify the roofing system to better withstand the increasing demands from forces of nature. In an effort to advance roofing solutions, IBHS has developed the Fortified Roofing System that provides independently tested guidelines to reduce the potential for property damage due to natural disasters.[15] In the same search for innovative solutions, research continues on how the integration of polymers can create a more resilient roofing material. The ability to blend asphalt with new modifiers opens the door for further modification and greater control of asphalt shingle properties, leading to resilient roofs and safer homes.

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Photo 4 – Untouched photograph of an oxidized asphalt shingle in the same neighborhood after the same hail event in El Dora, Iowa.

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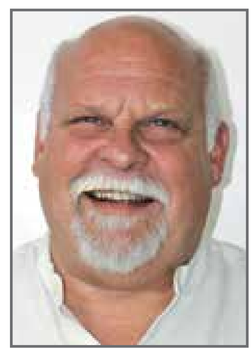
Traci Shaw

Traci Shaw is the communications coordinator at Malarkey Roofing Products. She grew up in a family-owned roofing business and now writes educational materials and external communications for Malarkey. She currently sits on the Communications, Marketing, and Education Committee of the Asphalt Roofing Manufacturers Association (ARMA).



Gregory Malarkey

Gregory Malarkey is the current president of the Asphalt Roofing Manufacturers Association (ARMA) and senior vice president at Malarkey Roofing Products. He has over 30 years of multidisciplinary experience in the asphalt roofing industry, is co-chairman of the Asphalt Roofing Environmental Council, and is active with the Asphalt Institute.

THUNDERSTORM DAMAGE RISES

Insured thunderstorm wind and hail losses topped $27 billion in 2011 and $14 billion in 2012, whereas in the early 2000s, they hovered around $5 billion. According to Eberhard Faust, head of climate risk and natural hazards research at MunichRE, inflation-adjusted annual losses due to severe thunderstorms ($250+ million in damage) have doubled since 1970.

Faust's study team has found that storm formation seems to be easier now than it was 40 years ago, though it is not clear whether this is due to natural climate variability or man-made climate change. At the same time, the median age of a home in the U.S. has increased from 25 years in 1987 to 35 years in 2010. In many parts of the country, the majority of homes still have their original roof, making them more likely to fail in storms than new roofs, built to stricter codes.

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