Can Acrylic Coatings save your Next Roof?

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The photograph shows the effects of weathering over a 20-year period on a portion of an untreated asphaltic roof. The remainder of the roof was coated with an all-acrylic elastomeric roof coating about 10 years after it was built, and has resisted additional weathering. (Photo courtesy of Rohm and Haas Co., Philadelphia.)

This research paper explains the process of asphalt degradation over time and reveals the performance of acrylic maintenance coatings, site aged for six to 10 years, over both BUR and shingle roofs.

The application of acrylic coatings to protect new systems and preserve existing membranes has become an important part of the services the professional roofing provides to the building owner.

But how effective are these products, particularly in the area of maintenance?

The results of current weathering research published here may help the industry answer this question.

In order to more completely understand the effect of elastomeric acrylic coatings on asphalt based roofing materials, the mechanism of asphalt degradation must first be understood.

Asphalt is a complex mixture of literally hundreds of aliphatic and aromatic hydrocarbons. One simple method is to separate the asphalt into fractions soluble in aliphatic hydrocarbon solvents and those soluble in aromatic solvents. This method is the basis for the Corbett fractionation technique and is referenced in ASTM D4124 and VS Patent 3,432,321 and other sources.

The asphalt fractions soluble in aliphatic hydrocarbon are called maltenes and those soluble in aromatics are called asphaltenes.

As asphalt weathers, the maltene fraction reacts with sunlight and oxygen in the air to form asphaltenes.

MALTENE+ SUNLIGHT+ HEAT+ OXYGEN > ASLPHALTENE

Like most reactions, the presence of heat will greatly increase its rate. A second reaction caused by weathering is the chain scission of the higher molecular weight fractions. This is also caused by the UV component of sunlight.

An additional weathering component is the exudation of low molecular weight fractions from the asphalt. These fractions are present in fresh asphalt and act as plasticizers to improve the flexibility of the roofing material. This exudate is most easily observed on freshly installed modified bitumen roofs as a residue collecting in shallow depressions or ponds. Its loss further contributes to asphalt degradation.

Experiments performed

In 1982, two separate experiments were initiated; designed to demonstrate the durability enhancement and life-cycle extension potential for 100 percent acrylic elastomeric roof coatings applied over asphaltic roofing substrates.

The first experiment involved coating a 10-year-old organic felt, asphalt shingle roof with a 20 dry mil (. SI-mm) acrylic coating. The coating formulation contained the polymer, titanium dioxide (TiO2), and zinc oxide (ZnO) pigments, calcium carbonate (CaC03) extender, polyphosphate and polyacrylic dispersants, an isothiazilone mildewcide and cellulosic thickener.

The polymer was based on 100 percent acrylic monomers and had a glass transition temperature, Tg, of -35 C.

The glass transition temperature can be measured on any polymeric material and is an important indicator of the tolerance for movement of a membrane or coating formulated with this polymer. The reference cited clearly describes the need for low glass transition materials in order to tolerate roof movement at low service temperatures.3-4 One small section of this roof was left uncoated and allowed to continue weathering.

After seven years of additional exposure in Spring House, PA, the roof was examined. The coated section clearly exhibited virtually no change in appearance, while the uncoated section was severely degraded. Similar experiments with built-up asphalt roofing mock-ups gave comparable results; the coated roof showed virtually no change while the uncoated section was severely degraded.

And now, a more fundamental explanation of the asphalt degradation process and the inhibiting effect of 100 percent acrylic coatings.

Acrylic maintenance coatings are applied over aged asphalt shingle and built-up roofs and allowed to weather for 6-10 years. Roof cut samples are analyzed chemically and via optical and scanning electron microscopy techniques compared to uncoated areas subject to the same weathering. A mechanism for weathering of asphaltic roofing materials is proposed here and the effect of acrylic maintenance coatings in reducing weathering is also documented.

Shingle roof experiment

Concurrent material science and analytical chemistry approaches were pursued. Individual asphalt shingle tabs were removed from the roof and tested for performance (mandrel bend flexibility at degrees O C.) and asphalt composition. Shingle tab samples were bent in both directions. The reverse method was employed to ameliorate or eliminate the effect of the coating possibly enhancing flexibility. This test is fashioned after the ASTM C-734 protocol, which is normally used for sealant evaluation.

The various components of the asphalt roof samples were separated using a combination of solvent extraction and filtration. Four separate one-inch squares of roofing material were taken from each sample and the results are the average with standard deviations noted. The data were evaluated on a weight/unit area basis. The maltene fraction was first extracted with heptane (C7H16). The heptane did not attack the acrylic coating, which remained intact as a strong flexible film and could not be physically separated from the shingle, indicating excellent adhesion. Greater than 95 percent of the granules were preferentially adhered to the acrylic coating when peeled from the shingle.

The second step was to extract out the asphaltene action with tetrahydrofuran (THF) (C4H80). The remaining insolubles were light colored and thus all of the asphalt had been removed from the roofing material. The residue was further rinsed with tetrahydrofuran to wash the granules and fine particle size inorganic fillers from the mat. The reinforcing mat was removed as a single, largely intact piece. The particulate material was dried and filtered through a 40-mesh sieve. The inorganic fillers and fines passed through while the coarser granules from the shingle surface were retained and removed.

Also present on the screen were widely varying amounts of loose fibers from the mat that were also removed and weighed. These fractions were kept separate from the other mat material.

In the initial analyses, the loose fibers were combined with the mat rinsings; however, significant differences were observed and later kept separate. The rinsings from the protected and coated areas appeared soluble but actually dried to a paper-like sheet. This is believed to be part of the original reinforcing matrix, but deteriorated during weathering. The acrylic coating prevented the deterioration of the reinforcing mat, protected the asphalt and retained the granules. The coating appeared to serve an additional purpose of providing some measure of reinforcing through its own physical properties.

The original chemical separation studies not reported here were done using weathered and coated weathered roofing only. The intent was to use the Corbett procedure and fractionate the asphalt into asphaltenes, paraffins, aromatics and polar aromatics and to compare the molecular weights of these fractions as well.

However, the small differences found were attributed to the fact that both samples had been weathered for seven years before coating and initiating the experiment. Numerous replicate samples were analyzed but no meaningful conclusions could be established.

This entire experimental study was hampered by the lack of an unweathered control. The best available unweathered control was to use the first course underlayment of the shingle roof at the eave. This section was not subject to direct sunlight and direct rain but would experience other weathering factors, such as temperature extremes and thermal shock. Unfortunately, even these protected layers had severely degraded and a second row of shingles, which were mechanically sound, was used.

As it turned out there was a small but real loss of the heptane solubles occurring in the uncoated weathered sample versus the coated sample. Interestingly, the tremendous loss in durability as evidenced pictorially or by low-temperature flexibility is not only caused by the conversion of maltenes to asphaltenes, but also by the loss of structural integrity of the mat. This loss is obviously reduced by the presence of the elastomeric acrylic coating.

This same set of samples was sliced into a top portion containing the roofing granules plus asphalt and a bottom layer consisting of mat and asphalt. This approach allowed for observing the more pronounced weathering effects in the portion of the roofing material receiving the most UV radiation. Similar separation techniques were employed using heptane and THF extractions. Since the thickness of the slice could not be controlled, the results are expressed as a percent of the asphalt, which is heptane-soluble.

The results show that the weathered sample contains a lower amount of heptane soluble material. This confirms the degradation of the shingle causes loss of asphalt preferentially from the top and the acrylic coating preserves the shingle by preventing asphalt loss.

Note that the sample was not taken on a Gm/Unit area basis since the study involves layers. The weathered and protected sample cleaved rather cleanly, leaving a granule layer and a mat layer. The coated sample had to be sliced with a knife trying to cut along the flaw lines.

The data confirms the earlier experiments that there is a loss of heptane solubles on aging. The balance of the data consists of the distribution of the insoluble components. Note that the weight of the mat is slightly lower for the coated sample than for the protected sample and much lower for the weathered sample.

The weight of the fines fraction passing through the sieve is much larger for the weathered sample. Other differences were also observed between the various insoluble fractions.

Note that the overall recovery (initial weight versus sum of all recovered fractions) and the standard deviation of the individual fraction weights is excellent.

Further analyses were conducted to better quantify the mat, granules, filler and fibers. The focus of evaluation was on the mat and inorganic components rather than the asphalt. The mat in the weathered sample was significantly degraded. It was isolated as a very compact plug, while the protected and coated samples were more fluffy and loose.

The composition of the mat was determined to be a calcium carbonate (CaC03) pigmented cellulose. In the protected and coated samples, the bulk of the mat weight was in the form of the mat and mat rinse. A very large fraction of the mat-related weight in the weathered shingle was from the fines. The fibers had become unglued during the extraction.

Fundamentally, the weathering process had degraded the reinforcing mat even though this layer was well below the surface of the shingle. In contrast, the acrylic coating prevented this mat degradation. The mat had not been broken down and the free fibers and the inherently fluffy nature had been preserved.

It is noteworthy that the mat rinse fraction is much lower for the weathered sample and it is physically different from the others. The material isolated from the protected and coated samples resembles a thin web or paper. It is not truly soluble in the solvents, but does form a film when rinse solvent is dried off. IR (infrared) analysis indicates this fibrous fraction is also cellulosic.

In contrast, this fraction is negligible in the weathered sample. This material no longer provides the necessary integrity required for the roof to function successfully. The acrylic coating protects the structural integrity of the shingle by preventing deterioration of both the mat and paper.

Built-up roofing study

An additional, more controlled study was conducted, evaluating the weathering effects on glass-reinforced asphalt built-up roofing (BUR). In this experiment, a 20-mil (.51-mm) elastomeric acrylic coating was applied prior to weathering and exposed at the Rohm and Haas Research Exposure facility at Spring House, PA. The results again show the loss of heptane solubles on weathering.

All measurements show that weathering involves some loss of heptane solubles from the asphalt. It is noteworthy that the mat in these three samples is very similar in weight and morphology but was different in the shingle experiment.

The level of fines, including inorganic filler is also relatively constant. This is due in part to the relative short duration of this study and to the increased tensile strength of the glass versus the cellulosic (organic) mat in the shingle experiment.

Scanning Electron Microscopy (SEM) and optical microscopy (OM) were used to investigate the differences in the structure of the asphalt roof shingles studied in the previous section. The same designations were used as protected, coated and weathered. All SEM was done on the Joel 840 using a 10KeV beam. Samples were sputter coated with palladium/ gold (Pd/Au) to provide a conductive surface necessary for this type of analysis. Images were taken in the normal (secondary) mode where higher atomic number and/or rougher materials appear brighter in contrast. For example, the shingle granules will appear bright, while the asphalt will appear dark in most of the images.

Environmental Scanning Electron Microscopy (ESEM) was used to obtain images of the materials that were otherwise difficult to obtain. These samples were examined without the need for sputter coating. The OM was done on the Wild Heerbrugg stereo microscope, in conjunction with a Sony image analyzer.

The three shingle samples were examined by OM. Each was prepared with a diamond saw using an aqueous lubricant to avoid dissolution of the asphalt. All three show distinct morphologies for the adhered granules, the darker asphalt and the lighter mat layers. Additionally the white acrylic-coated layer can easily be seen over the granules.

Closer examination of the different layers in the cross section reveals the effect of weathering in these three materials. By comparing the granules and asphalt layers in the different samples, a general decrease in the amount of asphalt coating of the granules is observed.

The weathered asphalt micrographs show significant degradation of the asphalt used to embed the mineral granules. Moreover, the granules are only adhered on the underside and deep fissures and cracks have propagated to the mat or scrim-reinforced asphalt.

Simply stated, weathering reduces the amount of asphalt binding the granules. Further comparison of the cross sections indicate a general delamination between the asphalt and mat containing layers, as well as delamination in the mat itself. The protected areas show some degree of degradation, but appear to be holding the granules more completely.

Also, there is no evidence of the deep fissures observed in the weathered samples. The coated samples show less degradation than the weathered samples and the coating has formed a monolithic single-ply membrane formed in-situ on the shingle. Some small fissures in the asphalt present at the time of coating were actually filled by the coating, thus preventing further degradation of the shingle.

These fissures would otherwise allow water to penetrate through the asphalt into the organic mat, causing the shingle to swell and subsequently shrink when dry. Additional stress would develop when the shingle would freeze and thaw. Ultimately, the shingle would leak and the roof would require replacing. The protected and weathered samples were then examined with SEM to determine finer changes in the topside of the asphalt surface morphology.

Cracks are difficult to detect in the asphalt of the weathered sample due to the roughness of its surface; however, there are crater-like indentations in addition to rough particulates, present both in and outside the craters. Further examination of the particulates at IO, OOOX shows their popcorn-like appearance. The cratering is probably due to the erosion and dislodgment of the inorganic filler, calcium carbonate (CaC03) found in the asphalt.

It was not possible to examine the asphalt under the acrylic coating for the presence of craters and roughness; however, it was hypothesized that the coating would conform to the irregularities, forming a type of negative mold of the asphalt morphology.

The coating containing the granules was isolated with heptane, as described above, and examined using SEM at 330X magnification. The backsides of the three asphalt shingles were examined for differences as a result of weathering. Interestingly, ditterences were observed visually so SEM studies were conducted. Magnification micrographs show the asphalt roughness increases in the following order: protected, coated and weathered. The same type of surface disruptions with aging are seen in the built-up roofing samples when examined by SEM. The coated, exposed BUR shows some cracking, but is smooth overall. The weathered BUR shows craters, but to a lesser degree than the shingles.

Extending roofing life

The experimental data from the roof exposures of both the asphalt shingle and built up roofs clearly show the life extension properties of the acrylic coating. It is theorized that the acrylic coating increases the longevity by two separate mechanisms.

First, while asphalt is subject to degradation by the UV radiation component of the sunlight, acrylic polymeric materials are transparent to UV radiation. As such, they do not absorb this intense radiation and are not subject to the polymeric degradation seen in less durable chemistries like aromatic urethanes and butyls. However, the acrylic material must be formulated with UV-blocking pigments in order to protect the substrate-in this case, the asphalt-from degradation. These pigments are usually titanium dioxide (TiO2) and zinc oxide (ZnO), as was the case in this study.

A second mechanism is the acrylic coating providing a water-resistant barrier over the existing asphalt shingle or built-up membrane.

While it is well known that acrylic coatings are "breathers" having a permeance rating of >1, and, when used alone, are not considered waterproofing barriers, they are able to resist penetration of bulk water. This analogy is similar to Gore-Tex5 fabric used in making breathable fabrics for cold-weather garments and camping equipment. The acrylic roof coating prevents contact of bulk water with the asphalt membrane, thus preventing low molecular weight asphalt fractions from leaching out of the asphalt.

Moreover, the coating prevents intimate contact of water with the membrane, and more importantly, the reinforcing mat, scrim or felt, thus eliminating the formation of ice and freeze/thaw-induced dimensional changes in the membrane. This is clearly evidenced by the fluffy, long stranded appearance of the coated shingle mat versus the short length, more compact mat appearance of the uncoated shingle.

Water infusion into the organic felt would also cause degradation of the mat via biological attack. This problem would theoretically be eliminated by using glass felt as the mat for asphalt shingles.

The introduction described the generally accepted mechanism for asphalt degradation, citing the contribution of heat. When the acrylic coating is pigmented with white pigments, the color of the dried coating will reduce the temperature of the roofing assembly, and reduce the rate of the asphalt degradation. This will further prolong the life of the coated roof. Because the acrylic coating is applied at 20-30 mils (.51-. 76mm), it acts more like a fully adhered functional membrane than merely a paint-type coating. The mechanical properties are approximately 300 percent elongation and 250 psi (1.72 N/mm2) tensile strength at room temperature and 100 percent elongation and 600 psi (4.14 N/mm2) at OF (- 17C.).

Studies conducted by Rohm and Haas have demonstrated over 80 percent retention of initial elongation properties even after five years exposure. As such, the coating actually provides reinforcement and structural integrity to the roofing material, similar to the reinforcing mat or scrim.

Conclusions

The results described in this paper clearly demonstrate the effectiveness of acrylic coatings in prolonging the life of asphaltic roofing materials used in low- and steep-slope roofing.

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