THE EFFECT OF REFLECTIVE ROOF COATINGS ON THE DURABILITY OF ROOFING SYSTEMS

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BACKGROUND

In 1997, the Roof Coating Manufacturers Association (RCMA) initiated a research program in cooperation with Oak Ridge National Laboratory (ORNL) to determine the effect of reflective coatings on heat transfer through a small-scale roofing system over time, using both aluminum-pigmented, asphalt-based coatings and white, elastomeric roof coatings. The solar reflectance and infrared emittance of these coatings were monitored, along with resulting roofing membrane temperatures. These measured properties impact the energy consumption used for heating and cooling, depending on geographic location, as has been clearly documented in Department of Energy, Lawrence Berkeley Laboratory, and Oak Ridge National Laboratory publications and energy calculators.

The roofing membrane chosen by ORNL and RCMA was a 4-ply, built-up roof assembly consisting of a nailed glass fiber base sheet, ASTM D-4601, Type II, and three plies of ASTM D-2178, Type IV asphalt glass felt adhered with ASTM D-312, Type IV asphalt. The assemblies were applied to the test deck as in a typical roofing system. The base sheet was nailed to the plywood, and then three plies of glass felt were applied in shingle fashion to the base sheet.

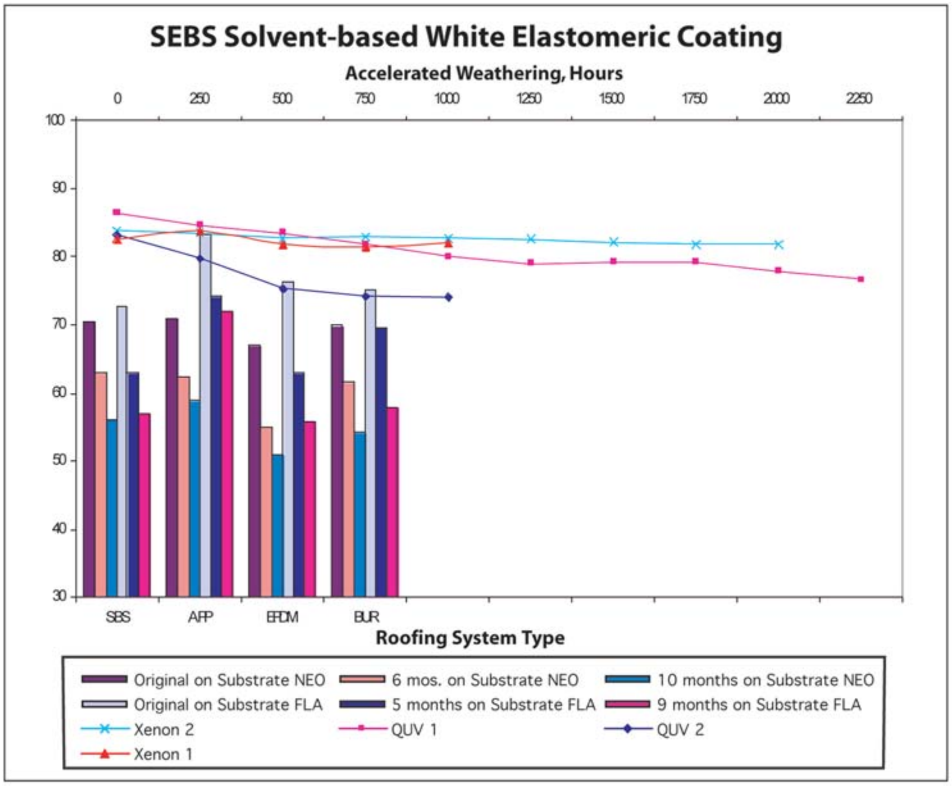
Each membrane was coated with the reflective coatings mentioned above and then weathered at ORNL for three years with reflectance and emittance measurements taken periodically. As originally conceived, the primary purpose of this program for the RCMA was to determine how well the various types of coatings maintained reflective properties over time. It was then decided, after the program had begun, to determine some simple properties of the roof cores before and after three years of weathering at ORNL. The objective was to determine if there was an effect on the performance of primarily the asphalt component in the roof membrane, related to the reflectance of the coatings. It had been postulated that the aging rate of asphalt in a roofing membrane is related to the temperature history of the membrane.

It was evident from the results of this study that the use of reflective coatings had a measurable effect on the rate of change of the properties measured. The differences in asphalt original and aged properties between the aluminum-coated BUR samples were relatively small and clustered. There was a significant and measurable difference in the rate of change in asphalt properties between the aluminum and white-coated BUR samples and the uncoated control. The white-coated membranes resulted in a significantly lower rate of change in asphalt properties as compared to the aluminum-coated membranes. The asphalt in the uncoated control exhibited the greatest rate of change. The results of the reflectance and emittance were previously reported by ORNL (Wilkes et al., 2000; Petrie et al., 2000) and the results of the change in asphalt properties were reported by RCMA (Mellot and Portfolio, 2003).

RCMA STUDY DESCRIPTION AND OBJECTIVES

RCMA began a second study in 2003 to determine the change in reflective properties of coatings over time at three different locations in the U.S. The study also noted changes in properties of roofing membranes, including BUR, modified bituminous SBS and APP membranes, and EPDM related to the changes in reflectance of the coatings. A second objective of the study was to determine if there was any relationship between accelerated aging using the Xenon Arc accelerated weathering tester (ASTM D-4798, Cycle A), as well as the Fluorescent UV-condensation accelerated weathering tester (ASTM D-4799, Cycle A).

The following roofing systems were constructed in triplicate for aging studies to be conducted in Akron, Ohio; Phoenix, Arizona; and Tampa, Florida:



Membrane Type: BUR

Deck: Plywood

Insulation: 2-in. isocyanurate/1/2-in. fiberboard (mechanically attached)

Ply: G2 base (hot mopped in Type IV asphalt, 25 lb./100 ft^2)
2 – G1 felts (hot mopped in Type IV asphalt, 25 lb./100 ft^2)

Surface membrane: Type IV asphalt glaze coat (15 lb./100 ft^2)

Membrane Type: SBS

Deck: Plywood

Insulation: 2-in. isocyanurate/1/2-in. fiberboard (mechanically attached)

Ply: G2 base (hot mopped in Type IV asphalt, 25 lb./100 ft^2)

Surface membrane: Granule SBS membrane (hot mopped in Type IV asphalt)

Membrane Type: APP

Deck: Plywood

Insulation: 2-in. isocyanurate/1/2-in. fiberboard (mechanically attached)

Ply: G2 base (hot mopped in Type IV asphalt, 25 lb./100 ft^2)

Surface membrane: Smooth APP membrane (torched)

Membrane Type: EPDM

Deck: Plywood

Insulation: 2-in. isocyanurate/1/2-in. fiberboard (mechanically attached)

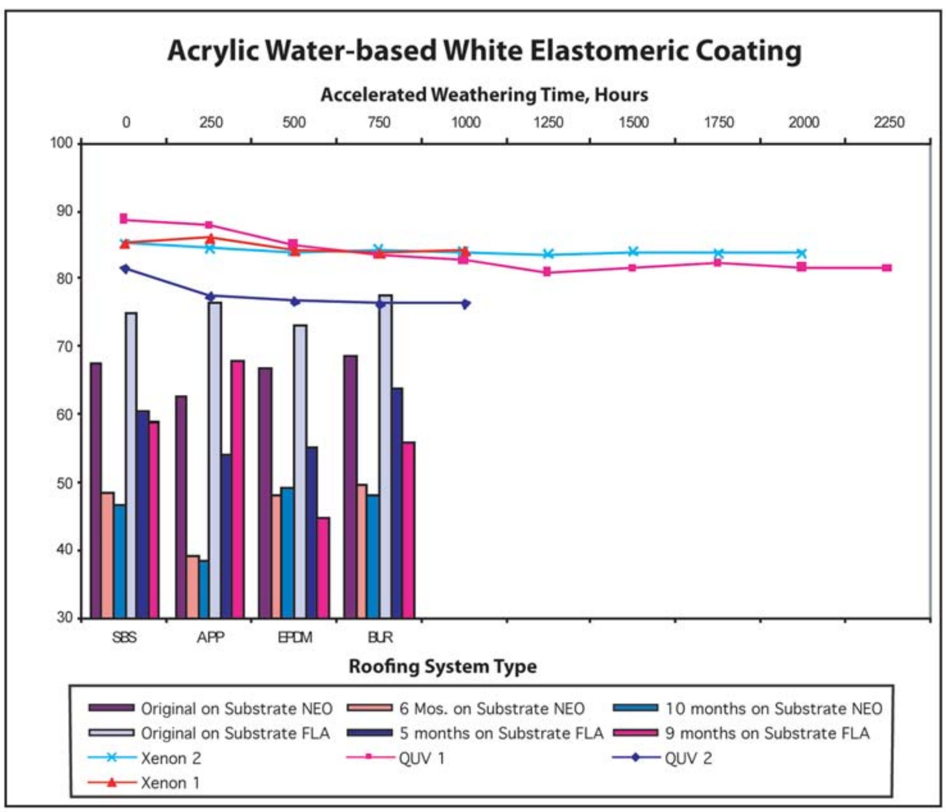
Surface membrane: Black unreinforced EPDM (fully adhered with adhesive)

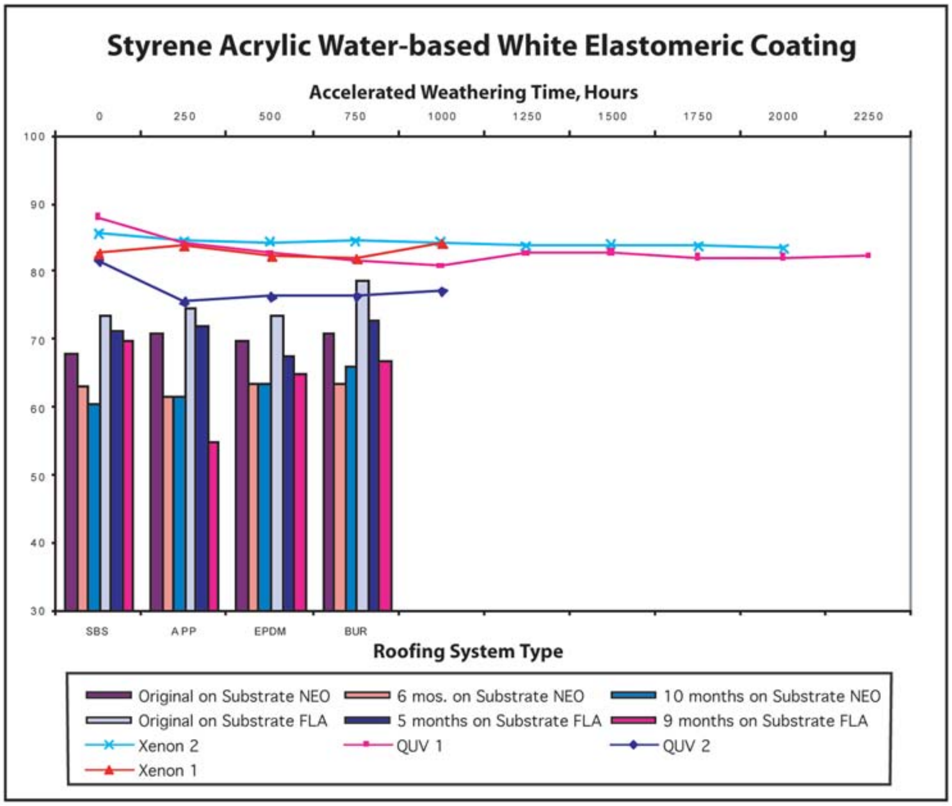
Along with the large decks, one smaller deck of identical construction was built to determine the initial physical properties of each of the membranes and relevant materials to be characterized.

The systems were constructed for subsequent destructive testing. Ply sheets were applied in one-over-one fashion so that the removal of cores for testing (to be made throughout the aging cycle) would result in an equivalent number of plies at each sampling.

Each of the decks was divided into equivalent areas and the following coatings applied to each of the membranes:

1. Asphalt/solvent-based aluminum pigmented roof coating
   a. High-softening-point asphalt (ASTM D-2824)
   b. Low-softening-point asphalt (ASTM D-2824)
2. Asphalt/water-based, aluminum, pigmented roof coating (ASTM D-6848)
3. White water-based elastomeric roof coating (ASTM D-6083)





a. Acrylic
b. Styrene-acrylic

4. White styrene-ethylene-butylene-styrene elastomeric solvent-based roof coating (no ASTM specification)
5. Asphalt emulsion (ASTM D-1227)

Several samples of each coating type were obtained from different manufacturers, and then one of the coatings was blindly chosen to be used in the study. The coatings were applied in a fashion and at the application rate suggested by the manufacturer.

The decks were shipped to each of the weathering locations in the summer of 2003 and were put out for exposure, at 1/2-inch slope facing south, within a couple of months of each other at the three locations. In most cases, it was necessary to recoat the samples due to minor scuffing that occurred during shipment.

PRELIMINARY PHYSICAL PROPERTY DATA

To date, original and limited first-phase properties have been determined for the exposure decks, as well as from accelerated aging studies.

Original Physical Property Data

The objective of this part of the project is to establish the base-line physical properties of the roofing systems. These properties will be used to determine the effect of the coatings on the rate of change of the base-line properties as related to time, weather, and the reflectance of the coatings used in the study. Throughout the exposure process, the reflectance of the field decks will be determined to monitor the changes in reflectance of the coatings. It is expected that the reflectance will change for any number of reasons throughout the exposure process. It is suspected that dirt pickup will be a major contributor. To relate to real-world conditions, the coatings will not be cleaned throughout the aging process. However, when cores are periodically removed for destructive analysis, the reflectance will be determined before and after cleaning to establish data relating to cleaned and uncleaned surfaces.

As described above, for each roofing system, a small-scale deck was constructed to be used to establish initial data. The small decks were used, realizing that the physical property analysis was destructive in nature. The roofing systems were analyzed for a variety of physical performance properties to established base-line properties. The procedures for the bitumen-based systems – APP, SBS, and BUR – were as follows:

- Softening point: ASTM D-36
- Penetration at 77˚F: ASTM D-5
- Tensile strength and elongation at 73˚F: ASTM D-2523
- Chemical composition using Iatroscan

PROPERTY	RESULTS		
Membrane Identification	**APP**	**SBS**	**BUR**
Softening point, °F	306	249	231
Penetration, dmm	16	22	10
Tensile strength, peak load, MD, lbf.	123	123	271
Elongation at peak load, MD, %	51	34	3.2
Iatroscan composition			
Saturates, %	16.2	13.9	TBD
Aromatics, %	39.7	24.2	TBD
Resins, %	36.5	52.7	TBD
Asphaltenes, %	7.6	9.2	TBD
DSR	TBD	TBD	TBD

TBD – To be determined

Table 1: Bituminous materials and membrane initial physical properties.

PROPERTY	RESULTS
Membrane Identification	**EPDM**
Thickness, in.	0.435
Tensile Strength, psi	1389
Ultimate Elongation, %	893
Tear Resistance, lbf.	10

Table 2: EPDM initial physical properties.

- Rheological properties using Dynamic Shear Rheometer (DSR)

The samples were cut from the small deck and the BUR and modified bituminous samples were chilled to approximately 40°F and split apart. The bituminous portions were then removed from the samples using a heated spatula.

For each property, ASTM procedures, where applicable, were followed. The results for each of the systems are listed in *Table 1*.

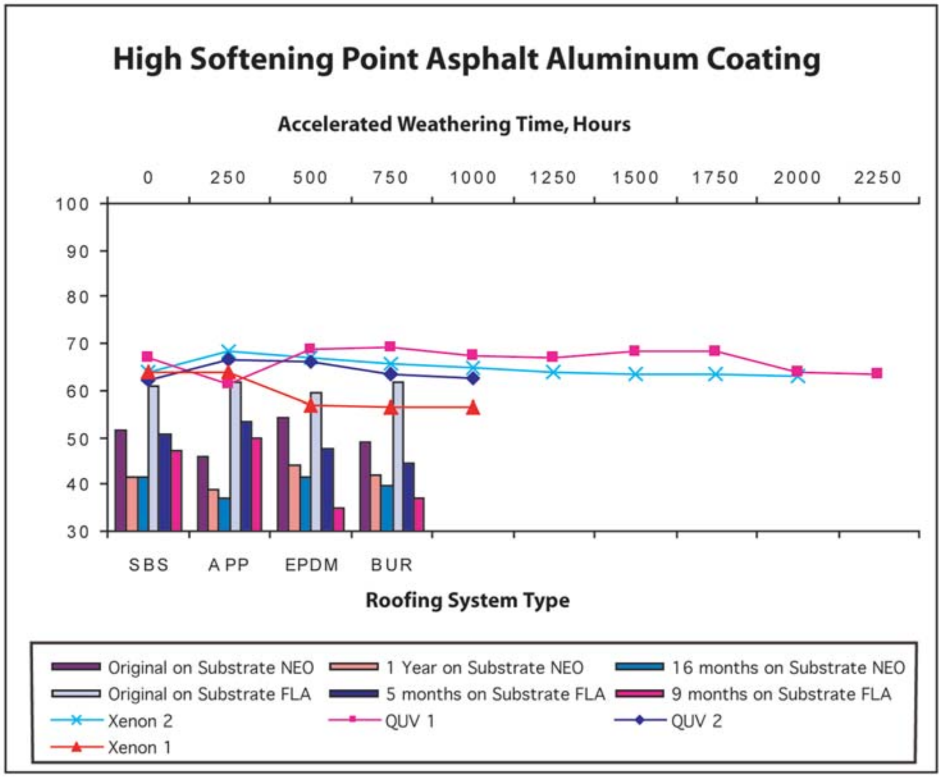
To determine the initial EPDM properties, the small deck was used, as in the case of the asphalt-based systems. The physical property testing on the EPDM system was different. The procedures used to determine each of the properties were as follows:

- Thickness by ASTM D-412
- Tensile strength and elongation at 73°F by ASTM D-412
- Tear strength at 73°F by ASTM D-624

The results are listed in *Table 2*.

Accelerated Weathering

The accelerated weathering part of the project involved 2,000 hours of exposure for



samples of each of the coatings on aluminum panels in two different types of weatherometers:

1. Xenon-arc type: ASTM D-4798: Cycle A: 51 minutes light, 9 minutes light and water spray.
2. Fluorescent UV condensation type (QUV): ASTM D-4799: Cycle A: 4 hours UV light at 60°C alternating with 4 hours condensation at 50°C.

The effect of accelerated weathering time on the reflectance of the coating on aluminum panels was measured. These changes in reflectance versus exposure time will be used to determine if there is a correlation between accelerated and natural weathering.

Comparison of Accelerated Weathering to Real-time Weathering:

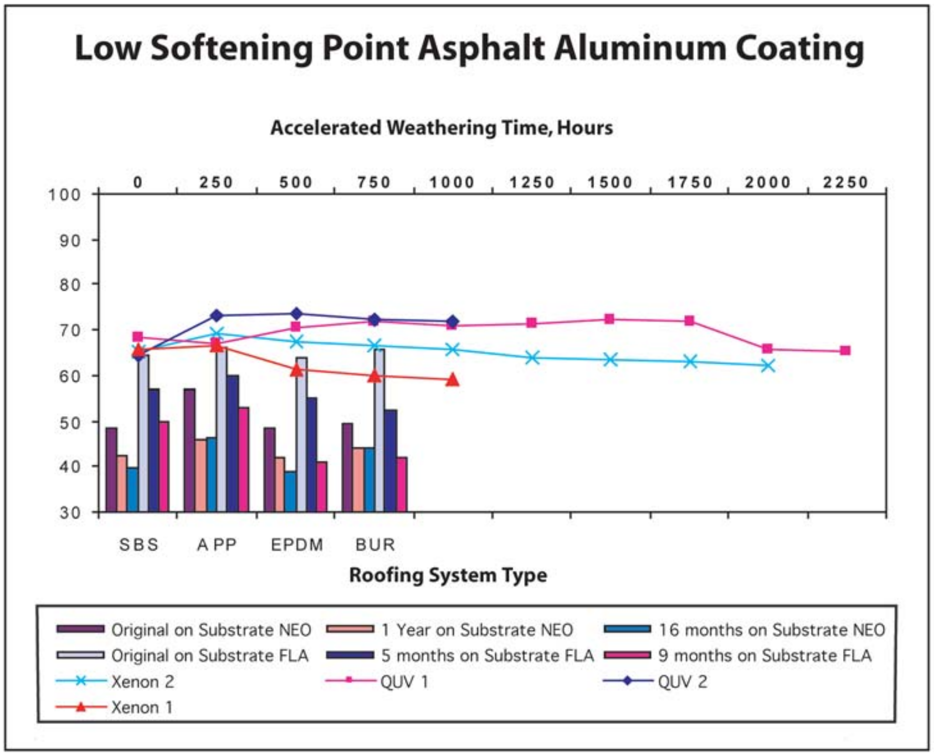
To date, reflectance data have been collected on initial and short-term exposed (9 to 10 months and 12 or 16 months in some cases) for all of the systems at two of the three locations: Florida and Northeast Ohio. The Arizona data will be collected when cores are extracted for analysis in the future. Each figure represents a different coating. The reflectance data are compiled to include the following conditions of exposure:

1. Florida exposed
2. Northeast Ohio exposed
3. Fluorescent UV-condensation (QUV) weatherometer: Laboratories 1 and 2.
4. Xenon-Arc: Laboratories 1 and 2.

Each figure compares the original reflectance versus periodic reflectance measurements taken throughout the exposure of the decks. These results are the colored bars on each of the graphs. The figures also show results of reflectance values taken from in-laboratory accelerated weathering samples. These samples were applied at manufacturers' suggested thicknesses, without primer, to standard aluminum exposure panels. Note that in all cases, the in-laboratory original reflectance results were greater than the applied samples. We will continue to investigate this observation and how it relates to the field exposure samples.

PRELIMINARY REFLECTANCE RESULTS

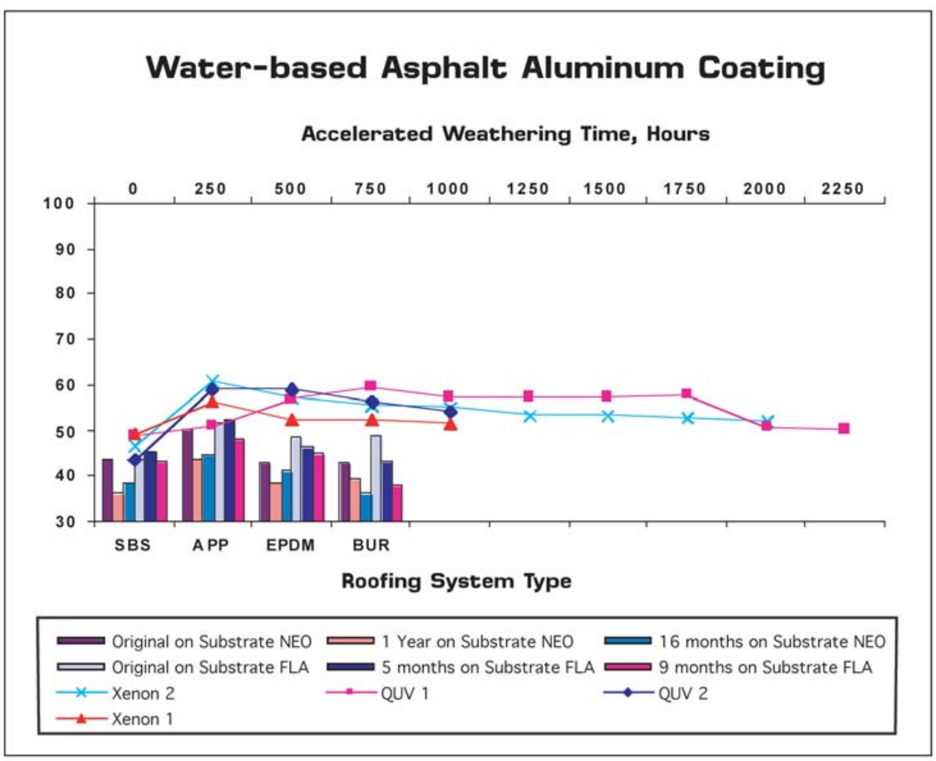
The systems are only a short period into their long-term aging cycle, and it is difficult to draw any conclusions from the data compiled thus far. Although trends may change, there are some obvious tendencies in the initial solar reflectance data. It can be seen that the substrate that is coated has an observable and measurable effect on the initial and aged reflectance of the coating. The reflectance result can be as much as a ten percent difference for some of the coat-



ing types.

It is also evident, in many cases, that the measured reflectance on the laboratory-prepared samples is higher than the measured reflectance recorded for the larger-scale deck systems. This has been an assumption, but the initial data supports this hypothesis. This difference may be confounded by the fact that the field samples are not being cleaned prior to performing the reflectance measurements. However, the study will attempt to address these phenomena by analyzing the periodically removed system cores for reflectance before and after cleaning. This data may shed some light on the need for field versus in-laboratory aging data on coatings.

The differences in change in reflectance of the various coatings and substrates as a result of accelerated weather testing using



the two different devices is also evident. It can be seen that the two methods generally result in different changes in reflectance values after 2,000 hours of exposure. It will be interesting to see if the change in reflectance as a result of accelerated weathering shows any correlation to natural weathering on any of the substrates. As was already indicated, the short-term change in reflectance measured in the natural weathering studies appears to be substrate-specific. The accelerated weathering samples were applied to aluminum panels.

No observations can be made concerning the physical performance of the systems to date. Only original properties have been captured and, once aged samples are analyzed, the data can begin to be compiled and analyzed.

PLAN FOR THE CONTINUATION OF THE STUDY

The roof systems will continue to be exposed until three years have elapsed. At the three-year point, one-foot square cores will be removed from each of the coating and membrane types, as well as controls from each of the systems. The physical properties of these samples will be determined and compared to the original data collected from the small decks. The systems will also be assessed and the plan for subsequent sample core collection will be determined. Based on the design of the decks, one-foot square cores can be removed up to four times, including the three-year sampling.

Throughout the exposure, reflectance data will be periodically determined – typically every six months. The data will continue to be compiled in an effort to determine if there is a correlation between field exposure and accelerated weathering. As mentioned above, as each deck is sampled by removing a core, the reflectance will be determined for both cleaned and uncleaned coatings in an effort to validate the effect of cleaning on enhancing coating performance.

The industry will be updated as additional data become available.

ACKNOWLEDGEMENTS

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Joseph W. Mellott II has a bachelor's degree in macromolecular engineering from Case Western Reserve University. He has served the roofing industry for the past 15 years in a variety of capacities, including product formulation, material testing, failure forensics, and raw material development. He specializes in the area of development and testing of polymeric modified bitumen systems, adhesives, sealants, and coatings. He most recently served as technical chair of the Roof Coatings Manufacturers Association from 2000 - 2004. He has written several published papers in the area of roof system testing and coatings science and technology. Mellot is currently vice president of technology for Momentum Technologies, Uniontown, Ohio.

Donald C. Portfolio

Donald C. Portfolio received a bachelor of science degree in chemistry from the University of Massachusetts and a master of science degree in organic chemistry from the University of South Florida. He has been involved in the roofing industry for more than 35 years in capacities ranging from product development to fundamental polymer research. He has had product development responsibility for materials, including asphalt shingles, conventional BUR, modified bituminous membranes, polyisocyanurate and glass fiber, insulations, and conventional and polymer-modified asphalt cements, coatings, and adhesives. He served as technical chair of the Roof Coatings Manufacturers Association from 1996 - 2000 and was a faculty member of the Roofing Industry Educational Institute for many years. He has published numerous papers in the area of roofing technology. Portfolio is currently vice president of PRI Asphalt Technologies, Tampa, Florida.

Roofing and Undocumented Immigrants

The Bureau of Labor Statistics released a report in March 2005 that estimated that 29% of roofers in the U.S. are undocumented immigrants. A survey by *RSI Magazine* in 2006 stated up to 40% of the average roofing contractor's workforce was Hispanic.

Newly-proposed immigration reform would subject employers to fines up to $50,000 for each violation of the law concerning employment of illegal aliens.