MRCA Roof Coatings Research
-- A Progress Report --

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KEY WORDS

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ABSTRACT

The Midwest Roofing Contractors Association (MRCA), in conjunction with three participating U. S. roof coating manufacturers, are conducting an in-situ research program to study the performance attributes (e.g., weather-shielding benefits, fire resistance, etc.) of liquid-applied roof coatings. Six full-scale test roofs have been coated and are exposed to the weather in four different climatic regions of the United States.

Six different, common types of bituminous roof membranes have been used as substrates for testing eight different, commonly available reflective roof coatings. All roofs are weathering into their third year of exposure. As the coatings age and weather, follow-up inspections are revealing interesting changes in the coatings' surface characteristics and performances. MRCA is learning much about the benefits of roof coatings, including which coatings appear to be working well over various bituminous membranes. For example, even at the test site in the harshest climate, the Minneapolis/St. Paul area of Minnesota, it has been discovered that several roof coatings are performing quite well and will undoubtedly prolong the service lives of the roof membranes over which they have been applied.

This paper is the first in a series of planned reports whereby MRCA's Technical & Research Committee wishes to share the learned information with the roofing industry at large.

AUTHORS' BIOGRAPHIES

Jim Carlson, serves as the Technical Director for Building Envelope Technology & Research (BET&R), which is a professional roofing, waterproofing and cladding consulting firm headquartered in Seattle, Washington. Prior to founding BET&R, Mr. Carlson worked with the National Roofing Contractors Association as their Deputy Director of Technology & Research. Jim has worked his way up through the ranks of the roofing industry beginning as a roofing apprentice, continuing on to serve as a foreman, superintendent, and estimator. After nearly 3 decades of involvement in the roofing industry, Jim serves as the Technical Advisor for the Western States Roofing Contractors Association, is a co-advisor to MRCA, and is an active author, guest lecturer, researcher. Jim is a member of ASTM, NRCA, RCI and other roofing industry groups.

Bill Collins, works as Senior Roof Technologist with Building Envelope Technology & Research. Mr. Collins has a twenty-one year background in the commercial roofing industry. Experience includes several years of joint ownership and management of a successful roofing company, twelve years of managing the technical departments for two major manufacturers of commercial roofing materials, several years of involvement in roof coating materials research, roof maintenance and roof science for Lockheed Martin/Marietta.

John Daly, a third generation, professional roofing contractor, and co-owner of Kaw Roofing and Sheet Metal, Inc.. Mr. Daly is active with the Midwest Roofing Contractors Association, and currently is a member of MRCA's Technical & Research Committee. Besides MRCA, CSI, SMACNA and other roofing industry activities, John works on various ASTM task groups and sub-committees helping to improve the standards for roofing materials.

Tony Spigarelli, owner of Central Roofing Company in Minneapolis, Minnesota. Mr. Spigarelli has been very active in the U.S. Roofing industry for many years, including service on the Board of Directors of MRCA. As a former member of MRCA's Technical & Research Committee, Tony is still serving the industry through his and his staffs' efforts with various projects, including the MRCA Roof Coatings Research Project.

INTRODUCTION

The Midwest Roofing Contractors Association (MRCA) has a reputation for its technical efforts put forth on behalf of the roofing contractor membership. In effort to further assist roofing contractors and manufacturers, MRCA has embarked on a roof coatings research and testing project. The purpose of the project is multifaceted:

1. Study the commonly available roof coatings' weathering performances, when applied over common asphalt-based roof membrane systems that are used throughout the midwestern United States. It is hoped this will help roofing

contractors more successfully select the appropriate roof coating(s) for their customers' roof systems that are in need of maintenance.

2. Determine which coatings may be most appropriate for shielding the underlying roof membrane from the direct effects of the sun and weather, thereby prolonging the service life of asphalt-based roof membranes.

3. Investigate and determine which coatings may help sustain, or possibly improve, the fire resistance of commonly used bituminous roof membranes.

4. Determine the benefits of using a water-based, asphalt emulsion primer prior to application of a roof coating.

5. Study the commonly available roof coatings' other attributes (e.g., solar reflectance, general longevity prior to need for recoating, etc.) to help roofing contractors, roof owners, manufacturers and designers better understand how, when and why roof coatings may be helpful.

6. Develop and publish a coatings users guide with unbiased technical information regarding the selection, use and application of commonly available roof coatings.

MRCA's Technical & Research Committee has been assisted in this research by three roof coating manufacturers: Bakor (formerly Monsey Bakor and Henry Co.), Fields Corp., and Karnak Corp. The manufacturers have generously provided roof coatings, primers and professional technical staff assistance. MRCA's membership has provided full-scale sites to be used as test roofs, and four MRCA-member roofing contractors have donated much time, financial assistance and select personnel to serve as designated field representatives that have helped to monitor the roofs and collect the data.

This paper includes: information about roof membrane and roof coating performance; roof maintenance; recommendations regarding roof membrane surfacing; recommendations regarding roof surface preparation prior to roof coating; preliminary recommendations for selection and use of roof coatings over certain membrane types.

BACKGROUND INFORMATION AND INDUSTRY PROBLEMS

Bituminous roof membranes, particularly asphalt-based membranes, are a major portion of the low-slope roofing market in many regional areas of North America. The Midwestern region of the United States' low-slope roofing market utilizes all three of the general types of asphalt-based membranes, including built-up roofing (BUR), APP- (atactic-polypropylene) polymer-modified asphalt roofing and SBS- (styrene-butadiene-styrene-) polymer-modified asphalt roof membranes. All three of these general membrane types are installed as hot- and cold- (ambient temperature) applied membranes in many of the larger market areas.

Due to the significant installed cost of insulated low-slope roof membrane assemblies, it is becoming more and more important to care for or maintain roof systems in order that roof owners can achieve the most cost-effective service lives from their roof. As such, many roofing contractors have established roof service departments that help owners maintain their roofs. Roof maintenance has become so important that numerous firms are specializing in roof asset management. Numerous contracting and consulting firms have developed preventative maintenance programs, which owners are utilizing to manage their roof-related assets.

Roof maintenance generally involves administering spot repairs to patch or repair weather-weakened, deficient locations in a roof membrane (see Photo 1). After spot repairs have been made to smooth- and granule-surfaced roof membranes, roof maintenance can involve preparing the existing roof surface, then applying a surface coating or a combination of coatings to reduce the effects of direct weathering, thereby prolonging the life of the existing roof membrane (see Photo 2).

Experience and research has taught roofing contractors, manufacturer, and building owners the weather-shielding benefits of various surfacings for roof membranes (Cullen 1963). More recent research has been conducted that establishes some of the benefits of using reflective roof coatings. As a part of the research, the roofing industry has learned that roof coatings can:

- Dramatically lower summer-time roof temperatures (Carlson, Christian and Smith 1992)
- Reduce summer-time cooling loads and save energy, thereby reducing cooling costs (Anderson 1989, Griggs and Shipp 1988, Griggs et al. 1989)
- Reduce the heat-island effect in some urban areas (Vaugen 1999)
- Prolong roof service life of certain bituminous roof membrane systems (Sofrance 1990; Kirn 1991; Carlson, Smith and Christian 1993; Portfolio and Dutton 1997).

However, in some North American roofing markets, roofing contractors, designers and building owners have reportedly experienced frustration when using various coatings with specific roof membranes. For example, when several manufacturers of APP-polymer-modified asphalt roof membranes required the application of a liquid-applied coating as a condition of their roof warranties, but gave minimal guidance on when and how to coat the roofs. Various coatings degraded prematurely (e.g., yellowed, faded, asphalt bleed-through the coating, etc.). Some roof systems experienced difficulties with coatings that crazed, cracked, peeled, flaked off, or eroded and wore off prematurely (see Photos 3, 4 and 5 for examples).

In many markets, as preventative roof maintenance has become important to roof-conscious building owners, roofing contractors and designers that had previously specified aggregate-surfaced BUR systems began to specify or use more smooth- and granule-surfaced BUR membranes. Without the visually obscuring gravel, slag or other aggregate surfacing, the smooth- and granule-surfaced membranes could be inspected more easily for defects, then to extend their service life could be repaired and maintained as they aged.

As more smooth-surfaced membranes were installed and weathered over time, the importance of durable, well performing roof coatings became more apparent. However, similar experiences with coatings have occurred with smooth-surfaced, hot or cold asphalt BUR membranes that have occurred with smooth-surfaced APP-modified membranes. Some coatings stretch-cracked, peeled, asphalt bled-through or otherwise did not perform satisfactorily, resulting in frustration for those involved.

Based on years of application experience, problem troubleshooting, and performance monitoring, it is the authors' opinion that the majority of problems that have occurred in the field with various roof systems and roof coatings can be attributed to the following:

1. Lack of experience in evaluating the suitability of new and existing roof surfaces and the applicability of using certain roof coatings.

2. Lack of knowledge about the various roof coatings on the market and where to use and not use specific types of coatings.

3. Lack of experience and knowledge about surface preparation procedures related to specific types of roof membranes and coatings.

4. Poorly formulated coatings or coatings that were not suitable for specific roof types or surface conditions.

5. Inadequately trained applicators and/or sales representatives. For example, some aluminum-pigmented coatings require not only thorough mixing upon opening of the drum or can, but also need regular or frequent mixing of the contained coating during the application. Also, application information should be provided as to when to spray apply, rather than roll apply certain coatings. Information is needed about why not to over-roll certain coatings. Clear information is needed about when to apply emulsions over slightly cool, dew-damp surfaces, instead of hot, black or dark colored roof surfaces that cook the coating prior to curing and adequate bond development. (i.e., The roofing industry needs to develop a good understanding of roof coatings' limitations and how to schedule applications that are properly balanced with the appropriate application techniques, temperature, humidity and sometimes even the time of day).

6. Failure of applicators to follow manufacturer's application instructions.

The aforementioned reasons indicate that significant sectors of the roofing industry lack experience with roof evaluation and roof coatings. And a comprehensive, written guide related to the selection and use of roof coatings would be helpful to the roofing industry. However, in the past, it has been difficult for the contracting, manufacturing and design communities of the roofing industry to reach a consensus on aspects related to development of accepted guidelines.

This lack of consensus may be partially due to the lack of unbiased, conclusive research that establishes which type(s) of coatings work best in certain climates over specific membranes. Nor has there been any nonproprietary research that explores the pros and cons of water-based primers and their application as part of roof surface preparation procedures prior to installation of roof coating(s).

Also, there has not been significant research that proves the other potential performance-related attributes of roof coatings. For instance, the industry has not conducted adequate research to establish the status of various generic roof membranes' fire resistances; how fire resistance may change over time; and how roof coatings may affect (e.g., improve) the fire resistance of certain roof membrane types.

MRCA and the participating manufacturers and contractors involved in this current research have sought to answer these questions and develop appropriate guidelines, through their joint research, beginning with studying coatings over bituminous roof membranes.

BITUMINOUS ROOF MEMBRANES

The bituminous roof membranes used in this study involved all of the common types of asphalt-based, multiple-ply roof membranes. Six different asphalt-based membranes are being examined in the research: two different BUR membranes, two different types of APP-polymer-modified asphalt membranes and two different types of SBS-polymer-modified asphalt membranes. Specifically, the types of membranes used in this research are further described as follows.

A. Three- and Four-ply Built-up Roof Membranes

Both hot asphalt-glazed and non-glazed multiple-ply BUR membranes are being studied in this research. The BUR membranes are installed over insulated substrates, and the ply construction is with Type-IV fiberglass plysheet. The glass-fiber plysheet reportedly complies with ASTM D 2178, *Standard Specification for Asphalt Glass Felt used in Roofing and Waterproofing*.

B. APP-polymer-modified Asphalt, Smooth-surfaced Membranes

Two quite different APP-polymer-modified asphalt roof membranes are involved in this study. One type may be referred to as a commodity-grade, APP-modified asphalt membrane. In other words, the commodity type of APP-modified asphalt membrane roll-good material is that which is typically mid reinforced with polyester, smooth-surfaced and is produced similarly by several U.S. roof membrane manufacturers. Note: Many coating experts acknowledge that the polyester-reinforced membranes, typically with more elongation and greater propensity for thermal movement than fiberglass reinforced membranes, present a less stable,

thus more challenging substrate for roof coatings to bond to for the long-term without adverse effects.
The other APP-polymer-modified asphalt roof membrane involved in this study may be referred to as a commercial-grade membrane, in that this more quality-oriented product is reinforced with two different layers of reinforcement (both polyester and fiberglass mats). With respect to cross-sectional configuration, the fiberglass mat is located relatively close to the top surface of the sheet; thus, this membrane material is thought to be more resistant to thermal movement, which creates a more stable substrate for the coating to adhere to for the long term.

All of the APP membrane roof membranes in the study are insulated membrane systems, thereby exerting the membrane to a higher degree of thermal exposure and thus a more rigorous service life than that of a non-insulated membrane.

C. Granule-surfaced, SBS-polymer-modified Asphalt Membranes

Because granule-surfaced, SBS-polymer-modified asphalt membranes make up the vast majority of the SBS-modified membrane inventory in North America and due to age are beginning to require maintenance in many U.S. markets, this membrane type was also selected for the study. As with the APP membranes, two differently reinforced SBS membranes are used in this research. Both fiberglass-reinforced and polyester-reinforced types of cap-sheet-surfaced SBS membranes were coated and are being examined in the study.

All of the SBS membrane roof systems in the study are insulated.

COMMON ROOF COATING TYPES

Eight different, commonly used roof coatings are utilized in the study: two differently pigmented asphalt emulsions; two differently formulated, white-colored pigmented acrylics; two differently pigmented, solvent-based asphalt (e.g., cutback asphalt) coatings; and two polymer-modified, solvent-based asphalt roof coatings. Following is a general description of these commonly used roof coatings.

Asphalt Emulsions

Emulsified asphalt coatings consist of asphalt particles dispersed in water with clay (typically bentonite) as the emulsifying component. As with most other types of roof coatings, asphalt emulsions contain various organic and/or inorganic fibers and fillers intended to help reinforce the dried coating film and improve performance properties.

Asphalt emulsions used in the U.S. roofing industry are available in their natural dark brown or black asphalt color or as reflective coatings that typically contain titanium dioxide or aluminum pigment. The titanium dioxide containing emulsions typically dry to a grayish white or gray hue, while the aluminum-pigmented emulsions are more silver in color.

Acrylic Roof Coatings

Water-based acrylic roof coatings contain various types and qualities of acrylic polymers, which are formulated to help extend the coatings' physical properties and improve durability. Acrylic roof coatings are available in numerous colors, but the majority used in the U.S. roofing market are pigmented as reflective, white coatings.

Solvent-based Asphalt Coatings

Solvent-based asphalt coatings are referred to as cutback coatings because the asphalt, which is solid at ambient temperature, is cut back with solvent(s) to liquify the coatings for ease of application. Solvent-based asphalt coatings are available in their natural black asphalt color or as reflective coatings that contain aluminum flakes or aluminum paste, which, depending upon formulation and on-site mixing, typically dry to a range of colors from a bright aluminum to duller silver hue.

Polymer-modified Asphalt Coatings

The majority of polymer-modified asphalt coatings on the market are solvent-based, aluminum-pigmented coatings. They differ from the more standard solvent-based asphalt coatings as the asphalt has been modified or blended with a polymer. For the sake of this project, the polymer is an SBS- or SEBS- (styrene-ethyl-butadiene-styrene-) polymer, which is intended to enhance the physical and performance properties of the coating.

MRCA TEST ROOF CRITERIA AND COATING LAYOUT

Regional Test Site Locations

The test roofs are located in three different climatic regions of the United States. Two test roofs are located in the Kansas City area of Missouri (see Photos 6 and 7), and two test roofs are located in the St. Louis area of Missouri (see Photos 8 and 9). One test roof is located in the Minneapolis / St. Paul area of Minnesota (see Photo 10), and one test roof is located in the Dallas area of Texas (see Photo 11).

Roofs Selected for Test

A. Roof Slope: All roofs have minimum slopes of 1/4 inch per foot (2%) and have positive drainage over a majority of the field of the roof.

B. Primed vs. Unprimed Test Areas: Each type of roof coating was installed over both of the general test substrates: the prepared, primed (with asphalt emulsion) roof membrane's surface and prepared, unprimed surface.

C. Test Roof and Coating Layout: The total square footage of each test roof was intended to allow for a minimum of 4 squares (i.e., approximately 400 square feet or $37m^2$) of each type of roof membrane or coating substrate.

Where possible, roofs were selected where the membrane plies were applied in strapped fashion. Roof coatings were applied in bands, laid out parallel to the slope of the roof.

Where possible, to minimize the effects of differential thermal movement of the roof membranes due to solar reflectivity and resultant fatigue that differential membrane movement can have on the coatings, the darkest shade of roof coating was installed adjacent to the control area. Also, where the roof's configuration allowed, the coatings were laid out to increase in brightness or reflectivity, beginning with the dark, exposed membrane to the darkest shade of coating (e.g., the gray-colored asphalt emulsion), then on to the bright gray or silver-colored aluminum pigmented coating, and finally to the bright white coatings (see Photo 12).

D. Control Areas: A portion of the roof membrane in each test roof area was designated to serve as a control (i.e., with the membrane left exposed to the weather for comparative purposes). One-half of the control area was coated with the nonpigmented asphalt emulsion (the primer), and the remaining half of the control area was left exposed.

PREPARATION OF EXISTING ROOF MEMBRANE SURFACE

Each existing roof membrane that was scheduled to receive coatings was prepared according to the following procedures:

A. Broom Clean

The roof membranes' surfaces were thoroughly swept with a stiff-bristled push broom to remove debris, dirt and dust buildup.

B. White Cloth Test

After sweeping, the roof membrane surface was tested for cleanliness and presence of adhered, weathered-on dust and particulate. The designated field representative (DFR) from each participating roofing contractor was to select a location in the field of the roof that was typical of the overall surface condition. Then, using a clean, white, cotton cloth placed over the index finger, the DFR was to rub the cloth over the surface of the membrane using a firm scrubbing motion. Without lifting the cloth (i.e., keeping the cloth pressed onto the roof membrane's surface), the membrane's surface was rubbed back and forth four times, covering an area of approximately 4 inches with each stroke.

If after rubbing the cloth over the existing roof membrane's surface the cloth was soiled a light-brownish color, the crew was to follow the steps described in Item C-1 below for cleaning the membrane's surface. If the cloth appeared dark brown and picked up loose particulate on the surface of the cloth, the crew was to follow the steps described in Item C-2 below for cleaning the membrane's surface.

C. Low-pressure Power Rinse or Rinse to Wet, Scrub and Rinse Clean

After testing the roof membrane's surface with the white-cloth test, the crew followed one of the following preparation sequences for cleaning the surface of the existing roof membrane:

1. Low-pressure Power Rinse:

After brooming, if the white-cloth test revealed only a light-brownish discoloration on the cloth, the roof's surface was rinsed with a pressure washer. The crew was instructed not to blast the surface with high pressure, but, rather, to use a broad or wide-fan tip (not a thin-stream blast tip) in the wand and keep the pressure between 500 and 800 psi ($3.45x10^6 N/m^2$ and $5.52x10^6 N/m^2$). They were to wet the membrane's surface in an overall general manner so that the area to be prepared remained wet to facilitate the loosening of dirt. After a general wetting of the area, the wand was held at a low angle to the roof's surface to allow the roof membrane's surface to be rinsed in a systematic fashion to clean the membrane's surface. Each DFR was instructed to monitor the water pressure and advise the crew to keep the wand at a relatively low angle to the surface of the roof. The intent was to gently remove dirt from the surface of the membrane but not blast or force water into the roof membrane.

2. Rinse to Wet-out Surface then Scrub and Rinse:

After brooming, if the white-cloth test revealed a dark-brown or light-blackish discoloration on the cloth indicating the roof's surface was dirtier, the crew was instructed to prepare the roof's surface using water and push brooms to scrub the areas scheduled to be coated. The roof's surface was wetted with a nozzled garden hose, then stiff-bristled push brooms were used to scrub the membrane's surface. The DFRs were instructed to remind each crew to scrub vigorously with the broom to loosen adhered dust and dirt. Then, while the membrane's surface was still wet, they were instructed to thoroughly rinse the area to remove the dirt that was loosened during scrubbing.

D. Rinse and Dry

After thoroughly rinsing the roof membrane, the surface was squeegeed dry with a rubber-bladed squeegee. Residual surface moisture not removed by the squeegee was allowed to air dry prior to application of roof coatings.

SPECIFIC ROOF COATINGS AND APPLICATION RATES USED

Following is a more specific description of the coatings and emulsion primer used in this research. The coatings are listed with their ASTM standard designations and the application rates that were strived for in this research.

A. Asphalt Emulsion (ASTM D 1227-95)

1. Aluminum-pigmented, fibered asphalt emulsion was applied in one coat at approximately 1 1/2 gallons per 100 square feet (.6L/m^2). Application was with a soft, nylon-bristled push broom.

2. Titanium-dioxide, pigmented, fibered asphalt emulsion was applied in two coats at approximately 1 1/2 gallons per 100 square feet (.6L/m^2) per coat. The second coat was applied at a right angle to the first coat. The application rate to be achieved was approximately 3 gallons per 100 square feet (1.2L/m^2). The first coat was allowed to dry prior to application of the second coat. The gray-white coating was broom-applied with soft, nylon-bristled push brooms.

3. Black (nonpigmented), clay-based asphalt emulsion was used as the water-based primer. The primer was applied over approximately one-half of each of the areas scheduled to receive coating. The black asphalt emulsion primer was applied at approximately 1 1/2 gallons per 100 square feet (.6L/m^2). The emulsion primer was broomed on with a soft, nylon-bristled push broom.

B. Solvent-based Asphalt Coating (ASTM D 2824-94)

1. Premium-grade, aluminum-pigmented, nonasbestos-fibered asphalt coating was applied in one coat at approximately 1 1/2 gallons per 100 square feet (.6L/m^2). Application was with heavy-nap rollers.

2. Commodity-grade, aluminum-pigmented, nonasbestos-fibered asphalt coating was applied in one coat at approximately 1 1/2 gallons per 100 square feet (.6L/m^2). Application was rolled with heavy-nap rollers.

C. Acrylic/Latex, White-Pigmented Roof Coating

1 and 2. Both of the acrylic coatings (i.e., the premium and commodity grades) were applied in two coats, with the second coat applied at a right angle to the first coat. The application rate for each coat was approximately 1 gallon per 100 square feet (.4L/m^2). The first coat was allowed to dry prior to application of the second coat. The acrylic coatings were roller-applied with medium-nap rollers.

D. Polymer-modified, Solvent-based Asphalt Roof Coatings

1. SEBS-polymer-modified, fibered-asphalt coating was applied in one coat at approximately 1 1/2 to 2 gallons per 100 square feet (.6 to .8L/m^2). Application was with heavy-nap rollers.

2. SBS-polymer-modified, fibered-asphalt coating was applied in one coat at approximately 1-1/2 to 2 gallons per 100 square feet (.6 to .8L/m^2). Application was with heavy-nap rollers.

COATING PERFORMANCE DATA COLLECTION

To facilitate data collection, the participating contractors, have each established a Designated Field Representatives (DFR) for making site visits to monitor the roof coatings' performance at planned intervals. To ensure that the various coatings' weathering and performance characteristics are evaluated appropriately by the DFR, MRCA assigned a designated roof coating technologist to perform annual inspections and collect data at each test site with the DFR.

Data Collection Forms

In an effort to maintain consistency with the data collection, a standardized Data Collection Form (see Table 1, page 14) was developed for use by the contractors' DFRs when making site visits to record specific coating and membrane conditions. In addition to utilizing the Data Collection Forms to record on-site specific weathering and performance characteristics for each membrane and coatings, color photographs are taken to record each membrane and roof coating's appearance at each site. These photos provide visual documentation to substantiate the conditions discovered during the site visits.

Roof Coating Evaluation Criteria

The Data Collection Form contains a comprehensive list of applicable criteria that was developed to assist the DFRs to decisively evaluate the coatings' weathering and performance characteristics, and to evaluate how various roof membranes may be affecting the performance of the overlying roof coating. The evaluation criteria take into account observable performance characteristics, such as whether the coating is fully adhered, peeling and/or delaminating, and whether the coating is maintaining a uniform color and hue or is dulling or becoming blemished, as a result of such factors as bleed-through of the light oils in the underlying membrane, etc.

In addition, the evaluation criteria contain items that pertain to the examination of the conditions of the membranes' surfaces at the control locations. For example the surface of the roof membrane at the control locations is closely examined for weathering conditions such as oxidization and/or signs of stress cracks, and how the condition(s) may be affecting the coating at locations where the membrane has been coated. Additionally, test scrapings are performed and closely examined at the areas of membrane that have been primed with asphalt emulsion, as well as at areas of unprimed membrane to determine if the primer provides a better surface for the overlying coating to bond. These are just a few examples of the criteria used during the data collection process during the in-situ evaluation of roof membrane and coating performance.

Coating Performance Inspection Intervals:

Coating performance data are being recorded by the DFRs at the following intervals:

A. Prior to Coating Installation

Prior to application of the roof coatings, each contractor's DFR was to visit the site to collect preliminary data related to the roof membrane(s) condition and surface characteristics.

B. At Time of Coating Application

During application of the roof coatings, the DFR was on-site to record temperature and humidity data pertinent to the application of the coatings. Also, the DFR collected other pertinent data related to the coating application, such as finished wet-mil thickness, dry time between sequential applications of the acrylic coating, etc. (see Data Collection Form, Table 1).

C. At Intervals After Coating Installation

As specific project conditions allowed, the DFR recorded changes in the coatings' appearances on the 10th and 30th days after application. Then, at six-month intervals, the DFR recorded changes in the coatings' appearances and performances, as well as changes visually evident at the control section of the roof membranes.

To help the participating contractors' DFRs, and ensure consistency with data collection, MRCA sends the same technical personnel to the test sites at the end of every summer to conduct the yearly inspections and collect the data. This is intended to ensure that the same trained eyes evaluate the roofs each year.

Data Collection Matrix

Subsequent to the evaluation inspections by the DFRs, the completed Data Collection Forms are assembled and the data for each membrane and coating are entered onto a master Data Collection Matrix. The matrices contain the same information listed in the Data Collection Forms; however, the matrices provide for compilation of the data, which can then be comparatively analyzed. The matrices are designed so that evaluation criteria and the DFRs respective inspection results appears in the rows, while the membranes and their test coatings are succinctly listed at heads of the columns. The findings at each inspection are entered into new columns that are progressively inserted next to the recorded results of the previous inspection. The design of the matrices allows for relative comparison and promotes an awareness of changes in the coating and performance characteristics. A portion of an actual Data Collection Matrix for a few coatings over glazed and unglazed, primed and unprimed BUR membrane surfaces from an inspection at the Minnesota site are shown in Table 2 on page 15.

DATA COLLECTION FORM
MRCA ROOF COATINGS
IN-SITU RESEARCH

Roof Membrane and Coating Designation of Section Inspected:

____

Building Name: ______________________________

Site Address: ______________________________

City:____________________ County: ______________

State: ________

Building Manager/Contact Person:

____

Phone:_______________

Recorded by (DFR): __________________________

Company: __________________________________

Phone: __________________ Fax: _________________

General Membrane Type (circle appropriate answers):

Control Area (CNT):

Hot Asphalt, Four-ply Built-up Roof

- Non glazed = (BUR)
- Glazed = G-(BUR)

APP-polymer modified Asphalt Membrane

- Commodity = (C)
- Premium = (P)

Granulated, SBS-polymer-modified Asphalt Membrane

- Fiberglass-reinforced = (F)
- Polyester-reinforced = (P)

Roof Surface: (underline one)

Primed (Prmd); Unprimed (UNP) with Asphalt Emulsion

Coated Area; Coating Type(S) Used on this Roof (Underline Type[S]):

A. Asphalt Emulsion (ASTM D 1227-95):
   1. Aluminum Pigmented
   2. Titanium-dioxide Pigmented

B. Solvent-based Asphalt Coating (ASTM D 2824-94):
   1. Premium-grade, Aluminum-pigmented, Nonasbestos Fibered
   2. Commodity-grade, Aluminum-Pigmented, Nonasbestos Fibered.

C. Acrylic, White-pigmented Coating:
   1. Premium-grade, Polymer-modified Acrylic Coating
   2. Commodity-grade Latex Coating

D. SBS and SEBS Polymer-modified, Solvent-based Asphalt Coatings:
   1. Quality SEBS Polymer-modified, Solvent-based, Fibered Coating
   2. Quality SBS Polymer-modified, Solvent-based, Fibered Coating.

COATING INSPECTION -- ____ YEAR (__ Months) AFTER COATING APPLICATION

Roof Membrane and Coating Designation of Section Inspected:

____

Inspection Date: ___________ Time: _____ a.m. p.m.
Temperature ___°F Relative Humidity ____%
Major Change in Weather Since Coating Application (underline one): Yes or No. If "Yes," describe change (for example, it changed from summer to winter):

____

____

Underline the following description that best describes the asphalt glaze coat or coating condition:

Asphalt Glaze Condition:

1. Glaze appears to be in relatively good condition
2. Uneven application
3. Oxidized in color (minor or major)
4. Pinholes (minor or large or both) (random or consistent)
5. Crazing (not really cracked but surface crazed)
6. Cracking (fissures extend down into thickness of glaze)
7. Condition (s) in asphalt glaze telegraphing through surface coating (minor or major).
8. Alligatoring (minor, major or both)
9. Eroding (fiberglass surfacing ply showing)

General Coating Condition:

1. Laying smooth, adhered to membrane, appears in good condition
2. No longer laying smooth, change in surface condition?
3. Coating appears similar to original color or hue. Describe: ______________________________
4. Coating has dulled in color and physical appearance
5. Brightest or dullest in appearance of type of coating
6. Primer improved appearance of coating compared to unprimed
7. Roller marks--variation of hue
8. Broom marks (primer or coating)

Coating Anomalies:

1. Color or hue uneven: blemished, blotchy, streaked, spotty
2. Small amounts of debris, fillers and fibers in coating
3. Pinholes (under magnification) (minor amount or many) (random or all over)
4. Wrinkling (slight delamination of coating from underlying membrane)
5. Peeling (coating supple but peeling from underlying membrane)
6. Crazing (not really cracked but surface crazed) (under magnification) (random or all over)
7. Cracking (fissures extend down into thickness of coating)
8. Flaking (coating embrittled, flaking off of underlying membrane in small pieces)
9. Eroding (Coating showing signs of deterioration in coating or broom marks)

Coating Problem Oriented or Extended In (underline one):

Machine direction; Cross machine direction; Both random

Relative Maintenance Foot Traffic on Roof (underline one):

None; Light (e.g., periodic inspection maintenance);

Heavy (e.g., routine maintenance using tools and equipment)

Photos:

Include one panoramic photo of the entire coated area of roof and close-ups of typical conditions. With marker or lumber crayon, write directly on the roof or coated surface. Note the code number of the coating, the membrane type and date photo is being taken.

Table 1: Data Collection Form

DATA COLLECTION MATRIX-(9 AND 24 Months After Coating Application)

Minneapolis–Coatings Applied Over Four-ply Asphalt Built-up Roof [BUR] (Glazed=G-BUR) Membrane

	CNT, G-BUR, PRMD (9 Months)	CNT, G-BUR, PRMD (24 Months)	CNT, G-BUR UNP (9 Months)	CNT, G-BUR UNP (24 Months)	CNT, BUR PRMD (9 Months)	CNT, BUR PRMD (24 Months)	CNT, BUR UNP (9 Months)	CNT, BUR UNP (24 Months)	A1, G-BUR PRMD (9 Months)	A1, G-BUR PRMD (24 Months)	A1, G-BUR UNP (9 Months)
Asphalt Glaze Condition											
Appears in good condition											
Uneven in application	X	X	X	X	XS	XS	XS		X	X	X
Oxidized in color		X	X	X			X	X			
Pinholes											
Crazing (not really cracked but surface crazed)	X										
Cracking (fissures extend down into thickness of glaze)	X	X	X	X	X1S	X1S	X1S	X1S		X	
Crazing, Cracking or listed condition telegraphing through coating.	X	X2	X1		X1S	X1S			X	X	X
Alligatoring		X2		X2							
Eroding (fiberglass surfacing ply showing)		X		X				X			
General Coating Conditions		**Prmd**			**Prmd**	**Prmd**					
Laying smooth, coating appears to be in good condition					X1		X				
No longer laying smooth, change in surface condition?		X				X					
Coating appears similar to original color or hue									X	X	X
Coating has dulled in color and physical appearance.		X				X					
Brightest or most reflective in appearance of type of coating									X+	X	
Primer improved appearance of coating compared to unprimed										X	
Roller marks--variation of hue											
Broom marks (primer or coating)	X	X			X1	X1			X	X	X1
Asphalt Coating Anomalies	**Prmd**	**Prmd**			**Prmd**	**Prmd**					
Color or hue uneven: blemished, blotchy, streaked or spotty											
Small amounts of debris, fillers and/or fibers in coating					X1				X1	XM	X1
Pinholes or pockmarks									XM	X	
Wrinkling (slight delamination of coating from membrane)											
Peeling (coating supple, peeling off of underlying membrane)											
Crazing (not really cracked but surface crazed)	XM	X				X	XMS		X1	X1	X1
Cracking (fissures extend down into thickness of coating)	X	X			XS	X	X1S			X	
Flaking, flaking off of underlying membrane in small pieces)											
Erosion (coating showing signs of deterioration)	X	X				X			XB	XB	XB

LEGEND: X = Condition Observed; **X1** = Condition is Minor; **X2** = Condition is Major; **XM** = Visible Under Magnification; **XB** = Visible in Broom Marks; **XS** = Visible Along Asphalt Bleed-out at Seams Only; **CNT =** Control Area (no coating) **Prmd=**Primed w/ Fiber Asphalt Emulsion **A1**=Aluminum Asphalt Emulsion;

Table 2: Data Collection Matrix

Findings Revealed to Date

Some of the more profound findings revealed to date are as follows:

1. The asphalt emulsion primer appears to be acting as a buffer to minimize the bleed-through of light oils over the glazed BURs and commodity-grade, APP-modified asphalt membranes. Where primer was not used over these same membranes, the light oils of the asphalt bled through some of the coatings. In the areas where the membranes were primed with asphalt emulsion, it appears that the emulsion has served as a buffer and the asphalt's oils are not staining or degrading the hue of the coating.

2. The adhesion/bond and peel strengths of the acrylic coatings were increased at the locations where the smooth-surfaced, asphalt-based membranes had been primed with asphalt emulsion (see Photos 13 and 14).

3. The emulsions and aluminum-pigmented coatings have stress-cracked and split directly over the end laps of the polyester-reinforced, SBS and commodity-grade, APP-polymer-modified asphalt membranes, indicating that these membranes are undergoing post application shrinkage (see Photos 15 and 16). However, at test areas where white acrylic coatings where applied over the same polyester-reinforced membranes, no stress cracks or shrinkage were observed in the coating over the end laps of the membranes (see Photo 17). This finding provides reason to believe that the white acrylics are moderating the thermal movement of the membrane, thereby keeping these polyester-reinforced sheets from noticeable shrinkage.

4. Regarding the coatings' performance over the APP-polymer-modified asphalt membranes, it appears that most of the coatings, particularly the acrylics and emulsions, are performing better over the more dimensionally stable, multiple-reinforced, commercial-grade, APP-modified membrane with the fiberglass mat near the top surface of the sheet(s).

5. The premium-grade, aluminum-pigmented, solvent-based asphalt coatings; SBS-polymer modified, aluminum-pigmented, solvent-based asphalt coating; and white acrylic coatings are performing very well, and, in some circumstances, extremely well, particularly over the asphalt emulsion primed areas (see Photo 18).

6. The black asphalt emulsion primed areas, which were left exposed as primed control areas, are showing some signs of cracking and erosion. This cracking is most pronounced where the lack of glazing craftsmanship during membrane application allowed the hot asphalt glaze coat to be applied too heavily, thereby promoting alligatoring of the glaze or “flood” coat of hot asphalt and the overlying emulsion primer (see Photo 19).
7. Most coatings are not showing signs of significant changes in hue or color. However, during the first year of the study, it appeared that the commodity-grade acrylic coating was as bright white and in some locations a bit brighter than the

premium-grade acrylic coating. However, this past year's weather exposure has proven that "you get what you pay for," as the commodity-grade acrylic coating no longer has the bright white hue that the premium-grade acrylic coating displays.

8. Also during the first year of the study, it appeared that the commodity-grade, solvent-based, aluminum-pigmented asphalt coating was as bright and visually reflective as the premium-grade, solvent-based, aluminum-pigmented asphalt coating. However, this past year's weather exposure has proven that quality is important, as the commodity-grade, aluminum-pigmented asphalt coating no longer has the bright hue that the premium-grade, aluminum-pigmented asphalt coating shows.

9. The SEBS- and SBS-polymer-modified, aluminum-pigmented, solvent-based, asphalt roof coatings are performing extremely well. However, in some locations, the SEBS-modified coating is dulling a bit. It appears the asphalts are migrating and staining the surface, thereby changing the surface hue of the coated areas. As of a recent visit to the Minnesota site, the SBS-modified coating appears to be doing superior, at least via judging the coating's appearance with the naked eye and under slight magnification. There is no visible interruption in film continuity, no crazing or micro-cracking, and no visible signs of erosion. In general, the SBS- and SEBS-modified asphalt, aluminum-pigmented coatings look very promising for long-term performance.

10. Most coatings in various climatic areas' test roofs are well-adhered and, in general, are performing quite well. Even in the area with the most severe temperature and weather extremes, the Minneapolis/St. Paul area of Minnesota, the coatings are well-bonded (e.g., not peeling), and in all but a few coated test areas, the coatings are laying smooth and continuous (e.g., not stress-cracked or crazed over the field of the underlying sheets).

11. All of the coatings are providing weather-shielding benefits for the underlying membranes by shielding the membrane from the adverse effects of direct exposure to sun and weather. This finding was verified by carefully removing small locations of the coating from coated membrane areas, then closely examining and comparing the once-coated membrane surface with the uncoated, exposed and weathered surface of the control areas.

PRELIMINARY CONCLUSIONS

Judging from the roof surveys performed to date, the following preliminary conclusions may be drawn:

1. Asphalt emulsion, applied as a primer over glazed BUR and commodity-grade APP-modified asphalt membranes appears to improve the performance of most of the overlying coatings.

2. The bleed-out of light oils from the properly glazed BUR and commodity-grade APP modified asphalt membranes appears to be buffered or blocked by the asphalt emulsion applied as a primer.

3. The white acrylics appear to moderate the thermal movements within the tested membranes, thereby minimizing the effects of post-application, thermally induced shrinkage of the polyester-reinforced membranes.

4. Thus far, the acrylic coatings appear to adhere well to asphalt emulsion when the emulsion is applied as a primer over commodity-grade, APP-modified asphalt membranes, in comparison to the adhesion resulting from direct coating application to the membrane.

5. Hot asphalt glaze coats and asphalt emulsion primer coats applied too thick or heavily will generally craze, crack, alligator and eventually telegraph the cracks through the overlying coating at exposed alligatoring crack locations. With time, the coatings are eroding along the edges of the cracked underlying asphalt, therefore hindering the long-term adhesion of the roof coatings along the cracks.

6. When examined under slight magnification, most of the roof coatings tested appear to be performing better over the more stable, fiberglass-surfaced reinforced, commercial-grade, APP-modified membranes and fiberglass-reinforced SBS-modified membranes.

7. In general, the roof coatings appear to adhere well to the asphalt-based roof membranes tested in the research program. However, the adhesion of coatings applied over membranes that are prone to dimensional and thermal changes, such as those that are polyester-reinforced, is better with coatings that contain elastomeric properties, such as the latex acrylics and polymer-modified asphalt coatings.

8. The premium-grade, aluminum-pigmented, solvent-based asphalt coatings; SBS-polymer-modified, aluminum-pigmented, solvent-based asphalt coating; and white acrylic coatings are performing quite well.

9. As a relatively new category of coating, the SEBS- and SBS-polymer-modified, aluminum-pigmented, solvent-based, asphalt roof coatings are performing well.

10. Commodity-grade coatings may require more frequent reapplications to maintain their brightness during their years of service.

11. Roof coatings appear to provide a lightweight weather shield or viable means to protect the underlying membrane from the adverse effects of direct exposure to sun and weather, providing the membrane and coatings are applied correctly.

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APPENDICES

Appendix 1: Matrices for Minnesota 2001 inspections.

Appendix 2: Photo log

Minneapolis–Coatings Applied Over Four-ply Asphalt Built-up Roof [BUR] (Glazed=G-BUR) Membrane

	CNT, G-BUR, PRMD (9 months)	CNT, G-BUR, PRMD (24 months)	CNT, G-BUR UNP (9 months)	CNT, G-BUR UNP (24 months)	CNT, BUR PRMD (9 months)	CNT, BUR PRMD (24 months)	CNT, BUR UNP (9 months)	CNT, BUR UNP (24 months)	A1, G-BUR PRMD (9 months)	A1, G-BUR PRMD (24 months)	A1, G-BUR UNP (9 months)	A1, G-BUR UNP (24 months)	A1, BUR PRMD (9 months)	A1, BUR PRMD (24 months)	A1, BUR UNP (9 months)	A1, G-BUR UNP (24 months)	A2, G-BUR PRMD (9 months)	A2, G-BUR PRMD (24 months)	A2, G-BUR UNP (9 months)	A2, G-BUR UNP (24 months)	A2, BUR, PRMD (9 months)	A2, BUR PRMD (24 months)	A2, BUR UND (9 months)	A2, BUR UND (24 months)
Asphalt Glaze Condition																								
Appears in good condition																								
Uneven in application	X	X	X	X	XS	XS	XS		X	X	X	X	XS	XS	XS	XS	X	X	X	X				
Oxidized in color		X	X	X			X	X																
Pinholes																								
Crazing (not really cracked but surface crazed)	X														X1S									
Cracking (fissures extend down into thickness of glaze)	X	X	X	X	X1S	X1S	X1S	X1S		X			X1S	X1S	X1S	X1S	X1	X	X	X2				
Crazing, cracking or listed condition telegraphing through coating	X	X2	X1		X1S	X1S			X	X	X	X	X1S	X1S	X1S	X1S	X1	X1	X	X				
Alligatoring		X2		X2								X								X				
Eroding (fiberglass surfacing ply showing)		X		X				X																
General Coating Condition		Prmd			Prmd	Prmd																		
Laying smooth, coating appears to be in good condition					X1		X								X		X				X	X	X	X
No longer laying smooth, change in surface condition?		X				X												X1		X1		X1		X1
Coating appears similar to original color or hue									X	X	X		X	X	X		X	X	X		X	X	X	
Coating has dulled in color and physical appearance		X				X						X				X				X				X
Brightest or most reflective in appearance of type of coating									X+	X				X				X				X	X-	
Primer improved appearance of coating compared to unprimed										X				X				X				X		
Roller marks--variation of hue																								
Broom marks (primer or coating)	X	X			X1	X1			X	X	X1	X2	X1	X1	M1	X1	X1	X1	X	X		X		X
Asphalt Coating Anomalies	Prmd	Prmd			Prmd	Prmd																		
Color or hue uneven: blemished, blotchy, streaked or spotty																								
Small amounts of debris, fillers and/or fibers in coating					X1				X1	XM	X1	X	X1	X1	X1	X1								X
Pinholes or pockmarks									XM	X			XM	XM		XM								
Wrinkling (slight delamination of coating from membrane)																								
Peeling (coating supple, peeling off underlying membrane)																								
Crazing (not really cracked, but surface crazed)	XM	X				X	XMS		X1	X1	X1	X2	X1	X1	X1	XM	XM	XM		XM		XM		XM
Cracking (fissures extend down into thickness of coating)	X	X			XS	X	X1S			X		X2					X1	X1	X	X		X		
Flaking, flaking off of underlying membrane in small pieces)												X1		XM	X1	XM								
Erosion (coating showing signs of deterioration)	X	X				X			XB	XB	XB	X2	XB	XB		XB						X1		

LEGEND: **X** = Condition Observed; **X1** = Condition is Minor; **X2** = Condition is Major; **XM** = Visible Under Magnification; **XB** = Visible in Broom Marks; **XS** = Visible Along Asphalt Bleed-out at Seams Only; **CNT =** Control Area (no coating) **Prmd=**Primed w/ Fiber Asphalt Emulsion **A1**=Aluminum Asphalt Emulsion; **A2**= Gray Asphalt Emulsion; **B1**= (3-lb Aluminum) Solvent-Based Asphalt Coating; **B2** = (1.5 lb Aluminum) Solvent-Based Asphalt Coating; **C1** = Premium Polymer-modified Acrylic White Coating; **C2 =** Commodity Latex White Coating; **D1**= SEBS-Polymer-modified, Solvent-Based Fiber Asphalt Coating; **D2** = SBS-Polymer-modified, Solvent-Based Fiber Asphalt Coating.

DATA COLLECTION MATRIX–(9 and 24 Months) AFTER COATING APPLICATION

Minneapolis–Coatings Applied Over Four-ply Asphalt Built-up Roof [BUR] (Glazed=G-BUR) Membrane

	B1, G-BUR, PRMD (9 months)	B1, G-BUR, PRMD (24 months)	B1, G-BUR UNP (9 months)	B1, G-BUR UNP (24 months)	B1, BUR PRMD (9 months)	B1, BUR PRMD (24 months)	B1, BUR UNP (9 months)	B1, BUR UNP (24 months)	B2, G-BUR PRMD (9 months)	B2, G-BUR PRMD (24 months)	B2, G-BUR UNP (9 months)	B2, G-BUR UNP (24 months)	B2, BUR PRMD (9 months)	B2, BUR PRMD (24 months)	B2, -BUR UNP (9 months)	B2, -BUR UNP (24 months)
Asphalt Glaze Condition																
Appears in good condition																
Uneven in application	X	X	X	X	XS	XS	XS	XS	X	X	X	X	XS	XS	XS	XS
Oxidized in color																
Pinholes																
Crazing (not really cracked but surface crazed)																
Cracking (fissures extend down into thickness of glaze)	X1	X1	X2	X2	X1S	X1S	X1S	XS	X1	X1	X1	X1	X1S	XS	X1S	XS
Conditions in asphalt glaze telegraphing through coating	X1	X1	X2	X2	X1S	X1S	X1S	XS	X1	X1	X1	X1	X1S	XS	X1S	XS
Alligatoring				X								X				
Eroding (fiberglass surfacing ply showing)																
General Coating Condition																
Laying smooth, appears to be in good condition	X	X	X	X	X	X	X	X	X		X		X		X	
No longer laying smooth, change in surface condition?										X		X		X		X
Coating appears similar to original color or hue	X	X	X	X	X		X	X								
Coating has dulled in color and physical appearance.						X				X		X		X		X
Brightest or most reflective in appearance of type of coating	X	X	X	X	X	X	X	X								
Primer improved appearance of coating compared to unprimed																
Roller marks--variation of hue																
Broom marks (primer or coating)																
Coating Anomalies																
Color or hue uneven: blemished, blotchy, streaked or spotty				X	X	X1				X1		X1		X1		X1
Small amounts of debris, fillers and/or fibers in coating																
Pinholes or pockmarks																
Wrinkling (slight delamination of coating from membrane)																
Peeling (coating supple, peeling off underlying membrane)																
Crazing (not really cracked but surface crazed)	XM	XM	X2	X2		XM	XM	XM	XM	XM	XM	XM	XM			
Cracking (fissures extend down into thickness of coating)	X1	X1	X2	X2	X1S	X1S	XS	XS	X1	X	X1	X	X1S	XS	X1S	XS
Flaking, flaking off underlying membrane in small pieces)																
Erosion (coating showing signs of deterioration)																

LEGEND: **X** = Condition Observed; **X1** = Condition is Minor; **X2** = Condition is Major; **XM** = Visible Under Magnification; **XB** = Visible in Broom Marks; **XS** = Visible Along Asphalt Bleed-out at Seams Only; **CNT =** Control Area (no coating) **Primed=**Primed w/ Fiber Asphalt Emulsion; **A1**=Aluminum Asphalt Emulsion; **A2**= Gray Asphalt Emulsion; **B1**= (3-lb Aluminum) Solvent-Based Asphalt Coating; **B2** = (1.5 lb Aluminum) Solvent-Based Asphalt Coating; **C1** = Premium Polymer-modified Acrylic White Coating; **C2 =** Commodity Latex White Coating; **D1**= SEBS-Polymer-modified, Solvent-Based Fiber Asphalt Coating; **D2** = SBS-Polymer-modified, Solvent-Based Fiber Asphalt Coating.

Appendix 1 (Cont.) **DATA COLLECTION MATRIX–(9 and 24 Months) AFTER COATING APPLICATION**

Minneapolis–Coatings Applied Over Four-ply Asphalt Built-up Roof [BUR] (Glazed=G-BUR) Membrane

	C1, G-BUR, PRMD (9 months)	C1, G-BUR, PRMD (24 months)	C1, G-BUR UNP (9 months)	C1, G-BUR UNP (24 months)	C1, BUR PRMD (9 months)	C1, BUR PRMD (24 months)	C1, BUR UNP (9 months)	C1, BUR UNP (24 months)	C2, G-BUR PRMD (9 months)	C2, G-BUR PRMD (24 months)	C2, G-BUR UNP (9 months)	C2, G-BUR UNP (24 months)	C2, BUR PRMD (9 months)	C2, BUR PRMD (24 months)	C2, -BUR UNP (9 months)	C2, -BUR UNP (24 months)
Asphalt Glaze Condition																
Appears in good condition																
Uneven in application	X	X	X	X	X	X	X1S	X1S	X1	X1	X1	X1				
Oxidized in color																
Pinholes																
Crazing (not really cracked but surface crazed)																
Cracking (fissures extend down into thickness of glaze)																
Conditions in asphalt glaze telegraphing through coating	X	X	X	X		X1S	X1S	X1S				X1				
Alligatoring																
Eroding (fiberglass surfacing ply showing)																
General Coating Condition																
Laying smooth, appears to be in good condition	X	X	X	X			X	X	X	X	X	X	X	X	X	X
No longer laying smooth, change in surface condition?																
Coating appears similar to original color or hue	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Coating has dulled in color and physical appearance				X												
Brightest or most reflective in appearance of type of coating	X	X	X	X	X	X	X	X								
Primer improved appearance of coating compared to unprimed	X	X			X	X				X				X		
Roller marks--variation of hue																
Broom marks (primer or coating)	X1	X1			X1	X1			X1	X1			X1	X1		
Coating Anomalies																
Color or hue uneven: blemished, blotchy, streaked or spotty																
Small amounts of debris, fillers and/or fibers in coating																
Pinholes or pockmarks	XM		XM	XM	XM	XM	XM	XM	XM	XM	XM	XM	XM	XM	XM	XM
Wrinkling (slight delamination of coating from membrane)																
Peeling (coating supple, peeling off underlying membrane)																
Crazing (not really cracked but surface crazed)																
Cracking (fissures extend down into thickness of coating)																
Flaking, flaking off underlying membrane in small pieces)																
Erosion (coating showing signs of deterioration)																

LEGEND: **X** = Condition Observed; **X1** = Condition is Minor; **X2** = Condition is Major; **XM** = Visible Under Magnification; **XB** = Visible in Broom Marks; **XS** = Visible Along Asphalt Bleed-out at Seams Only; **CNT =** Control Area (no coating) **Prmd=**Primed w/ Fiber Asphalt Emulsion **A1**=Aluminum Asphalt Emulsion; **A2**= Gray Asphalt Emulsion; **B1**= (3-lb Aluminum) Solvent-Based Asphalt Coating; **B2** = (1.5 lb Aluminum) Solvent-Based Asphalt Coating; **C1** = Premium Polymer-modified Acrylic White Coating; **C2 =** Commodity Latex White Coating; **D1**= SEBS-Polymer-modified, Solvent-Based Fiber Asphalt Coating; **D2** = SBS-Polymer-modified, Solvent-Based Fiber Asphalt Coating.

DATA COLLECTION MATRIX–(9 and 24 Months) AFTER COATING APPLICATION

Minneapolis–Coatings Applied Over Four-ply Asphalt Built-up Roof [BUR] (Glazed=G-BUR) Membrane

	D1, G-BUR, PRMD (9 months)	D1, G-BUR, PRMD (24 months)	D1, G-BUR UNP (9 months)	D1, G-BUR UNP (24 months)	D1, BUR PRMD (9 months)	D1, BUR PRMD (24 months)	D1, BUR UNP (9 months)	D1, BUR UNP (24 months)	D2, G-BUR PRMD (9 months)	D2, G-BUR PRMD (24 months)	D2, G-BUR UNP (9 months)	D2, G-BUR UNP (24 months)	D2, BUR PRMD (9 months)	D2, BUR PRMD (24 months)	D2, -BUR UNP (9 months)	C2, -BUR UNP (24 months)
Asphalt Glaze Condition																
Appears in good condition																
Uneven in application	X	X	X	X	XS	XS	XS	XS	X	X	X	X	XS	XS	XS	XS
Oxidized in color																
Pinholes																
Crazing (not really cracked but surface crazed)	X															
Cracking (fissures extend down into thickness of glaze)																
Conditions in asphalt glaze telegraphing through coating	X	X2	X1	X2	X1S	X1S	X1S	X1S	X1	X1	X1	X1	X1S	X1S	X1S	X1S
Alligatoring		X		X						X1		X1				
Eroding (fiberglass surfacing ply showing)																
General Coating Condition																
Laying smooth, appears to be in good condition	X		X		X		X		X	X	X	X	X+	X	X	X
No longer laying smooth, change in surface condition?		X		X		X		X								
Coating appears similar to original color or hue	X		X		X		X		X	X	X	X	X	X	X	X
Coating has dulled in color and physical appearance	X	X		X		X		X								
Brightest or most reflective in appearance of type of coating									X	X	X	X	X	X	X	X
Primer improved appearance of coating compared to unprimed		X			X	X			X	X			X	X		
Roller marks--variation of hue																
Broom marks (primer or coating)																
Coating Anomalies																
Color or hue uneven: blemished, blotchy, streaked or spotty	X	X2	X	X2		X1		X1	X1	X1						
Small amounts of debris, fillers and/or fibers in coating																
Pinholes or pockmarks																
Wrinkling (slight delamination of coating from membrane)																
Peeling (coating supple, peeling off underlying membrane)								X1								
Crazing (not really cracked, but surface crazed)	XM	X	XM	X	XM	X	XM	X	XM		XM					
Cracking (fissures extend down into thickness of coating)	X	X	X	X	X1S	X	X1S	X	X1	X1	X1S	X1S	X1	X1	X1S	X1S
Flaking, flaking off underlying membrane in small pieces)																
Erosion (coating showing signs of deterioration)																

LEGEND: **X** = Condition Observed; **X1** = Condition is Minor; **X2** = Condition is Major; **XM** = Visible Under Magnification; **XB** = Visible in Broom Marks; **XS** = Visible Along Asphalt Bleed-out at Seams Only; **CNT =** Control Area (no coating) **Primed=**Primed w/ Fiber Asphalt Emulsion **A1**=Aluminum Asphalt Emulsion; **A2**= Gray Asphalt Emulsion; **B1**= (3-lb Aluminum) Solvent-Based Asphalt Coating; **B2** = (1.5 lb Aluminum) Solvent-Based Asphalt Coating; **C1** = Premium Polymer-modified Acrylic White Coating; **C2 =** Commodity Latex White Coating; **D1**= SEBS-Polymer-modified, Solvent-Based Fiber Asphalt Coating; **D2** = SBS-Polymer-modified, Solvent-Based Fiber Asphalt Coating.

Appendix 1 (Cont.)

DATA COLLECTION MATRIX–(9 and 24 Months) AFTER COATING APPLICATION
Minneapolis– Coatings Applied Over Commodity-grade Atactic Polypropylene-(C-APP) Polymer-modified Asphalt Roof Membrane

	CNT, PRMD (9 months)	CNT, PRMD (24 months)	CNT, UNP (9 months)	CNT, UNP (24 months)	A1, PRMD (9 months)	A1, PRMD (24 months)	A1, UNP (9 months)	A1, UNP (24 months)	A2, PRMD (9 months)	A2, PRMD (24 months)	A2, UNP (9 months)	A2, UNP (24 months)	B1, PRMD (9 months)	B1, PRMD (24 months)	B1, UNP (9 months)	B1, UNP (24 months)	B2, PRMD (9 months)	B2, PRMD (24 months)	B2, UNP (9 months)	B2, UNP (24 months)
Surface Polymer-modified Asphalt Condition																				
Appears to be in good condition	X		X																	
Uneven in application																				
Oxidized in color			X	X																
Pinholes			X1	X																
Crazing (not really cracked but surface crazed)			XM	X																
Cracking (fissures extend into surface APP above reinforcement)	X1S	XS	X1S	X	X1S	X1S	X1S	X1S	X1S	X1S	X1S	X1S								
Condition(s) in asphalt telegraphing through surface coating	X1S	XS			X1S	X1S	X1S	X1S	X1S	X1S	X1S	X1S								
Alligatoring																				
Eroding (fiberglass or polyester reinforcement showing)				X																
General Coating Condition	Prmd	Prmd																		
Laying smooth, adhered to membrane, appears to be in good condition	X				X	X	X	X	X	X	X	X	X	X	X	X	X		X	X
No longer laying smooth, change in surface condition?		X																X1		
Coating appears similar to original color or hue					X	X	X	X	X		X		X	X	X	X	X		X	X
Coating has dulled in color and physical appearance	X	X2								X		X						X		
Brightest in appearance of type of coating					X	X	X	X			X	X			X	X			X	X
Primer improved appearance of coating compared to unprimed					X															
Roller marks--variation of hue																	X			
Broom marks (primer or coating)	X	X			X	X			X	X	X	X	X	X						
Coating Anomalies	Prmd	Prmd																		
Color or hue uneven: blemished, blotchy, streaked or spotty		X															X	X	X	X
Small amounts of debris, fillers and/or fibers in coating		X			X1	X1	X1	X1												
Pinholes or pockmarks						X		X									X	X		
Wrinkling (slight delamination of coating from underlying membrane)																		X		
Peeling (coating still supple but peeling off underlying membrane)																			X1	X1
Crazing (not really cracked but surface crazed)	XM	X											XM	XM	XM	XM	XM	XM	XM	XM
Cracking (fissures extend down into thickness of coating)	X1S	X			X1S	X1S	X1S	X1S	X1S	X1	X1S	X1S						X		X1
Flaking, flaking off underlying membrane in small pieces)																		X1		X1
Erosion (coating showing signs of deterioration)		X			X1B	X2B			X1B	XB										

LEGEND: **X** = Condition Observed; **X1** = Condition is Minor; **X2** = Condition is Major; **XM** = Visible Under Magnification; **XB** = Visible in Broom Marks; **XS** = Visible Along Asphalt Bleed-out at Seams Only; **CNT =** Control Area (no coating) **Prmd=**Primed w/ Fiber Asphalt Emulsion **A1**=Aluminum Asphalt Emulsion; **A2**= Gray Asphalt Emulsion; **B1**= (3-lb Aluminum) Solvent-Based Asphalt Coating; **B2** = (1.5 lb Aluminum) Solvent-Based Asphalt Coating; **C1** = Premium Polymer-modified Acrylic White Coating; **C2 =** Commodity Latex White Coating; **D1**= SEBS-Polymer-modified, Solvent-Based Fiber Asphalt Coating; **D2** = SBS-Polymer-modified, Solvent-Based Fiber Asphalt Coating.

DATA COLLECTION MATRIX–(9 and 24 Months) AFTER COATING APPLICATION
Minneapolis– Coatings Applied Over Commodity-grade Atactic Polypropylene-(C-APP) Polymer-modified Asphalt Roof Membrane

	C1, PRMD (9 months)	C1, PRMD (24 months)	C1, UNP (9 months)	C1, UNP (24 months)	C2, PRMD (9 months)	C2, PRMD (24 months)	C2, UNP (9 months)	C2, UNP (24 months)	D1, PRMD (9 months)	D1, PRMD (24 months)	D1, UNP (9 months)	D1, UNP (24 months)	D2, PRMD (9 months)	D2, PRMD (24 months)	D2, UNP (9 months)	D2, UNP (24 months)
Surface Polymer-modified Asphalt Condition																
Appears to be in good condition																
Uneven in application																
Oxidized in color																
Pinholes																
Crazing (not really cracked but surface crazed)																
Cracking (fissures extend down into surface APP above reinforcement)																
Condition(s) in asphalt telegraphing through surface coating																
Alligatoring																
Eroding (fiberglass or polyester reinforcement showing)																
General Coating Condition																
Laying smooth, adhered to membrane, appears to be in good condition	X	X	X	X	X	X	X	X	X		X		X	X	X	X
No longer laying smooth, change in surface condition?										X		X				
Coating appears similar to original color or hue	X	X	X	X	X	X	X	X	X		X		X	X	X	X
Coating has dulled in color and physical appearance																
Brightest or dullest in appearance of type of coating	X	X	X	X	X	X			X	X	X	X			X	X
Primer improved appearance of coating compared to unprimed					X	X										
Roller marks--variation of hue																
Broom marks (primer or coating)	X1	X1			X1	X1			X				X	X		
Coating Anomalies																
Color or hue uneven: blemished, blotchy, streaked or spotty										X		X				
Small amounts of debris, fillers and/or fibers in coating																
Pinholes or pockmarks	XM	XM	XM	XM	XM		XM	XM								
Wrinkling (slight delamination of coating from underlying membrane)																
Peeling (coating still supple but peeling off underlying membrane)																
Crazing (not really cracked but surface crazed)			XM	XM						X1		X1				
Cracking (fissures extend down into thickness of coating)										X1		X1				
Flaking, flaking off underlying membrane in small pieces)																
Erosion (coating showing signs of deterioration)																

__LEGEND__*:* **X** = Condition Observed; **X1** = Condition is Minor; **X2** = Condition is Major; **XM** = Visible Under Magnification; **XB** = Visible in Broom Marks; **XS** = Visible Along Asphalt Bleed-out at Seams Only; **CNT =** Control Area (no coating) **Prmd=**Primed w/ Fiber Asphalt Emulsion **A1**=Aluminum Asphalt Emulsion; **A2**= Gray Asphalt Emulsion; **B1**= (3-lb Aluminum) Solvent-Based Asphalt Coating; **B2** = (1.5 lb Aluminum) Solvent-Based Asphalt Coating; **C1** = Premium Polymer-modified Acrylic White Coating; **C2 =** Commodity Latex White Coating; **D1**= SEBS-Polymer-modified, Solvent-Based Fiber Asphalt Coating; **D2** = SBS-Polymer-modified, Solvent-Based Fiber Asphalt Coating

APPENDIX 2

MRCA Coating Research Program Photo Log

Photo 1: Shows installation of a spot repair at weather-weakened deficient location of roof membrane.

Photo 2: Application of surface coating to shield roof membrane from direct effects of weather and prolong life of roof membrane.

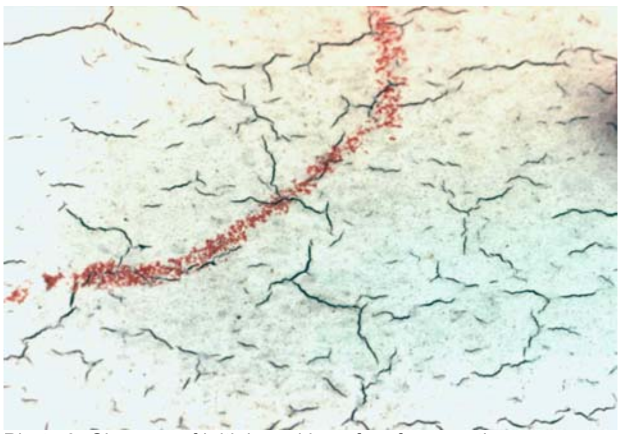


Photo 3: Close up of initial cracking of surface coating.

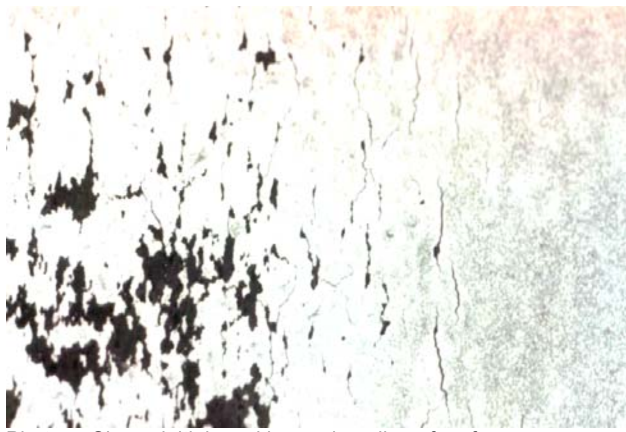


Photo 4: Shows initial cracking and peeling of surface coating.

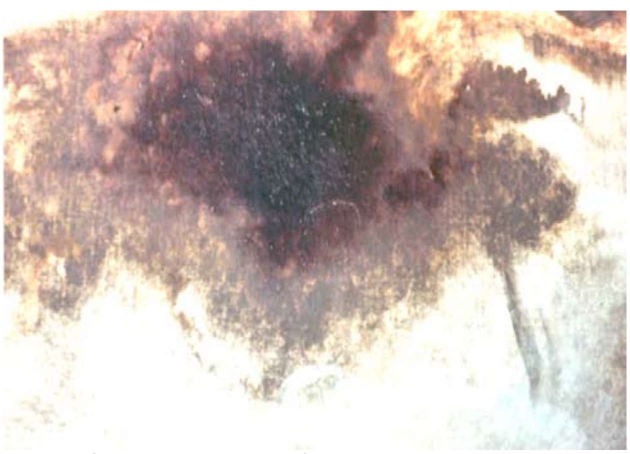


Photo 5: Shows accumulation of asphalt bleed-through on the surface of coating

Photo 6: Shows overview of coated test roof located in Kansas City, Mo.

MRCA Coating Research Program Photo Log

Photo 7: Shows overview of coated SBS cap sheet surfaced test roof located in Kansas City, Mo.

Photo 8: Shows overview of coated test roof located in St. Louis, Mo.

Photo 9: Shows overview of coated test roof located in St. Louis, Mo.

Photo 10: Shows overview of test roof located in St. Paul/Minneapolis, Minn.

Photo 11: Shows overview of test roof located in Dallas, Texas.

Photo 12: Depicts orientation of roof coatings applied to minimize the effects of differential thermal movement upon the coated roof membranes.

MRCA Coating Research Program Photo Log

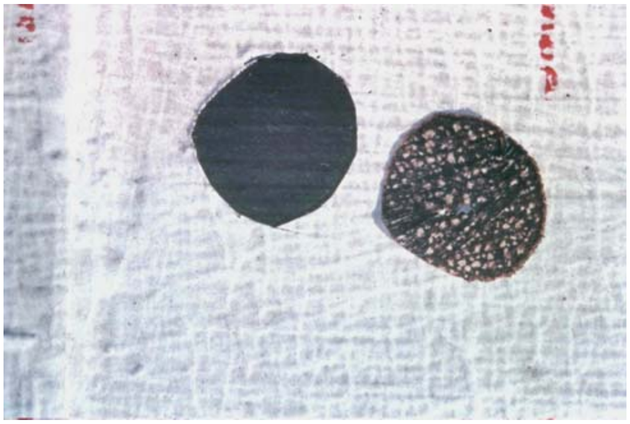
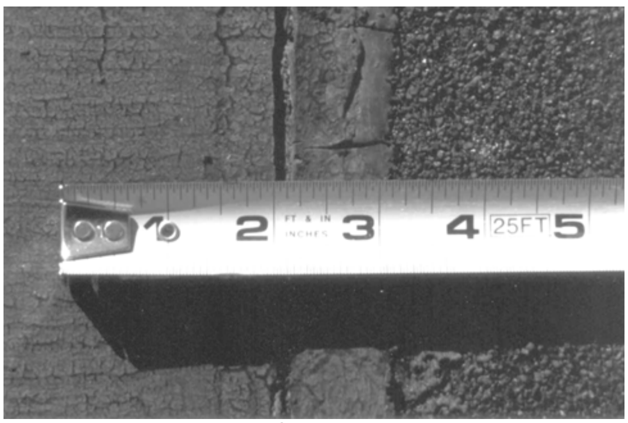


Photo 13: White acrylic coating applied to an asphalt-based membrane primed with asphalt emulsion revealed increased adhesion and peel strength, as evidenced by well bonded emulsion on the bottom side of acrylic coating.

Photo 14: White acrylic coating applied to an asphalt-based membrane, that lacks asphalt emulsion primer, revealed less bond and peel strength. Note only minor traces of asphalt residue on the bottom side of acrylic coating.



Photos 15 and 16: Stress cracks through emulsion and aluminum coating at end laps of polyester-reinforced, APP-Polymer-modified asphalt cap sheet indicates that membranes are experiencing post-application shrinkage.

Photo 17: No stress cracks or shrinkage was evident at same SBS polymer modified asphalt cap sheet end laps coated with white acrylic coating.

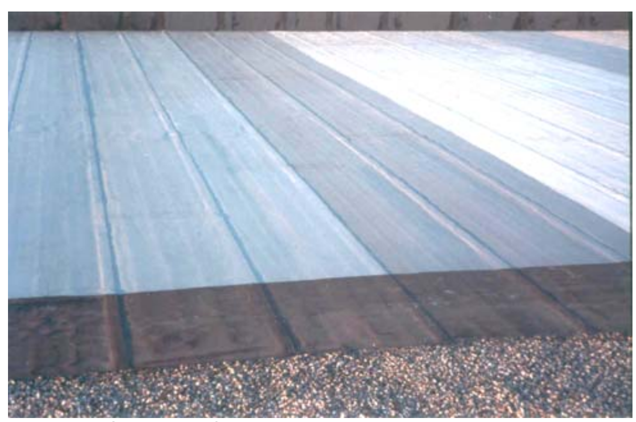


Photo 18: Overview of aluminum-pigmented, solvent-based SBS-polymer-modified and premium-grade coatings, as well as acrylic coatings that are performing well.

Appendix 2 (cont.) MRCA Coating Research Program Photo Log

Photo 19: Depicts cracking and erosion of exposed asphalt-emulsion primer that was applied over hot asphalt glaze coat that was installed too heavy and is subsequently telegraphing, alligatoring/cracking through the overlying emulsion.