DURABILITY OF TWO-PLY SBS MODIFIED BITUMEN ROOFING MEMBRANES: 10-YEAR PERFORMANCE RESULTS

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During the Third International Symposium in Montreal in 1991, a paper was presented on the durability of styrene-butadiene-styrene (SBS) modified bitumen roofing membranes. This paper was primarily based on experiences in Europe, where SBS modified bitumen roofs have been applied since 1969.

Homogeneous roof membrane systems consisting of two plies of SBS modified bitumen have been applied in the United States for more than 15 years utilizing hot asphalt, torch, and cold adhesive applications. Over the past several years, SBS modified bitumen roof systems have been one of the fastest growing market segments in the United States.

In today's roofing market, there is a broad range of SBS products, some of which offer economical alternatives without proven long-term performance. Meaningful technical standards will be necessary to ensure that the long-term durability of SBS modified bitumen membranes is not compromised. To be effective, these standards must incorporate performance before and after heat aging.

To promote this effort, the authors have tested 10-year-old SBS roof membrane samples taken from various locations in the United States. Job sites were selected with regard to different parameters (e.g., climate, altitude, roof construction, etc.).

A comparison between French and U.S. blend formulations, membrane systems, and application methods will be shown. Correlation will be made between results from these 10-year-old roofs and artificial aging.

KEYWORDS

American Society for Testing and Materials, European Union of Agrément, gel permeation chromatography, International Waterproofing Association, modified bitumen, styrene-butadiene-styrene.

INTRODUCTION

At the Third International Symposium in Montreal, one of the authors of this paper presented performance results of two-ply SBS modified bitumen roofing on French jobs after 10 and 20 years in the field. Results from one 10-year-old roof membrane in Florida were also mentioned.

These results had to be confirmed by an American study concentrating on jobs in the United States after the same duration.

Within that framework, samples of roof membrane analyzed in the laboratory were:

- manufactured with U.S. raw materials: bitumen, SBS polymer, fiberglass mat carrier;
- applied with Type IV mopping asphalt (interply asphalt);
- installed by American contractors following traditional U.S. practice.

SCOPE OF STUDY

Samples

The authors chose five jobs in the United States representing different climatic regions:

- Tallahassee, Florida
- Jacksonville, Florida
- Mesa, Arizona
- Barberton, Ohio
- Kirkland, Washington

The prevalent conditions represented at these sites are:

- intense UV and high heat (Arizona)
- high heat and high humidity (Florida)
- aggressive cyclic thermal shock (Ohio)
- high humidity (Washington)

Systems

All of the membranes reported in this study consisted of two-ply SBS modified bitumen reinforced with random fibrous glass mat. Each membrane consisted of an independently watertight base sheet and a granule-surfaced cap sheet. In these systems, the base and cap sheet were composed of identical SBS modified bitumen formulations. The sheets were fully adhered to the substrate and used American Society for Testing and Materials (ASTM) D 312 Type IV mopping asphalt in the interply. Each roof membrane was 10 years old at the time samples were taken.

The study consisted of two parts:

- description
- performance of the roofing sheets and mopping asphalt

PERFORMANCE-RELATED TEST METHODS

Performance tests were:

- for mopping asphalt
  - ring-and-ball softening point
  - penetration at 25°C (77°F) and 50°C (122°F)

- for SBS modified bitumen

The authors tested the blend, individual sheets, or membrane as appropriate in function of the test method and performance characteristic.

Tests performed included:

- ring-and-ball softening point (blend)
- penetration at 25°C (77°F)/50°C (122°F) (blend)
- polymer loading (blend)
- permanent set (elastic recovery) (blend)
- filler loading (blend)
- breaking load (sheet)
- ultimate elongation (sheet)
- low-temperature flexibility (sheet)
- compound stability (sheet)
- granule coverage (sheet)
- cyclic fatigue (membrane)

Test methods utilized in this study were in accordance with:

- ring-and-ball softening point (ASTM D 36)
- penetration (ASTM D 5)
- low-temperature flexibility (ASTM D 5147)
- elastic recovery presented at International Waterproofing Association (IWA) in Amsterdam, April 1995

  [This test assists in calculating the capacity of the blend to return to its initial dimension after one elongation cycle of 24 hours and relaxation of 24 hours at a constant temperature. The reported value is the residual strain (or permanent set) after elongation to 25 percent or 50 percent and relaxation.]
- Breaking load and elongation (ASTM D 5147) (temperature: 23°C±2°C [73°F±4°F])
- Polymer rate: Gel permeation chromatography (GPC) using Waters/GPC 150 to measure the quantity of SBS in the blend.
- Filler loading: by extraction filtering and gravimetric analysis
- Compound stability: ASTM D 5147 using 10°C (18°F) increments.
- Cyclic fatigue: ASTM D 5849 tested at -10°C (14°F) with initial opening of 2 mm (0.079 inches) and amplitude of ± 1 mm (0.039 inches).
- Granule coverage: Canadian General Standards Board (CGSB test).

PROJECT INFORMATION

Project information is presented in Table 1.

TEST RESULTS

Test results are presented in Tables 2, 3, 4A, and 4B.

CORRELATION WITH ARTIFICIAL AGING

The reference for correlation with artificial aging is an SBS modified bitumen blend of identical formulation and raw materials as those used to manufacture the sheet goods. The blend was prepared in the laboratory and aged in a forced air convection oven for 180 days at 70°C (158°F). (See Table 5A.)

The following reference is a French product manufactured with French raw materials and also tested after 180 days heat aging in a forced air convection oven at 70°C (158°F). (See Table 5B.)

INTERPRETATION OF RESULTS

The authors found that samples taken from 10-year-old jobs had no appearance anomalies, notably, little to no granule loss or surface cracking problems. As noted in the table, a couple of areas exhibited some minor mud curling but, in

TABLE 1: JOB PROFILES

STATE	FLORIDA	FLORIDA	ARIZONA	OHIO	WASHINGTON
CITY	Tallahassee	Jacksonville	Mesa	Barberton	Kirkland
Installed (Year)	1985	1986	1986	1986	1986
Building Use	Office	Sports Arena	School	Apartment Building	School
Area (squares)	276	187	90	115	517
Slope (%)	1	1	1	0.5	5
Support	Steel deck with existing BUR	Concrete	Plywood	Concrete	Plywood
Insulation	Lightweight Concrete (NVS)	Lightweight Concrete	Perlite	1.6 inch polyiso	None
Membrane System	Two ply SBS modified bitumen/recover over BUR	Two ply SBS modified bitumen/new roof	Two ply SBS modified bitumen/ new roof	Two ply SBS modified bitumen/BUR tear off	Two ply SBS modified bitumen / BUR tear off
Roof Membrane Condition	-Good granule adhesion. -No curling.	-Good granule adhesion -No curling.	-Good granule adhesion. -Light curling.	-Good granule adhesion -Light curling.	-Good granule adhesion -No curling

general, were in good condition (see photos).

SBS modified bitumen blend

- Polymer rate—The GPC data after 10 years shows active polymeric linkages (SBS) present in most samples. This is reported to be informative, but the key indicator is the performance of the modified bitumen blend.
- Ring-and-ball softening point—This result gives good information on blend rheology. Results are greater [100°C (212°F)], than the value required by the European Union of Agrément Directives after aging. The positive field observations support these lab results.
- Penetration @ 25°C (77°F) and 50°C (122°F)—Penetration at 25°C (77°F) gives some information on blend stability over time. Note the change in penetration values over the course of laboratory oven aging; see Tables 5A and 5B.

  Although penetration has traditionally been tested at 25°C (77°F) for conventional bituminous materials, penetration values tested at 50°C (122°F) show a more demonstrable change in properties before and after aging.
- Low-temperature flexibility—Results reported in this paper were taken from tests performed on the roofing sheets. Compared to results from tests on the extracted blend, this eliminates variables involved in remelting the SBS bitumen.

  Except for the Jacksonville cap sheet, results are good and consistent within this performance parameter and confirm blend test results.

  As expected, physical properties of the cap sheet after 10 years are not as good as the base sheet. This is because the cap sheet receives most of the climatic abuse, oxidation, and heat load. The base layer is encapsulated by an asphalt adhesive layer on either side, and it is shielded by the cap sheet. Thus, the base sheet's aging rate is less severe than that of the cap sheet.
- Permanent set (elastic recovery)—The SBS modified bitumen blend must maintain elastic performance after aging because it is the elastomeric quality of the blend that allows the system to withstand cyclic movement on the roof without cracking.

  Even with lower results in Arizona and Florida, it

TABLE 2: PERFORMANCE RESULTS OF MOPPING ASPHALT

MOPPING ASPHALT	FLORIDA (Tallahassee)	FLORIDA (Jacksonville)	ARIZONA	OHIO	WASHINGTON
Ring-and-ball °C (F)	131 (268)	128 (262)	140 (284)	111 (232)	112 (234)
Penetration (dmm)					
-25°C (77°F)	3	2	3	4	5
1-50°C (22°F)	11	7	9	17	17

TABLE 3: PERFORMANCE RESULTS OF SBS MODIFIED BITUMEN BLEND AFTER EXTRACTION

SBS MODIFIED BITUMEN BLEND	FLORIDA	FLORIDA	ARIZONA	OHIO	WASHINGTON
	Tallahassee	Jacksonville	Mesa	Barberton	Kirkland
Ring-and-ball °F (°C)					
Base Sheet	104 (220)	104 (220)	103 (217)	110 (230)	108 (234)
Cap Sheet	103 (217)	106 (223)	106 (223)	104 (219)	112 (234)
Penetration					
- 25°C (77°F)					
Base Sheet	24	20	38	31	25
Cap Sheet	16	18	28	25	19
- 122°F (50°C)					
Base Sheet	85	64	92	88	78
Cap Sheet	60	55	78	82	68
Polymer loading (%)					
- Base Sheet	12	11.5	-	11.5	12.5
- Cap Sheet	10	-	-	11	12
Elastic Recovery (%)					
- Base Sheet					
25%	6	18	15	0	0
50%	15	-	-	10	8.5
- Cap Sheet					
25%	13	20	17	0	6
50%	-	-	-	12	17
Filler (%)					
- Base Sheet	25	24	26	25	25
- Cap Sheet	27	26	26	25	26

TABLE 4A: PERFORMANCE RESULTS of SHEET MATERIALS

SHEET TESTING	FLORIDA Tallahassee	FLORIDA Jacksonville	ARIZONA Mesa	OHIO Barberton	WASHINGTON Kirkland
Low Temp.Flex. °C (°F)					
—Base Sheet	-25 (-13)	-30 (-22)	-15 (5)	-15 (5)	-25 (-13)
—Cap Sheet	-20 (-4)	-5 (23)	-15 (5)	-15 (5)	-10 (14)
Breaking Load kN/m (lbf/in)					
—Base Sheet MD\XD	6.7/7.8 (38/44)	8.2/7.1 (47/41)	12.5/3.2 (71/18)	11.5/4.6 (66/26)	14.1/4.9 (81/28)
—Cap Sheet MD\XD	6.9/5.7 (39/33)	8.1/4.2 (46/24)	3.6/3.0 (21/17)	6.3/3.2 (36/18)	15.6/14.1 (89/81)
Ultimate Elongation (%)					
—Base Sheet MD\XD	26/19	26/33	14/20	22/32	24/47
—Cap Sheet MD\XD	12/12	7/12	9/16	16/21	20/19
Compound stability passing temperature °C (°F)					
—Base Sheet	110 (230)	110 (230)	100 (212)	110 (230)	110 (230)
—Cap Sheet	110 (230)	110 (230)	100 (212)	110 (230)	120 (248)
Granule Coverage (%)	91	90	97	98	97

MD = machine direction XD = cross-machine direction

TABLE 4B: PERFORMANCE RESULTS of ROOFING MEMBRANES

Cyclic Fatigue Resistance (cycles passed)	500	500	500	500	500

Cyclic fatigue tests are conducted on the membrane comprised of all sheets as constructed on the roof.

demonstrates that the system maintains a good potential for durability.

- Resistance to cyclic fatigue—These results confirm the performance of elasticity recovery, because the system is not cracked after 500 cycles. Future samples taken after 20 years will confirm U.S. membrane durability as was done with French samples after 20 years.
- Mopping asphalt—Mopping asphalt serves only as an adhesive to bond the two plies of SBS modified bitumen together, and theoretically, it does not contribute or interfere with the watertightness of the system. However, the type of mopping asphalt, the asphalt application temperature, and its thickness are parameters that can affect the quality and durability of the system.

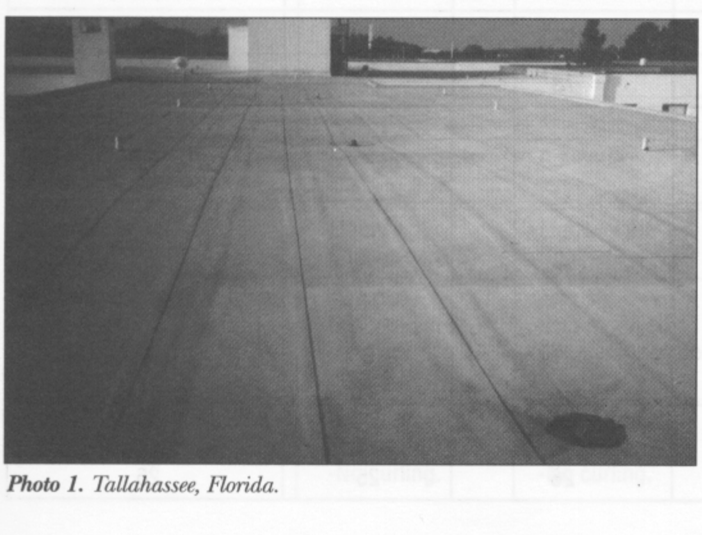

Photo 1. Tallahassee, Florida.

CONCLUSIONS

The general characteristics of the materials tested in this study were good, but the authors cannot, however, overlook other SBS modified bitumen roofs that have been reported to have problems in the United States. Slippage and interply blistering have been reported by the National Roofing Contractors Association (NRCA), but no leaks have been indicated. Rather than performance problems, these appear to be aesthetic in nature.

Mopping asphalt (interply adhesive)

Aside from the primary objective of this study, performance of the interply adhesive used in these systems must be considered. In this case, the choice of mopping asphalt is important concerning its stability with SBS modified bitumen.

Although no leaks have been associated with NRCA reports of interply problems with SBS modified bitumen roof systems, it is prudent to say that these issues are similar to those of BUR regarding oxidized mopping asphalt. Some

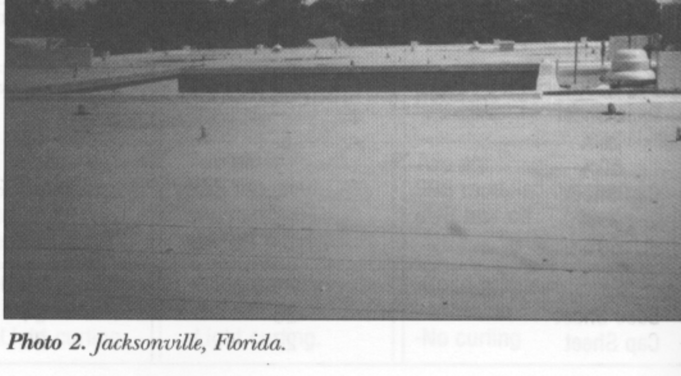

Photo 2. Jacksonville, Florida.

TABLE 5A: U.S. ARTIFICIAL AGING

U.S. Materials	0 DAY	After 2 months @ 70°C (158°F)	After 4 months @ 70°C (158°F))	After 6 months @ 70°C (158°F))
Polymer rate: %	12.5			
Ring-ball: °C (°F)	130 (266)	120 (248)	115 (239)	110 (230)
Penetration @ 25°C (77°F)	42	23	20	15
Penetration @ 50°C (122°F)	95	70	65	60
Low-Temperature Flexibility °C (°F)	-35 (-31)	-30 (-22)	-25 (-135)	-20 (-4)

TABLE 5B: FRENCH ARTIFICIAL AGING

French Materials	0 DAY	After 2 month @ 158°F (70°C)	After 4 months @ 158°F (70°C)	After 6 months @ 158°F (70°C)
Polymer rate: %	12.5			
Ring-ball: °C (°F)	140 (284)	132 (270)	128 (262)	118 (244)
Penetration @ 25°C (77°F)	32	20	16	17
Penetration @ 50°C (122°F)	83	67	65	62
Low-Temperature Flexibility °C (°F)	-30 (-22)	-25 (-13)	-25 (-13)	-15 (5)

asphalt is unstable, some membrane may not properly bond, or both. Knowing that some concerns surrounding hot asphalt applications exist, other very successful application methods are available with SBS modified bitumen.

Torching of SBS membranes has been practiced in Europe and Canada for more than 20 years and by some companies in the United States for more than 15 years. Solvent-based adhesive (asphalt cutback) has also been used in the United States with these two-ply SBS systems for more than 15 years, but has become more popular in recent years. Both torching and cold applications offer viable technical solutions for installing SBS systems. As such, they must be considered as the future interply adhesives of choice when mopping asphalt is called into question because of quality, availability, health, or environmental reasons.

Membrane Performance

It is important to understand that the base and cap sheets reported in this study are basically identical products except for the granules on the cap. They contain the same glass carrier, but more critically, they contain the very same SBS modified bitumen compound, thus making these systems truly homogeneous in nature.

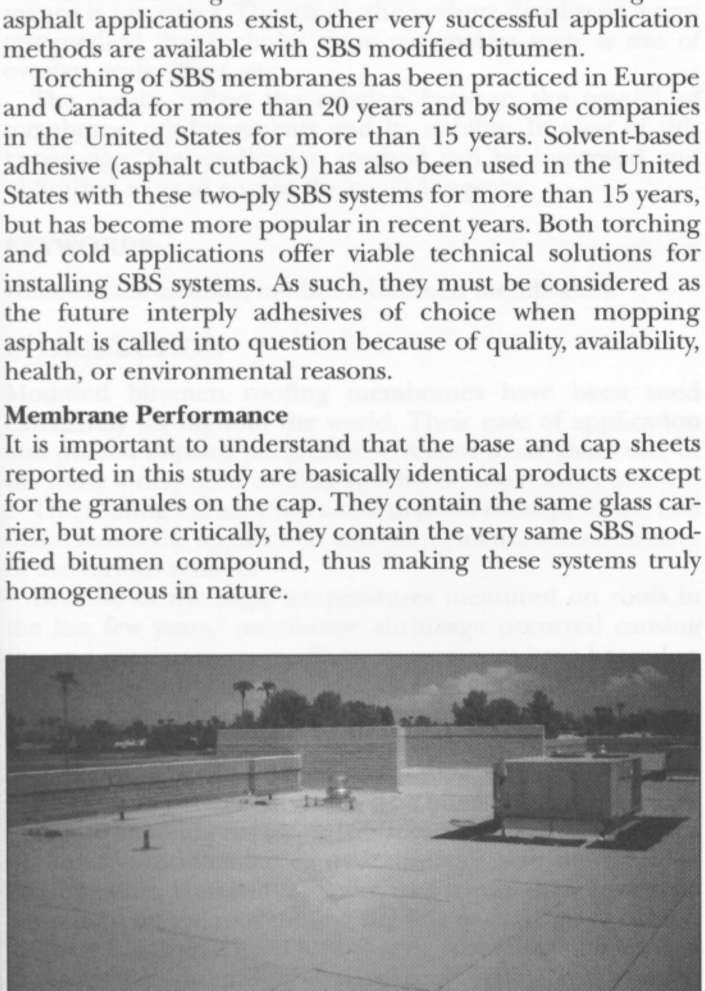

Photo 3. Mesa, Arizona.

Furthermore, the long-term success of these membranes is based on the careful selection of asphalt and SBS polymer chemically matched and properly formulated and blended. A relatively high percentage of high-molecular-weight SBS polymer was utilized in these formulations with only a reasonable loading of inert filler to maximize elastomeric properties and to minimize premature deterioration of the blend.

Quality control testing during manufacturing is very necessary to ensure daily product consistency. More important, however, is the initial research needed to choose the right raw material components and be able to predict their performance over time. Once the proper raw material selection is made, the key is then to avoid deviation from the established formulation. There must be a reproducible method to artificially age materials under accelerated conditions and to accurately forecast performance.

Referring to Tables 5A and 5B, it is possible to show the method by which long-term performance was predicted in the laboratory during the development of modified bitumen. Oven aging at 70°C (158°F) for 180 days has been used for

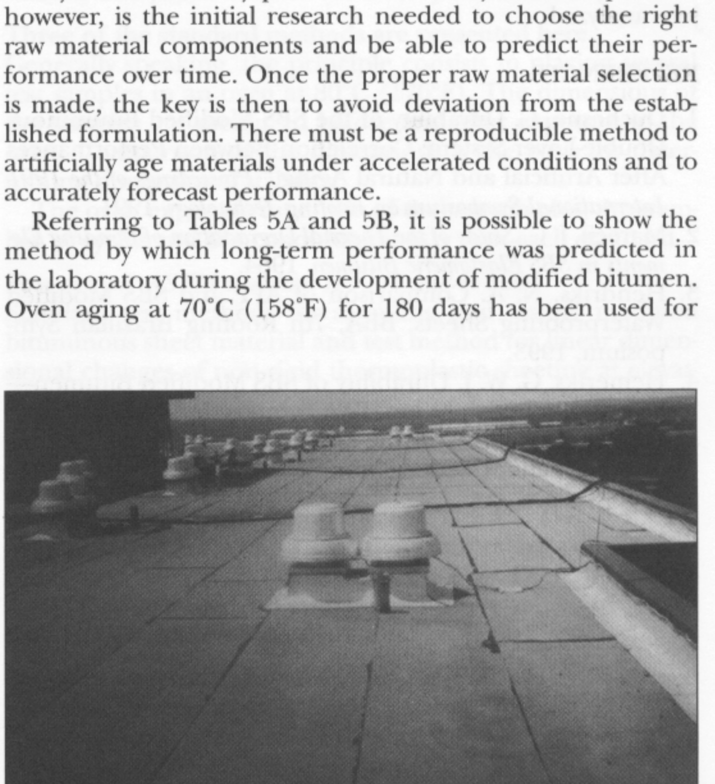

Photo 4. Ohio.

Photo 5. Washington.

more than 25 years with documented consistency to provide the means for extrapolating modified bitumen blend performance. Here again, correlation can be drawn between results obtained from field samples and those found in both U.S. and French oven aging. It is interesting to point out the consistency between the two lab results using different raw material sources in different countries. Of equal interest is the similarity in overall performance of the French and U.S. materials. The U.S. formulation was chemically patterned from the French product and is blended and processed in the same fashion.

This study, and its results, are consistent with the 1991 paper presented in Montreal. It confirms the sound choice of two-ply, homogeneous SBS modified bitumen roof systems in the United States. Good results were obtained from the five jobs analyzed.

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