WEATHERING CHARACTERISTICS OF POLYMER MODIFIED ASPHALT ROOFING MEMBRANE

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This paper examines the weathering characteristics of polymer modified bituminous compounds. The materials tested include both atactic polypropylene (APP) and styrene-butadiene-styrene (SBS) modified bitumen blends. Both polyester and fiberglass reinforced membranes are included in this study.

Comparative tests were conducted on membranes subjected to heat conditioning alone and membranes subjected to weathering in a QUV accelerated weathering panel. The Q-panel utilizes cycles of heat and ultraviolet light alternating with cycles of constant condensation. The finished products were evaluated for tensile and elongation properties, moisture content and absorption, tear resistance, compound stability, and low temperature flexibility.

Also, this study investigates the use of thin films of bitumen/polymer blends. Several different APP and SBS blends were examined using fluorescent microscopy and the QUV weathering process to look at the surface deterioration of the blends. The thin film bitumen/polymer blends were prepared using an adaptation of ASTM D 1669 with the primary difference being that the bitumen polymer blends are pressed out in thinner layers than the asphalt coatings for which this test method is intended. The samples exposed to QUV weathering were then compared microscopically to samples were also exposed to natural weathering conditions. The samples are examined using a spark tester in accordance with ASTM D 1670 in an attempt to gain a quantitative measure of ultraviolet resistance of the polymer/bitumen blends.

KEYWORDS

Atactic polypropylene (APP), isotactic polypropylene (IPP), polymer modified asphalt membranes, styrene-butadiene-styrene (SBS), weathering.

INTRODUCTION

Weathering characteristics of polymer modified asphalt roofing membranes have been observed in the field to vary significantly, with apparent variations attributable to asphalt batch types and asphalt/polymer ratios, reinforcement types and location of the reinforcing mat(s) in the plane of the polymer modified asphalt roofing membrane.

It has long been recognized that ratios between polymer modifiers and thermoplastic asphalts have been critical to the long-term performance qualities of polymer modified asphalt roofing membranes and the percentage of polymer modifiers by weight included in the finished roofing membranes has been studied extensively by suppliers of some polymer modifiers used in asphalts for roofing and paving and finished polymer modified asphalt roofing membranes.

Asphalt "fillers" used in all polymer modified asphalt roofing membranes have received less attention in evaluating physical properties and weathering characteristics of polymer modified asphalt roofing membranes. In following the evaluation of polymer modified asphalt roofing membranes containing both atactic polypropylene (APP) and styrene-butadiene-styrene (SBS) modifiers from completed roofing membranes of varying ages in various geographical locations, it became apparent that filler type and filler content in polymer modified asphalt batches might significantly affect the long-term weathering characteristics of polymer modified asphalt roofing membranes.

Several samples of polymer modified asphalt containing varying quantities of both APP and SBS modifiers and powdered limestone ($CaCO_3$) filler were prepared for evaluation using criteria set forth in ASTM D-1669, "Preparation of Test Panels for Accelerated Weathering of Bituminous Coatings." The samples were slightly modified to evaluate polymer modified asphalt samples by means of the "thin film" weathering test. The asphalt, resin and filler types were identical in all samples to minimize variables; only percentages by weight of filler and resin/asphalt ratios were varied in the test samples. The sample panels were placed in a standard weatherometer chamber for 2,200 hour test cycle (alternate six hours QUV at 70°C and six hours condensation) after which they were removed and visually examined by fluorescent microscopy for surface weathering characteristics.

Samples of finished polymer modified asphalt roofing membranes containing varying quantities of filler and asphalt/resin ratios produced under typical manufacturing conditions during normal production cycles were placed in the weatherometer for a 2,200 hour test cycle (alternate six hours QUV at 70°C and six hours constant condensation) to evaluate the effects of the various combinations of polymer modifiers and filler on the physical properties and surface weathering characteristics of the finished polymer modified asphalt roofing membrane. All evaluated material was produced with asphalt having similar qualities using the same type resins; asphalt resins were evaluated for compatibility prior to manufacture.

The aged, finished roofing membrane samples were evaluated for tensile strength, elongation properties, water absorption, tear resistance, compound stability and low-temperature flexibility. The results of the physical testing on the various samples are presented in the attached tables. Two samples of each type of material were evaluated by a weathermoter due to limited space in the test equipment; in all other cases, five samples of each type of material were evaluated.

Capacity limitations in the accelerated weathering equipment would not allow for sample evaluation beyond the initial period, and therefore test results are limited to the 2,200 hour period. Testing of samples for longer periods may have provided some better indication of longer term effects of weathering on the physical properties of the finished membranes.

Some controlled, normal production samples of polymer modified asphalt roofing membranes containing various reinforcements, filler quantities and asphalt/resin ratios were available for evaluation after natural weathering on a low-sloped roof in Kansas City, Kan., for approximately two years. Results of the evaluation of the naturally exposed samples are indicated where information was available for naturally exposed samples of know age, content and date of manufacture. There was a reasonable correlation between artificially and naturally aged finished roofing membranes.

All samples were prepared in general compliance with recommendations contained in Building Science Series 167, "Interim Criteria for Polymer Modified Bituminous Roofing Membrane Materials," which was published by the National Institute of Standards and Technology (NIST) for compound stability, asphalt compatibility, etc. Evaluation of the effects of cracking and separation of the surface asphalt on long-term weathering properties of the finished roofing membranes was not within the scope of this study.

The type and location of reinforcing mats included in polymer modified asphalt roofing membranes also appeared to have an effect on the weathering properties of the finished polymer modified asphalt roofing membranes, and an attempt was made to subjectively evaluate the effects of the type and placement of reinforcing materials on surface weathering characteristics of both APP and SBS modified asphalt roofing membranes during the period of evaluation. Insufficient samples were available for definitive evaluation of polymer modified asphalt roofing membranes with varying reinforcement locations in the finished roofing membranes; however, initial observations of variations in weathering properties of the finished membranes indicate that the effects of location and type of reinforcements in the finished membranes may warrant additional study.

OBSERVATIONS

Observations on weathering characteristics of all evaluated materials were made visually, with some magnification, and by fluorescent microscopy. Samples were subjectively ranked by their physical appearance using all visual methods.

APP Modified Asphalt/APP Modified Asphalt Membranes

The physical properties and weathering characteristics of APP modified asphalt were dramatically affected by the addition of fillers in excess of 25 percent. Although tensile properties, percent elongation and load-strain properties of samples containing high filler content were only marginally affected by heat aging, the cold flexibility properties of the finished membranes dropped precipitously to levels below normal manufacturing tolerances.

Reinforcements in the finished membrane were the controlling factor in tensile strength, percent elongation and load-strain properties. There was no apparent long-term weathering effect on the reinforcements. Cold flex properties appear to be directly attributable to properties of the polymer modified asphalt. Visual and fluorescent microscopy evaluation of polymer modified asphalt samples on thin film test panels indicated that excessive quantities of filler were detrimental to the surface weathering of polymer modified asphalt, the sample containing high filler content showing excessive surface crazing and discoloration of the polymer modified asphalt.

When filler content was reduced to approximately 15 percent by weight of the polymer modified asphalt batch, poor surface weathering of both finished membrane samples and thin film panel samples was apparent, indicating that the acceptable range of filler content by weight of the APP polymer modified asphalt batch mix should be 15-25 percent.

It has been the informal consensus of opinion in polymer modified asphalt circles that inclusion of higher percentages of isotactic polypropylene (IPP) in the polymer modified asphalt batch improves overall handling properties of the APP modified asphalt roofing membranes, but diminishes the cold temperature flexibility and weathering characteristics of the finished roofing membranes. "Normal" APP batches contain 16-18 percent APP, 4-5 percent IPP, approximately 20 percent filler and the balance of the weight selected asphalt. Thin film samples containing in excess of 5 percent IPP weathered most poorly of the thin film APP modified asphalt samples with significant degradation of APP modified asphalt and some of the thin film weathered completely off the panel after 2,200 hours of weatherometer exposure (1,100 hours QUV light exposure). But finished membranes manufactured using higher IPP weights typically exhibited good initial physical characteristics and retained their physical properties through heat aging and natural exposure. The overall effects of higher IPP content in APP modified asphalt batches did not appear to be as detrimental to the physical properties of the finished roofing membrane as previously believed, although weathering characteristics of finished membranes containing higher percentages of IPP were not as good as membranes containing "normal" quantities of IPP.

Glass fiber mat close to the top surface of the APP modified asphalt roofing membranes appeared to improve the cohesion of the weathering asphalt on the roof membrane surfaces and apparently improved surface weathering characteristics of the finished membranes, but cold flex properties were marginal in membranes of this configuration. The affectation of cold flex characteristics on the finished roofing membranes were apparently not corollary to the type of binders used in the glass fiber mat, with both acrylic and urea formaldehyde based binders used in the samples of the finished membranes evaluated.

APP modified asphalt roofing membranes reinforced with non-woven polyester mats typically exhibited significant "crazing" and cracking of the polymer modified asphalt on the surface of the finished membranes observed after accelerated and natural weathering, a phenomenon not observed on APP modified asphalt roofing membranes containing glass fiber scrim or non-woven glass fiber mats close to the top surface of the finished membrane.

SBS Modified Asphalt Membranes

SBS modified asphalt roofing membranes containing relatively high percentages of filler (30-45 percent batch weight) exhibited better weathering qualities with less surface crazing than membranes manufactured using the more usual filler content approximating 20 percent by weight of the asphalt batch. Cold flex properties of SBS roofing membranes with high filler content were better than cold flex properties of finished membranes containing 20 percent filler by weight; however, elongation properties of SBS membranes containing high filler content was unacceptably low. Improvement in cold flex properties is probably attributable to higher resin/asphalt ratios in the finished batch.

SBS modifiers typically approximate 8-12 percent by weight of the asphalt batch in SBS modified asphalt membranes. Samples of SBS modified asphalt batches with very high (45 percent) powdered $CaCO_3$ (limestone) filler exhibited the best weathering characteristics contained only about 6 percent SBS by total batch weight. Lesser quantities of SBS modifiers (resulting in lower resin/asphalt ratios) may have contributed to the low elongation properties of the finished membranes, but the membranes constructed with high filler and relatively low polymer resin quantities were judged as having the best weathering appearance after evaluation of in-service properties.

Increasing the quantity of filler in the SBS modified asphalt membranes did not have as dramatic an impact on the physical characteristics of the finished roofing membranes as with the APP modified asphalt membranes.

When evaluating the polymer modified asphalt membranes surfaced with ceramic or slate granules (white or light gray/green), the type and color of surfacing granules on SBS membranes made no apparent difference on physical properties of artificially or naturally aged finished roofing membranes indicating that both types of surfacing granules appeared to be equally effective in protecting polymer modified asphalt roofing membranes from QUV exposure. Dark gray or black ceramic granule surfacings were not evaluated.

Location of nonwoven polyester reinforcing mats apparently affected the weathering characteristics of the finished SBS polymer modified asphalt membranes. When reinforcing mats were close to the top surface of the finished membranes, significantly less surface crazing/cracking was obvious in the membranes after weathering. When reinforcing mats were placed near the center of the membrane plane, cracks and separation of the surfacing asphalt/granules were more pronounced.

Observations made during the evaluation of the polymer modified asphalt roofing membranes indicated that inclusion of a glass fiber weathering mat near the top surface of the SBS modified asphalt roofing membranes improved surfacing weathering properties significantly, reducing the tendency for formation of surface cracks and crazing.

There was very little difference in cold flex properties in SBS modified asphalt roofing membranes constructed with glass fiber mats and nonwoven polyester mats.

CONCLUSION

Filler content significantly above present common percentages by weight in polymer modified asphalt roofing membranes improves weathering properties of SBS modified asphalt, but some physical properties decrease below acceptable levels. Increasing filler content in APP modified asphalt roofing membranes much above current, common percentages results in precipitous drops in general physical properties to unacceptable levels, with no apparent improvement in weathering properties.

Increasing the filler content in SBS modified asphalt batches (thereby maintaining the same quantity of resin but reducing the total quantity of asphalt in the batch) increases the modifier/asphalt ratio in the finished roofing membrane, and better weathering performance appears likely by increasing filler content and slightly decreasing the modifier content. Too much reduction in the percentage of SBS by weight in the polymer modified asphalt batch may result in unacceptably low elongation properties in the finished membrane. The placement and type of reinforcing mats in the finished polymer modified asphalt membranes apparently have a significant effect on weathering characteristics of the finished roofing membranes. Placement of nonwoven polyester mats closer to the top of SBS modified asphalt membranes appears to minimize crazing of asphalt on the finished membrane surfaces. Nonwoven polyester mats with high elongation characteristics used in typical APP modified asphalt roofing membranes allow cracking and separation of asphalt on the surface of the finished roofing membrane, although placement of the reinforcement at a higher plane in the finished roofing membrane appears to minimize the cracking and separation of the waterproofing bitumen.

Inclusion of nonwoven glass fiber mats near the surface of both SBS and APP polymer modified asphalt roofing membranes improved the weathering performance of the polymer modified asphalt on the surface of the finished membranes. Use of higher percentages of IPP in APP modified asphalt roofing membranes apparently adversely affects the weathering properties of the finished roofing membranes. APP asphalt batches containing approximately 16-20 percent APP, 4-6 percent IPP and approximately 20 percent powdered $CaCO_3$ (limestone) filler produced the best weathering characteristics during this study.

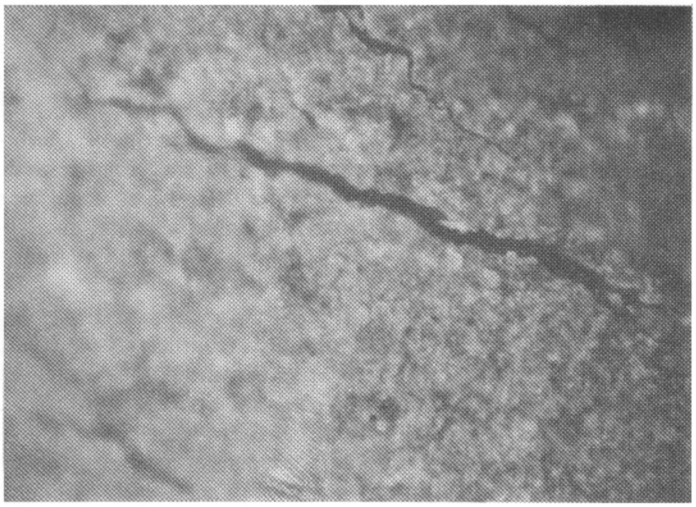

Figure 1 APP mid-reinforced polyester naturally aged, high percent APP and low percent.

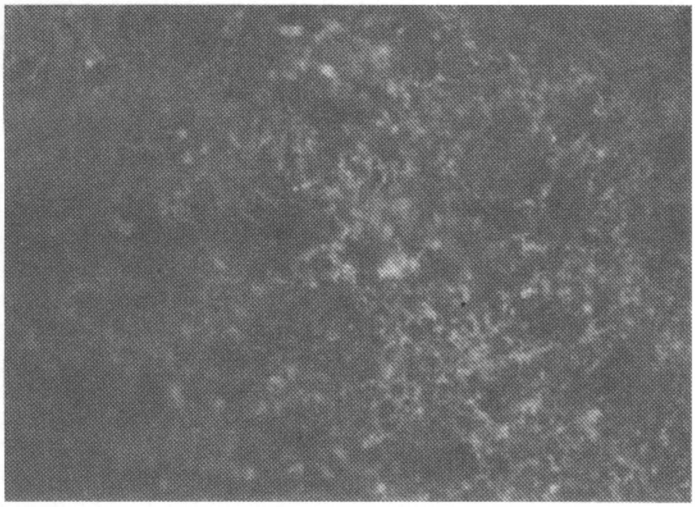

Figure 2 Glass reinforced SBS, naturally aged.

Figure 3 Naturally aged glass reinforced, normal APP mix.

Figure 4 Naturally aged mid-reinforced polyester, "normal mix."

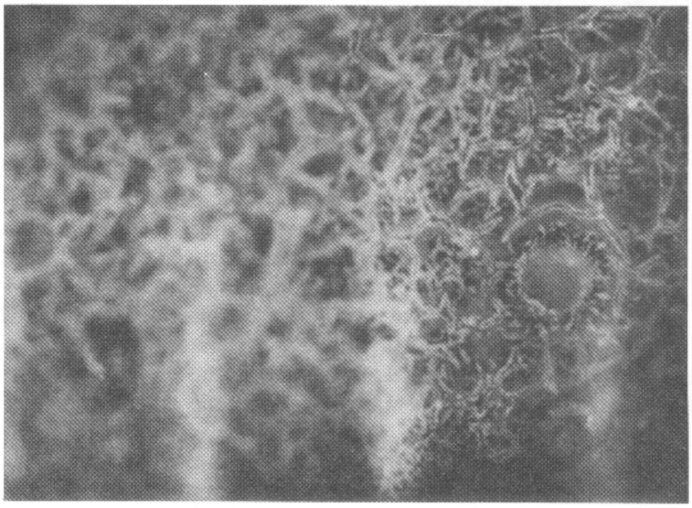

Figure 5 QUV aged glass reinforced APP.

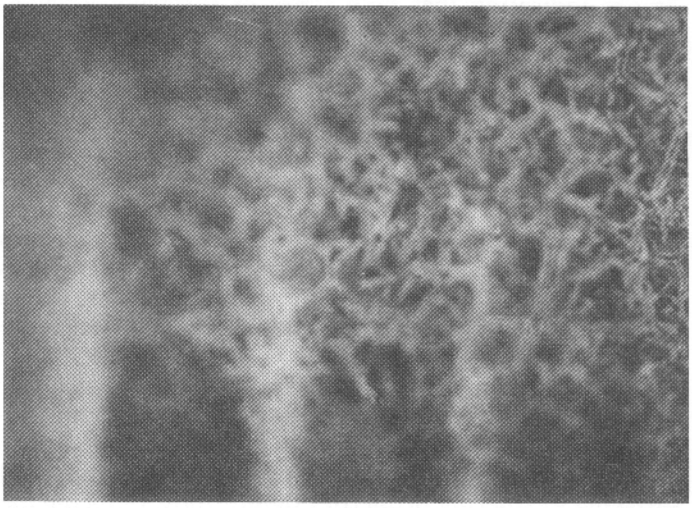

Figure 6 APP glass reinforced QUV aged.

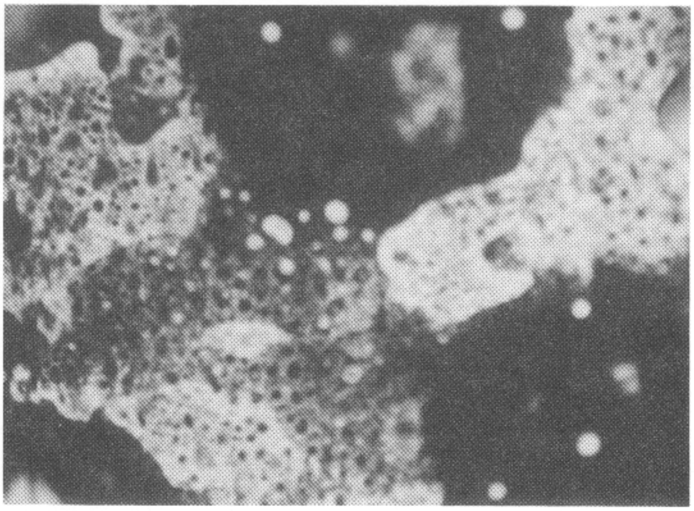

Figure 7 Heat aged APP, mid-reinforced polyester.

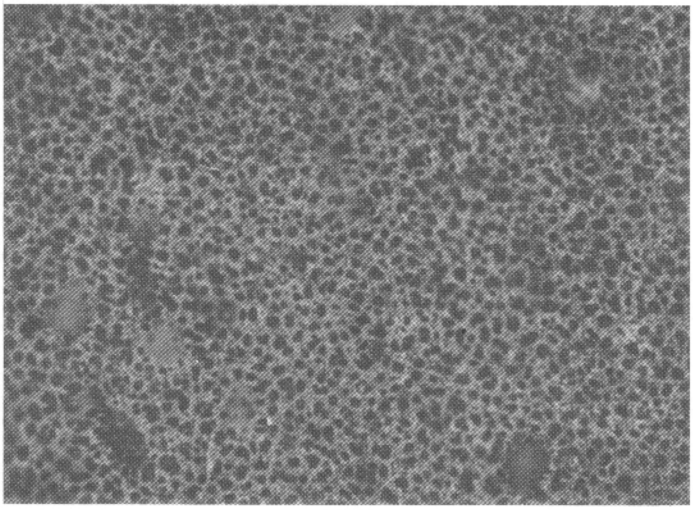

Figure 8 Glass fiber reinforced APP membrane after 10,400 hours QUV exposure.

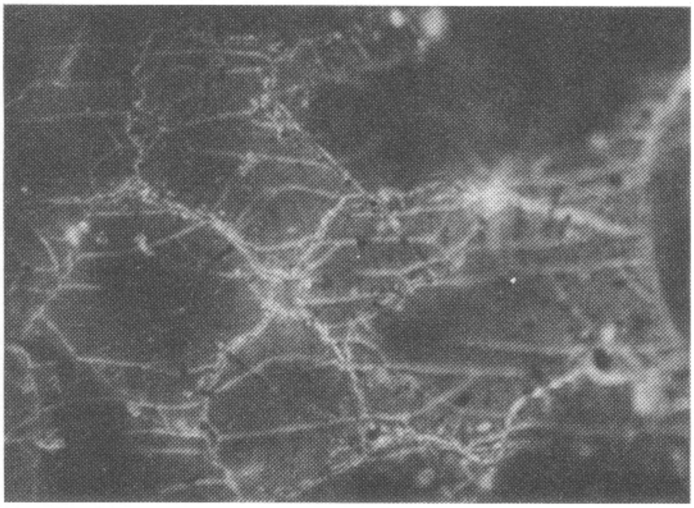

Figure 9 QUV aged, high percent APP and low percent filler, mid-reinforced polyester.

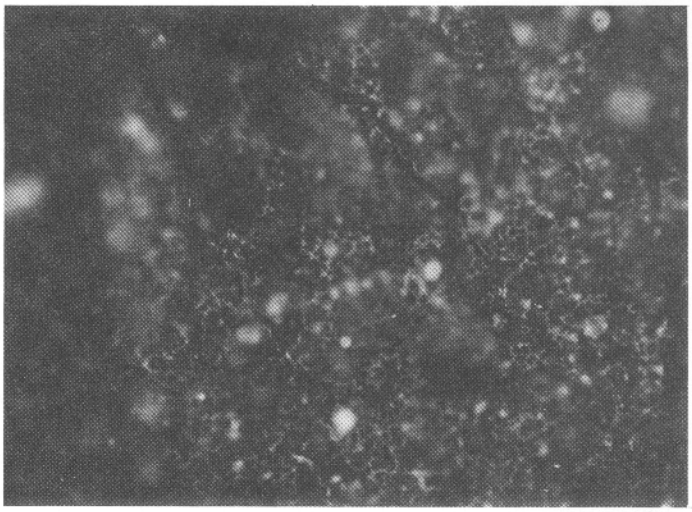

Figure 10 Naturally aged mid-reinforced polyester, high percent IPP mix.

Product Type	%APP	%IPP	%Fill	MD Initial Tensile	%EL	TEA	CMD Initial Tensile	%EL	TEA	MD Heat Aged Tensile	%EL	TEA	CMD Heat Aged Tensile	%EL	TEA
High % APP Low % Filler	20.7	4.8	15.0	114.9	22.1	17.7	51.6	36.41	15.14	107.6	19.91	16.628	54.8	36.14	17.229
Normal APP Normal IPP	17.5	4.6	18.5	127.1	33.78	32.35	81.9	33.96	21.48	106.1	25.66	21.93	83.2	29.12	19.91
High IPP, Less APP	14.3	7.3	20.0	110.4	24.15	18.97	57.8	40	17.61	98.9	19.48	15.192	56.7	35.22	17.37
Normal % APP, High Filler	17.0	4.8	25.0	127.1	33.78	32.35	81.9	33.96	21.49	106.1	25.66	21.93	83.2	29.12	19.928
High Filler Low APP	12.4	6.8	33.5	119.9	24.14	20.43	62.4	35.12	17.25	107.6	20.53	17.20	51.0	23.46	10.56
Normal Mix, Glass Reinforced	18.5	5.0	19.0	191.9	2.56	2.731	167.7	2.42	2.29	222.8	2.82	3.648	158.3	2.49	2.309
Normal Mix, Glass, Stabilizer	18.5	5.0	19.0	186.5	2.15	2.454	159.5	2.12	2.093	211.3	2.68	3.195	156.5	2.39	2.067
SBS, 20% Filler, Slate Gran.	8.6	20.0	71.4	196.7	2.6	2.931	209.3	3.15	3.665	231.6	3.08	4.16	200.1	2.65	3.011
SBS, 20% Filler White Gran.	8.6	20	71.4	186.5	2.51	2.549	227	3.45	4.265	192	2.26	2.45	231.8	3.09	3.928
SBS, 45% Filler	7.4	45.0	47.6	172.3	2.32	2.368	237.8	3.39	4.647	222	2.41	3.236	224.5	2.7	3.59
SBS, 30%F Filler Pet Mat	7.7	30.0	62.3	99.7	24.02	17.2	56.7	48.08	20.33	100.8	23.47	16.862	62.3	48.18	23.747
SBS, 20% Filler Pet Mat	8.6	20.0	71.4	102.3	40.21	29.49	64.8	39.87	18.76	109.7	35.72	29.38	74.1	42.36	23.075

MD — Machine Direction
CMD — Cross Machine Direction
% EL — Percent Elongation
TEA — Tensile Energy Absorption
Polyester — 77°F 2.0 in/min
Glass Fiber — 0°F .08 in/min

Table 1 Weathering study results tensile properties ASTM D 2523.

Reinforcing	% APP	% IPP	% Filler	Cold Flex (°C) Initial	Heat Aged	QUV	Outdoor	Water Absorption (G)	
200 G Polyester	20.7	4.8	15.0	−12	−9	−14	−6	0.59	
200 G Polyester	17.5	4.6	18.5	−13	−10	−12	−10	0.32	
200 G Polyester	14.3	7.3	20.0	−13	−10	−12		0.46	Mid-Reinforced
200 G Polyester	17.0	4.8	25.0	−13	−12	−13	−10	0.21	
200 G Polyester	12.4	6.8	33.5	−12	+25	+25		0.51	
2.5 LB GM & Polyester Scrim	18.5	5.0	19.0	−12	2	2		0.42	Glass Mat to Exposed Surface
2.5 LB GM & Polyester Scrim	18.5	5.0	19.0	−12	25	2		0.38	Mix Contained .05% UV & Heat Stab.
	% SBS	% Fill	%Asph						
FG Laminate	8.6	20.0	71.4	−31	−10	−12	−12	0.63	Slate Granule
FG Laminate	8.6	20	71.4	−30	−18	−12		0.11	White Granule
2.5 LB FG Mat	7.4	45.0	47.6	−29	−16	−17		0.28	Mid-Reinforced
200 G Polyester	7.7	30.0	62.3	−31	−15	−14		0.16	
200 GM Polyester	8.6	20.0	71.4	−27	−13	−14		0.16	

TEST METHODS:

Cold Flex: 180° Bend Over 25mm Mandrel in Less Than 5 Seconds.

Water Absorption and Water Content: NIST BSS167 "Interim Criteria for Polymer Modified Bituminous Membranes"

- Water content did not exceed 0.5% for any sample tested.
- Water absorption range from 0.2% to 0.4% for all products tested.

Heat aging: 80°C for 28 days

QUV = 1 Cycle = 6 hrs. UV Light @ 70°C and 6 hrs. Condensation @ 40°C for Samples Tested

Table 2 Weathering study results.