NATIONAL BUREAU OF STANDARDS REPORT

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A STUDY OF RUBBER-ASPHALT PAVING MATERIALS

by

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Floor, Roof and Wall Coverings Section
Building Technology Division

to

Division of Materials, Engineer Department
District of Columbia

NBS

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REPORT ON A
STUDY OF RUBBER ASPHALT PAVING MATERIALS

1. INTRODUCTION

Considerable interest has developed over the last two decades in the use of rubber additive in asphalt paving materials in order to improve durability as well as short-term performance of the so-called flexible pavement (Public Roads, vol. 28, No. 4, October 1954.) Many types of rubber in various forms and concentrations and using various methods of blending have been used, both in laboratory and in experimental field section studies (ibid). The Division of Materials, Engineer Department of the District of Columbia Government as part of its continuing program for improving District of Columbia roads and streets has sponsored and conducted studies in both of these phases. This report gives the results of the laboratory phase of one such study requested under District of Columbia Laboratory No. 3135-55.

This study was confined to a single type of rubber latex, in emulsion form, as used in one concentration with an asphalt cement, and combined with a closely graded aggregate. In scope, this report is confined to a laboratory study of the properties of the asphalt cement and the effect of the addition of the latex, in the recommended manner and amount, on these properties. In addition, a laboratory evaluation was made to determine the effect of the latex on the properties of a plant-made paving mix using these constituents. A Flexural-Fatigue Endur-

ance Test which, it is our understanding, was developed under sponsorship of the Company furnishing the rubber latex, was used in evaluating the plant-made mixes.

2. MATERIALS

The materials included a latex rubber emulsion, an asphalt cement and a number of modified asphaltic concrete surface paving mixes. All materials are identified below.

2.1 Modified Asphaltic Concrete Surface Paving Mixes:

Mix No.	Marked
1	R-Rubber
1	Controlled
2	R-Rubber
2	Controlled
3	R-Rubber
3	Controlled
4	R-Rubber
4	Controlled
5	R-Rubber
5	Controlled
6	R-Rubber
6	Controlled
7	R-Rubber
7	Controlled
8	R-Rubber
9	Controlled
10	Controlled
11	R-Rubber
11	Controlled
12	R-Rubber
No #	R-Rubber

2.2 Asphalt Cement -- The asphalt cement was contained in three, 16 oz. ointment boxes and was represented as being a product of the American Oil Company of 85/100 penetration grade.

2.3 Latex Rubber Emulsion -- The rubber was contained in two quart bottles and was represented as containing 50% rubber and 50% water. The type of rubber was not given.

3. TEST METHODS

3.1 Flexural-Fatigue Endurance Tests

Three mixes of each type (Control and Rubberized) were used for the tests. Selection was random but the mixes chosen were paired as to type. For instance, control mix no. 1 and Rubberized mix no. 1 were paired and specimens were prepared on the same day. Flexural-Fatigue Endurance was also determined on the same day for each pair.

Three specimens from each mix were made and tested for Flexural-Fatigue Endurance in accordance with the procedure described in the method submitted with the samples, except that the preparation required reheating. Reheating was done in accordance with A.S.T.M. Designation D1074-52 T, Sect. 5 (a). In all, 18 specimens were used.

For purposes of comparison, four specimens of a sheet asphalt surface mix (D.C. No. 2990-55) were also prepared and tested in the manner described.

In order to study the effect of compacting load, additional tests were made on each type for a fourth mix (No. 11). For

these tests, compacting loads of 4,000 and 8,000 pounds were used (Note: in the regular series the compacting load was 6,000 pounds.)

Bulk density determinations were made at 25°C after the Flexural-Fatigue Endurance Tests, using the following equation:

$$\text{Bulk Density} = \frac{\text{wt. in grams}}{\text{volume}}$$

Volume was determined by calculation from the dimensions of the specimen as measured by micrometer. The weight-in air, weight-in water method for determining volume proved impractical because of the porosity of the specimens.

Oxygen determinations were made in order to measure the degree of oxidation of the bitumen. These were made on a micro-scale on the mineral-free benzene-extracted bitumens from the mixes, and on the original asphalt cement, by the modified Unterzaucher procedure (Anal. Chem. vol. 23, p. 1408, 1951.)

Asphalt content and sieve analysis of the separated aggregate were determined on two of the control-type specimens after Flexural Fatigue Endurance Test, using carbon tetrachloride and standard procedures.

3.2 Tests on Bitumens

A series of conventional tests was made on the unblended asphalt cement, heat-treated unblended asphalt cement, and two blends of the asphalt cement and rubber latex in the proportion of 95 parts of asphalt cement to 10 parts of rubber emulsion.

The asphalt cement (394 g) was placed in a quart can and, under constant stirring, carefully brought to a temperature of 190°F in an oil bath. Thirty one grams of the latex emulsion were added, the temperature of the oil bath was gradually raised until all the water was driven off and the temperature of the blend reached 300°F. Vigorous stirring was applied mechanically throughout the blending process.

Blend A was made in accordance with the procedure just outlined and required 3 hours for completion. Blend B was prepared in the same way except that, in an effort to reduce the time for completion, a pint can was used. Some of the mixture foamed over while adding the latex in blend B and an estimated 10% of the emulsion was lost thereby.

For purposes of comparison, a heat treatment was given to a 390 gram sample of the asphalt cement in a manner identical to blend A except, of course, that no latex was added.

In addition to the conventional tests, a number of other tests were performed on the four bitumens mentioned. These included ordinary penetration tests (100 g load, 5 sec.) at different temperatures, and successive penetrations at 77°F using 100 g load.

The log of ordinary penetration (100 g, 5 sec.) was plotted against temperature in order to obtain a measure of the temperature susceptibility of the bitumens (Public Roads, vol. 27, No. 1, March 1940.) Such plots gave practically straight lines through the points at 50°F, 77°F, and 95°F. Susceptibility

indices were calculated from the following:

$$S.I. = \frac{\log \text{pen. at } 95^\circ F - \log \text{pen. at } 77^\circ F}{18}$$

Successive penetrations, at 77°F using 100 grams load, were made increments of 5 sec. penetration time with 5 sec. allowed between increments to allow for readings to be made and to allow partial recovery of non-permanent deformation to occur. Three 5 sec. increments of penetration time were used in this series, for a total of 15 sec. penetration time. Finally, penetrations were obtained, also at 77°F and 100 g load, using a 15 second un-interrupted penetration time. For convenience this latter is called: Individual Penetration. These special penetration tests (Successive and Individual) were made to determine whether the bitumens showed elastic properties.

4. RESULTS

The results are given in tables 1 to 3 inclusive.

Table 1. Results of Flexural-Fatigue Endurance Tests

		Type Mix					
		Control			Rubberized		
Mix No.	Specimen	Flexural Units 4/	Bulk Density g./ml.	Thickness .001 in. 3/	Flexural Units 4/	Bulk Density g./ml.	Thickness .001 in. 3/
1	a	2497 1/	1.80	1.71 1/	1935	1.91	1.61
	b	1114	1.97	1.57	843	1.93	1.61
	c	1944	----	----	1534	----	----
	Average	1852	----	----	1461	----	----
5	a	1865	----	----	1306	----	----
	b	1731	1.94	1.56	1005	1.90	1.62
	c	3899	1.94	1.59	1583	1.76	1.74
	Average	2498	----	----	1298	----	----
7 7/	a	992	----	----	2391	1.94	1.59
	b	1762	1.98	1.56	577	----	----
	c	927	1.96	1.57	1268	1.95	1.58
	Average	1227	----	----	1412	----	----
TOTALS	Average	1858	----	----	1382	----	----
	Standard Deviation	870	----	----	520	----	----
SAS 2/	a	1975	1.91	1.62			
	b	1963	1.92	1.62			
	c	2035	1.86	1.63			
	d	1985	1.89	1.62			
	Average	1990	----	----			
	Standard Deviation	25	----	----			
11	a 5/	2167	2.03	1.52	867	1.95	1.58
	b 6/	2999	1.99	1.59	2002	1.93	1.60
	c 5/	----	----	----	1405	1.96	1.58

See next page for footnotes

1/ Specimen not fully compressed due to hold-up of cover plate and compacting bar on one edge of mold.

2/ S.A.S. Sheet Asphalt Surface Mix, D. C. Lab. No. 2990-55.

3/ At plane of fracture.

4/ Flexural Units required to attain complete severance of specimen.

5/ 8,000 lb. compaction load used.

6/ 4,000 lb. compaction load used.

7/ Oxygen content of bitumens:

Original untreated asphalt cement	0.59 %
No. 7 Control mix before reheating	0.93 %
No. 7 Rubber mix before reheating	0.86 %
No. 7 Control mix specimen c after Flexural Fatigue Test	1.09 %
No. 7 Rubber mix specimen a after Flexural Fatigue Test	0.98 %

Table 2. Results of Analysis of Bar Specimens

Bar Speciman No.	5 CC	7 CC
Flexural-Fatigue Endurance, Flex Units for Failure	3899	927
Bitumen, %	7.2	7.1
Sieve analysis of aggregate 1/		
% Passing		
3/8"	100	100
No. 4	100	100
No. 10	84	84
No. 20	59	58
No. 30	46	46
No. 40	33	33
No. 50	22	21
No. 80	14	14
No. 200	11	11

1/ Bitumen extracted before sieve analysis, i.e. bitumen-free aggregate.

Table 3. Tests on Asphalt Cement and Asphalt Cement-Rubber Blends

Material	Unblended A.C.	Unblended A.C.	Blend A	Blend B
Heat Treatment:				
Temp., °F	300	200-300	190-300	205-300
Time, Hrs.	0	3	3	2
Penetration, 100 g 5 sec.:				
at 32°F,	5	5	5.5	6.5
at 50°F,	17	14	12	17
at 77°F,	80	62	49	61
at 95°F,	207	155	99	125
Susceptibility Index	0.0229	0.0221	0.0170	0.0173
Successive Pen. 100g, 77°F:				
5 sec.	80	62	49	61
10 sec.	109	83	63	79
15 sec.	130	99	74	91
Individual Penetration, 77°F, 100g. 15 sec.	125	93	68	85
Softening Point, °F	118	124	155	154
Ductility at 77°F, cm	150+	150+	61.2	54.0
Vol. Loss at 325°F for 5 hrs., %	0.03	0.02	L0.01	0.02
Tests on Residue:				
Pen. at 77°F, 100g. 5 sec.	67	57	47	56
Softening Point, °F	120	126	165	163
Ductility at 77°F, cm	150+	150+	70.8	82.5

5. DISCUSSION OF RESULTS

5.1 Flexural-Fatigue Endurance Tests

On the average, about 475 more Flexural Units were required to cause complete fracture in the control mixes than in the rubberized mixes. However, the Standard Deviations (820 for the control mixes and 520 for the rubberized mixes) show a wide scattering in the results among individual specimens for each type. They also show considerable over-lapping between types and, when compared to the difference in averages, greater differences among individual specimens of each type than between the averages for the two types. It appears that, as presently constituted, the Flexural-Fatigue Endurance Test is of little value in differentiating between the two types of mixes tested.

Several factors that might possibly have contributed to the results are considered below.

1. Sampling. If the samples submitted were not homogeneous, variable results could be expected. However, previous long experience indicates that heterogeneity rarely occurs in this type of mix. Indeed, comparison of the analyses of the two bar specimens reported in Table 2 confirms this and indicates excellent homogeneity and plant control. When one compares the closeness of the analytical results on the two specimens with the very wide difference in their Flexural-Fatigue Endurance, as determined, one is forced to reject simple heterogeneity as a causative factor and seek elsewhere for significant factors.

2. Preparation of Test Specimens. In the only procedure available under the circumstances, the mix had to be reheated in order to mold the specimens. But in considering reheating as a factor it should be recalled that ASTM Method D1074 permits it. Also, the tests on D. C. No. 2990-55 (Sheet Asphalt Surface) gave excellent reproduc ibility, despite reheating.

In preparing specimens, the recommended compaction load (6,000 lbs.) was used. This may be a legimate factor for consideration since the procedure originally was developed for a different mix. The results reported under Mix No. 11, where different compacting loads were used, indicate, however, that mere variation of the load would be ineffectual in improving reproduc ibility.

3. Type of mix. The type of mix used in the tests contained an appreciable proportion of somewhat coarse and plate-like aggregate particles. It was observed that during the test fracture appeared to develop around a coarse, elongated particle and progressively continue, in serpentine fashion, around adjacent particles to complete failure. When one considers the close reproduc ibility obtained with the Sheet Asphalt Surface Mix (D.C. No. 2990-55) which contains aggregate that is essentially spherical, this factor is a valid one since orientation of aggregate particles in the latter is not a factor.

4. Bulk Density. Bulk density measurements showed no significant correlation with Flexural-Fatigue Endurance. It is true that if the data are broken down and comparisons made

between specimens of the same sample (e.g. between specimens b & c of Control mix 5 or between specimens b & c of Rubberized mix 5 etc.) a trend in favor of the lower bulk density (thicker, less dense) specimens would be indicated. In other words it might be claimed that Flexural Fatigue Endurance was inversely proportional to bulk density. However, the wide scattering between individual specimens of the same samples and the results obtained with the Sheet Asphalt Surface Mix (D.C. No. 2990-55), where the thinner but denser specimens showed greater endurance, compel one to conclude that such a claim is unwarranted.

5. Oxidation. The oxygen determinations showed that oxidation had occurred. They also indicate that approximately 3/4 of the reaction took place during plant mixing, before the mixes were reheated, and that both types were at similar stages of oxidation when the Flexural-Fatigue Endurance Tests were made. It appears, therefore, that oxidation was not a significant factor in the tests.

5.2 Tests on Bitumens

In general, the results show that the addition of the rubber latex, in the manner described, affected the characteristics of the asphalt cement. They also show that, as expected, heat treatment without addition of latex also affected these characteristics, although to a lesser extent. It may be said therefore, that the changes occurring in making the blends were brought about by the addition of the latex and to a lesser extent by the heat treatment required to effect the blend.

Both the additions of rubber and the simple heat treatment increased the consistency (as measured by penetration) at 50°F, 77°F, and 95°F, and the softening point while decreasing the ductility and the susceptibility to temperature of the original asphalt cement. In general, the changes in consistency (penetration) Susceptibility Index and in softening point are considered desirable while the change in ductility is considered undesirable. In regard to the change in susceptibility index, it should be noted that all are within the range of values for paving asphalts as reported in the literature (Public Roads, vol. 21, No. 1 and vol. 19, No. 11).

Comparison between successive penetration and individual penetration for 15 seconds indicates that all four bitumens have elastic properties (D. Mack Journal of the Society for Chemical Industry, Transactions, vol. 58, 1939, p. 306). For a purely viscous bitumen both penetrations would be the same. A quantitative approximation on this basis would indicate elastic qualities to be most pronounced in Blend A, followed in descending order by Blend B, the heated Treated Asphalt Cement, with the original, untreated asphalt cement possessing the least.

As stated previously, the results of the tests on the bitumens show definite differences in physical characteristics among them, however, final judgment should not be made until correlation with other tests, especially the experimental field section tests, are made. The results of the latter will probably not be known for some time. Even when these results are

available, equating the characteristics of the blends as accomplished in the laboratory with those of the rubber-asphalt blend as it exists in the plant-made mix is not entirely valid. This is due to the fact that mixing and blending are accomplished over a period of hours in the laboratory, and in a matter of minutes (approx. 2 minutes) in the plant. The 2-3 hour blending process insures a better dispersion of the rubber in the asphalt cement.

6. CONCLUSIONS

1. The addition of rubber latex to the asphalt cement, in the amount and manner described, increased its consistency (as measured by penetration) at 50°F, 77°F, and 95°F, its softening point, and its elastic qualities, while at the same time decreasing its ductility, susceptibility, and consistency (as measured by penetration) at 32°F.

2. The three-hour heat treatment of the asphalt cement effected similar changes but to a lesser degree, except for ductility, and consistency at 32°F. No effect was detected in the latter two characteristics.

3. The Flexural_Fatigue Endurance Test, as constituted, did not give a reliable differentiation between the two types of Modified Asphaltic Concrete Surface Plant Mixes(control vs rubberized) tested.

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