FIELD EXPERIMENTS WITH POWDERED RUBBER IN BITUMINOUS ROAD CONSTRUCTION

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SYNOPSIS

Information concerning foreign experiments with rubber in bituminous road surfaces indicates that such combinations may have merit. It is claimed that the addition of small percentages of rubber results in a more durable mixture - one that is less susceptible to temperature change, thereby having less tendency to bleed or shove at high temperatures or to crack at low temperatures. Resistance to skidding is also said to be improved.

This report describes three field experiments with powdered rubber built during the summer of 1949 by the Virginia Department of Highways on Route 250 west of Richmond. In Section 1 powdered natural rubber was incorporated in the bituminous concrete sand asphalt wearing surface. Section 2 was a similar surface to which reclaimed powdered rubber was added. The third section was a seal treatment with cut-back asphalt (RC-2) to which natural powdered rubber was added and mixed in the distributor prior to application. Identical sections (1-C, 2-C, and 3-C) without rubber were constructed adjacent to the experimental ones for purposes of comparison. Sections 1 and 1-C were constructed in May, 1949 and the remaining ones in September, 1949.

Complete records were secured at the time of construction concerning materials, quantities, procedures, temperatures, workability, etc. Follow-up studies since construction included visual observations, road roughness measurements, and skid tests. Since Section 1 and 1-C were constructed earlier, more data are available on their performance, particularly as related to skid resistance.

At this time little, if any, difference can be noted between comparable sections with and without rubber. Road roughness measurements made on Sections 1 and 1-C shortly after construction indicated no significant differences between the two sections that could be attributed to the use of rubber. In both sections, however, the outside lanes which carry the majority of traffic were considerably rougher than the inside or passing lane.

Two series of skid tests have been conducted on Sections 1 and 1-C - one immediately after construction (May, 1949), and the other six months later (November, 1949). Only one test series has been performed on the remaining sections. These were made in November, 1949.

Resistance of the surface to skidding was determined by the stopping distance method. All surfaces including the control sections were found to have satisfactory resistance to skidding, both in a dry and in a wet condition. Stopping distances on Section 2, containing reclaimed rubber, were practically identical with those on the control section (2-C). The seal treatment (Section 3), including natural powdered rubber, indicated a slight beneficial effect since the stopping distance on the wet surfaces at 40 mph. was about 3 ft. shorter than on Section 3-C. It is possible that slight surface texture variations may at least partially account for the difference. Additional tests at later dates will have to be made for further evaluations.

Skid results on the older sections (1 and 1-C) in a wet condition appear to be more significant. Results are summarized below:

STOPPING DISTANCE (FT.)

Speed (mph.)	10	20	30	40
IMMEDIATELY AFTER CONSTRUCTION				
Section 1-C, *Plain*	4.9	21.3	49.9	93.7
Section 1, *with natural rubber*	5.1	21.1	49.1	87.9
Difference	-0.2	0.2	0.8	5.8
SIX MONTHS AFTER CONSTRUCTION				
Section 1-C, *Plain*	6.0	25.5	57.0	101.2
Section 1, *with natural rubber*	5.1	22.6	49.2	87.5
Difference	-0.9	2.9	7.8	13.7

From the data it appears that the incorporation of natural rubber in the bituminous concrete (F-1 sand asphalt) resulted in a slight difference in stopping distance at the time of construction, particularly at higher speeds. After six months, greater differences in stopping distances on wet pavements were found between the section containing natural rubber and the one without it. On the rubber section (1), stopping distances for the two test series were practically identical; however, on the plain section (1-C) they had increased considerably during the six-month period.

While conclusions cannot be drawn at this early date regarding improvement in durability characteristics, small percentages of natural rubber may be beneficial in minimizing the change in resistance to skidding to bituminous plant mix sand asphalt surfaces when wet. In order for such mixtures to be generally accepted they must not only show improved performance but also prove economical to the user.

REVIEW OF PREVIOUS WORK

Experiments with rubber-asphalt mixtures have been conducted for several years in other countries, principally by the Dutch in Holland and the East Indies. The first published report of results of a systematic investigation into the changes produced by the addition of rubber to asphalt was published by Van Heurn and Begheyn (*1*)[1] in 1934. In 1931 Fol and Bijl (*2*) reported some experiments conducted for the Technical Department of the International Rubber Association. This work was continued in 1933, by Plazier (*3*) who used unvulcanized powdered rubber instead of latex rubber solutions or vulcanized rubber (such as ground automobile tires) which were used in most of the earlier investigations. Mixtures with varying percentages of rubber were made by stirring the required amount of rubber powder into the melted bitumen and heating for one hour to about 150 deg. C. It was found that the addition of a small amount of rubber made the asphalt less susceptible to temperature changes and therefore less likely to bleed in summer or crack in winter.

Several methods of constructing rubber asphalt pavements were employed in these experimental projects. A premixed material was used in a light surface course at the rate of 10 to 13 lb. per sq. yd. Seal treatments consisted of applying the rubber-asphalt mixture on the surface, covering with aggregate and rolling lightly. Other surfaces constructed were asphaltic concrete carpets containing rubber powder throughout their entire thickness.

Dr. F. T. Bokma (*4*) reviews the status of experimental work in his paper "Rubber in the Construction of Roads". He states that between the years 1935 - 1940, some 30 test areas were constructed by the Rubber Foundation in collaboration with government institutions. Of these areas, many in both Holland and the East Indies were destroyed as a result of inundation or fighting during the recent war. However, of the remaining areas, the rubber-asphalt section performed much better than the control section with a life of 8 to 10 yr. where only a thin surface dressing was used over coarse asphaltic concrete. Where rubber was used throughout the entire thickness of asphaltic concrete mixtures there was very little difference between these sections and the controls, so that a period longer than 10 yr. is necessary to determine the effects of adding rubber-powder. Dr. Bokma also found that the use of small percentages of rubber in asphaltic mixtures increased the skid resistance of the surface and reduced maintenance costs.

Rubber has been used in the United States in rubber-asphalt compounds for sealing joints in concrete pavement for several years. However, to the writers' knowledge, it was not used in surface courses until the summer of 1948 when the city of Akron, Ohio (*5*) constructed a street using a mixture of powdered synthetic rubber with the

[1]Italicized figures in parentheses refer to list of references at the end of the paper.

asphalt. In this work the asphalt was heated to approximately 300 deg. F. and the rubber powder slowly sifted in with agitation and mixed for two hours. Rubber was added in the amount of 5 and 7.5 percent by weight of the asphalt. A bituminous concrete surface was constructed using a 1-1/2-in. binder course over which was placed a 1-1/2 in. surface course containing rubber. This plant-mixed surface course is much thicker than was used in most of the Dutch experiments and a longer period may be required to evaluate it.

specific gravity and flow. These tests indicated that blending temperatures were critical and that best results were obtained at a temperature range of from 170 to 190 deg. C. (340 to 375 deg. F.). At lower temperatures uniform results were not secured and at higher temperatures decomposition of the rubber was noted For mixes blended (from 0 to 15 percent rubber) within this temperature range the penetration, ductility and flow decreased and the softening point increased with increasing amounts of rubber The addition of rubber powder

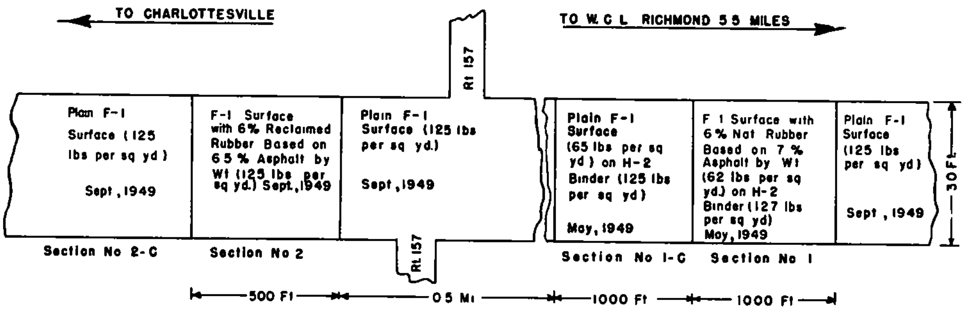

Figure 1. Field Experiments with Rubber in Bituminous Plant Mix, Route 250, Henrico County

Theories have been advanced regarding what actually happens when powdered rubber is incorporated with asphalt. It is reported that a study of photomicrographs indicates that homogenous solutions do not result, since particles of rubber can be distinctly seen in the mixture. Some investigators speculate that the lighter oily constitutents of the asphalt are slowly absorbed by the rubber, causing it to swell, and that this process can be hastened by heating The writers have no data on this subject; however, prior to the initiation of the field experiments some exploratory tests were conducted in the laboratory by the Division of Tests (6) to determine if various percentages of natural rubber powder affected standard test results of asphalts. Accordingly, various percentages of rubber were mixed with 85-100 and 200-300 penetration grade asphalts (AP-3 and AP-00, Va. Spec.) and tested for penetration, softening point, ductility,

to the two grades produced parallel results which indicate that comparable effects could be expected with intermediate grade asphalts

CONSTRUCTION OF FIELD SECTIONS

Originally it was proposed to construct experimental sections containing natural, synthetic and reclaimed rubber; however, since synthetic rubber was not available, only natural and reclaimed rubber were used. Most foreign experiments were reported to have been constructed by hand methods It was believed that if these experiments were to be of maximum value they should be built by machine methods. It was, therefore, decided to construct a section 1,000 ft. in length using a binder course and a bituminous concrete (F-1 sand asphalt) wearing surface, in which a small percentage of powdered natural rubber had been incorporated at the plant. Otherwise, this bituminous concrete was to be designed and constructed in accordance with our standard procedures. Adjacent to this section was constructed a control section identical in every respect except that no rubber was added These sections are identified in Figure 1 as 1 (experimental) and 1-C (control). Section 2, in which reclaimed rubber was incorporated and 2-C, without rubber, were constructed later in the season as part of a large project (Fig. 1).

Realizing that several years might be necessary before any decided differences in performance might be apparent between the sections containing rubber and the control sections, it was decided to try the natural rubber in a seal treatment. The life of such surfaces is much less than that of the bituminous concrete and such treatments are usually rather critical as to weather conditions and control of quantities. Often seal treatments bleed excessively. The location of this (Section 3) and the control (Section 3-C) is shown in Figure 2. Design and construction details follow for each of the three experiments.

Sections 1 and 1-C - Sections 1 and 1-C constructed of Type F-1 sand asphalt are located on US Route 250 about 5 5 mi. west of Richmond, Virginia. The road is 30 ft. in width with a macadam base and old plant-mix surface. The average 24-hr traffic volume for the year ending June 30, 1949 was 3,135 vehicles, 768 of which were trucks and buses.

The aggregate (3/8-in. max. size) selected for this section was a 50-50 mixture of natural sand and granite screenings. The percentage of asphalt (85-100 pen grade) required was determined by the surface area method and checked by density and stability tests. It was found that 7 percent asphalt gave a satisfactory mix Based on the grading of the aggregates and the above tests, Dr. F. T Bokma, who furnished technical advice on the use of rubber, recommended a rubber content of 6 percent by weight of asphalt, or 0. 42 percent by weight of the total mix. This rubber powder was predominately between the 20 and 80 mesh sieves. Only 2. 3 percent was retained on the No. 20 and 4. 9 percent passed the No. 80 sieve. The mix was set for 7. 0 percent asphalt, 0. 42 percent powdered rubber and 92. 58 percent aggregate.

The mix was produced in a "Simplicity" plant of the stationary pug mill type Rubber powder for each batch was weighed and placed in a bag from which it was dumped into the pug mill along with the dry aggregate which had been heated to 300 to 325 deg. F. After mixing the aggregate and rubber for 15 sec., the asphalt (heated to 215 deg. F.)

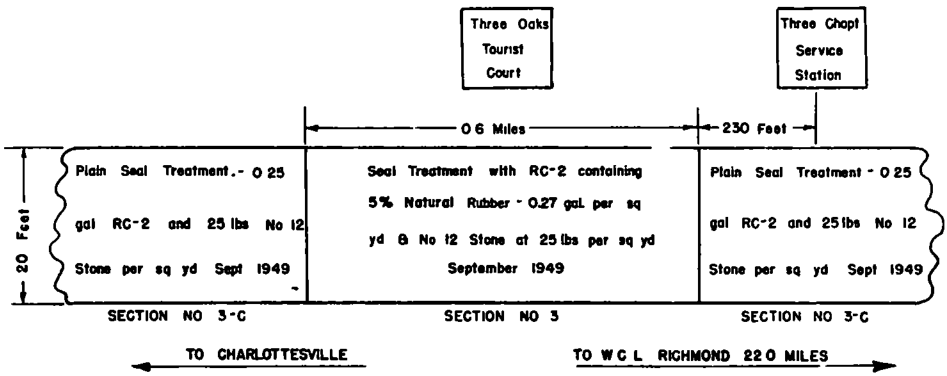

Figure 2. Field Experiments with Rubber in Bituminous Seal Treatment, Route 250, Goochland County

was added and mixing continued for an additional 45 sec. It was attempted to produce the mixture with a temperature of 260 deg. F., but due to break down of equipment and delays there was considerable variation.

The existing surface was cleaned and a tack coat of AP-3 asphalt (85-100 penetration) was applied at the rate of 0.065 gal. per sq. yd. This was followed by a bituminous concrete binder course (H-2) applied at 127.5 lb. per sq. yd (Fig. 3). As soon as the binder course was completed in each lane of Section 1 it was covered immediately with the bituminous concrete (F-1, sand asphalt) wearing surface containing rubber (Fig. 4). An attempt was made to lay the wearing course as thin as possible. Average amounts were 62.5 and 65.5 lb. per sq. yd. for Sections 1 and 1-C, respectively. Both courses

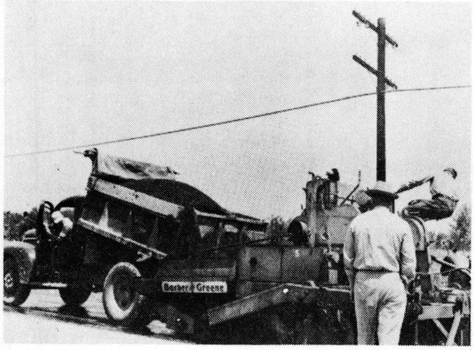

Figure 3. Laying H-2 Binder Course with Barber-Greene Paver Prior to Placing Type F-1 Rubber-Asphalt Surface - Note asphalt tack coat on pavement ahead of paver.

were placed with a Barber-Greene paver and rolled with 7 - and 12-ton tandem rollers.

Sections 2 and 2-C - Section 2, 500 ft. in length, was constructed of Type F-1 sand asphalt containing reclaimed rubber. It is located about 0.5 mi. west of Section 1. The old pavement was also a macadam road which had an old plant-mix surface. For the year ending June 30, 1949 it carried an average 24-hr. traffic volume of 2,919 vehicles, 746 of which were trucks and buses.

On this project, the aggregate (3/8-in. max. size) was a mixture of 2/3 natural sand and 1/3 crushed gravel. As the rubber-asphalt section was only a small part of a large project, the mix had been designed and a considerable amount of material placed before the section containing rubber was constructed. An asphalt (AP-3) content of 6.5 percent had been found to be the most desirable for the aggregates being used. Since the grading of this aggregate was about the same as the aggregate used in Section 1, a rubber content of 6 percent by weight of asphalt was used. The reclaimed rubber was much coarser than the natural rubber. It was predominately between the 10 and 40 mesh sieves. Only 0.2 percent was retained on the No. 10 and 6.0 percent passed

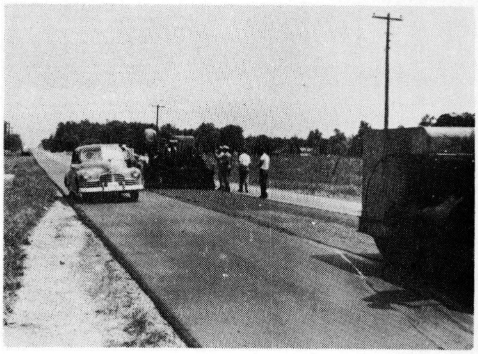

Figure 4. Placing Type F-1 Surface Containing Natural Rubber with Barber-Greene Paver - Note slight ''pulling'' of uncompacted surface. Picture shows completed westbound lane and eastbound lane where binder course has not been applied.

the No. 40 sieve.

This mix was also produced in a "Simplicity" plant of the stationary pug mill type. Rubber was weighed, added to the hot dry aggregate and mixed as described for Section 1. However, in order to produce the mix with a temperature of 275 to 285 deg. F. the asphalt was heated to about 270 deg. F.

After the surface of the road was

cleaned, a tack coat of 0.059 gal. per sq yd. of AP-3 was applied. Since no binder course was used on this project the F-1 mixture containing reclaimed rubber was placed on the tack coat at the rate of 124.7 lb. per sq. yd. The regular F-1 surface course (without rubber) on either end of the section containing rubber was designated as Section 2-C (control section). These mixtures were placed with an Adnun paver (Fig. 5) and rolled with 8-and 10-ton tandem rollers.

the operation required considerable time so that progress of the work was retarded.

When the rubber was uniformly mixed with the asphalt, it was applied on the road at the rate of 0.27 gal. per sq. yd. (Fig. 7) and covered with about 25 lb. per sq. yd. of No. 12 crushed stone (3/8-in. -No. 8). The stone was then rolled with a 7-1/2-ton tandem roller followed by a rubber-tired roller. When rolling was completed the treatment was allowed to cure for a minimum of 1-1/2 hr. before it was opened to traffic. Again, this section was a part of a large project and the regular surface without rubber was used for a control section (3-C).

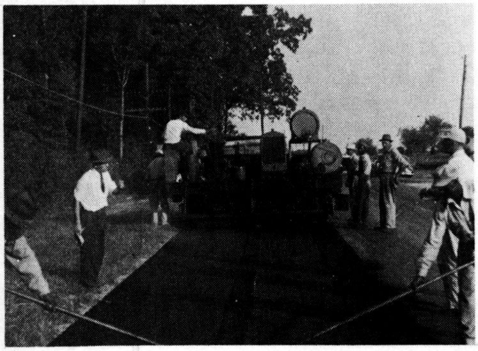

Figure 5. Placing Type F-1 Surface Containing Reclaimed Rubber with Adnun Paver - Note absence of "pulling" in uncompacted material.

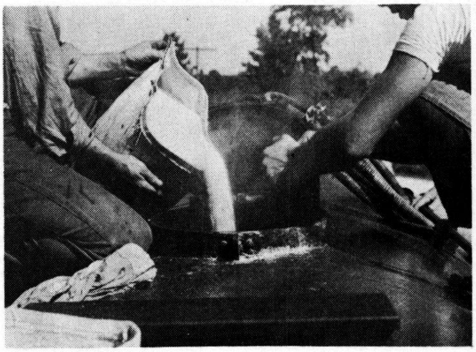

Figure 6. Mixing Powdered Natural Rubber with Asphalt (RC-2) in Distributor - The rubber was added slowly, stirred with a paddle and agitated by the distributor.

Sections 3 and 3-C - Section 3 which is 0.6 mi. in length is on US Route 250, about 22 mi. west of Richmond. It consists of a seal treatment of cut-back asphalt (RC-2) containing natural rubber and No. 12 stone chips placed on a 20-ft. macadam road that had an old broom-drag surface treatment. The average 24-hr. traffic volume for the year ending June 30, 1949 was 1,500 vehicles, 423 of which were trucks and buses.

Approximately 600 gal. of cut-back asphalt (RC-2) was placed in a 1,000 gal. distributor and heated to 180 deg. F. Powdered natural rubber in the amount of 5 percent by weight was slowly added and agitated (Fig. 6) until thoroughly mixed. Two mixings of powdered rubber and cut-back asphalt were necessary for each lane. While the rubber mixed with the asphalt readily,

OBSERVATIONS AND RECORDS DURING CONSTRUCTION

During the construction, the temperature and workability of the various F-1 mixes were carefully observed and recorded. Temperature of the material was taken at the plant when it was being weighed and again on the road when the material was placed in the paver. There was considerable variation in temperatures between different loads of material and between different batches in the same load. This variation was attributed to failure of equipment, or other delays which caused the aggregate to remain in the drier for a longer period than usual, and in some cases to aggregate being put through the drier too rapidly. Some temperatures at the plant were probably low due to removal of the thermometer from the mix before max. temperature had been recorded.

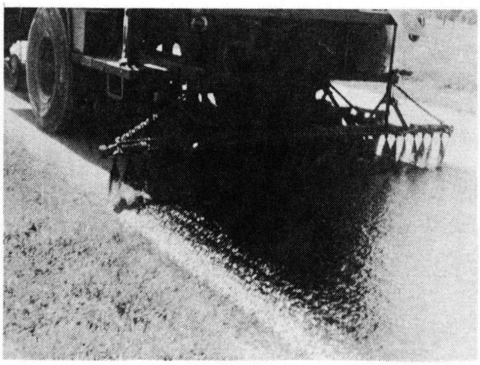

Figure 7. Applying Mixture of Powdered Natural Rubber and Asphalt (RC-2) with Powder Distributor - Note that no difficulty was experienced with clogging of the nozzles.

On Sections 1 and 1-C temperatures recorded at the plant averaged 250 deg. F. and on the road 248 deg. F. The average recorded from Sections 2 and 2-C were 272 deg. F. at the plant, and 276 deg. F. at the paver.

The type F-1 mix containing natural rubber was placed very readily with the Barber-Greene paver. It was found, however, that in order to prevent "pulling", the machine had to be operated slower (8 ft. per min.) with rubber than without (12 ft. per min.). An attempt was made to place the rubber-asphalt mixture at the rate of 50 lb. per sq. yd. instead of the 62.5 lb. obtained. It is believed that with a smoother binder, trained operators, and a machine in good adjustment it would be feasible to place this material at rates as low as 50 lb. per sq. yd.

With the type F-1 mix containing reclaimed rubber, no difficulty was encountered in placing the material with the Adnun paver. There was very little "pulling" in evidence with the reclaimed rubber. Immediately after rolling, particles of rubber were visible above the compacted surface; however, most of these particles appeared to be whipped off under traffic.

The rollers worked equally well on both materials. Good compaction was obtained with little or no pushing in front of the roller. There was no delay in rolling the sections containing rubber and while the surface was new it appeared to scar less under traffic than the surface without rubber.

On Section 3, where natural rubber was mixed with (RC-2) in the distributor, it was necessary to add the rubber slowly, stir with a paddle and agitate the asphalt with the distributor. When it was thoroughly stirred the rubber mixed readily with the asphalt. The volume of the asphalt was increased about 10 percent by the addition of 5 percent of rubber by weight.

The power distributor applied the rubber-asphalt mixture without difficulty. Even distribution of the material on the road was obtained with no clogging of the nozzles that could be attributed to the presence of the rubber.

Many photographs were taken during the construction of each section. In addition, moving pictures were made during construction and while performing skid-resistance tests on Section 1. These pictures show many construction details that will be of value in future studies.

FOLLOW-UP STUDIES

Since construction, follow-up studies of the experiments have included visual observations, road roughness measurements, and skid tests.

Visual Observations - Visual inspections of each section are made frequently, but to date, there has been no noticeable difference in appearance between the sections containing rubber and their respective control sections, except as previously described for Section 2 and 2-C. These inspections will be continued and complete performance surveys made when pronounced differences are apparent.

Road-Roughness Tests - Road-roughness measurements were made on Sections 1 and 1-C in June 1949, with the single-wheel type of road roughness indicator designed by the Bureau of Public Roads (7). The section containing natural

Figure 8. Skid Tests on Sand Asphalt Surface - Note mark on pavement and dust from chalk bullet fired by detonator as wheels were locked.

rubber with an average roughness index of 98 in. per mi. was slightly rougher than the control section which had an average roughness index of 92 in. per mi. This difference is small, and since considerable difficulty was experienced in keeping the paver properly adjusted, it is believed that differences in roughness may have resulted from operation of equipment rather than from the presence or absence of rubber in the mix. It was found that a greater difference existed between the outside lanes and the inside or passing lane. For example, the outside lanes averaged 103 in. per mi. and the center lane 79 in. per mi.

The other sections have not been tested for riding qualities; however, it is planned to make these measurements as soon as possible.

Skid Resistance Tests - One of the benefits claimed for the use of powdered rubber in asphalt mixtures is improvement in skid resistance of the surface. In order to evaluate this quality, skid resistance tests (8) have been made on each section. Results shown in Table 1 are the average of two or more tests made at each speed for each surface condition. The individual measurements checked very closely with repeat tests under the same conditions.

Skid resistance tests (Fig. 8) were

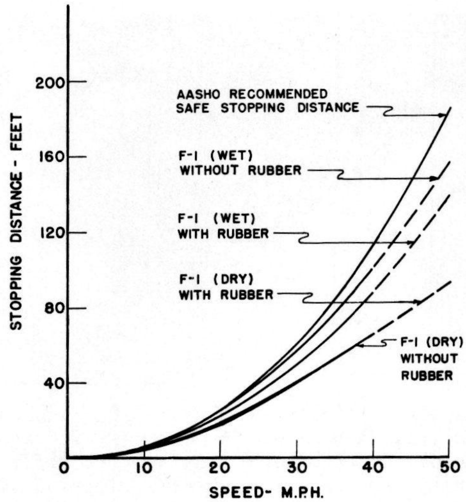

Figure 9. Skid Test Results on Bituminous Concrete (Type F-1) Surfaces with and without Natural Rubber (Six Months After Construction)

made on Sections 1 and 1-C in May, soon after completion. At that time, with the surface wet at 40 mph., an average stopping distance of 93.7 ft. was measured on the plain surface and 87.9 ft. was measured on the F-1 surface containing natural rubber. The difference of 5.8 ft. in favor of the mix containing rubber indicates that natural rubber in F-1 mixes tends to improve skid resistance of the surface at early ages.

Sections 1 and 1-C were again tested for skid resistance in November, 1949. These tests at 40 mph. on wet surfaces gave an average stopping distance of 101.2 ft. on the plain section and 87.5 ft. on the one containing natural rubber. Results of these tests are shown graphically in Figure 9 in comparison with the AASHO recommended max. safe stopping

TABLE 1

SKID RESISTANCE MEASUREMENTS

Section Number	Surface Condition / Speed - mph.	Dry 10 S	Dry 10 f	Dry 20 S	Dry 20 f	Dry 30 S	Dry 30 f	Dry 40 S	Dry 40 f	Wet 10 S	Wet 10 f	Wet 20 S	Wet 20 f	Wet 30 S	Wet 30 f	Wet 40 S	Wet 40 f	Date Tested
	Bituminous Concrete, Sand Asphalt (F-1)																	
1-C	Without Natural Rubber	4.8	0 69	18 2	0 73	37 4	0.80	63 4	0 84	4 9	0 68	21 3	0 63	49 9	0 60	93 7	0 55	May 1949
1	With Natural Rubber	3 7	0 90	17 2	0 78	38 9	0 77	60.7	0 88	5 1	0 65	21 1	0.63	49 1	0 61	87 9	0 61	May 1949
	Difference in S	1.1		1.0		-1.5		2 7		-0 2		0 2		0 8		5 8		
1-C	Without Natural Rubber	4 5	0 74	19 6	0 68	40.1	0.75	65 9	0 81	6.0	0 56	25 5	0 52	57 0	0 53	101 2	0 53	November 1949
1	With Natural Rubber	4 2	0 79	18 6	0 72	40 2	0 75	66 6	0 80	5 1	0 66	22 6	0 59	49 2	0 61	87 5	0 61	November 1949
	Difference in S	0 3		1.0		-0 1		-0 7		0 9		2 9		7 8		13 7		
2-C	Without Reclaimed Rubber	4 5	0 74	18 3	0 73	40 1	0 75	64 7	0 82	5.3	0 63	22 6	0 59	49 8	0 60	88 2	0 60	November 1949
2	With Reclaimed Rubber	4 4	0 76	18 6	0 72	40 5	0 74	67 9	0.78	5 4	0.62	21 5	0 62	48 8	0 61	88 5	0 60	November 1949
	Difference in S	0 1		-0 3		-0 4		-3 2		-0 1		1 1		1 0		-0 3		
	Seal Treatment																	
3-C	Without Natural Rubber	5 0	0 67	20 4	0 65	44.2	0 68	73 5	0 72	5 9	0 56	24 3	0 55	55 0	0 55	93.1	0 57	November 1949
3	With Natural Rubber	4 2	0 79	19 3	0 69	41.0	0 73	71 7	0 74	5 6	0 60	24 0	0 54	53 0	0 57	90 0	0 59	November 1949
	Difference in S	0.8		1 1		3 2		1 8		0 3		0 3		2 0		3 1		

S = stopping distance in feet
f = average coefficient of friction, as determined from $f = \frac{v^2}{30S}$ where
v = velocity in mph

Note Each stopping distance value is the average of two or more determinations distances. It will be noted that even for the wet surface without rubber, the stopping distance is well below the recommended max. safe stopping distance of 113 ft. at 40 mph. The above tests

Tests will have to be conducted over a longer period of time to evaluate any improvement due to rubber in this type of surface.

Figure 10 shows skid tests results

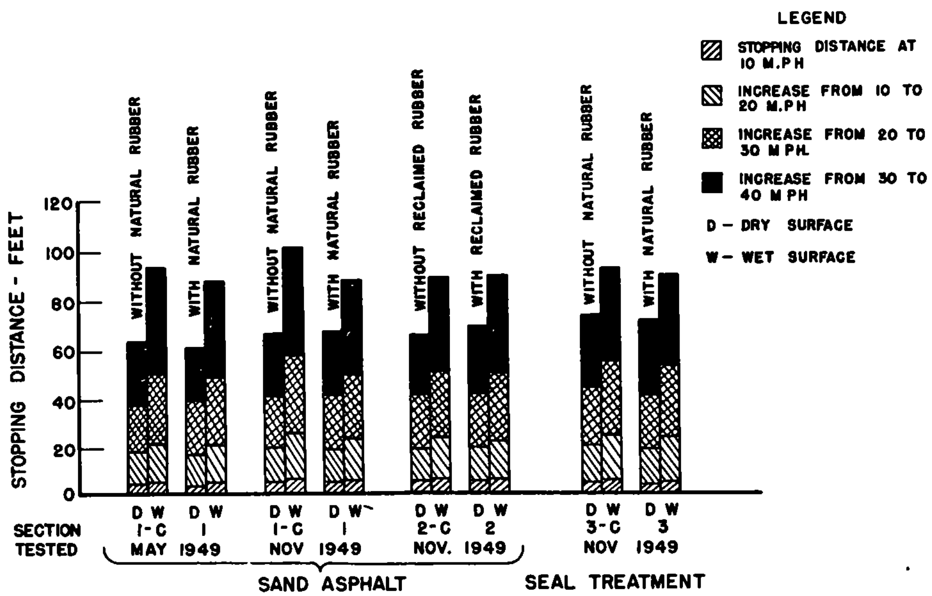

Figure 10. Skid Resistance Measurements

show that while the skid resistance of the section containing natural rubber remained the same six months after construction, there was an increase in stopping distance on the plain section.

Results of skid resistance tests at 40 mph. on Sections 2 and 2-C gave an average stopping distance of 88.5 ft. on a wet F-1 surface containing reclaimed rubber, and 88.2 ft. on a wet F-1 surface without rubber. These results indicate that, at the time the tests were conducted, the reclaimed rubber had not been effective in improving skid resistance of this F-1 surface.

Skid resistance tests on Section 3 at 40 mph. with the surface in a wet condition gave a stopping distance of 90.0 ft. on the seal treatment containing natural rubber and 93.1 ft. on the seal treatment without rubber. The difference of 3.1 ft. in stopping distance is small and may have been affected by the surface texture which is rather harsh.

to date. It will be noted that all surfaces tested have good skid resistance even in a wet condition and are well below the max. safe stopping distance as recommended by the AASHO. With the surfaces dry, stopping distances for the various F-1 surfaces are very close together. On the seal treatment, there is very little difference between the stopping distance for the sections with and without rubber. Since results of a large number of tests on surfaces of various types show that all pavement surfaces in Virginia have good skid resistance in a dry condition, only results of tests on wet surfaces at 40 mph. are used to evaluate their skid resistance.

SUMMARY OF RESULTS

While definite conclusions regarding the economics and durability of sand-asphalt (F-1) bituminous plant mixes and seal treatments to which small percentages of natural or reclaimed powdered rubber have been added cannot be made at this early date, the following tentative conclusions may be drawn:

1. It is feasible to incorporate small percentages of natural or reclaimed powdered rubber in sand-asphalt (F-1) mixes at the plant and in the manner followed in these experiments. Also, no difficulty was encountered in adding a small percentage of powdered natural rubber to asphalt cut-back (RC-2) and applying it with a distributor. No method was devised to determine the distribution of the rubber throughout the mix, and consequently no data are available on this feature.

2. It was found to be practical to lay such a mixture with Barber-Greene and Adnun pavers. With the equipment available, however, the thinnest rate of application that could be applied successfully was approximately 60 lb. per sq. yd. It was further found that with the natural rubber in the mixture, the max. speed of the Barber-Greene paver for good results was about 8 ft. per min., while without the rubber a speed of 12 ft. per min. could be maintained with equally good results. Reclaimed rubber in the mixture did not affect the results obtained with the Adnun paver.

3. No difference in appearance has been observed between the sections with natural rubber and the ones without. The surface containing reclaimed rubber showed particles of rubber standing above the compacted surface when rolling was completed.

4. Since the natural and reclaimed powdered rubber was furnished gratis to the Department, no information is available concerning added costs for these materials.

5. Immediately after construction, measurements of resistance to skidding indicated that in a wet condition the section of F-1 sand asphalt with natural powdered rubber had slightly better resistance to skidding than the control section. In a dry condition there was very little difference between the stopping distance on the sections with and without natural rubber. Similar tests six months later, on the wet surface, showed an increase in stopping distance for the control section, but no change in the skid resistance of the rubber-asphalt surface.

6. After two months there is no indication that the reclaimed rubber has been effective in improving skid resistance of type F-1 sand asphalt. Skid resistance measurements on the section with reclaimed rubber were about the same as those for the control section.

7. A slight difference in stopping distances on a seal treatment with and without natural rubber was indicated in favor of the rubber section, two months after construction.

8. The outside lanes which carry the majority of traffic were found to be rougher than the inside or passing lane; however, no differences were found in the riding qualities of Sections 1 and 1-C that could be attributed to the presence or absence of rubber in the mix.

9. Based upon experience with similar sand-asphalt mixes not containing powdered rubber, it is believed that several years will be required before decided differences in performance on these sections may be apparent. It is believed that where small percentages of powdered rubber are incorporated with the asphalt and applied in conjunction with a seal treatment, an evaluation of the effectiveness of the rubber-asphalt combination may be possible at a much earlier date.

In conclusion it is suggested that comprehensive laboratory research be conducted to determine fundamental properties of rubber-asphalt mixtures.

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