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DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

Materials and Research Department

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Transportation Laboratory

FIELD TRIALS WITH ANTI-STRIPPING AGENTS IN BITUMINOUS MIXTURES

Research No. .00215

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47-02

September 15, 1947

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Trade Name	Manufacturer
Anti-stripping emulsion	American Bitumuls Company
Colas mixing emulsion	Shell Oil Company

Liquid asphalt used was ROMC-3, SC-4 and MC-5.

The prupose of the experimental installations was to secure information on three points:

1. To find out whether hydrophilic aggregate could be treated to prevent ravelling and softening of a bituminous mixture under two conditions.

   (a) When newly completed surface was subjected to rain immediately after being opened to traffic and

   (b) Whether any improved resistance to water would be manifest after a substantial period of time.

2. Whether there is any difference in performance or effectiveness between the several available additives,

3. The degree of correlation between laboratory tests and the actual performance on the road.

The following conclusions may be drawn under these three headings:

1. Observations made to date indicate that certain hydrophilic aggregates can be improved by the use of certain additives. However, the improvement is not general. Under condition (a) on the Afton project, No-strip showed little improvement when the surface was wetted immediately after construction but did show definitely beneficial results after the elapse of one or two months. On the other hand, Armeen-T on the same job appeared to be effective temporarily but later gave no protection.

2. There are differences in performance but so far no consistent difference has been established. An additive that may be effective with one aggregate may show little improvement with another and vice-versa.

3. Laboratory swell and stripping tests are not very reliable in indicating the probable performance under

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traffic. Much better correlation is shown by stability and cohesion tests on samples that have been subjected to the Moisture Vapor Susceptibility test procedure.

The poor performance of the sections mixed with emulsified asphalt should not be considered as evidence of unsuitability under more normal conditions. The experimental sections were subjected to water within one or two days after construction and the emulsion sections had not been given time to thoroughly dry out. Under favorable conditions it is probable that the emulsified asphalt sections would have given a satisfactory performance.

The experimental sections were designed to compare performance under unfavorable conditions.

Thus far the additives developed for the Standard Oil Company by the California Research Corporation seem to be the most promising, judged by performance in both field and laboratory tests.

The following outlines give the construction details and the conclusions which have been drawn from each of the separate sections.

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Summary

This report covers experimental projects which were instituted for the purpose of comparing the effectiveness of commercial anti-stripping agents. Construction of these projects was first proposed in a memorandum, Hveem to Stanton, dated November 1, 1945, and later discussed in a memorandum Stanton to Dennis, November 14, 1945, and memorandum Stanton to Dennis, February 4, 1946.

Work Order Number 13NN16 was issued April 25, 1946, alloting a total of $3,000 to cover all laboratory work in connection with these projects and maintenance work orders as follows were issued to cover the actual construction costs in the Districts:

Location	Work Order Number	Amount Allotted
II-Mod-73-C,D	2K165 2K166	$ 7,005.00
VIII-SBd-31-J	8V8	7,000.00
XI-S.D-2-F	11X28	14,200.00

The first of these projects to get under way was on II-Mod-73-C,D, between Likely and Alturas. This project was completed during the week of July 17th to 24th, 1946, the section in District VIII, 30 miles E. of Barstow, VIII-SBd-31-J, was constructed during September and October, 1946, while the unit in San Diego County, Road XI-S.D-2-F, was constructed between January 6th and 10th, 1947. In general, the work was carried out in accordance with local construction procedure, the first two jobs listed being constructed by the road-mix method while the project in District XI was carried out by plant-mixing with heated aggregate.

Anti-stripping agents used included:

Trade Name	Manufacturer
No-Strip	Maguire Industries, New York
Armeen-T	Armour & Company, Chicago
Experimental additives identified as "No. 1" and "No. 2" furnished by	Standard Oil Co. of California

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ALTURAS EXPERIMENTAL PROJECT
FOR ANTI-STRIPPING AGENTS

II-Mod-73-C

A site between Alturas and Likely was selected based on past experience with bituminous road surfaces in this area and from laboratory tests which indicated that the local mineral aggregates were hydrophilic. Funds being limited, a section was proposed at a point approximately 15 miles south of Alturas between Stations 471+56 and 497+30, road II-Mod-73-C. This gave an over-all length of 2574 feet divided into three units as shown on the attached sketch. This division provided one section mixed with cutback asphalt containing No-strip, one section mixed with cutback containing Armeen-T, and a third section mixed with untreated cutback for comparison.

The work on this project included the placing of approximately 4" of gravel base over the existing roadbed, the upper one-tenth foot being road-mixed with ROMC-3 liquid asphalt.

Mineral Aggregates. The aggregates used were produced by screening from a deposit of cemented gravel known as the McGarva Pit immediately south of Likely. Test results on this material are given in the attached tabulation.

It will be noted that preliminary tests made in the Laboratory were not conclusive inasmuch as all samples tested registered fairly high results in the swell test and also displayed bad stripping regardless of method of treatment. However, the test results indicate that the swell was somewhat reduced when the aggregate contained a certain amount of water at the time of mixing with the oil. Therefore, in order to try out the effects of mixing with wet aggregate, one-half of each unit was wetted on the road prior to the addition of the asphalt. This detail is also shown on the attached sketch.

Construction. Mixing of the untreated section began Wednesday morning, July 17th. Because of the delay in applying water, etc., mixing was not completed until afternoon and there was not enough time remaining to complete construction of the second unit in which the asphalt contained No-strip. Thursday morning, July 18th, construction of the No-strip portion was completed and in the afternoon the third section containing the Armour product was mixed, final spreading being completed at about 5:30 P.M.

An effort was made to introduce the same quantity of oil on a unit basis in each of the three sections. However,

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this intent was not perfectly realized as indicated on the attached sketch and it was evident that the untreated ROMC-3 section was distinctly dry in appearance and displayed a slight tendency to ravel under traffic.

Testing. Friday Morning, July 19th, the entire surface was swept with a power broom and the finished surface was subjected to an application of water. Water was spread by means of a 750 gallon tank with a gravity spray bar, the water being spread on a strip ranging from 10' to 12' in width along the centerline of the surfacing. It was thought that by applying the water in this manner, it would be possible to better observe any contrast in performance between the wet and dry portion of the surface. Furthermore, the small truck available could not supply water fast enough to maintain the entire road surface in a wet condition.

Traffic on this section is very light and was insufficient to develop ruts or grooves in the 3 or 4 hours during which the surface was kept wet. Within an hour after the first water was applied, it became evident that both the untreated section and that containing the No-strip were softened and the asphalt was readily stripping from the larger stone particles. This softening and stripping was much less noticeable in the section treated with the amines.

Numerous examinations were made of the wet surface both by District Materials Engineer A. W. Hislop and Staff Materials and Research Engineer F. N. Hveem, and taking all factors into consideration, it was evident that the section containing the No-strip was little if any, superior to the section containing no additive. If any differences existed, the No-strip section was the inferior. By comparison, the section containing amines (Armeen-T) showed definite superiority under this first application of water although some softening and stripping was evident.

Conclusions

After the initial wetting in July, 1946

1. It is evident that definitely hydrophilic aggregate was used in the experiment.

2. The addition of 1-1/2% of No-strip did not prevent softening and disintegration of the surface when subjected to water immediately following construction.

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3. The section containing high molecular weight primary amines purchased from Armour & Company of Chicago, (designated on the container as "Armeen-T") gives definite evidence of improved resistance to the action of water. Whether or not this resistance is sufficient to withstand a prolonged rainy period and heavier traffic cannot be determined until later.

This project was handled efficiently and with excellent cooperation on the part of the personnel in District II. It is desired to make reference to Maintenance Superintendent P. L. Dito and Foreman F. M. Bunyard. Acknowledgment is also made of the efforts of District Materials Engineer A. W. Hislop in the conduct of the experimental work.

Attachments: Table I, giving laboratory tests on aggregates from the McGarva Pit sampled prior to construction.

Table II, Road-mixed Experimental Section to compare Anti-Stripping agents.

Sketch of Alturas Experimental Section, II-Mod-73-C.

Photographs.

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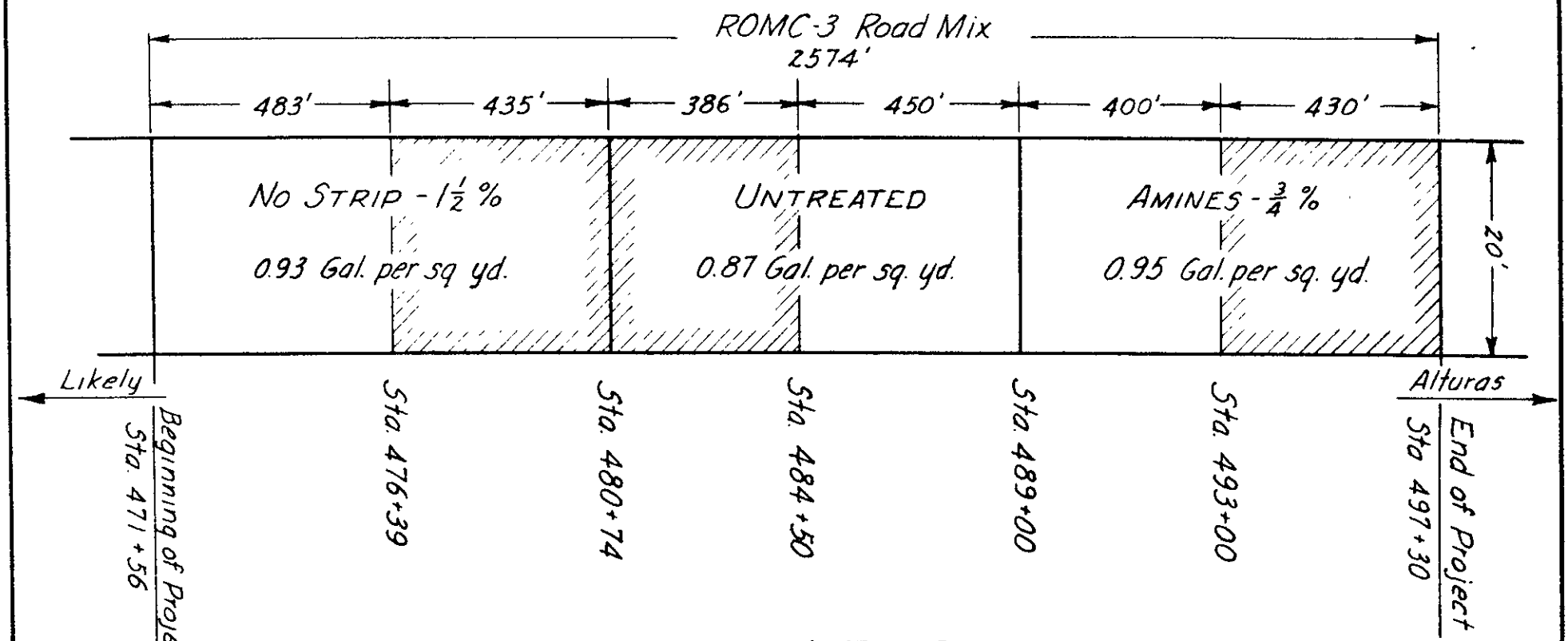

11-Mod-73-C

ALTURAS EXPERIMENTAL SECTION

NOTE:

Shaded areas represent sections of pavement with 3% moisture added before mixing.

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Table 1

II-Mod-73-C

PRELIMINARY TESTS PRIOR TO CONSTRUCTION OF EXPERIMENTAL SECTION

Test No.	Type Bitumen	Bitumen Ration	Stability	Cohesion	Swell	Stripping	Swell Test When Mixed with Moist. Aggr.
48948 D4275	ROMC-3	10.0	35	174	.046 .060	Bad	.024 .024
	ROMC-3 3/4% Amines	10.0			.081 .070	Bad	.024 .034
	ROMC-3 1-1/2% No-strip	10.0			.071 .103	Bad	.055 .077
48949 D4276	ROMC-3	6.9	39	113	.028 .054	Bad	.030 .025
	ROMC-3 3/4% Amines	6.9			.040 .034	None " (check)	.062 .039
	ROMC-3 1-1/2% No-strip	6.9			.058 .082	Bad	.049 .037

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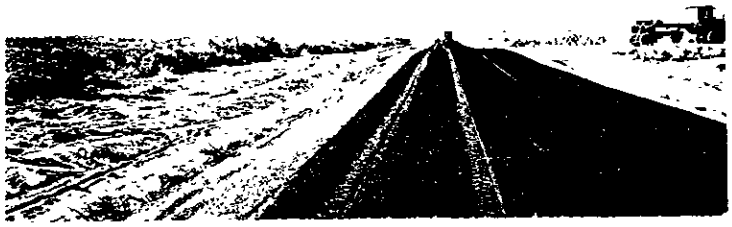
Views Facing North



Mix being spread
Untreated section in foreground

Untreated section after wetting

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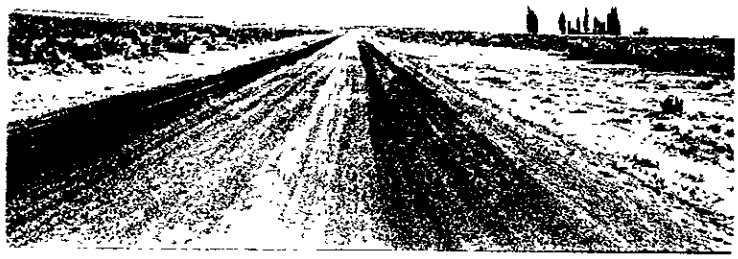
Views Facing South

Water applied to central portion of roadway
Untreated section in foreground



Fading and ravelling of wetted section
No-Strip section in foreground

After wetting Amine section in foreground fading less noticeable than untreated section in distance

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AFTON EXPERIMENTAL PROJECT FOR ANTI-STRIPPING AGENTS

VIII-SBD-31-J

This report covers the construction of a test section of road-mixed blanket placed during September and October, 1946, in San Bernardino County near Afton, approximately forty (40) miles east of Barstow, on Road VIII-SBd-31-J, for the purpose of evaluating various commercial stripping resistant additives.

In general, the experimental mixtures were mixed, placed and compacted first by rolling with a pneumatic roller and then under traffic for one day. The surface was then kept wet from 9:00 A.M. until 4:00 P.M. on two successive days and the softening noted.

Five separate sections were placed using commercial additives and one additional section was placed without special treatment. Each section was constructed in two parts. On one portion, the liquid asphalt was mixed with dry aggregate and on the other, with wet aggregate containing approximately 5% moisture.

Construction Details

The aggregate for the mix was obtained from an ancient beach deposit located left of Station 380, road VIII-SBd-31-J. This same material was used previously on Contract 28VC10, road VIII-SBd-31-J, constructed in 1930. Laboratory tests on the aggregate shown in Table I, gave swell test values ranging from 0.026" to 0.061".

A mixing table of SC-4 mix was constructed adjacent to the deposit and the material bladed from the bank to the mixing table. Mixing was accomplished with two motor patrols working on windrows two hundred twenty-five (225) feet long. The completed mix was loaded into trucks and spread on the road by end dumping. The material was then spread to a uniform cross-section with the motor patrols, and compacted by rolling with a pneumatic tired roller.

Liquid asphalt grade SC-4 was used on all sections except one which was mixed with Bitumuls stripping resistant asphalt emulsion. The quantity of aggregate was determined by measuring the cross-sectional area of the windrow and the quantity of liquid asphalt spread was determined by measuring the depth remaining in the distributor truck.

Each separate test section was placed half width of the pavement and one thousand feet (1000') in length. The sections were divided into two parts with the liquid asphalt mixed with wet aggregate for one five-hundred foot (500') portion and with dry aggregate for the remainder. The layout

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of the sections is shown in Figure I.

Each additive was mixed with the liquid asphalt by circulating through the pump of the distributor truck for one-half hour. In order to secure complete mixing, a flexible pipe was connected to the pump and the oil was discharged into the top of the tank. In general, water was applied to each section after compaction under traffic for a period of one (1) day. Deviations from this procedure are covered in the detailed discussion of each section. The water was applied to the inside portion of the traffic lane with sufficient water being used to keep the surface from drying out.

Details of Each Section

1. No-strip

Mixing of the No-strip section was started on September 24, 1946. An amount of No-strip equivalent to two per cent (2%) of the weight of the oil was used. A uniform mix was obtained which appeared to contain sufficient oil. The aggregate, particularly in the dry windrow, seemed slightly more rocky, however, than that used on the other sections.

The section of No-strip mixed with wet aggregate was placed on September 27, 1946. On September 28th, the section mixed with dry aggregate was placed and the top one inch (1") of the wet aggregate section was rebladed because of the rough finish which had been obtained the previous day. Maintenance men working with the material reported that the No-strip mix was more difficult to place than the section mixed with untreated SC-4, as the mix was sticky and tended to drag under the blade.

Plans called for the application of water to the No-strip section, starting at 9:00 A.M. of September 30, 1946. However, rain occurred sometime during the night or early morning and it was unncessary to use the water trucks until approximately 3:00 P.M.

II. Section without Treatment

On this section, the portion mixed with dry aggregate was mixed at the same time as the No-strip and placed on the road September 28, 1946. The mix handled well while placing and compacted to form a satisfactory surface.

The section mixed with wet aggregate was mixed on October 14th. Unfortunately on this section, poor control of the quantities of material resulted in a deficiency of oil and as a result, the surfacing ravelled considerably even before water was applied. A Laboratory representative was not present

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during the mixing and placing of this section however, the dates of the various construction operations shown in the attached table II were secured frmm noted made by Mr. M. Glen, District Materials Engineer.

III. Standard No. I

Both the wet and dry section of Standard No. 1 were mixed at the same time as the untreated section. These mixes also were considerably under-oiled particularly the section of Standard No. 1 wet, which was very dry and mealy with practically no cohesion. The Standard No. 1, dry, was also under-oiled although darker in color than either Standard No. 1 wet, or untreated, wet.

All three sections mixed, at this time, the Standard No. 1, wet, the Standard No. 1, dry and the untreated, wet, ravelled badly before water was applied. The Standard No. 1, wet, ravelled the most and the untreated, wet, ravelled the least. The surface of the mixes at the time of applying water, was quite rough and rocky with the possible exception of the untreated, wet, which had compacted somewhat better than the other two.

IV. Standard No. 2

The Standard No. 2 section was placed on October 16th. Extraction tests showed that this mix contained the highest oil ratio of any of the test sections. The mix was difficult to place, being gummy and pushing under the blade but compacthg very well to form a well knit surface even though somewhat rough.

The fine portion of the mix appeared slightly over-oiled, being unstable during the heat of the day so that indentation of the fine portions could be made with the fingers altnough the stability of the complete mix was sufficiently high.

V. Bitumuls

Mixing was started on the bitumuls section on October 18th, which was a relatively hot, dry day considering the season of the year. Mr. Jim Reed of the American Bitumuls Co. was on the job to advise on mixing procedure..

The first windrow of material was wet with the sprinkler truck to a moisture content considered sufficient by Mr. Reed before applying any emulsion. Because of the rapid drying

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conditions which existed however, this moisture evaporated very quickly and it soon became apparent that by the time all of the emulsion was added to the aggregate, the material would be too dry for proper dispersion of the asphalt. Because of the arrangement of equipment on the job, it was not practicable to add additional water to the windrow at this time and accordingly, the adding of the emulsion was continued until complete. This windrow was then bladed aside and a sufficient quantity of water added to the second windrow to provide proper dispersion of the asphalt emulsion even after evaporation losses. The second windrow mixed quite readily although requiring considerable more time than the SC-4 mixes. After completion of the second windrow, which will be called "Bitumuls, wet" in this report, additional water was added to the first windrow and mixing continued. This material is referred to in the report as "Bitumuls, dry" although the moisture content of the two mixes at the time they were placed on the road was very nearly the same. From experience on this project, it does not appear that motor patrols are the proper equipment to use for mixing asphalt emulsion mixes as the action is too slow to prevent small portions of the emulsion from breaking before coating the aggregate.

The Bitumuls sections compacted quite well although there was quite a bit of loose material present on the surface on the day watering was started. In order to prevent this loose material from obscuring the results obtained on this section, the material was broomed off before applying any water.

VI. Armeen-T (Amines)

Mixing of the Armeens section was started October 23rd. Since the amines were not fluid at atmospheric temperature, it was necessary that the material be heated before mixing with the asphalt. This was accomplished by means of an asphalt kettle partly filled with water. The five-gallon cans containing the amines were placed in the water bath until melted and were then measured out and poured into the asphalt truck for circulation and complete mixing with the SC-4.

The portion of the Armeen section mixed with wet aggregate appeared to contain slightly less oil than that mixed with the dry aggregate, however, extraction tests indicate the oil ratio is higher. The two mixes, after being placed, however, compacted equally well with possibly the smoothest surface of any of the sections being obtained on the one using the Armeens with wet aggregate. As the atmospheric temperature during the mixing of the Armeens reached a maximum of only 86°F, it was not possible to dry the moisture out of the Armeen portion mixed with wet aggregate because of the large windrow which was necessary on the relatively small area of the mixing table. It was decided accordingly, to place the material on the

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roadway and accomplish this drying by blading the smaller windrow.

A rain occurred during the night preceeding the watering of the amine section. Local residents reported that the rain started about midnight and continued until about 5:00 A.M.

Variables Not Subject to Control

1. Mixing Method

It was apparently not possible to measure accurately the quantity of asphalt in any one given mix because of the inaccuracies in measuring the cross-section of the large windrow used for the project and also because of difficulty in securing a windrow of uniform cross-section throughout its length. It was also difficult to be sure that additional material was not picked up from the mixing table or that material from the windrow was not left on the mixing table.

The mixing action secured by the motor patrols was also too slow to satisfactorily disperse the emulsified asphalt through the large quantities of material contained in the windrow. Because of the high moisture content used in the asphalt emulsion mixes, particularly at the start of mixing operations, it was difficult to turn the material with the blades because of lack of traction for the motor patrols.

2. Temperature Variations

The work was started the latter part of September when atmospheric temperatures during the day were in the neighborhood of 110°F. At the completion of mixing operations in October, the atmospheric temperature rarely exceed 86°F. This variation in temperature made considerable difference in ease and thoroughness of mixing and also caused a wide variation in moisture content to exist at the time the various sections were placed.

3. Bitumen Content

The inaccuracies in measuring the quantity of materials resulted in a definite deficiency of the bitumen content by this blade mix method. Control by eye was not effective because part of the mixes were mixed with dry aggregate while the others were made with wet aggregate. Variation in moisture content caused considerable variation in the appearance of the

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mix and made visual control impractical. While the fine portion of the aggregate was reasonably uniform thmughout the job, a considerable quantity of large rocks of 2-1/2" to 3-1/2" diameter were present. While much of the oversize was removed by hand, nevertheless these large stones made placing of the mix difficult and resulted in most cases, in a rather rough and uneven surface texture.

4. Wetting of the Road Surface

The plan of operation agreed upon required that each separate mix be compacted for one day by traffic before applying the water. However, a rain occurred on September 30th and again on October 27th. This resulted in the compaction period for the No-strip section, for the untreated dry section and for the amine section being somewhat reduced. Observations at the time, indicated that the destructive action of the rain was somewhat more severe than that caused by the water from the sprinkling trucks. It is believed that this is caused by the finer dispersion of the rain drops and because of the high humidity which retards evaporation from the surface. Dissolved carbon dioxide in the rain water may also affect stripping.

5. Traffic

Observations indicated that the traffic during the later part of the project was more severe than that at the beginning although no actual counts were made. At all times there was a tendency for traffic to avoid the portion of the roadway which was being wetted. This was particularly true when only one-half of the roadway had been covered by the new blanket.

Relative Perfrmance

1. No-strip Section

The No-strip section was subjected to rain for several hours before the intended start of watering operations. The mixes soon developed a quite definite mushiness although the No-strip wet mix sectionappeared slightly firmer than the No-strip mixed dry. By the end of the first day of watering, however, both sections appeared about the same, At the start of the second day of watering, these sections had improved and were quite firm showing little signs of softening for the first hour of watering. In general, the performance of the section was slightly better than on the first day of watering. However, the No-strip

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sections softened to such an extent that approximately 1/8" could be scraped loose with the toe of the shoe on the No-strip wet mix and a slightly greater amount on No-strip, dry.

2. Untreated Section

The sections placed without anti-stripping additives, displayed a marked softening on both days of watering. The softening apparently extended to a depth of approximately 1/4" to 3/8". The untreated wet section was definitely under oiled and considerable ravelling continued during the application of water and it was not possible to tell to what extent the addition of water increased the ravelling. In spite of the low oil content and the ravelling which occurred, it was noted that the fine portion of the untreated wet section did not soften to the same extent as was observed on the untreated dry.

3. Standard No. 1

The Standard No. 1 sections were both under oiled although the Standard No. 1, Wet, appeared to have a much lower oil content than the Standard No. 1, Dry. These sections behaved very much the same as the untreated wet section with decided ravelling before water was applied and about the same amount of softening of the fines during application of the water. No conclusion can be drawn from the performance of this section as it was too low in oil content.

4. Standard No. 2

The oil content of the Standard No. 2 section appeared to be the highest of any placed. The mix compacted well to form a stable surfacing although the fine portion of the mix seemed to be slightly unstable during the hot portion of the day. This mix showed very little effect from the water except a change in color. The surface became muddy in appearance but it did not appear that any softening had occurred.

5. Bitumuls Sections.

The bitumuls section compacted quite well although there was a small amount of loose material on the surface which was broomed off before water was applied. In order to make the emulsion sections comparable with the SC-4 sections placed, it was not possible to allow sufficient time for the water to evaporate completely from the mix. Tests showed that the Bitumuls Section contained a moisture content of 5%± at the time water was first applied. These sections did not react to the water as did the other sections. During the first day, the mix

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became somewhat plastic but apparently did not distort or whip off the road. By the end of the second day of watering, this same plastic condition was present although the surfacing had by this time, roughened to a marked degree. The roughening was apparently caused by the small portions of the plastic mix being picked up by tires and deposited at other points.

6. Armeen-T Section

The amine sections were subjected to a rain starting in the early morning hours of October 27th, and continuing until approximately 5 A.M. Watering was started at 9 A.M. and continued the same as with the other sections. This section showed a muddy discoloration of the surface together with slight softening. The amine, dry section was slightly better than the amine, wet. The two sections also shed water quite well in the morning of the second day, appearing similar to the No-strip section in this respect.

Relative Performance

After application of water for two successive days, the test sections were rated from best to poorest in the following order:

1. Standard No. 2 (Wet and Dry)

A discoloration of the surface was the only apparent effect caused by watering on this section. Although the mix was unquestionably benefitted by the higher oil ratio used on this section, it would still have to be classed as the most effective treatment.

2. Armeen (dry)

3. Armeen (wet)

This section developed a muddy discoloration of the surface together with a slight softening. Although the difference was slight, the Armeen (dry) was slightly better than the Armeen (wet).

4. Nostrip (wet)

The No-strip section softened to a depth of approximately 1/8". The performance of this section may have been somewhat adversely influenced by the fact that a rain occurred in the early morning of the day that watering was to start. There is reason to believe that the action of rain is more severe than sprinkling with a water truck.

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5. Standard No. 1 (dry)

The Standard No. 1 section was under oiled and ravelled under traffic before the application of water. The overall condition of the pavement after watering would justify a much lower rating, however, the fine portion of the mix did not soften to any appreciable extent and for this reason this section was placed fifth.

6. No-strip (dry)

The No-strip (dry) section became muddy on the surface and softened to a depth of approximately 1/4".

7. Bitumuls (wet and dry)

The Bitumuls section did not develop the same appearance as the SC-4 sections and is difficult to classify in the same category. The above rating is based on general appearance and degree of softening.

8. Standard No. 1 (wet)

This section was so badly under oiled that the classification is of little significance. With a higher bitumen content, this section would doubtless have withstood the action of water much better.

9. Untreated (wet)

This section was also badly under oiled and ravelled to a greater extent than any other. The ravelling was a good deal more noticeable after watering than before. The fines did not soften to the same extent as that observed on the untreated dry section, however, this may have been caused by the renewing of the surface layer through ravelling out of the large rocks.

10. Untreated (dry)

This section softened to the greatest depth of any of the sections placed. After two days of watering the surface had softened to a depth of approximately 3/8". This softened material had absorbed sufficient water so that it was readily whipped off by traffic. This section demonstrated clearly, that the aggregate is definitely hydrophilic.

The above classification is based on evidence of softening of the fine portion of the mix. Ravelling which had already started before the water was applied, was disregarded as much as possible in rating the mixes for resistance to water.

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A classification based on the overall condition of the pavement on November 1, 1946, would be as follows:

1. Standard No. 2 (Wet and Dry)
2. Armeens (Wet and Dry)
3. No-strip, Wet
4. No-strip, Dry
5. Bitumuls (wet and dry)
6. Untreated (Dry)
7. Standard No. 1 (Dry)
8. Standard No. 1 (Wet)
9. Untreated (wet)

On January 16, 1947, an inspection of the project was made by W. R. Lovering and M. Glen, District Materials Engineer. Since completion in late October, the surface had been subjected to a heavy rain which occurred on November 13, 1946. Daily precipitation records at Barstow indicate that 0.6 inches of rain fell in a period of 24 hours.

The most noticeable change had occurred in the Armeen section. At the time watering was completed on October 28, 1946, the surface of the Armeen section was dark brown in color and there was no evidence of ravelling. However, on January 16, 1947, the Armeen treated blanket was completely gone in spots and ravelling badly throughout its length.

Both the Standard No. 2 and No-strip sections were in good condition.

Based on condition of blanket as of January 16, 1947, the sections would be classified as follows:

1. Standard No. 2 (Wet and Dry)

2. No-strip (Wet)

3. No-strip (Dry)

The No-strip sections are only slightly inferior to the Standard No. 2 sections. The No-strip section mixed with wet aggregate appears somewhat better than that mixed with dry aggregate.

4. Untreated (Dry)

Ravelled but in better condition than either the Armeen or Bitumuls sections.

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5. Armeens

Badly ravelled in many places completely through the blanket to the old pavement.

6. Bitumuls

The Bitumuls section is only slightly poorer than the Armeen section. A surface application of SC-4 over part of this section has effectively halted ravelling.

The Standard No. 1 (Wet and Dry) and the Untreated (Wet) had been re-oiled and reworked and are therefore, not included in the above listing.

Conclusions

Although several of the treatments showed an improvement in performance, this improvement did not appear to be great enough for material of the quality used in the experiment to justify an appreciable cost premium with the exception of the Standard No. 2 additive.

The No-strip section gave satisfactory resistance to water during the rain which occurred 46 days after construction. The softening which occurred under artificial watering indicated that a prolonged rain shortly after construction would cause complete failure.

The performance of the Armeens was good during the early period of watering but the almost complete failure at a later date, during the rains, indicate that this additive may not be effective as a permanent cure.

With the type of aggregate used on the project, asphalt emulsion is not practicable for blade mixing. Blade mixing is not rapid enough to permit complete dispersion of the asphalt in the limited time available before evaporation of the moisture.

It was also clearly demonstrated that emulsified asphalt mixes that have not had time to completely dry out will not resist surface water action.

The bitumen content of the Standard No. 1 was not sufficiently high to permit accurate conclusions regarding this additive.

It is strongly recommended that further experimental sections of this type be constructed only where plant control of materials and mixing operations can be obtained. The

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validity of the conclusions drawn on this project is substantially affected by the variable amount of oversize in the aggregate and the lack of accurate control of mixing operations.

Attachments

Table I Preliminary Test Results

Table II Table showing type of Treatment, etc.

Table III "Road Mixed Experimental Section to Compare Anti-stripping Agents constructed near Mt. Afton in San Bernardino County in Sept. and October 1946. VIII-SBd-31-J"

Sketch Afton Experimental Section October, 1946"

Photographs

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TABLE I

O.M. #49121 - 150' LT. STA. 380 ROAD SBD-31-J

Type Bitumen	Bit. Ratio	Stabilometer	Swell	Average Swell	Stripping
SC-3	4.3	34	.061 .026 .044 .052	.046	Very bad
SC-3, 3/4% Amine	4.3		.023 .031 .054 .043	.038	Bad
SC-3, 1-1/2% No Strip.	4.3		.123 .115	.119	Very Bad
Stripping Resistant Mixing Emul	7.6		.008 .003	.006	No
Tests in which bitumen was added to wet aggregate					
SC-3	4.3		.005 .007		Bad Stripping (45%)
SC-3, 3/4% Amine	4.3		.002 .009		Slight (20%)
SC-3, 1-1/2 No Strip.	4.3		.016 .008		Bad Stripping (40%)

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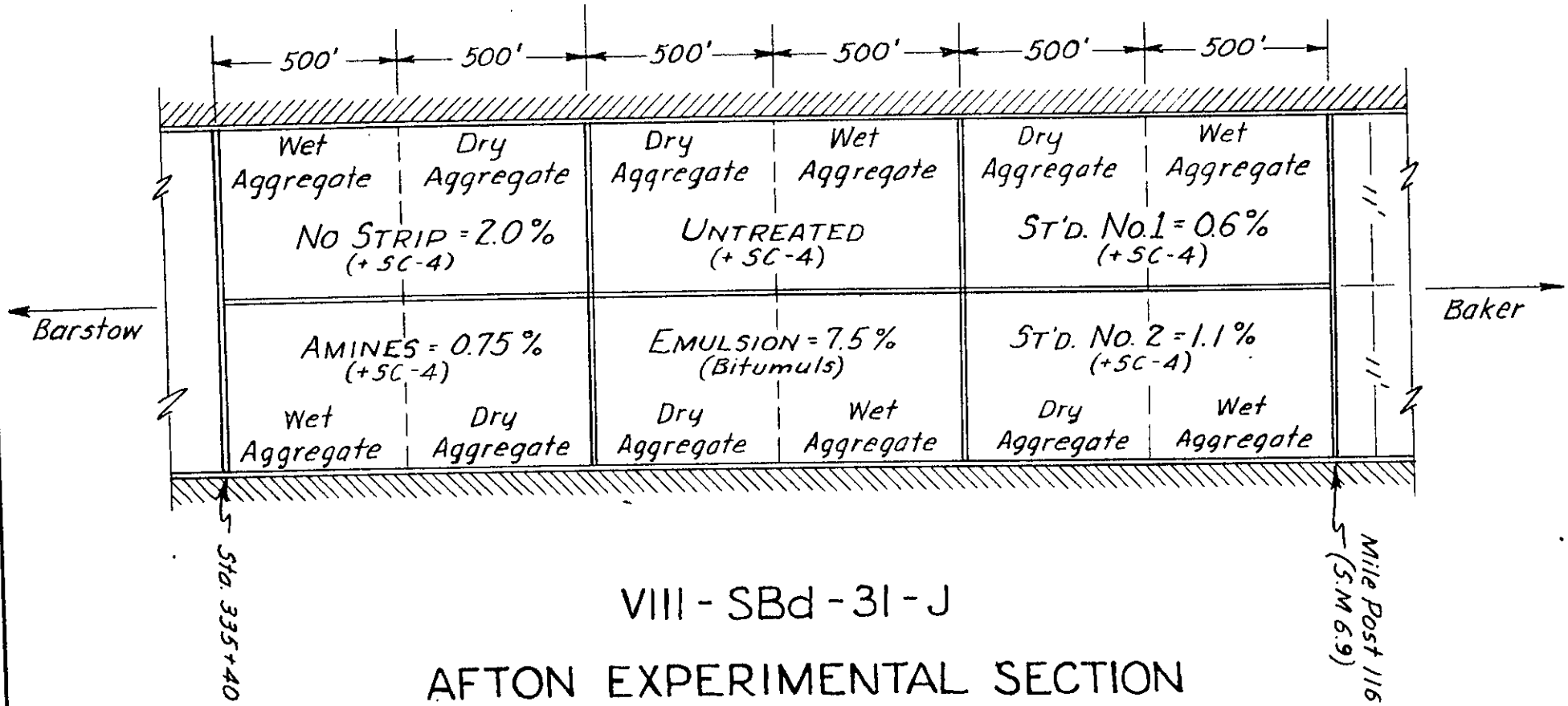

VIII - SBd - 31 - J

AFTON EXPERIMENTAL SECTION

October, 1946

47-110

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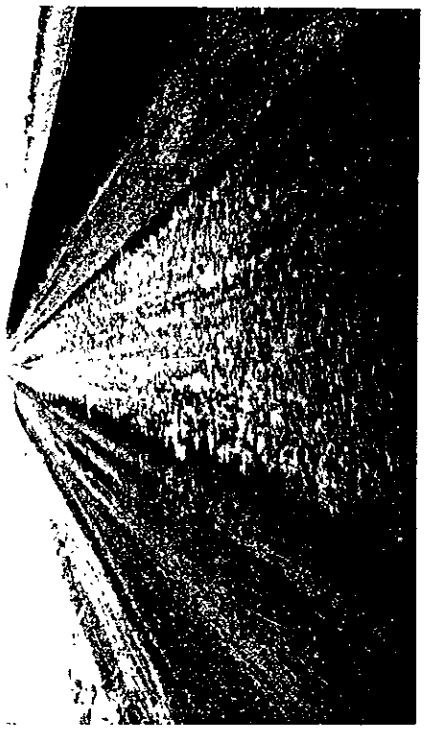
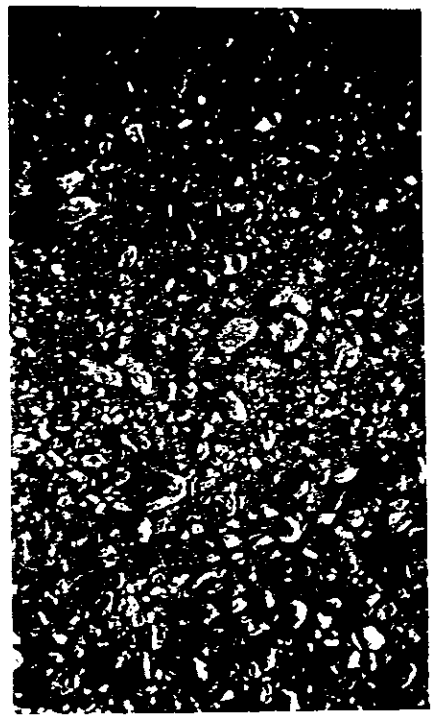
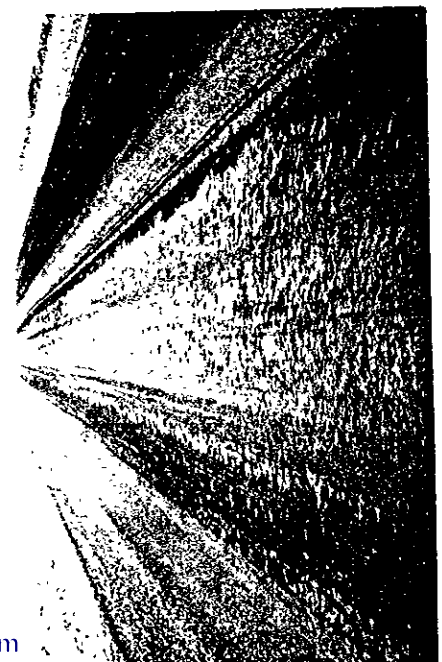
Mt. Afton Experimental Section
VIII-SBd-31-J



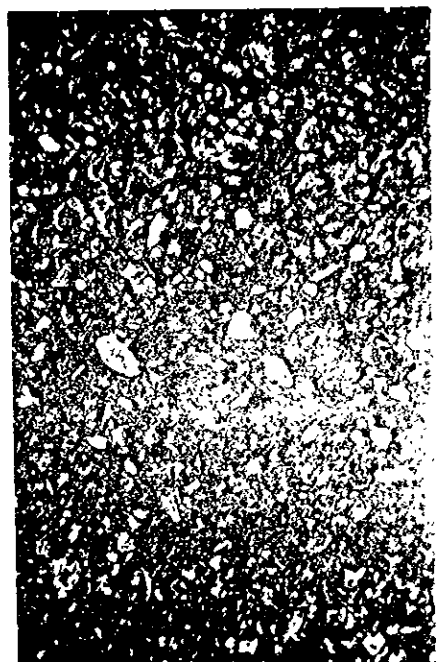
Untreated Wet
2nd Day Watering



Untreated Dry



Untreated Wet
1st Day Watering



Untreated Wet

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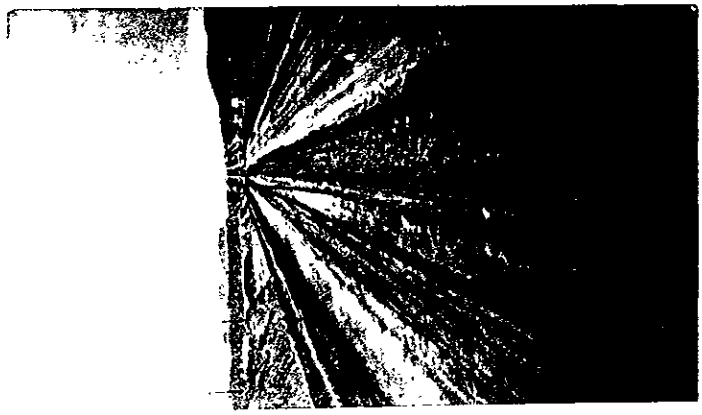
Mixing Table
Left - Nostrip (Mixed Wet)
Center - Untreated Oil
Right - Nostrip (Mixed Dry)



Untreated (Mixed Dry)
Sept. 30 - 2:30 PM

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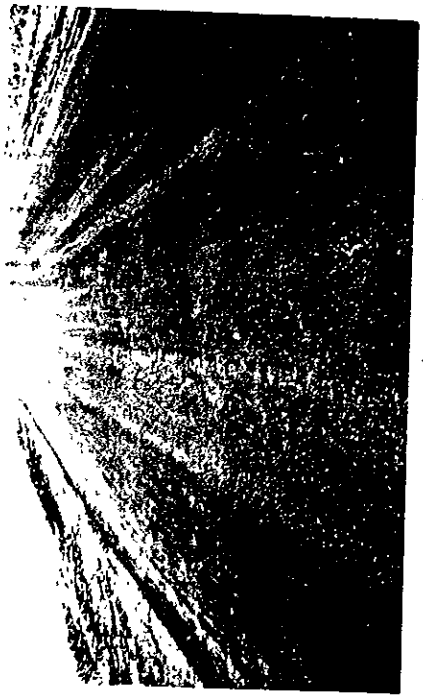
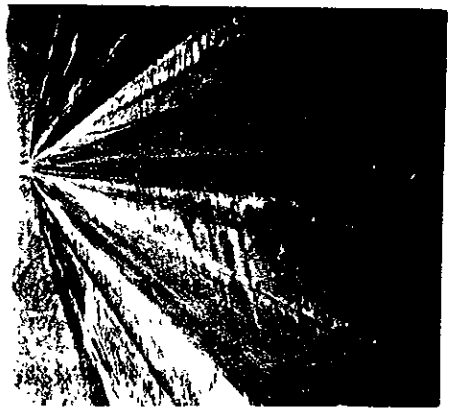
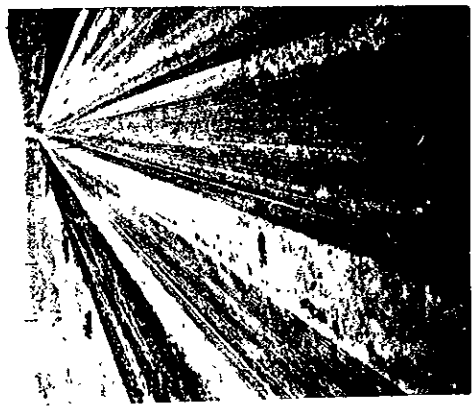


Nostrip (Mixed Wet)
10:00 AM - Oct. 2



Nostrip (Mixed Wet)
2:30 PM - Sept. 30

Nostrip (Mixed Dry)
10:00 AM - Oct. 2



Nostrip (Mixed Dry)
2:30 PM - Sept. 30

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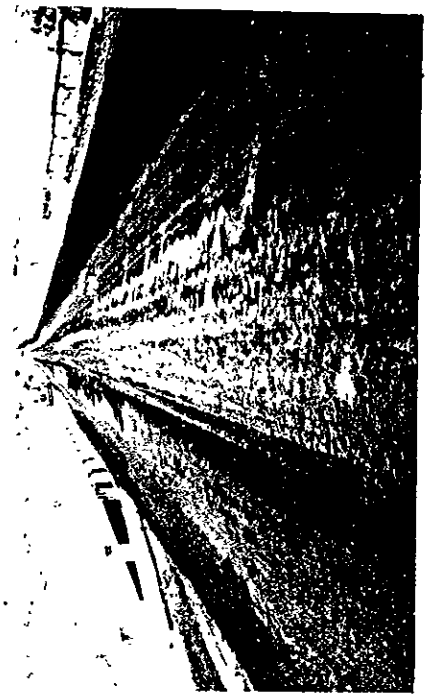
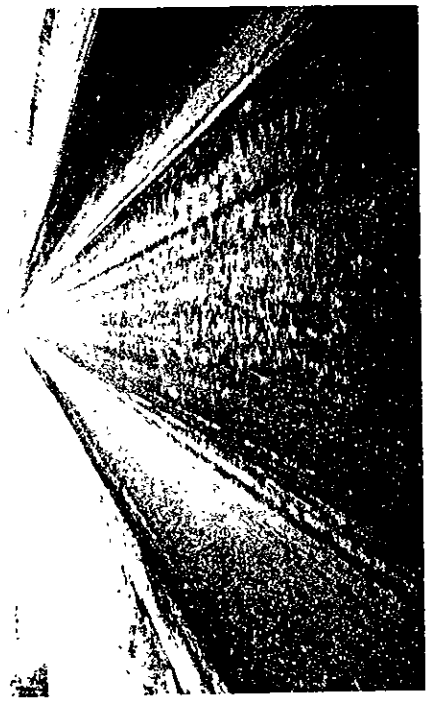
Mt. Afton Experimental Section
VIII-SBd-31-J

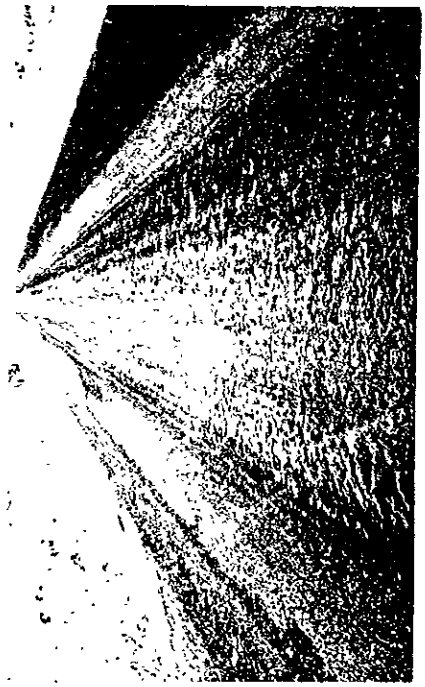
Standard #1 Wet
2nd Day Watering



Standard #1 Dry
2nd Day Watering



Standard #1 Wet
1st Day Watering



Standard #1 Dry
1st Day Watering

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Standard #1 Dry

Standard #2 Dry

Standard #1 Wet

Standard #2 Wet

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September 15, 1947

CHULA VISTA EXPERIMENTAL PROJECT FOR ANTI-STRIPPING AGENTS

XI-S.D-2-F

The third of a series of three projects was constructed during the week January 6th to 10th inclusive, on road XI-S.D-2-F, immediately north of the town of San Ysidro.

Mineral Aggregates. Aggregates for this project were obtained from the commercial plant owned by V. R. Dennis in Mission Valley. This material was selected primarily because of failures which had occurred on previous work and particularly in Rose Canyon, road XI-S.D-2-S.D, Contract 11VMC1, completed in 1944.

Every effort was made to secure mineral aggregates which would be in all respects, similar to the material used on the Rose Canyon project. In order to duplicate the original conditions, the experimental project was deferred until after a period of rainy weather in order that clay coatings would be present on the coarser aggregate particles.

Mixing was accomplished at the Dennis central mixing plant and mixed material was hauled approximately 21 miles after which it was spread on the road and shaped by means of motor patrol blades. After being under traffic for one day, water was applied with a sprinkling truck during the period from 6 A.M. until 10 P.M. for each of five successive days.

Construction Details

The aggregates used consisted of a blend of crushed stone and gravel, the crushed rock being produced in the plant of the Canyon Rock Company, owned by V. R. Dennis, the major portion being taken from a quarry located at the juncture of 2 lava flows, one of which is prophritic andesite and the other a diorite breccia. These formations also have small inclusions of secondary minerals predominately calcite and lime. The sand portion of the aggregate and a small part of the coarse rock is obtained from a pit in the San Diego River. The aggregate is separated into various size classifications at the rock plant and is later hauled to the paving plant where it is stockpiled and fed on to the plant conveyor belt by means of a bull dozer operating over a tunnel. The proportioning of the material on the conveyor belt in blending the various sizes to maintain a constant grading in the plant, is more or less controlled by the bull dozer operator as more than one size rock is fed through the same opening on the tunnel. This method does not lend itself to accurate control however. Mr. F. B. Stewart, the plant inspector assigned by the District, has had considerable experience with this particular plant and maintained a

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very accurate control of materials. Mr. Stewart deserves commendation particularly in view of the plant set-up.

While it was the original intention on the part of the District to secure materials from stockpiles which had been wetted by the recent rains, a resurvey at the start of construction revealed that there was insufficient coated aggregate for the entire project. It was, therefore, necessary to distribute the more adverse material throughout the entire project as equally as possible. Detailed sieve analyses of aggregates in each of the four plant bins together with the plant proportions used in the combined grading analyses, are shown in the following table.

Table I

Bin No.	4	3	2	1		Combined
				40% screened Dry	Washed	
% Used	10%	24%	26%			100
1"	100					99
3/4"	95	100				85
1/2"	8	75	100			75
3/8"	5	38	99			56
No. 4	1	8	54	100	100	46
No. 8		3	20	99	99	39
No. 16		1	11	91	89	29
No. 30			7	72	66	19
No. 50			5	44	43	9
No. 100			4	17	19	5
No. 200			2	4	9	
No. 270				3	8	

Temperature of the aggregate at the time of mixing, was maintained at approximately 275°F. Temperatures of the mix at the time of placing on the street ranged from 225°F to 275°F for the mixes containing MC-5 and 160°F to 190°F for the mixes including emulsified asphalt. These differences in temperature between the types were undoubtedly due to the cooling caused by the evaportaion of water in the emulsion.

After being subjected to traffic for a period of one day, water was applied to the central portion of the completed pavement but before the end of the 5-day period of watering, water had spread over the entire surface.

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Performance

Mixtures containing MC-5 liquid asphalt. Up to the present date, there is no evidence of any substantial differences between the untreated cutback sections and those including the various additives. About the only evidence of susceptibility which could be detected was the appearance of coarse rock from which the asphalt had been stripped. This appearance developed progressively until by the end of the fifth day of watering, the asphalt film was removed from most of the exposed coarse stone surfaces. To date, however, all sections using cutback asphalt would be considered entirely satisfactory.

Asphalt Emulsion Sections. While emulsified asphalt was mixed in the plant with heated aggregate and a considerable amount of water evaporated during the mixing period, it was, nevertheless, evident that some moisture remained in the mixture even after placing on the road. In any event, within a few hours after watering of the road surface had been started, the section mixed with Bitumuls began to ravel and disintegrate and this behavior continued as long as the surface was wet. Ravelling of the Colas section did not start as promptly but after the end of the first day, ravelling was evident on this section as well.

The application of water to the sections containing emulsified asphalt was discontinued on the second day as the Bitumuls section had ravelled completely through the thickness of the blanket in several places. While the Colas section was in somewhat better condition, it had also softened and ravelled to such an extent that repairs and resurfacing would be necessary to prevent traffic accidents.

Conclusions

The performance of two sections mixed with emulsified asphalt from two different vendors indicates that emulsified asphalt mixtures are not resistant to disintegration if subjected to rain shortly after construction or before the water has completely evaporated from the mixture. The performance of a thoroughly cured section mixed with emulsified asphalt was not demonstrated by this experiment. All cutback sections withstood the application of water for 5 days including incidental showers of rain and gave no evidence of any softening or disintegration of the surface which would be any cause for concern.

The performance of the wet road surface under traffic appears to be in good agreement with laboratory tests on this aggregate which have not indicated any undue susceptibility to water and have not confirmed the belief expressed that this

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aggregate is definitely and consistently hydrophilic. It can only be assumed that the failures on previous construction in which this aggregate was involved, were due to other causes or that the aggregate secured for the experimental project was not in all respects, identical with that which has given trouble on previous projects. The nature of the quarry and the facilities for processing aggregates at the Dennis Plant does not make this latter an unreasonable supposition.

Attachments: Table II. Plant-Mixed Experimental Section to compare anti-stripping agents constructed between Chula Vista and San Ysidro in Jan. 1947.

Sketch "Chula Vista Experimental Section" XI-S.D-2-F.

Photographs.

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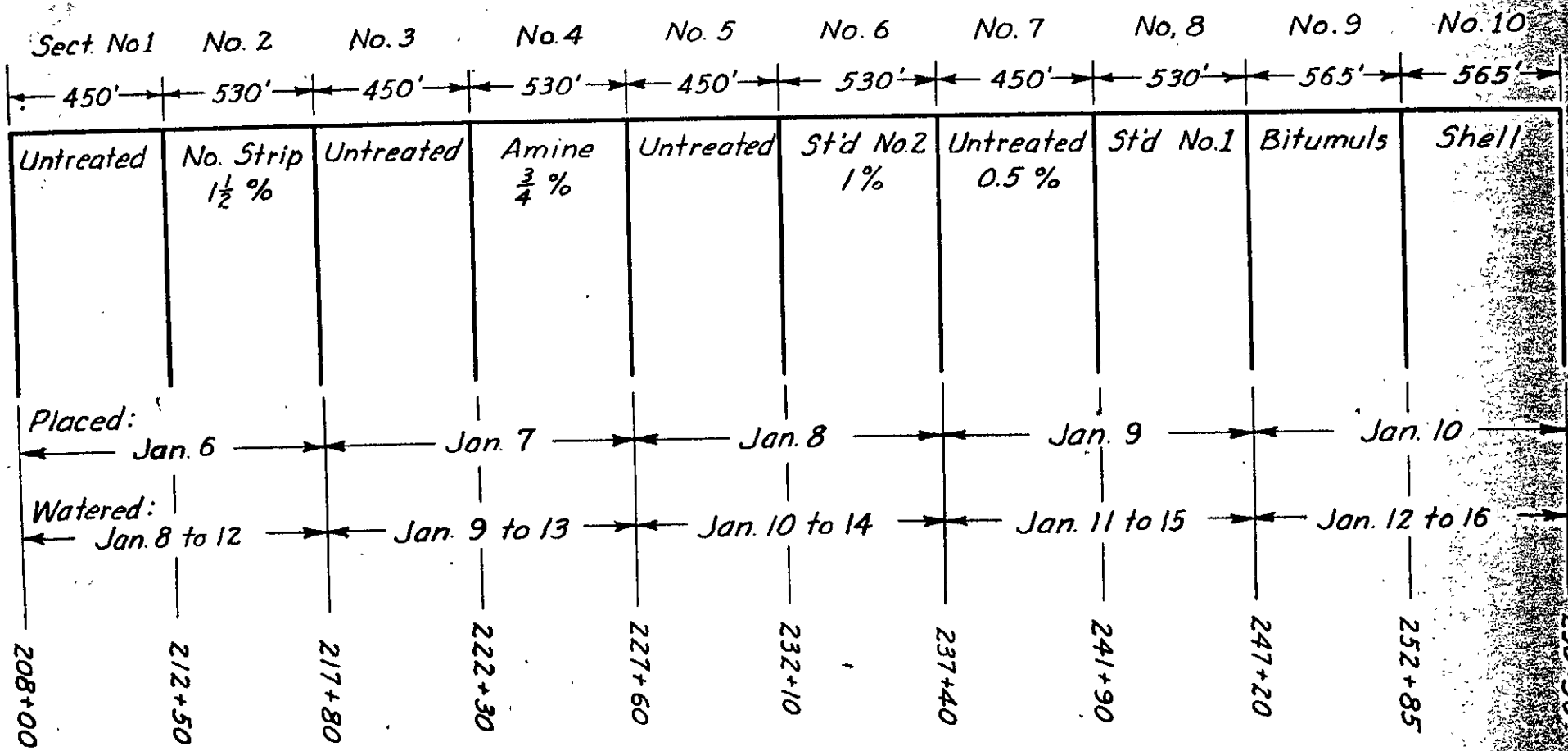

XI-SD-2-F

CHULA VISTA EXPERIMENTAL SECTION

W.O. 11X28

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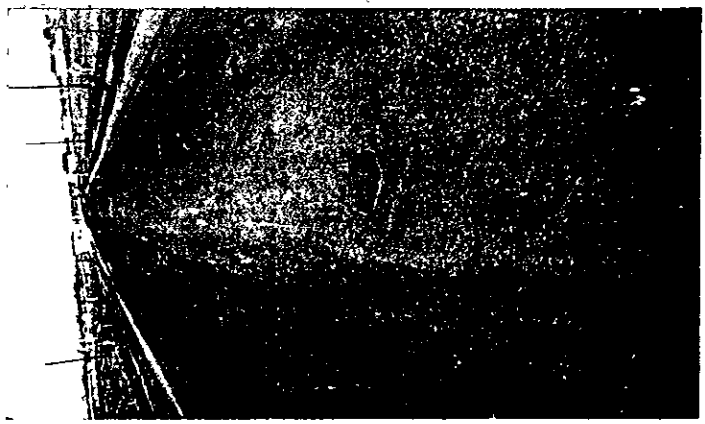
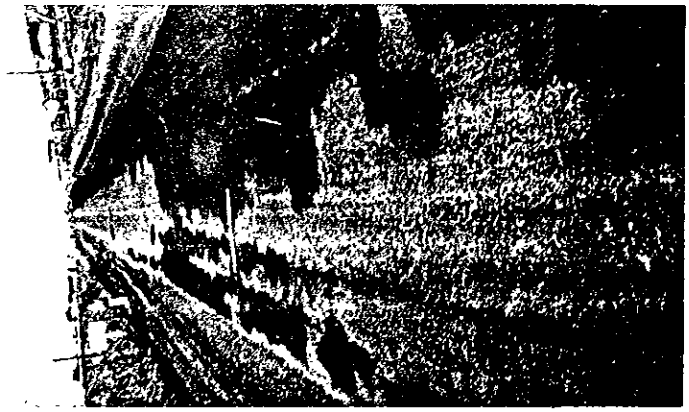


MC-5 Section After Watering 5 Days. Typical of all cut-back Sections.



Raveling in Shell Section.

Raveling in Bitumuls Section.

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TABLE II

PLANT MIXED EXPERIMENTAL SECTION TO COMPARE ANTI-STRIPPING AGENTS CONSTRUCTED BETWEEN CHULA VISTA AND SAN YSIDRO IN JANUARY, 1947

XI-S.D-2-F

FIELD DATA							LABORATORY DATA									
							Determined by Extraction		Tests on Samples as Received				After Moist. Vapor Susceptibility			
					Anti-Strip. Additive					Stability						
Station	Dist. Sample No.	Lab Test Number	Date Sampled	Type Bit.	%	Name	Bit. Ratio	% Moist. in Sple.	Swell Inches	at Room Temp.	at 140°F	Cohes 140°F	Stab. 140°F	% Moist. Absorb	Cohes 140°F	Relative Order of Apprnce.
210/00	1	51515	1-6-47	MC5	0	Untreated	4.4	0.3	0.003	40	---	112	30	0.9	153	Good
221/00	3	51519	1-7-47	MC5	0	Untreated	5.1	0.3	0.003	43	---	96	30	0.6	169	Good
231/00	-	51529	1-9-47	MC5	0	Untreated	4.8	0.3	0.000	44	----	40	32	0.8	97	Good
241/00	7	51573	1-10-47	MC5	0	Untreated	5.1	0.3	0.005	40	---	71	28	0.7	104	Good
- - -	2	51514	1-6-47	MC5	1.5	No Strip	4.2	0.4	0.005	46	---	275	34	0.8	133	Good
243/00	8	51575	1-10-47	MC5	0.5	Std. #1	4.5	0.3	0.003	44	---	154	30	0.8	85	Good
235/50	6	51528	1-9-47	MC5	1.0	Std. #2	5.9	0.2	0.001	49	---	73	26	0.3	226	Good
226/00	4	51518	1-7-47	MC5	0.75	Armor Amines	5.0	0.4	0.003	48	---	93	35	0.8	162	Good
255/00	10	51574	1-10-47	Emul.	Shell *		4.6	0.6	0.005	--	44	135	36	0.7	166	Poor
250/00	9	51576	1-10-47	Emul.	Bitumuls *		4.3	1.7	0.002	--	47	118	27	0.8	209	Very Poor

*Emulsion mixes undoubtedly failed because of rain before the mixes had thoroughly dried out on the road.

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TABLE II

Type of Treatment	2.0% Nostrip		Untreated		Standard #1	
Condition of agg.	5% Moisture	Dry	Dry	5% Moisture	Dry	5% Moisture
Grade of bitumen	SC-4	SC-4	SC-4	SC-4	SC-4	SC-4
Mixing started	9/24/46	9/25	9/24	10/9	10/9	10/10
Mixing completed	9/25/46	9/26	9/26	10/9	10/9	10/11
Started laying	9:00 AM 9/27	2 PM 9/27	12 N 9/28	1 PM 10/10	1:00 PM 10/10	12 N 10/11
Completed laying	11:00 AM 9/28	2 PM 9/28	2:30 PM 9/28	5 PM 10/10	11 AM 10/11	3:30 10/11
Compacted by roller	4-3/4 Hours	1-3/4 Hours	1-3/4 Hours	4 Hours	4 Hours	3 Hours
Water : From	6 AM 9/30	6 AM 9/30	6 PM 9/30	9 AM 10/14	9 AM 10/14	9 AM 10/14
Applied : To	4 PM 10/1	4 PM 10/1	4 PM 10/1	4 PM 10/15	4 PM 10/14	4 PM 10/14
	500'	500'	500'	500'	500'	500'

Type of Treatment	Amines		Bitumuls		Standard #2	
Condition of agg.	5% Moisture	Dry	Dry	Wet	Dry	5% Moisture
Grade of bitumen	SC-4	SC-4	Str.Res.Mix.Emul.	Str.Res.Mix.Emul.	SC-4	SC-4
Mixing started	12:30 PM 10/23	10 AM 10/24	2 PM 10/19	2 PM 10/18	2 PM 10/15	11 AM 10/16
Mixing completed	5 PM 10/23	2:30 PM 10/24	4 PM 10/21	2 PM 10/19	11 AM 10/16	4 PM 10/16
Started laying	10 AM 10/24	10 AM 10/25	12:30 PM 10/22	10 AM 10/22	11 AM 10/16	9 AM 10/17
Completed laying	12 AM 10/24	12 AM 10/25	3:30 PM 10/22	2 PM 10/22	4 PM 10/16	12 N 10/17
Compacted by roller	2 Hours	4 Hours	2 Hours	2 Hours	4 Hours	5 Hours
Water : From	*12 M 10/27	12 N 10/27	10 AM 10/24	10 AM 10/24	10:15 AM 10/18	10:15 AM
Applied : To	4 PM 10/28	4 PM 10/28	4 PM 10/25	10 AM 10/25	4 PM 10/19	4 PM 10/19

* Rained 5 hours during night

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Table III

September 15, 1947

ROAD MIXED EXPERIMENTAL SECTION TO COMPARE ANTI-STRIPPING AGENTS
CONSTRUCTED NEAR MT. AFTON IN SAN BERNARDINO COUNTY
IN SEPTEMBER AND OCTOBER, 1946

VIII-SBd-31-J

FIELD DATA						LABORATORY DATA										
						Determination by Extraction		Tests on Samples as Received				After Moist.-Vapor Susceptibility			Relative Order of Appearance	
			Anti-Strip Additive						Stability							
Lab Test No.	Date Sampled	Type Bit.	%	Name	Water Add. to Aggr. Prior to Oil	Bit. Ratio	% Moist. in Sample	Swell In.	at Room Temp.	at 140°F	Cohes. 140°F	Stab. 140°F	% Moist. Absorb	Cohes. 140°F	Nov. 1 1946	Jan. 16 1947
50828	9-27-46	SC-4	0	Untreated	None	3.1	0.4	0.006	40	-	60	23 20	2.6 3.2	85 101	F	D
50947	10-46	"	0	Untreated*	3%	2.3	1.3	0.003	38	-	147	8	3.1	32	I*	I
50829	9-27-46	"	2.0	No Strip	None	3.2	0.4	0.013	41	-	150	21 15	2.3 3.6	246 108	D	C
50827	9-27-46	"	2.0	No Strip	3%	3.3	1.1	0.001	38	-	180	25 33	1.2 2.2	135 184	C	B
50946	10-8-46	"	-	Std. #1 *	None	2.8	1.0	0.006	37	-	111	24 ° 21	1.5 2.1	124 127	G*	G
50945	10-8-46	"	-	Std. #1 *	3%	2.1	1.4	0.002	41	-	73	5 15	5.1 3.7	50	H*	H
50974	- -	"	-	Std. #2	None	3.4	0.7	0.007	41	-	141	25	2.0	295	A	A
51027	- -	"		Std. #2	3%	4.3	1.7	0.000	-	37	282	19 16	0.5 1.0	484 447	A	A
51059	10-24-46	"	0.75	Armour Amines	None	3.3	0.7	0.007	38	-	244	20	3.4	174	B	E
51060	10-24-46	"	0.75	"	3%	3.8	0.6	0.017	35	-	178	15	4.2	[illegible]	B	E
51028	- -	Emuls	Bitumuls Non-Stripping		None	3.0	4.6	0.035	3	29	202	7 8	5.6 7.0	58 64	E	F
51026	- -	"	"		3%	2.3	5.8	0.007	2	40	37	11 5	5.8 6.5	89 33	E*	F

*Asphalt content too low for fair comparison

°Failed due to ravelling before water was applied

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TABLE II

ROAD MIXED EXPERIMENTAL SECTION TO COMPARE ANTI-STRIPPING AGENTS
CONSTRUCTED BETWEEN ALTURAS AND LIKELY IN JULY, 1946

September, 1947

II-Mod-73-C

FIELD DATA									LABORATORY DATA									
									Determined by Extract.		Tests on Samples as Received				After Moist. Vapor Susceptibility			
			Date Sampled			Anti-Strip Additives						Stability						
Station	Dist. Sample Number	Lab Test No.	Date 1946	Time	Type Bit.	%	Name	Water Add to Aggr. Prior to Oil	Bit. Ratio	% Moist. in Sple.	Swell In.	at Room Temp	at 140°F	Cohes 140°F	Stab. 140°F	% Moist Absorb	Cohes 140°F	Relative Performance
86/50	11-153B	49832	7-17	11:00A	ROMC3	0	Untr.	None	None	4.7	---	55	--	255				Failed
86/50	"	49829	"	"	"	0	"	"	4.3	3.2	---	43	--	225				"
86/50	11-155B	49822	"	2:30P	"	0	"	"	3.6	-	0.156 0.147	-	43	95				"
33/00	11-152B	49831	"	11:00A	"	0	"	3.0	---	6.4	---	44	--	200				"
33/00	"	49828	"	11:00A	"	0	"	3.0	3.8	4.6	---	38	--	312				"
33/00	11-154B	49821	"	2:30P	"	1.5	"	3.0	2.6	---	0.070 0.094	--	41	Broke	14	6.2	Broke	"
39/00	11-158B	49833	"	3:30P	"	1.5	No Strip	3.0	---	5.7		36		211				"
39/00	"	49827	"	3:30P	"	1.5	"	3.0	4.5	3.8	---	39	--	207				"
33/00	11-160B	49826	--	---	"	1.5	"	None	None	2.2	---	38	--	190	16	5.0	393 cold	"
33/00	--	49819	7-18	11:00A	"	1.5	"	None	5.8	---	0.145 0.147	--	35	248	10	5.4	334	"
30/00	11-166B	49834	"	--	"	0.75	Armour Amines	None	None	3.4	---	41	--	184				Fairly Good
30/00	11-165B	49825	"	2:30P	"	"	"	"	"	2.7	---	34	--	190	15	4.0	494 cold	"
30/00	11-165B	49818	"	4:00P	"	"	"	"	5.9	---	0.134 0.125	--	35	299	11	5.0	236	"
35/00	11-163B	49830	"	2:30P	"	"	"	3.0	None	3.2	---	32	--	153	19	4.5	373 cold	"
35/00	"	49835	"	"	"	"	"	3.0	"	5.6	---	45	--	262				"
35/00	11-164B	49823	"	4:00P	"	"	"	3.0	5.4	--	0.079 0.071	--	37	290	17	3.6	740 cold	"