47

Louisiana Highway Research

FIELD EVALUATION

OF

SKID RESISTANT SURFACES

Louisiana Department of Highways – Research & Development Section

FIELD EVALUATION OF SKID RESISTANT SURFACES

Final Report

Part I

by

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FIELD EVALUATION OF SKID RESISTANT SURFACES

SYNOPSIS

This project was undertaken to establish a thin bituminous surface course that would possess good skid resistant qualities as well as, being both economical and durable.

This is the final report on the evaluation of skid resistant surfaces which was conducted by the Louisiana Department of Highways in cooperation with the Bureau of Public Roads.

The study consisted of constructing eleven duplicate 1000 foot test sections on a roadway that carried approximately 9700 vehicles per day. These test sections included four different types of bituminous mixtures, such as, asphaltic concrete, sand asphalt, plant mix seals and slurry seal. The various aggregates used in these test sections consisted of crushed gravel, slag, expanded clay and granite.

The evaluation of the test sections was based primarily on the skid resistant qualities of the mixtures with some consideration given to the ease of construction and finished riding surface. Skid resistance was obtained on each of the test sections at approximately four month intervals up to eleven months after completion. At eleven months the final results were obtained on the test sections, which had carried a total of 3,209,346 vehicles. The evaluation included comparisons of skid numbers and roughness results for the various test sections at different time intervals after completion.

In general, the plant mix seals proved to be the most favorable of the different mixtures. The slag and expanded clay plant mix seals gave higher skid numbers than did the crushed gravel. The expanded clay slurry seal and Kentucky sand asphalt also resulted in high skid numbers. Of the asphaltic concrete mixtures the expanded clay hot mix showed the highest skid number after eleven months of traffic.

Of all the test sections evaluated the plant mix seals gave the lowest roughness readings up to eleven months after construction, whereas, the Kentucky sand and slurry seals gave the highest.

IMPLEMENTATION

Due to the favorable results obtained from this study on the bituminous plant mix seals. A slag plant mix seal was constructed on State Project 450-16-72. Interstate 10 in New Orleans which is a six lane highway that carries approximately 70,000 vehicles per day. This project has been completed approximately three weeks and the appearance is very favorable.

Arrangements are also being made by several of the nine districts in the state to construct some plant mix seals on maintenance projects.

It is anticipated that in time, the plant mix seals may play a very important role in most of our bituminous construction as a thin skid resistant surface.

The following are the conclusions obtained from this study.

1. Of the four different types of surface courses evaluated, namely plant mix seal, asphaltic concrete, sand asphalt and slurry seal; the plant mix seals possessed the most desirable features, such as: ease of construction, high skid resistance and low roughness values.

2. After being subjected to traffic for eleven months (3,209,346 vehicles) the Kentucky sand asphalt and expanded clay plant mix seal possessed the highest skid numbers of 63 at 40 miles per hour than any of the other test sections.

3. The expanded clay slurry seal had an average skid number of 63 after eight months or 2,244,591 vehicles.

4. The skid numbers for the plant mix seals increased with traffic up to four months and levelled off up to eleven months. The asphaltic concrete mixtures increased at four and eight months and slightly decreased at eleven months.

5. The crushed gravel plant mix seal with 95 percent crushed material had an average skid number of 49 at 40 miles per hour as compared to only 41 for the 75 percent crushed gravel seal after eleven months of traffic. This clearly indicates that when using gravel plant mix seal, a minimum of 95 percent crushed material should be required.

6. The percent decrease in the average skid numbers when testing at 40 and 60 miles per hour was the least (12 to 16 percent) on the plant mix seals and the expanded clay slurry seal, with the exception of the 75 percent crushed gravel plant mix seal which decreased as much as 29 percent. The other test sections decreased in skid numbers in the range of 22 to 31 percent.

7. The plant mix seals showed the least amount of roughness after eleven months of traffic. The range of roughness values in inches per mile were 108 to 111 for the slurry seals and Kentucky sand sections, from 88 to 104 for the asphaltic concrete and from 76 to 81 for the plant mix seals.

INTRODUCTION

For too many years the topic of skid resistance in the finished hot mix pavement has been neglected. Pavements in the past were designed for strength, durability, resistance to cracking and flexibility with very little emphasis on skid resistance. Skid resistance was probably considered in many mix designs, however these were very few reliable and practical methods of determing skid resistance until recently.

Highway engineers appear to be more safety oriented than ever before, especially with the increasing volumes of traffic being encountered. Due to the advances in the field of Highway Engineering there is reliable and practical equipment for determining the skid resistance of a roadway that is open to traffic without presenting any additional hazard to the motoring public. This equipment is a skid trailer which is capable of obtaining the coefficient of friction of a given surface at various speeds.

In 1967 our Concrete research section completed the construction of a skid trailer which was built in accordance with ASTM Designation E 274-65T entitled "Skid Resistance of Pavements using a Two Wheel Trailer". Many miles of roadway were tested for skid resistance on projects varying in age, and for the first time comparisons of skid resistance were made between projects. In some cases it was very alarming to see that some of the types of hot mix being used did not yield very good skid resistant surfaces. This acknowledged a need for obtaining a thin highly skid resistant surface course which would be both economical and durable.

In an effort to satisfy this criteria a research study was initiated by the Louisiana Department of Highways in cooperation with the Bureau of Public Roads to evaluate eleven different thin surfaces for their skid resistant qualities.

SCOPE

The primary purpose of this research was to evaluate the skid qualities of several different bituminous surface courses, as well as, their pavement performance after being subjected to traffic.

This was accomplished by constructing eleven different types of thin bituminous surfaces. Skid resistance was checked periodically as was the roughness measurements. Visual observations were made to evaluate the pavement performance under traffic.

METHODOLOGY

Location and Description of Test Sections

Eleven different types of bituminous surfaces were constructed on State Project 13-05-18 on La. U.S. 190, Baton Rouge - Denham Springs Highway. The project consisted of ten duplicate 1000 foot test sections and one single 1000 foot test section. The test sections were constructed on the westbound roadway which has an average traffic volume of approximately 9700 vehicles per day.

The following is a description of each of the eleven types of bituminous surfacing with a diagram of the test sections.

Test Section	Description
1	Control Section - Type 1 hot mix surface consisting of crushed gravel, coarse sand, fine sand, mineral filler and asphalt cement. Approximate thickness one inch.
2	Open graded crushed gravel hot mix, consisting of a minimum of 15 percent gravel screenings, crushed gravel, coarse sand, mineral filler and asphalt cement. Approximate thickness one inch.
3	Type 4 expanded clay hot mix surface, consisting of expanded clay aggregate, coarse sand, fine sand, mineral filler and asphalt cement. Approximate thickness one inch.

4 Louisiana sand asphalt hot mix surface, consisting of local coarse sand, fine sand, mineral filler and asphalt cement. Approximate thickness 0.75 inches.

5 Kentucky sand asphalt hot mix surface, consisting of asphalt impregnated sandstone rock and asphalt cement. Contains approximately 3 1/2 to 4 1/2 percent natural bitumen. Approximate thickness 0.75 inches.

6 Crushed gravel plant mix seal, consisting of crushed gravel (95 percent crushed) and asphalt cement. Approximate thickness 5/8 inch.

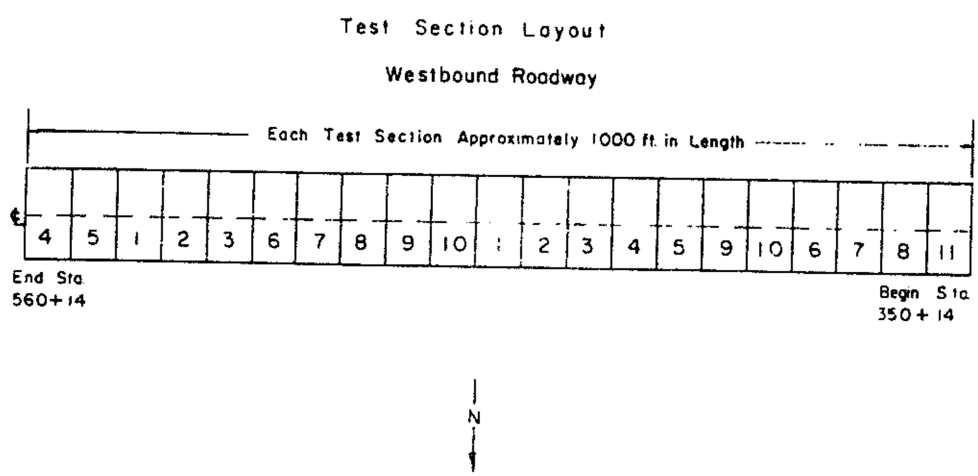
7 Expanded clay plant mix seal, consisting of expanded clay aggregate and asphalt cement. Approximate thickness 5/8 inch.

8 Slag plant mix seal consisting of blast furnace slag and asphalt cement. Approximate thickness 5/8 inch.

9 Expanded clay slurry seal, consisting of expanded clay aggregate, two percent cement and a cationic quickset emulsion. Approximate thickness 3/8 inch.

10 Granite slurry seal, consisting of granite, two percent cement and a cationic quickset emulsion. Approximate thickness 3/8 inch.

11 Crushed gravel plant mix seal, consisting of crushed gravel (75 percent crushed) and asphalt cement. Approximate thickness 5/8 inch.



Test Section Reduced Layout

The test sections consisted of three asphaltic concrete mixtures, two sand asphalt mixtures, four plant mix seals and two slurry seals. All of the test sections with the exception of the slurry seals were constructed under contract by Barber Brothers Construction Company of Baton Rouge. The two slurry seal sections were constructed by the District 61 maintenance forces.

Construction Control

Each of the various mixtures were controlled during construction. The asphaltic concrete and sand asphalt mixtures were tested at the plant and on the roadway for such properties as Marshall Stability, voids, voids filled, gradation, asphalt content and roadway density. The plant mix seals were tested for extracted gradation and asphalt content only, whereas the slurry seals were tested for gradation only. The Rex slurry-seal machine was calibrated prior to construction to determine the quantity of emulsion in the mixture. All of the average test results for the various test sections may be found in Table 1, Appendix A.

Each of the test sections were constructed in one lift with the exception of the slurry seals which were constructed in two lifts. The hot bituminous mixtures were spread with a spreader having automatic screed control to the approximate thickness mentioned in the description of the test sections.

Rolling of the asphaltic concrete mixtures was accomplished by a tandem, pneumatic and tandem in that order. The sand asphalt mixtures were rolled with a tandem only and the plant mix seals with a tandem and then a pneumatic roller. The slurry seals were rolled with a pneumatic roller only after curing of the emulsion.

Test Performed to Evaluate Test Sections

The evaluation of the test sections consisted of obtaining skid resistance values at zero, four, eight and eleven months after completion. Roughness results were also obtained at four and eleven months after completion. These tests results were compared for the various test sections and the relationship between skid resistance and volume of traffic obtained. The skid resistance was obtained by the Louisiana Department of Highways skid trailer (Figure 1).

The roughness results were used primarily to compare the riding surface between test sections after being subjected to traffic.

Visual observation was also used as a basis for evaluating the test sections.

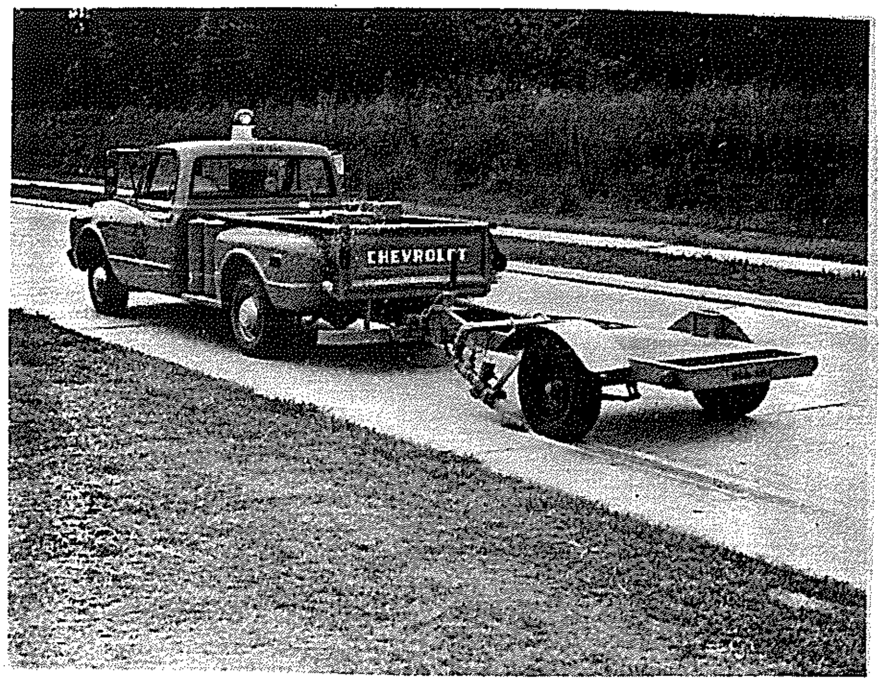


Figure 1 - Photograph of the skid trailer.

DISCUSSION OF RESULTS

The evaluation of the test sections were based primarily on comparative results for skid resistance, roughness and visual observation over an eleven month period. The test results obtained represented four different types of bituminous mixtures utilizing five different aggregate types. This provided a means of comparing results of asphaltic concrete, sand asphalt, plant mix seals and slurry seals, as well as, determining the most desirable aggregates for improving skid resistance.

Of the eleven test sections constructed each of the various type mixtures have been used in Louisiana before, with the exception of the plant mix seals and the Kentucky sand asphalt. Plant mix seals have been used for several years in a number of the Western States and all reports indicate excellent results.

Plant mix seals are somewhat different than most bituminous mixtures. As the name refers, a plant mix seal is merely a seal coat material mixed in a hot mix plant. The mix contains an asphalt coated aggregate without the use of sand or mineral filler. The gradation of the aggregate is as shown in Table 1, Appendix A for plant mix seals.

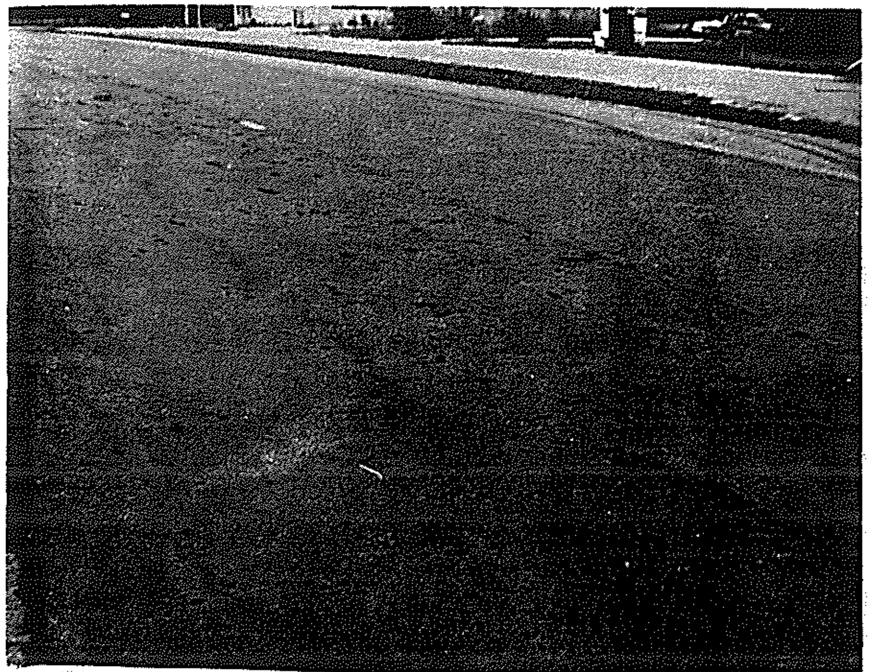
The materials are mixed in a hot mix plant at high asphalt contents and at temperatures below 260°F. The object of the high asphalt content and low mixing temperature is to obtain a greater film thickness of asphalt on the aggregate. The mix is applied through a conventional spreader and rolled with a tandem and pneumatic roller.

The Kentucky sand asphalt was constructed similar to other sand asphalts. The Kentucky sand is a asphalt impregnated quartz sandstone rock which contains approximately 3 1/2 to 41/2 percent natural bitumen. Additional asphalt is added to the Kentucky sand as in other sand asphalt mixtures.

Problems Encountered During Construction

There were certain problems encountered during construction for some of the test sections. On one of the Kentucky sand asphalt sections the material began to ravel out after approximately two days of traffic. This pitting or ravelling only occurred in one lane for a distance of approximately 200 feet. Figure 2 shows two photographs of the pitting that occurred. The reason for this has never definitely been determined, however, it is believed that it was possibly due to improper mixing of one or two batches at the plant. The length of the pitting was approximately the distance one truck load of material would cover. Since a manual batch plant was being used it was assumed that an error was made during batching. Improper mixing would be difficult to see visually since the sand is already black from the natural asphalt in it. The bad section was taken out and replaced and there was no other detrimental effects observed on the Kentucky sand asphalt sections.

Another less severe problem occurred while constructing the expanded clay plant mix seal. The specifications state that the mix when discharged from the pugmill should not exceed 260°F, however, on one particular truck the mix was approximately 300°F which resulted in some of the asphalt dripping to the bottom of the truck. This was not detrimental to the mix on the roadway, however, it did cause some of the mix to stick to the truck bed when dumping the mix into the spreader. Figure 3 shows a photograph of what may occur when heating the mixture above 250°F on a plant mix seal.



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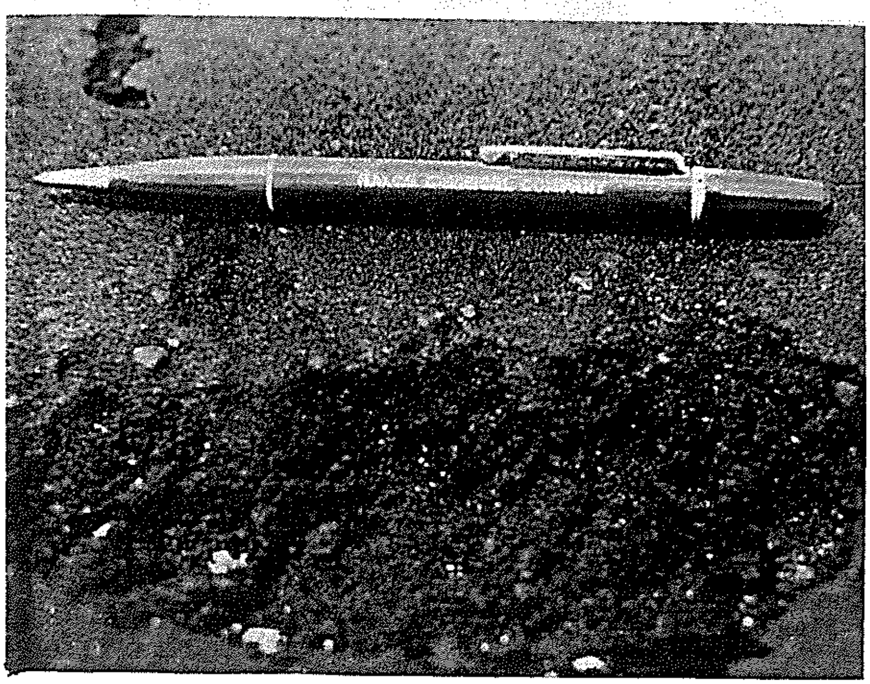

B

Figure 2 - Photograph of failures in the Kentucky Sand Asphalt sections.

The mix at the bottom of the truck bed may not appear to be very critical, however, it will cause more mix to accumulate on succeeding loads, in addition to being very difficult to clean at the end of the day. It is recommended that a soap solution be used to wet down the truck bed before each load to prevent the mix from sticking.

Figure 3 - Photograph of overheated Plant Mix Seal sticking to truckbed.

Skid Resistance

The most important results of this study is the skid resistant qualities of the various mixtures. Skid resistance was obtained on most of the test sections immediately after completion and at four, eight and eleven months after completion. The skid resistance values are referred to as skid numbers, which is merely the coefficient of friction multiplied by 100. The skid resistance was obtained at speeds of 20, 40 and 60 miles per hour however, 40 miles per hour is the standard accepted speed to run skid measurements and therefore most of the evaluation was based on skid numbers at 40 miles per hour.

Of the eleven test sections constructed,two of the mixtures were not included in the complete evaluation of the surfaces. A comparison of the average skid numbers for all the test section are shown in Table 3 of Appendix A. As indicated by the table,the Louisiana sand asphalt has the lowest skid numbers of all the test sections. There is no universal skid number at 40 miles per hour designating whether the skid resistance is satisfactory. However, the Bureau of Public Roads has tenatively set a skid value of 35 plus as acceptable when tested at 40 miles per hour.

The skid number of the Louisiana sand asphalt at 40 miles per hour was 33, which was below the Bureau of Public Roads standard. There were also reports that the Louisiana sand asphalt section was slick when wet, causing several vehicles to leave the roadway at relatively low speeds. For this reason it was decided to construct a slurry seal over the Louisiana sand asphalt section and therefore a full evaluation of the sand asphalt was not made.

The other mixture not included in the full evaluation is the granite slurry seal. Skid resistance was measured and recorded as shown in Table 3 of Appendix A. There is some question as to whether or not these values are representative of a granite slurry seal. The uncertainty of the validity of these results have stemmed from problems encountered during construction. The problems resulted from the quickset cationic emulsion "breaking" in the spreader box, causing the operator to add more water to the slurry which proved to be excessive, thereby causing the emulsion to float to the top of the surface. This resulted in having less granite aggregate in the mix causing a less skid resistant surface. Therefore it was decided that the skid numbers be reported in the tables, but comparisons of the granite slurry seal with the other mixtures was not made.

There are several factors that affect skid resistance of a surface. Probably the most influential are:surface texture, type of aggregate, and the resistance to polishing under traffic. Appendix B consists of a series of photographs showing the appearance and surface texture of the various test sections.

As indicated in Appendix B, there is a variety of surface textures as well as aggregate types. This is most important in studying skid resistance.

Figure 4 shows the relationship of the average skid numbers at 40 miles per hour versus time and traffic. In most cases the skid numbers increased from immediately after construction to four months and the asphaltic concrete mixtures had an additional increase after eight months before a slight decrease

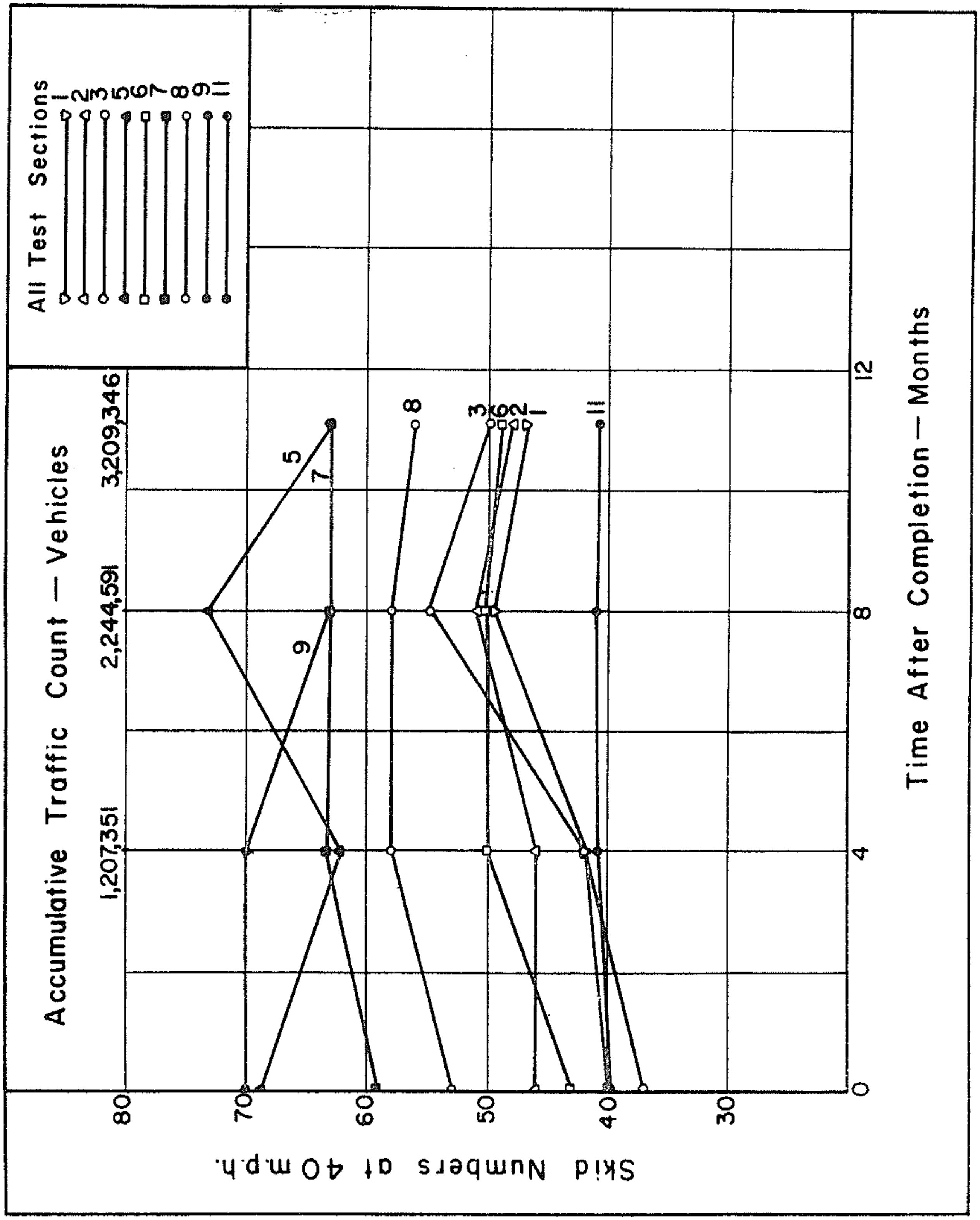

Figure 4 - Relationship of skid numbers at 40 MPH versus time and traffic for all test sections.

at eleven months. The skid numbers on the Kentucky sand asphalt were erratic as there was a drop at four months an increase at eight and another decrease at eleven months. The Kentucky sand did give the highest skid number of all the test sections with a value of 73 at eight months. However, the skid number dropped to 63 at eleven months, which is equivalent to that obtained by the expanded clay plant mix seal for the same period of time.

The expanded clay slurry seal section had skid numbers of 70 up to four months of traffic and dropped to 63 at eight months. The eleven month interval for the slurry seals were not yet due since the slurry seals were constructed approximately three months after the other test sections. Results will be obtained at longer intervals on the slurry seals, as well as, on the other test sections.

The total traffic count on the test sections after eleven months was 3,209,346 vehicles as determined by a traffic station near the job site. The eleven month results indicate a slight decrease in the skid numbers for the asphaltic concrete sections, however, there does not appear to be any excessive polishing of the aggregate.

Figure 5 shows the skid number versus time for the Kentucky sand and asphaltic concrete test sections only. In each case the asphaltic concrete sections showed an increase of skid resistance up to eight months or 2,244,591 vehicles after which a slight decrease occurred at eleven months. It is interesting to note that of the asphaltic concrete mixtures, the expanded clay hot mix had a lower skid number at zero and four months after completion. It has been proven on past studies that the expanded clay hot mixes have superior skid resistant qualities to the standard crushed gravel hot mixes, due primarily to the nature of the coarse expanded clay aggregate.

The Kentucky sand asphalt as shown in Figure 5 did give very high skid numbers, however there was some difficulty in obtaining a satisfactory riding surface and it is believed that the cost for shipping the material into Louisiana would be prohibitive.

Figure 6 shows the skid numbers versus time for the plant mix seals and expanded clay slurry seal sections. The plant mix seal curves showed similar trends. There was an increase in skid resistance from zero to four months and very little change from four to eleven months even though being subjected to over two million more vehicles. This would indicate that skid resistance on plant mix seals tend to level off quicker than a mix that contains sand and

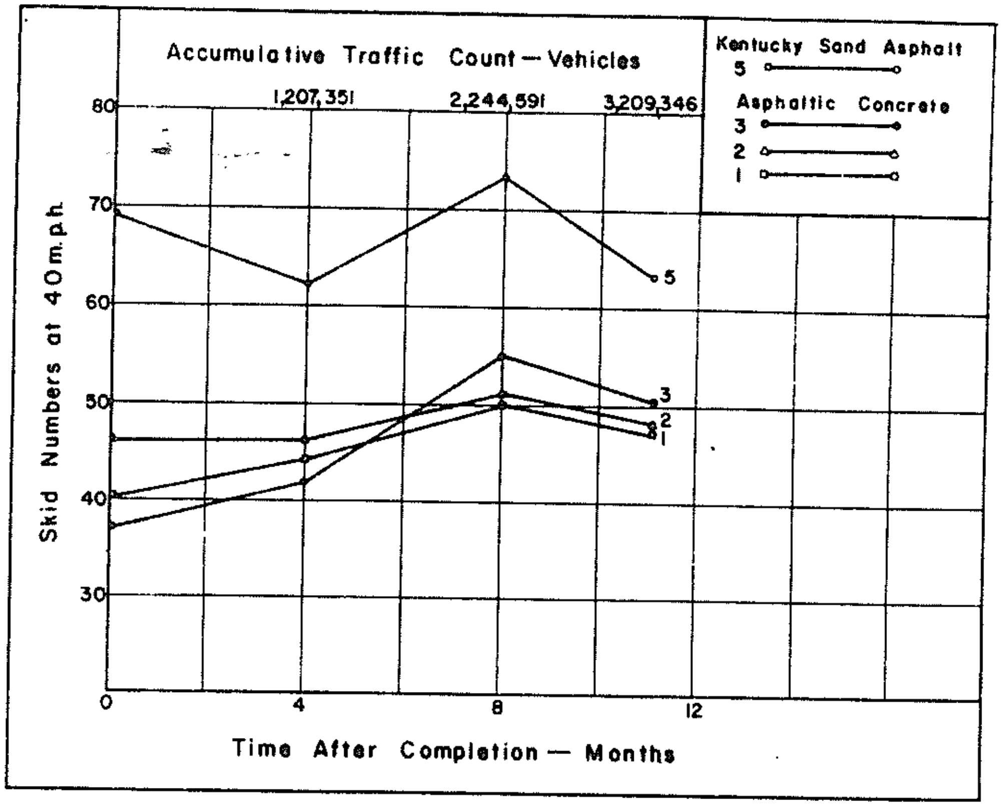

Figure 5 - Relationship of skid numbers at 40 MPH versus time and traffic for the Asphaltic Concrete and Kentucky Sand Asphalt sections.

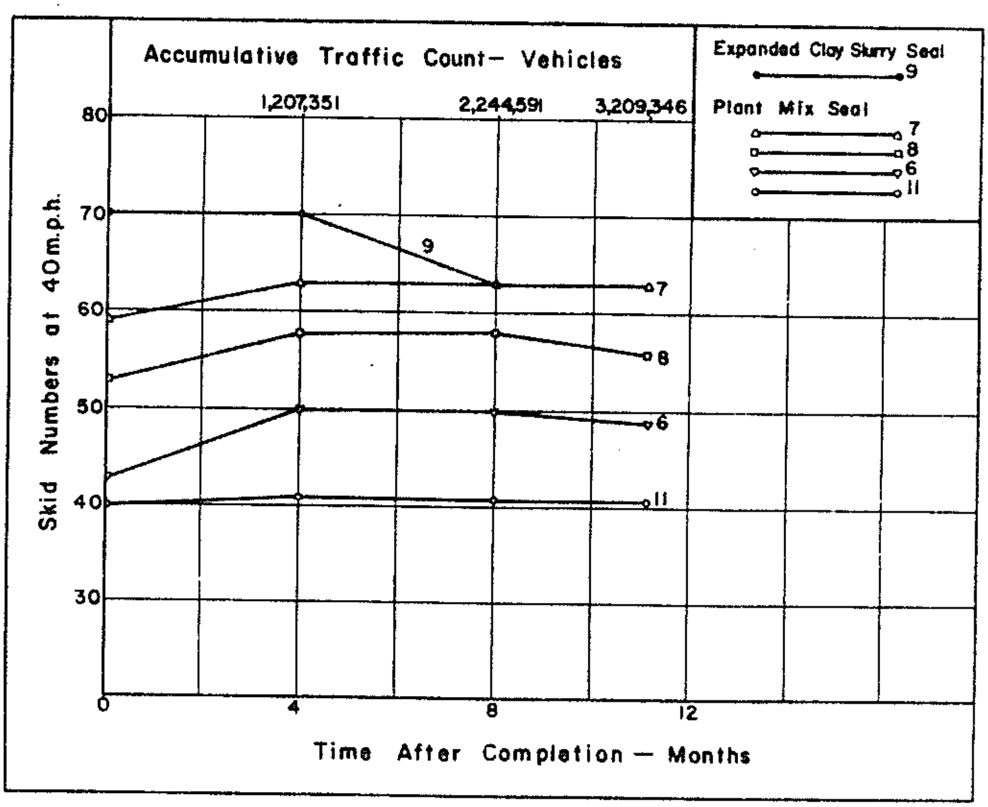

Figure 6 - Relationship of skid numbers at 40 MPH versus time and traffic for the Plant Mix Seals and expanded Clay Slurry Seal.

coarse aggregate. It also seems reasonable that the plant mix seal would maintain a constant skid resistance, as long as, the aggregate being used is not susceptible to excessive polishing.

Figure 6 also illustrates the importance of the type of aggregate used in the mix. Each of the plant mix seals conformed to the same gradation requirements, however, the expanded clay and slag plant mix seals had superior skid resistance to the crushed gravel seals. Again this is characteristic of the aggregate. It is very interesting to note that the 95 percent crushed gravel seal was superior to the 75 percent crushed gravel seal, indicating that increased angularity of a particular aggregate should result in higher skid resistance.

The expanded clay slurry seal shows extremely high skid numbers at zero and four months after completion and a decrease equivalent to that of the expanded clay plant mix seal after eight months of traffic. Additional results will be obtained on all the test section, however, it is anticipated that the slurry seal will fall below that of the plant mix seals with increasing traffic although maintaining a satisfactory skid resistance value.

Although the adopted speed for running skid resistance is presently 40 miles per hour, it is very important to know how the skid resistance changes with increasing speeds since the speed limits on most highways are above 40 miles per hour. Figure 7 shows bar graphs illustrating the percent decrease in skid numbers at eight months for the various test sections when testing from 40 to 60 miles per hour. The bar graphs indicate that the percent change in skid resistance varies on different surfaces, depending again on the surface texture, type of aggregate and its susceptibility to hydroplaning. Of the nine sections in Figure 7, the plant mix seals and expanded clay slurry seal showed the least percent decrease in skid numbers when testing from 40 to 60 miles per hour. The 75 percent crushed gravel plant mix seal was higher than all but one of the other mixes, indicating the importance of crushed aggregate in a gravel plant mix seal. It is believed that plant mix seals are less susceptible to hydroplaning than the dense graded hot mixes due to its open graded texture.

Roughness

One of the other important criteria in which the test sections were evaluated was roughness. Roughness measurements were taken on all of the test sections at four and eleven months after construction. The results in Figure 8

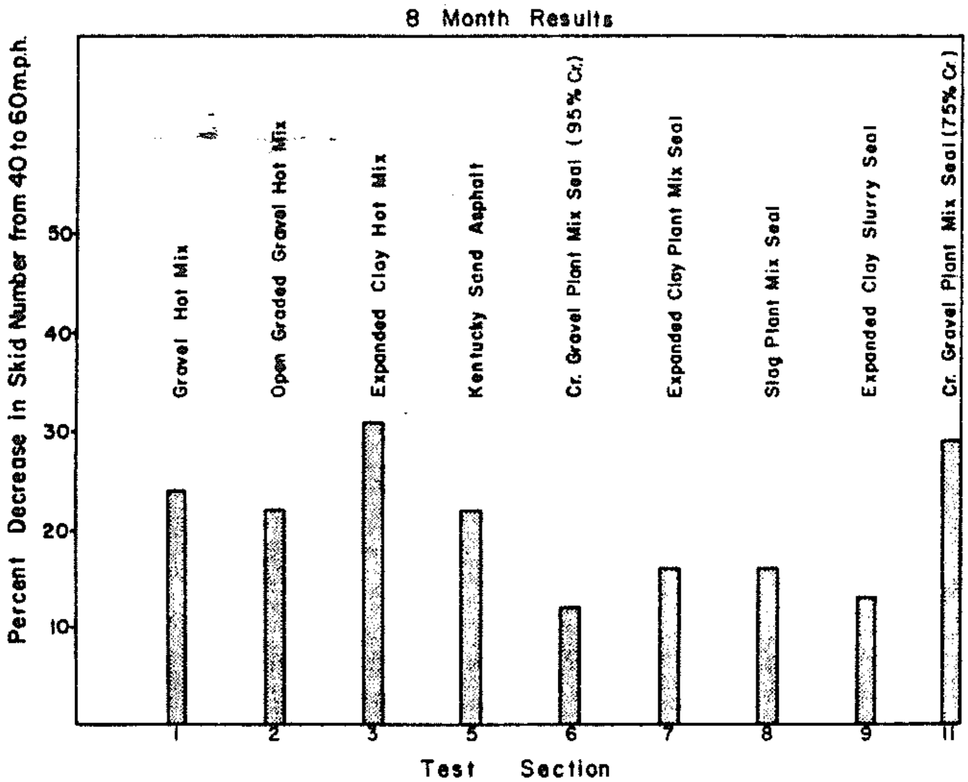

Figure 7 - The eight month results for the percent decrease in skid numbers from 40 to 60 MPH.

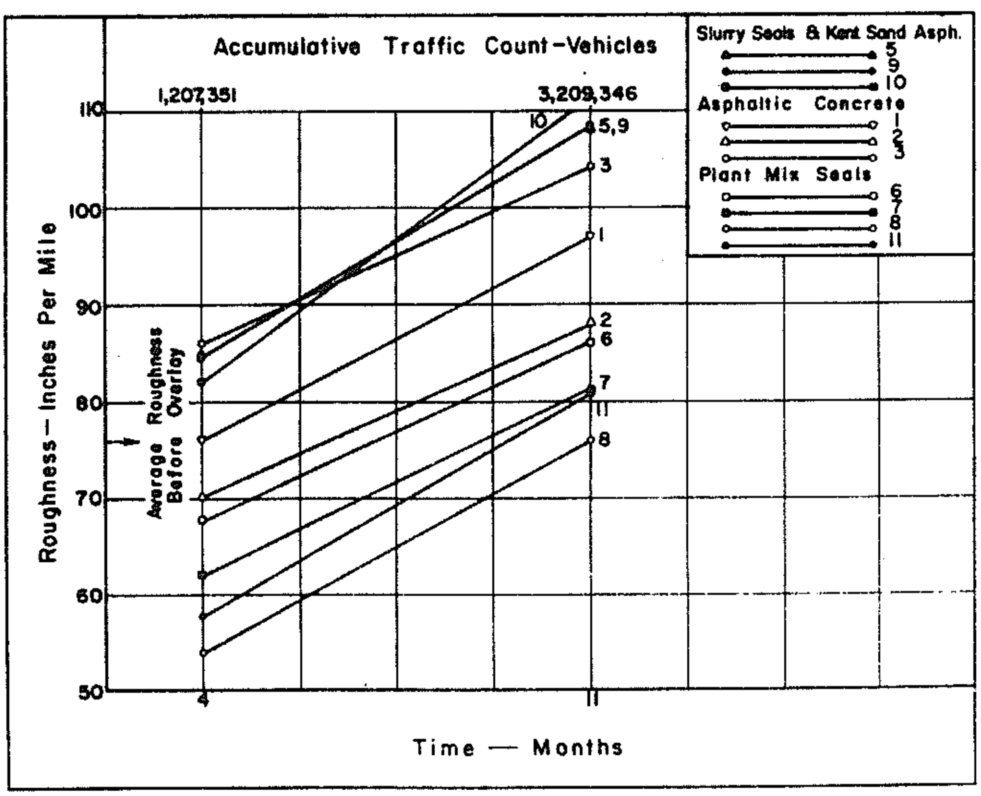

Figure 8 - Relationship of roughness versus time and traffic for all of the test sections.

shows that the plant mix seals had the lowest roughness of all the test section. The slurry seals and Kentucky sand asphalt gave the highest roughness values at both four and eleven months. The average roughness of the roadway before overlay was approximately 76 inches per mile. After eleven months and three million vehicles the plant mix seals show a roughness range of 76 to 81 which for all practical purposes may be rated as good, as based on the following description.

Adjective Description	Roughness Values Inches Per Mile Flexible Pavement
Very Good	Less than 65
Good	65-80
Fair	80-100
Rough	More than 100

This is considered very good for a surface that is only approximately 5/8 of an inch thick. The asphaltic concrete mixtures ranged from 88 to 104 and the slurry seals and Kentucky sand asphalt from 108 to 111.

In general the plant mix seals appear to be most satisfactory for use as a thin skid resistant surface. It is easy to construct and results in higher skid numbers with lower roughness values. Although a complete cost estimate cannot be made from this project, it is believed that the cost per square yard will be very competitive with most other types of seal coats being used.

CONCLUSIONS

1. Of the four different types of surface courses evaluated, namely plant mix seal, asphaltic concrete, sand asphalt and slurry seal; the plant mix seals possessed the most desirable features, such as: ease of construction, high skid resistance and low roughness values.

2. After being subjected to traffic for eleven months (3, 209, 346 vehicles) the Kentucky sand asphalt and expanded clay plant mix seal possessed the highest skid numbers of 63 at 40 miles per hour than any of the other test sections.

3. The expanded clay slurry seal had an average skid number of 63 after eight months or 2, 244, 591 vehicles.

4. The skid numbers for the plant mix seals increased, with traffic, up to four months and leveled off up to eleven months. The asphaltic concrete mixtures increased at four and eight months and slightly decreased at eleven months.

5. The crushed gravel plant mix seal with 95 percent crushed material had an average skid number of 49 at 40 miles per hour as compared to only 41 for the 75 percent crushed gravel seal after eleven months of traffic. This clearly indicates that when using gravel plant mix seal, a minimum of 95 percent curshed material should be required.

6. The percent decrease in the average skid numbers when testing at 40 and 60 miles per hour was the least (12 to 16 percent) on the plant mix seals and the expanded clay slurry seal, with the exception of the 75 percent crushed gravel plant mix seal which decreased as much as 29 percent. The other test sections decreased in skid numbers in the range of 22 to 31 percent.

7. The plant mix seals showed the least amount of roughness after eleven months of traffic. The range of roughness values in inches per mile were 108 to 111 for the slurry seals and Kentucky sand sections, and from 88 to 104 for the asphaltic concrete and from 76 to 81 for the plant mix seals.

APPENDIX "A"

AVERAGE PHYSICAL PROPERTIES OF THE VARIOUS BITUMINOUS MIXTURES
TEST RESULTS OF ASPHALT CEMENT
AVERAGE SKID NUMBERS
AVERAGE ROUGHNESS RESULTS

TABLE 1

AVERAGE PHYSICAL PROPERTIES OF THE VARIOUS BITUMINOUS MIXTURES

Test Section 1 - Type IV Hot Mix, Crushed Gravel (Control)

Mineral Aggregate	95%	
Asphalt Content	5%	(AC-3 60/70 penetration)
Crushed Aggregate	79%	

Lab. Specific Gravity	2.339
Voids -%	5.3
Voids Filled	68.2
Marshall Stability lbs.	1885
Flow 1/100"	12
Roadway Density -%	96.3

Extracted Gradation

U.S. Sieve	Percent Passing
3/4"	100
1/2"	98
3/8"	86
No. 4	59
No. 10	44
No. 40	30
No. 80	13
No. 200	9

Test Section 2 - Open Graded Crushed Gravel Mix

Mineral Aggregate	95%	
Asphalt Content	5%	(AC-3 60/70 penetration)
Crushed Aggregate	85%	

Lab. Specific Gravity	2.302
Voids -%	5.9
Voids Filled -%	65.7
Marshall Stability lbs.	2041
Flow 1/100"	9
Roadway Density %	93.2

Extracted Gradation

U.S. Sieve	Percent Passing
3/4"	100
1/2"	98
3/8"	87
No. 4	66
No. 10	43
No. 40	23
No. 80	7
No. 200	4

TABLE 1 (cont'd)

Test Section 3 - Type 4 Expanded Clay Hot Mix

Mineral Aggregate -	92.5	
Asphalt Content -	7.5	(AC-3 60/70 penetration)

Lab. Specific Gravity -	1.722
Voids %	7.9
Voids Filled %	63.6
Marshall Stability lbs.	1496
Flow 1/100"	8
Roadway Density %	96.5

Extracted Gradation

U.S. Sieve	Percent Passing
3/4"	100
1/2"	98
3/8"	89
No. 4	73
No. 10	66
No. 40	45
No. 80	16
No. 200	10

Test Section 4 - Louisiana Sand Asphalt

Mineral Aggregate -	93.5	
Asphalt Content % -	6.5	(AC-3 60/70 Penetration)

Lab. Specific Gravity -	2.225
Voids %	8.1
Voids Filled %	63.4
Marshall Stability lbs.	802
Flow 1/100"	12
Roadway Density %	94.0

Extracted Gradation

U.S. Sieve	Percent Passing
No. 4	100
No. 10	92
No. 40	59
No. 80	18
No. 200	9

TABLE 1 (cont'd)

Test Section 5 - Kentucky Sand Asphalt

Mineral Aggregate -	94.5%	
Asphalt Content -	5.5%	(AC-3 60/70 penetration)

Lab. Specific Gravity -	2.068
Voids -%	10.3
Voids Filled -%	51.9
Marshall Stability lbs.	1082
Flow 1/100"	10
Roadway Density %	92.3

Extracted Gradation

U.S. Sieve	Percent Passing
1/2"	100
No. 4	98
No. 100	13

Test Section 6 - Gravel Plant Mix Seal (95% crushed)

Mineral Aggregate -	93%	
Asphalt Content -	7%	(AC-3 60/70 penetration with 0.5% Redicote 80-S antistripping additive)

Extracted Gradation

U.S. Sieve	Percent Passing
1/2"	100
3/8"	98
No. 4	46
No. 10	13
No. 40	4
No. 200	1

TABLE 1 (Cont'd)

Test Section 7 - Expanded Clay Plant Mix Seal

Mineral Aggregate - 84%
Asphalt Content - 16% (AC-3 60/70 penetration with 0.5% Redicote 80.S antistripping additive)

Extracted Gradation

U.S. Sieve	Percent Passing
1/2"	100
3/8"	98
No. 4	49
No. 10	10
No. 40	2
No. 100	1

Test Section 8 - Slag Plant Mix Seal

Mineral Aggregate - 91%
Asphalt Content - 9% (AC-3 60/70 penetration with 0.5% Redicote 80-S antistripping additive)

Extracted Gradation

U.S. Sieve	Percent Passing
1/2"	100
3/8"	98
No. 4	41
No. 10	6
No. 40	2
No. 100	1

TABLE 1 (cont'd)

Test Section 9 - Expanded Clay Slurry Seal

Emulsion Content - 25% by volume of Aggregate (Chevron Quickset Cationic Emulsion)

Gradation

U.S. Sieve	Percent Passing
3/8"	100
No. 4	100
No. 16	54
No. 50	23
No. 100	15
No. 200	11

Test Section 10 - Granite Slurry Seal

Emulsion Content - 35% by volume of Aggregate (Bitucote-Blakat Cationic Emulsion)

Gradation

U.S. Sieve	Percent Passing
3/8"	100
No. 4	99
No. 16	48
No. 50	20
No. 100	9
No. 200	5

TABLE 1 (cont'd)

Test Section 11 - Gravel Plant Mix Seal (75% crushed)

Mineral Aggregate - 93%
Asphalt Content - 7% (AC-3 60/70 penetration with 0.5% Redicote 80-S antistripping additive)

Extracted Gradation

U.S. Sieve	Percent Passing
1/2"	100
3/8"	96
No. 4	53
No. 10	26
No. 40	11
No. 100	2

TABLE 2

TEST OF ASPHALT CEMENT

Laboratory Number	6352
Specific Gravity 77°F.	1.031
Specific Gravity 60°F.	1.034
Wt. Per Gallon at 60°F., lbs.	8.620
Flash Point, C.O.C., °F.	610
Viscosity	
Saybolt Furol Sec. @ 275°F.	309
Absolute @ 140°F, Poises	4088
Penetration @ 39.2°F, 200G., 60 sec.	25
Penetration @ 77°F, 100G., 5 sec.	62
Thin Film Oven Test	
Loss % @ 325°F, 5 hrs.	.03
Penetration of Residue @ 77°F.	45
Residue Penetration, % of Original	72.6
Ductility of Residue @ 77°F.	100+
Solubility in CS_2%	99.82
Homogeniety Test	Negative
Mixing Temperature	319-326

Remarks: This sample conforms to the specifications for A. C.-3.

TABLE 3

AVERAGE SKID NUMBERS AT VARIOUS TIME INTERVALS AFTER COMPLETION

	AVERAGE SKID NUMBERS											
	0-Months			4-Months			8-Months			11-Months		
	20mph	40mph	60mph	20mph	40mph	60mph	20mph	40mph	60mph	20mph	40mph	60mph
1. Control-Gravel Hot Mix Type 1	55	40	33	-	44	-	60	50	38	56	47	37
2. Open Graded Gravel Mix	60	46	39	-	46	-	58	51	40	58	48	38
3. Expanded Clay Hot Mix Type 4	56	37	29	-	42	-	64	55	38	65	50	38
4. Louisiana Sand Asphalt	48	33	23	-	-	-	-	-	-	-	-	-
5. Kentucky Sand Asphalt	74	69	60	-	62	-	76	73	57	71	63	50
6. Crushed Gravel Plant Mix Seal (95% Crushed)	55	43	40	-	50	-	55	50	44	53	49	44
7. Expanded Clay Plant Mix Seal	70	59	51	-	63	-	75	63	53	70	63	50
8. Slag Plant Mix Seal	62	53	49	-	58	-	63	58	49	57	56	49
9. Expanded Clay Slurry Seal (La.)	77	70	63	81	70	59	64	63	55	-	-	-
10. Granite Slurry Seal	50	41	26	51	38	30	48	36	28	-	-	-
11. Crushed Gravel Plant Mix Seal (75% Crushed)	52	40	36	-	41	-	51	41	29	50	41	-

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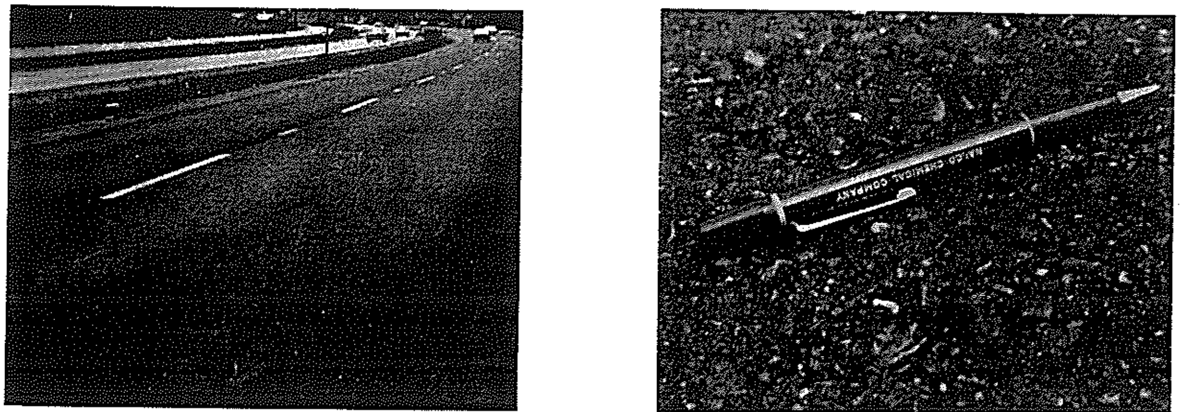
TABLE 4

AVERAGE ROUGHNESS RESULTS

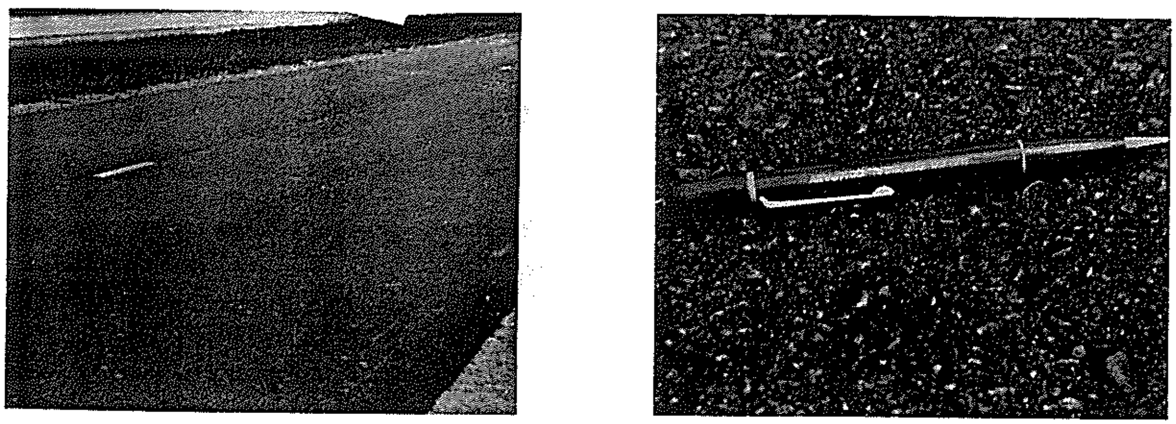
Test Section	ROUGHNESS 4 MONTHS	ROUGHNESS 11 MONTHS
1. Control-Gravel Hot Mix Type 1	76	97
2. Open Graded Gravel Mix	70	88
3. Expanded Clay Hot Mix Type 4	86	104
4. Louisiana Sand Asphalt	80	-
5. Kentucky Sand Asphalt	85	108
6. Crushed Gravel Plant Mix Seal (95% Crushed)	68	86
7. Expanded Clay Plant Mix Seal	62	81
8. Slag Plant Mix Seal	54	76
9. Expanded Clay Slurry Seal (La.)	85	108
10. Granite Slurry Seal	82	111
11. Crushed Gravel Plant Mix Seal (75% Crushed)	58	81

APPENDIX "B"

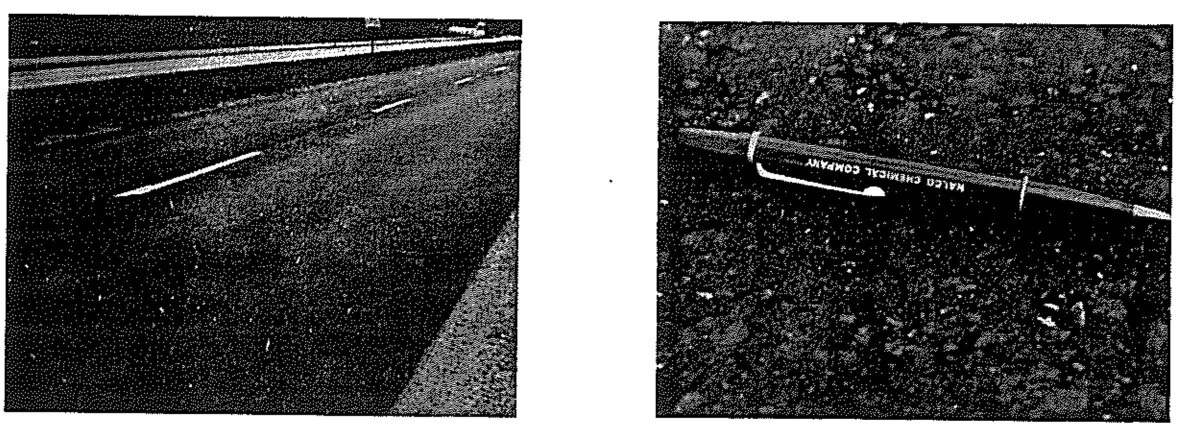
PHOTOGRAPHS OF THE VARIOUS TEST SECTIONS



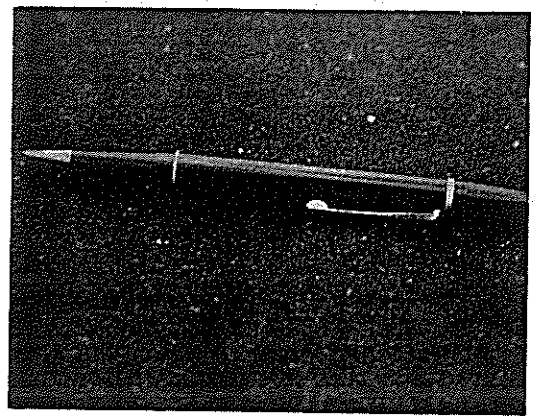
Section 1- Type 1 Crushed Gravel Mix



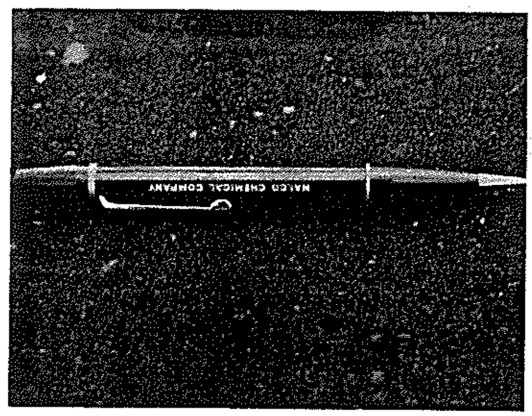
Section 2- Open Graded Crushed Gravel Mix



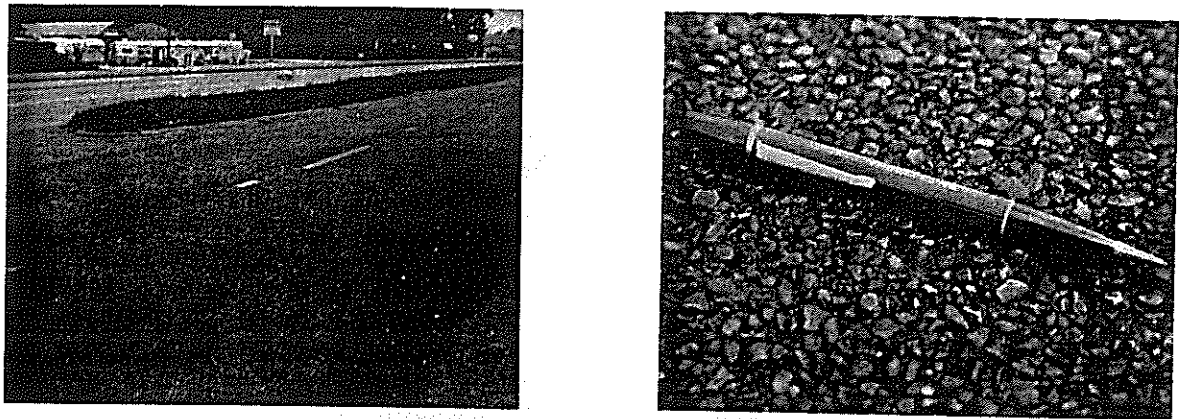
Section 3- Type 4 Expanded Clay Hot Mix



Section 4- Louisiana Sand Asphalt

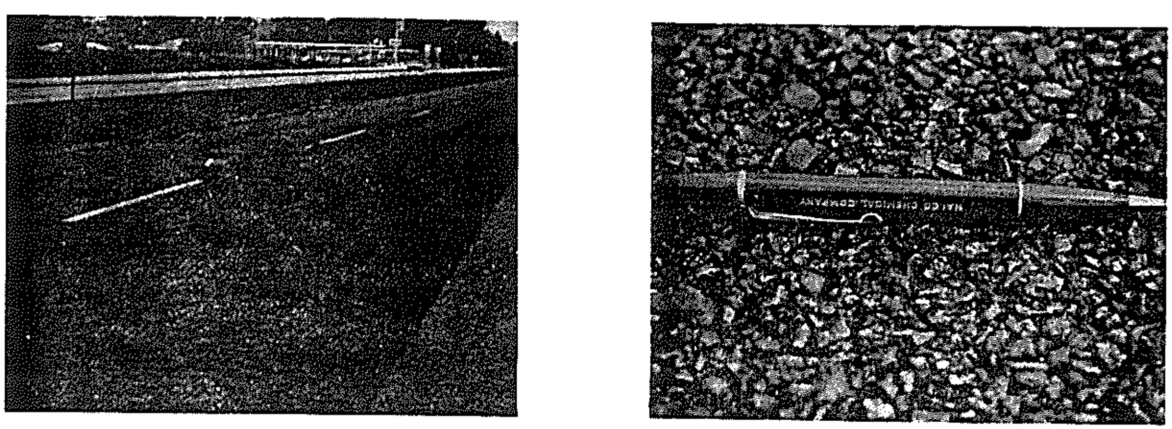


Section 5- Kentucky Sand Asphalt

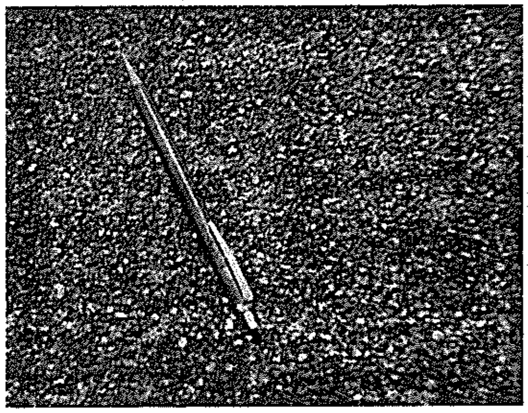


Section 6- Crushed Gravel Plant Mix Seal

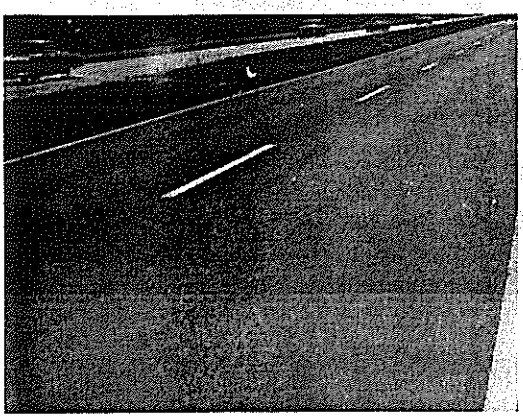
Section 7- Expanded Clay Plant Mix Seal

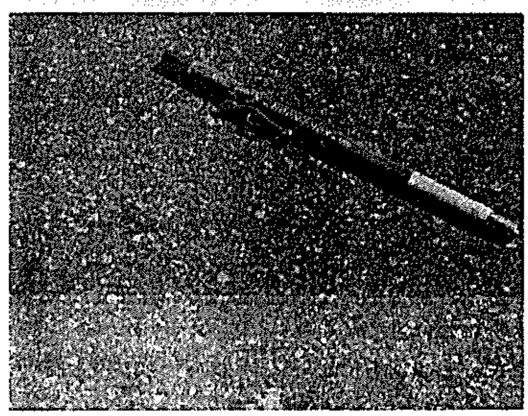


Section 8- Slag Plant Mix Seal



Section 9- Expanded Clay Slurry Seal





Section 10- Granite Slurry Seal