Skid Resistance of Screenings for Seal Coats

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Providing and maintaining a skid-resistant surface is a very important factor in the performance of any highway. All types of pavement surfaces will eventually show some reduction in coefficient of friction values during their service life. This reduction is caused by wear and polish of traffic.

A satisfactory method has been devised for determining in the laboratory the original coefficient of friction of seal coat screenings by use of fabricated test panels and the California skid tester. Friction values obtained from the test panels correlate very well with field test installations.

A laboratory method for wear and polish studies has been developed which shows good correlation with actual service performance of screenings.

•ONE of the primary purposes of a screening seal coat is to improve the skid-resistance characteristics of an existing asphalt concrete pavement. It is very important that suitable tests be developed that will provide screenings having a high original friction value and a high degree of resistance to reduction in the friction factor by wear and polish due to traffic.

Maclean and Shergold (1), in their studies on British screening sources, indicated definite differences in wear and polish, and serious reduction in the friction factor after a relatively short service life. This reduction was directly caused by traffic wear and polish since the seal coats remained in excellent condition with full chip retention.

This report presents studies by the California Division of Highways on the development of laboratory tests for measuring the original coefficient of friction value for seal coat screenings, and a laboratory method for determining the amount of wear and polish that may be expected during service life. The various laboratory tests have been correlated with field performance by placing screenings from different California commercial sources at two test locations.

This project is only one phase of a Bureau of Public Roads supported program on skid resistance. Other phases involve the determination of a minimum friction figure for remedial action and methods for raising the skid resistance of existing pavements, such as grooving of the surface. Also planned are studies on wear and polish of portland cement and asphalt concrete surfaces.

MEASUREMENT OF SKID RESISTANCE

The California skid tester used in determining the coefficient of friction of laboratory and field seal coat screening test surfaces has been previously described (2). The present test method, using this equipment, is presented in Appendix A.

The skid tester has been calibrated with the towed cart equipment constructed by R. A. Moyer of the University of California, Institute of Transportation (3). Previous studies by Moyer and others indicated that the skid-resistance value for any given surface approaches a low figure when the brakes are locked on a vehicle having smooth tread tires and traveling at speeds of 50 mph on a wet pavement. Therefore, in the correlation program, the coefficient of friction values obtained from Moyer's unit using

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locked wheels, smooth tires, wet pavement and a speed of 50 mph were compared to our readings obtained under identical operating conditions.

We are presently using a value of 0.25f as the minimum requirement for indicating the need for remedial action. An active program is under way to study the adequacy of this value. The studies to date appear to indicate that the value should possibly be raised to 0.28f on curves and perhaps could be reduced to 0.22f on long tangents. However, in this paper we will consider any screening seal coat surface adequate for skid resistance if the average value is 0.25f or above. This, of course, means that at no time during the service life of the seal coat shall the surface have a lower value than 0.25f. The change in the value during service life is assumed to be caused by traffic wear and polish and not from "bleeding," loss of screenings by displacement or from ice formation.

LABORATORY STUDIES: TESTS FOR ORIGINAL SKID RESISTANCE

Since all screenings will ultimately wear and polish during service life, it is important to purchase materials having the highest possible original coefficient of friction, and maintaining a satisfactory value. Therefore, a method was developed for fabricating laboratory test plates that closely simulate the field wearing surface. Test panels are prepared on 30-lb roofing felt using 0.2 gal/sq yd of penetration or high viscosity emulsion and 20 lb/sq yd of chips. The surface is immediately rolled with a small hand roller and, after curing for 24 to 48 hours, surplus chips are removed by inverting the test specimen. The panel is then heated to 120 to 140 F and rolled again. After cooling to room temperature, the panels are then tested with the California skid resistance tester (2). The friction values for laboratory prepared specimens are compared with the original readings on field test patches (Table 1 and Fig. 1). The results are considered quite good since friction values above 0.40 may be quite variable.

The preparation of the test plates requires considerable time so studies were undertaken to develop a method that would be simple and require only one sample of

TABLE 1

COMPARISON OF ORIGINAL COEFFICIENT OF FRICTION VALUES OF LABORATORY TEST PLATES AND FIELD TEST PATCHES

Code No.	Sample No.	Size	Original Coefficient of Friction (f)			
			Lab Test Plate	Field Test Patch		
				Auburn	Stockton	Avg.
1	56-1438	¼ × No. 10	0.42	0.39	0.38	0.39
2	60-4034	5/16 × No. 8	0.43	0.41	0.43	0.42
3	61-507	5/16 × No. 8	0.41	0.39	0.41	0.40
4	61-509	5/16 × No. 8	0.35	0.35	0.40	0.38
5	61-511	⅜ × No. 6	0.38	0.39	0.39	0.39
6	61-516	5/16 × No. 8	0.42	0.41	0.41	0.41
7	61-543	5/16 × No. 8	0.40	0.42	0.43	0.43
8	61-545	5/16 × No. 8'	0.42	0.41	0.43	0.42
9	61-551	5/16 × No. 8	0.41	0.41	0.38	0.40
10	61-552	5/16 × No. 8	0.38	0.42	0.44	0.43
11	61-573	5/16 × No. 8	0.40	0.40	0.42	0.41
12	61-574	5/16 × No. 8	0.40	0.41	0.44	0.43
13	61-586	5/16 × No. 8	0.39	0.40	0.43	0.42
14	61-588	¼ × No. 10	0.41	0.41	0.44	0.43
15	61-590	5/16 × No. 8	0.43	0.41	0.43	0.42
16	61-600	⅜ × No. 6	0.40	0.41	0.41	0.41
17	61-601	¼ × No. 10	0.40	0.42	0.43	0.43
18	61-602	⅜ × No. 6	0.41	0.38	0.42	0.40
19	61-603	¼ × No. 10	0.41	0.41	0.45	0.43
20	61-893	5/16 × No. 8	0.37	0.35	0.41	0.38
21	61-1240	5/16 × No. 8	0.41	0.41	0.40	0.41
Avg.			0.40	0.40	0.42	0.41

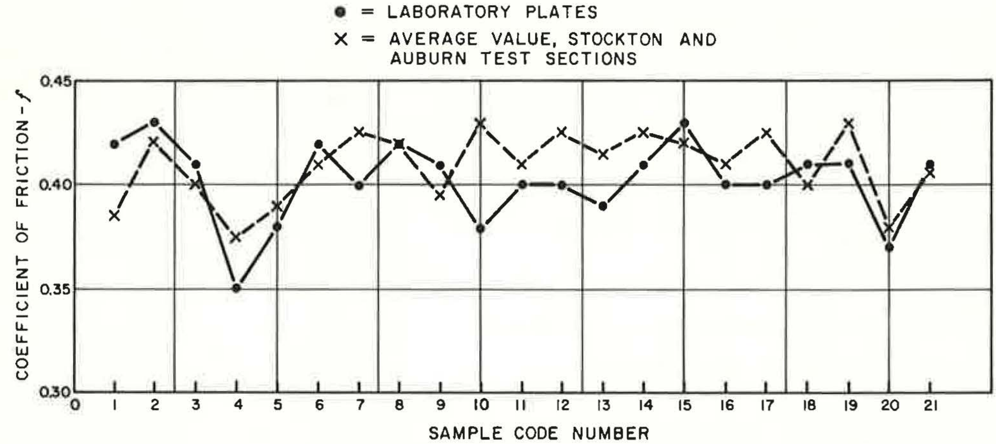


Figure 1. Comparison of original coefficient of friction values of laboratory test plates and field test patches.

screenings. The method finally developed makes use of our centrifuge kerosene equivalent test (CKE), California Method 303, and provides a value for the surface texture and particle shape characteristics of seal coat screenings (Appendix B). Briefly, the sample consists of 100 g ± 1.0 g of washed and dried aggregate passing a No. 3 sieve and retained on a No. 4 sieve. The sample is saturated in kerosene for 10 min and centrifuged for 2 min at 400x gravity. The weight of the sample is then recorded to the nearest 0.1 g. (This operation satisfies the absorption.) The sample is then removed from the centrifuge cup and placed in the CKE test funnel. The funnel is submerged in S.A.E. No. 10 lubricating oil, raised immediately and allowed to drain. The difference in weights after centrifuging and after draining represents a surface factor for the screening sample. This factor, after a specific gravity correction, is designated K_S.

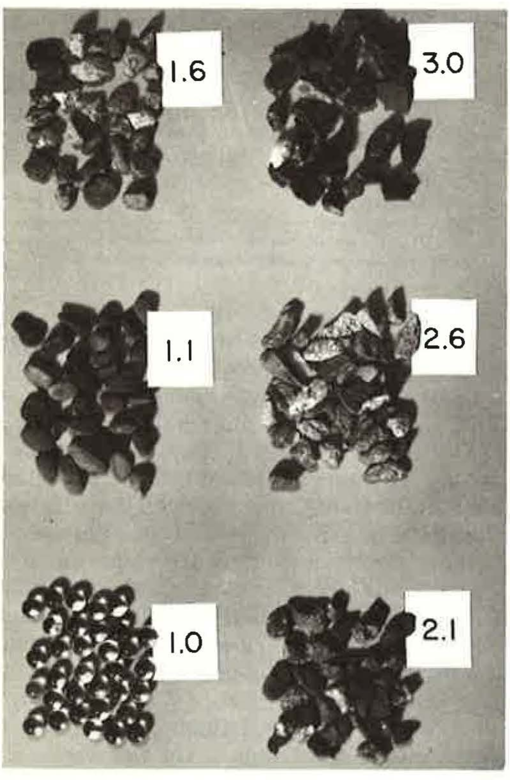


Figure 2. Surface constant K_s values for glass beads and various screenings.

TABLE 2

CHANGE IN K_S VALUE ON ADDITION OF CRUSHED QUARTZ TO GLASS BEADS

Material	K_S Value
Glass beads	1.00
75% Glass beads 25% Crushed quartz	1.39
70% Glass beads 30% Crushed quartz	1.44
50% Glass beads 50% Crushed quartz	1.83
40% Glass beads 60% Crushed quartz	1.93
10% Glass beads 90% Crushed quartz	2.28

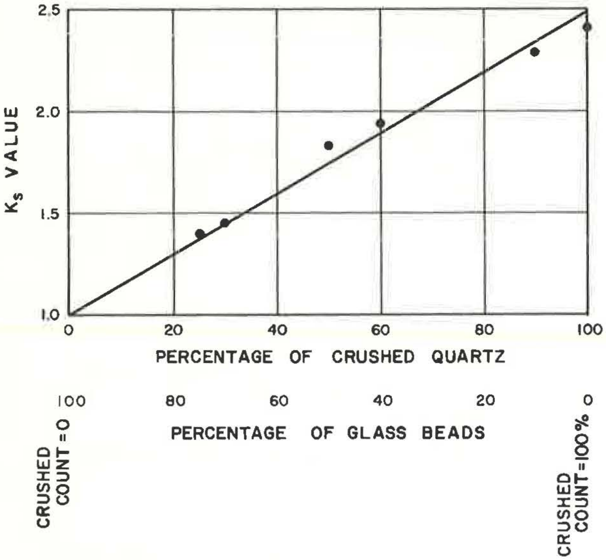
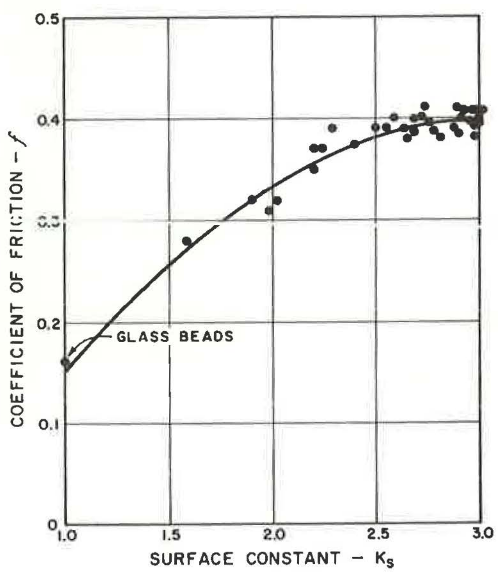


Figure 3. Change in K_s value on addition of crushed quartz to glass beads.



COEFFICIENT OF FRICTION VALUES DETERMINED AT 50 MI/HR. WITH WET PAVEMENT, SMOOTH TIRES AND LOCKED WHEELS. TESTS PERFORMED ON LABORATORY PREPARED TEST PLATES.

Figure 4. Relation between surface constant K_s and coefficient of friction of laboratory prepared test plates.

TABLE 3

RELATION BETWEEN SURFACE CONSTANT-K_s AND COEFFICIENT OF FRICTION OF LABORATORY PREPARED TEST PLATES

Material	K_s Value	Coefficien of Friction f
Glass beads	1.00	0.16
Screenings	1.58	0.28
Screenings	1.90	0.32
Screenings	1.98	0.31
Screenings	2.02	0.32
Screenings	2.20	0.35
Screenings	2.20	0.37
Screenings	2.24	0.37
Screenings	2.28	0.39
Screenings	2.40	0.37
Screenings	2.50	0.39
Screenings	2.52	0.39
Screenings	2.58	0.40
Screenings	2.64	0.39
Screenings	2.66	0.38
Screenings	2.68	0.385
Screenings	2.70	0.40
Screenings	2.72	0.40
Screenings	2.74	0.41
Screenings	2.76	0.395
Screenings	2.78	0.385
Screenings	2.82	0.38
Screenings	2.88	0.39
Screenings	2.90	0.385
Screenings	2.90	0.41
Screenings	2.92	0.40
Screenings	2.92	0.405
Screenings	2.96	0.405
Screenings	2.96	0.395
Screenings	2.98	0.405
Screenings	2.98	0.38
Screenings	2.99	0.39
Screenings	2.99	0.39
Screenings	3.00	0.40
Screenings	3.00	0.395
Screenings	3.00	0.405

[a]Coefficient of friction values determined at 50 mph with wet pavement, smooth tires and locked wheels.

The K_s factor has been determined for a large number of screening sources in California, and shows a range from 1.1 to 3.0. Typical screenings having varying K_s values are shown in Figure 2. Glass beads, 100 percent passing the No. 3 and all retained on a No. 4 sieve (B.K.H. size No. 6) have a K_s value of 1.0. This should be an absolute minimum K_s value since the glass beads are spherical and have no surface roughness. When increasing amounts of crushed quartz are added to glass beads, the K_s value of the combination increases in a linear manner (Table 2 and Fig. 3). The results clearly indicate that K_s values are a measure of angularity and surface roughness. The K_s value also may be used in place of the presently used qualitative crush count method for screenings.

The fact that the K_s value provides a measure of angularity and surface roughness indicates that the value should also be related to the skid resistance of the screenings.

This was confirmed by testing screening test plates with our skid tester and comparing these values with the K_s factors for various screening sources. The results are shown in Table 3 and Figure 4. The correlation obtained is considered excellent and indicates that the K_s value may be used to control the original skid resistance value of seal coat screenings.

TEST FOR WEAR AND POLISH

A most comprehensive study concerning the wear and polish characteristics of screenings has been conducted by the British Road Research Laboratory (1). They found a satisfactory correlation when the friction factors of laboratory polished screenings were compared with those obtained from test patches placed on the roadway. The results of this study indicated that methods could be developed for predicting future wear and polish of screening sources, and thereby prevent the use of screenings that would have a rapid reduction in coefficient of friction during traffic action. Therefore, an apparatus was constructed which permitted the polishing of our standard laboratory prepared plates. The apparatus (Fig. 5) consists of two wheels with 8.00 × 16.00 tires mounted on a revolving unit. The wheels move sideways over the seal coat test plate as the assembly revolves. This permits tracking over the entire test plate area. The assembly rotates at a speed of 13 rpm with a minimum radius of 24 in. and a maximum of 38 in. The speed of the wheel varies from 2.7 to 3.4 mph, depending on the radius. The movement along the shaft is actuated by a screw-type cut in the shaft and a key which kicks out when the wheel reaches the inner end of its travel. By providing the wheels with a slight toe out, they automatically return to the starting point where the key is released and caused to mesh with the threads of the screw.

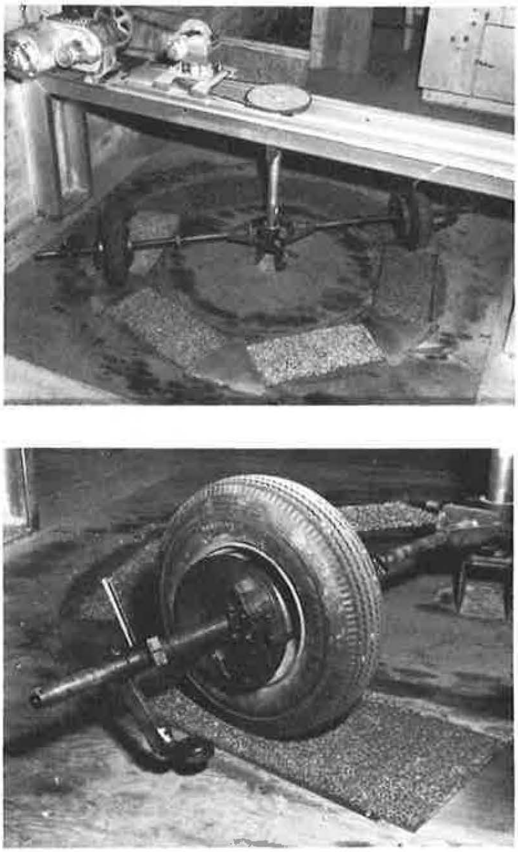


Figure 5. Laboratory polishing machine.

The seal coat test plates are anchored by triangular sheets of galvanized iron attached to the plywood floor with wood screws (Fig. 5). Preliminary studies indicated that some form of temperature control was required, since high atmospheric temperatures permitted excessive movement of the screenings during the circular movement of the wheels. Therefore, the entire assembly was enclosed in an air-conditioned room and the temperature maintained at 80 ± 5 F.

Screenings were obtained from various commercial sources in California. Most of the samples were medium-fine, $\frac{5}{16}$ in. × No. 8, the most commonly used size for seal coat work. Twenty-one samples representing various sources were chosen for the wear and polish study. Test plates were placed in the laboratory polishing unit, and periodically removed for skid resistance measurements. Each plate was subjected to a total of one million passes. No abrasive materials were used during the test. Friction values before and at intervals through one million passes are given in Table 4; typical wear and polish curves are shown in Figure 6. All screening samples showed a rapid drop in friction values during the first 200, 000 or 300, 000 passes, and thereafter attained an equilibrium figure. There was no further evidence of wear and polish up to one million passes.

TABLE 4

CHANGE IN FRICTION VALUES DURING SIMULATED TRAFFIC ACTION BY LABORATORY POLISHING MACHINE

Code No.	× 10^3 Passes						
	Orig.	15	60	160	355	670	1000
1	0.42	—	—	—	0.35	0.32	0.34
2	0.43	0.41	0.42	0.36	0.32	0.31	0.32
3	0.41	0.42	0.36	0.32	0.34	0.31	0.33
4	0.35	0.34	0.35	0.33	0.31	0.30	0.33
5	0.38	0.36	0.37	0.34	0.31	0.29	0.31
6	0.42	0.41	0.40	0.35	0.35	0.30	0.34
7	0.40	0.43	0.38	0.35	0.33	0.32	0.35
8	0.42	0.42	0.43	0.36	0.34	0.33	0.33
9	0.41	0.38	0.38	0.36	0.34	0.31	0.33
10	0.38	0.41	0.36	0.34	0.34	0.29	0.33
11	0.40	0.40	0.34	0.31	0.32	0.30	0.32
12	0.40	0.41	0.41	0.35	0.31	0.31	0.33
13	0.39	0.41	0.37	0.33	0.32	0.30	0.33
14	0.41	0.43	0.44	0.39	0.36	0.33	0.37
15	0.43	0.42	0.38	0.33	0.33	0.31	0.34
16	0.40	0.41	0.42	0.37	0.35	0.31	—
17	0.40	0.42	0.43	0.37	0.33	0.33	0.35
18	0.41	0.40	0.41	0.34	0.33	0.30	0.32
19	0.41	0.43	0.40	0.35	0.34	0.31	0.32
20	0.37	0.37	0.35	0.32	0.30	0.29	0.31
21	0.41	0.41	0.37	0.34	0.31	0.30	0.32
Avg.	0.40	0.40	0.39	0.35	0.33	0.31	0.33

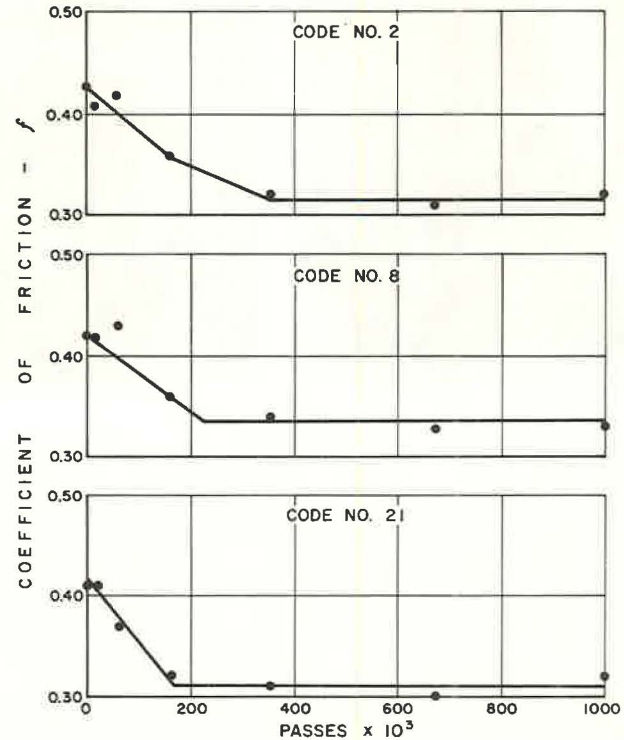
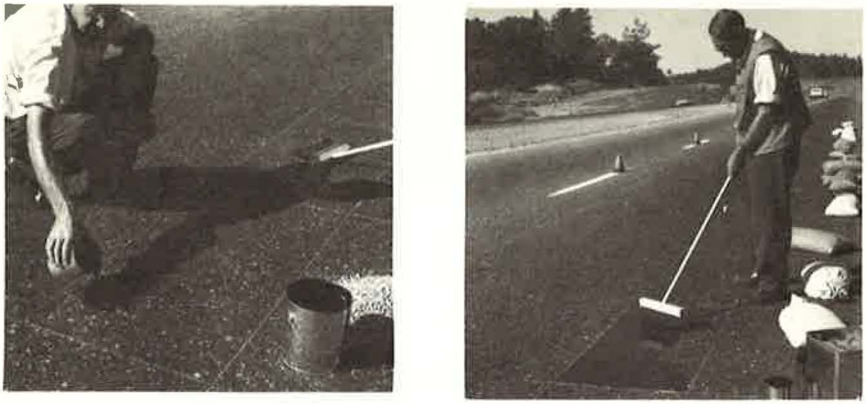
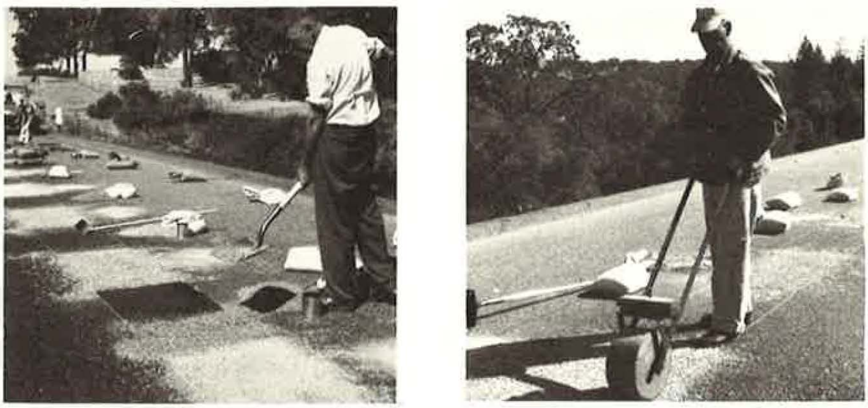


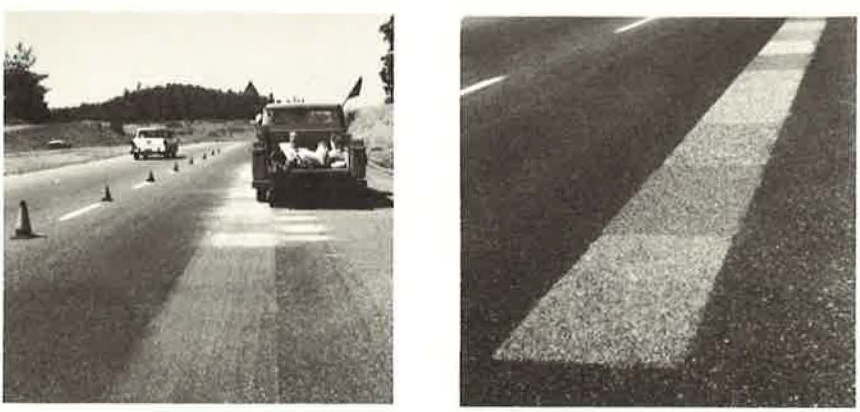
Figure 6. Change in friction values during laboratory simulated traffic action.



APPLYING EMULSION



SPREADING AND INITIAL ROLLING OF SCREENINGS



FINAL COMPACTION WITH A LIGHT DUTY TRUCK

OVERALL VIEW OF AUBURN TEST SECTION AFTER 6 DAYS OF TRAFFIC

Figure 7. Procedure for construction of field test sections.

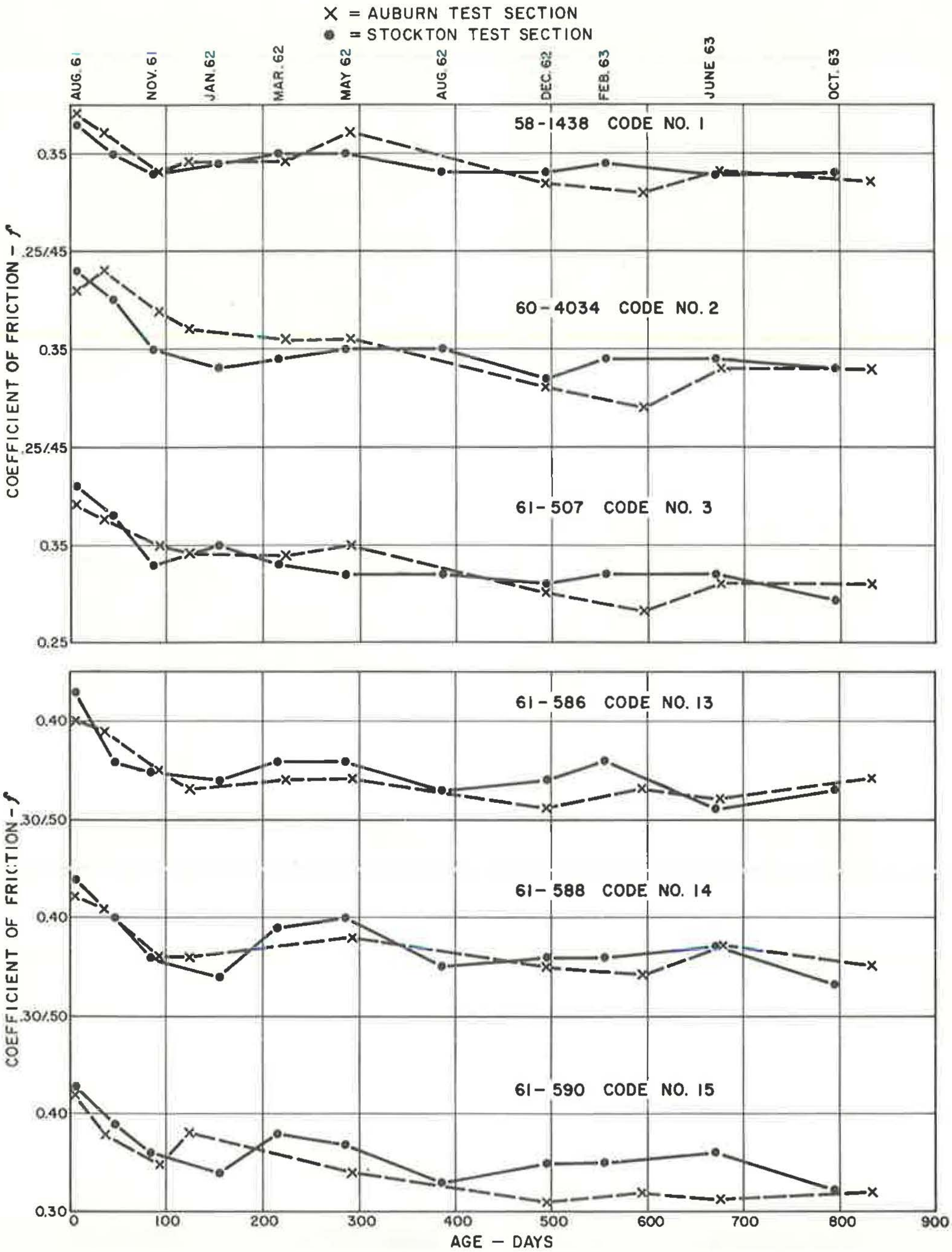


Figure 8. Change in friction values for various California seal coat screening sources under field traffic.

FIELD STUDIES

The results from laboratory polishing of screenings indicated that a state of equilibrium was attained in the coefficient of friction values after approximately 200 to 300 thousand passes. To verify this under actual traffic, it was decided to place test patches on two heavily traveled roads, and determine if a correlation existed between the equilibrium results obtained from the laboratory polishing unit and those obtained under traffic.

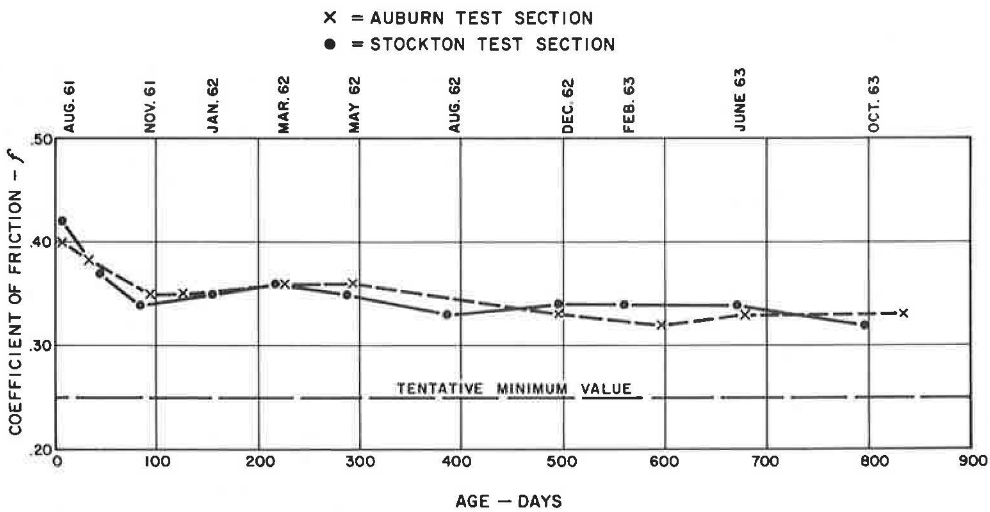


Figure 9. Change in average friction values for various California seal coat screening sources under field traffic.

TABLE 5

CORRELATION OF LABORATORY SCREENING POLISHING UNIT RESULTS WITH FIELD TEST SECTIONS AFTER TRAFFIC

Code No.	Equilibrium (f) Lab. Test Plates	Latest f-Value of Field Test Sections		Avg.
		Auburn 831 Days	Stockton 796 Days	
1	0.34	0.32	0.33	0.325
2	0.32	0.33	0.33	0.33
3	0.33	0.31	0.29	0.30
4	0.32	0.31	0.30	0.305
5	0.30	0.31	0.32	0.315
6	0.34	0.34	0.35	0.345
7	0.35	0.34	0.35	0.34
8	0.33	0.34	0.36	0.35
9	0.33	0.31	0.33	0.32
10	0.33	0.31	0.33	0.32
11	0.31	0.28	0.32	0.30
12	0.32	0.33	0.29	0.31
13	0.32	0.34	0.33	0.335
14	0.35	0.35	0.33	0.34
15	0.33	0.32	0.32	0.32
16	0.33	0.34	0.36	0.35
17	0.34	0.36	0.34	0.35
18	0.32	0.34	0.30	0.32
19	0.32	0.34	0.33	0.335
20	0.31	0.33	0.28	0.305
21	0.31	0.35	0.29	0.32
Avg.	0.33	0.33	0.32	

Two locations were chosen for field testing. The first is on I-80 about 2 miles west of Auburn, and the second on Calif. 99, between Stockton and Manteca. Both roads are 4-lane freeways and carry over 12,000 vpd with about 12 percent consisting of trucks.

Each test patch, 2 by 4 ft in area, was placed in the outer wheeltrack of the travel lane. The sequence of patch preparation is shown in Figure 7. The measured amount of emulsion, 0.14 gal/sq yd to 0.25 gal/sq yd, depending on screening size, was poured

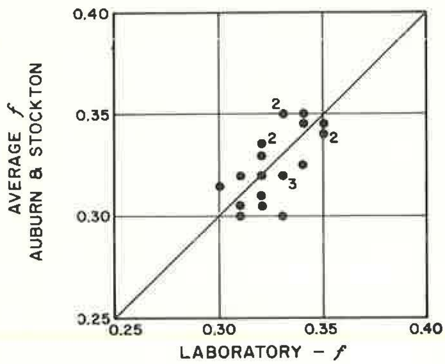


Figure 10. Correlation of laboratory screening polishing unit results with field test sections after traffic.

on the surface of the existing pavement and spread uniformly by a squeegee. Chips were then spread with a square-point shovel which produced a very uniform spread. The completed seal coat patch was then rolled with a hand roller. To avoid contamination, every other patch was placed, and by the time that these were completed, the first had set up sufficiently so that they could be walked on and the edges swept clean without damage. After completion of all the patches, they were rolled for approximately 2 hours with a light duty truck, and cured for approximately 4 hours before opening to traffic. The initial coefficient of friction readings were attained after 7 days of traffic. This time delay after placement allowed whip-off to be completed. Since completion in August 1961, periodical measurements of the coefficient of friction have been performed. Typical curves are shown in Figure 8. The greatest decrease in coefficient of friction occurs during the first six months. Thereafter, there is little decrease up to 800 ± days and it is apparent that equilibrium conditions have substantially occurred for all 21 screening sources. This is the same type of curve found for the laboratory polishing unit. Further, Maclean and Shergold (1) state: "The stones on a straight length of road approached their ultimate (equilibrium reading) in three to four months." Our studies, therefore, are in excellent agreement with those found by the British Road Research Laboratory. The average curves for all screening sources at both test sections are shown in Figure 9. There are indications, at least for the Stockton test section, that the winter rains improve the coefficient of friction over that found during the summer. Maclean and Shergold also found this in their studies. They state: "When a period of wet road surface conditions preceded the testing of the areas of stone chippings the 'skid resistance' values were increased. This effect was found to be associated with an actual roughening of the surface of the stones. On further investigation, it was found that the detritus on the road surface was coarser during wet than during dry conditions. As was established by laboratory investigations, the presence of coarser detritus would result in a roughening of the stones. It is thus apparent that polishing of stones is facilitated during summer when the road surface is predominantly dry, and delayed or reversed in winter when the surface is predominantly wet."

LABORATORY POLISHING UNIT: FIELD TEST SECTION CORRELATION

As previously mentioned, the primary purpose of the field test sections was to provide information for a possible correlation with the laboratory polishing unit. Results are shown in Table 5. Since the final friction values at Stockton and Auburn are almost the same, an average of the values is shown in Figure 10. Although screenings were obtained from various California sources, unfortunately all of the screenings have good resistance to wear and polish, and the equilibrium values tend to form a cluster within a range of 0.30 - 0.35f. The correlation appears quite satisfactory, considering the normal variations in the skid resistance test, and the fact that no screening source showed a high degree of wear and polish.

The equilibrium friction values obtained after subjecting a screening test plate to the laboratory polishing machine appears to check very closely with the equilibrium value attained under heavy traffic action. This test method may, therefore, be used for selecting screenings that will show a minimum reduction in coefficient of friction values due to wear and polish under traffic.

CONCLUSIONS

1. The original friction values on laboratory prepared screening test plates correlated with field test panels that had been subjected to 7 days of traffic in order to remove excess screenings. An excellent correlation was found between the K_s value determined by laboratory tests and the original friction value of laboratory prepared test plates. Therefore, it is possible to approximate the original coefficient of friction of screenings with a simple test method.

2. A satisfactory correlation between a laboratory wear and polish apparatus and wear and polish under traffic has been established. Therefore, the wear and polish characteristics of screenings may be specified, if necessary, by a minimum friction value after a specified period of simulated traffic action in a laboratory apparatus.

3. There appears to be a slight increase in the coefficient of friction of the field test patches after winter rains.

4. Screenings from various California sources do not show excessive reduction in friction values under heavy traffic, and appear to have low rates of wear and polish.

RECOMMENDATIONS

Our studies indicate that it is possible to predetermine the original skid-resistance characteristics of seal coat screenings by a simple test that provides a quantitative measure of the angularity and surface roughness. We have set a minimum value for K_s of 2.2 which will insure a minimum friction value of 0.35f. The use of this test will insure uniform characteristics for screenings together with a high initial friction factor.

The determination and control of the original friction value will not insure against a rapid change in friction characteristics by the effect of traffic wear and polish. When tested in a unit of the type described, the friction value at equilibrium should not be lower than 0.25f. We believe that commercial plants which produce screenings from a constant aggregate source would only require an occasional wear and polish test. It appears that control of shipments could be maintained by use of the K_s value test.

ACKNOWLEDGMENT

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Appendix A

MATERIALS AND RESEARCH DEPARTMENT

Test Method No. Calif. 342-C

April, 1966

METHOD OF TEST FOR PAVEMENT SURFACE SKID RESISTANCE

SCOPE

This method describes the apparatus and procedure for obtaining surface skid resistance values of Bituminous and Portland Cement Concrete pavements.

PROCEDURE

A. Apparatus

1. Skid test unit.

a. Reference is made to Figures I through III in connection with the following description of the construction of the test unit. A 4.80/4.00 × 8, 2-ply tire with (25 ± 2 psi) air pressure (A), manufactured with a smooth surface, together with rim, axle, and driving pulley is mounted on a carriage (B). The tire is brought to desired speed by motor (H). The carriage moves on two parallel guides (C), and the friction is reduced to a low uniform value by allowing three roller bearings fitted at 120° points to bear against the guide rod at each corner of the carriage. The bearing assembly may be noted on Figure III (D). The two guide rods (C) are rigidly connected to the end frame bars (E). The front end of this guide bar frame assembly is firmly fastened to a restraining anchor. The bumper hitch provides for swinging the skid tester to the right or left after positioning the vehicle. The rear end of the frame assembly is raised by a special adjustable device (F), Figure II, so as to hold the tire ¼-inch off the surface to be tested. This device is so constructed that the tire may be dropped instantaneously to the test surface by tripping the release arm (G), Figure II. Tachometer (K) indicates the speed of the tire.

2. Hitch for fastening unit to vehicle.

3. Special level to determine grade of pavement.

a. A 28" long standard metal carpenter's level, Fig. IV, is fitted at one end with a movable gauge rod which is calibrated in % of grade.

B. Materials

1. Glycerine
2. Water
3. 2-inch paint brush
4. Thickness gauge ¼-inch (a piece of ¼-inch plywood 2' × 1" is satisfactory).

C. Test Procedure

1. Determine and record grade with special level, see Fig. IV.

a. Place level on pavement parallel to direction of travel with adjustable end down grade.

b. Loosen locking screw and raise level until bubble centers and then tighten locking screw on sliding bar.

c. The grade is indicated on the calibrated sliding bar.

2. Remove apparatus from vehicle and attach to bumper hitch, Fig. V.

3. Position apparatus with tire over selected test area and parallel to direction of traffic.

4. Raise tire and adjust to ¼-inch (—1/16" tolerance) above surface to be tested with device (F).

5. Wet full circumference of tire and pavement surface under tire and 16" ahead of tire center with glycerine, using a paint brush.

6. Set sliding gauge indicator (P) against carriage end.

7. Depress starting switch (J) and bring the speed to approximately 55 mi/hr.
8. Release starting switch.
9. The instant the tachometer shows 50 mi/hr. trip arm (G) dropping tire to pavement.
10. Read gauge (N) and record.
11. Release rebound shock absorber.
12. Move to next section and repeat.
13. In any one test location, test at 25' intervals in a longitudinal direction over a 100' section of pavement.

D. Precautions

1. The rear support rod (O), Fig. II, must be cleaned by washing frequently with water and a detergent to prevent sticking.
2. Sliding gauge indicator (P) must be kept clean so that it will slide very freely.
3. On slick pavements glycerine remaining on the pavement should be flushed off with water to prevent possible traffic accidents.

E. Field Construction Testing of Portland Cement Concrete Pavement

The following procedure shall be followed in the field testing of a portland cement concrete pavement for specification compliance of the minimum friction value. A minimum of seven days after paving shall lapse before testing.

1. The total length of pavement shall be visually surveyed for uniformity of surface texture. All areas which do not have definite striations or which appear smooth shall be noted. This survey should be conducted with the Resident Engineer or an Assistant who has knowledge of any difficulties in attaining a proper surface texture during construction. The attached photograph, Figure VIII, may be used as an aid in the evaluation of the existing texture in relation to the coefficient of friction, but is not to be used in lieu of actual coefficient of friction measurements.

2. The determination of test locations, as outlined below, shall apply only to that portion of the pavement which has well formed striations. All areas that appear smooth, or those that have been ground shall be excluded.

a. A minimum of three test locations shall be made for each days pour and a minimum of three pour days shall be checked per contract.

The location of test sites shall be determined in a random manner through use of a Random Number table. The use of this method requires that the area for test be uniformly textured and placed in one operation. As an example, a 4-lane pavement may be placed with a three lane width in one operation and the fourth lane placed separately. Each of these areas must be treated separately in selecting test locations. The following example illustrates the use of this table.

A section of pavement is 24' wide and 4000' long and is part of a 4-lane freeway. This section of pavement has been placed in one operation and skid tests are required. From 2-a, it is required that three test locations be determined.

Using the random numbers, as shown, choose the three locations in the following manner:

Random Numbers

Longitudinal	Lateral
0.6	6
0.9	9
0.2	2
0.7	7
0.5	5
0.1	11
0.4	4
0.8	8
0.3	3

Starting at any point and proceeding up, or down, but not skipping any numbers, read three pairs of numbers and set up each location as follows:

	Distance from Start of Pour	Distance from Right Edge of Pour Looking up Station
Location A	0.6 × 4,000' = 2,400'	6 × 2 = 12'
Location B	0.9 × 4,000' = 3,600'	9 × 2 = 18'
Location C	0.2 × 4,000' = 800'	2 × 2 = 4'

In case any location as determined above falls in a smooth or ground area which does not appear representative of the general surface texture, then the next number in the random table shall be chosen and a new location selected.

At each test location the first reading shall be obtained at the specified random location. The next four readings shall be obtained at 25' intervals beyond the first reading. All readings shall be obtained at sites parallel to the centerline of the lane. After correction for grade as shown in F, average the five readings. This average shall be recorded as the friction value for the specific test location.

3. In all areas that present a smooth textured appearance or have been ground, the following shall apply:

a. A minimum of three ground area locations and all smooth appearing surfaces shall be checked on each contract.

b. If the area is less than 100' in length perform at least three individual tests in separate spots, correct for grade and average the results.

c. If the area is greater than 100' in length, sufficient test locations shall be selected to insure that the area is above the minimum requirement. If the average value of all locations is below the required minimum then additional tests shall be performed until the area is localized for remedial action.

F. Calculations

1. Make grade corrections using charts shown in Figures VI and VII.

2. Average the 5 corrected readings in any one test location. Example—The following readings were taken at 25' intervals in a test location. The grade of the pavement, determined as described in C-1, was +4%.

Station	Measured Coefficient of Friction	Corrected Coefficient of Friction*
1+00	0.33	0.38
1+25	0.34	0.39
1+50	0.34	0.39
1+75	0.33	0.38
2+00	0.33	0.38

Final Average for Test Site. 0.38

*Corrected coefficients of friction were taken from chart in Figure VI.

G. Reporting of Results

For all results determined under E-2, report the result for each station location and the average of 5 readings and the grand average. For all results determined under E-3, part (b), report the result for each station location and the average. For E-3, part (c), report the result for each station location and the average for each set of five determinations.

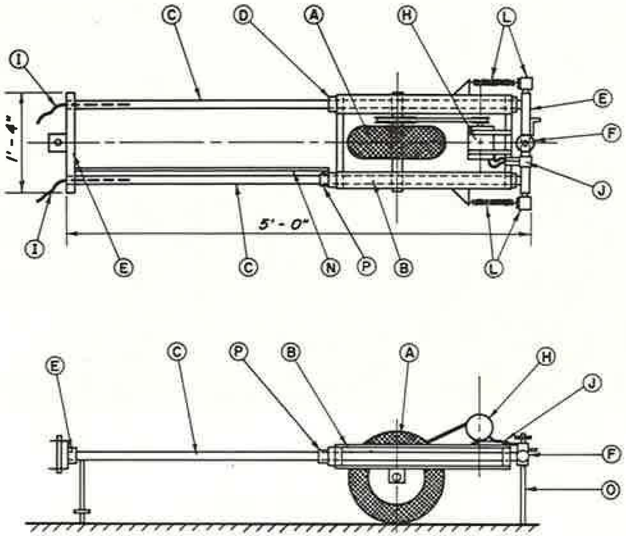

DIAGRAM OF SKID TESTER

Figure I

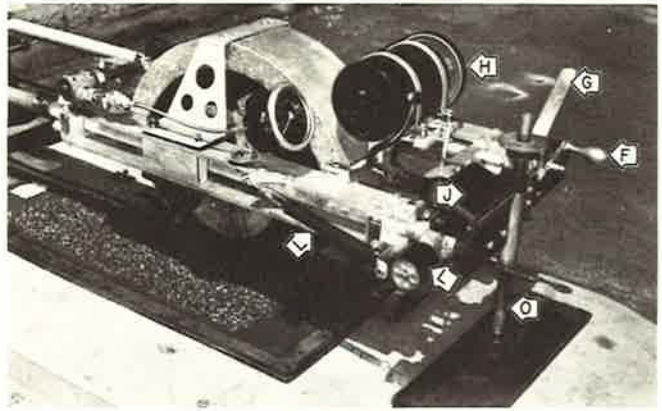

Figure II

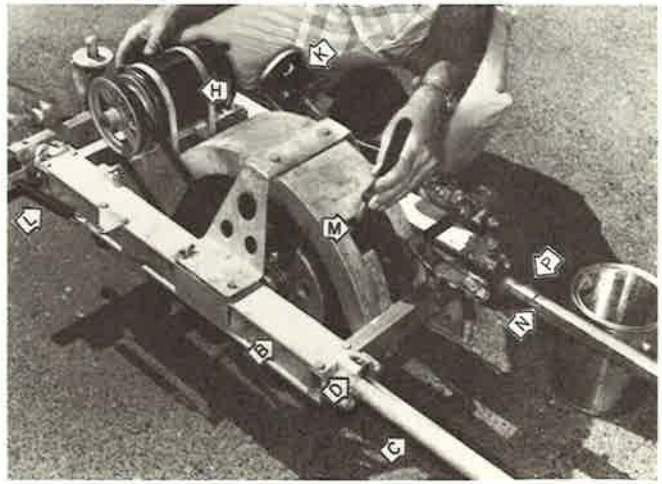

Figure III

Close-up Views of Skid Tester

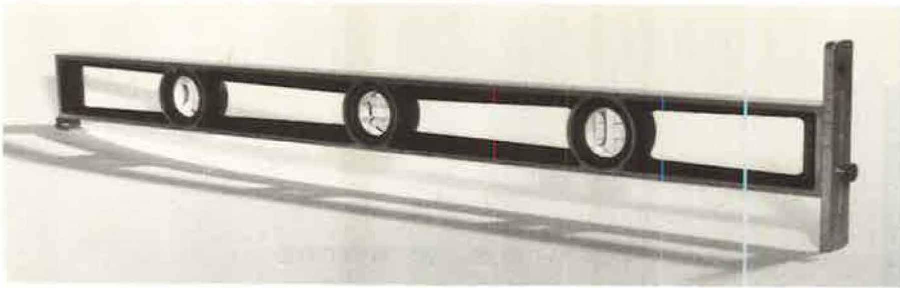

Figure IV

Level for Determining Grade

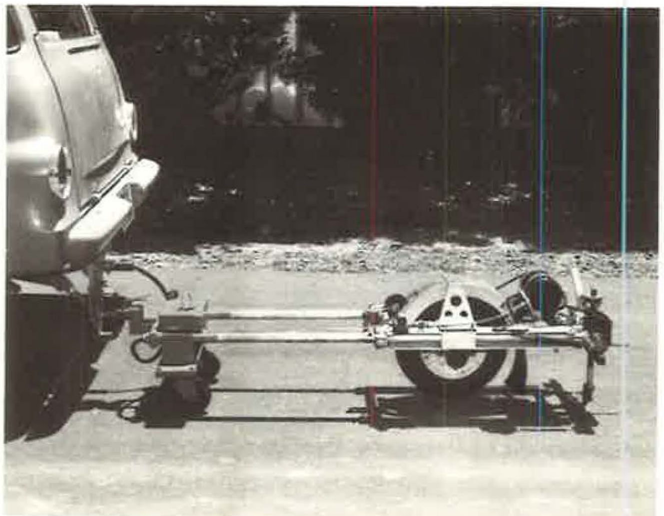

Figure V

Apparatus in Position for Testing

COEFFICIENT OF FRICTION CORRECTION CHART FOR MEASUREMENTS MADE ON GRADES

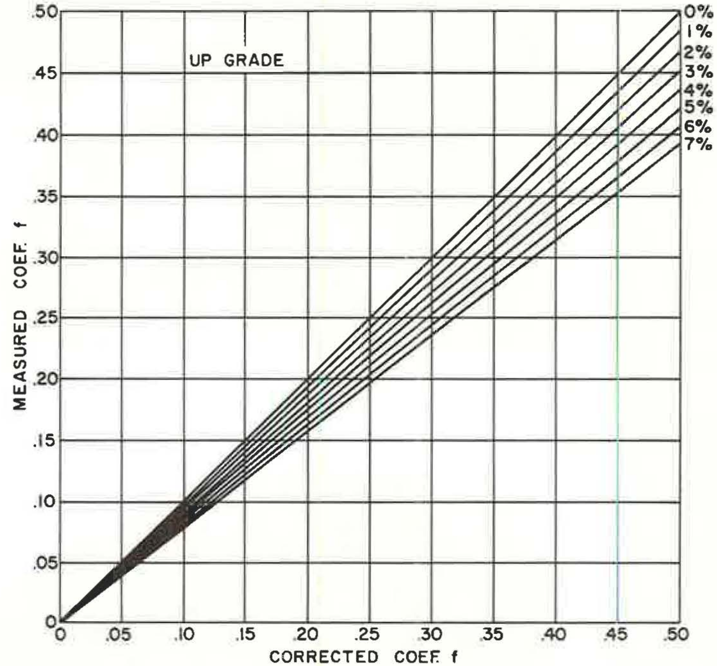

Figure VI

COEFFICIENT OF FRICTION CORRECTION CHART
FOR MEASUREMENTS MADE ON GRADES

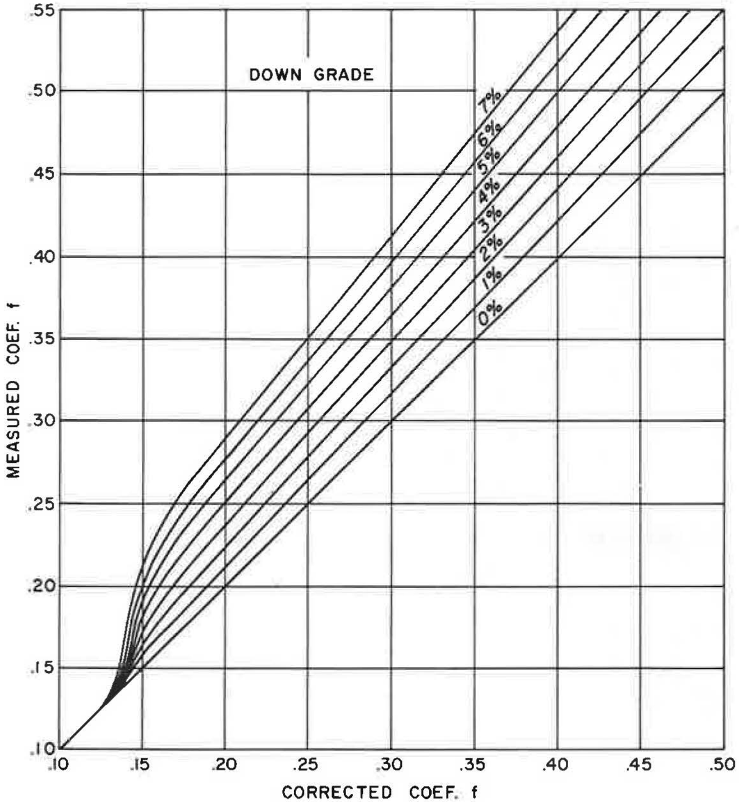

Figure VII

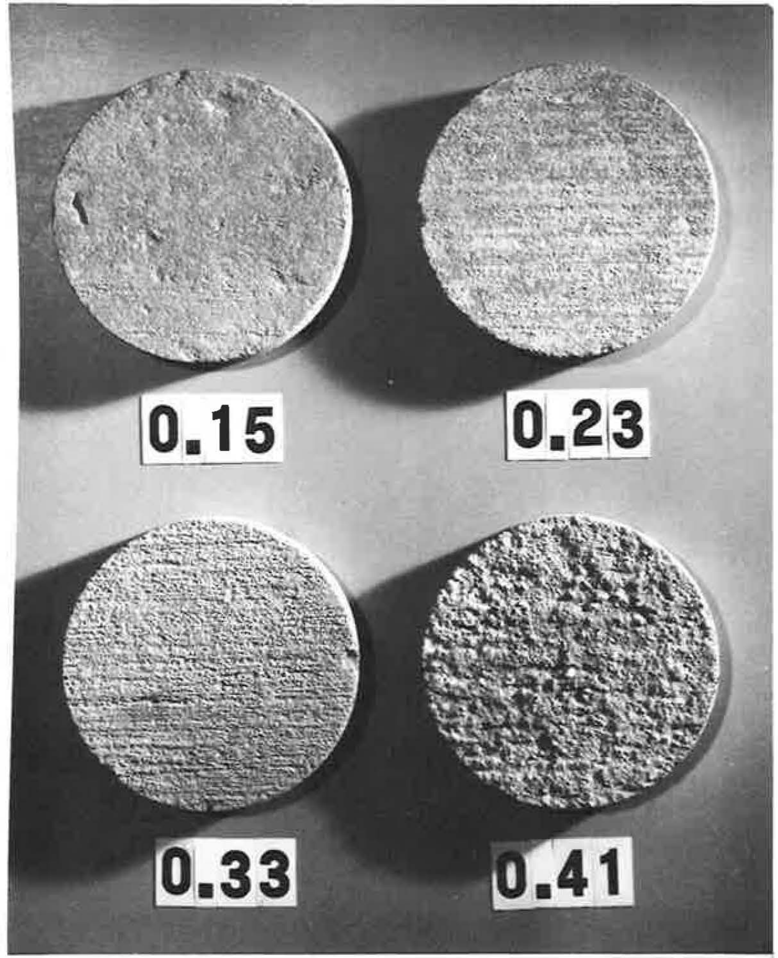

Figure VIII

Photos of Surface Textures

Figure IX

Apparatus Being Placed in Vehicle
Note cable and winch for moving skid tester.

Figure X

Apparatus in Position for Transportation

Appendix B

METHOD OF TEST FOR ANGULARITY AND SURFACE ROUGHNESS OF SCREENINGS

SCOPE

The test furnishes a measure of the surface capacity as it is affected by surface texture and particle shape characteristics.

PROCEDURE

A. Apparatus

1. Centrifuge (hand or power driven) capable of exerting a force of 400 times gravity (400G) on a 100 gram sample

$$\text{Required RPM of centrifuge head} = \sqrt{\frac{14,000,000}{r}}$$

Where r = radius in inches to center of gravity of sample.

2. Centrifuge cups $2^{13}/_{16}$" in height and $2^{1}/_{16}$" in diameter complete with perforated brass plate, .031" thick with a minimum of 100 holes, .062" in diameter, per square inch.
3. Torsion balance, 500 g. capacity ± 0.1 g. accuracy.
4. Metal funnels, top diameter $3^{1}/_{2}$", height $4^{1}/_{2}$", orifice $^{1}/_{2}$", with a piece of No. 10 sieve soldered to the bottom of the opening.
5. Glass beakers (1, 500 ml.).
6. Timer with sweep second hand.
7. 140°F oven.
8. Hot plate or 230°F oven
9. Small drain pans approximately 5" in diameter by 1" deep.

B. Materials

1. Kerosene.
2. S.A.E. No. 10 lubricating oil.
3. Filter paper, Eaton-Dikeman Co. size $5^{1}/_{2}$ cm. No. 611.

C. Test Record Form

Use work form T-302 for recording test data.

D. Preparation of test sample

Screen sufficient material to obtain approximately 100 g. of aggregate passing a No. 3 sieve and retained on a No. 4 sieve. Wash this sample clean, dry thoroughly and allow to cool.

E. Tests and calculations

1. Nomenclature
   a. K_S = a factor arrived at by subtracting the weight of the test sample after soaking in kerosene and centrifuging from the weight after submerging in the lubricating oil and draining.
   b. K_S corrected - the factor K_S corrected for specific gravity of the aggregate.
2. Procedure for K_S
   a. Weight to the nearest 0.1 gms. 100 gms. ± 1.0 gm. of the washed and dried test sample.
   b. Place sample in tared centrifuge cup and submerge sample and cup in a beaker of kerosene for 10 minutes.
   c. Remove sample and cup from kerosene and centrifuge for 2 minutes at 400 times gravity (400G).
   d. Remove from centrifuge and re-weigh to the nearest 0.1 gm. Subtract original weight and record the difference as grams of kerosene retained.
   e. Immediately after obtaining the weight of kerosene retained, remove the sample from the cup and place in a funnel (standard C.K.E. test funnel) and submerge sample and funnel in a beaker of S.A. E. No. 10 lubricating oil, raise immediately and allow to drain for 2 minutes.
   f. Sample and funnel are then placed in a 140°F oven for 15 minutes additional draining time.

g. Remove from oven and empty sample from funnel into a small pan 4 or 5 inches in diameter and allow to drain for 1 minute at room temperature.

h. Empty sample from drain pan into a tared container and weigh to the nearest 0.1 gm.

i. Subtract from the final weight, the weight obtained after centrifuging, and record the difference which will be designated as K_S, representing a surface constant for the particular aggregate tested.

j. If the specific gravity of the aggregate is greater than 2.70 less than 2.60 make correction to K_S value as follows:

$$K_S \times \frac{\text{Sp. Gr. of Agg.}}{2.65} = K_S \text{ corrected}$$

k. Perform the test in triplicate and average the results.

F. Reporting of Results

Report the K_S value to nearest 0.1 gm. on Test Report Form T-374.