HIGHWAY RESEARCH REPORT

A STUDY OF THE SAND PATCH AND OUTFLOW METER METHODS OF PAVEMENT SURFACE TEXTURE MEASUREMENT

By

R. N. Doty

Presented at the ASTM 1974 Annual Meeting

Symposium on Surface Texture and Standard Surfaces

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BUSINESS AND TRANSPORTATION AGENCY

DEPARTMENT OF TRANSPORTATION

DIVISION OF HIGHWAYS

TRANSPORTATION LABORATORY

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ABSTRACT: A study of the sand-patch and outflow meter methods of pavement surface texture measurement was completed. Included in this study was repeatability testing and testing to determine the degree to which pavement surface texture, as measured by these procedures, correlates with pavement coefficient of friction, skid number, and skid number speed gradient. Test locations were selected on open-graded and dense-graded asphalt concrete, chip-sealed and fog-sealed asphalt concrete, and new, polished, and grooved PCC pavements. The results of the testing indicated that the repeatability of the sand patch test procedures studied was poor to fair and that the outflow meter test results were independent of water temperature. A general trend toward higher skid numbers and coefficients of friction was evident with increasing texture depth, as measured with both the modified sand patch and the outflow-meter procedures. However, neither relationship was considered definitive enough to use as a basis for a minimum texture depth construction specification requirement for pavement surfaces. Also, neither method provided a definitive measure of skid number speed gradient.

KEY WORDS: pavement, skid resistance, friction, texture, gradient, sand patch, outflow meter.

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Introduction

The California Department of Transportation has been studying the subject of skid resistance of highway pavements for many years. These studies have included an examination of the skid resistance provided by seal coats[1]; the effectiveness of grooving portland cement concrete pavements as determined by skid resistance measurements[2] and accident statistics[3,4,5], correlations between various methods and pieces of equipment used to measure skid resistance[6,7,8], and the effect of "heavily" textured and grooved portland cement concrete pavement on motorcycle handling and safety[9,10]. During the course of these investigations, the measurement of skid resistance was accomplished by measuring the tractive or drag force developed at the interface of a rubber surface and the pavement surface being tested. Another approach that appeared to be worthy of investigation was that of measuring the average surface texture depth (macrotexture) available to the tire. The influence of macrotexture is of particular importance when high speeds and wet pavement are encountered in that the macrotexture provides the channels through which the water between the tire and the pavement surface can be displaced. Macrotexture has, therefore, often been associated with the magnitude of skid numbers and speed gradients exhibited by highway pavements. For these reasons, plus the possibilities that macrotexture may 1) correlate with accident frequency data better than skid numbers because it is a measure of a pavement property in all directions and/or 2) be useful as a partial measure of the durability, or life, of the skid resistant surface, studies of methods to measure surface texture appeared to be warranted. After conducting a literature search of the surface texture measuring procedures then in use, two approaches were selected for investigation. These were the sand patch and outflow meter tests.

The Sand Patch Test

When reviewing the published results of some previous studies of this texture measurement method, it became apparent that some refinement of this procedure might be required to provide a

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satisfactory indication of a pavement's skid resistance and/or speed gradient using this approach. B. E. Sabey[11] reported test results that supported the hypothesis that pavements with deep surface textures provide skid resistant surfaces with lower speed gradients than do those pavements with shallow surface textures. However, Galloway and Rose[12] reported poor correlation between skid resistance and texture depth, as measured with the sand patch equipment, and Hegmon and Mizoguchi[13] reported poor repeatability as indicated by their sand patch test results, especially between operators. The appeal of this approach to surface texture measurement was considerable, however, due to the simplicity, low cost, and portability of the test. Consequently, a study was conducted to measure the surface texture of several different pavements with a sand patch device and compare this data with skid resistance data acquired using the California Portable Tester and towed trailer skid testing equipment. The repeatability of the sand patch test was also studied.

The first test device tried consisted of a 1/4-inch thick steel plate containing a 12-inch square opening. Lips were welded around the perimeter of the plate to contain any excess sand and a steel screed used to level the sand with the top surface of the plate (See Fig. 1).

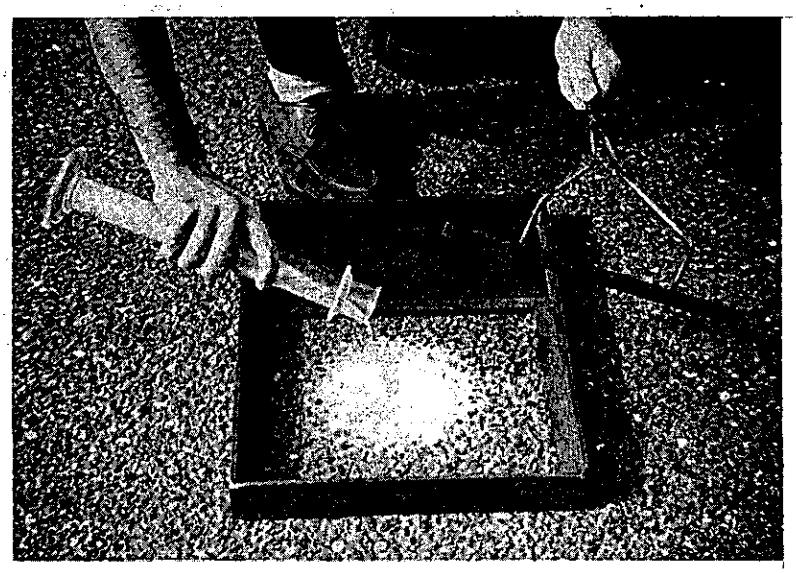

Figure 1.

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This device was then used to test 44 different pavement locations. The pavement surfaces included open-graded and dense graded asphalt concrete, chip-sealed and fog-sealed asphalt concrete, and deeply textured, smooth, and grooved portland cement concrete pavements. The California Portable Skid Tester was used to test each location as per Test Method No. Calif. 342 (see Appendix). A towed trailer skid tester (See Fig. 2) was then used to determine the skid resistance of the right wheel track in accordance with the applicable portions of ASTM Designation E274-65T. The towed trailer skid tests were conducted at speeds of 40 and 50 mph using both smooth and ribbed tires at each location. The "portable" tests were conducted per the test procedure, i.e., 50 mph tire speed with a smooth tire on a "wetted" surface.

Figure 2.

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At each location, five "portable" tests were completed 25-feet apart in the wheel track followed by five sand patch tests in the same wheel track at 25-foot intervals beginning midway between the location of the first and second "portable" skid tests. The average depth of the surface texture was computed based upon the volumetric ratio of the sand required to fill the 12-inch square aperature when the apparatus was placed upon the pavement and when the apparatus was placed upon a smooth surface. The test results were then assembled so that the following relationships could be studied:

1. Average texture depth vs. coefficient of friction using California Portable Tester.

2. Average texture depth vs. towed trailer skid number - ribbed tire.

3. Average texture depth vs. towed trailer skid number - smooth tire.

4. Average texture depth vs. 40-50 mph towed trailer speed gradient - ribbed tire.

5. Average texture depth vs. 40-50 mph towed trailer speed gradient - smooth tire.

The data presented in Figures 3, 4, and 5 indicate that there was a general trend toward increasing coefficients of friction and skid numbers when deeper surface textures were encountered. However, the scatter of the data about the line of best fit was such that the establishment of a specification requirement for texture depth minimums would be of questionable value.

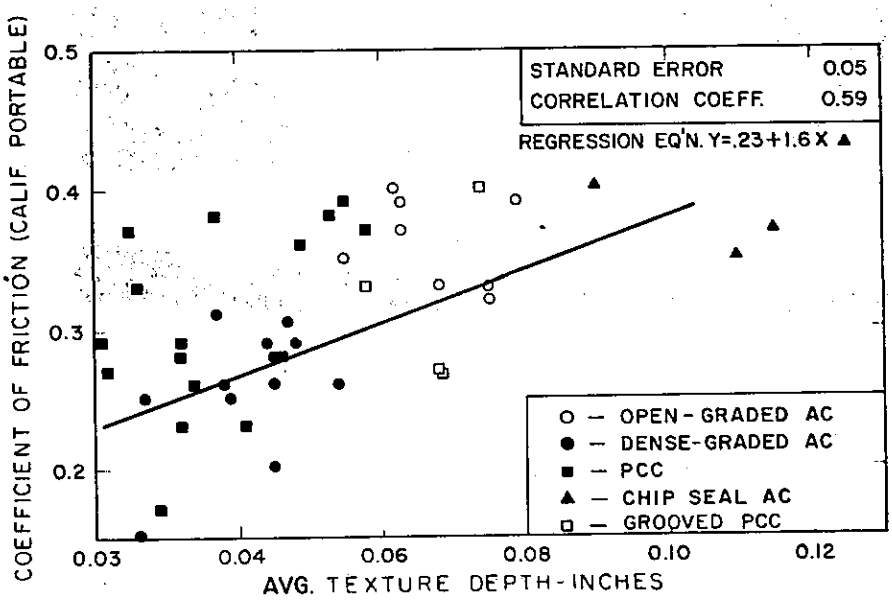

Fig.3 MODIFIED SAND PATCH TEXTURE VS COEFFICIENT OF FRICTION (BY CALIF PORTABLE)

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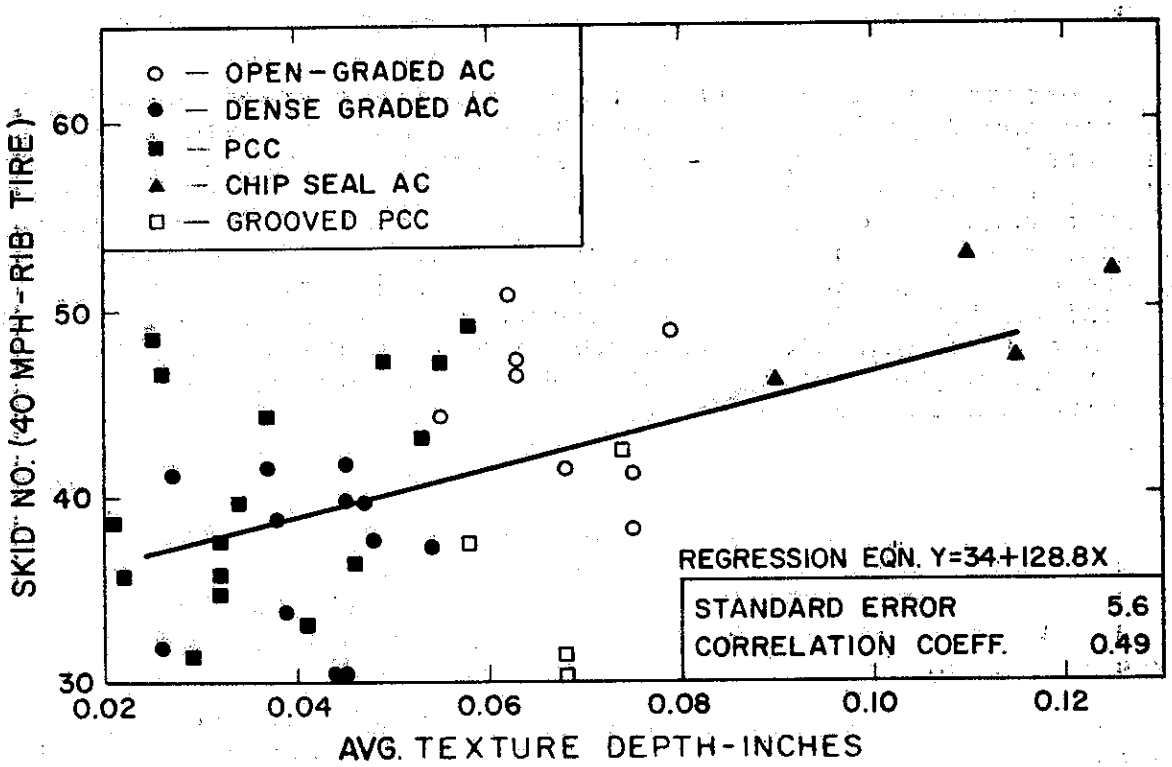

Fig. 4 MODIFIED SAND PATCH TEXTURE VS RIB TIRE SKID NO.

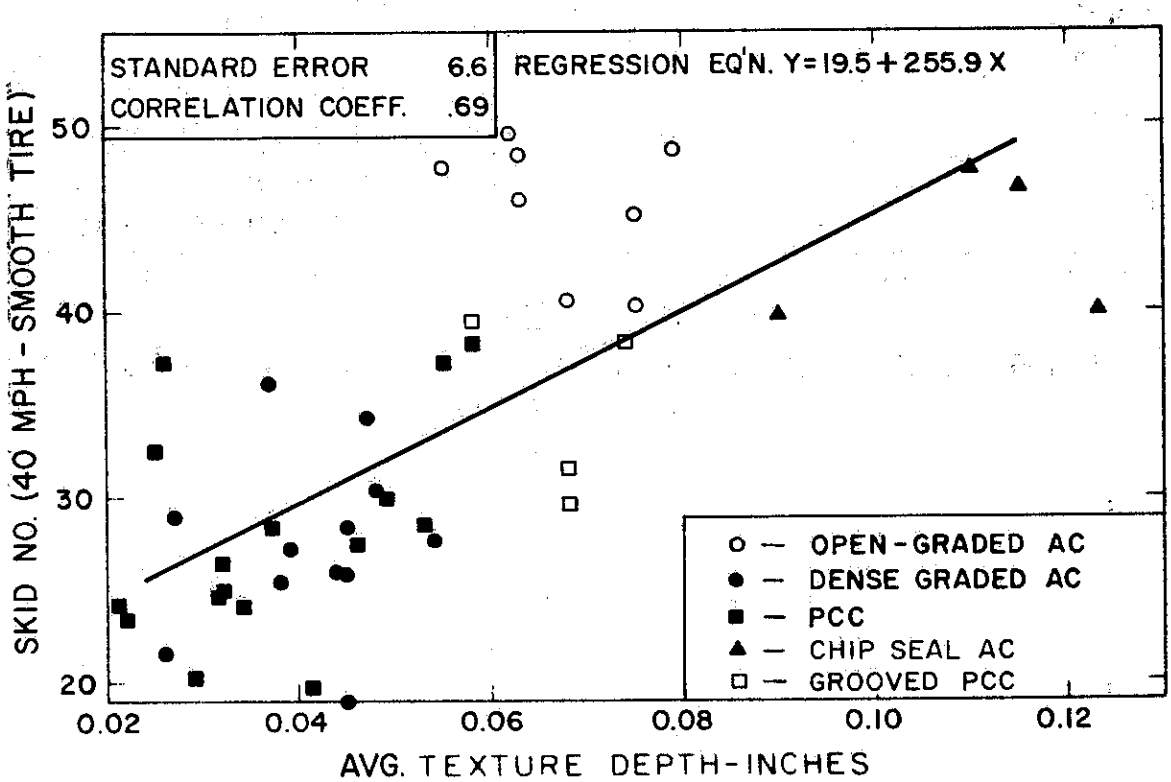

Fig. 5 MODIFIED SAND PATCH TEXTURE VS SMOOTH TIRE SKID NO.

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The data presented in Figures 6 and 7 indicate a trend toward decreasing speed gradients as the texture depth increases. This is the trend that was expected but the scatter of the data about the straight line of best fit was again such that the measurement of a given texture depth would give only moderate assurance that a particular speed gradient would be provided by the pavement being tested. Comparison of the smooth tire and ribbed tire towed trailer data indicates that the relationship between texture depth, as measured by the sand patch apparatus used, and skid number or speed gradient is about equally well defined by the ribbed tire and the smooth tire.

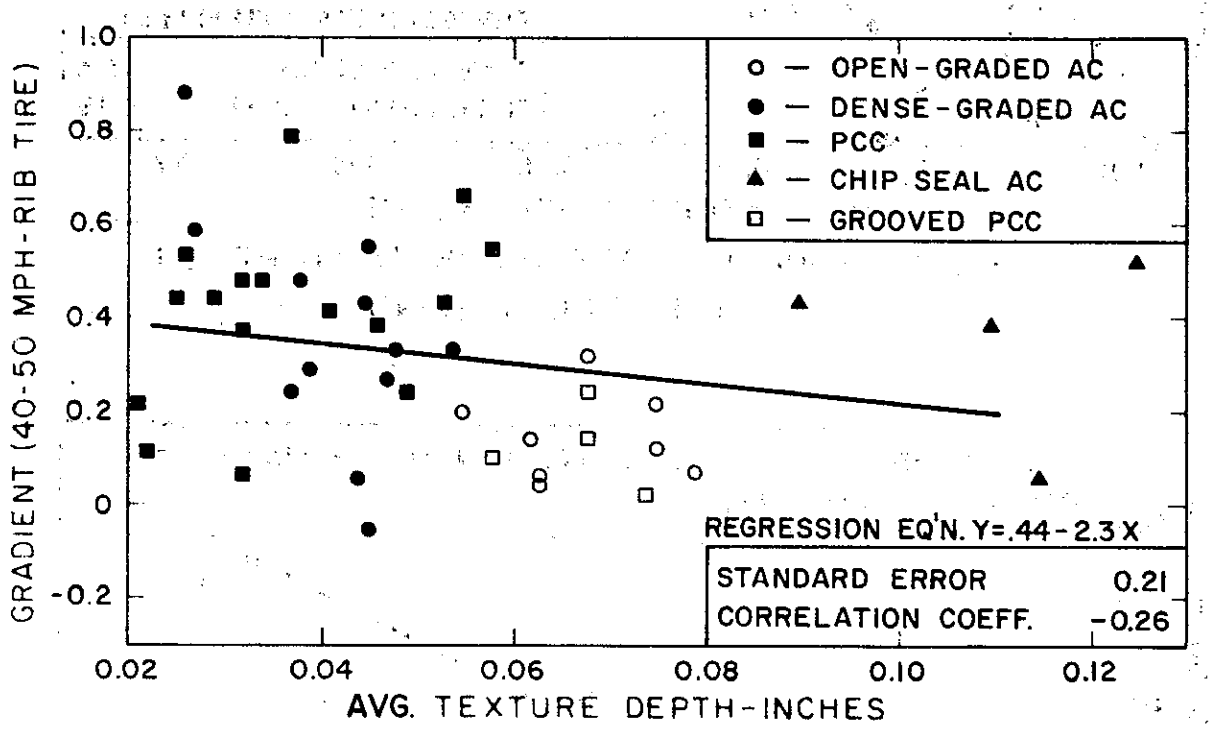

Fig 6 MODIFIED SAND PATCH TEXTURE VS GRADIENT USING RIB TIRE

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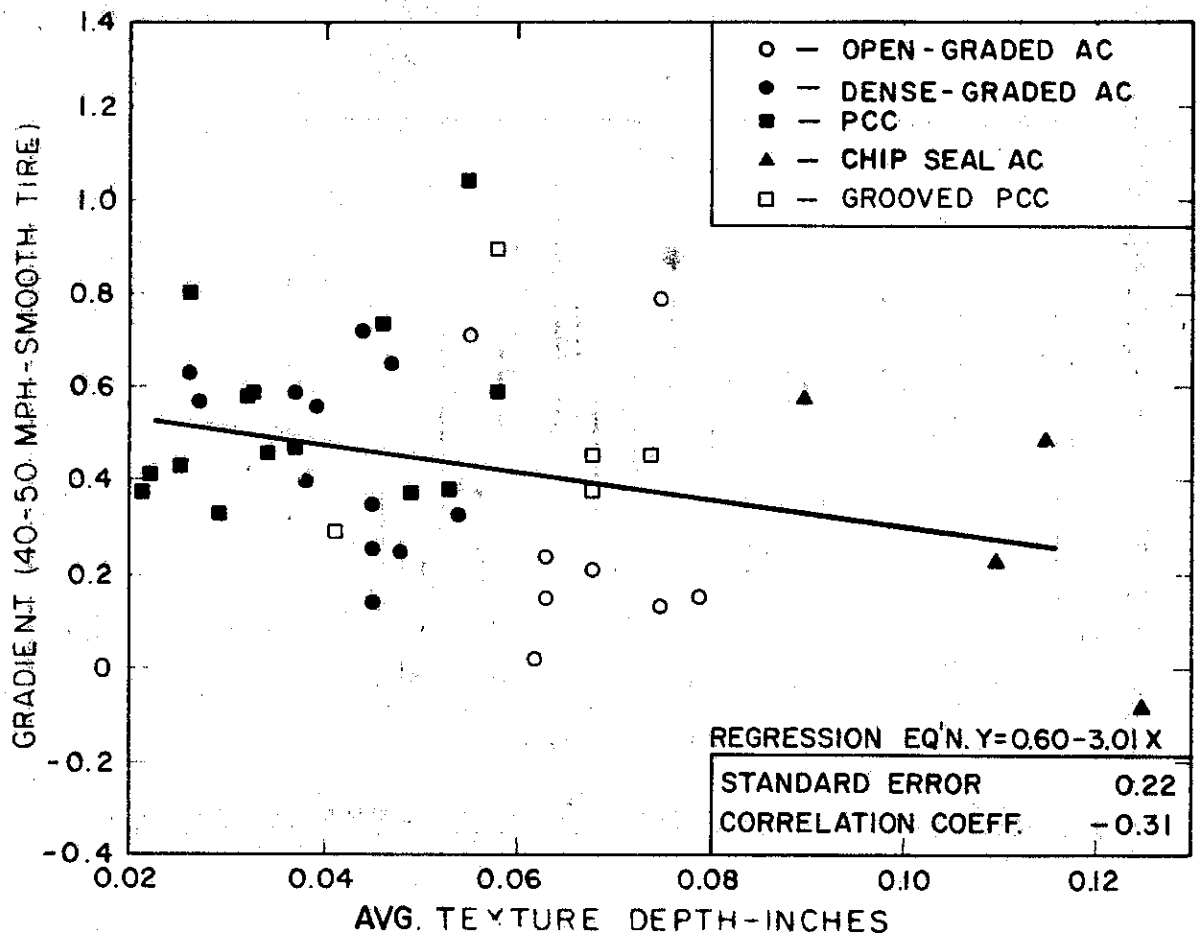

Fig. 7 MODIFIED SAND PATCH TEXTURE VS GRADIENT USING SMOOTH TIRE

The lack of definitive relationships between texture depth and both skid number and speed gradient was disappointing and attributed, in part, to the possibility of poor test repeatability. To study the repeatability of the sand patch apparatus, forty test locations were selected at random within a 12-foot by 40-foot portion of a new, broomed portland cement concrete pavement. No skid numbers or coefficients of friction were determined for this pavement but the SN40 for the pavement was estimated to be 50±10, which is consistent with the data presented in Figure 4. Two identical apparatuses were used by two operators to test each location - i.e., a total of 160 tests. The results of this study indicated that the repeatability of the test was not very good (See Figure 8). The average range was 24% of the mean value for each location but there was considerable scatter even in this value.

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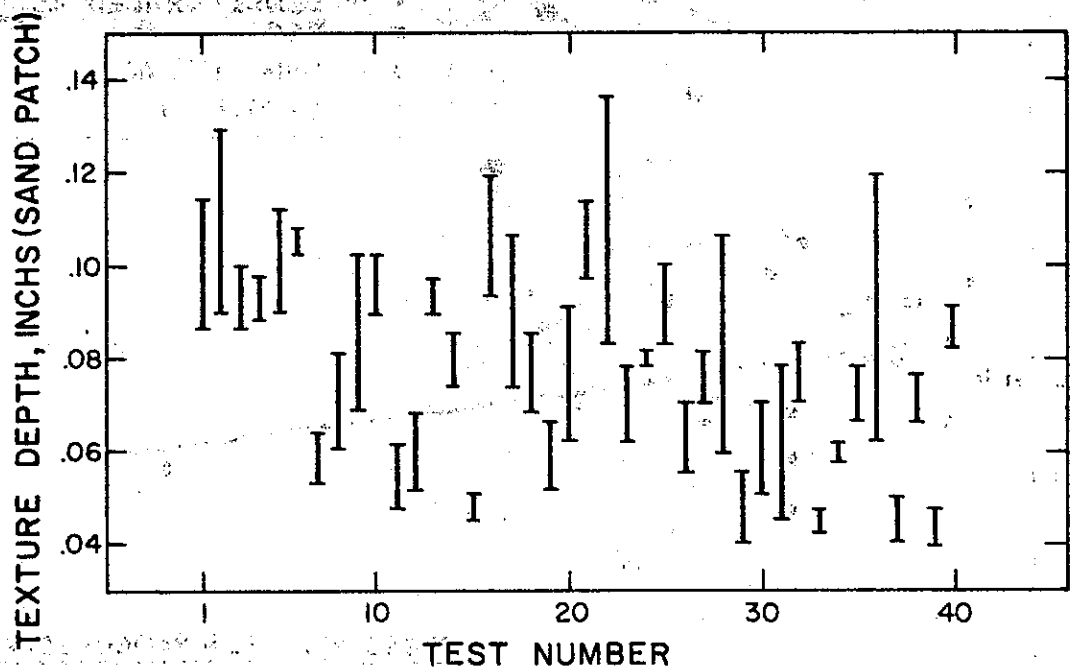

Fig. 8 MODIFIED SAND PATCH TEST REPEATABILITY

To try and improve upon this apparent lack of good repeatability, another apparatus was constructed using a 1/4-inch thick sheet of rubber that, it was reasoned, would more closely conform to the tops of the pavement asperities than did the rigid steel plate. A six-inch diameter hole was cut in the rubber and small brass weights embedded in the rubber on the periphery of the circular hole (See Figure 9). Repeatability tests involving two operators were conducted with this device on the flat smooth surface (counter top) used for "calibrating" the device and also on an asphalt concrete surface of moderate texture depth. A finer sand (Ottawa 30 x 50) was also used for this testing. Although somewhat better than the steel plate, there was a moderate amount of variation in this data also. The range of test values was 10% of the mean value for the smooth surface and 20% of the mean value for the asphalt concrete surface. Further testing with this device was then discontinued in favor of the outflow meter test.

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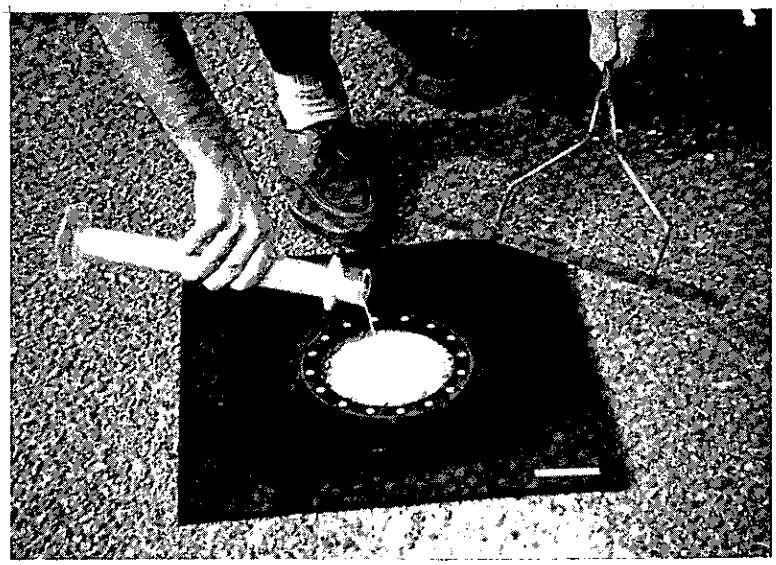

Figure 9.

The Outflow Meter Test

The other method of surface texture measurement considered worthy of investigation was the outflow meter. Previous work by Moore[14], and Hegmon and Miyoguchi[13] indicated that this approach to surface texture measurement had potential. The device used for this study was a 4 1/2-inch diameter plastic cylinder with a neoprene gasket attached to one end and circumferential reference lines placed 4" apart in the middle third of the cylinder (See Figures 10 and 11). The surface to be tested was pre-wetted by flooding for a period of 1 minute, after which the device was placed upon the wetted surface, filled with water, and the water permitted to drain out of the cylinder through the opening present beneath the neoprene gasket. The time required for the water level in the cylinder to drop from the upper reference line to the lower reference line was recorded. Using this approach, very short outflow times were indicative of rough surface textures and long outflow times were indicative of smooth surfaces. Inherent in this approach is the assumption that none of the water penetrates into the pavement and flows laterally within the pavement, such as might occur with an opened graded asphalt concrete.

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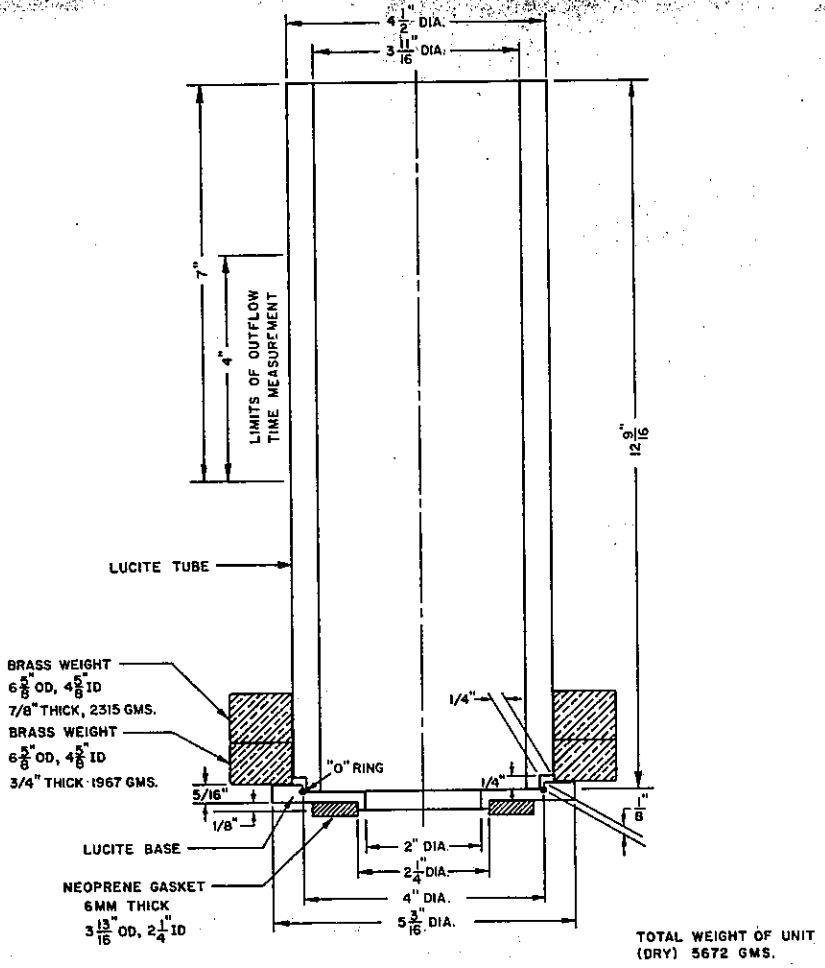

DIMENSIONS OF THE OUTFLOW METER

Figure 10

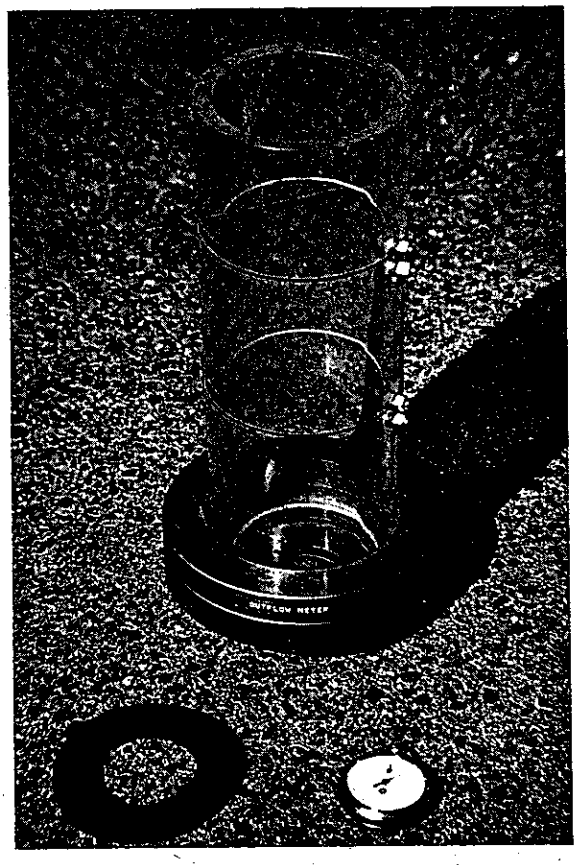

Figure 11.

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Twenty-three test sites were selected on un-opened and operational portland cement concrete pavements. Skid tests were conducted using the towed trailer in accordance with the applicable portions of ASTM Designation E274-65T in the right wheel track at speeds of 20, 30, 40, 50, and 60 mph. Both ribbed and smooth tires were used. The location of the 40 mph test skid at each of the twenty-three sites was then divided into eight equal lengths and the smoothest appearing portion of each was tested once using the outflow meter. This approach was chosen because it was reasoned that a texture depth specification would probably require a texture depth exceeding some minimum value.

Comparisons of the smooth and ribbed tire 20, 40, and 60 mph skid numbers with average texture depth are presented in Figures 12 through 17. As was the case with the modified sand patch test, the trend toward increasing skid numbers for rougher textures (i.e., lesser outflow times) was evident in all cases. The trend was somewhat more pronounced for the ribbed tire tests than for the smooth tire tests. These observations also apply to the 30 and 50 mph data that is not included in this paper but is included in Reference 15. The data also indicates that the ribbed tire SN- outflow time relationship is more definitive at higher speeds. The scatter of the data about the regression line of best fit is considerable, however. The selection of the worst condition (i.e., smoothest locations) for comparison with the skid numbers may have contributed to this scatter somewhat.

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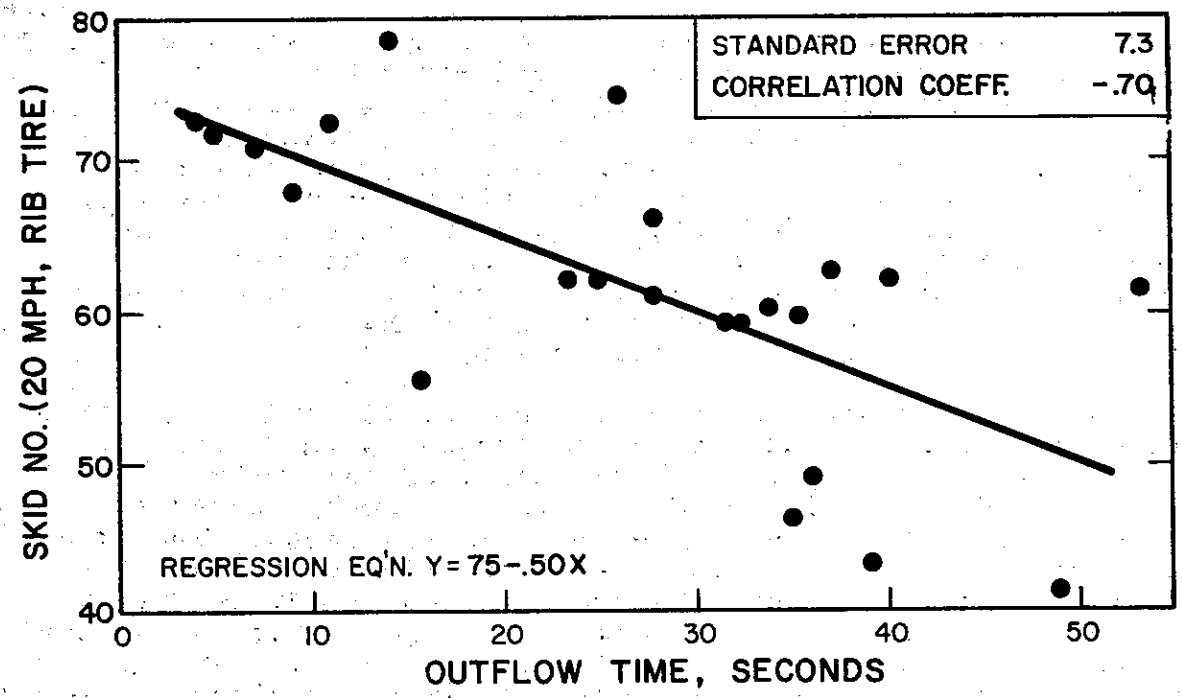

Fig. 12 OUTFLOW TIME VS SKID NO. AT 20 MPH USING RIB TIRE

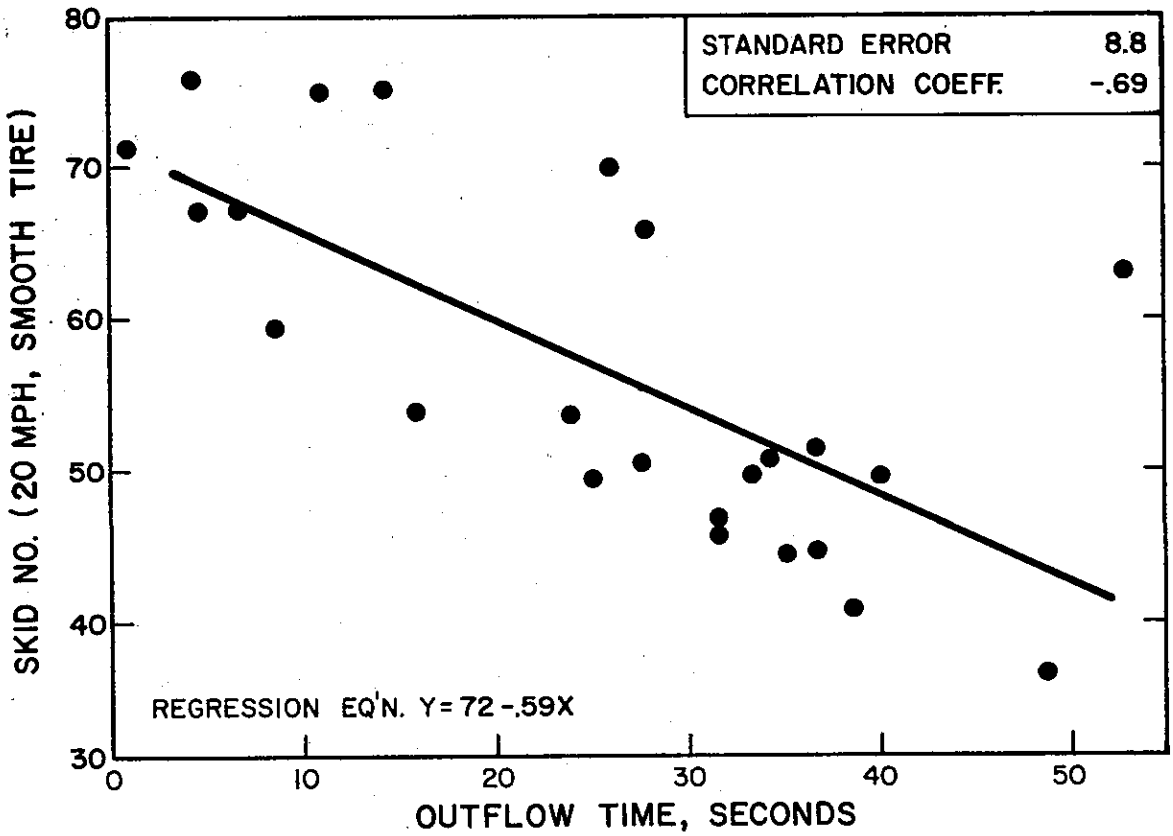

Fig. 13 OUTFLOW TIME VS SKID NO. AT 20 MPH USING SMOOTH TIRE

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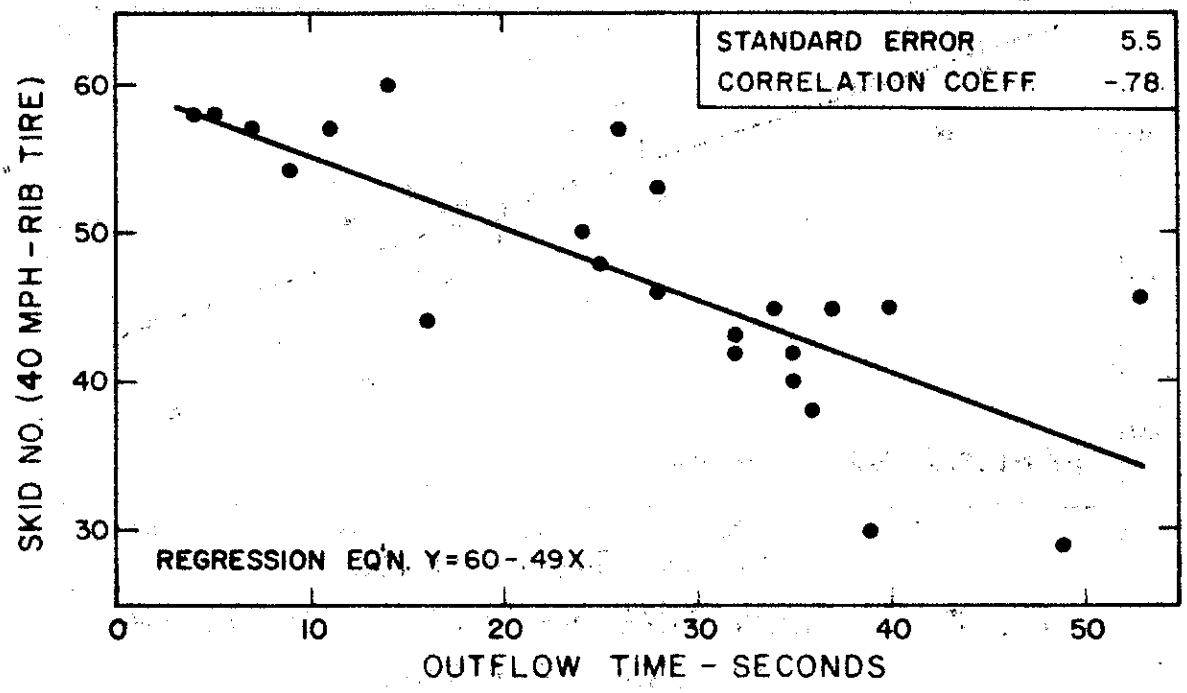

Fig. 14 OUTFLOW TIME VS SKID NO. AT 40 MPH USING RIB TIRE

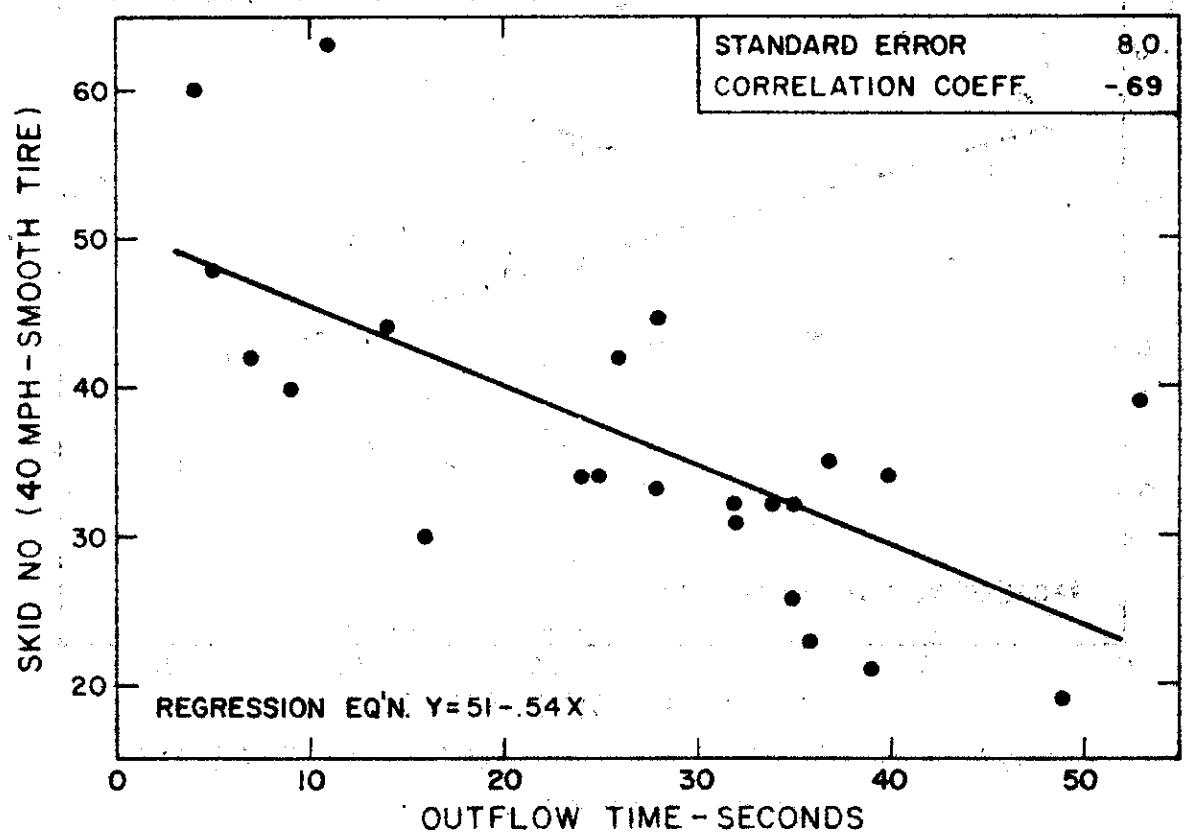

Fig. 15 OUTFLOW TIME VS SKID NO. AT 40 MPH USING SMOOTH TIRE

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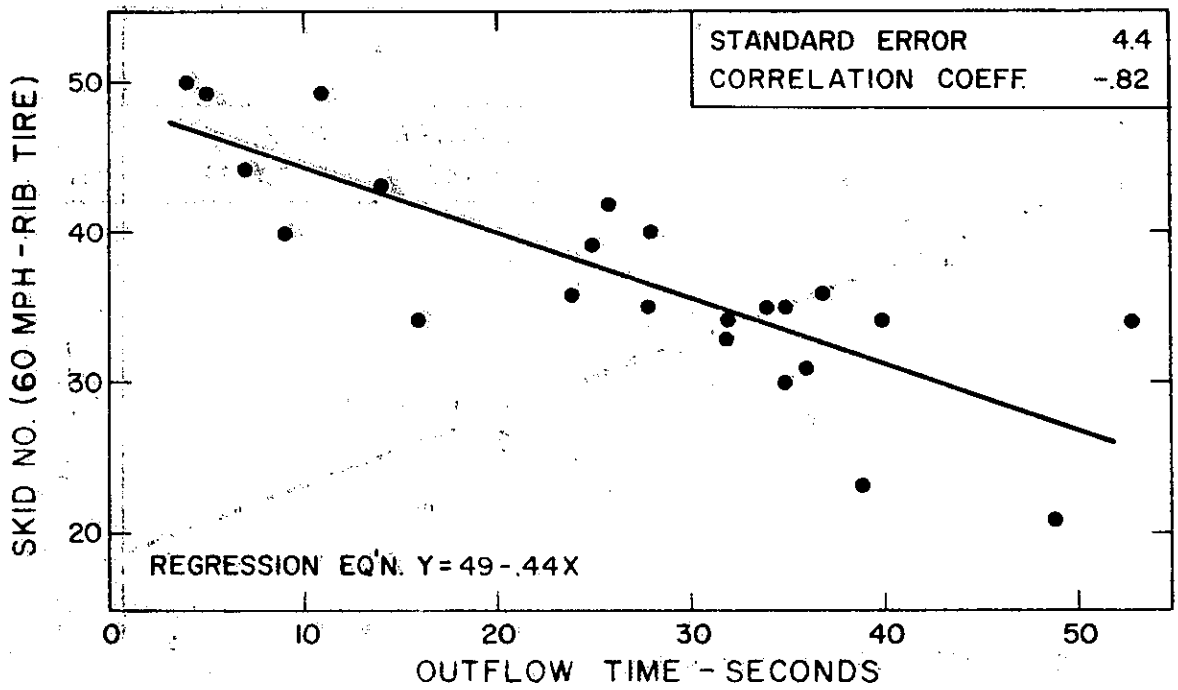

Fig. 16 OUTFLOW TIME VS SKID NO. AT 60 MPH USING RIB TIRE

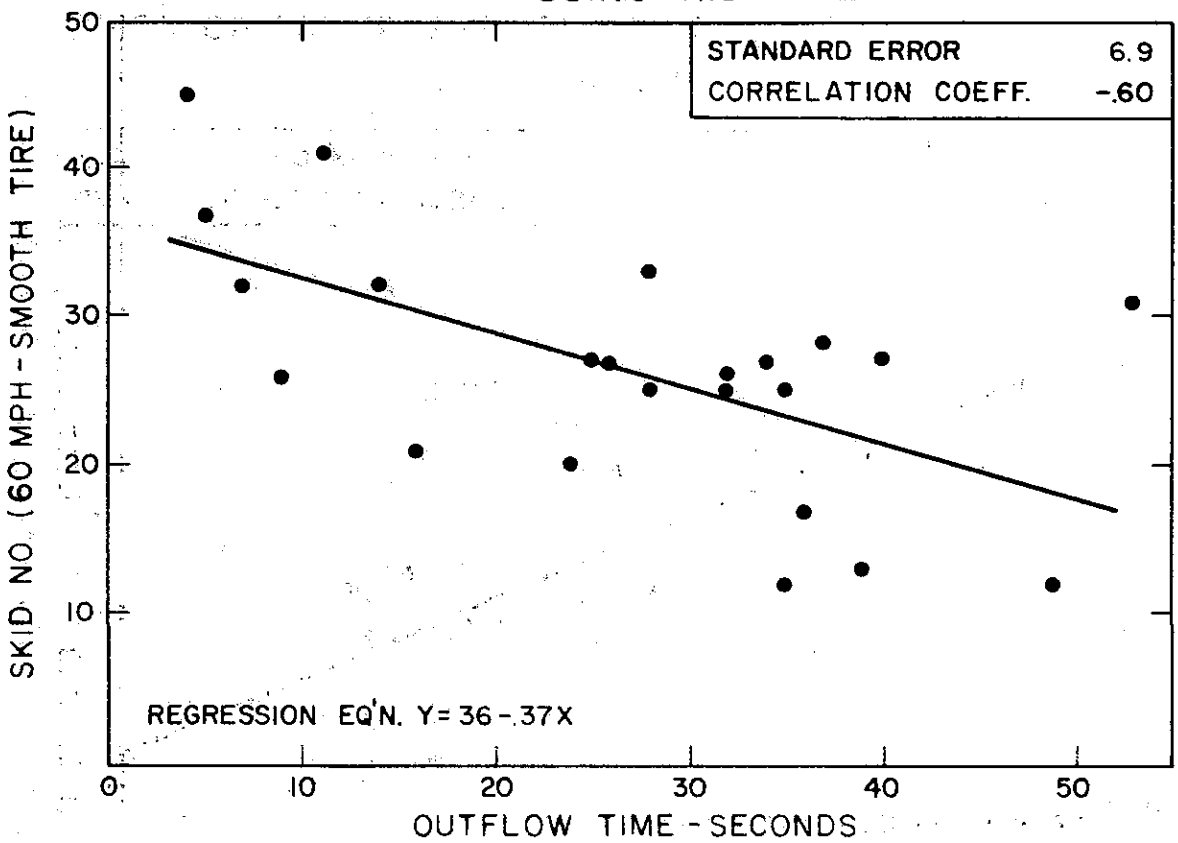

Fig. 17 OUTFLOW TIME VS SKID NO AT 60 MPH USING SMOOTH TIRE

The 20-60 mph speed gradient correlation with outflow time was poor for both the ribbed and smooth tires (See Figures 18 and 19). This was quite disappointing in that it was originally felt that one of the main attributes of surface texture measurement would be an indication of the speed gradient of the surface.

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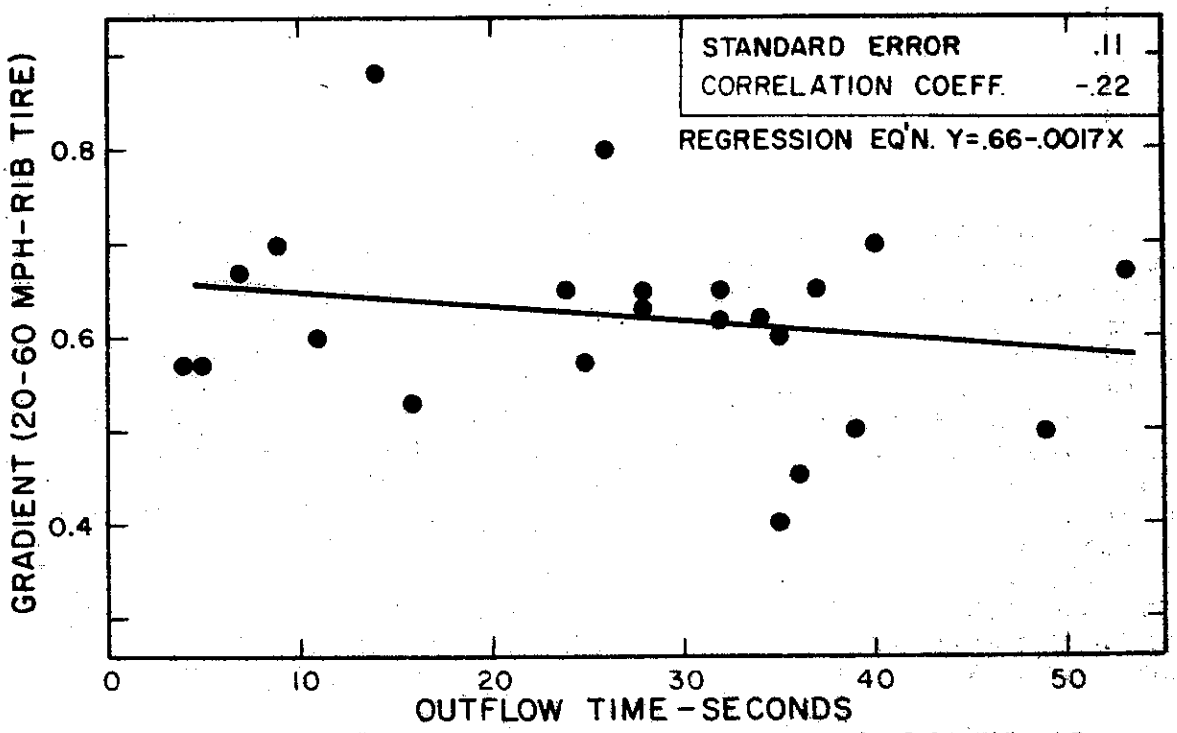

Fig. 18 OUTFLOW TIME VS GRADIENT 20-60 MPH USING RIB TIRE

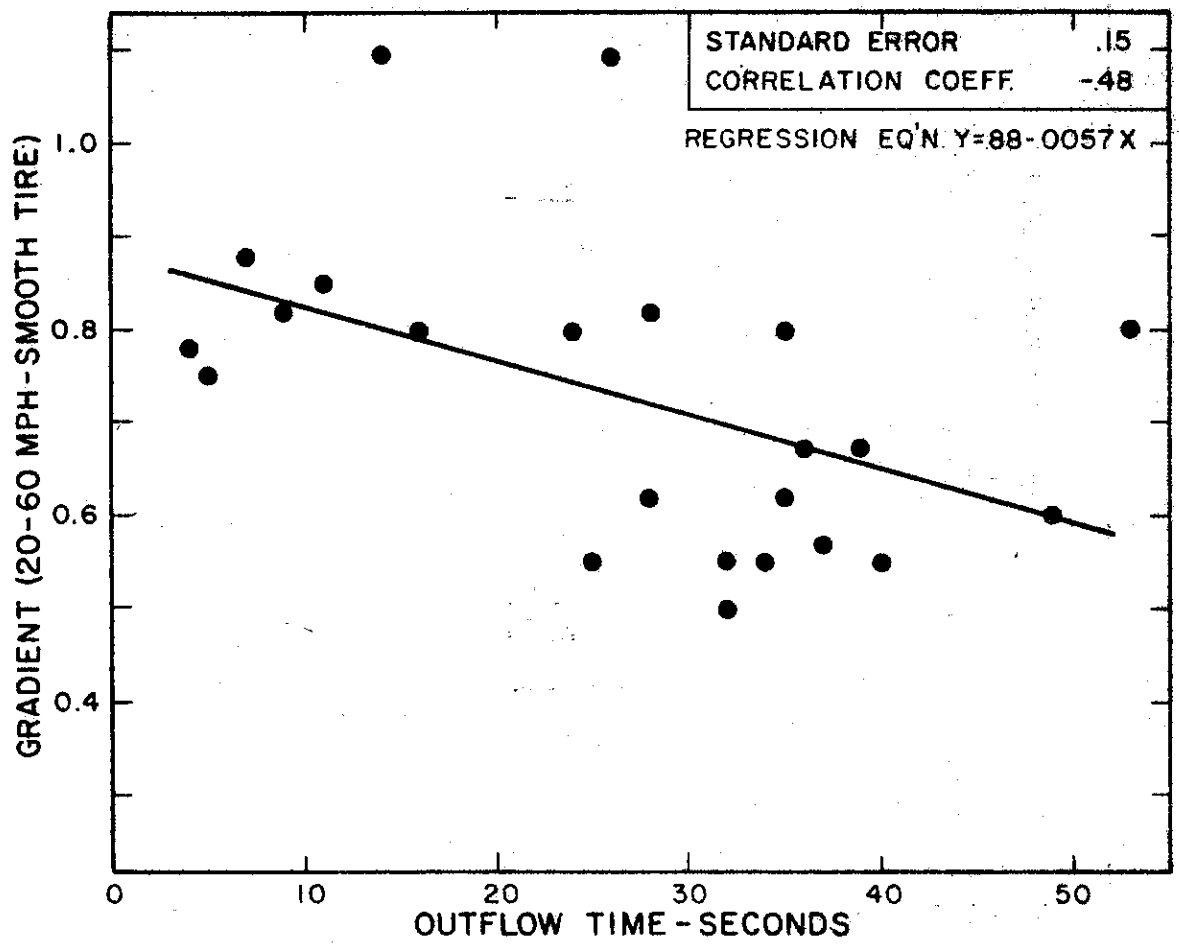

Fig. 19 OUTFLOW TIME VS GRADIENT 20-60 MPH USING SMOOTH TIRE

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In an attempt to explain this lack of correlation, the effect of water temperature upon the repeatability of the outflow test was studied. Portland cement concrete pavement cores with friction coefficients of 0.15, 0.23, 0.33, and 0.41 were used for this testing. Through the use of targets, the outflow meter was placed within 0.1-inches of the same relative location on each core for each test. However, the outflow meter was rotated approximately 10° between tests. Figure 20 shows the apparent effect of water temperature on the outflow times measured for each of the four cores. For pavements with the more common coefficients of from 0.23 to 0.41 (approximate SN40 values of from 34 to 48), the temperature of the water, within the limits tested, had no undue influence upon the test results. The effect of changes in water temperature upon the hardness of the neoprene gasket was also studied and very little effect was noted.

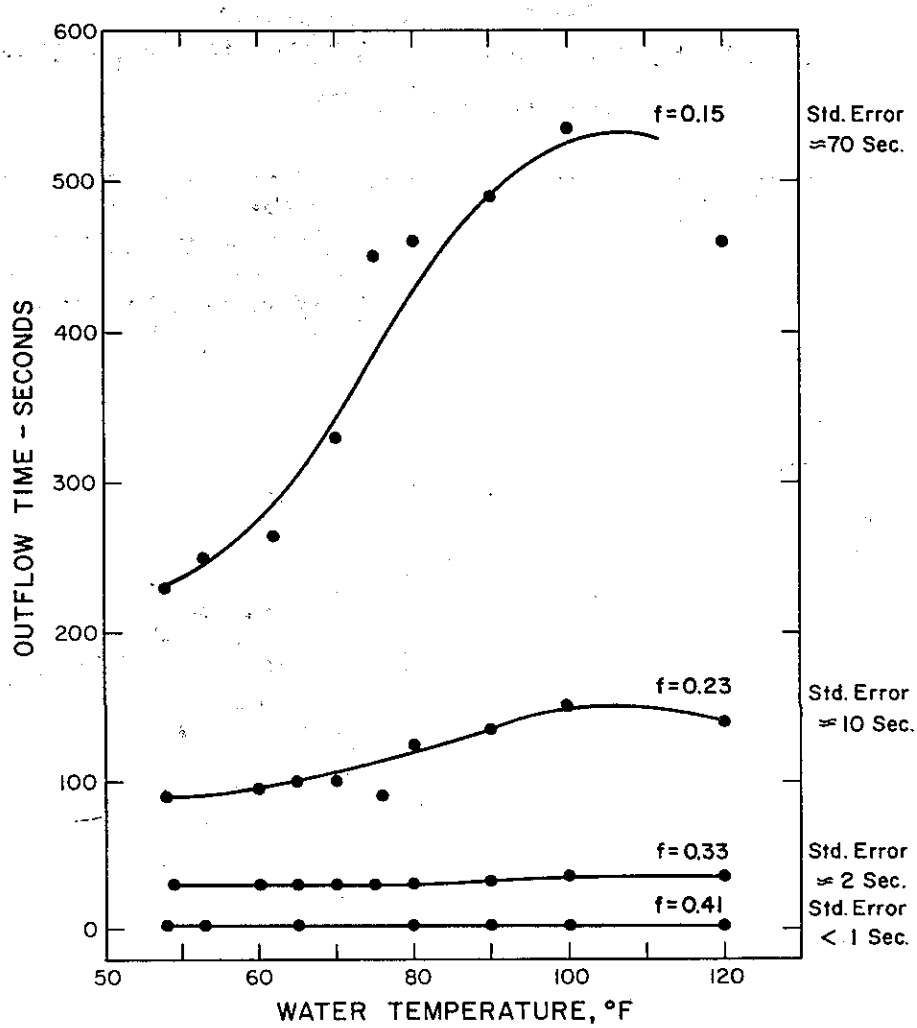

Fig. 20 OUTFLOW TIME VS WATER TEMPERATURE USING PAVEMENTS WITH VARIOUS COEFFICIENTS OF FRICTION.

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Figure 21 contains all the towed trailer data for the outflow meter testing. The data indicates that the difference between the smooth tire data and the ribbed tire data is fairly predictable, at least for portland cement concrete pavement surfaces under the conditions tested. This indicates that the ribbed and smooth tire skid numbers may not be separate and distinct values and that including the results of both tests in calculations of an overall numerical measure of a pavement's skid resistance may be of questionable benefit.

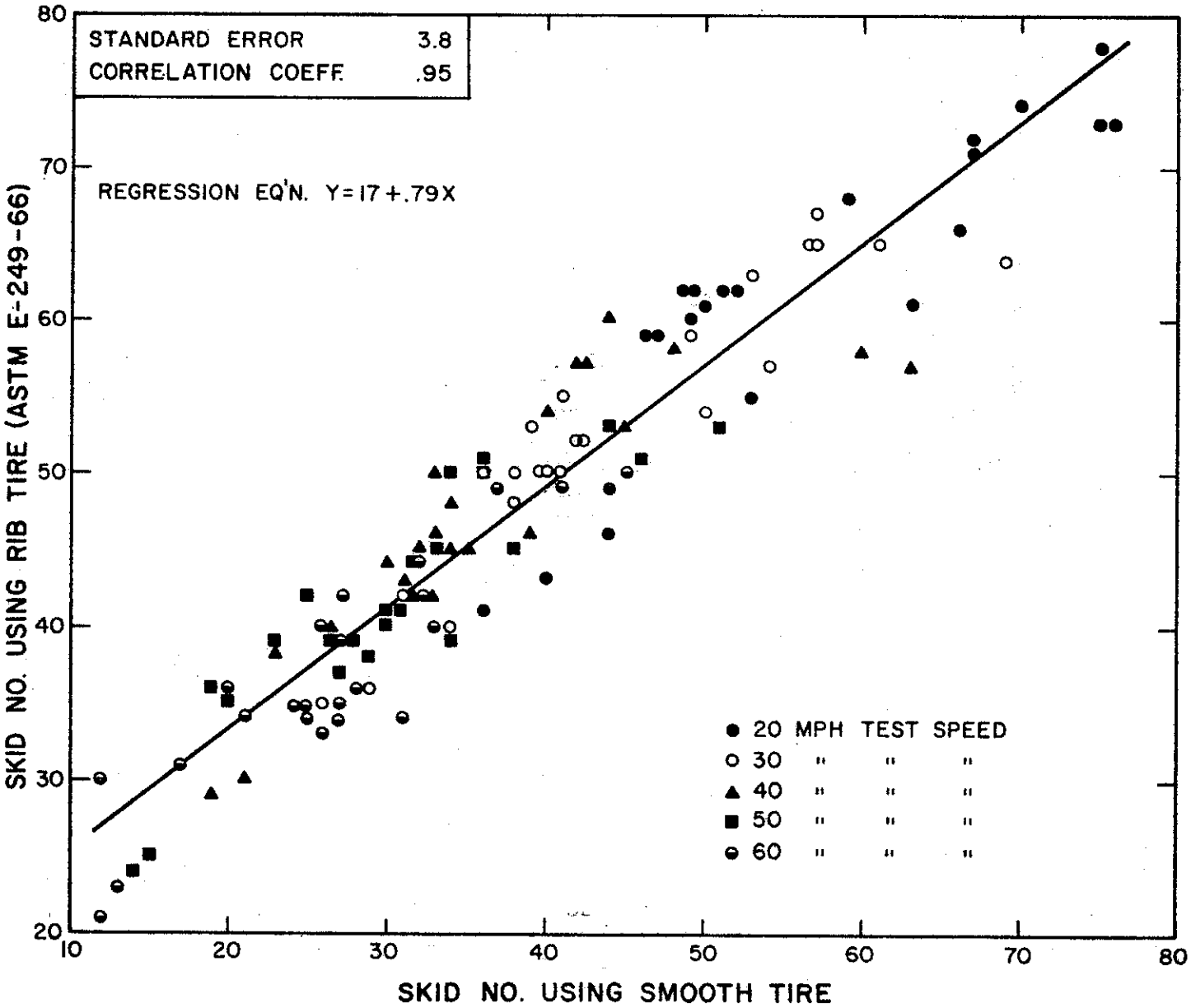

Fig. 21 SKID NO'S. USING RIB AND SMOOTH TIRES ON PCC PAVEMENTS

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Conclusions

The following conclusions are based upon the data reported herein and are applicable for the pavement types and test conditions used:

1. The sand patch test, as modified for this study, exhibited poor repeatability.

2. Although a general trend toward higher skid numbers and coefficients of friction was evident with increasing texture depths, as measured with both the modified sand patch and the outflow meter tests, neither relationship was definitive enough to use as a basis for a minimum texture depth specification requirement.

3. Neither the modified sand patch nor the outflow meter texture measuring procedure will provide a definitive measure of the skid number speed gradient of the pavement being tested.

4. Any further studies of the outflow meter approach should include open graded and dense graded asphalt concrete surfaces. The effect of pre-wetting the surface should be studied closely, particularly with regard to the open-graded pavement surface. Also, a random technique should be used to select the location of the outflow meter test within the area tested with any skid resistance apparatus.

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METHOD OF TEST FOR SURFACE SKID RESISTANCE WITH THE CALIFORNIA PORTABLE SKID TESTER

Scope

The apparatus and procedure for obtaining coefficient of friction values of bituminous and portland cement concrete pavements and bridge decks using a portable skid tester are described in this test method.

Procedure

A. Apparatus

1. Skid test unit.

a. Reference is made to Figures I through III in connection with the following description of the test unit. A 4.80/4.00x8, 2-ply tire (A, Fig. I) with 25 (±2) psi air pressure manufactured with a smooth tread, together with rim, axle and driving pulley is mounted on a carriage (B, Figs. I, II & III). The tire is brought to desired speed by motor (H, Figs. I, II & III). The carriage moves on two parallel guides (C, Figs. I & III). Friction is reduced to a low uniform value with three roller bearings fitted at 120° points to bear against the guide rod at each corner of the carriage. The bearing assembly (D) may be noted on Figures I & III. The two guide rods (C) are rigidly connected to the end frame bars (E, Fig. I). The front end of this guide bar frame assembly is firmly fastened to a bumper hitch to restrain forward movement. 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, Figs. I & II) to hold the tire ¼-inch above the surface to be tested. This device is constructed so that the tire may be dropped instantaneously to the test surface by tripping the release arm (G, Fig. II). The tachometer (K, Figs. II & III) indicates the speed of the tire in miles per hour. The springs (L, Figs. I, II & III) are calibrated by procedures outlined in Method No. Calif. 914A.

2. Hitch for fastening unit to vehicle.

3. Special level to determine grade of surface.

a. A 28″ long metal carpenter's level, Figure 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′x1″ is satisfactory).
5. A stiff fiber push broom.

C. Test Procedure

1. Clean extraneous material from the test surface with a fiber broom.

2. Determine the grade with the special level and record. See Figure IV.

a. Place level on the surface parallel to test direction with adjustable end down grade.

b. Adjust level until bubble centers.

c. The grade is indicated on the calibrated sliding bar. Record grade to nearest 0.5 percent.

3. Remove the skid test unit from vehicle, attach to bumper hitch and connect power cables (I, Fig. I) as shown in Figure V.

4. Position the skid tester with the tire over selected test area. (Normally parallel to direction of traffic.)

5. Adjust tire ¼-inch (1/16″ tolerance) above surface to be tested (F, Figs. I & II).

6. Using a paint brush, wet the full circumference of the tire (M, Fig. III) and surface under the tire to 16″ ahead of tire center with glycerine.

7. Release rebound shock absorber. (In front of switch J, and below motor, H, Figs. I & II.)

8. Set sliding gauge indicator (P, Figs. I & III) against carriage end.

9. Depress starting switch (J, Figs. I & II) and bring the speed to approximately 55 mi/hr.

10. Release starting switch.

11. The instant the tachometer shows 50 mi/hr., trip the arm (G, Fig. II) dropping tire to surface.

12. Read gauge (N, Figs. I & III) at the rear edge of indicator, P, and record the test measurement.

For a pavement surface, obtain 5 test measurements and report the average as the coefficient of friction. Make the tests in a longitudinal direction at 25-foot intervals unless any test measurement is less than the specified minimum. If less, then make five test measurements at 2-foot intervals within or including the smoothest appearing area.

For a bridge deck, obtain the coefficient of friction value by averaging 3 test measurements. Space each test location for this average no nearer than 2 feet nor farther than 4 feet, from any other test location. The spacing may be lateral or longitudinal but perform the test measurement in a longitudinal direction.

For any coefficient of friction value less than the specified minimum, use a combination of visual observations and individual test measurements to define the area of non-compliance.

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D. Calculations

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

2. Average the corrected readings representing any one test location. Example—The following readings were taken at 25′ intervals in a test location.

Station	*Test Measurement*	*Percent Grade*	*Corrected Test Measurement**
1+00	.37	+2	.39
1+25	.38	+1	.39
1+50	.40	+1	.41
1+75	.39	+1	.40
2+00	.41	+1	.42
	Average = Coefficient of Friction		.40

* Corrected values for upgrade measurements were taken from chart in Figure VI.

E. Precautions

1. The rear support rod (O, Figs. I & II) must be cleaned by washing frequently with water and a detergent to prevent sticking. A coating of light oil should be applied.

2. Sliding gauge indicator (P, Figs. I & III) must be kept clean so that it will slide very freely, and adjusted so that it will not shift upon carriage recoil impact.

3. Glycerine remaining on the surface after the test should be flushed off with water.

4. A minimum of seven days should lapse after PCC placement before testing.

5. A minimum of one day should lapse after AC placement before testing.

6. Temperatures less than 40°F will cause glycerine to become viscous and yield lower values. For full accuracy, coefficient of friction values must be obtained at temperatures greater than 40°F.

7. At the conclusion of a testing period, thoroughly wash the entire tester with water and carefully dry all parts with a cloth to combat the corrosive properties of glycerine.

F. Reporting of Results

The report shall normally include the following data:

1. Date tested and operators.
2. Contract number, location, and limits.
3. Date of surface placement.
4. Location of test measurements.
5. Grade of surface at the test site.
6. Measured and corrected test measurements and the average as a coefficient of friction value for each test location.
7. Average air temperature.
8. If noncompliance is determined, delimit the areas to be corrected.

Form TLB T-3111 as shown in Figure X is available for reporting.

REFERENCE

A California Method

End of Text on Calif. 342-D

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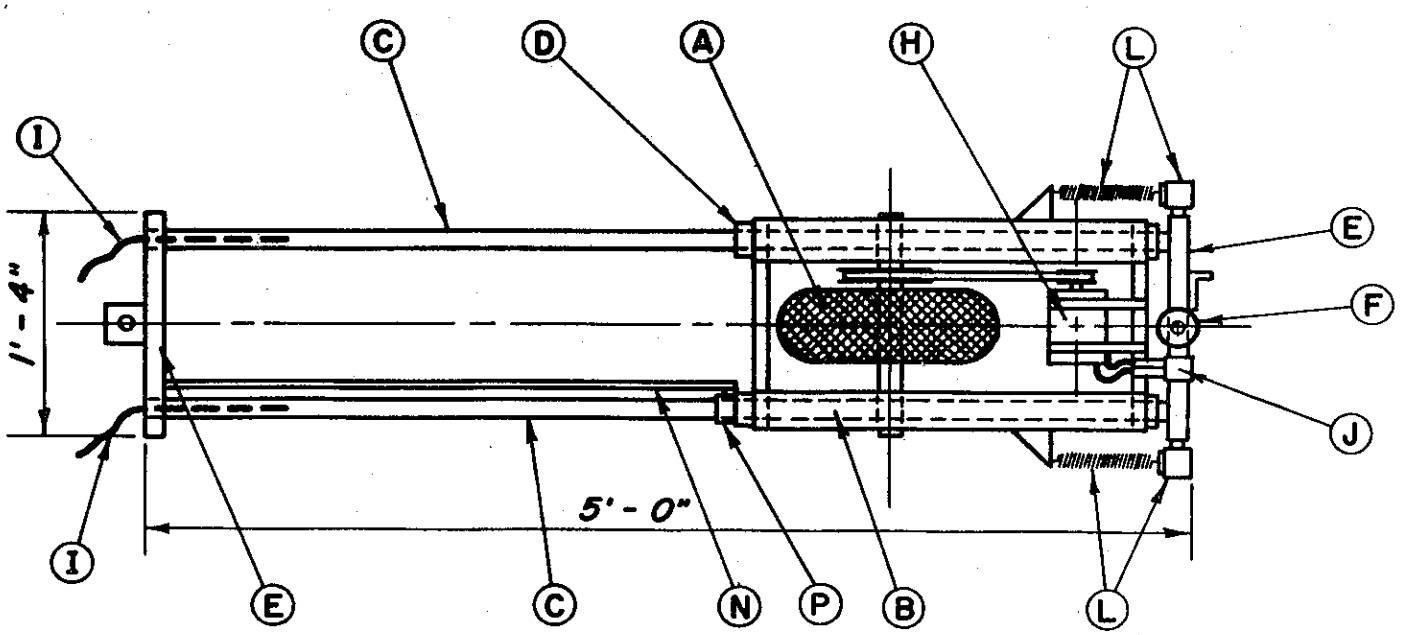

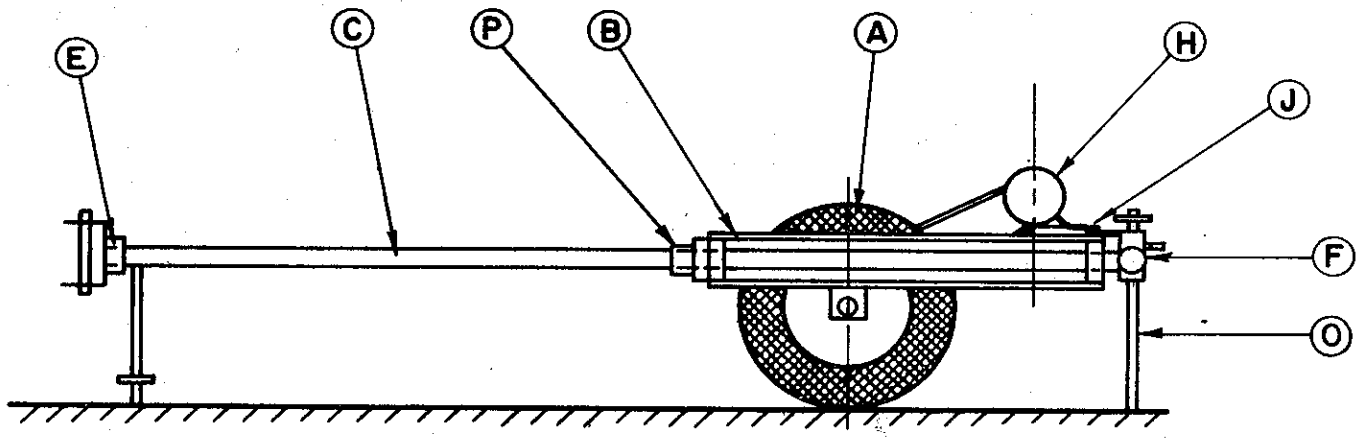

FIGURE 1

DIAGRAM OF SKID TESTER

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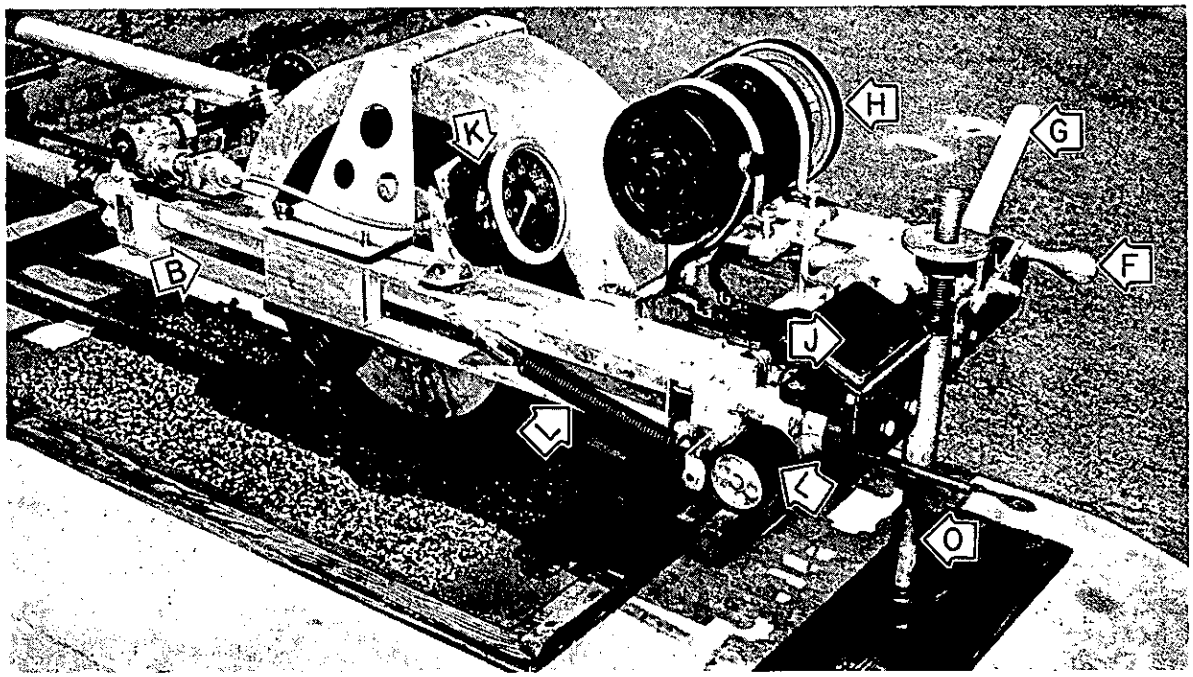

FIGURE II

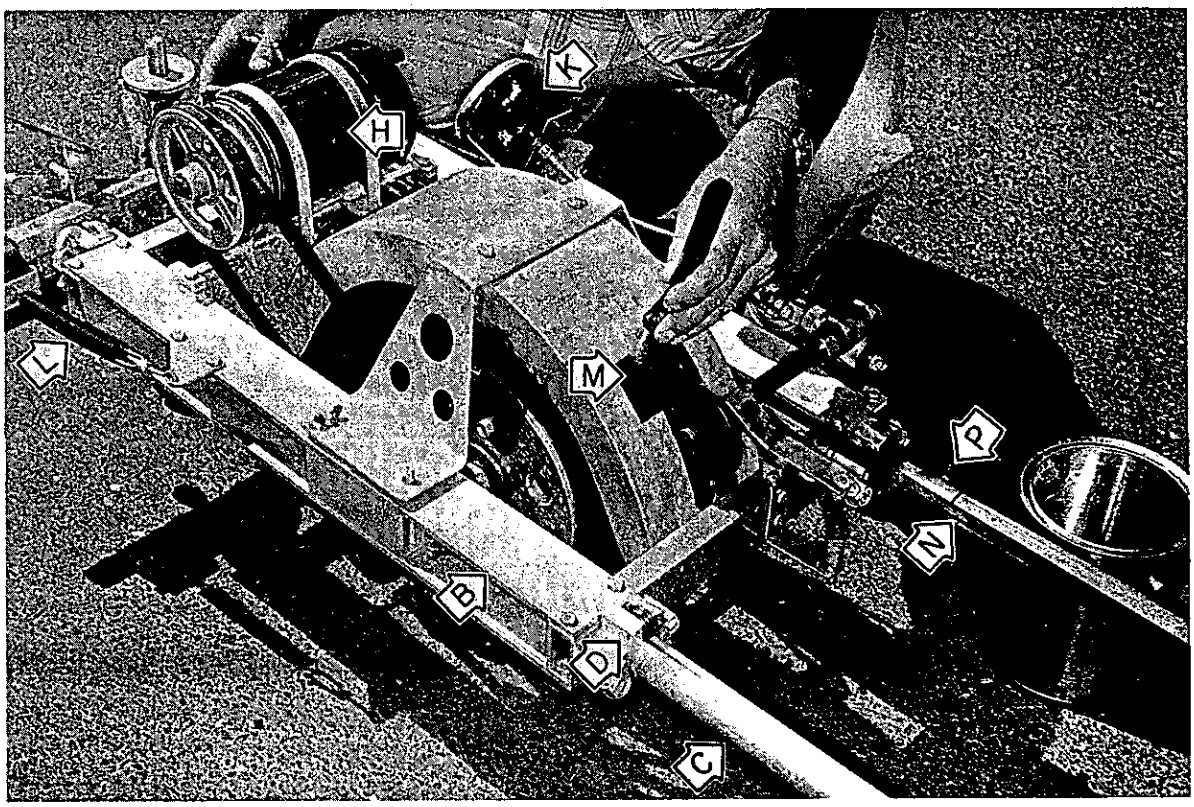

FIGURE III

CLOSE-UP VIEWS OF SKID TESTER

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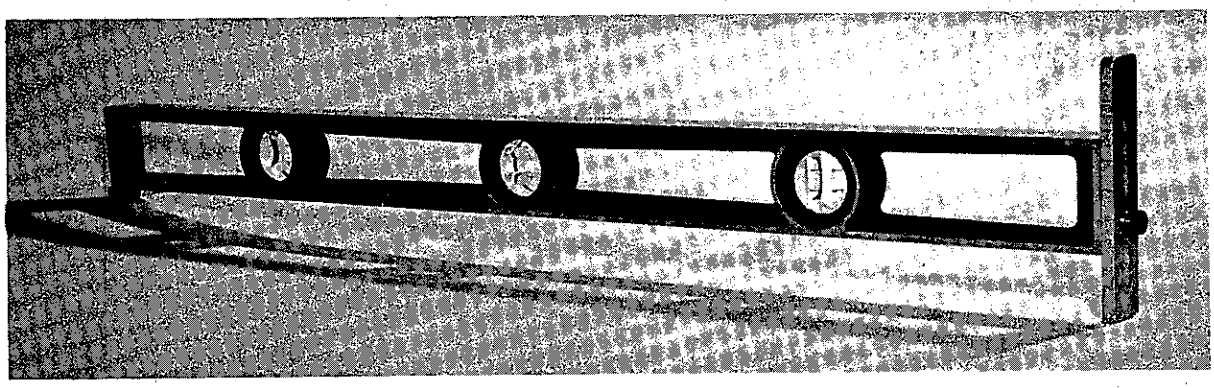

FIGURE IV
LEVEL FOR DETERMINING GRADE

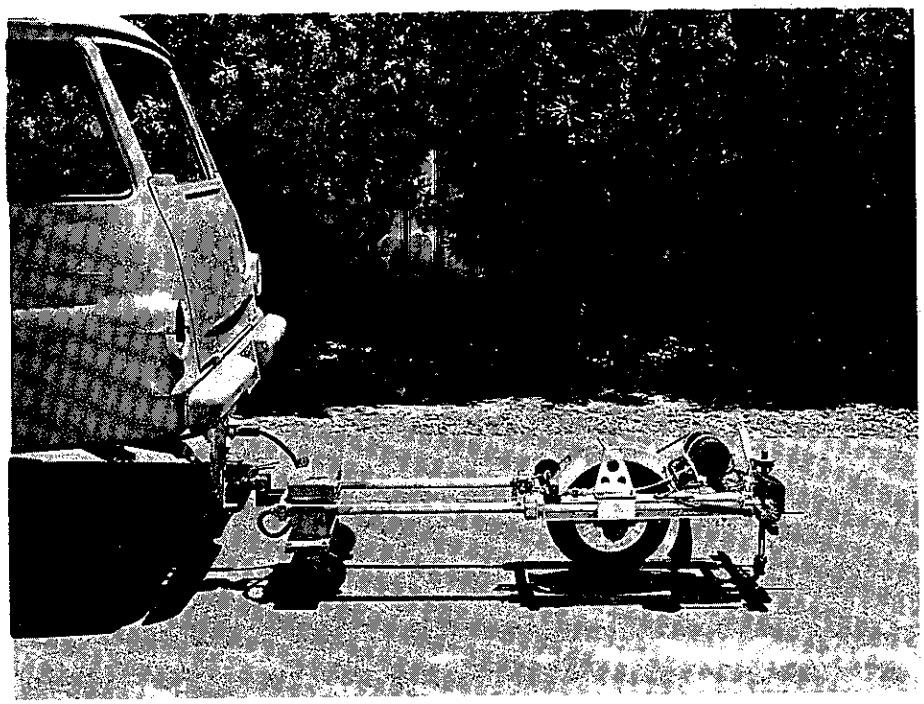

FIGURE V
APPARATUS IN POSITION FOR TESTING

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COEFFICIENT OF FRICTION CORRECTION CHART FOR MEASUREMENTS MADE ON GRADES

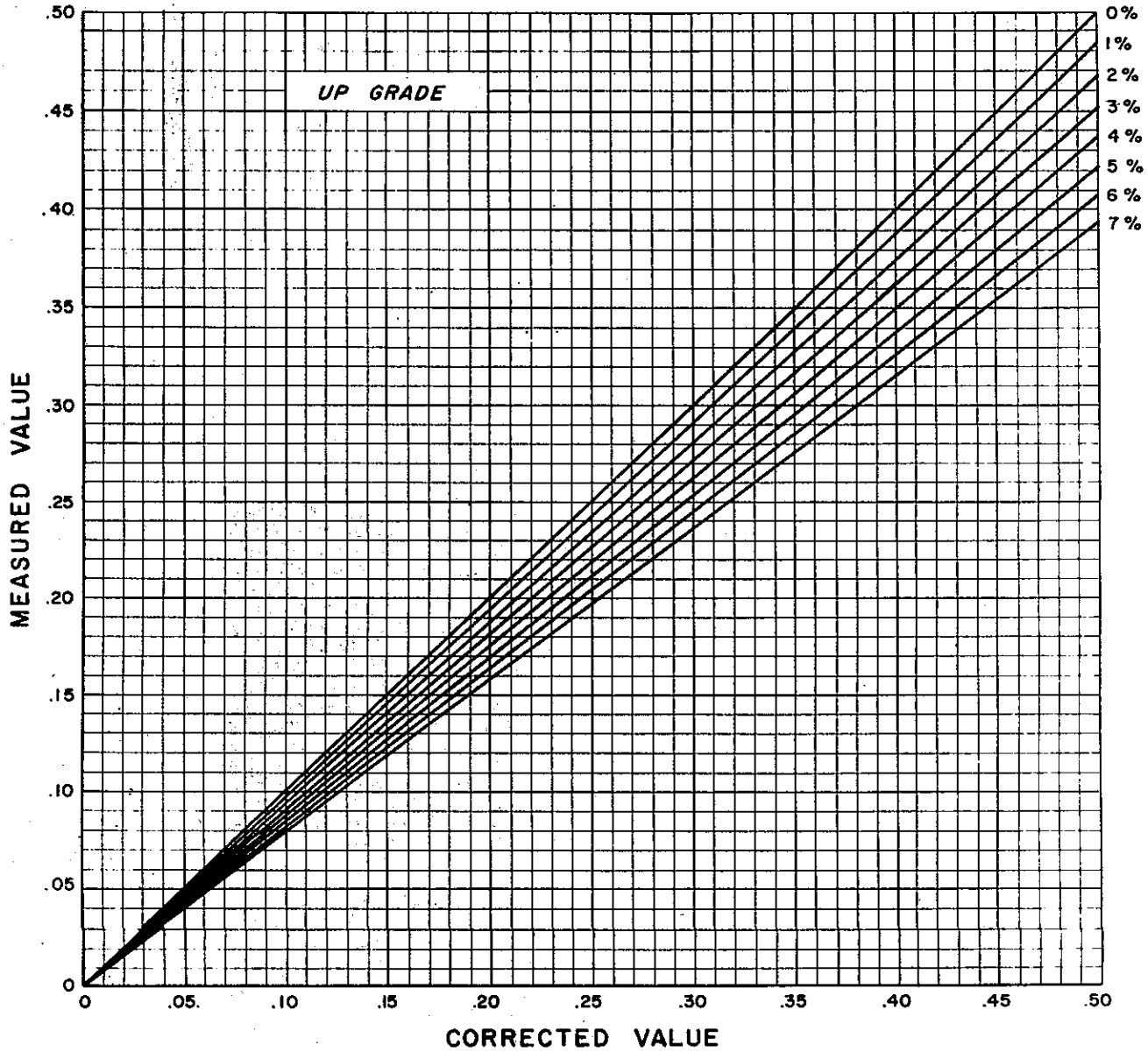

FIGURE VI

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COEFFICIENT OF FRICTION CORRECTION CHART FOR MEASUREMENTS MADE ON GRADES

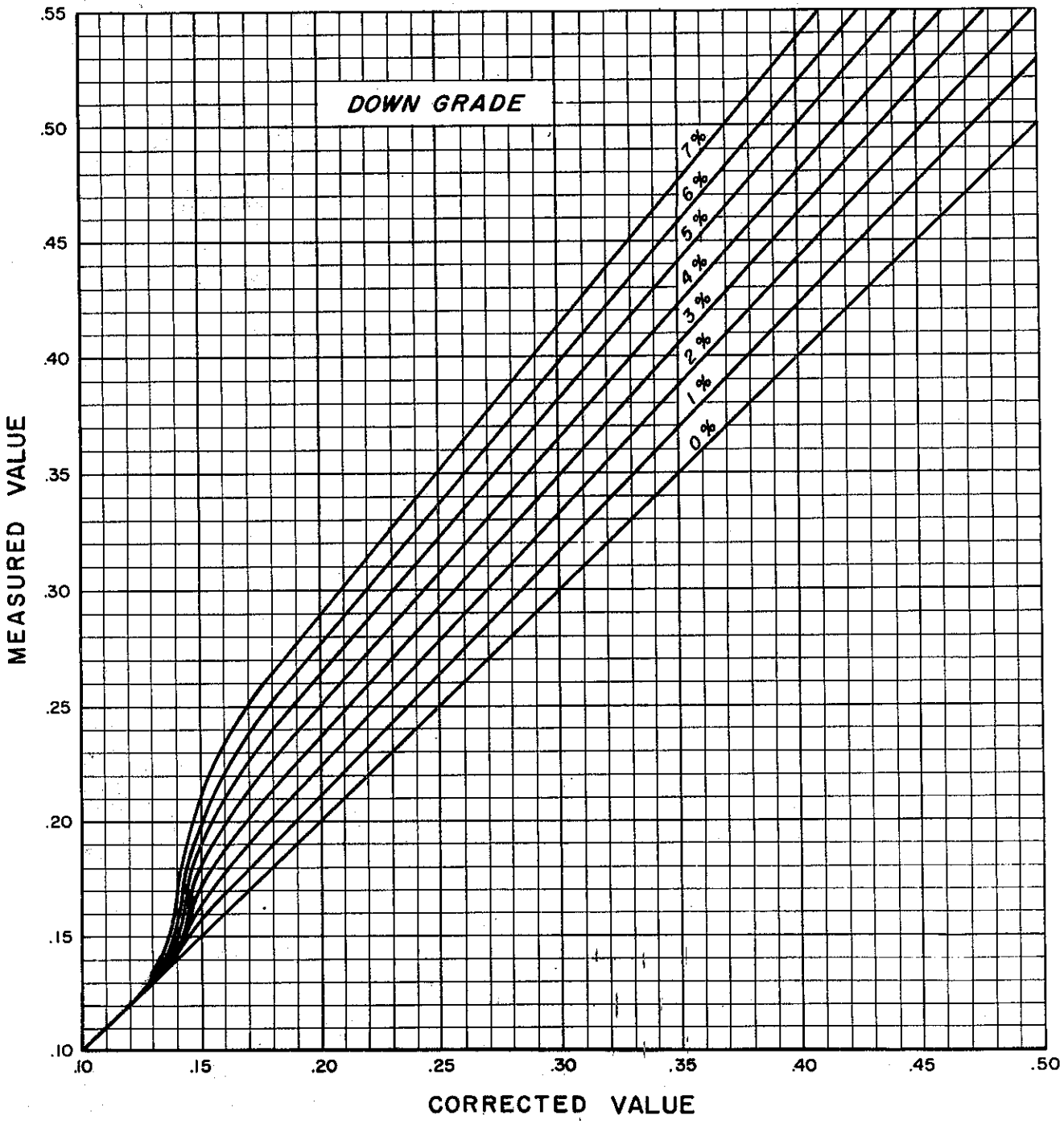

FIGURE VII

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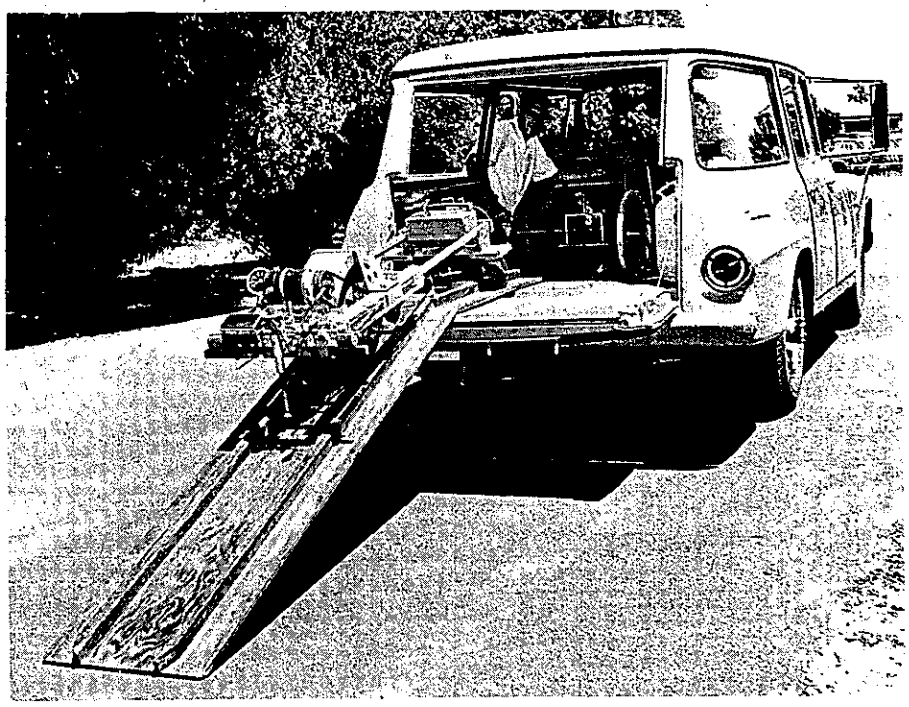

FIGURE VIII

APPARATUS BEING PLACED IN VEHICLE
NOTE CABLE AND WINCH FOR MOVING SKID TESTER

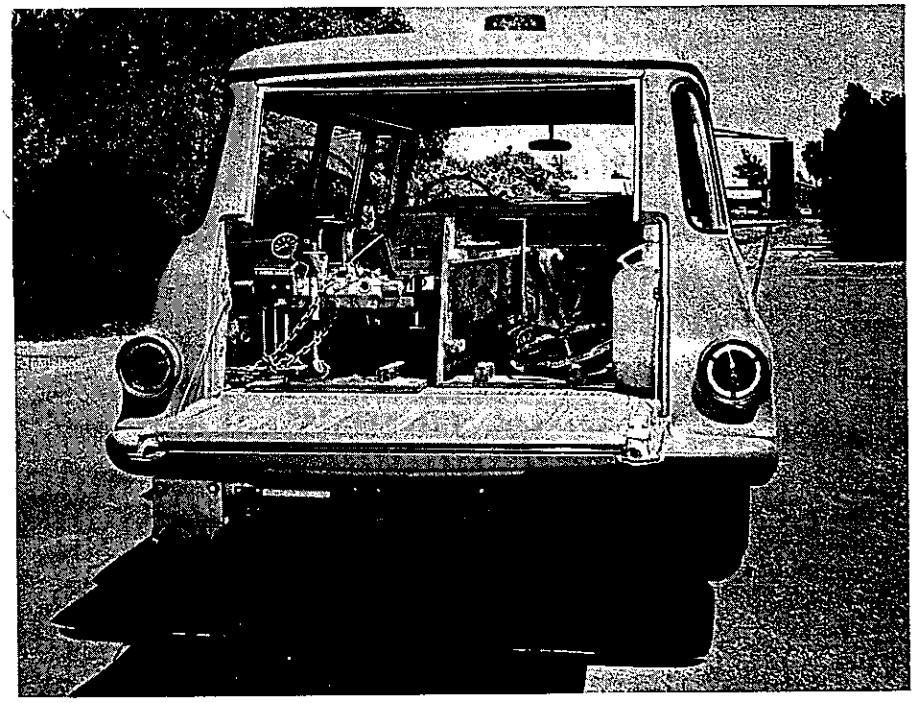

FIGURE IX

APPARATUS IN POSITION FOR TRANSPORTATION

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STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS

TRANSPORTATION LABORATORY

REPORT OF SKID TESTS

Sheet ______

DISTRIBUTION
- O TRANSPORTATION LAB.
- O RESIDENT ENGINEER
- O ASST. DIST. DIR. OF TRANS-CONST.
- O OFFICE OF STRUCTURES

Dist, Co, Rte, P.M. ______________________

Contract No. ______________ Number of lanes ______________

Federal No. ______________ or bridge width ______________

Contract Limits ______________________

____

Test By: ______________ Test Date ______________ Bridge No. & Name ______________

Avg. Air Temp. ______________ °F

Lane: Right, R or Left, L looking ahead.

Position: In the direction of traffic flow, position denotes feet to the right of the left edge of pavement or the inside face of left bridge rail.

TEST NO.	DATE PLACED	LOCATION			% GRADE	TEST MEASUREMENT			REMARKS
		STATION	LANE	POSITION		MEASURED	CORRECTED	AVERAGE *	

* The coefficient of friction value

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Figure X

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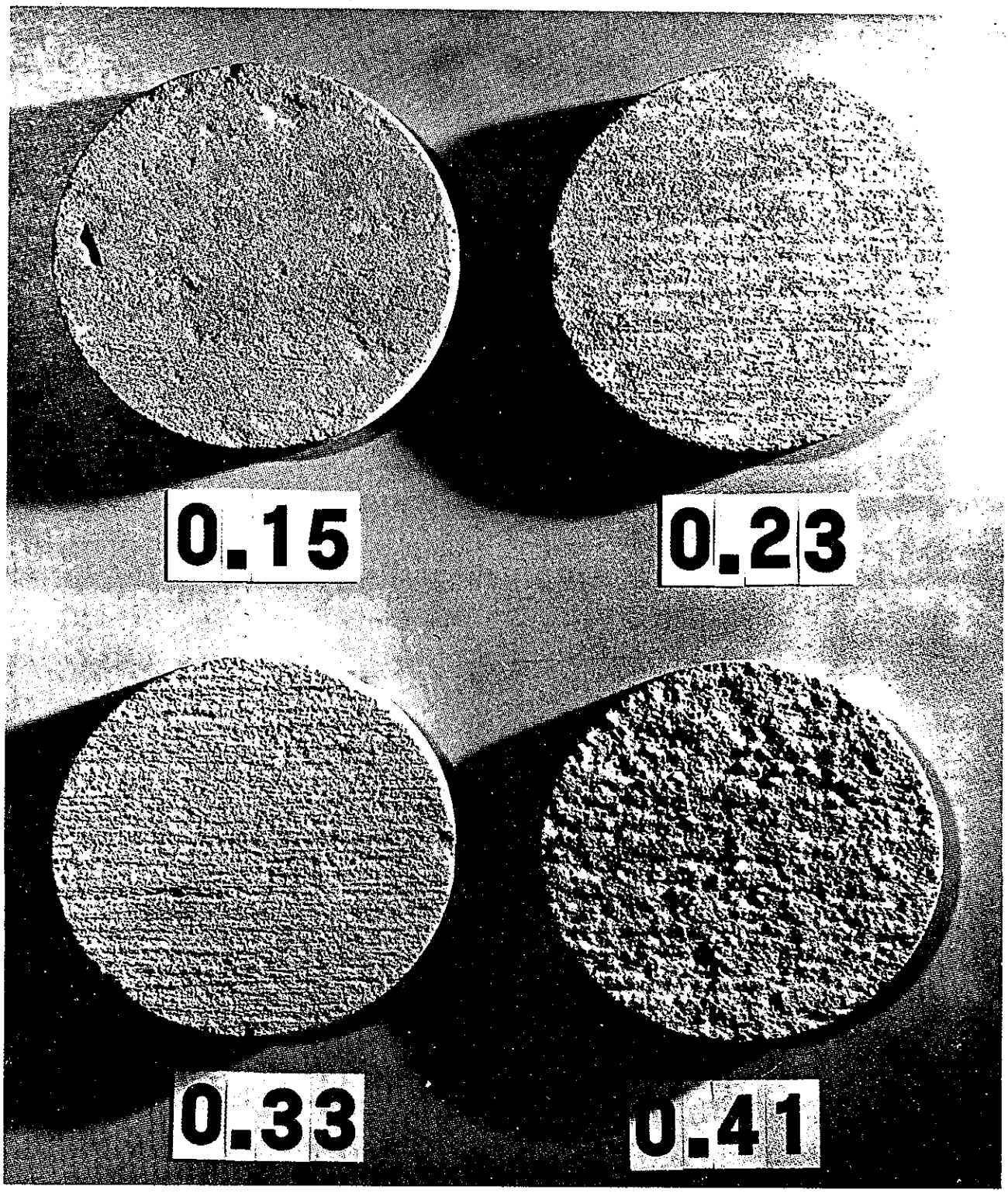
Appendix

COEFFICIENT OF FRICTION VALUES FOR TYPICAL PORTLAND CEMENT CONCRETE SURFACES ILLUSTRATING A RANGE OF TEXTURES



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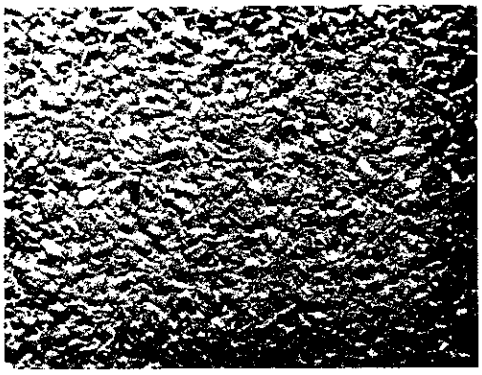
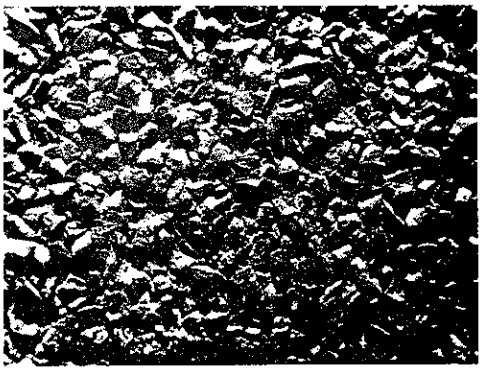
COEFFICIENT OF FRICTION VALUES FOR VARIOUS ASPHALT CONCRETE SURFACES

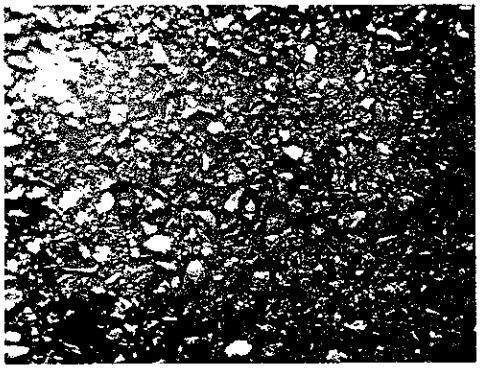


TYPICAL OPEN GRADED
0.39

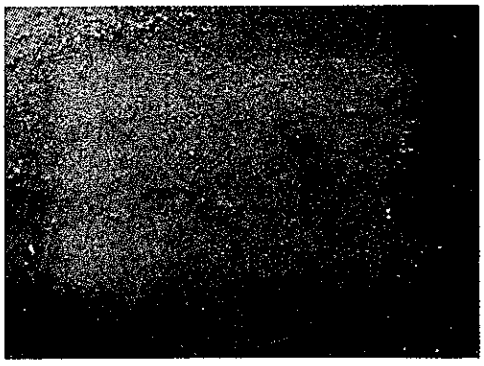
TYPICAL DENSE GRADED
0.37



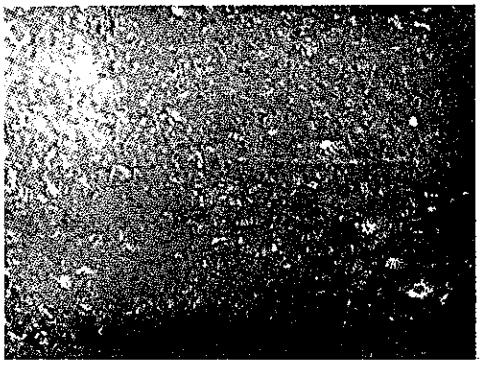
MEDIUM AGGREGATE
CHIP SEAL
0.43



CHIP SEAL WITH SOME
CHIPS IMBEDDED OR MISSING
0.37



EXCESSIVE FOG SEAL
OVER DGAC
0.15



BLEEDING OR FLUSHING
DGAC
0.13

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