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Correlation Between California And BPR Skid Testers

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16. ABSTRACT

A correlation study was conducted between the California Skid Tester and the U.S. Bureau of Public Roads Skid Trailer. Skid resistance tests were made on seven types of pavement surfaces, encompassing both PCC and AC, at eleven locations in the vicinity of Sacramento, California. Coefficients of friction were obtained with the California unit at the standard test conditions of locked wheel, smooth tire, wet pavement and a speed of 50 mph. Skid numbers were obtained with the BPR Skid Trailer operating at its standard test conditions of locked wheel, ribbed tire, wet pavement and a speed of 40 mph. The BPR unit made additional tests with the speed parameter changed to 50 mph. Tests were also made by the BPR unit both the speed increased to 50 mph and the ribbed test tire replaced by a smooth tire. For the three test conditions investigated, correlations were obtained that indicate that the California coefficient of friction can be used to predict the Bureau of Public Roads Skid Number. Comparison of results of tests conducted at the standard conditions reveals that the present California tentative minimum coefficient of friction for pavement evaluation (.25f) corresponds quite well to the tentative minimum skid number for main rural highways (37N) as recommended in NCHRP 37.

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Correlation, skid resistance testing, pavements, surfaces, Portland cement concrete pavements, bituminous pavement, coefficient of friction

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HIGHWAY RESEARCH REPORT

CORRELATION BETWEEN CALIFORNIA AND BPR SKID TESTERS

INTERIM REPORT

69-36

STATE OF CALIFORNIA

BUSINESS & TRANSPORTATION AGENCY

DEPARTMENT OF PUBLIC WORKS

DIVISION OF HIGHWAYS

MATERIALS AND RESEARCH DEPARTMENT

RESEARCH REPORT

NO. M & R 633126-5

Prepared in Cooperation with the U.S. Department of Transportation, Bureau of Public Roads July, 1969

STATE OF CALIFORNIA—TRANSPORTATION AGENCY

RONALD REAGAN, Governor

DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
MATERIALS AND RESEARCH DEPARTMENT
5900 FOLSOM BLVD., SACRAMENTO 95819

July 1969
Interim Report
M&R No. 633126-5

Mr. J. A. Legarra
State Highway Engineer

Dear Sir:

Submitted herewith is a research report titled:

CORRELATION BETWEEN CALIFORNIA
AND BPR SKID TESTERS

JOHN B. SKOG
Principal Investigator

MELVIN H. JOHNSON
Co-Investigator

Assisted by
Gene S. Stucky

Very truly yours,

JOHN L. BEATON
Materials and Research Engineer

REFERENCE: Skog, J. B. and Johnson, M. H., "Correlation Between California and BPR Skid Testers," State of California, Department of Public Works, Division of Highways, Materials and Research Department, Research Report 633126-5, July 1969.

ABSTRACT: A correlation study was conducted between the California Skid Tester and the U. S. Bureau of Public Roads Skid Trailer. Skid resistance tests were made on seven types of pavement surfaces, encompassing both PCC and AC, at eleven locations in the vicinity of Sacramento, California. Coefficients of friction were obtained with the California unit at the standard test conditions of locked wheel, smooth tire, wet pavement and a speed of 50 mph. Skid numbers were obtained with the BPR Skid Trailer operating at its standard test conditions of locked wheel, ribbed tire, wet pavement and a speed of 40 mph. The BPR unit made additional tests with the speed parameter changed to 50 mph. Tests were also made by the BPR unit with both the speed increased to 50 mph and the ribbed test tire replaced by a smooth tire. For the three test conditions investigated, correlations were obtained that indicate that the California coefficient of friction can be used to predict the Bureau of Public Roads Skid Number. Comparison of results of tests conducted at the standard conditions reveals that the present California tentative minimum coefficient of friction for pavement evaluation (.25f) corresponds quite well to the tentative minimum skid number for main rural highways (37N) as recommended in NCHRP 37.

KEY WORDS: Correlation, skid resistance testing, pavements, surfaces, portland cement concrete pavements, bituminous pavement, coefficient of friction.

ACKNOWLEDGMENTS

The authors wish to express their appreciation to the U. S. Bureau of Public Roads, and especially to Mr. Roland Cowger, for their cooperation in obtaining skid resistance data.

This is the fifth in a series of interim reports on a research project to determine the skid resistance of pavement surfaces. This work was done in cooperation with the U. S. Department of Transportation, Federal Highway Administration, Bureau of Public Roads. The opinions, findings and conclusions expressed in this publication are those of the authors and not necessarily those of the Bureau of Public Roads.

ACKNOWLEDGMENTS

[illegible] express their appreciation to the [illegible] and especially to Mr. Roland Cowger, [illegible] in obtaining skid resistance data.

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INTRODUCTION

The California Division of Highways has been engaged in skid resistance research for several years. The development of a small skid tester, for field and laboratory use, has previously been reported (1). The California Skid Tester was originally calibrated using the towed trailer unit developed by Professor R. A. Moyer of the University of California. The unit was calibrated to read coefficient of friction at standard test conditions of locked wheel, smooth tires, wet pavement and a speed of 50 mph. This skid resistance tester has been used in many research projects for which results have previously been reported (2,3,4 & 5). Existing pavements are tested with this unit in order to check for conformance to California's present tentative minimum coefficient of friction requirements for pavement evaluation.

The U. S. Bureau of Public Roads Skid Trailer was in California, on a demonstration skid testing program, during the month of September, 1968. The standard test conditions of this unit are locked wheel, ribbed tire (ASTM E249-64T), wet pavement and a 40 mph speed. These test conditions are essentially in accordance with ASTM Method E-274, for which Kummer and Meyer (6) have recommended tentative minimum skid number requirements for main rural highways.

The visitation of the Bureau of Public Roads unit presented an excellent opportunity to not only check the original calibration of the California unit, but also to compare California's skid resistance requirements for pavement evaluation with those recommended by Kummer and Meyer in NCHRP 37. Therefore, skid resistance tests, using this unit at standard conditions, were made on seven types of pavement surfaces at eleven locations in the vicinity of Sacramento. Additional tests were made with the speed increased to 50 mph. Tests were also made at a speed of 50 mph and the ribbed tire replaced by a smooth one. The locations were then tested with the California Skid Tester. This interim report discusses the results of this correlation study and is the fifth in a series of reports dealing with skid resistance research studies.

CONCLUSIONS

1. Correlations exist, for the three test conditions investigated in this study, that indicate that the California coefficient of friction can be used to predict the Bureau of Public Roads Skid Number.

2. At the standard conditions, the present California tentative minimum coefficient of friction for pavement evaluation (.25f) corresponds quite well to the tentative minimum skid number for main rural highways (37N) as recommended in NCHRP 37.

SKID RESISTANCE MEASUREMENT

The test sites were selected to provide a large range in skid resistance values and included both portland cement concrete and asphalt concrete pavements. The Bureau of Public Roads Skid Trailer (Figure 1), as described by Loutzenheiser, et al (7), utilizes a 3/4 ton pickup as the tow vehicle. The pickup is equipped with a water tank and pumping system, a Brush oscillograph and amplifier for recording data and an electronic activator sequence timer to activate segments of the test cycle. The test trailer is equipped with a nylon brush for distributing water, four active SR-4 strain gages for determining skid resistance by measuring the torque on the axle and standard ribbed pavement testing tires (ASTM designation E 249-64T).

The normal test speed for the BPR tester is 40 mph. The test operator activates the sequence timer by pressing a control button as the selected location is traversed. The recorder and watering system and the trailer left wheel brake are activated by the timer. The total test cycle lasts seven seconds, in which the brake is locked for two seconds. This gives a length of skid of about 117 feet. The pavement skid resistance data is reported in the form of skid number (SN), which is the coefficient of skid resistance times 100. The coefficient of skid resistance is defined as the ratio of the frictional force of the locked test tire to the wheel load.

Each location was tested by the BPR unit at a speed of 50 mph in addition to the 40 mph tests. Each site was also tested by the BPR unit at 50 mph with the standard rib tire replaced by a conventional tire which had been ground smooth.

The California skid testing apparatus and test procedure are described in the Appendix. The California Skid Tester was originally calibrated to indicate the coefficient of skid resistance that would be obtained with Professor Moyer's skid trailer unit with locked wheels, smooth tires, wet pavement and a speed of 50 mph. When considering data obtained with the California tester it must always be kept in mind that this data represents only skid resistance values that would be obtained under the above test parameters. These skid resistance values are reported as "coefficient of friction", which Moyer (8) has defined as the ratio of braking force provided by a given trailer wheel to the load carried by that wheel. This reporting practice has been followed for some time; however, in the future the system of reporting skid resistance data as a skid number will be utilized. This will merely involve multiplying the coefficient of friction by 100.

DISCUSSION

A list of the pavement types tested, as well as the corresponding skid resistance values, are presented in Table 1. A linear regression correlation analysis was made with the California coefficient of friction versus the Bureau of Public Road Skid Number at 40 mph, California coefficient of friction versus the Bureau of Public Roads Skid Number at 50 mph and the California coefficient of friction versus the Bureau of Public Roads Skid Number at 50 mph and smooth tire. The skid resistance data, as well as correlation curves, regression equations and coefficients of correlation, are presented in Figures 2 through 4. It can be seen in these figures that a correlation was obtained in all cases and that the California coefficient of friction can be used to estimate the Bureau of Public Roads Skid Number.

Figure 2 illustrates that the California tentative minimum coefficient of friction for pavement evaluation (.25f) corresponds quite well to the tentative minimum skid number for main rural highways (37SN) recommended by Kummer and Meyer (6). This particular skid number would be that measured by a skid trailer with rib tires in late summer or fall in accordance with ASTM Method E-274 at 40 mph in the most polished wheel track. These test conditions correspond essentially to those of the Bureau of Public Roads skid trailer as used in the first series of tests in this study.

Kummer and Meyer's recommended value is based on normal frictional needs of traffic as derived from driver behavior studies and is in close agreement with those from accident studies. The California minimum value is based on a skid resistance inventory of a large number of different pavements in the California Highway System. The value has been checked against those used in England, Virginia and Florida (4). The present finding of a close correlation with the minimum skid number adds credence to its use in pavement evaluation when coupled with geometric section data, wet weather accident data and other appropriate information.

Kummer and Meyer also recommend tentative minimum skid numbers measured at mean traffic speeds. A skid number of 37 obtained at 40 mph would correspond to a skid number of 32 measured at 50 mph. It can be seen in Figure 3 that when the Bureau of Public Roads unit increased its speed to 50 mph, the recommended minimum skid number again correlates well with the minimum coefficient of friction for pavement evaluation. In this case the test speeds of the two machines are the same; however, the California value is obtained with a smooth tire and the Bureau of Public Roads value with a rib tire.

When the Bureau of Public Roads skid trailer speed is 50 mph and the ribbed test tire is replaced with a smooth test tire, the test parameters are essentially the same as those which existed on Moyer's trailer when the California tester was first calibrated. In Figure 4 it can be seen that by using the regression equation, a California coefficient of friction of .25 would correspond to a Bureau of Public Roads skid number of approximately 24. Since the skid number has previously been defined as 100 times the coefficient of friction, these values tend to substantiate the original correlation. The fact that two different skid trailers, at different times, with like test parameters can correlate with the California Skid Tester is encouraging. The coefficient of correlation obtained in this case (0.71) is not as high as might be desired; however, it is felt that the smooth tire used on the trailer has some bearing on this value. The tire used was not a standard manufactured smooth tire, but out of necessity was a commercial tire with the tread ground off. It can be readily realized that a ground tire's characteristics would not be uniform along the circumference; however, the time element prevented acquisition of a standard smooth tire.

In a previous report (5) it was noted that 1/8" x 1/8" grooves spaced greater than 3/4" centers did not provide as great an improvement as expected over the original low coefficient of friction values exhibited by PCC test sections. At that time it was felt that this was a result of the small contact area of the tire used on the California Skid Tester. However, the use of the Bureau of Public Roads tester on grooved areas revealed that a larger tire did not result in larger skid resistance readings.

The work performed in this correlation study further substantiates the practicality of using a towed trailer skid testing unit on existing traveled roadways. A portable skid tester is useful for laboratory work, special studies and on new pavements or bridge decks; however, once roadways have been open to traffic, towed trailer skid resistance testing is much faster, safer, and results in less inconvenience to the motoring public.

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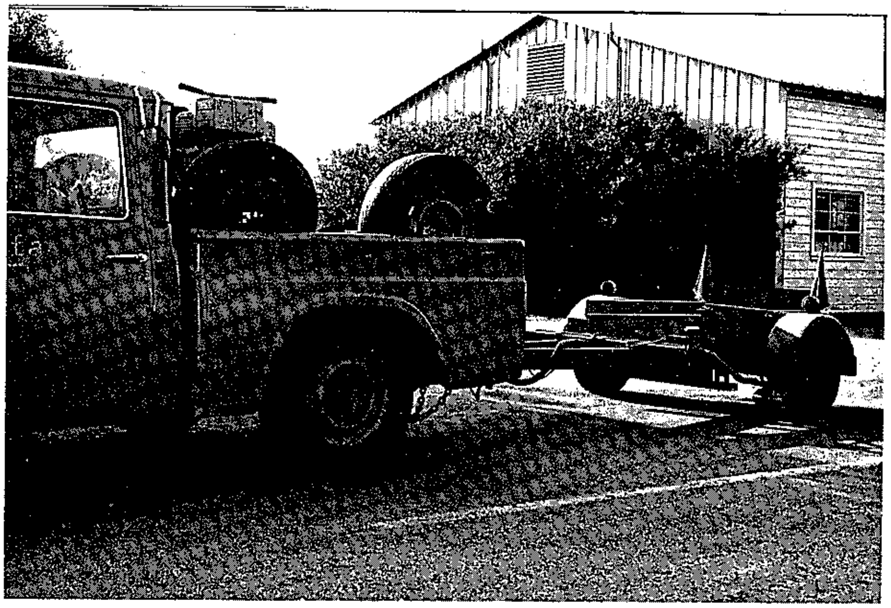
TABLE 1

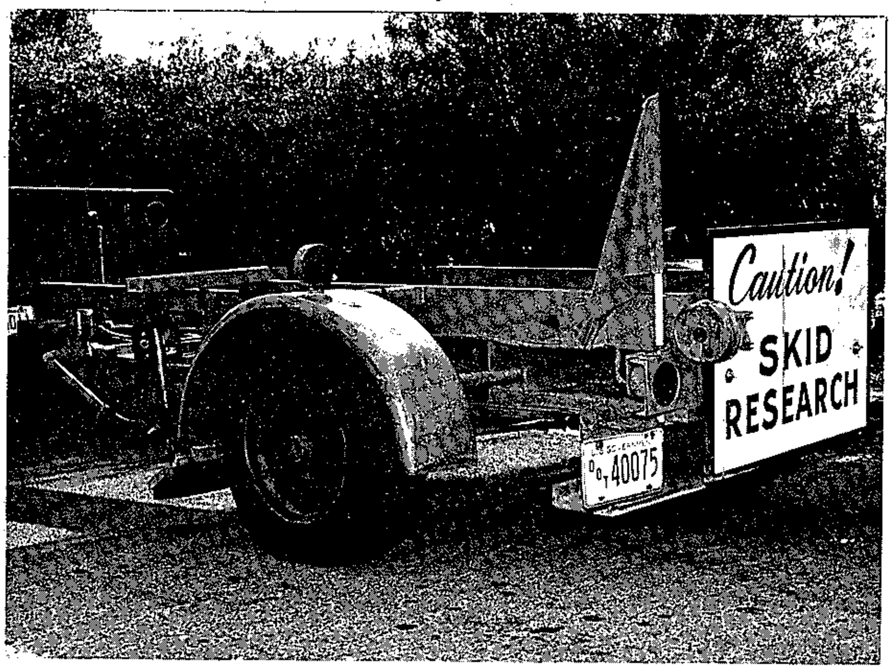
Type of Surface	BPR SN Rib Tire 40 MPH	BPR SN Rib Tire 50 MPH	BPR SN Smooth Tire 50 MPH	Calif. Coefficient of Friction 50 MPH
Smooth PCC	38	26.5	17	.17
	30	28	12	.14
	34	28	14	.19
	36	30	17	.22
	32	30	12	.21
	30	30	17	.21
	38	38	21	.28
	36	32	17	.28
	43.5	36	21	.23
	38	34	17	.19
	38	36	17	.28
	43.5	36	19	.28
High Friction PCC	51	49	36	.39
	49	45	26.5	.35
	49	45	26.5	.37
	55	55	34	.42
	59	57	38	.41
	49	45	24.5	.35
	49	45	28	.36
	45	47	26.5	.38
	49	47	28	.39
	45	45	21	.38
	47	43.5	24.5	.37
	47	43.5	34	.30
	45	39.5	30	.31
	47	39.5	30	.33
	45	38	34	.35
Grooved PCC	30	30	24.5	.26
	34	32	26.5	.26
	34	28	24.5	.27
	32	30	24.5	.27
	39.5	38	36	.35
	43.5	38	34	.35
	47	36	34	.34
	45	41.5	41.5	.36
Open Graded AC	45	41.5	34	.29
	43.5	39.5	34	.29
	41.5	47	36	.31
	43.5	45	36	.31
	49	49	41.5	.34
	49	49	41.5	.35

TABLE 1 (con't.)

Type of Surface	BPR SN Rib Tire 40 MPH	BPR SN Rib Tire 50 MPH	BPR SN Smooth Tire 50 MPH	Calif. Coefficient of Friction 50 MPH
Open Graded AC	49	49	41.5	.34
	53	55	41.5	.34
	47	49	34	.31
	47	47	34	.32
	47	47	36	.33
	45	47	36	.32
Bleeding AC	28	21	12	.20
	34	26.5	15.5	.22
Stardard AC	49	45	30	.33
	45	43.5	30	.32
	43.5	41.5	41.5	.31
	39.5	38	38	.30
	36	34	28	.27
	47	51	43.5	.32
Screening Seal Coat	38	39.5	30	.32
	47	49	39.5	.35
	51	57	45	.38
	51	47	43.5	.40
	51	51	45	.39
	36	53	32	.35
	45	39.5	36	.33
	51	47	39.5	.31

Figure 1





Bureau of Public Roads' Skid Tester

Figure 2

CALIF. COEFFICIENT OF FRICTION VS BPR SKID NUMBER

(BPR SKID TRAILER WITH RIB TIRE @ 40 MPH)

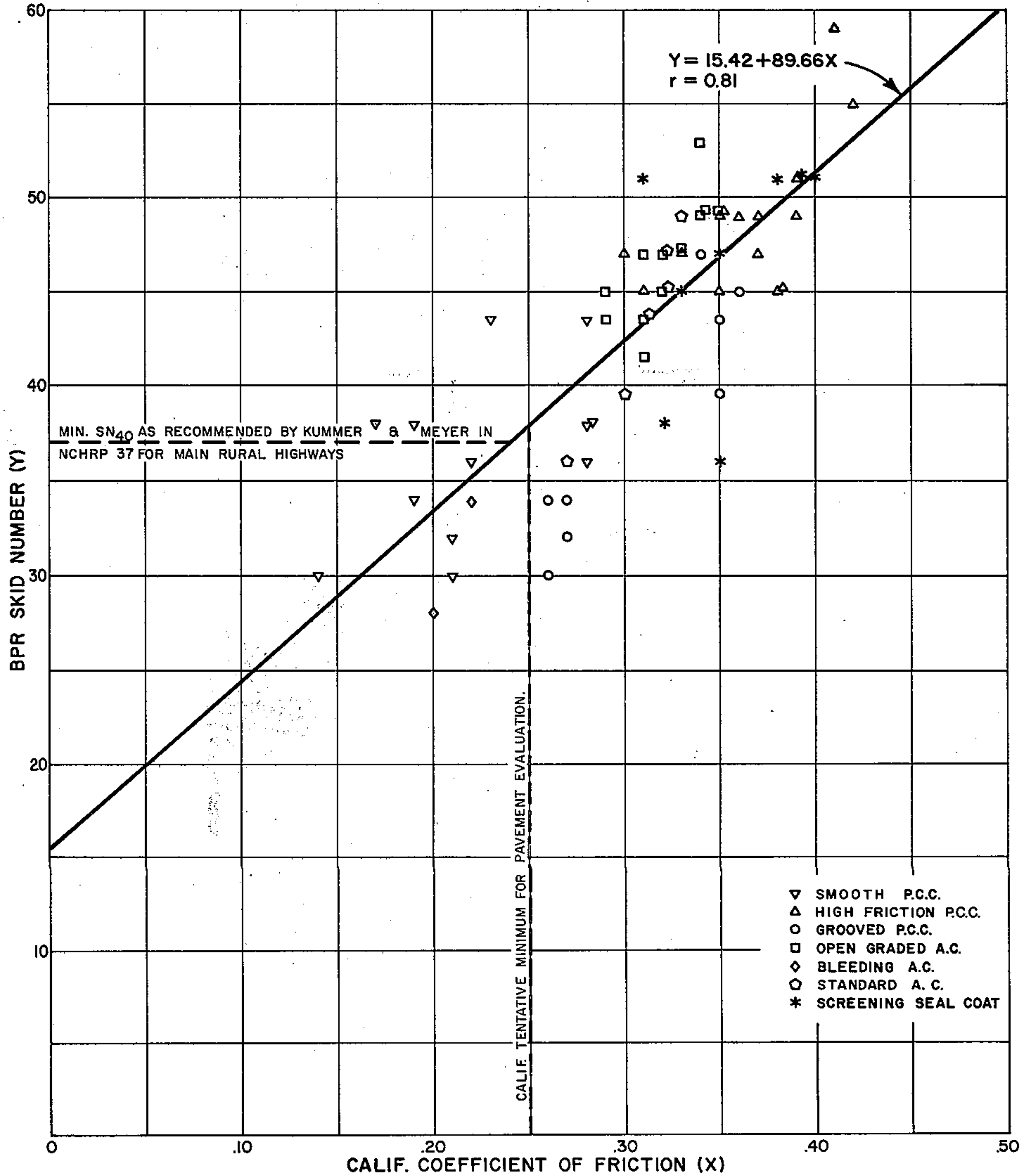


Figure 3

CALIF. COEFFICIENT OF FRICTION VS BPR SKID NUMBER

(BPR SKID TRAILER WITH RIB TIRE @ 50 MPH)

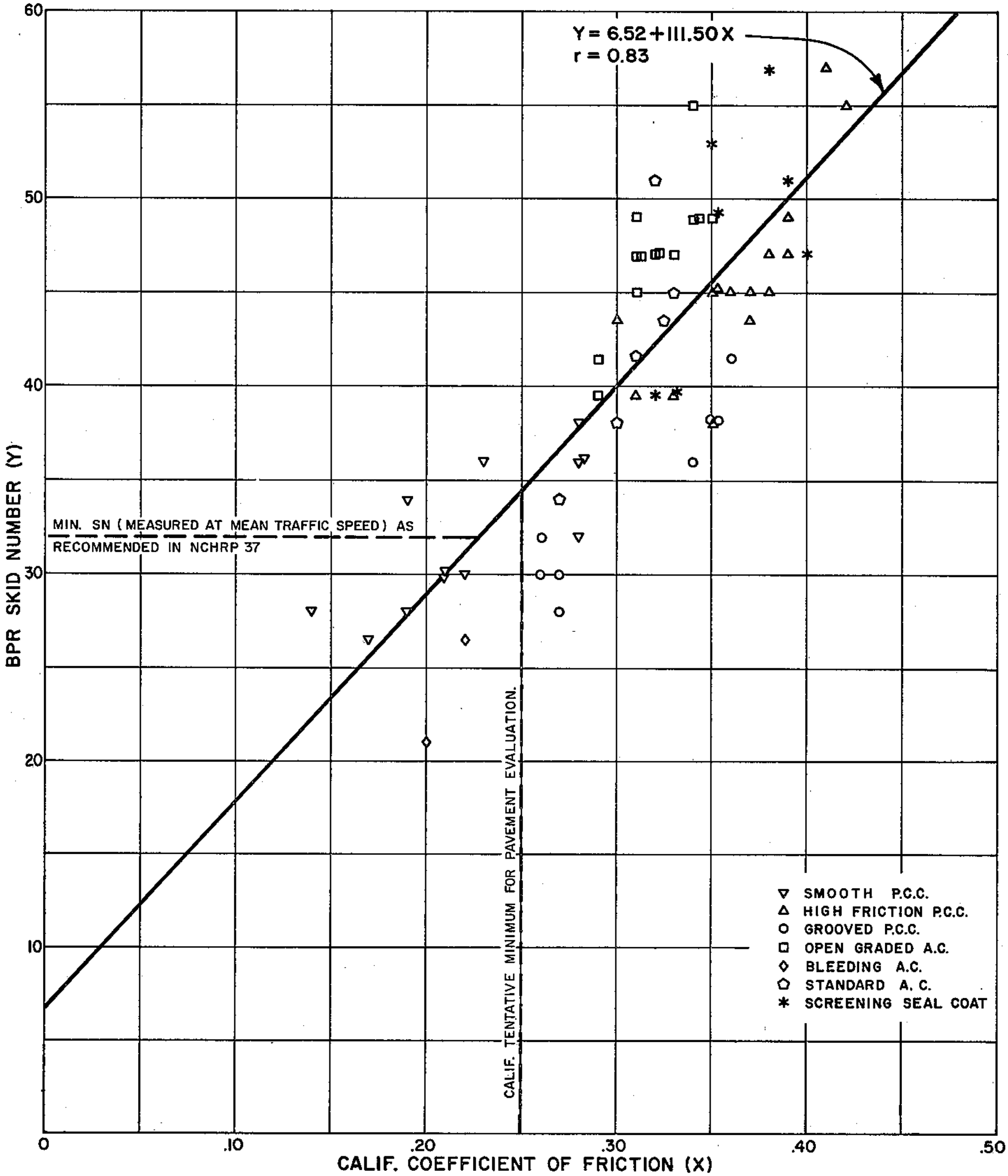
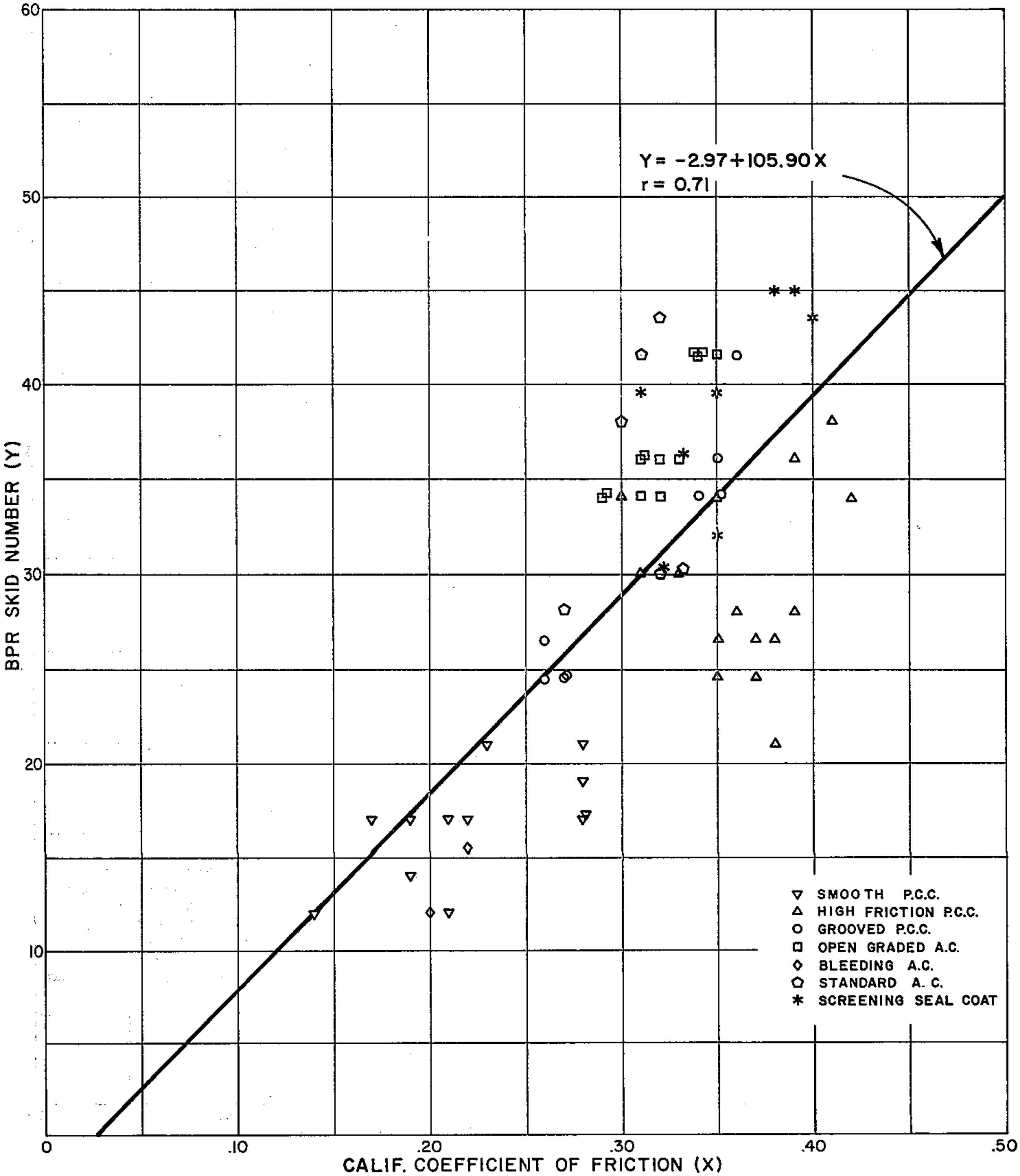


Figure 4

CALIF. COEFFICIENT OF FRICTION VS BPR SKID NUMBER

(BPR SKID TRAILER WITH SMOOTH TIRE @ 50 MPH)



State of California
Department of Public Works
Division of Highways

MATERIALS AND RESEARCH DEPARTMENT

Test Method No. Calif. 342-C
October 3, 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 x 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′ x 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. Visually survey the total length of pavement for uniformity of surface texture. Note all areas which do not have definite striations or which appear smooth. Conduct this survey 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.* (See E-3 for procedure to follow for smooth pavements).

a. Select a minimum of three test locations for each day's pour and check a minimum of three pour days per contract.

Determine the location of test sites 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 choose the next number in the random table and select a new location.

At each test location obtain the first reading at the specified random location (using the method described under C-Test Procedure). Obtain the next four readings at 25′ intervals beyond the first reading. Obtain all readings at sites parallel to the centerline of the lane. After correction for grade as shown in F, average the five readings. Record this average 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. Check a minimum of three ground area locations and all smooth appearing surfaces 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, select sufficient test locations to insure that the area is above the minimum requirement. If the average value of all locations is below the required minimum then perform additional tests 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.

REFERENCE

A California Method

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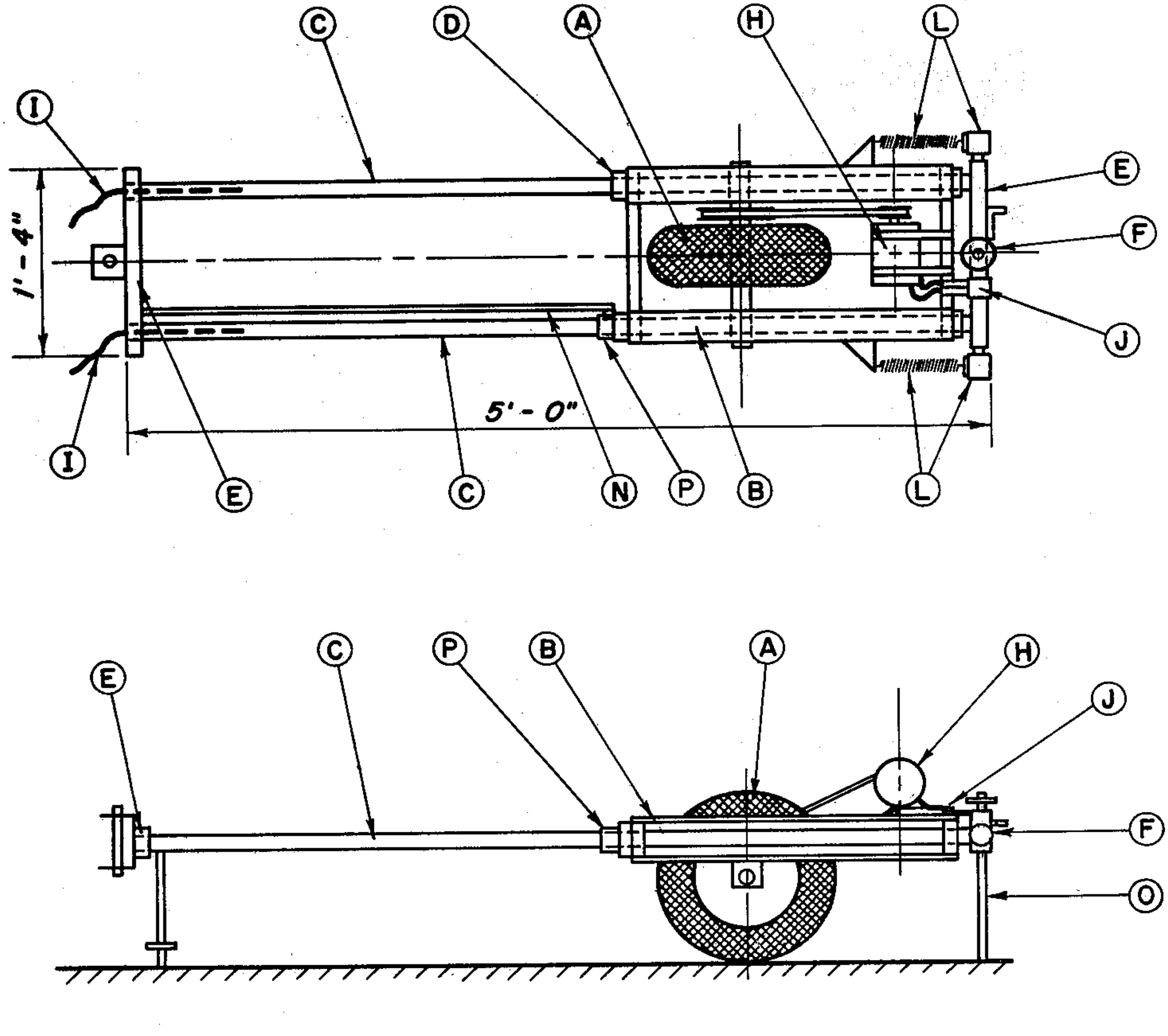

FIGURE 1
DIAGRAM OF SKID TESTER

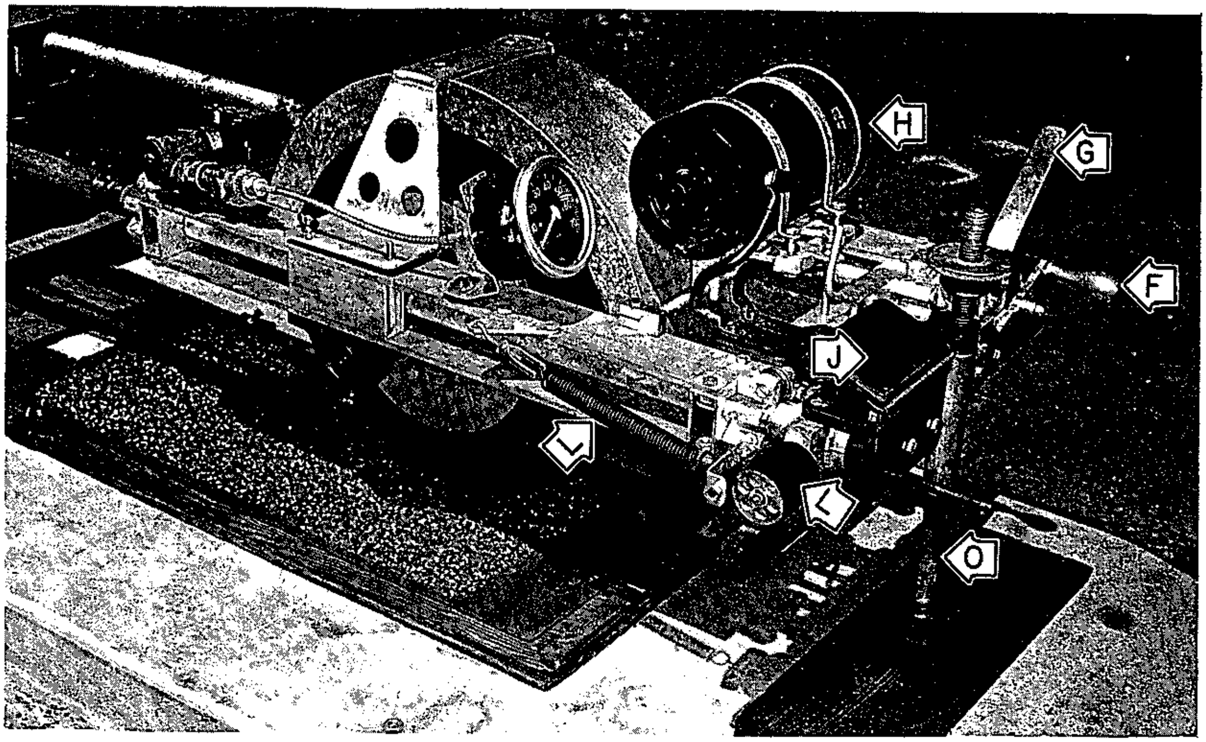

FIGURE II

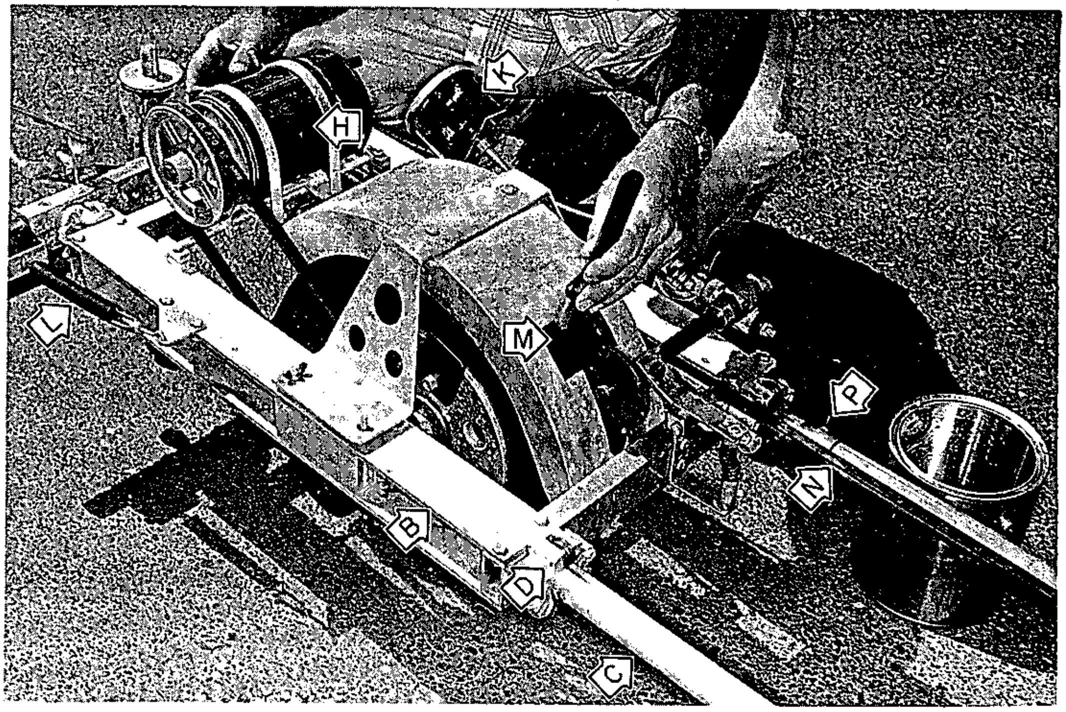

FIGURE III
CLOSE-UP VIEWS OF SKID TESTER

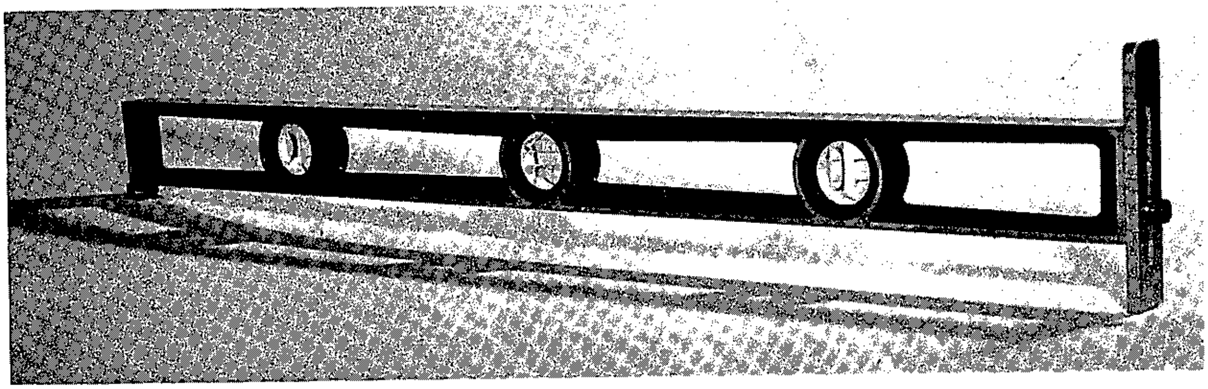

FIGURE IV
LEVEL FOR DETERMINING GRADE

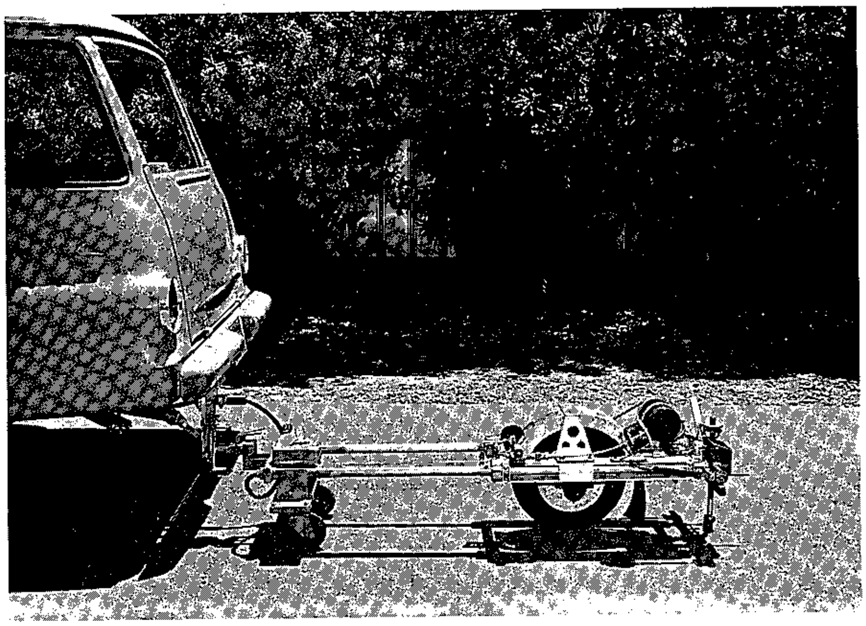

FIGURE V
APPARATUS IN POSITION FOR TESTING

COEFFICIENT OF FRICTION CORRECTION CHART FOR MEASUREMENTS MADE ON GRADES

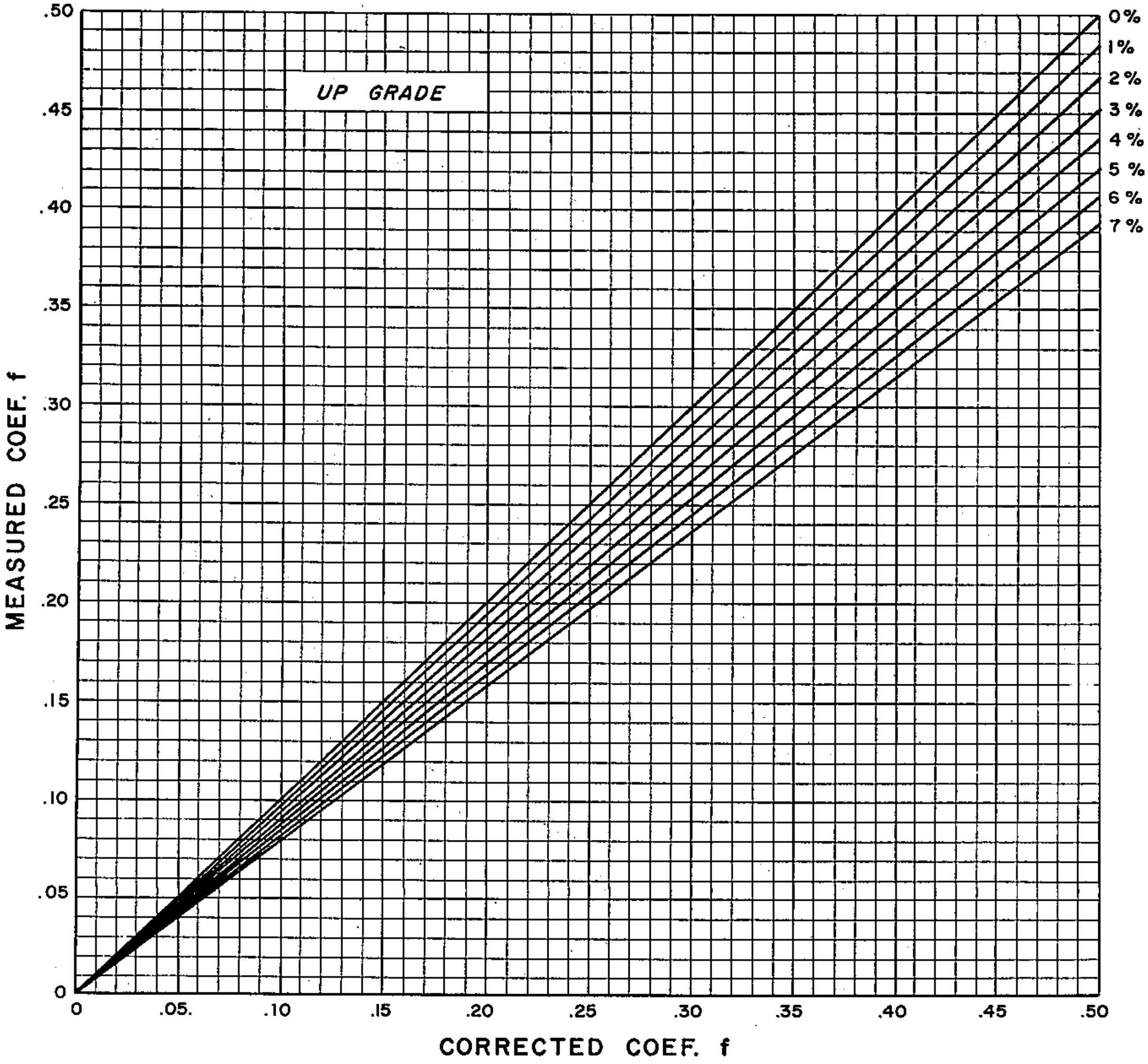

FIGURE VI

COEFFICIENT OF FRICTION CORRECTION CHART FOR MEASUREMENTS MADE ON GRADES

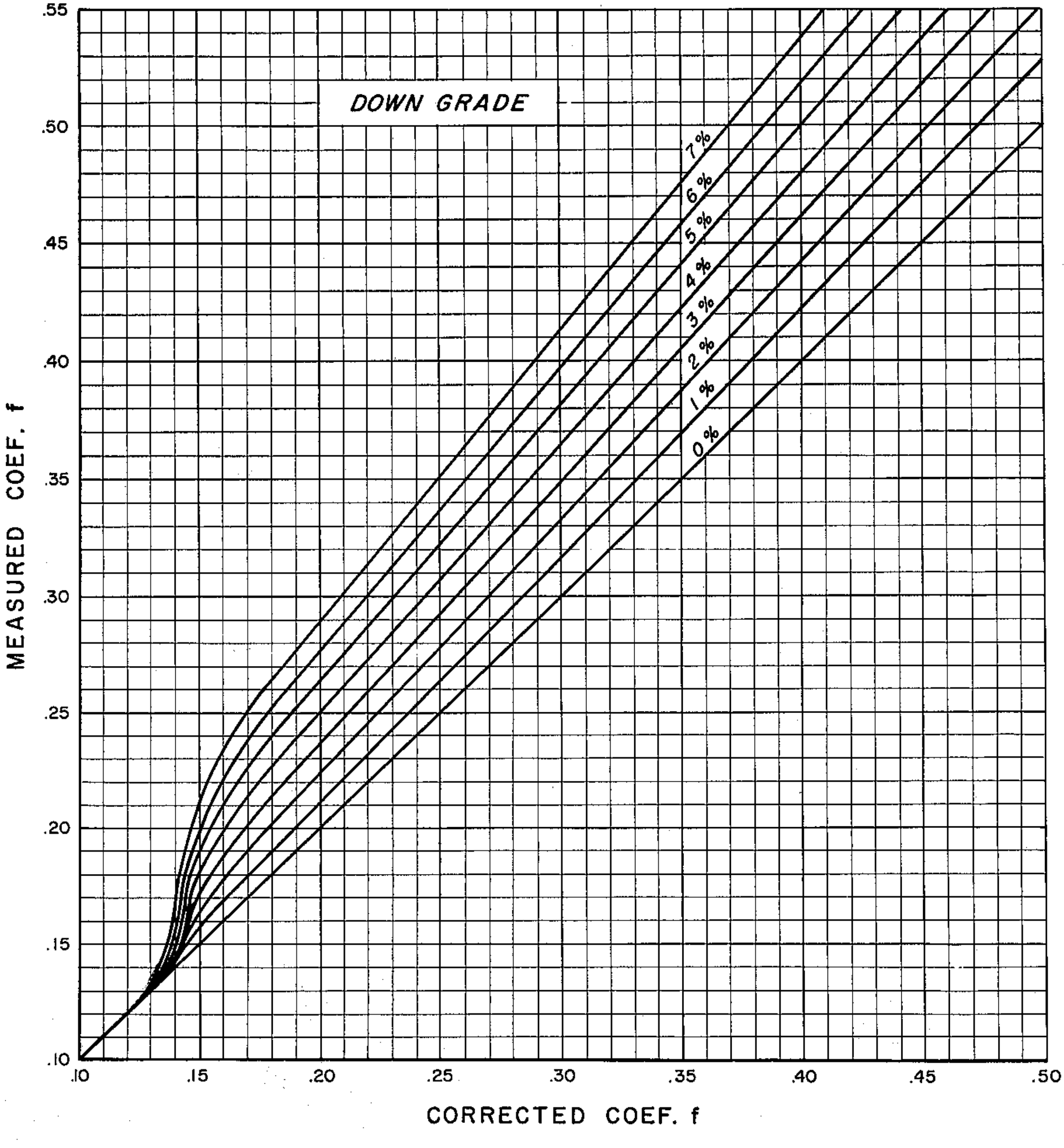

FIGURE VII

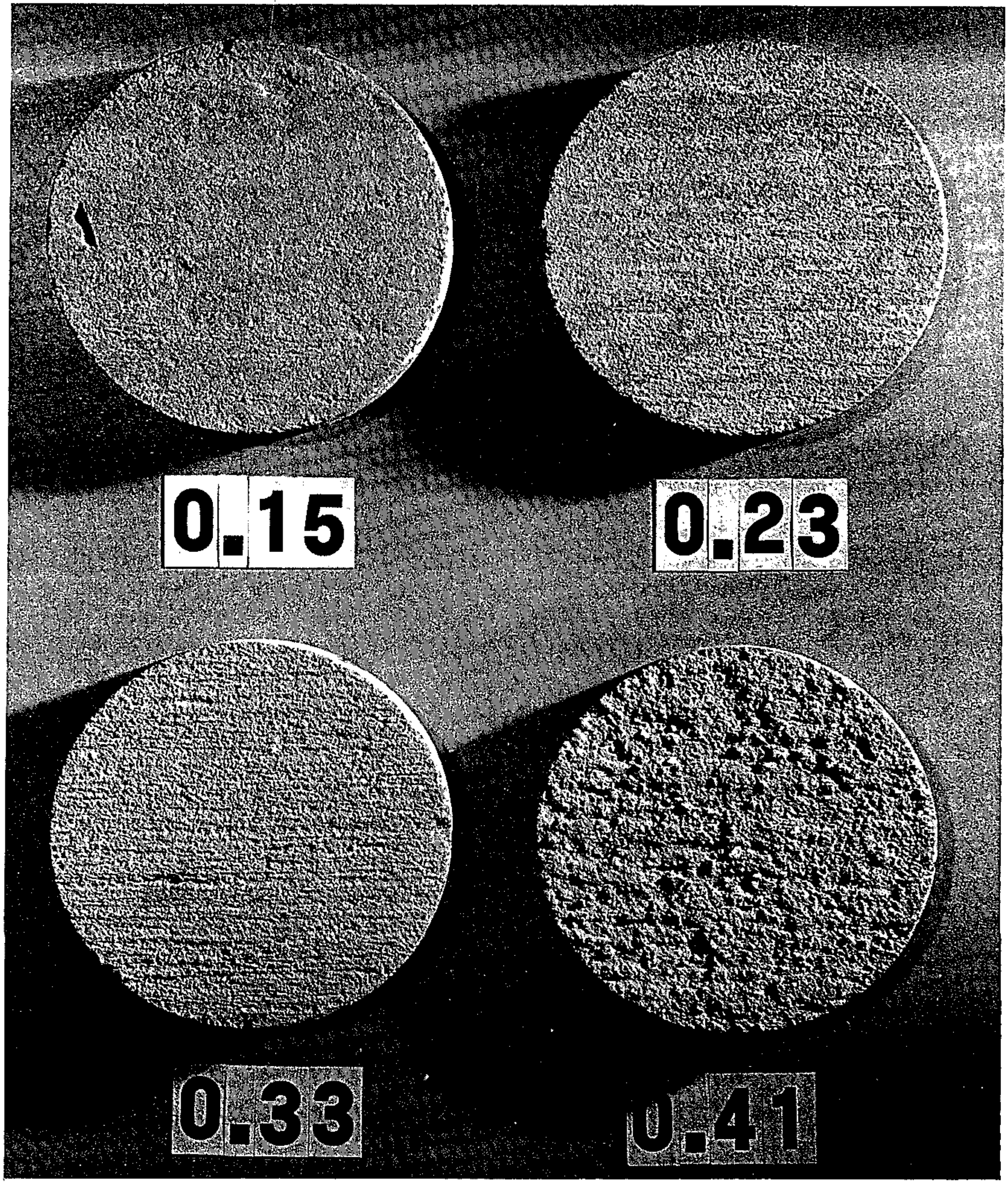

FIGURE VIII
PHOTOS OF SURFACE TEXTURES

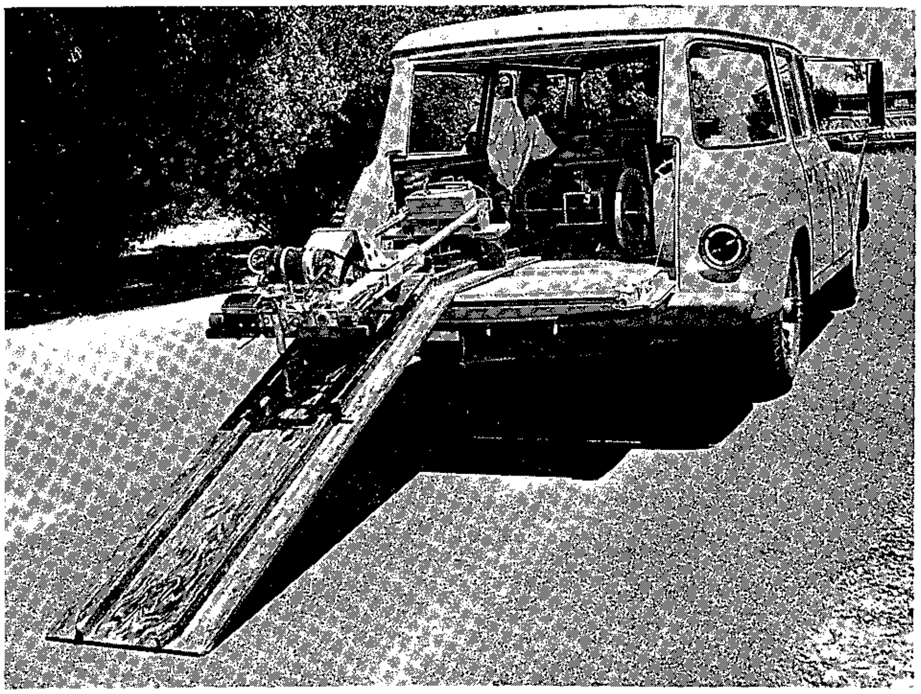

FIGURE IX

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

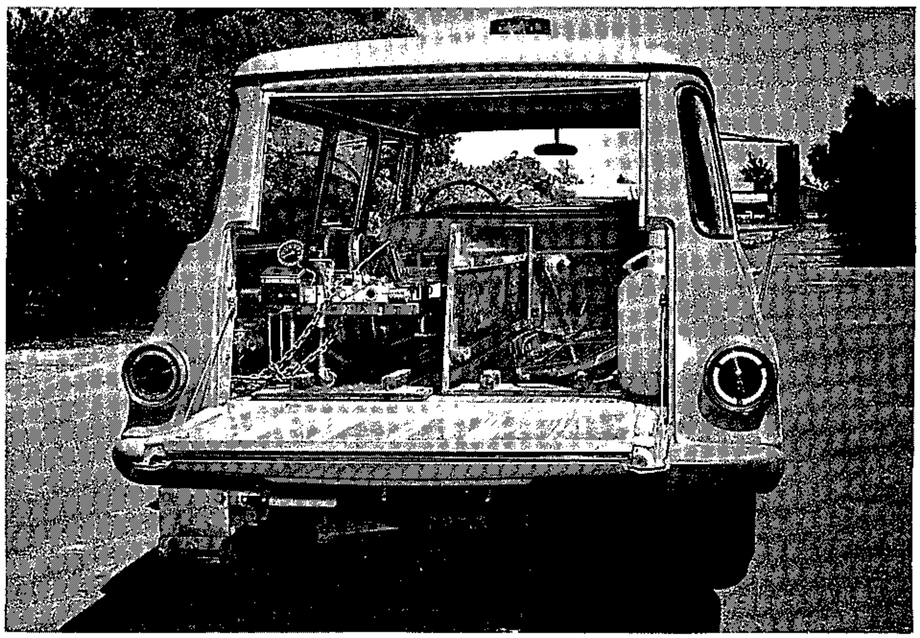

FIGURE X

APPARATUS IN POSITION FOR TRANSPORTATION