STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF FACILITIES CONSTRUCTIONS
OFFICE OF TRANSPORTATION LABORATORY

AN EVALUATION OF PCC PAVEMENT TINE TEXTURING PATTERNS

Study Made by .... Pavement Branch

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Report Prepared by .... B. F. Neal, P.E.

Very truly yours,

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Chief, Office of Transportation Laboratory

85-05

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16. ABSTRACT

This report provides a limited comparison of transverse and longitudinal tine texturing of PCC pavements. Skid test results and accident data are provided and analyzed. The advantages and disadvantages of each method and the reasons for California's adoption of the longitudinal tining procedure are discussed.

It is concluded that, while the skid values of transverse textured surfaces are generally slightly higher than those textured longitudinally, both types are performing satisfactorily. Thus, because of the lesser cost of longitudinal tining, it is recommended that longitudinal tining continue to be specified by Caltrans for PCC pavement.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
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CONVERSION FACTORS

English to Metric System (SI) of Measurement

Quality	English unit	Multiply by	To get metric equivalent
Length	inches (in)or(")	25.40	millimetres (mm)
		.02540	metres (m)
	feet (ft)or(')	.3048	metres (m)
	miles (mi)	1.609	kilometres (km)
Area	square inches (in^2)	6.432×10^{-4}	square metres (m^2)
	square feet (ft^2)	.09290	square metres (m^2)
	acres	.4047	hectares (ha)
Volume	gallons (gal)	3.785	litre (l)
	cubic feet (ft^3)	.02832	cubic metres (m^3)
	cubic years (yd^3)	.7646	cubic metres (m^3)
Volume/Time (Flow)	cubic feet per second (ft^3/s	28.317	litres per second l/s)
	gallons per minute (gal/min)	.06309	litres per second (l/s)
Mass	pounds (lb)	.4536	kilograms (kg)
Velocity	miles per hour (mph)	.4470	metres per second (m/s)
	feet per second (fps)	.3048	metres per second (m/s)
Acceleration	feet per second squared (ft/s^2)	.3048	metres per second squared (m/s^2)
	acceleration due to force of gravity (G) (ft/s^2)	9.807	metres per second squared (m/s^2)
Density	(lb/ft^3)	16.02	kilograms per cubic metre (kg/m^3)
Force	pounds (lbs)	4.448	newtons (N)
	(1000 lbs) kips	4448	newtons (N)
Thermal Energy	British termal unit (BTU)	1055	joules (J)
Mechanical Energy	foot-pounds (ft-lb)	1.356	joules (J)
	foot-kips (ft-k)	1356	joules (J)
Bending Moment or Torque	inch-pounds (in-lbs)	.1130	newton-metres (Nm)
	foot-pounds (ft-lbs)	1.356	newton-metres (Nm)
Pressure	pounds per square inch (psi)	6895	pascals (Pa)
	pounds per square foot (psf)	47.88	pascals (Pa)
Stress Intensity	kips per square inch square root inch ($ksi\sqrt{in}$)	1.0988	mega pascals$\sqrt{metre}$ ($MPa\sqrt{m}$)
	pounds per square inch square root inch ($psi\sqrt{in}$)	1.0988	kilo pascals$\sqrt{metre}$ ($KPa\sqrt{m}$)
Plane Angle	degrees (°)	0.0175	radians (rad)
Temperature	degrees fahrenheit (F)	$\frac{+F - 32}{1.8} = +C$	degrees celsius (°C)

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INTRODUCTION

In 1967, the minimum requirement for friction coefficient of new PCC pavements in California, as determined by Calif. Test 342 (see Appendix), was increased from 0.25 to 0.30. This requirement proved difficult to attain consistantly by traditional means, thus pointing out the need for an improvement in texturing methods. At that time, the most popular texturing device was a burlap drag which produced a sandpaper-like surface finish that usually met the 0.25 friction coefficient requirement. However, in some instances, it took very little traffic to result in a reduction of this friction coefficient to a value below 0.25. Clearly, there was a need to develop a method of texturing and a specification that would result in a friction coefficient of 0.25 or more for a substantial period of time.

To develop better texturing methods, a number of experimental procedures were tried. A 1975 report(1) contains the details of some of this work and the results of several experiments. One of the devices studied was a drag with stiff bristled brooms. This was found to give a texture meeting the 0.30 (minimum) friction coefficient requirement and was adopted by most contractors. Two other procedures which appeared promising were (1) grooving of the plastic concrete with some type of texturing device and (2) broadcasting of aggregates on the plastic concrete surface.

A continuation of this study was reported in 1978(2). The following texturing procedures were evaluated on several projects for this continuation study:

1. Aggregates broadcast on the pavement surface.

2. Transverse texturing using, a) a steel ribbed grooving plate, b) a nylon bristle broom, and c) several steel tine devices with various spacings and tine lengths.

3. Longitudinal texturing with steel tines spaced 3/4 inch on centers.

Forming grooves in the plastic concrete appeared to produce the most satisfactory friction coefficient numbers and using steel tines required the least effort. Longitudinal tine texturing was adopted as a standard with the determining factors being California's long experience with longitudinal drag texturing and the proven accident reduction by longitudinal saw-cut grooving. Comparative noise level studies indicated that transverse texturing resulted in more noise than longitudinal texturing. In addition, it was felt that the deeper grooves and wider land areas obtained with steel tines spaced 3/4 inch on centers could reasonably be expected to last longer than a broomed surface with very narrow land areas.

Although longitudinal tine texturing was adopted, it was felt that one project with both transverse and longitudinal tine texturing warranted additional monitoring by periodic skid testing and by checking accident data. The project is located on Interstate 580, Alameda County, east of Oakland near the town of Dublin. This eight-lane freeway has a 1983 two-way AADT of 85,000 vehicles with about 7,700 trucks. The area is not subject to chain or studded tire wear.

CONCLUSIONS

After eight years of traffic use, both longitudinal and transverse tine textured pavements are performing satisfactorily based on skid resistance values and accident history. Thus, there is no reason to change the California requirement for longitudinal tine texturing.

IMPLEMENTATION

California has adopted longitudinal tine texturing. This procedure is now included in the Standard Specifications. No further implementation is needed.

SKID TESTING AND PAVEMENT TEXTURE CONDITION

Table 1 lists skid test results obtained periodically with an ASTM-type towed trailer (the portable tester described in Calif. Test 342 is used only for acceptance testing of new pavements and bridge decks). The eastbound and westbound two outer lanes were tested at a speed of 40 mph. From two to five tests were made for each section and the results averaged. Adjacent projects with asphalt concrete surfacing and PCC with a longitudinal broomed texture were also tested and the results included in the table for comparison purposes.

TABLE 1

TOWED TRAILER SKID TEST RESULTS - SN_{40}

Transverse Tine Texture

	Eastbound		Westbound	
	Lane 3	Lane 4	Lane 3	Lane 4
Jan. 1980	50	41	47	41
Nov. 1980	44	39	41	34
Mar. 1985	50	44	50	40

Longitudinal Tine Texture

Jan. 1980	46	38	46	32
Nov. 1980	40	35	40	33
Mar. 1985	46	40	39	41

Longitudinal Broomed Texture

Jan. 1980	40	35	42	35
Nov. 1980	38	34	40	32
Mar. 1985	43	36	42	37

Asphalt Concrete

Jan. 1980	38	35	44	35
Nov. 1980	34	32	37	30
Mar. 1985	41	39	36	34

The test results are somewhat variable, perhaps because each test represents skidding over a distance of approximately 100 feet and/or because each test was not necessarily conducted at exactly the same location each time. The lower values for November are not unusual in California where there is normally very little rain during the summer and early fall months to help clean the pavements of oil, rubber and other contaminants. However, two trends are evident from the data: 1) the inner lanes (Lane 3 in each direction), which receive less traffic, have higher skid values than the outer lanes, and 2) the transverse tine texture generally has slightly higher skid values than those associated with longitudinal tining.

Photographs taken in April, 1985 show typical conditions of the transverse (1 and 2) and longitudinal (3, 4, and 5) texturing on the I-580 project. The tine devices had the metal tines spaced at 3/4 inch on centers. Photo 6 is of longitudinal texturing on an earlier project where the tines were spaced at 1/2 inch on centers. This was considered to form land areas too narrow, many of which were sharp edges. After this construction project, the 3/4 inch c-c spacing was adopted as standard.

On the other project with transverse tine texturing, there was no longitudinal tine texturing, but there was longitudinal brooming. After about eight years of service, skid tests (SN_{40}) show the transverse texture to have a skid number of about 38 compared to a 32 on the broom texture.

As a further indication of the effectiveness of tine texturing in one direction as compared to the other, accident data on the I-580 project were examined. After four years of traffic, accidents averaged 20 per mile for 5.3 miles of longitudinal tine texturing and 24.4 per mile for the 1.8 miles of transverse tine texturing. Most of these were classified as "rear-enders" or "run off the road" type accidents. None were attributed to wet, slick pavement, although some occurred during rainy weather.

DISCUSSION AND SUMMARY

In order to provide longer lasting concrete pavement skid resistance, it has been necessary to construct deeper grooves in the fresh concrete. The initial texturing by burlap or broom followed by the dragging of steel tines for the purpose of imparting a groove with appreciable depth is believed to be an efficient, economical method of texturing that will result in greatly improved texture durability. After the land microtexture is worn away, the grooves remain to provide escape routes for water between a tire and the pavement surface.

The question of whether pavement grooves should be oriented longitudinally or transversely has been controversial, whether for new construction or on older pavements. There are advantages and disadvantages for each and a clear superiority for either has not been established.

Transverse tine texturing offers the advantage of improved stopping ability and rapid removal of rainwater from the pavement surface. However, greater tire noise is generated and some highway engineers believe that wear rates are higher, especially in areas where chain or studded tire wear occurs. Also, construction is more complicated due to equipment requirements and it can be difficult to coordinate the tining with paving progress on hot, dry days.

Longitudinal tine texturing imparts a "tracking" effect to the pavement surface by providing resistance to lateral movement. The ability of longitudinal diamond grooving to reduce accidents, especially on curving highways, is well established. There is no reason to believe that the grooves resulting from steel tines on new construction will not be equally successful as long as some groove depth remains. Also, longitudinal tine texturing lends itself more readily to pavement construction under a variety of conditions. However, an "uneasy" ride condition is imparted to light motorcycles with certain tire treads, and light passenger cars sometimes experience some lateral oscillation. These problems are considered to be relatively minor.

Since 1977, California has specified longitudinal tine texturing on new concrete pavement construction. The spacing of the grooves is 3/4 inch center to center, the width of the groove is 3/32 inch to 1/8 inch, and the dept is a nominal 3/16 inch. This texturing procedure is providing a desirable, safe pavement texture with significantly improved durability. After more than eight years successful experience with longitudinal tine texturing, there is no reason to change this belief.

REFERENCES

1. Neal, B. F., R. J. Spring, J. H. Woodstrom and D. L. Spellman, "Portland Cement Concrete Pavement Texture Quality Investigation", Caltrans, Report No. CA-DOT-TL3126-10-75-07, January, 1975.

2. Neal, B. F., D. E. Peck, J. H. Woodstrom, D. L. Spellman, "Surface Textures for PCC Pavements", Report No. FHWA-CA-TL-78-14, April, 1978.

Photo 1. Transverse tine texture, 3/4 inch c-c.

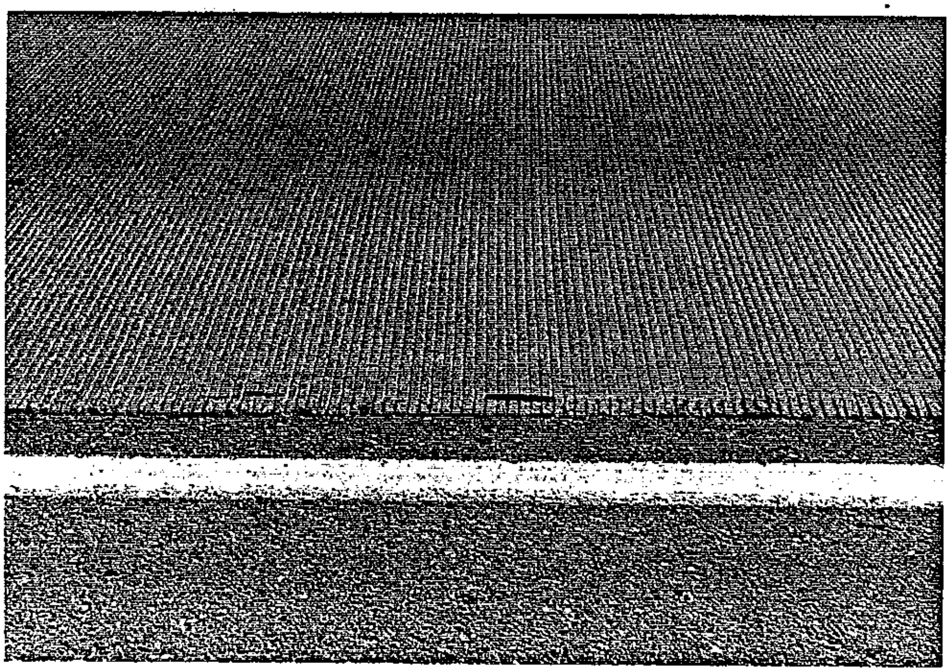

Photo 2. Close-up of transverse tine texture.

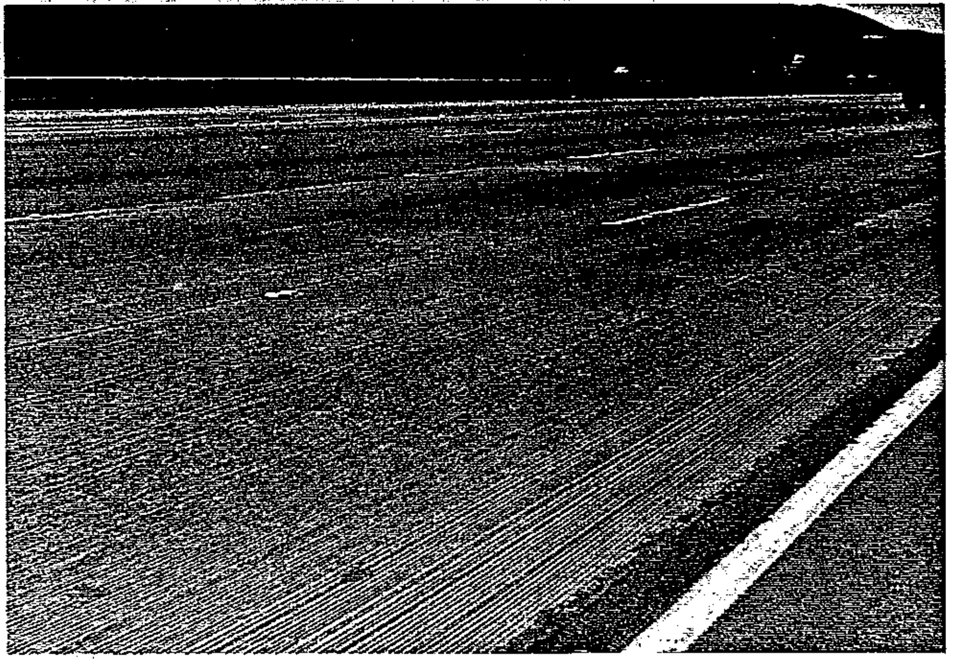

Photo 3. Longitudinal tine texture, 3/4 inch c-c.

Photo 4. Close-up of longitudinal tine texture.

Photo 5. Longitudinal tine texture, 3/4 inch c-c.

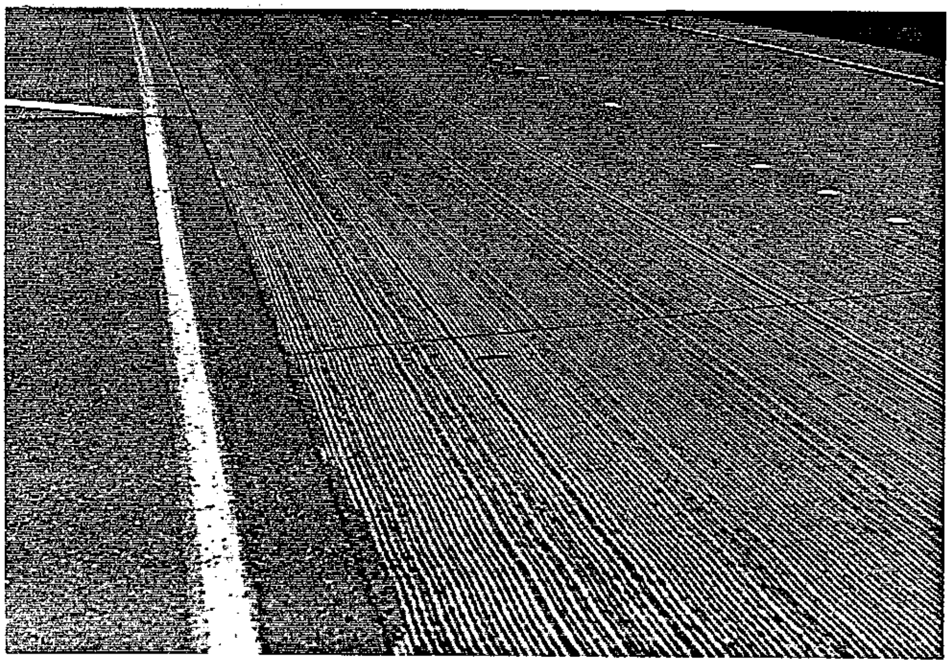

Photo 6. Longitudinal tine texture, 1/2 inch c-c.

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California Test 342
1978

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

A. 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.

B. APPARATUS

1. Skid test unit.

a. Reference is made to Figures 1 through 3 in connection with the following description of the test unit. A 4.80/4.00 × 8, 2-ply tire (A, Fig. 1) 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. 1, 2 & 3). The tire is brought to desired speed by motor (H, Figs. 1, 2 & 3). The carriage moves on two parallel guides (C, Figs. 1 & 3). 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 1 & 3. The two guide rods (C) are rigidly connected to the end frame bars (E, Fig. 1). 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. 1 & 2) 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. 2). The tachometer (K, Figs 2 & 3) indicates the speed of the tire in miles per hour. The springs (L, Figs. 1, 2 & 3) are calibrated by procedures outlined in California Test 114.

2. Hitch for fastening unit to vehicle.
3. Special level to determine grade of surface.

a. A 28" long metal carpenter's level, Figure 4, is fitted at one end with a movable gauge rod which is calibrated in % of grade.

C. 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).
5. A stiff fiber push broom.

D. 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 4.
   a. Place level on the surface parallel to test direction with adjstable 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. 1) as shown in Figure 5.
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. 1 & 2).
6. Using a paint brush, wet the full circumference of the tire (M, Fig. 3) 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. 1 & 2.)
8. Set sliding gauge indicator (P, Figs. 1 & 3) against carriage end.
9. Depress starting switch (J, Figs. 1 & 2) 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. 2) dropping tire to surface.
12. Read gauge (N, Figs. 1 & 3) 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.

E. CALCULATIONS

1. Make grade corrections using charts shown in Figures 6 and 7.

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 6.

F. PRECAUTIONS

1. The rear support rod (O, Figs. 1 & 2) 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. 1 & 3) 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.

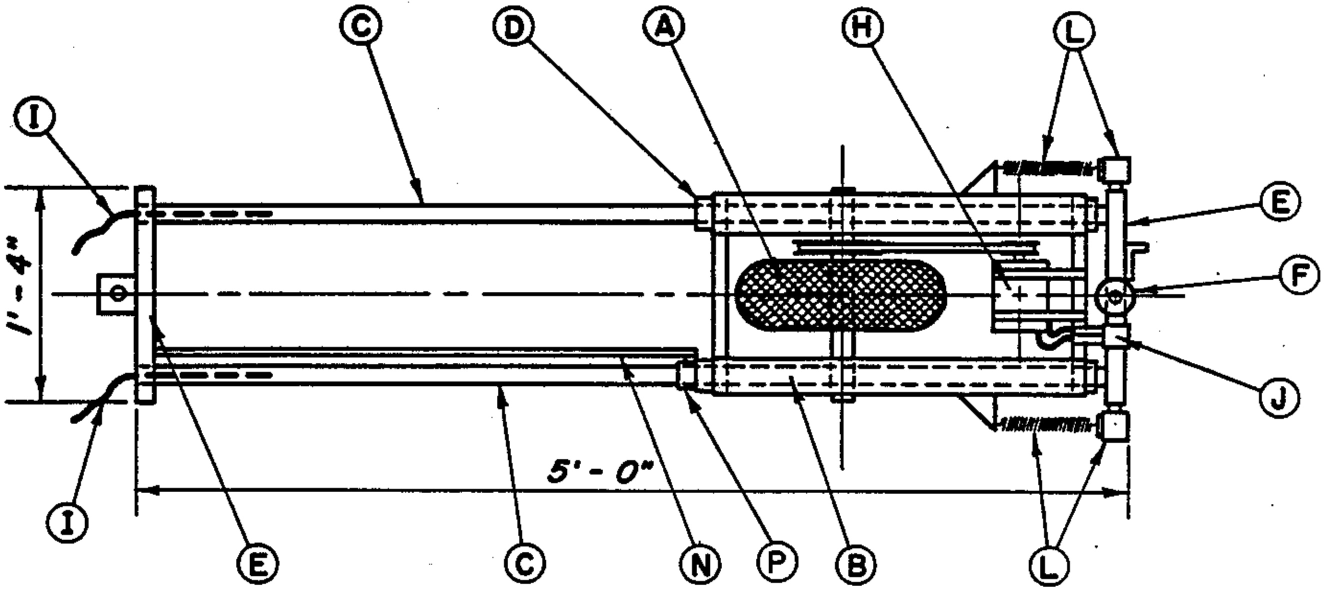
F. REPORTING OF RESULTS

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 noncompiance is determined, delimit the areas to be corrected.

Form T.L.-3111 as shown in Figure 10 is available for reporting.

End of Text (11 pgs.) on Calif. 342



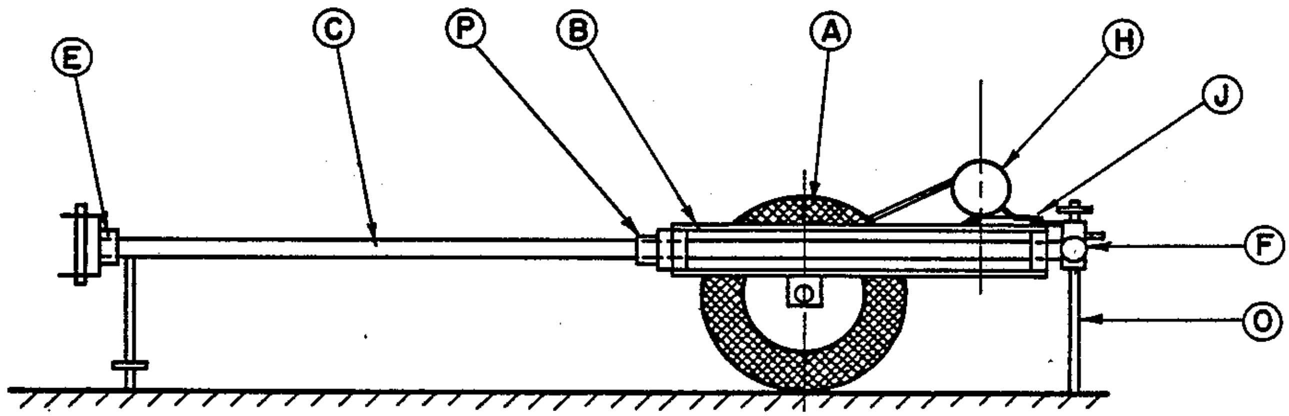


FIGURE 1
DIAGRAM OF SKID TESTER

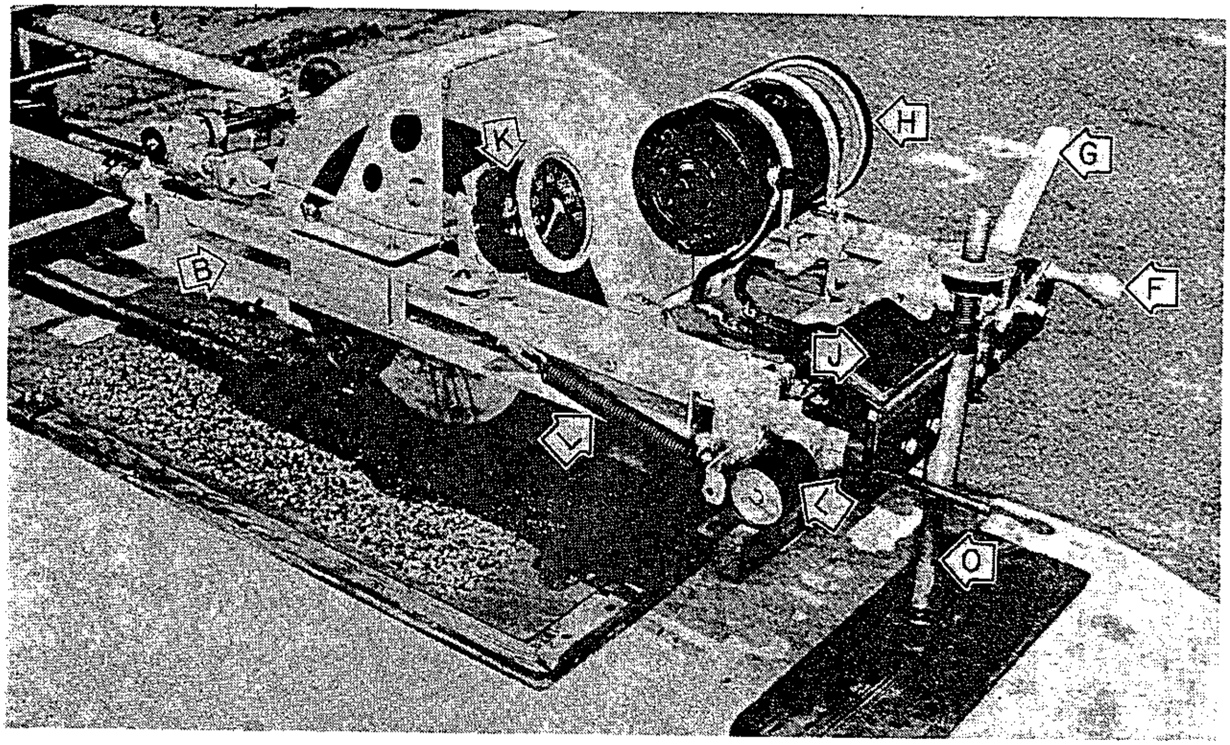
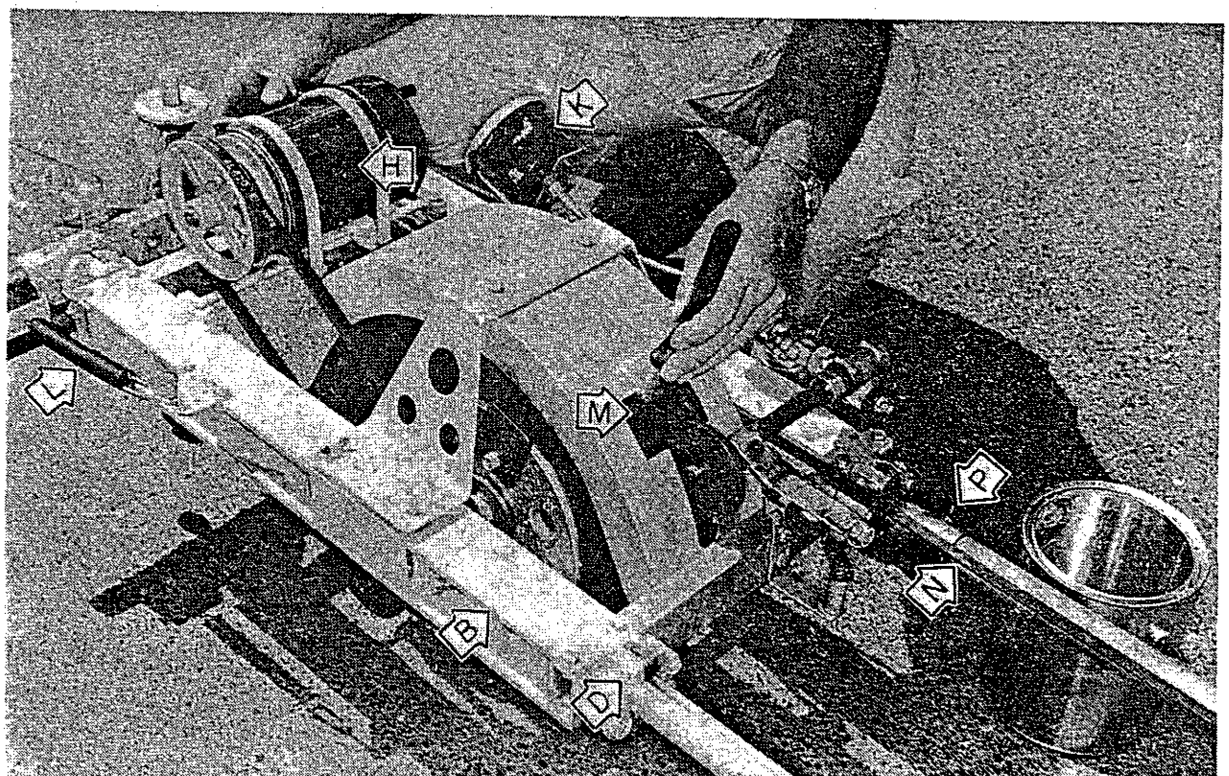


FIGURE 2



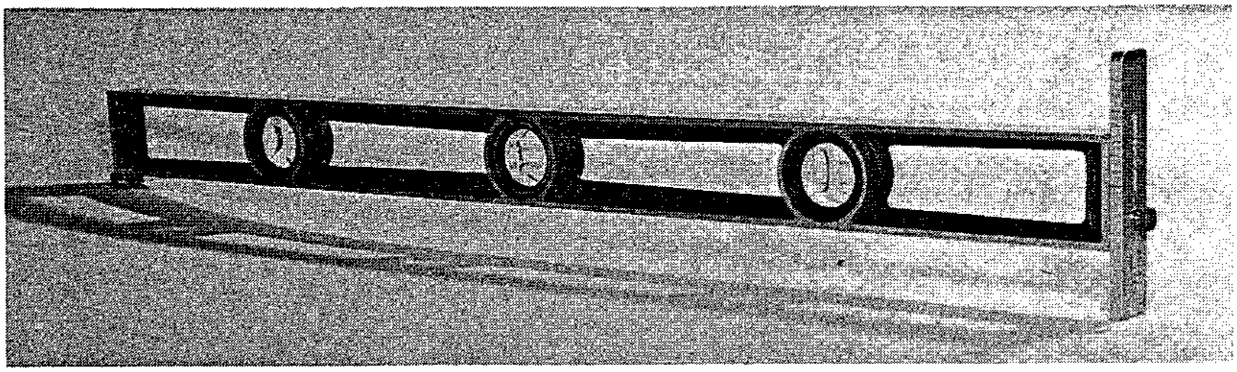


FIGURE 4
LEVEL FOR DETERMINING GRADE

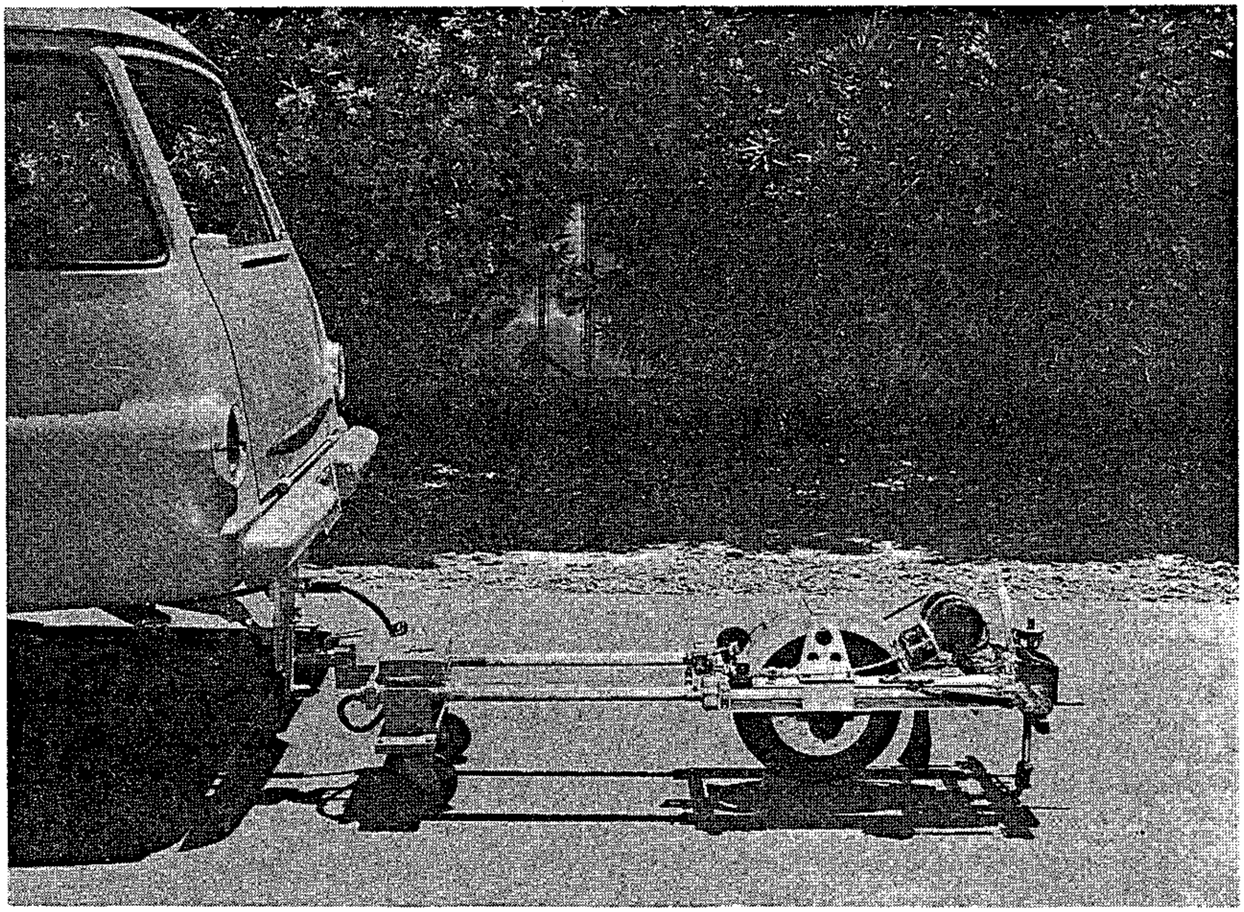


FIGURE 5
APPARATUS IN POSITION FOR TESTING

COEFFICIENT OF FRICTION CORRECTION CHART FOR MEASUREMENTS MADE ON GRADES

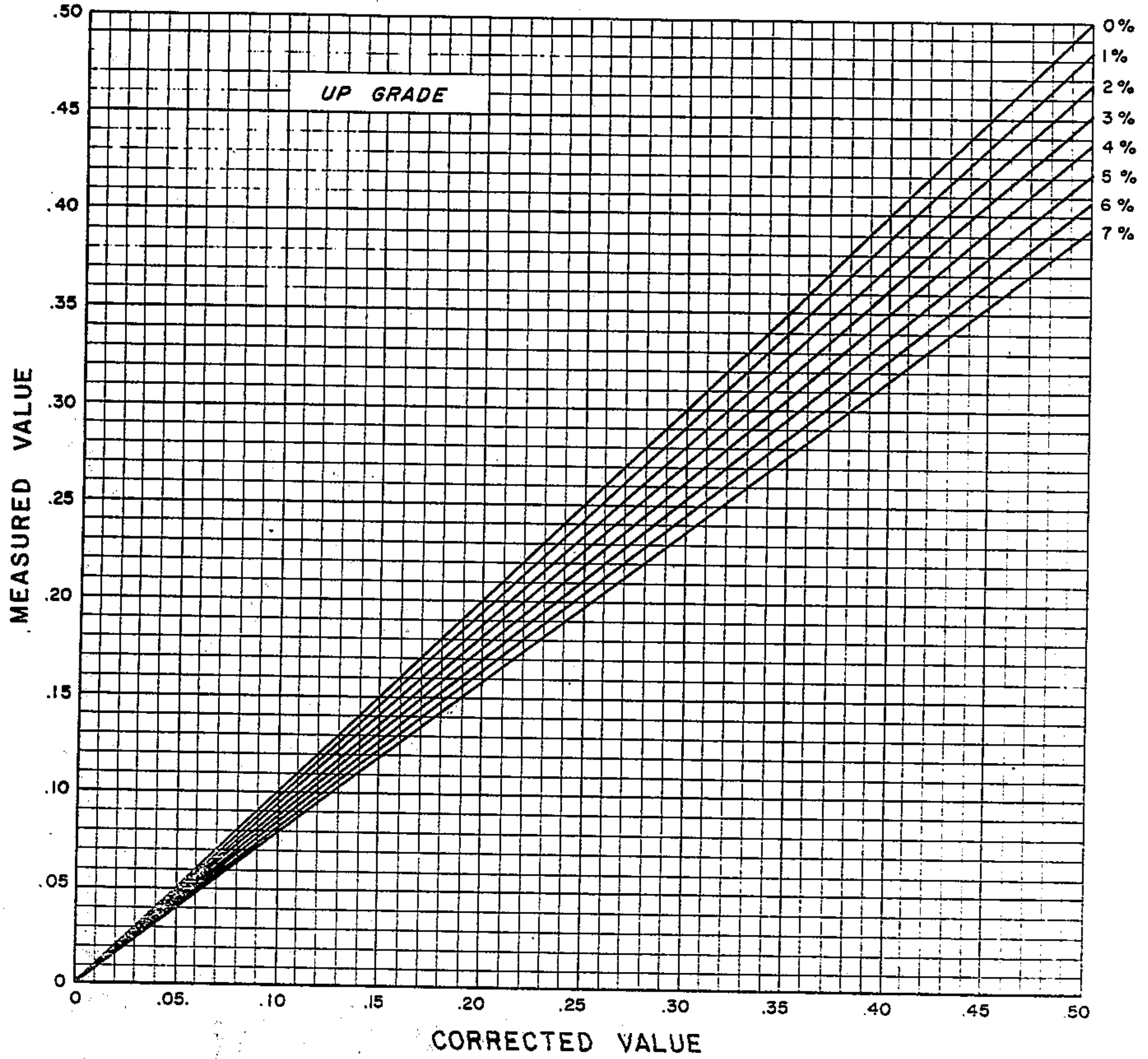


FIGURE 6

COEFFICIENT OF FRICTION CORRECTION CHART FOR MEASUREMENTS MADE ON GRADES

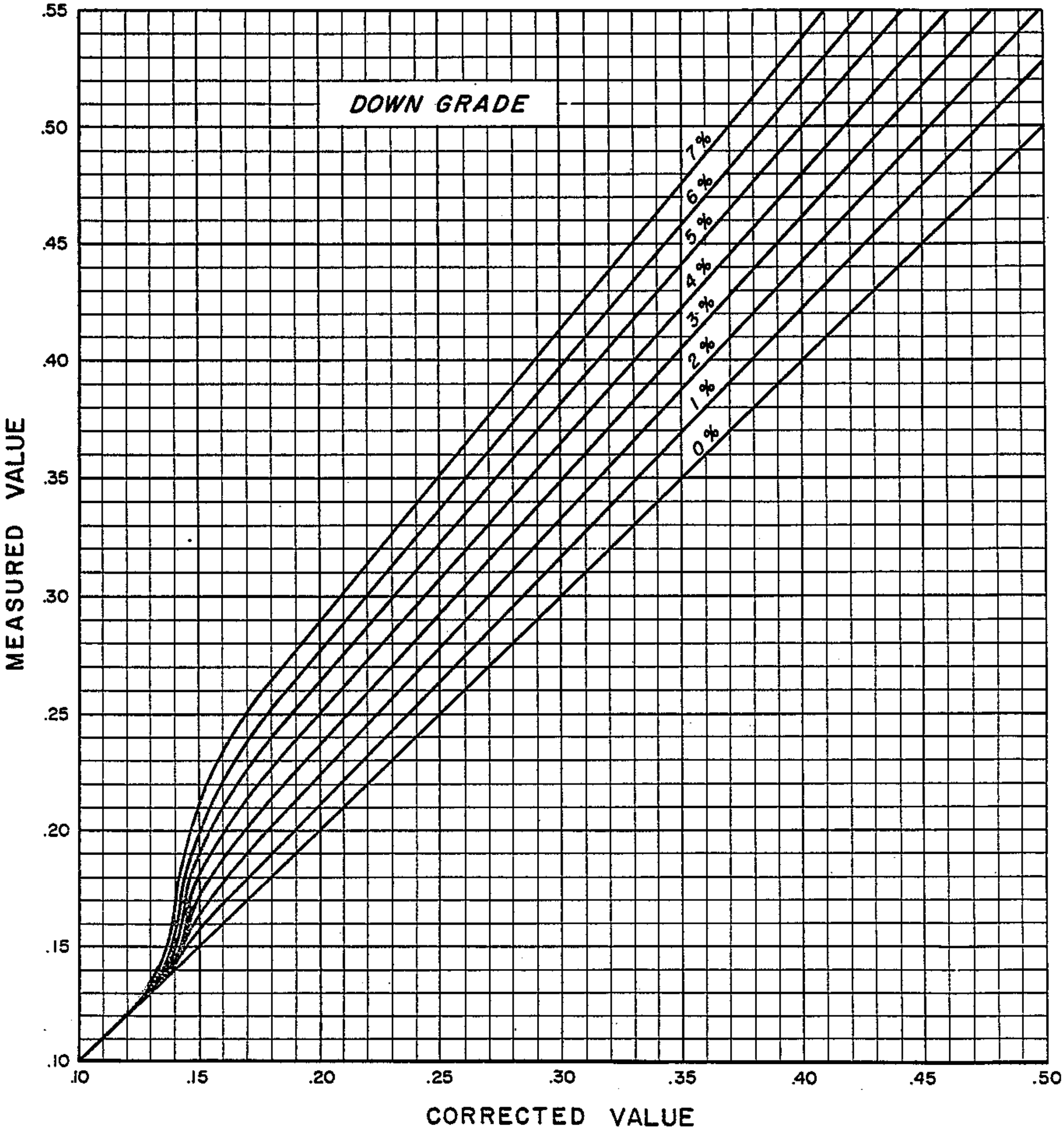


FIGURE 7

FIGURE 8
APPARATUS BEING PLACED IN VEHICLE
NOTE CABLE AND WINCH FOR MOVING SKID TESTER

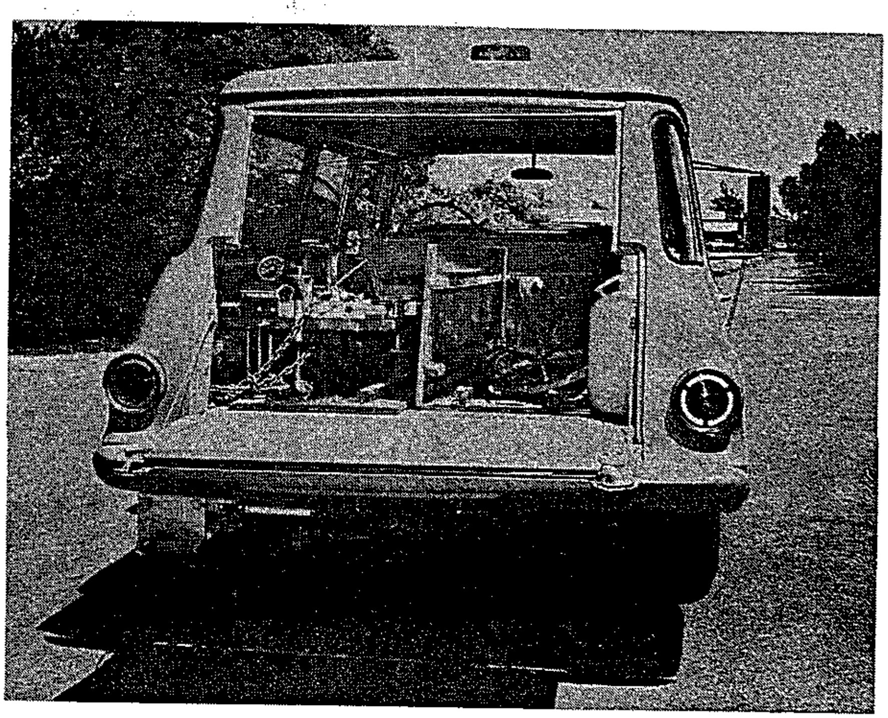


FIGURE 9
APPARATUS IN POSITION FOR TRANSPORTATION

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

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.

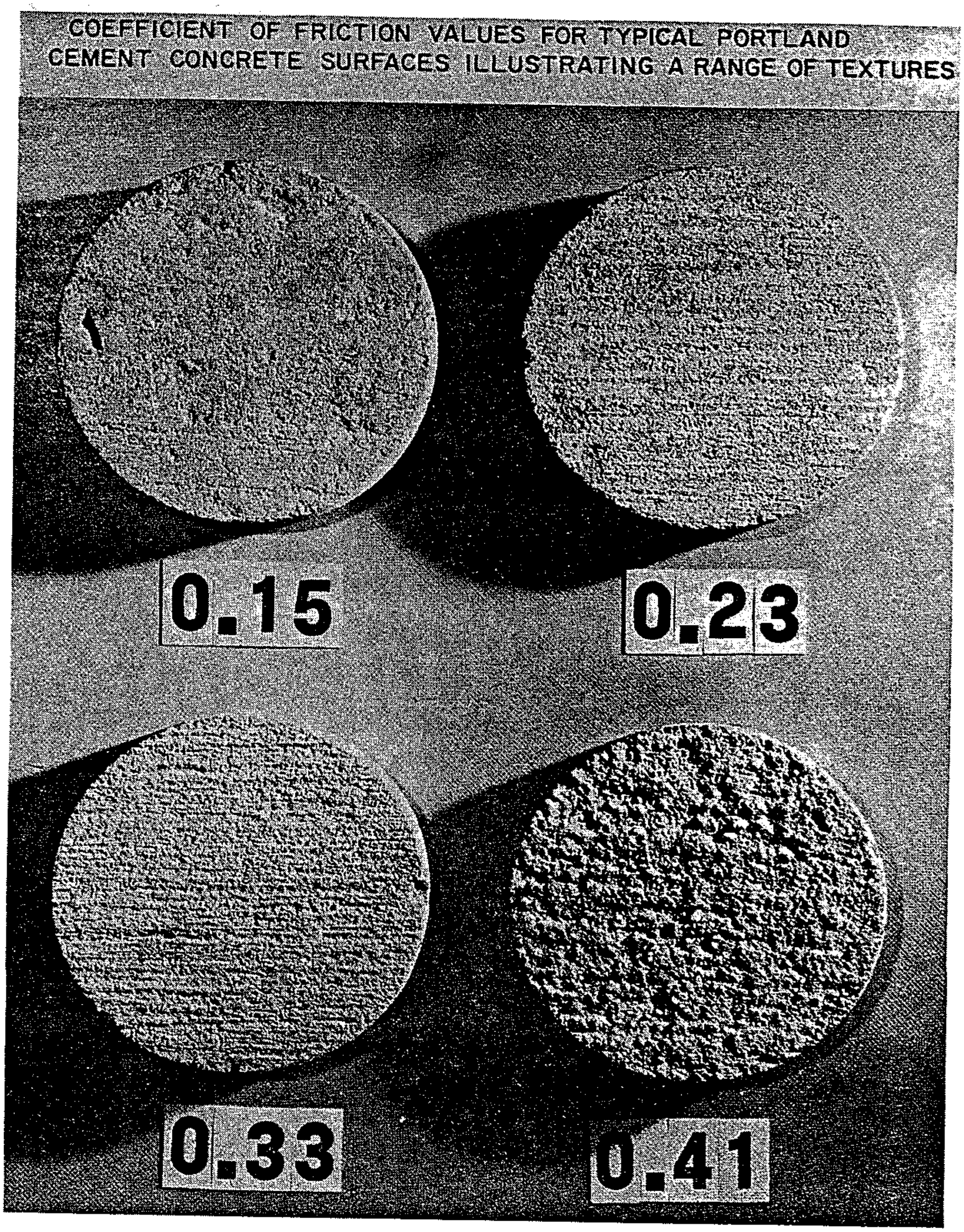
TEST NO.	DATE PLACED	LOCATION			% GRADE	TEST MEASUREMENT			REMARKS
		STATION	LANE	POSITION		MEASURED	CORRECTED	AVERAGE *	

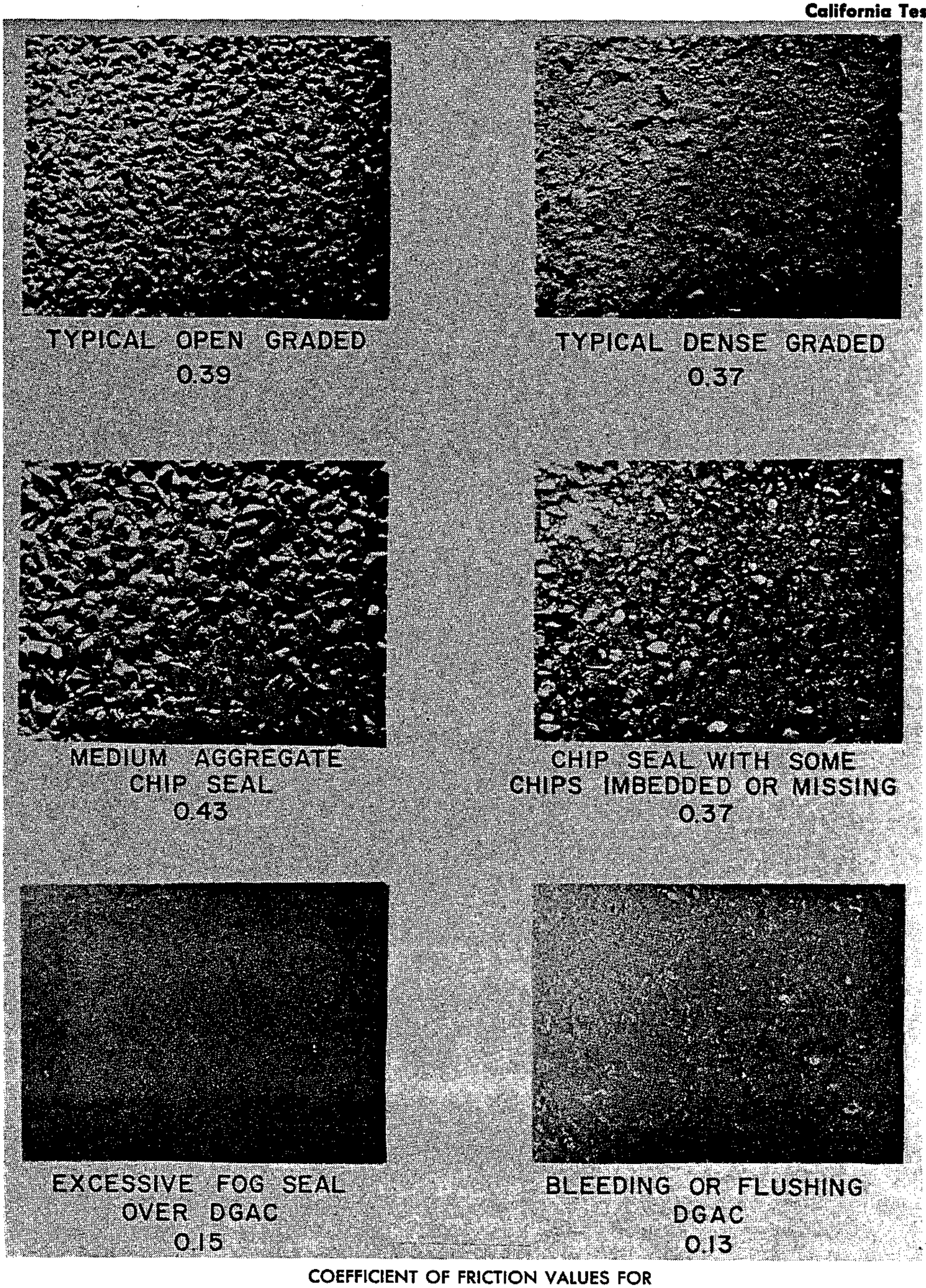
* The coefficient of friction value

TL-3111 (Rev. 8-73)

FIGURE 10

APPENDIX


COEFFICIENT OF FRICTION VALUES FOR TYPICAL PORTLAND CEMENT CONCRETE SURFACES ILLUSTRATING A RANGE OF TEXTURES
0.15
0.23
0.33
0.41



COEFFICIENT OF FRICTION VALUES FOR
VARIOUS ASPHALT CONCRETE SURFACES