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22 December 1964
SUPERSEDING
MIL-STD-621 (CE)
18 May 1961

MILITARY STANDARD

SUBGRADE, SUBBASE, AND TEST METHOD FOR PAVEMENT BASE-COURSE MATERIALS

FSC MISC

DEPARTMENT OF DEFENSE

WASHINGTON 25, D.C.

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Test Methods for Pavement Subgrade, Subbase, and Base-Course Materials

22 DECEMBER 1964

MIL-STD-621A

1. This Military Standard has been approved by the Department of Defense and is mandatory for use by all Departments and Agencies of the Department of Defense.

2. Recommended corrections, additions, or deletions should be addressed to the U.S. Army Engineer Research and Development Laboratories, Mobility Command, Fort Belvoir, Va., Attention: SMOFB-KT.

FOREWORD

This standard was developed to establish methods of testing materials for use as subgrade, subbase, and base course for pavement in those instances not covered by American Society for Testing and Materials (ASTM) tests or American Association of State Highway Officials (AASHO) procedures, or where tests for which the procedure required by the military services differs from that prescribed by ASTM or AASHO.

CONTENTS

1. SCOPE

This standard establishes test methods that set forth ways and means of determining the suitability of materials for subgrade, subbase, and base for pavements.

2. REFERENCED DOCUMENTS

The issues of the following documents in effect on the date of invitation for bids form a part of this standard to the extent specified herein.

2.1 GOVERNMENTAL.

MIL-STD-619— Unified Soil Classification System for Roads, Airfields, Embankments, and Foundations.

(Copies of standards required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 NONGOVERNMETAL.

ASTM-E-11 — Specification for Sieves for Testing Purposes (Wire Cloth Sieves, Round-Hole and Square-Hole Plate Screens or Sieves).

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pa. 19103.)

3. DEFINITIONS

3.1 NOT APPLICABLE.

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4. GENERAL STATEMENT

In the usual operation, samples of soils are obtained during the soil survey and are tested in the laboratory to determine the suitability of the properties of the samples. The specific test methods contained herein are designed to meet the Department of Defense requirements in those instances where the established industry tests and procedures are inadequate for military application.

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5. DETAILED REQUIREMENTS

5.1 TESTS. Tests shall be as specified in the individual test methods.

11/12

Custodians:

Army—MO(ERDL)

Navy—YD

Air Force—81

Review interest:

Army—MO

Navy—None

Air Force—81

User interest:

Army—GL MD MU

Navy—YD, CG

Air Force—None

Preparing activity:

Army—MO(ERDL)

Project No. MISC-0182

METHOD 100

DETERMINATION OF MOISTURE-DENSITY RELATIONS OF SOILS

1. SCOPE

1.1 This method is used for determining in the laboratory the relation between the moisture content of a soil and its density (oven-dried weight per cubic foot) when the soil is compacted as specified herein.

2. APPARATUS

2.1 Cylinder mold. A mold, 6 in. in diameter and 7 in. high, provided with a collar extension about 2 in. long and a detachable metal base plate. The mold-and-collar assembly should be constructed so that it can be fastened firmly to the detachable base plate and can be used in CBR tests. Figure 100-1 shows a satisfactory mold for moisture-density tests.

2.2 Spacer disk. A metal spacer disk, 5 15/16 in. in diameter and 2½ in. thick, for use as a false bottom in the mold during compaction of the test specimen (see fig. 100-1).

2.3 Compacting hammer or tamper. A compacting tamper of the sliding-weight type, as shown in figure 100-2, having a 2-in. diameter steel striking face, a 10-lb weight, and an 18-in. fall. The striking face and weight shall be so constructed that tamping blows can be applied adjacent to the sides of the mold. The maximum allowable weight of the assembled compaction hammer is 17½ lb.

2.4 Straightedge. A steel straightedge, 12 in. long.

2.5 Balances. A balance or scale of 25-lb capacity sensitive to 0.01 lb (or equivalent metric balance), and a 200-g-capacity balance sensitive to 0.1 g.

2.6 Drying oven. A thermostatically controlled drying oven capable of maintaining temperature of 110° plus or minus 5° C. (221° to 239° F.).

2.7 Sieves. A No. 4 (4760-micron) sieve and a ¾-in. sieve conforming to ASTM E 11.

2.8 Mixing tools. Miscellaneous tools such as mixing pan, spoon, trowel, spatula, or a mechanical device for thoroughly mixing the sample of soil with increments of water.

Note. It is convenient, but not essential, to have a mechanical device for removing the compacted soil from the mold. Such a device may consist of a closed, cylindrical sleeve slightly less than 6 in. in diameter, or a piston of like diameter actuated mechanically or by hydraulic or air pressure.

3. SPECIMEN

3.1 Size of sample. The amount of material required for the compaction test will vary with the kind, condition, and gradation of the material to be tested but will generally fall within the following limits:

(a) Fine-grained soils, 75 to 100 lb.

(b) Granular soils, 100 to 208 lb.

3.2 Preparation of test specimen. Dry the soil sample, as received from the field, until it becomes friable under a trowel. Drying may be done in the air or by use of drying apparatus providing the temperature of the sample does not exceed 60° C. (140° F.). Break up the soil thoroughly but in such a manner as to avoid reducing the size of the individual particles. Granular soils, stone, or gravel containing particles larger than ¾ in must be processed by removing all material larger than ¾ in. and replacing this with an equal percentage by weight of material passing the ¾-in. and retained on the No. 4 sieve. The percentage of material finer than the No. 4 sieve thus remains constant.

3.3 Mixing. First, separate the sample into portions for each point desired on the compaction curve. Add the desired amount of mixing water for each compaction test specimen, mix well, place the material in a container, cover with an airtight cover, and allow to cure for 24 hours. A shorter curing time may be used where tests show that shortening the curing time will not affect the results. Redetermine the moisture content if appreciable condensation forms on the wall of the container. Use a separate, fresh portion of material for each specimen; do not reuse any material.

4. TEST PROCEDURE

4.1 Assembly of mold. Clamp the 6-in.-diameter mold with detachable collar extension to the base plate, and insert the spacer disk in the base plate. Place a coarse filter paper on top of the disk.

4.2 Compacting. Place the mold on a concrete floor or pedestal during compaction. Place the soil in the mold in five layers of equal thickness (as near as practicable), with each layer receiving the specified compaction effort (number of blows of the tamper). The thickness of these layers should be such that after compaction the total thickness of the sample is not less than 4.6 in. or more than 5.0 in.

Note. To assure conformance with the specified thickness, average total thickness may be determined by weighing trimmings (see below) and computing total thickness on the basis of wet density of trimmed sample.

After the specimen has been compacted, remove the collar from the mold, and carefully trim and smooth the compacted soil flush with the top of the cylinder. For cohesive materials, the moisture content tested shall range from below to above the estimated optimum; for cohesionless materials, it shall range from air-dried to as high as practicable. Height of fall of the hammer (18 in.) must be controlled carefully and the blows distributed uniformly over the specimen.

4.3 Compaction effort. The following tabulation lists the compaction efforts commonly used in determining moisture-density relations and in preparing specimens for CBR tests. Other compaction efforts may be used for special purposes as required.

Compaction effort designation	Blows per layer	Compaction effort ft-lb/cu ft of compacted soil[1]
CE 55	55	55,000
CE 26	26	26,000
CE 12	12	12,000

Note. The compaction effort designated CE 55 is the same as that formerly designated as modified AASHO. CE 12 approximates the compaction effort used in the standard AASHO test. The densities obtained by means of CE 12 will approximate those obtained by the standard AASHO procedures but will not be identical because of differences in sample preparation, mold size, and hammer. Although the compaction method used by the Corps of Engineers has been commonly known as "Modified AASHO," neither of the above-described methods coincides exactly with the methods listed by the American Association of State Highway Officials under either T 180 or T 99.

[1] Based on a sample height, after compaction but before trimming, of 4.6 in., which will result in the maximum compaction effort within the allowable tolerance for total thickness.

4.4 **Moisture-content sample.** Detach the base plate, push the specimen from the mold, and slice it vertically through the center. Take a representative specimen from one of the cut faces, weigh it immediately, and dry it in an over at 110° plus or minus 5° C. (221° to 239° F.) for at least 12 hours, or to constant weight, to determine the moisture content. For granular materials, it is advisable to use the whole sample in moisture-content determinations.

5. CALCULATIONS.

5.1 The computation sheet, figure 100-3, shows the step-by-step procedure for calculating the moisture content as well as both the wet and dry densities of the compacted soil specimen.

6. MOISTURE-DENSITY RELATION

6.1 **Plotting.** Plot the dry densities in pounds per cubic foot as ordinates and the corresponding moisture contents as abscissas. Figure 100-4 shows a typical plot of compaction results for the three designated compaction efforts. To aid in determining the validity of the compaction data, a semilog plot of maximum dry density versus compaction effort may be made as illustrated in figure 100-4. This relation is usually a straight line when plotted as illustrated. Using the specific gravity of the material involved, a zero percent air voids curve can be plotted using data from table I. This relation to the moisture-density curves gives an idea of percent saturation for the compaction curves and provides a check on the validity of the wet side of the compaction curves.

6.2 **Optimum moisture content.** When the moisture-density relations have been determined for a soil and the results have been plotted as described in 6.1, connect the plotted points with a smooth line; the curve produced is generally parabolic in form. The moisture content corresponding to the peak of the curve is the optimum moisture content for the specific compaction effort. Report this value to the nearest 0.1 percent and indicate the compaction effort; e.g., CE 55 optimum moisture content equals 14.4 percent.

6.3 **Maximum dry density.** The dry weight in pounds per cubic foot of the soil at optimum moisture content is termed the maximum dry density for the specific compaction effort. Report this value to the nearest 0.1 lb per cu ft, and indicate the compaction effort; e.g., CE 55 maximum dry density equals 116.9 lb per cu ft.

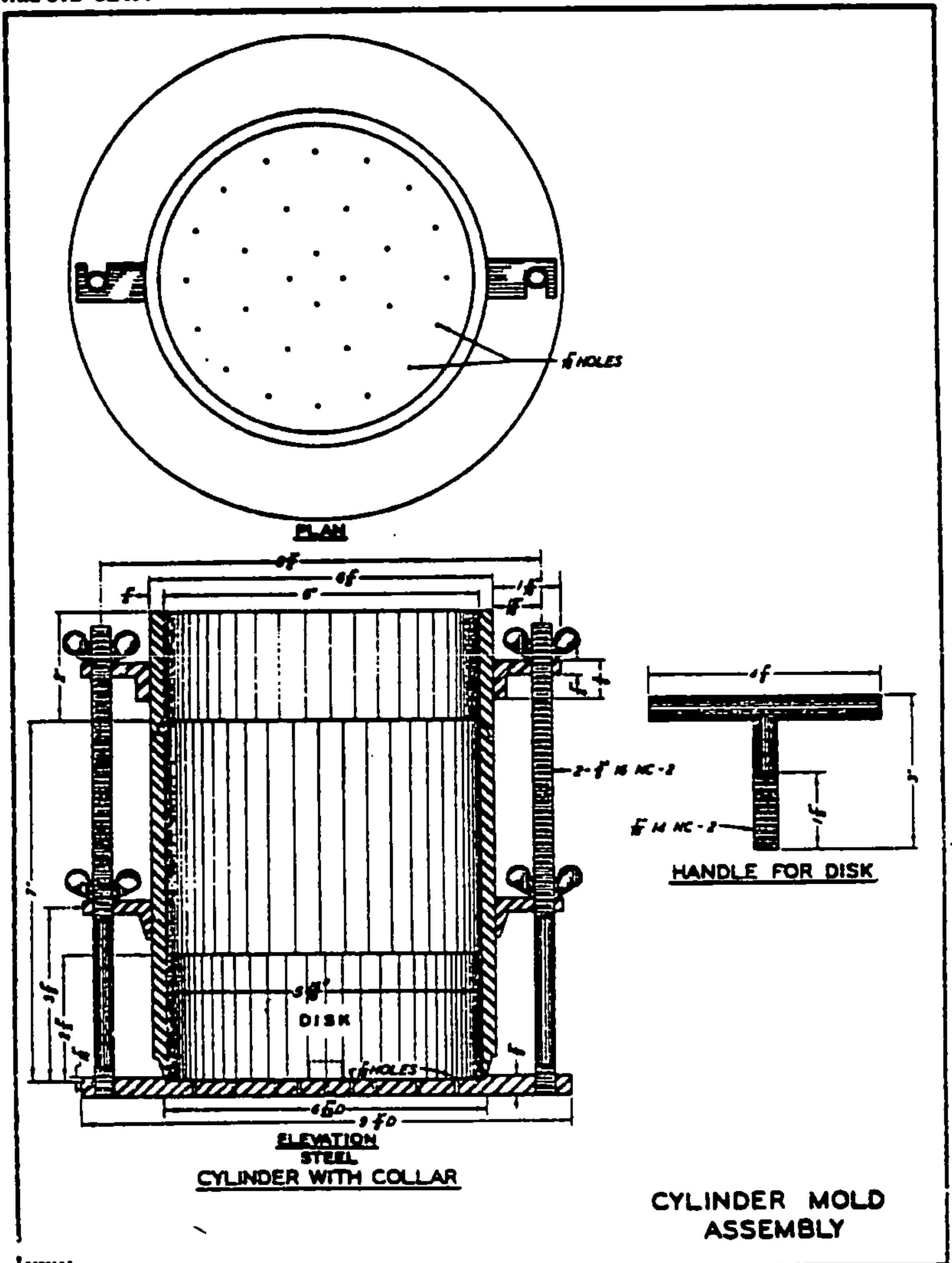


FIGURE 100-1. *Cylinder mold assembly.*

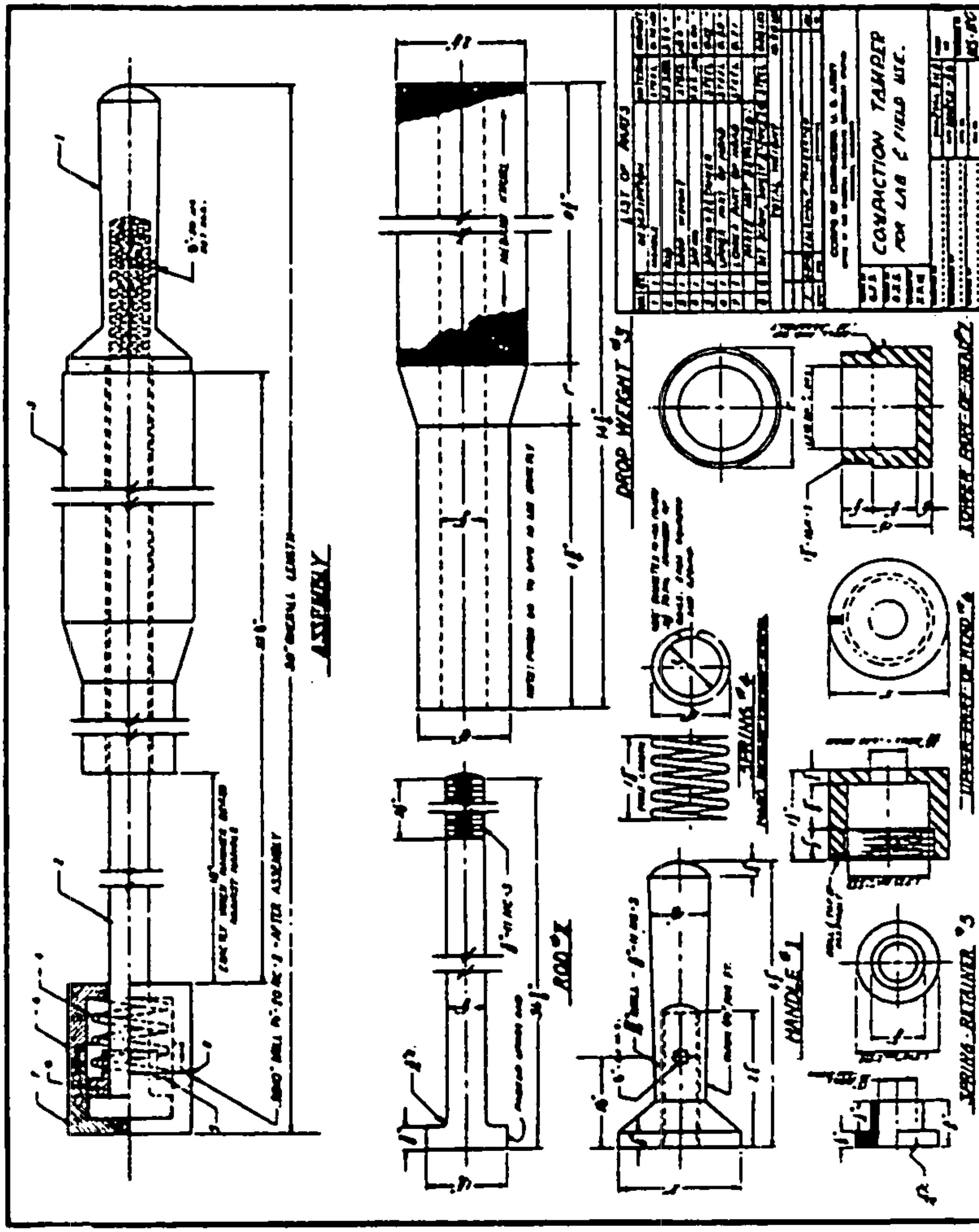


FIGURE 100.2. Compaction tamper.

SOIL COMPACTION TEST

PROJECT Ardmore AFB	DATE 9 June 52
SAMPLE NO. 3243	JOB NO. 32181
INITIAL WATER CONTENT, w_o = 4.5 %	AS MOLDED / SOAKED ✓

55 BLOWS PER EACH OF 5 LAYERS 10 -LB HAMMER 18 -IN. DROP

Specimen		A	B	C	Remarks
Desired dry weight	W_s'	5000			
$1 + w_o$		1.045	1.	1.	Subgrade Material
Soil weight W_s' $(1+w_o)$ =	W_o	5225			
Bowl tare	W_b				
$W_o + W_b$					
Test water content	w'	6 %	%	%	
Add water, W_s' $(w' - w_o)$		75			
Mold No.		4			
Weight mold + soil	W	14787			
Mold tare	W_m	10742			
Less tare, $W - W_m$ =	W_c	4045			
Average water content	w	5.3 %	%	%	
Mold constant	C	0.0298	0.	0.	
Wet density, CW_c =	m	120.5			
Dry density, $m \div 1 + w$ =	d	114.4			

WATER CONTENTS	A		B		C	
Tare	4	29				
Tare + wet soil	159.8	180.3				
Tare + dry soil	153.0	172.5				
Water W_w	6.8	7.8				
Tare	25.3	25.4				
Dry soil W_s	127.7	147.1				
Water content w	5.3 %	5.3 %	%	%	%	%

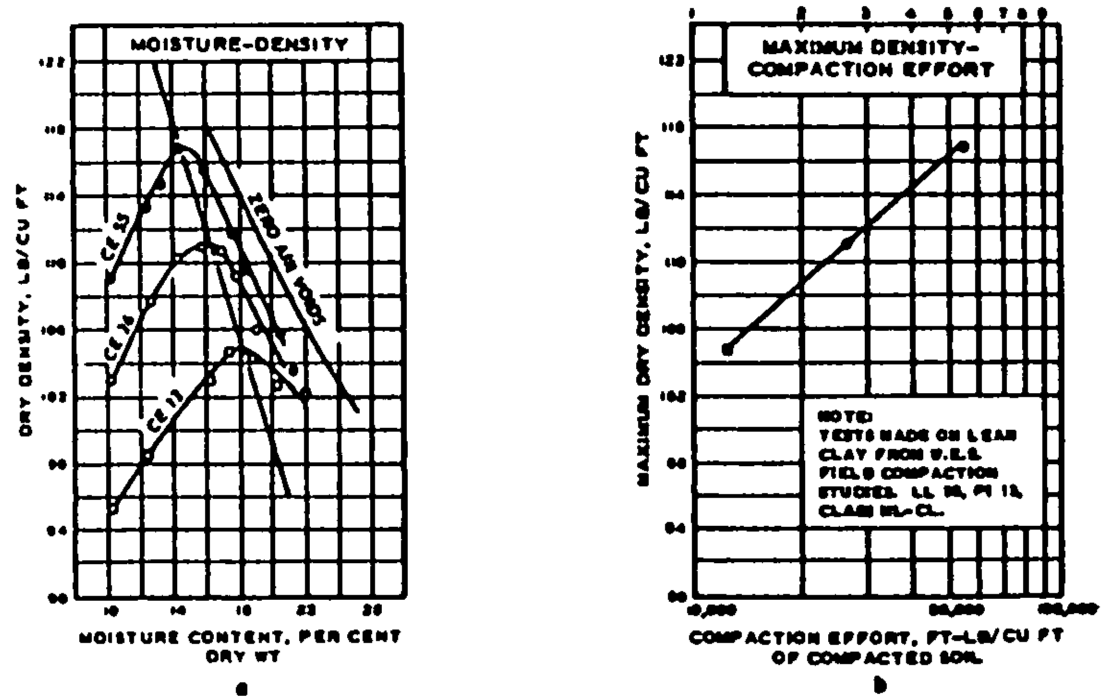
Densities in pounds per cubic foot. Weights in grams.

TECHNICIAN	COMPUTED	CHECKED
ACB	SSW	TH

C'1137 B

Figure 100.5. Computation sheet.

COMPACTION EFFORT DESIGNATION	BLOWS PER LAYER	COMPACTION EFFORT FT-LB/CU FT*
CE 55	55	56,000
CE 26	26	26,000
CE 12	12	12,000



TYPICAL PLOTS OF COMPACTION TEST RESULTS

* BASED ON 4.6-IN. SAMPLE HEIGHT

021100

FIGURE 100.4. *Typical plots of compaction test results.*

Table I. DATA FOR ZERO AIR VOIDS CURVE

Specific Gravity of Soil	Water Content, w, in Per Cent of Dry Weight for Dry Unit Weight, γ_d, in Pounds per Cubic Foot of																			
	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145
2.40	83.2	71.8	62.4	54.4	47.5	41.6	36.4	31.8	27.7	24.1	20.8	17.8	15.1	12.6	10.4	8.3	6.4	4.6	2.9	1.4
2.45	84.0	72.7	63.2	55.2	48.4	42.4	37.2	32.6	28.6	24.9	21.6	18.6	15.9	13.5	11.2	9.1	7.2	5.4	3.8	2.2
2.50	84.9	73.5	64.1	56.1	49.2	43.2	38.0	33.5	29.4	25.7	22.4	19.5	16.8	14.3	12.0	9.9	8.0	6.2	4.6	3.1
2.51	85.0	73.7	64.2	56.2	49.4	43.4	38.2	33.6	29.5	25.9	22.6	19.6	16.9	14.5	12.2	10.1	8.2	6.4	4.8	3.2
2.52	85.2	73.8	64.4	56.4	49.5	43.6	38.4	33.8	29.7	26.0	22.8	19.8	17.1	14.6	12.4	10.3	8.3	6.6	4.9	3.4
2.53	85.3	74.0	64.5	56.5	49.7	43.7	38.5	33.9	29.8	26.2	22.9	19.9	17.2	14.8	12.5	10.4	8.5	6.7	5.1	3.5
2.54	85.5	74.1	64.7	56.7	49.8	43.9	38.7	34.1	30.0	26.4	23.1	20.1	17.4	14.9	12.7	10.6	8.7	6.9	5.2	3.7
2.55	85.6	74.3	64.8	56.8	50.0	44.0	38.8	34.2	30.2	26.5	23.2	20.2	17.5	15.1	12.8	10.7	8.8	7.0	5.4	3.8
2.56	85.8	74.5	65.0	57.0	50.1	44.2	39.0	34.4	30.3	26.7	23.4	20.4	17.7	15.2	13.0	10.9	9.0	7.2	5.5	4.0
2.57	86.0	74.6	65.1	57.1	50.3	44.3	39.1	34.5	30.5	26.8	23.5	20.6	17.8	15.4	13.1	11.0	9.1	7.3	5.7	4.2
2.58	86.1	74.8	65.3	57.3	50.4	44.5	39.3	34.7	30.6	27.0	23.7	20.7	18.0	15.5	13.3	11.2	9.3	7.5	5.8	4.3
2.59	86.3	74.9	65.4	57.4	50.6	44.6	39.4	34.8	30.8	27.1	23.8	20.9	18.1	15.7	13.4	11.3	9.4	7.6	6.0	4.5
2.60	86.4	75.1	65.6	57.6	50.7	44.8	39.6	35.0	30.9	27.3	24.0	21.0	18.3	15.8	13.6	11.5	9.6	7.8	6.1	4.6
2.61	86.6	75.2	65.7	57.7	50.9	44.9	39.7	35.1	31.1	27.4	24.1	21.2	18.4	16.0	13.7	11.6	9.7	7.9	6.3	4.8
2.62	86.7	75.3	65.9	57.9	51.0	45.1	39.9	35.3	31.2	27.6	24.3	21.3	18.6	16.1	13.9	11.8	9.9	8.1	6.4	4.9
2.63	86.8	75.5	66.0	58.0	51.2	45.2	40.0	35.4	31.4	27.7	24.4	21.4	18.7	16.3	14.0	11.9	10.0	8.2	6.6	5.0
2.64	87.0	75.6	66.2	58.2	51.3	45.4	40.2	35.6	31.5	27.8	24.6	21.6	18.9	16.4	14.2	12.1	10.1	8.4	6.7	5.2
2.65	87.1	75.8	66.3	58.3	51.5	45.5	40.3	35.7	31.6	28.0	24.7	21.7	19.0	16.6	14.3	12.2	10.3	8.5	6.9	5.3
2.66	87.3	75.9	66.5	58.5	51.6	45.7	40.5	35.9	31.8	28.1	24.8	21.9	19.2	16.7	14.4	12.4	10.4	8.7	7.0	5.5
2.67	87.4	76.1	66.6	58.6	51.7	45.8	40.6	36.0	31.9	28.3	25.0	22.0	19.3	16.8	14.6	12.5	10.6	8.8	7.1	5.6
2.68	87.6	76.2	66.7	58.7	51.9	45.9	40.7	36.1	32.1	28.4	25.1	22.2	19.4	17.0	14.7	12.6	10.7	8.9	7.3	5.8
2.69	87.7	76.3	66.9	58.9	52.0	46.1	40.9	36.3	32.2	28.6	25.3	22.3	19.6	17.1	14.9	12.8	10.9	9.1	7.4	5.9
2.70	87.8	76.5	67.0	59.0	52.2	46.2	41.0	36.4	32.3	28.7	25.4	22.4	19.7	17.3	15.0	12.9	11.0	9.2	7.6	6.0
2.71	88.0	76.6	67.2	59.2	52.3	46.3	41.1	36.6	32.5	28.8	25.5	22.6	19.9	17.4	15.1	13.0	11.1	9.3	7.7	6.2
2.72	88.1	76.8	67.3	59.3	52.4	46.5	41.3	36.7	32.6	29.0	25.7	22.7	20.0	17.5	15.3	13.2	11.3	9.5	7.8	6.3
2.73	88.2	76.9	67.4	59.4	52.6	46.6	41.4	36.8	32.7	29.1	25.8	22.8	20.1	17.7	15.4	13.3	11.4	9.6	8.0	6.4
2.74	88.4	77.0	67.6	59.6	52.7	46.7	41.5	37.0	32.9	29.2	25.9	23.0	20.3	17.8	15.5	13.4	11.5	9.7	8.1	6.6
2.75	88.5	77.2	67.7	59.7	52.8	46.9	41.7	37.1	33.0	29.4	26.1	23.1	20.4	17.9	15.7	13.6	11.7	9.9	8.2	6.7
2.76	88.6	77.3	67.8	59.8	53.0	47.0	41.8	37.2	33.1	29.5	26.2	23.2	20.5	18.1	15.8	13.7	11.8	10.0	8.4	6.8
2.77	88.8	77.4	68.0	60.0	53.1	47.1	41.9	37.4	33.3	29.6	26.3	23.4	20.7	18.2	15.9	13.8	11.9	10.1	8.5	7.0
2.78	88.9	77.5	68.1	60.1	53.2	47.3	42.1	37.5	33.4	29.8	26.5	23.5	20.8	18.3	16.1	14.0	12.1	10.3	8.6	7.1
2.79	89.0	77.7	68.2	60.2	53.4	47.4	42.2	37.6	33.5	29.9	26.6	23.6	20.9	18.5	16.2	14.1	12.2	10.4	8.8	7.2
2.80	89.2	77.8	68.3	60.3	53.5	47.5	42.3	37.7	33.7	30.0	26.7	23.8	21.0	18.6	16.3	14.2	12.3	10.5	8.9	7.4
2.81	89.3	77.9	68.5	60.5	53.6	47.7	42.5	37.9	33.8	30.1	26.8	23.9	21.2	18.7	16.4	14.4	12.4	10.7	9.0	7.5
2.82	89.4	78.1	68.6	60.6	53.7	47.8	42.6	38.0	33.9	30.3	27.0	24.0	21.3	18.8	16.6	14.5	12.6	10.8	9.1	7.6
2.83	89.5	78.2	68.7	60.7	53.9	47.9	42.7	38.1	34.0	30.4	27.1	24.1	21.4	19.0	16.7	14.6	12.7	10.9	9.3	7.7
2.84	89.7	78.3	68.8	60.8	54.0	48.0	42.8	38.2	34.2	30.5	27.2	24.3	21.5	19.1	16.8	14.7	12.8	11.0	9.4	7.9
2.85	89.8	78.4	69.0	61.0	54.1	48.2	43.0	38.4	34.3	30.6	27.3	24.4	21.7	19.2	16.9	14.9	12.9	11.2	9.5	8.0
2.86	89.9	78.5	69.1	61.1	54.2	48.3	43.1	38.5	34.4	30.8	27.5	24.5	21.8	19.3	17.1	15.0	13.1	11.3	9.6	8.1
2.87	90.0	78.6	69.2	61.2	54.4	48.4	43.2	38.6	34.5	30.9	27.6	24.6	21.9	19.5	17.2	15.1	13.2	11.4	9.8	8.2
2.88	90.1	78.8	69.3	61.3	54.5	48.5	43.3	38.7	34.7	31.0	27.7	24.7	22.0	19.6	17.3	15.2	13.3	11.5	9.9	8.3
2.89	90.3	78.9	69.5	61.5	54.6	48.6	43.4	38.9	34.8	31.1	27.8	24.9	22.2	19.7	17.4	15.3	13.4	11.6	10.0	8.5
2.90	90.4	79.0	69.6	61.6	54.7	48.8	43.6	39.0	34.9	31.2	28.0	25.0	22.3	19.8	17.6	15.5	13.5	11.8	10.1	8.6
2.95	91.0	79.6	70.2	62.2	55.3	49.3	44.1	39.6	35.5	31.8	28.5	25.6	22.9	20.4	18.1	16.0	14.1	12.3	10.7	9.2
3.00	91.5	80.2	70.7	62.7	55.9	49.9	44.7	40.1	36.0	32.4	29.1	26.1	23.4	21.0	18.7	16.6	14.7	12.9	11.3	9.7
3.05	92.1	80.7	71.3	63.3	56.4	50.5	45.3	40.7	36.6	32.9	29.6	26.7	24.0	21.5	19.2	17.2	15.2	13.5	11.8	10.3
3.15	93.1	81.8	72.3	64.3	57.4	51.5	46.3	41.7	37.6	34.0	30.7	27.7	25.0	22.5	20.3	18.2	16.3	14.5	12.8	11.3

Note: Zero air voids curve equivalent to a degree of saturation, S, equal to 100 per cent. Data for zero air voids curve computed from the following formula (using a γ_w value of 62.43):

$$S = 100\% = \frac{w}{\frac{\gamma_w}{\gamma_d} - \frac{1}{G_s}}$$

The above equation may also be used to determine curves representing degrees of saturation other than 100 per cent.

METHOD 101

CALIFORNIA BEARING RATIO OF SOILS

21

1. SCOPE

1.1 This test method is used for determining the California Bearing Ratio (CBR) of soils either in the field or in the laboratory.

2. APPARATUS

2.1 *Cylinder mold assembly* meeting the requirements indicated in figure 101-1. For any group of molds, one extra base plate is desirable as two plates are required when a mold is inverted during the preparation of the specimen.

2.2 *Disk* as shown in figure 100-1.

2.3 *Compaction hammer* as shown in figure 100-2.

2.4 *Apparatus for measuring expansion of soil*, consisting of adjustable stem and perforated plate, tripod, and dial micrometer (reading to 0.001 in.), as shown in figure 100-1.

2.5 Weights, including one annular surcharge weight and several slotted or split surcharge weights as shown in figure 101-1.

2.6 *Soaking tank* of sufficient size to accommodate several test molds and of sufficient depth to ensure submergence of the sample.

2.7 *Penetration piston* as shown in figure 101-1.

2.8 *Loading device*, either a laboratory testing machine or screwjack and frame arrangement (as illustrated in fig. 101-2), which can be used to force the penetration piston into the specimen at a uniform rate of 0.05 in. per minute.

2.9 Compaction apparatus. The general laboratory equipment specified in method 100.

2.10 *Loading device* consisting of a mechanical screwjack to apply the load, and a loaded truck to provide the resistance for the screwjack (see fig. 101-3).

2.11 Calibrated proving rings.

2.12 *Penetration piston*, 1.95 in. in diameter, with internally threaded pipe extensions and connectors.

2.13 Dial micrometers and support.

2.14 *Steel plate*, 10 in. in diameter, having a 2 1/32-in.-diameter hole in the center, and weighing 10 lb.

2.15 Surcharge weights.

3. TEST PROCEDURE.

3.1 Penetration test procedure.

3.1.1 The following penetration test procedure applies to laboratory and field in-place CBR tests. Satisfactory forms for recording penetration data for laboratory tests and field tests are shown in figure 101-4 and figures 101-5 and 101-6, respectively.

3.1.1. *Applying surcharge*. Apply sufficient penetration surcharge on soil being tested to produce an intensity of loading equal to the weight (within plus or minus 5 lb) of the base material and pavement that overlie the soil being tested, but the surcharge weight shall be not less than 10 lb. (80 lb for field test). If the sample has been soaked previously, the penetration surcharge must be equal to the soaking surcharge. To prevent upheaval of soil into the hole of the surcharge weights, it is advisable to place one 5-lb annular disk surcharge weight on the soil surface prior to seating the piston and finally applying the remainder of the weights.

3.1.1.2 *Seating piston*. To seat the penetration piston, bring it into contact with the sample with sufficient pressure to cause the load dial to register a load of between zero and 1 lb.

3.1.1.3 *Applying load*. Apply loads on the penetration piston so that the rate of penetration is approximately 0.05 in. per minute. Obtain load readings at 0.025-, 0.050-, 0.075-, 0.100-, 0.125-, 0.150-, 0.175-, 0.200-, and 0.300-in. deformation. In manually operated loading devices, it may be necessary to take load readings at closer intervals to control the rate of penetration.

3.1.1.4 *Determining moisture content*. Determine the moisture content in the upper 1 in., and in the case of laboratory tests determine an average moisture content for the entire depth of the sample.

3.2 Procedure for soaking laboratory CBR specimens.

3.2.1 Place the adjustable stem and plate on the surface of the sample, and apply an annular weight to produce an intensity of loading equal to within plus or minus 5 lb of the weight of the base material and pavement that overlie the soil being tested, but in no case should the surcharge weight be less than 10 lb.

3.2.2 Set tripod on mold and dial stem on adjustable stem from plate and make initial measurement from which to determine swell or consolidation of specimen.

3.2.3 Immerse the mold in water to allow free access of water to top and bottom, and allow the specimen to soak for 4 days. (A shorter soaking period is permissible for soils that take up moisture readily if tests show that a shorter period does not affect the results.)

3.2.4 Make final swell or consolidation measurements, and calculate the swell or consolidation as a percentage of the initial specimen height.

3.2.5 Wipe the free water from the specimen, being careful not to disturb the surface of the specimen; then allow it to drain for 15 minutes. It may be necessary to tilt the specimen in order to achieve good drainage.

3.2.6 Remove the perforated plate and surcharge weights, and weigh the specimen. The specimen is now ready for the penetration test.

3.3 General procedure for testing laboratory compacted CBS specimens.

3.3.1 For testing laboratory compacted specimens for the CBC method of design, materials have been grouped into three classes with respect to behavior during saturation: (a) cohesionless sands and gravels, (b) cohesive soils, and (c) highly swelling soils. The first group usually includes the GW, GP, SW, and SP classifications of MIL-STD-619. The second group usually includes the GW, GP, SW, and SP classifications of MIL-STD-619. The second group usually includes the GM, GC, SM, SC, ML, CL, and OL classifications. Swelling soils usually comprise the MH, CH, and OH classifications. Separate procedures are given for each of the groups.

23 3.3.2 *Cohesionless sands and gravels.*

3.3.2.1 Cohesionless soils usually compact readily under rollers or traffic. Specimens shall be prepared, as specified in method 100, at high densities and at a range of moisture contents bracketing those anticipated in the field, including moisture contents as high as practicable. If soaking does not lower the CBR, it may be omitted for further tests on the same material.

3.3.3 *Cohesive soils.*

3.3.3.1 Representative samples of cohesive soils are tested in a manner to develop data that will show their behavior over the entire range of anticipated moisture contents. Test specimens are prepared and compaction curves are developed for the CE 55, CE 26, and CE 12 compaction efforts as described in test method 100. Each specimen shall be soaked and penetrated to develop a complete family of curves showing the relation between density, moisture content, and CBR. To aid in determining the validity of the compaction data, a semilog plot of maximum density versus compaction effort in energy per unit volume usually gives a straight-line relation as illustrated in test method 100.

3.3.3.2 The data from a CBR test are plotted as in figure 101-7, and the resulting family of CBR curves represents the characteristics encompassing a wide range of field conditions. The design CBR shall be based on the density and molding moisture content anticipated in the field. For example, assume that the lean clay soil, for which results are plotted in figure 101-7, can be processed to an average moisture content of 13 percent to 16 percent and that it can be compacted to a density varying from 110.5 (95 percent of modified maximum density) to 115 lb per cu ft. (see cross-hatched area on lower left-hand plot of fig. 101.7). If construction could be controlled so that the density and moisture content were within these ranges, the right-hand plot of figure 101-7 indicates that the soils, after moisture conditions had become adjusted, would have a CBR (see cross-hatched area on right-hand plot of fig. 101-7) varying between about 11 (110.5-lb-per-cu-ft density and 13 percent moisture content) and 26 (115-lb-per-cu-ft density and 15 percent moisture content). The design CBR selected should be near the lower value, say 12. The right-hand plot in figure 101-7 shows that close control of moisture content within those limits (13 percent to 16 percent) is necessary because low CBR values will be obtained if the moisture content is allowed to increase appreciably above the desired range.

3.3.4 *Swelling soils.*

3.3.4.1 The test procedures for highly swelling soils are the same as those previously described for cohesive soils; however, the objectives of the testing program are not exactly the same. Tests shall be performed on soils having expansive characteristics to determine a moisture content and a density which will minimize expansion. The proper moisture content and density are not necessarily the optimum moisture content and density for the CE 55 compaction effort. Generally, the minimum swell and highest soaked CBR will occur at a molding moisture content slightly wet of optimum. When testing highly swelling soils, it may be necessary to prepare samples for a wider range of moistures and densities than that normally used in order to establish the relation between moisture content, density, swell, and CBR for a given soil. A careful study of the test results will permit the selection of the proper moisture content and density required in the field. It should be noted that the possibility exists that thickness design may be governed by the compaction requirements instead of the CBR in some cases.

3.4 Field in-place tests (see fig. 101-6 for data sheet).

3.4.1 Field in-place CBR tests are used for design under any one of the following conditions: (a) when the in-place density and water content are such that the degree of saturation (percentage of voids filled with water) is 80 percent or greater; (b) when the material is coarse grained and cohesionless so that it is not affected by changes in water content; and (c) when construction was completed several years before. In the last-named case, the water content does not actually become constant but appears to fluctuate within rather narrow ranges, and the field in-place test is considered a satisfactory indicator of the load-carrying capacity. The time required for the water content to become stabilized cannot be stated definitely, but the minimum time is approximately 3 years.

3.4.1.1 *Penetration*. Level the surface to be tested, and remove all loose material. Then follow the procedure described in 3.1.1.

3.4.1.2 *Number of tests*. Three in-place CBR tests should be performed at each elevation tested in the base course and at the surface of the subgrade. However, if the results of the three tests in any group do not show reasonable agreement, additional tests should be made at the same location. A reasonable agreement between three tests where the CBR is less than 10 permits a tolerance of 3; where the CBR is from 10 to 30, a tolerance of 5; and from 30 to 60, a tolerance of 10. For CBR's above 60, variations in the individual readings are not of particular importance. For example, actual test results of 6, 8, and 9 are reasonable and can be averaged as 8; results of 23, 18, and 20 are reasonable and can be averaged as 20. If the first three tests do not fall within the specified tolerance, the three additional tests are made at the same location, and the numerical average of the six tests is used as the CBR at that location.

3.4.1.3 *Moisture content and density*. After completion of the CBR test, a sample shall be obtained (a) at the point of penetration for moisture-content determination, and (b) 4 to 6 in. away from the point of penetration for density determination.

3.5 Undisturbed specimens.

3.5.1 Because of the difficulty of obtaining reliable CBR test results on so-called undisturbed specimens, these tests will be performed only in special cases.

Note. The past practices of obtaining and testing samples in wooden boxes and of leaving an annular space between sample and container wall to be filled with plastic material such as paraffin shall be discontinued as these practices leave some doubt as to the adequacy of the lateral confinement of specimen during the CBR test.

4. CALCULATIONS.

4.1 The CBR shall be calculated immediately after completion of the test, as follows.

4.1.1 *Plotting load-penetration curve*. Calculate the penetration load in pounds per square inch, and draw the load-penetration curve. It is sometimes necessary to correct the CBR value because of surface irregularities and/or the concave-upward shape of the curve that characterizes samples on the wet side of optimum for certain soils. Figure 101-8 shows both the uncorrected and the corrected CBR curves. Correction can be made graphically by adjusting the zero point of the curve as in figure 101-8 or it can be made mathematically by selecting the largest CBR value based on load increase divided by the standard loads for any consecutive 0.1-in. or 0.2-in. penetration. The mathematical correction has the advantage of eliminating the personal error in drawing the corrected curve. However, the curve should be drawn in any case so that erratic data will be more easily recognized.

4.1.2 *Calculating CBR.* Determine the corrected load values at 0.1- and 0.2-in. penetration from which the CBR values are obtained by dividing the corrected unit loads at 0.1 and 0.2 in. by the standard loads of 1,000 and 1,500 psi, respectively. Each ratio is multiplied by 100 to obtain the bearing ratio in percent. The CBR is usually selected at 0.1-in. penetration. If the ratio at 0.2-in. penetration is greater, the test should be rerun. If check tests give similar results, use the CBR at 0.2-in. penetration.

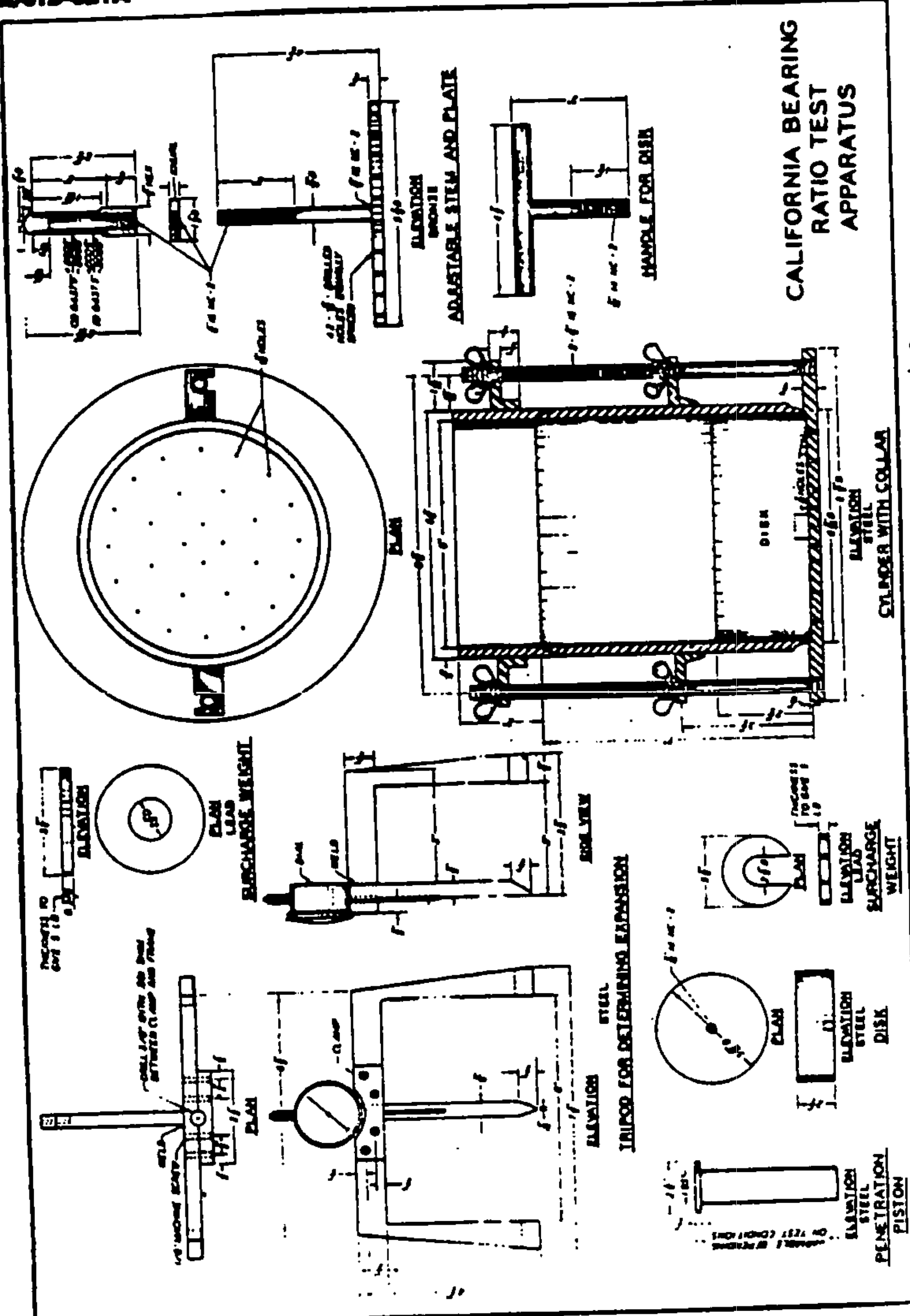


Figure 101-1 California bearing ratio test apparatus.

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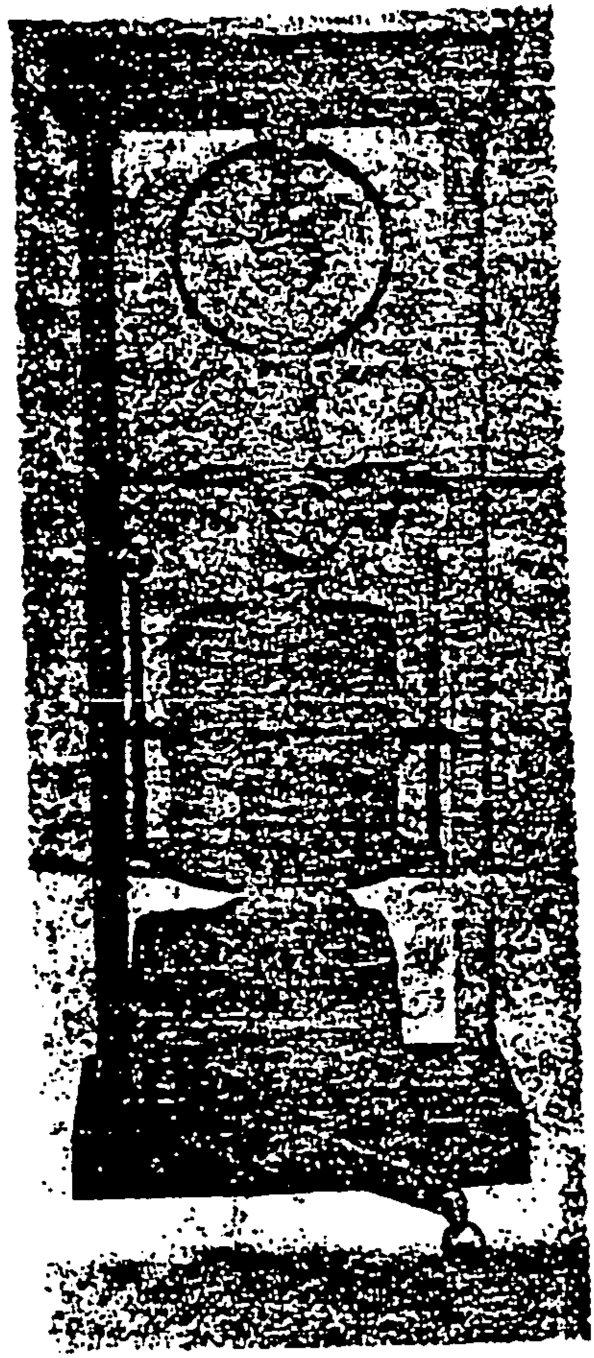

FIGURE 101-2. *Laboratory CBR test equipment.*

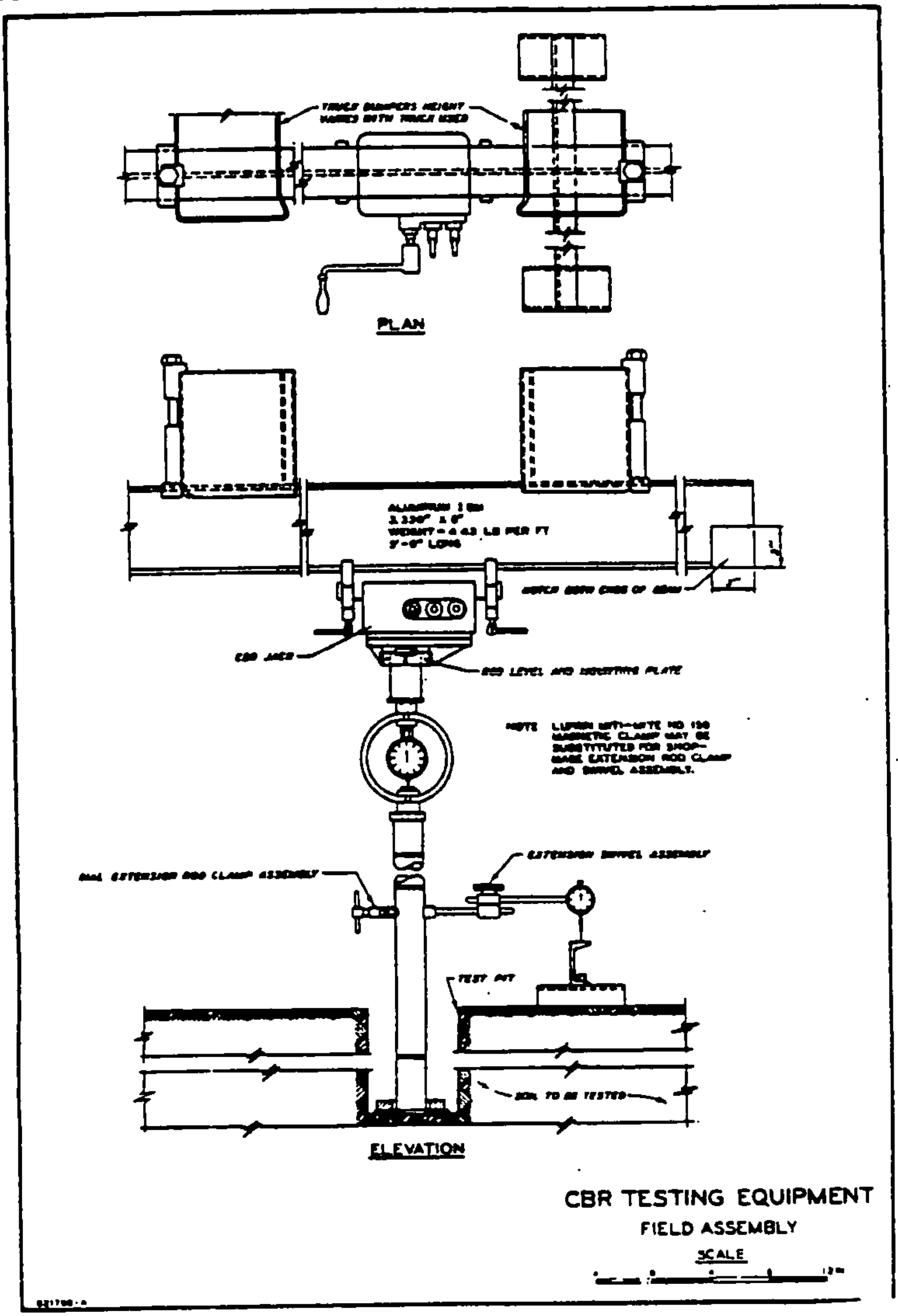

Figure 101-3 CBR testing equipment.

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CALIFORNIA BEARING RATIO (CBR) TEST
Penetration

PROJECT		DATE
SAMPLE NO.		JOB NO.
NO. BLOWS	AS MOLDED	SOAKED
MOLD NO.	Surcharge weights, in pounds: Soaking ________ Penetration ________	

Date	Time	Days	Reading in.	Swell in.	Swell %	BEARING RATIO DATA (3-sq-in. piston. 0.05 in. per min.)			
						Penetration in.	Total Load	Bearing Value* lb/in.^{2}	Corr. CBR
		0	0.	0.					
			0.	0.					
			0.	0.		0.025			
			0.	0.		0.050			
			0.	0.		0.075			
			0.	0.		0.100**			
			0.	0.		0.125			

WATER CONTENTS AFTER SOAKING	Whole Specimen Drained	Top in.	Penetration in.	Total Load	Bearing Value* lb/in.^{2}	Corr. CBR
			0.150			
			0.175			
Tare			0.200†			
Tare + wet soil			0.250			
Tare + dry soil			0.300			
Water			0.350			
Tare			0.400			
Solids			0.450			
Water Content	%	%	0.500			

Note: Standard load at 0.1-in. penetration = 1000 psi.
Standard load at 0.2-in. penetration = 1500 psi.
* (0.734 x total load in kilograms) or (total load in pounds ÷ 3).
** Total load in pounds ÷ 30 = CBR.
† Total load in pounds ÷ 45 = CBR.

TECHNICIAN	CHECKED	DATE

FIGURE 101-4. *CBR laboratory record form.*

FIELD CBR TEST

1. Date ____________ 19 ____

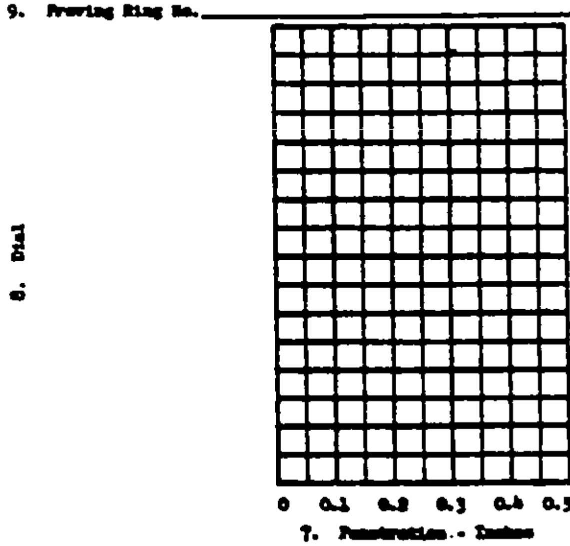
2. Project ____________ 3. Project Location ____________

4. Test Location ____________

____________ 5. Material ____________

6. Depth, In. ____________ 9. Proving Ring No. ____________

7. Pene. In.	8. Dial	7. Pene. In.	8. Dial	7. Pene. In.	8. Dial
.025		.175		.325	
.050		.200		.350	
.075		.225		.375	
.100		.250		.400	
.125		.275		.450	
.150		.300		.500	



CBR at 0.1 In.

10. Corrected Dial ____________

11. CBR [%]

CBR at 0.2 In.

12. Corrected Dial ____________

13. CBR = $\frac{\_\_\_\_}{1.5}$ = ______ %

	14. Water Content for CBR	15. Water Content for Dens.	16. Density Sample
17. Container No.			
18. Wet Soil + Container			
19. Dry Soil + Container			
20. Wt Water			
21. Wt Container			
22. Wt Wet Soil			
23. Wt Dry Soil			
24. Water Content			
25. "K" Factor			
26. Unit Wet Wt			
27. Unit Dry Wt			

28. Sand Volume

29. Wt Filled	
30. Wt Empty	
31. Wt Sand	
32. Vol. Container	
33. Calibrated Dens.	
34. Wt After	
35. Wt Sand	
36. Wt After	
37. Wt Sand	
38. Wt Sand Used	

39. Remarks ____________

____

____

40. Field Test By ________ 41. Lab. Test By ________ 42. Computed By ________ 43. Chkd ________

FIGURE 101-6. *CBR field record form.*

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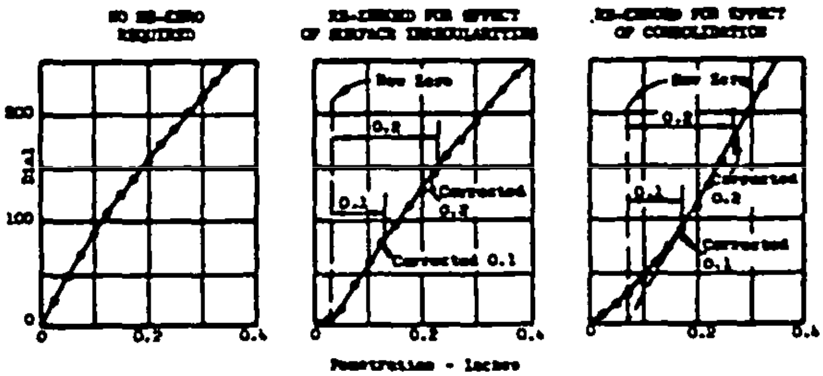
INSTRUCTIONS FOR FILLING OUT FIELD CBR TEST FORM

1. Date. Date field test is made.
2. Project. Write name of job.
3. Project Location. Give location of job.
4. Test Location. Describe location of test pit on job.
5. Material. Material being tested; base, subgrade, etc.
6. Depth. Depth from surface in inches.
7. Penetration. Penetration of CBR piston into soil in inches.
8. Dial. Reading on proving ring dial. When plotting the curve select the largest reasonable scale that will include the maximum value obtained in the test. Be sure to show this scale on the plot.
9. Ring No. Serial Number of proving ring (for selecting calibration sheet).
10. Corrected Dial. Plot curve of dial readings versus penetration and re-zero curve as shown in samples below. Read dial at corrected 0.1 in.
11. CBR. Read CBR from calibration curve (calibration curve reads direct CBR).
12. Corrected Dial. Same as 10 except read dial at corrected 0.2 in. penetration.
13. CBR. Same as 11 except divide reading from calibration sheet by 1.5. Show to nearest per cent.
14. Use this column for the water content from the CBR test.
15. Use this column for the water content from the density sample.
16. Use this column for the soil part of sand volume sample or for the entire computations in cylinder samples.
17. Self-explanatory.
18. and 19. Show weight in grams.
20, 21, 22, 23. For columns 14 and 15 obtain 23 first by subtracting 21 from 19. Then obtain 20 by subtracting 19 from 18. For column 16 obtain 22 by subtracting 21 from 18 when computing cylinder densities.
24. Water content is 20 divided by 23 multiplied by 100 per cent. Show nearest 0.1%.
25. "K" factor for cylinder obtained by following formula; K equals 4.85 over diameter squared times height.
26. For sand apparatus densities; 22 times 33 over 38. For cylinder densities; 22 by 25.
27. 26 divided by 1 plus water content in hundredths. Example: 1 plus water content of 16.7 equals 1.167. May also be computed in the same manner as 26 by using the dry weight of soil 23 in place of the wet weight 22. Show to the nearest lb/cu ft.
28. Use for sand part of sand volume density.
29. Total weight of sand apparatus filled in grams.
30. Total weight of sand apparatus empty in grams.
31. Weight of sand used to fill cylinder; obtained by subtracting line 30 from line 29.
32. Volume of sand apparatus used. Obtained by using formula: weight of water required to fill cylinder in pounds over unit weight of water in lb/cu ft.
33. Density of sand in lb/cu ft obtained by multiplying line 31 by .002205 over line 32.
34. Re-weigh for total weight of sand apparatus in grams after pouring sand for surface calibration.
35. Total weight of sand used in surface calibration obtained by subtracting line 34 from line 29.
36. Re-weigh after filling hole for amount of sand used in hole.
37. Total weight of sand used in hole and surface calibration obtained by subtracting line 36 from line 34.
38. Weight of sand used in hole obtained by subtracting line 35 from line 37.
39. Explain any variations. Also use to record additional facts about test location.
40, 41, 42, 43. Insert initials.

Use figures in black for making tables and plots, except use underlined CBR (0.2 in.) when this figure is constantly higher for material being tested.



These curves show a case requiring no re-zeroing and two typical cases where re-zeroing is required. The curves themselves are not necessarily typical as the slope and shape of curves vary considerably. In general, the points should line up so that reasonable curves can be drawn with a French curve. Tests should be re-run where the points do not line up sufficiently well to permit drawing reasonable curves.

FIGURE 101-4. *CBR field record form (reverse side).*

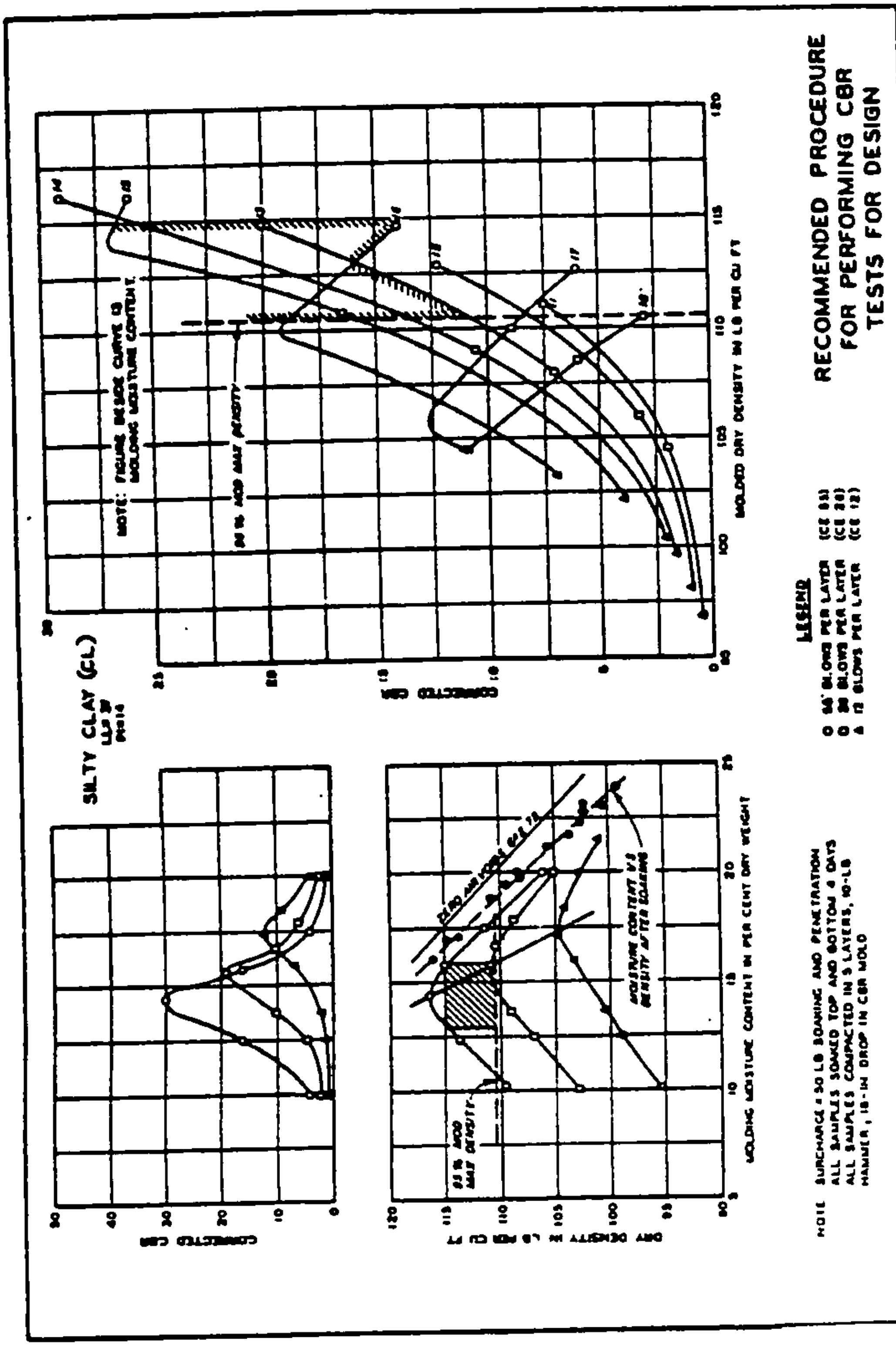


FIGURE 101-7. *Recommended procedure for performing CBR tests for design.*

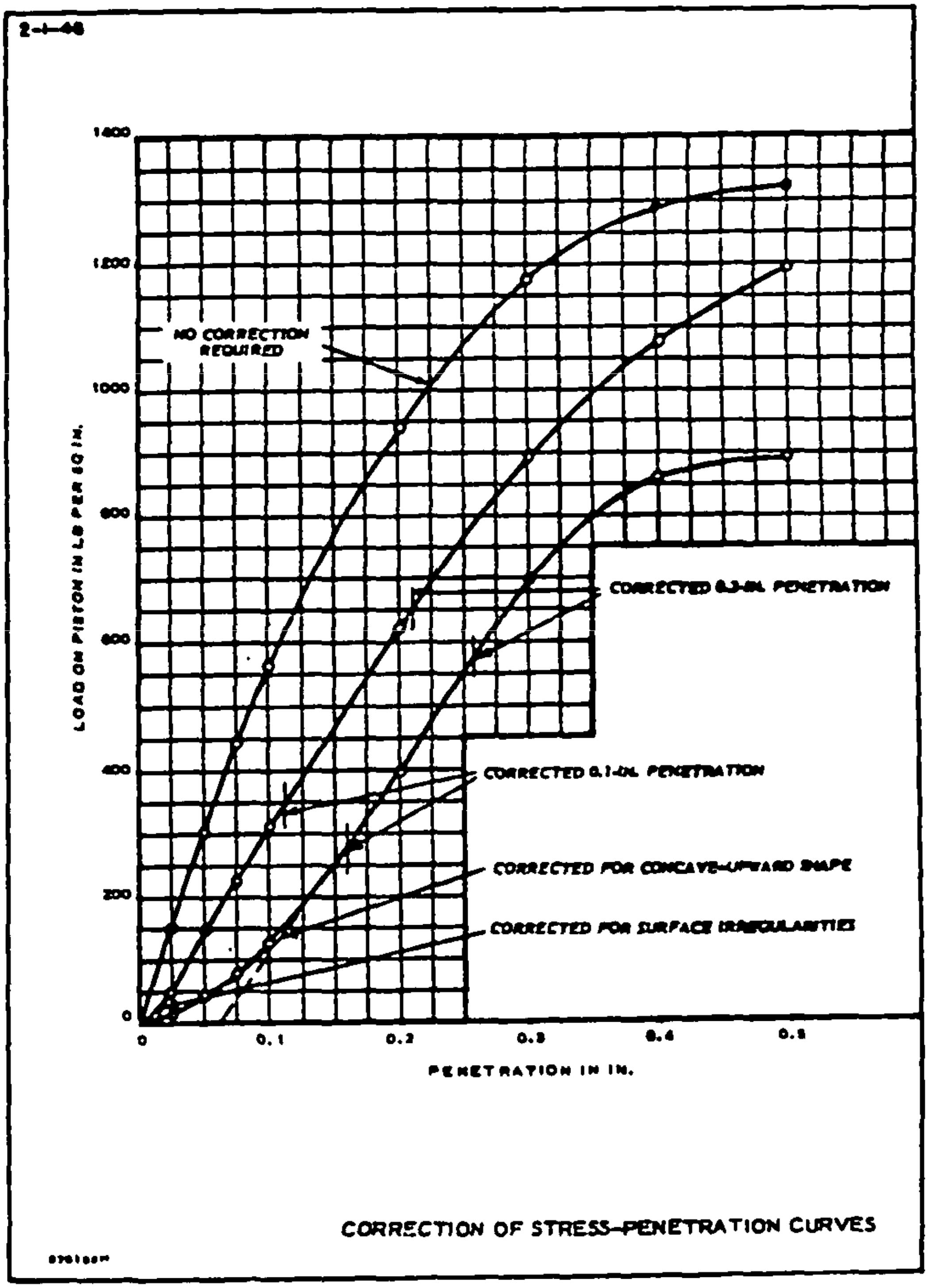


FIGURE 101-8. *Correction of Stress-penetration curves.*

METHOD 102

DETERMINATION OF DENSITY OF SOIL IN PLACE BY THE DRIVE CYLINDER

35

1. SCOPE

1.1 This method of testing is used for determining the in-place density of cohesive, fine-grained soils.

2. APPARATUS

2.1 **Drying equipment.** Oven or other suitable equipment for drying moisture-content samples.

2.2 **Balances.** A balance or scale of 10-kg capacity accurate to 1.0 g, and a balance of 500-g capacity accurate to 0.1 g.

2.3 **Drive cylinders.** Two types of drive cylinders of 0.01-cu-ft capacity conforming to the details shown in figures 102-1 and 102-2.

2.4 **Drivehead.** Two types of driveheads and appurtenances conforming to the details shown in figures 102-1 and 102-2.

2.5 **Miscellaneous equipment.** Ten-pound sledge hammer, 4-in. Iwan-type auger, shovel or spade, steel straightedge with one sharp edge, 8-in.-long butcher knife, seamless tin cans with lids.

3. TEST PROCEDURE

3.1 **Weight and volume of cylinder.** Determine and record the tare weight and volume of the drive cylinder in grams and cubic centimeters, respectively.

3.2 **Determining density and moisture content at or near the surface.** Place the drive cylinder on the surface with the sharp edge down, and seat the drivehead on the cylinder. Drive the cylinder by means of the drop hammer until the top of the cylinder is approximately ½ in. below the original surface. Remove the drivehead, and dig the cylinder from the ground with a shovel or spade. Clean the soil from the sides of the cylinder, and trim the sample flush with both ends of the cylinder, using a straightedge. Determine and record the wet weight of the sample and cylinder as soon as trimming has been completed. Remove the sample from the cylinder, and obtain a moisture-content specimen of approximately 100 g. Determine the wet weight of the moisture-content specimen, and then dry it to constant weight in an oven at 110° plus or minus 5° C. (221° to 239° F.) and determine the dry weight.

3.3 **Determining density and moisture content below the surface.** Drill a hole to the desired depth with an Iwan-type auger. Clean the bottom of the hole of loose material. Lower the drive cylinder into the hole with sufficient length of rod to permit driving with a 10-lb sledge hammer. Drive the sampler until the top of the cylinder is approximately 1 in. below the bottom surface of the auger hole. Break the sampler from the hole. Remove the cylinder from the drivehead, clean the cylinder, and trim sample ends with straightedge. Determine and record the wet weight of the sample and cylinder as soon as trimming has been completed. Remove the sample from the cylinder, and obtain a moisture-content specimen of approximately 100 g. Determine the wet weight of the moisture-content specimen, and then dry it to constant weight in an oven at 110° plus or minus 5° C. (221° to 239° F.) and determine the dry weight.

4. CALCULATIONS

4.1 The density is calculated as follows:

$$\text{Moisture content, \%} = \frac{\text{Weight of water, g}}{\text{Weight of dry soil, g}} \times 100$$

$$\text{Wet density, lb/cu ft} = \frac{\text{Wet weight of sample, g}}{\text{Volume of cylinder, cu cm}} \times 62.43$$

$$\text{Dry density, lb/cu ft} = \frac{\text{Wet density, lb/cu ft}}{1 + \text{moisture content}}$$

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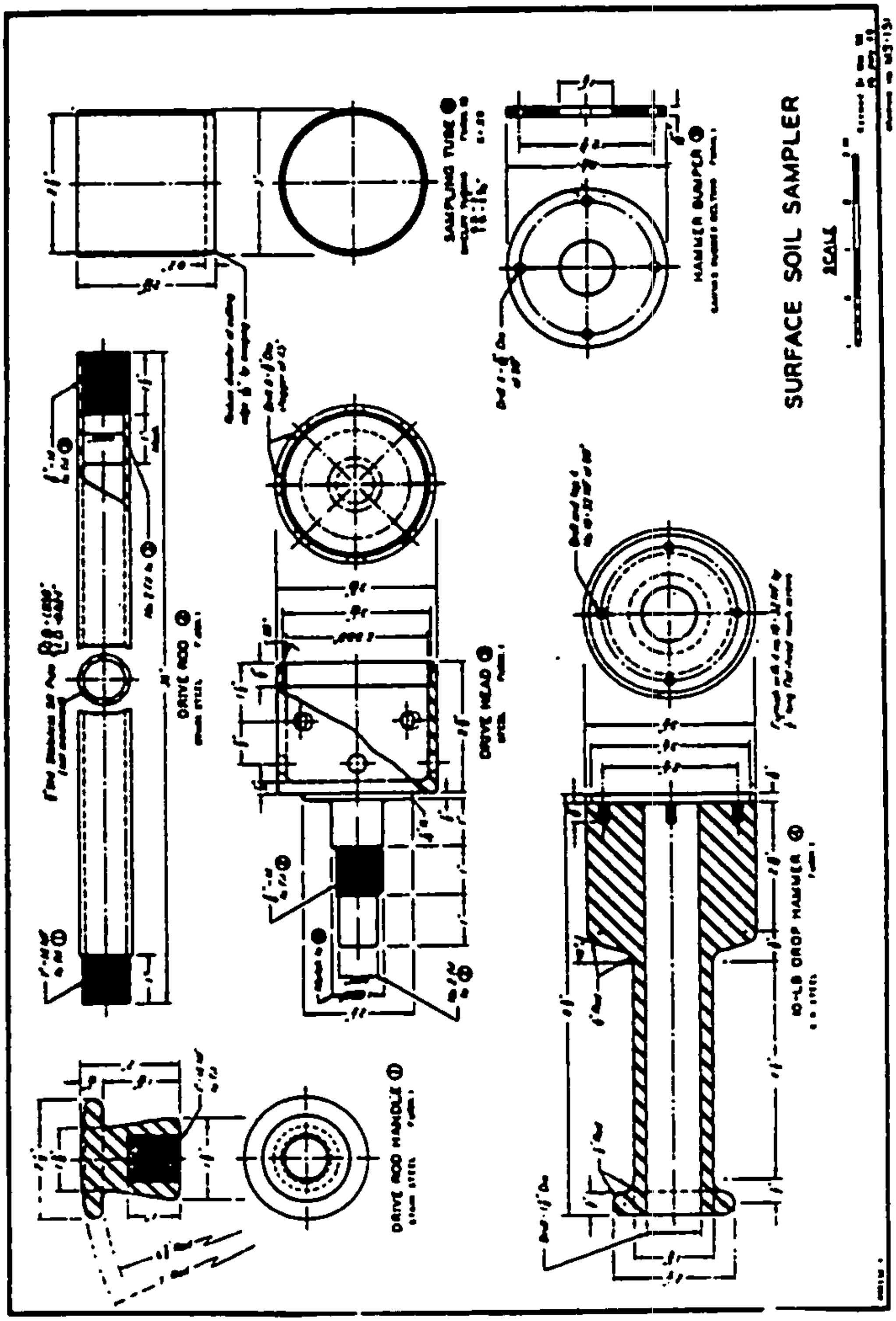

Figure 102-1. Drive Cylinder.

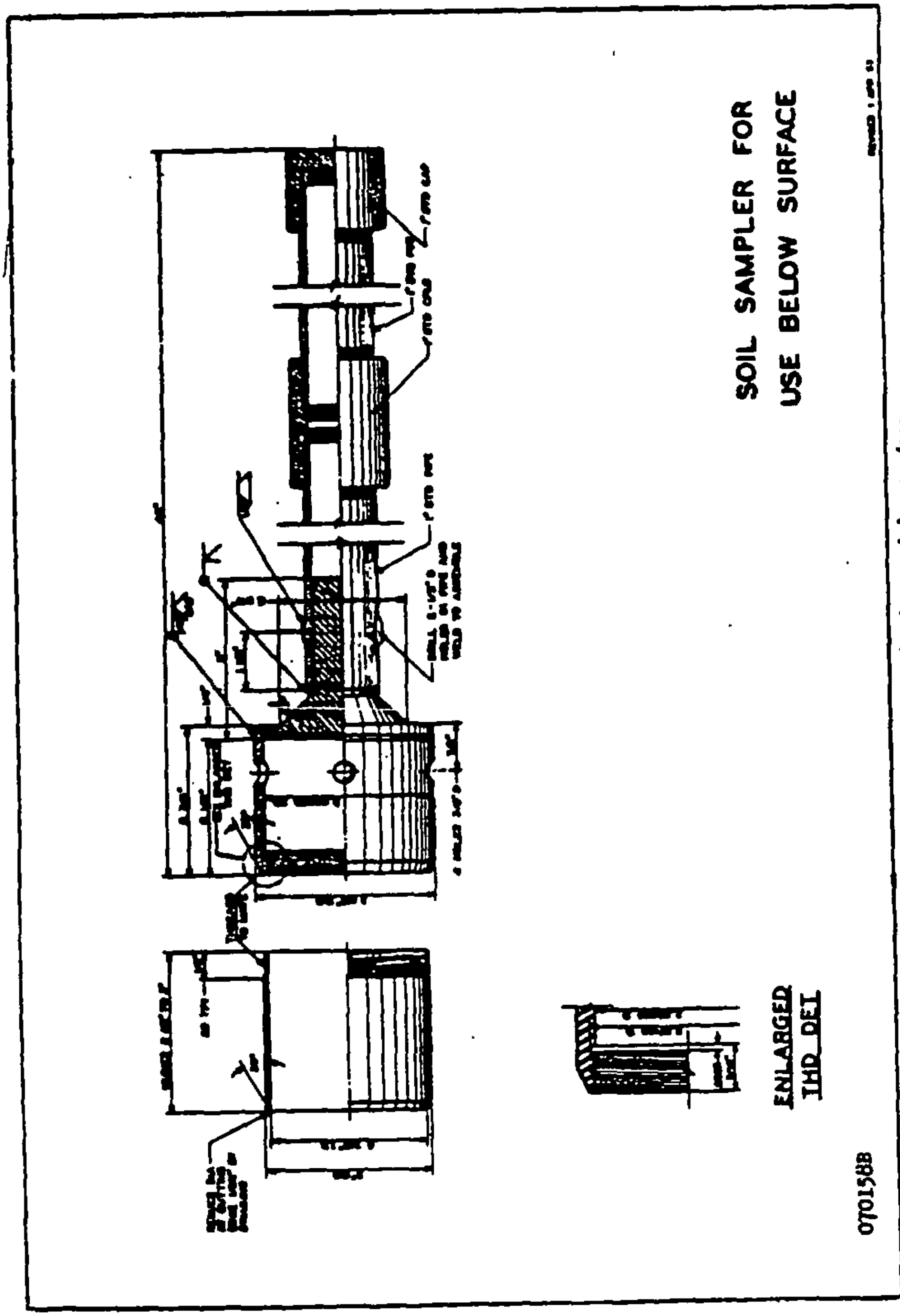

FIGURE 102-2. *Drive cylinder for use below surface.*

METHOD 103

LIQUID AND PLASTIC LIMITS OF SOILS

1. SCOPE

1.1 This method describes procedures for: (a) preparing samples for the liquid and plastic limits tests; and (b) determining the liquid and plastic limits and the plasticity index.

2. APPARATUS

2.1 Sampler. A riffle sampler, sample splitter, or quartering cloth.

2.2 Sieve. A No. 40 (420-micron) sieve conforming to ASTM E 11.

2.3 Containers or pans. Containers or pans in which to soak, wash, sieve, and dry the sample. Containers shall be smooth inside (preferably seamless), nonporous, and of a size to allow the sample to be covered with water and to permit vigorous agitation (i.e., shaking of the container) without loss of any part of the sample. Enameled or stainless steel pans 12 in. in diameter and 8 in. high are recommended. Containers, such as seamless metal boxes with tight friction lids, that will prevent loss of moisture during weighing and containers for the drying of the sieve fractions after separation are also required.

2.4 Evaporating dish. A porcelain evaporating dish about 4½ in. in diameter.

2.5 Spatula. A spatula or pill knife having a blade about 3 in. long and about ¾ in. wide.

2.6 Liquid limit device. A mechanical device consisting of a brass cup and carriage constructed according to the plan and dimension shown in figure 103-1.

2.7 Grooving tools. Grooving tools of the type and dimensions shown in figure 103-1.

2.8 Surface for rolling. A ground-glass plate about 8 in. square.

2.9 Balance. A balance or scale sensitive to 0.01 g.

2.10 If the alternate procedure described in 3.3.3(b) is used for removing the wash water, then the following additional items of equipment will be required:

(a) Buchner funnel.

(b) Supply of No. 3, 11 cm, J. H. Munktell filter paper.

(c) Tubulated flask (see fig. 103-2).

(d) Vacuum pump or aspirator for application of vacuum.

2.11 If the alternate procedure described in 3.3.3(c) is used for removing the wash water, the following additional items will be required:

(a) Two to four filter candles, as required, of the size and pore radius specified in paragraph 3.3.3(c).

(b) Metal pan sufficiently large to hold filter candles (see fig. 103-2).

(c) Small manifold and four pieces of rubber hose as pictured in figure 103-2.

(e) Vacuum pump or aspirator for application of vacuum.

3. SAMPLE

3.1 **Handling and storage.** Certain soil colloids, particularly those in organic soils, undergo irreversible changes on drying, and tests on samples of these soils that have been dried usually produce lower liquid limit values than tests on samples that have not been dried. Oven-drying will produce even lower liquid limit values than air-drying. Thus, although the effect of drying is negligible for many soils, it is significant in certain instances. These instances cannot be predicted and can be determined only by comparing the liquid limits of dried and undried samples. Since the test results should indicate the characteristics that will exist at the construction site, it follows that no drying should be permitted (where drying affects the results significantly) for soils that will not be subjected to drying either during or after construction. This restriction applies specifically to foundation soils and to other soils that will not be disturbed during construction, such as those to be used as embankment, subgrade, and fill materials, since these soils are rarely ever subjected to significant drying. On the other hand, subbase and base course materials will be subjected to at least partial drying during the construction process. In no instance will the construction operations produce drying that exceeds air-drying; therefore, no artificial drying should be employed prior to start of the test procedures. Based on these considerations, the following pretreatment procedures are specified.

3.1.1 For all soils except subbases and base courses, samples shall be maintained at natural moisture content and no drying shall be permitted before soaking (initial step in processing sample) unless check tests show that drying produces no significant change in the liquid limit.

3.1.2 For subbases and base courses, no specific measures will be taken to prevent loss of moisture between time of sampling and start of soaking; however, artificial drying is not permitted prior to soaking of the sample.

3.2 **Size.** The sample shall be of sufficient size to produce 150 to 200 g of material passing the No. 40 sieve. If grain-size analysis is to be made also, the sample shall be large enough to furnish sufficient material for both the grain-size analysis and the limits tests.

3.3 **Preparation.** If the soils contain particles which will be retained on a No. 40 sieve, the following procedure shall be followed to separate the plus and minus No. 40 sieve size material. For soils which are obviously finer than the No. 40 sieve, this procedure is unnecessary.

3.3.1 Place the soil sample in one or more pans as necessary, cover with water, and soak for 24 hours.

Note. A shorter soaking time may be used when tests show that it will not affect the results.

3.3.2 Place empty No. 40 sieve in a pan, and pour the water from the sample over it. Add water, if necessary, to bring the surface of the water to approximately ½ in. above the mesh of the sieve.

3.3.3 Place a portion of the soaked material, about ½ lb. in weight, in the water on the sieve and stir by hand while agitating the sieve up and down. If lumps are retained on the sieve that can be crumbled between the thumb and forefinger, break these lumps and wash the material through the sieve.

3.3.4 Lift the sieve above the soil and water in the pan, and wash the remaining material with a small amout of water until the wash water is completely clear.

3.3.5 Transfer the material retained on the No. 40 sieve to a clean pan, and place another increment of the soaked sample on the sieve.

3.3.6 Repeat this process until all of the soaked sample has been washed.

3.3.7 Dry the material retained on the No. 40 sieve in an oven, and dry-sieve on the No. 40 sieve. Add the material passing the No. 40 sieve in this sieving to that already washed through the No. 40 sieve.

3.3.8 Prepare the minus No. 40 fraction for testing by one of the following methods:

(a) Set the pan containing the wash water and minus No. 40 fraction of the sample aside, and do not disturb until all the soil particles have settled to the bottom and the water abvoe the soil is clear. Decant, siphon, or wick off as much of the clear water as possible. For soils containing dissolved salts and those in which the wash water will not become clear in a reasonable time, the water must be removed by evaporation, using an oven or heat lamp, until the soil reaches a moisture content that appears likely to be just above the liquid limit. During the evaporation process, stir the soil frequently to prevent over-heating. Chemicals may not be added to hasten the settlement of fines.

(b) Use a No. 3, 11 cm. J. H. Munktell, No. 604 or 597 S&S, or No. 1 or 3 Whatman filter paper in a Buchner funnel mounted in a tubulated flask, and filter the minus No. 40 fraction of soil from the wash water by applying a high vacuum to the flask.

(c) A rapid reduction of the moisture content of the sample, after removal of excess water or by wicking or siphoning, can be effected by spreading the slurry to a depth of about 1/4 in. in a dry plaster-of-Paris mold. The soil loses moisture through absorption by the mold until it reaches the desired consistency. The sizes and shapes of the molds for processing samples vary widely, the optimum size depending primarily upon the kind of material and size of sample to be processed. Molds are easily cast in the laboratory using laboratory pans for both internal and external forms. Pans should be lightly greased with petroleum jelly to permit their easy removal after molding. The molds may be cleaned after use by wiping them with a moist sponge or rag. They should then be air-dried for several days before reuse. Placing the moist mold in an oven to hasten drying often causes it to fall apart. Prime the filter candles with water and lay them in the bottom of a rectangular metal container. Pour the washed sample, usually contained in a gallon jar, onto the filter candles as vacuum is applied to them through the manifold and hose. Before the unwashed samples are poured, and in order for the soil to assist in the filtering process, spoon the sand sizes that have quickly settled in the bottom the jar onto the top of the filter candles and then pour the remaining soil suspended in the excess water into the metal container. If the removed water should become clouded, the pore radius is too large and finer candles should be substituted.

After the excess water is removed, place the soil in a sealed container to eliminate any drying action until the test can be accomplished. To remove the soil from the filter candles, use a rubber scraper. Tests have indicated that between 0.5 percent and 1.0 percent of the total sample is lodged within the pores of the filter candles. This is insignificant as far as affecting the test results is concerned, and the pores can be cleaned readily by applying a back pressure of water to the candles and flushing after each use.

4. TEST PROCEDURE

4.1 Liquid limit test.

4.1.1 *Definition.* The liquid limit of a soil is the moisture content expressed as a percentage of the weight of the oven-dry soil, at which two halves of a soil cake will flow together for a distance of ½ in. along the bottom of the groove separating the two halves in a liquid-limit test cup, when the cup is dropped a distance of 1 cm (0.3937 in.) 25 times at the rate of 2 blows per second.

4.1.2 *Sample.* Take about 100 g from the thoroughly mixed portion of the material passing the No. 40 sieve (prepared in accordance with the method described in 4.1.3.).

4.1.3 *Adjustment of mechanical device.*

4.1.3.1 Inspect the liquid limit device to determine that it is in good working order, that the pin connecting the cup is not worn sufficiently to permit side play, that the screws connecting the cup to the hanger arm are tight, and that a groove has not been worn in the cup from long usage. Inspect the grooving tool to determine that the critical dimensions are as shown in figure 103-1.

4.1.3.2 By means of the gage on the handle of the grooving tool and the adjustment plate A, figure 103-1, adjust the height to which the cup B is lifted so that the point on the cup that comes in contact with the base is exactly 1 cm (0.394 in.) above the base. Secure the adjustment plate by tightening the screws, C. With the gage still in place, check the adjustment by revolving the crank D at a rate of 120 revolutions a minute. If the adjustment is correct, a slight click will be heard each time the crank is turned. If the cup is raised off the gage or no sound is heard, make further adjustments.

4.1.4 Place a portion of the thoroughly mixed soil sample in the cup over the spot where the cup rests on the base, and squeeze and spread it into the position shown in figure 103-3 with as few strokes of the spatula as possible, taking care to prevent the entrapment of air bubbles within the mass. With the spatula, level the soil and at the same time trim it to a thickness of about 8 mm at the point of maximum thickness. Return excess soil to the evaporating dish. Divide the soil in the cup with a firm stroke of the grooving tool along the diameter through the centerline of the cam follower so that a clean, sharp groove will be formed (see fig. 103-3). Sandy or flaky soils may require several strokes of the grooving tool to avoid tearing the sides of the groove. Increase the depth of the groove with each stroke, and with the last stroke scrape the bottom of the cup clean. Make the groove with as few strokes as possible.

In extremely sandy or organic soils where it is not possible to draw the grooving tool through the soil without tearing the sides of the groove, use a spatula for the initial grooving and use the grooving tool for the final shaping of the groove. Grooving tools shall be checked frequently for accuracy of dimensions because of rapid point wear.

4.1.5 Lift and drop the cup, by turning the crank at the rate of two revolutions per second, until the two halves of the soil cake come in contact at the bottom of the groove for a length of ½ in. (fig. 103-4). Record the number of blows required.

4.1.6 Remove a slice of soil approximately the width of the spatula, extending from edge to edge of the soil cake at right angles to the groove and including that portion of the groove in which the soil flowed together, and place it in a tared container. Weigh and record the weight. Oven-dry the soil in the container to constant weight at 110° plus or minus 5° C. (221° to 239° F.), and reweigh as soon as it has cooled but before hygroscopic moisture can be absorbed. Record this weight. Record the loss in weight due to drying as the weight of water.

4.1.7 Transfer the soil remaining in the cup to the evaporating dish. Wash and dry the cup and grooving tool in preparation for the next trial.

4.1.8 Repeat the foregoing operations on at least two additional samples with lower moisture contents. The objectives of this procedure is to obtain samples of such consistency that the number of blows required to close the groove will bracket 25; the number of blows should be less than 35 and more than 15. In reducing the moisture content, the soil shall not be dried below its plastic limit except when the liquid limit is lower than the plastic limit. Under no circumstances shall dried soil be added to the seasoned soil being tested.

4.1.9 *Calculation.* Calculate the moisture content of the soil, expressed as a percentage of the weight of the oven-dried soil, as follows:

$$\text{Moisture content, \%} = \frac{\text{weight of water}}{\text{weight of oven-dried soil}} \times 100$$

Figure 103-5 is a convenient form for recording data.

4.1.10 *Preparation of flow curve.* Plot a "flow curve" representing the relation between moisture contents and corresponding numbers of blows of the cup on a semilog plot, with the moisture contents as ordinates on the arithmetical scale and the numbers of blows as abscissas on the logarithmic scale. See figure 103-5 for data and graph sheet. The flow curve is a straight line drawn as nearly as possible through the three or more plotted points.

4.1.11 *Liquid limit.* Take the moisture content corresponding to the intersection of the flow curve with the 25-blow abscissa as the liquid limit of the soil. Report this value to the nearest whole number (see fig. 103-5)

4.2 Plastic limit test.

4.2.1 *Definition.* The plastic limit of a soil is the water content, expressed as a percentage of the weight of oven-dry soil, at which the soil begins to crumble when rolled into a thread ⅛ in. in diameter.

4.2.2 *Sample.* Take about 50 g from the thoroughly mixed portion of the material passing the No. 40 sieve (prepared in accordance with the method described in 3.3). The sample may be taken from that used for the liquid limit test provided uniform drying has occurred which has not produced lumps. Air-dry until the soil mass becomes plastic enough to be easily shaped into a ball. Take a portion of this ball weighing about 8 g for the test.

4.2.3 Squeeze and form the 8-g specimen into an ellipsoidal-shaped mass. Roll this mass between the fingers and the ground-glass plate with just enough pressure to form a thread uniform in diameter throughout its length (fig. 103-6). The rate of rolling shall be between 80 and 90 strokes per minute, counting a stroke as one complete motion of the hand forward and back to the starting position.

4.2.4 When the diameter of the thread becomes ⅛ in., break the thread into six or eight pieces. Squeeze the pieces together between the thumbs and fingers of both hands into a uniform mass roughly ellipsoidal in shape, and reroll. Continue this action (i.e., in turn, rolling to a thread ⅛ in. in diameter, breaking, gathering together, kneading, and rerolling) until the thread crumbles under the pressure required for rolling and the soil can no longer be rolled into a thread (fig. 103-7). The crumbling may occur when the thread has a diameter greater than ⅛ in. This shall be considered a satisfactory end point provided the soil has been previously rolled into a thread ⅛ in. in diameter. At no time shall the operator attempt to produce failure at exactly ⅛-in. diameter by allowing the thread to reach ⅛ in., then reducing the rate of rolling or the hand pressure, or both, and continuing the rolling without further deformation until the thread falls apart. It is permissible, however, to reduce the total amount of deformation for feebly plastic soils by making the initial diameter of the ellipsoidal-shaped mass nearer to the required ⅛-in. final diameter

Note. The crumbling will manifest itself differently with various types of soils. Some soils fall apart in numerous small aggregations of particles. Others may form an outside tubular layer that starts splitting at both ends; the splitting progresses toward the middle, and finally the thread falls apart in many small platy particles. Heavy clay soils require much pressure to deform the thread, particularly as they approach the plastic limit, and the thread finally breaks into a series of barrel-shaped segments each about ¼ to ⅜ in. in length.

4.2.5 Gather the portions of the crumbled soil together, and place them in a tared container. Weigh the container and soil, and record the weight. Oven-dry the soil in the container to constant weight at 110° plus or minus 5° C. (221° to 239° F.) and weigh. Record this weight. Record the loss in weight due to drying as the weight of water.

4.2.6 *Plastic limit.* Calculate the plastic limit, expressed as the moisture content in percentage of the weight of the oven-dried soil, as follows:

$$\text{Plastic limit, \%} = \frac{\text{weight of water}}{\text{weight of oven-dried soil}} \times 100$$

Report the plastic limit to the nearest whole number. See figure 103-5 for data sheet.

4.2.7 *Plasticity index.*

4.2.7.1 Calculate the plasticity index of a soil as the difference between its liquid limit and its plastic limit, as follows:

Plasticity index = liquid limit − plastic limit.

See figure 103-5 for data sheet.

4.2.7.2 Report the difference calculated as indicated in 4.2.7.1 as the plasticity index, except under the following conditions:

(a) When the liquid limit or plastic limit cannot be determined, report the plasticity index as NP (nonplastic).

(b) When the soil is extremely sandy, the plastic limit test shall be made before the liquid limit. If the plastic limit cannot be determined, report the soil as NP.

(c) When the plastic limit is equal to, or greater than, the liquid limit, report the plasticity index as NP.

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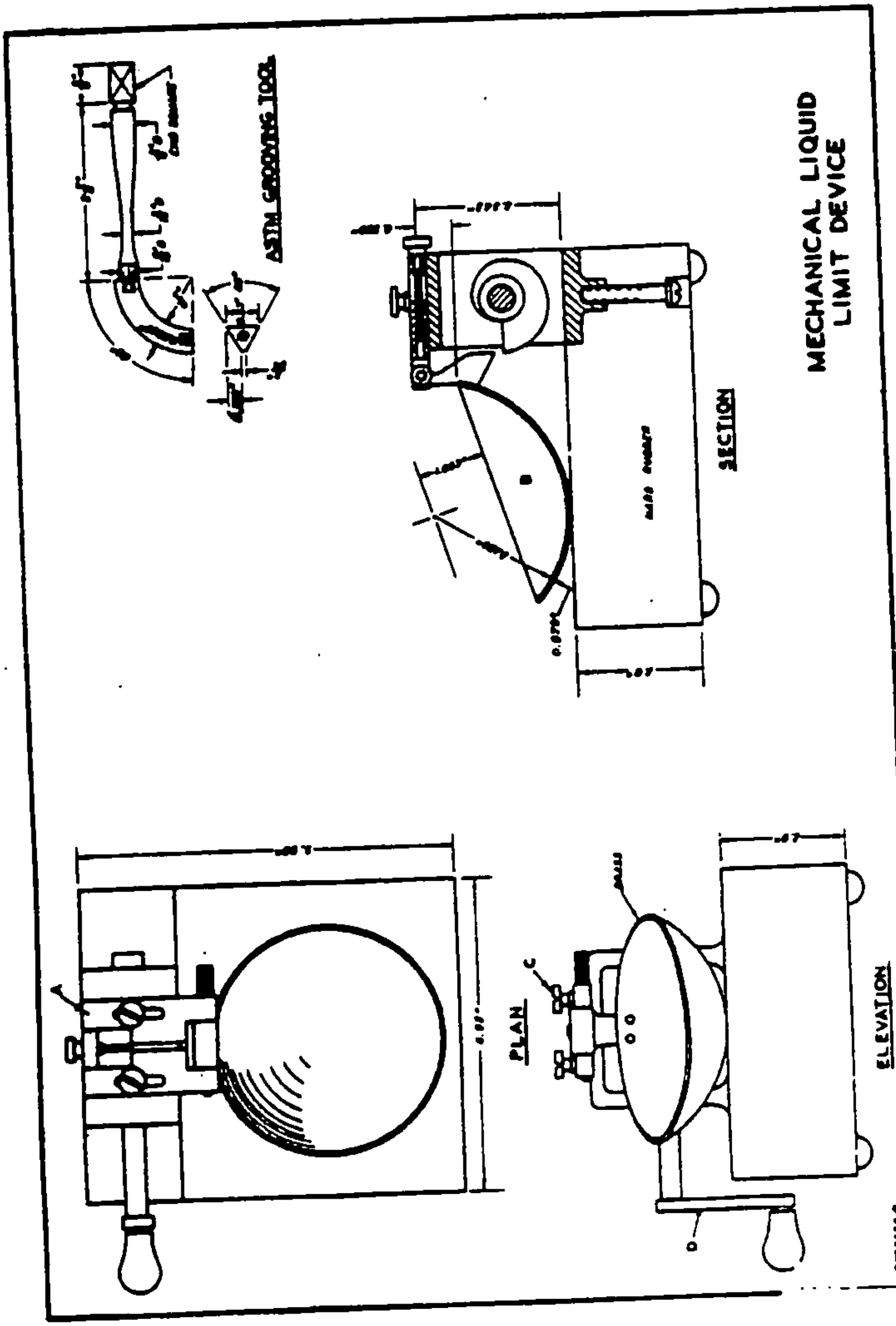

FIGURE 103-1. *Mechanical liquid limit device.*

FIGURE 103-X. Filler-candle test after priming.

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FIGURE 103-3. a. *Grooving liquid limit specimen.*

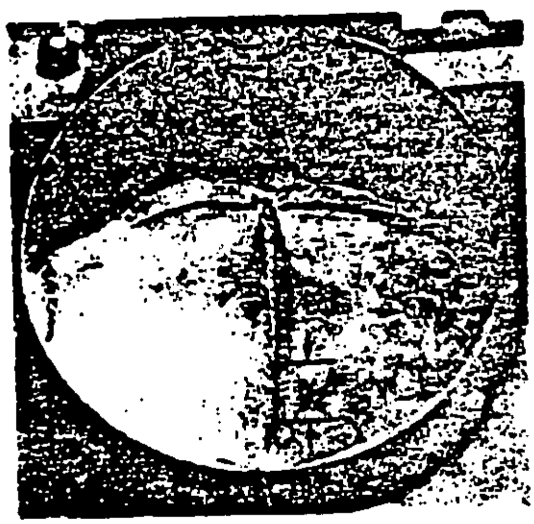


FIGURE 103-4. b. *Closed liquid limit groove.*

LIQUID AND PLASTIC LIMIT TESTS

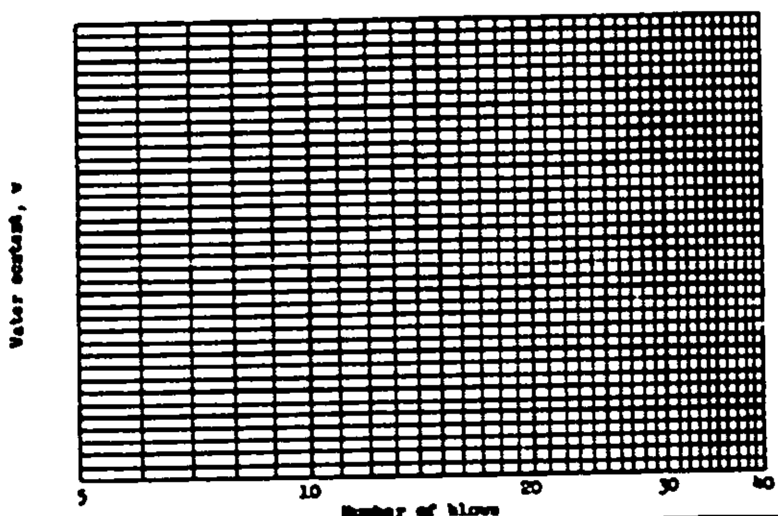
Date ____________

Project ____

Boring No. ______________________ Sample No. ____________

LIQUID LIMIT

			1	2	3	4	5	6
Run No.								
Tare No.								
Weight in grams	Tare plus wet soil							
	Tare plus dry soil							
	Water	W_w						
	Tare							
	Dry soil	W_s						
Water content		w						
Number of blows								



LL ____________

PL ____________

PI ____________

Classification:

____

____

PLASTIC LIMIT

			1	2	3	4	5	Natural Water Content
Run No.								
Tare No.								
Weight in grams	Tare plus wet soil							
	Tare plus dry soil							
	Water	W_w						
	Tare							
	Dry soil	W_s						
Water content		w						
Plastic limit								

Remarks ____

____

Technician ____________ Computed by ____________ Checked by ____________

FIGURE 103-5. *Data sheet.*

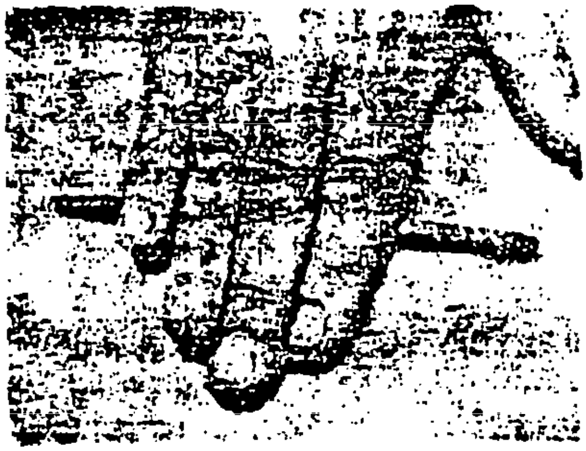


FIGURE 103-6. a. *Plastic limit determination.*

FIGURE 103-7. b. *Crumbling of soil threads at plastic limit.*

METHOD 104

MODULUS OF SOIL REACTION

1. SCOPE

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1.1 This method of testing is used for determining the modulus of reaction of soils by means of the plate-bearing test and for determining the corrections to be applied to the field test values by means of laboratory tests. The modulus of soil reaction is required in rigid pavement design and evaluation.

2. APPARATUS

2.1 Field test apparatus. The required field test apparatus, part of which is shown in figure 104-1, is as follows.

2.1.1 *Load reaction* equipment consisting of a truck, trailer, anchored frame, or similar device having a dead load of at least 25,000 lb.

2.1.2 *Bearing plates* consisting of a 30-in.-, 24-in.-, and 18-in.- diameter steel plate, each plate 1 in. thick. Aluminum alloy No. 24ST plates 1½ in. thick may be used in lieu of steel plates.

2.1.3 *Hydraulic jack* capable of applying loads of at least 25,000 lb.

2.1.4 *A ball joint* to be inserted between the jack and load reaction equipment or between the jack and bearing plates to prevent eccentricity of loading.

2.1.5 *A load-measuring device* consisting of either a hydraulic gage on the jack, or a steel proving ring. Either is satisfactory for measuring applied load, but must be accurately calibrated.

2.1.6 *Three dial micrometers*, reading to 1/10,000 in., *dial stems, and support*.

2.1.7 *Clean sand or plaster-of-Paris*.

2.1.8 *Cribbing* of short pieces of hardwood or steel H- or I-beams.

2.1.9 *Stopwatch*.

2.1.10 *Containers* for undisturbed soil samples.

2.2 Laboratory test apparatus.

2.2.1 *Consolidometer apparatus*.

2.2.2 *Necessary equipment* for cutting an undisturbed specimen of the soil into a consolidometer test ring.

2.2.3 *Scales, oven, and miscellaneous tools* for making moisture-content determinations.

3. FIELD TEST PROCEDURE

3.1 The setup of the test apparatus and the first load increment are the same regardless of soil type or strength. Following the first two load increments, the test procedure is different for low-strength soils and high-strength soils. The test setup and loading procedure are as follows.

3.1.1 *Preparation of test area.* Strip an area of the soil to be tested to the proposed elevation of the subgrade surface. The stripped area should be at least twice the diameter of the plates to eliminate surcharge composed of fill material, construct a test embankment at least 30 in. in height using the proposed fill material compacted to the moisture content and density that will be required during construction. Clear the area to be tested of any loose materials and make it level. Extreme care should be taken not to disturb the soil in the test area, especially in granular material. Apply and level a thin layer of clean sand or plaster-of-Paris, not to exceed 1 in. in thickness, on the test area.

3.1.2 *Test apparatus setup.* Seat the 30-in.-diameter bearing plate on the sand or plaster-of-Paris. Turning or working the plate back and forth will help to provide uniform seating of the plate. Center the 24-in.- and 18-in.-diameter plates on the 30-in.-diameter plate, and center the hydraulic jack on the 18-in.-diameter plate. If cribbing is needed, crib between the top plate and the jack. If a steel proving ring is being used to measure load, it should be placed on top of the jack and the ball joint used between the proving ring and load reaction device. The load reaction device must be long enough so that its supports will be at least 8 ft from the bearing plate. A steel beam between two loaded trucks provides a good load reaction device. Three dial micrometers shall be used to measure deformation of the soil under load. Place these micrometers so that the dial stems rest on the bottom 30-in.-diameter plate not more than ¼ in. from the outer edge, spaced 120 degrees apart. Fasten the micrometers to a frame whose supports are at least 4 ft from the edge of the 30-in.-diameter plate. A typical apparatus setup is shown in figure 104-1.

3.1.3 *Loading procedure.* Seat the loading system and bearing plate by applying a load of 707 lb (1 psi) when the design thickness of the pavement will be less than 15 in., or a load of 1414 lb (2 psi) when the design thickness of the pavement is 15 in. or more. Allow the seating load to remain in place until practically complete deformation has taken place. Then take a reading on all three dial micrometers, which will be used as the "zero" reading. The seating load is also considered to be the "zero" load. Cyclic loading under the seating load may be used to assure good seating of the apparatus and bearing plate. Then, without releasing the seating load, apply two load increments of 3535 lb (5 psi) each with each load increment being held until the rate of deformation is less than 0.0001 in. per minute. Read all three dial micrometers at the end of each load increment. Following the completion of the 7,070-lb. (10 psi) load increment, determine the average deflection by averaging the total movement between the "zero" and 10-psi increment for each dial. Then compute a value of k'_u (uncorrected modules of soil reaction) using the following formula:

$$k'_u = \frac{10 \text{ psi}}{\text{average deflection}}$$

If the value of k'_u is less than 200, the test is considered complete and the load may be released. Should the value of k'_u be 200 or greater, apply additional load increments of 3,535 lb (5 psi) until a total load of 21,210 lb (30 psi) is reached, allowing each load increment to remain until the rate of deformation is less than 0.0001 in. per minute. Read all three dial micrometers at the completion of each load increment.

3.1.4 *Soil sampling.* An undisturbed sample of the foundation material must be obtained for laboratory testing to determine the saturation correction to apply to the field test value. The undisturbed sample must be large enough to obtain two consolidometer specimens side by side (i.e. at the same ele-

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vation). Take the sample in a container suitable for sealing to preserve the mosture content until the laboratory correction tests can be performed. When the plate-bearing test is performed directly on cohesive subgrade material, obtain the undisturbed specimen from the foundation at the same elevation at which the test is performed, but alongside rather than under the plates. When the test is performed on a granular base course material which is underlaid by a cohesive material, and when the base course is less than 75 in. in thickness, take the undisturbed sample from the cohesive material at the bottom of the base course.

3.2 Load-deformation curve. When the k'_u value, as computed in 3.1.3, is less than 200, load-deformation curves need not be prepared. However, when the k'_u value is 200 or greater, it is necessary to plot a load-deformation curve and correct the curve for such things as poor seating of the plates, nonlinear load-deformation relations, or shear failure. The unit load (pounds per square inch) on the plate is plotted versus the average deflection for each load increment. The average deflection is the average of the three dial readings between the "zero" and the end of each load increment. If the load-deformation relation plots as a straight line passing through the origin, no correction is necessary. However, if the load-deformation relation results in a curve or a straight line not passing through the origin, the curve is corrected as shown by figure 104-2. Generally, the load-deformation curve will approximate a straight line between the unit loads of 10 and 80 psi. The correction consists of drawing a straight line, parallel to the straight-line portion of the plotted curve, through the origin. When correcting the load-deformation curve, good engineering judgment will be required. If the curve is nonlinear throughout its length, the straight-line correction will be based on the average slope of the curve through at least three points in the region of the curve having the least curvature.

3.3 An uncorrected modulus of soil reaction, k'_u, is computed from the field test data using the formula:

$$k'_u = \frac{10 \text{ psi}}{\text{average deflection}}$$

When a load-deformation curve is unnecessary, as outlined in 3.2, the average deflection is the average of the total deflection recorded on each of the three dial micrometers between the "zero" and the completion of the load increment. If a load-deformation curve is required, the average deflection is read from the corrected curve at a load of 10 psi. The value of k'_u computed from the above formula must then be corrected for bending of the bearing plates and and saturation of the soil as outlined in the following paragraphs.

3.3.1 *Correction for bending of the plate.* There is a certain amount of bending in the bearing plate, even when a nest of plates are used. The bending results in a greater deflection at the center of the plate than at the rim where the deflections are measured. Since the modulus of soil reaction is actually a measurement of volume displacement under load, the lower deflections measured at the rim result in a k'_u value higher than actually exists. The amount of plate bending is related only to the strength of the soil being tested. Hence, for any one k'_u value, the correction to be made is always the same. This correction has been determined by test and is shown by the curve in figure 104-3. The correction of k'_u is made by entering the plot in figure 104-3 with the computed value of k'_u on the ordinate and projecting horizontally to the intersection of the plotted curve. The corrected value for the modulus of soil reaction, k'_u, is then determined by projecting vertically to the abscissa of the plot and reading the value.

3.3.2 *Correction for saturation of the soil.* The design of pavement is generally based upon the modulus of soil reaction when the soil is saturated. It is not feasible to saturate the soil in the field prior to the field test and seldom will the soil be in a saturated condition in its natural state. Therefore, the field test value must be corrected to reflect the value that will obtain when the soil becomes saturated. Cohesionless soils are insensitive to saturation, and when the field test is performed on this type soil, the correction for saturation is not necessary. The most applicable method for correcting for saturation is through an adaption of the consolidation test. The correction test will be made on undisturbed specimens of the soil from the location of the field test. For the case where a field test is performed on the surface of a cohesionless base course material, but which is underlain by a cohesive soil, the saturation correction will be determined by tests on the underlying cohesive material.

The saturation correction factor is the ratio of the deformation of the consolidation specimen at the natural moisture content to the deformation in a saturated specimen under a 10-psi loading. Two specimens of the undisturbed material are placed in a consolidometer. One specimen will be tested at the *in-situ* moisture content, and the other specimen will be saturated after the seating load has been applied. Each specimen is then subjected to the same seating load (1 or 2 psi) that was used for the field test (see 3.1.3). The seating load is allowed to remain on the *in-situ* moisture-content specimen until all deformation occurs, at which time a "zero" reading is taken on the vertical deformation deal. Without releasing the seating load, an additional 10-psi load is applied to the specimen and allowed to remain until all deformation has occurred. A final reading is then taken on the vertical deformation dial.

The other specimen is allowed to soak in the consolidometer under the seating load (1 or 2 psi). After the specimen is saturated, a "zero" dial reading is obtained; then without releasing the seating load an additional 10-psi load is applied. This load is allowed to remain on the specimen until all vertical deformation has occurred, after which a final reading on the dial is obtained. For soils of certain types, the specimen may swell under the seating load as it becomes saturated. Swelling of the material will result in extrusion of material above the top of the consolidometer ring, so that when the 10-psi load is applied, the material may squeeze out over the ring rather than consolidate, which will lead to erroneous results. To prevent this, when dealing with a swelling-type soil or one that is suspected of being a swelling-type soil, the consolidometer ring will not be completely filled with soil. This can be accomplished by trimming the top of the specimen a sufficient amount, generally 1/16 in., to allow for the swelling. When the specimen for saturation is trimmed to allow for swelling, the specimen to be tested at the *in-situ* moisture content will also be trimmed an equal amount so that the heights of the specimens will be equal at the beginning of the test.

The correction for saturation will be applied in proportion to the deformation of the two specimens under a unit load of 10 psi as follows:

$$k = k_u \times \left[\frac{d}{d_s} + \frac{b}{75} \left(1 - \frac{d}{d_s} \right) \right]$$

where

k = corrected modulus of soil reaction, lb per cu in.

k_u = modulus of soil reaction uncorrected for saturation, lb per cu in.

d = deformation of a consolidometer specimen at *in-situ* moisture content under a unit load of 10 psi.

d_s = deformation of a saturated consolidometer specimen under a unit load of 10 psi.

b = thickness of base course material, in.

In no case will a value of d/d_s greater than 1.0 be used in the above formula. This formula is applicable for the computation of the corrected k value, whether there is a granular base course or not. However, if the base course is 75 in. or more in thickness, a saturation correction for the cohesive subgrade material will not be made.

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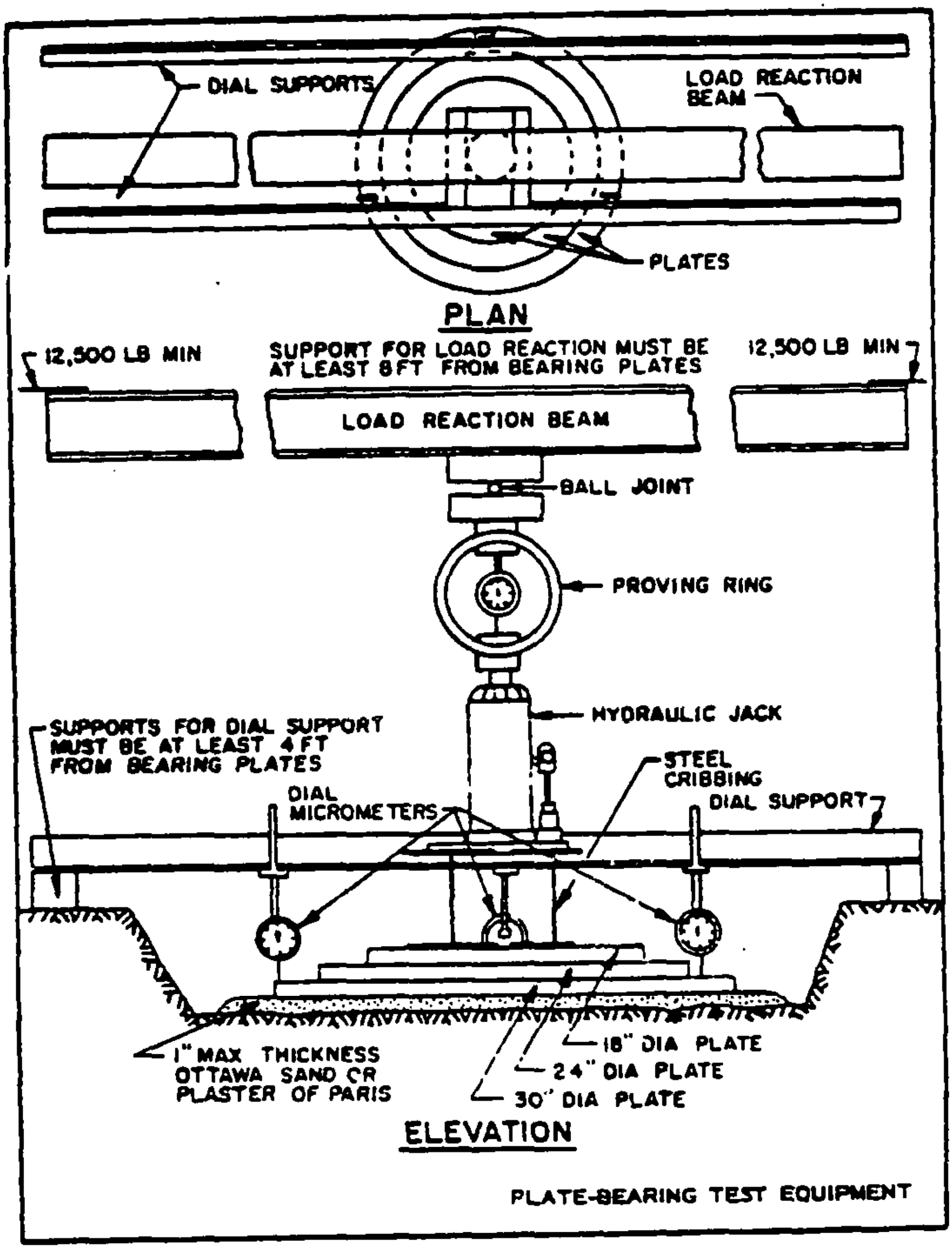

FIGURE 104-1. *Plate-bearing test equipment.*

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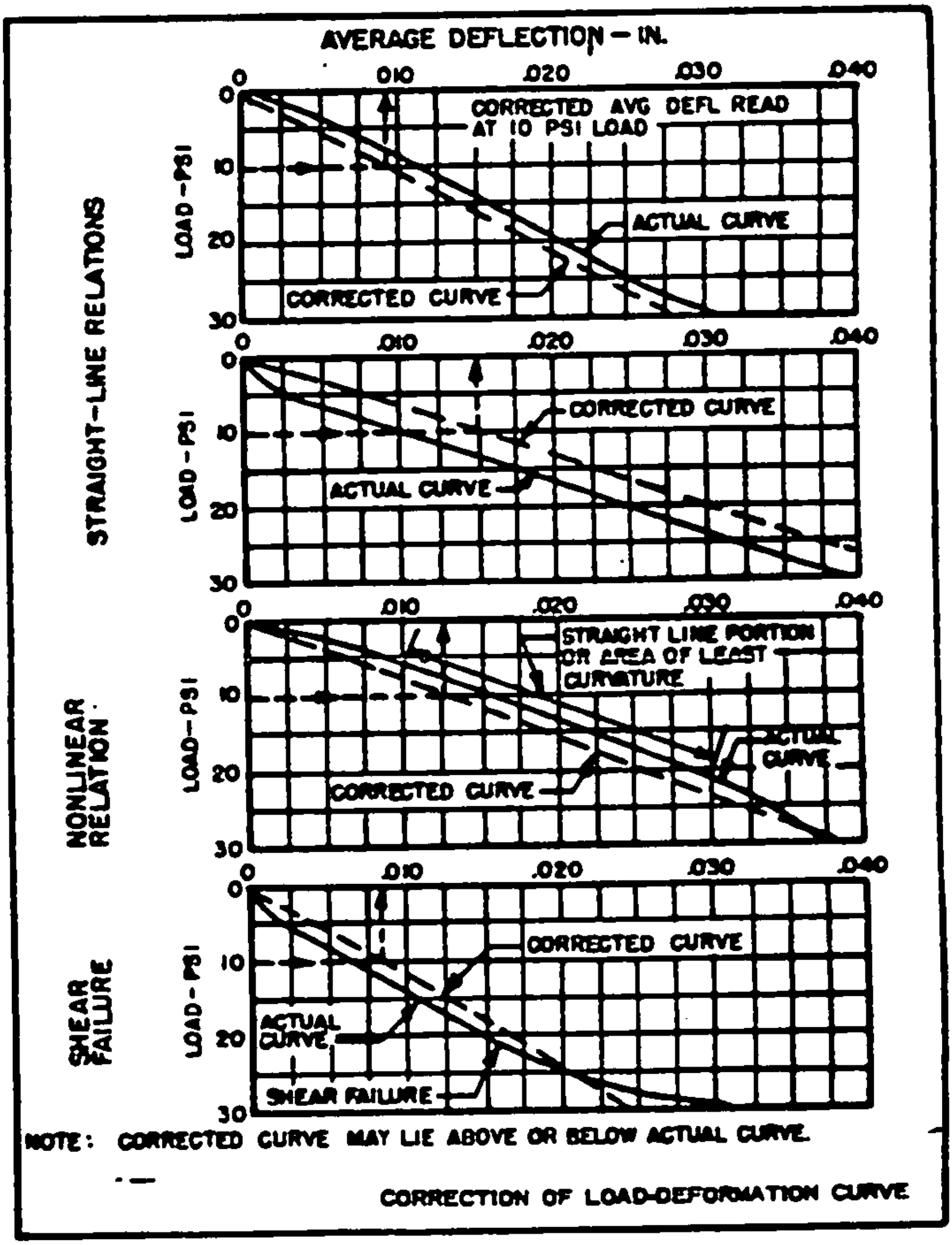

FIGURE 104-2. *Correction of load-deformation curve.*

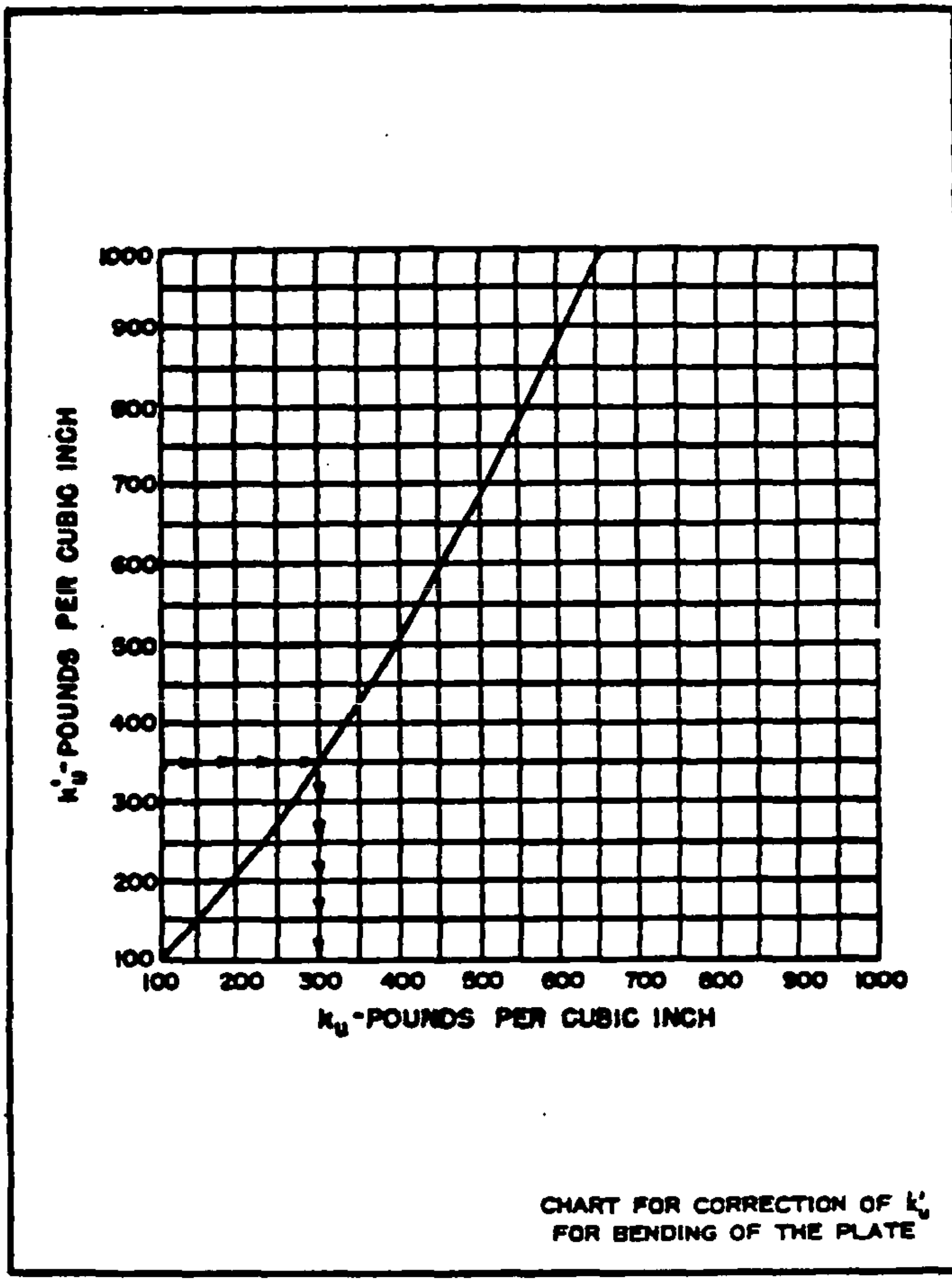

FIGURE 104-3. *Correction of k'_u for bending of the plate.*

METHOD 105

MOISTURE CONTENT OF SOIL OR AGGREGATE

1. SCOPE

1.1 This method of testing is used for determining the moisture content of soils and aggregates proposed for use in flexible pavement construction.

1.2 Moisture content is defined as the ratio, expressed as a percentage, of the weight of water in a given soil mass to the weight of solid particles.

2. APPARATUS

2.1 *Oven,* preferably of the forced-draft type, automatically controlled to maintain a uniform temperature of 110° plus or minus 5° C. (221° to 239° F.) throughout the oven.

2.2 *Balances,* sensitive to 0.01 g for samples weighing less than 50 g; 0.1 g for samples weighing 50 to 500 g; 1.0 g for samples weighing over 500 g.

2.3 Specimen containers. Seamless metal containers with lids. The containers should be of a metal resistant to corrosion and not subject to change in weight on repeated heating and cooling. The containers should be as small as practicable in relation to the amount of material to be used in the determination. For routine water-content determinations in which specimens weighing between 100 to 200 g are used, a 2-in.-high by 3½-in.-diameter container is considered adequate.

3. SAMPLES

3.1 The amount of material used in the moisture-content determination will generally depend on the maximum size of particles, the amount of material available, and the requirement that the sample be representative of the material for which the determination is made. When the water is not uniformly distributed throughout the sample, larger specimens will be needed than would otherwise be required. For routine moisture-content determinations on material passing a No. 4 sieve, specimens weighing between 100 and 200 g are considered adequate. A minimum sample weight of 500 g is recommended for material having a maximum particle size in the range of the No. 4 to ¾-in. sieves, and a minimum sample weight of 1,000 g is recommended for material having a maximum particle size in the range of the ¾-in to 1½-in. sieves.

4. TEST PROCEDURE

4.1 Record all identifying information for the sample, such as project, boring number, sample number, or other pertinent data on a data sheet. (Fig. 105-1 is a typical data sheet.)

4.2 Record the number and tare weight of the specimen container.

4.3 Place the specimen in the container, set the lid securely in position, and immediately determine the weight of the container and wet soil by weighing on an appropriate balance.

4.4 Before the specimen is placed in the oven, remove the lid. Place the lid under the container in the oven. Place the sample and container in the oven heated to 110° plus or minus 5° C.[1] Leave the specimen in the oven

[1] Laboratory oven drying at 110° C. does not result in reliable water-content values for soils containing gypsum or significant amounts of organic material. Reliable water-content values for these soils can be obtained by drying in an oven at 70° to 75° C., or by vacuum desiccation.

until it has dried to a constant weight. The time required for drying will vary depending on the type of soil, size of sample, oven type and capacity, and other factors. The influence of these factors generally can be established by good judgment and experience with the soils being tested and the equipment available in the laboratory. When in doubt, reweigh oven-dried samples at periodic intervals to establish the minimum drying time required to attain a constant weight. For routine moisture-content determinations, samples consisting of clean sands and gravels should be oven-dried for a minimum of 4 hours. For most other soils, a minimum drying time of 16 hours is considered adequate. Dry soil may absorb moisture from wet samples; therefore, any dried samples must be removed before wet samples are placed in the oven.

4.5 After the sample has dried to constant weight, remove it from the oven and let it cool until it can be handled comfortably with bare hands. If the sample cannot be weighed immediately after cooling, it should be placed in a desiccator. If a sample is left in the open air for a considerable length of time, it will absorb moisture.

4.6 After the sample has cooled, determine its dry weight and record it on the data sheet (fig. 105-1).

5. COMPUTATIONS.

5.1 The following quantities are obtained by direct weighing:

(a) Weight of tare plus wet soil, g.

(b) Weight of tare plus dry soil, g.

5.2 The water content in percent is equal to:

$$\frac{(\text{weight of tare plus wet soil}) - (\text{weight of tare plus dry soil})}{(\text{weight of tare plus dry soil}) - (\text{tare})} \times 100$$

or

$$w\% = \frac{W_w}{W_s} \times 100$$

where

$w\%$ = water content in percent.
W_w = weight of water in grams.
W_s = weight of dry soil in grams.

MOISTURE CONTENT

SHEET ____ OF ____

DATE ____________

PROJECT ______________________ JOB ______________________ TEST ____________

______________________ SAMPLE ______________________

SAMPLE NO.								
TARE NO.								
WEIGHT IN g	TARE + WET SOIL							
	TARE + DRY SOIL							
	WATER	W_w						
	TARE							
	DRY SOIL	W_s						
WATER CONTENT		w	%	%	%	%	%	%

SAMPLE NO.								
TARE NO.								
WEIGHT IN g	TARE + WET SOIL							
	TARE + DRY SOIL							
	WATER	W_w						
	TARE							
	DRY SOIL	W_s						
WATER CONTENT		w	%	%	%	%	%	%

SAMPLE NO.								
TARE NO.								
WEIGHT IN g	TARE + WET SOIL							
	TARE + DRY SOIL							
	WATER	W_w						
	TARE							
	DRY SOIL	W_s						
WATER CONTENT		w	%	%	%	%	%	%

$$w\% = \frac{W_w}{W_s} \times 100$$

REMARKS ____

____

ANALYZED BY ______________ COMPUTED BY ______________ CHECKED BY ______

FIGURE 105-1. *Data sheet.*

ALPHABETIC INDEX OF TEST METHODS

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(TO DETACH THIS FORM, CUT ALONG THIS LINE.)

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

(See Instructions – Reverse Side)

1. DOCUMENT NUMBER	2. DOCUMENT TITLE

2a. NAME OF SUBMITTING ORGANIZATION

b. ADDRESS (Street, City, State, ZIP Code)

4. TYPE OF ORGANIZATION (Mark one)

☐ VENDOR

☐ USER

☐ MANUFACTURER

☐ OTHER (Specify): ______

5. PROBLEM AREAS

a. Paragraph Number and Wording:

b. Recommended Wording:

c. Reason/Rationale for Recommendation:

6. REMARKS

7a. NAME OF SUBMITTER (Last, First, MI) – Optional

b. WORK TELEPHONE NUMBER (Include Area Code) – Optional

c. MAILING ADDRESS (Street, City, State, ZIP Code) – Optional

8. DATE OF SUBMISSION (YYMMDD)

DD FORM 1426 82 MAR

PREVIOUS EDITION IS OBSOLETE.