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The object of the Stabilometer test when applied to soils or base materials is to determine the resistance to plastic deformation, hereafter designated simply as the Resistance or "R" value. The soil test specimen is formed in a manner that is intended to represent the worst condition, i.e. lowest density and highest degree of moisture saturation which it may reach after it is in place on the road. When the "R" value for the worst condition is known it is then possible to determine how thick the courses must be above the soil in question so that failure due to plastic flow of the soil will not occur under traffic.

It is generally impossible to predict whether the material forming a given subgrade will ever reach saturation or not, but as a design premise we assume that the void space in all soils being tested will become filled with water sooner or later. For this reason the Stabilometer test is made on saturated soils. (Saturation does not necessarily mean a plastic "sloppy: or a muddy condition of the soil).

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DESIGN METHOD TO ESTABLISH THICKNESS FOR PAVEMENT SECTIONS BASED ON STABILOMETER AND EXPANSION PRESSURE MEASUREMENTS

May 1, 1952

TABLE OF CONTENTS

TO

DESIGN METHOD TO ESTABLISH THICKNESS FOR PAVEMENT SECTIONS BASED ON STABILOMETER AND EXPANSION PRESSURE MEASUREMENTS

INTRODUCTION

DESIGN METHOD TO ESTABLISH THICKNESS FOR PAVEMENT SECTIONS BASED ON STABILOMETER AND EXPANSION PRESSURE MEASUREMENTS

The object of the Stabilometer test when applied to soils or base materials is to determine the resistance to plastic deformation, hereafter designated simply as the Resistance or "R" value. The soil test specimen is formed in a manner that is intended to represent the worst condition, i.e. lowest density and highest degree of moisture saturation which it may reach after it is in place on the road. When the "R" value for the worst condition is known it is then possible to determine how thick the courses must be above the soil in question so that failure due to plastic flow of the soil will not occur under traffic.

It is generally impossible to predict whether the material forming a given subgrade will ever reach saturation or not, but as a design premise we assume that the void space in all soils being tested will become filled with water sooner or later. For this reason the Stabilometer test is made on saturated soils. (Saturation does not necessarily mean a plastic "sloppy" or a muddy condition of the soil).

In addition to the moisture content two other conditions must be developed in the test specimen before it will be in a condition to simulate the soil in place in the road. First, it must be compacted to a typical density or dry weight per cu. ft. which in turn establishes the <u>initial</u> moisture content that will saturate (fill) the void space, and second, the soil grains and coarse particles must have the proper placement or arrangement in the specimen. <u>Two "identical" specimens compacted by different methods may have the same moisture content and density, yet have entirely different "R" values if the soil grains do not have similar structural arrangements with respect to one another.</u> In the laboratory the particle arrangement is accomplished by a special compacting machine which gives the specimen a kneading action rather than a direct static load, and produces a test specimen that resembles the condition of materials compacted on the road by construction equipment and subsequent traffic.

Therefore, the three most important requirements which the test specimen should meet are degree of saturation, proper density, and <u>proper contact pressure between the particles.</u> Of these, particle orientation and arrangement is taken care of by the compactor, but additional steps are necessary in order to determine what ultimate in-place density should be expected after the road has been under traffic for a period of time and how much moisture will be required to produce saturation at that density.

Many granular soils could be prepared for testing merely by adding varying amounts of water to a series of samples, tamping them into cylindrical molds and then compressing under a confining load until water is exuded, showing saturation. The specimen showing saturation under a compression reproducing the compaction it would receive in the field during construction might be assumed to be the one which would have the "proper density" and give the correct "R" value.

However, most soils, especially clays, have a tendency to take up more water even after reaching saturation. The additional water must enter by expanding the soil mass often with considerable force and a reduced density corresponding to the higher moisture content. This results in a marked lowering of the "R" value. In such soils water will be taken up until the tendency to expand, (expansion pressure) is exhausted or balanced by the confining pressure, which is the pressure due to the weight of the layers above. Therefore, the ultimate equilibrium "R" value of the soil in the roadbed depends on the weight of the layers above, and the thickness of these layers which is necessary to prevent plastic flow or deformation under vehicle wheel loads in turn depends on the "R" value.

In order to find the correct final density for the soil or base material a series of specimens are prepared at different initial moisture contents and after they are compressed to the point where the water just fills the voids (saturation) they are tested for expansion pressure by confining them under a spring steel bar (in a special device) and measuring the deflection of the bar due to pressure developed in the soil when additional water is available. Thus the expansion pressure is measured without permitting the specimen to expand appreciably. After sixteen hours in the expansion pressure measuring device the "R" value of each saturated specimen is determined by means of the Stabilometer.

The next step is to determine the thickness of cover indicated by each specimen in the condition in which it was tested. The theoretical thickness (weight) required to counteract the expansion pressure is determined and the thickness required to carry the traffic load as indicated by the design chart is found for each "R" value. The thickness values from the expansion pressure are plotted against those from the "R" values for each test specimen in the series and the point on the curve where the two thicknessess are identical will be the minimum that will satisfy both factors. In other words the thickness that is necessary to support traffic loads when the soil soaks up a certain amount of water is also the thickness (weight) that will prevent the soil from taking up any more water, i.e. becoming more unstable. The soil is in equilibrium with the environment.

Test Method No. 1-52

METHOD OF PREPARING MATERIALS TO BE TESTED FOR "R" VALUE

Apparatus

(a) Water Spray and Turntable
(b) Scales, 5 Kg capacity, accurate to one gram
(c) Mixing Pans, Trowel, 1/2 gallon cans

Procedure - Normal

1. (a) Air dry the material and break down all clay and soil lumps until they will pass the #4 screen. All fine material should be broken loose from coarse material.

(b) Grade and separate the sample into the following sizes:

1. Retained 1"
2. Passing 1" Retained 3/4"
3. Passing 3/4" Retained 3/8"
4. Passing 3/8" Retained #4
5. Passing #4

(c) Scalp on 3/4" or 1". If 75% or more passes the 3/4" sieve, as received, scalp the sample on the 3/4" sieve, otherwise, scalp on the 1" sieve.

(d) Quarter all passing #4 material to approximate quantities needed for each specimen.

(e) Recombine sample according to grading. Weighing out four 1200 gram samples. Use a sample ticket with each sample. It is convenient to use colored tickets when cement or lime is added because these samples must be cured after they are compacted.

(f) While mixing sample with a hand trowel add approximately 1/2 to 2/3 the amount of moisture necessary to saturate the sample using a fine water spray. Continue mixing for one minute. Note amount of water added and place each sample of mixed, loose material in a covered container and allow to stand overnight.

(g) Add additional moisture by use of the water spray until the estimated saturation moisture is reached. Mix well while adding water and continue mixing for one minute thereafter.

The "R" Value test requires the preparation of four test briquettes, one of which is used as a pilot specimen. The purpose of the pilot specimen is to obtain the proper height and moisture content for the three stabilometer test specimens. Stabilometer specimens should when possible conform to the following limitations.

Height = 2.5 ± 0.1 inches

Exudation pressure - one sample should be above and two below 400 psi or 2 above and one below 400 psi.

All samples should exude moisture between 100 and 800 psi.

By estimating the weight of material and moisture needed a pilot or trial briquette is fabricated and its height and exudation pressure measured. From the attached chart (Fig. 1) the correct weight of material for a 2-1/2" stabilometer specimen can be determined. From the exudation pressure determine whether to use more or less water in the remaining samples than was used in the pilot specimen. If the pilot specimen conforms to the requirements for a stabilometer specimen it may be used as such, otherwise, it should be discarded.

2. (a) Portland cement or lime treated samples are prepared in the same manner but are allowed to cure in a moisture cabinet for six days after compaction. The sample mold should be turned so that the specimen is in the top of the mold while curing and covered with a small pan to prevent an accumulation of water.

(b) The amount of cement or lime is expressed as a percentage of the dry weight of soil.

3. (a) Samples containing asphalt, or oil cake, should have the lumps broken down to pass 3/4" sieve and all rocks over 3/4" removed.

(b) Quarter sample well and then follow normal procedure.

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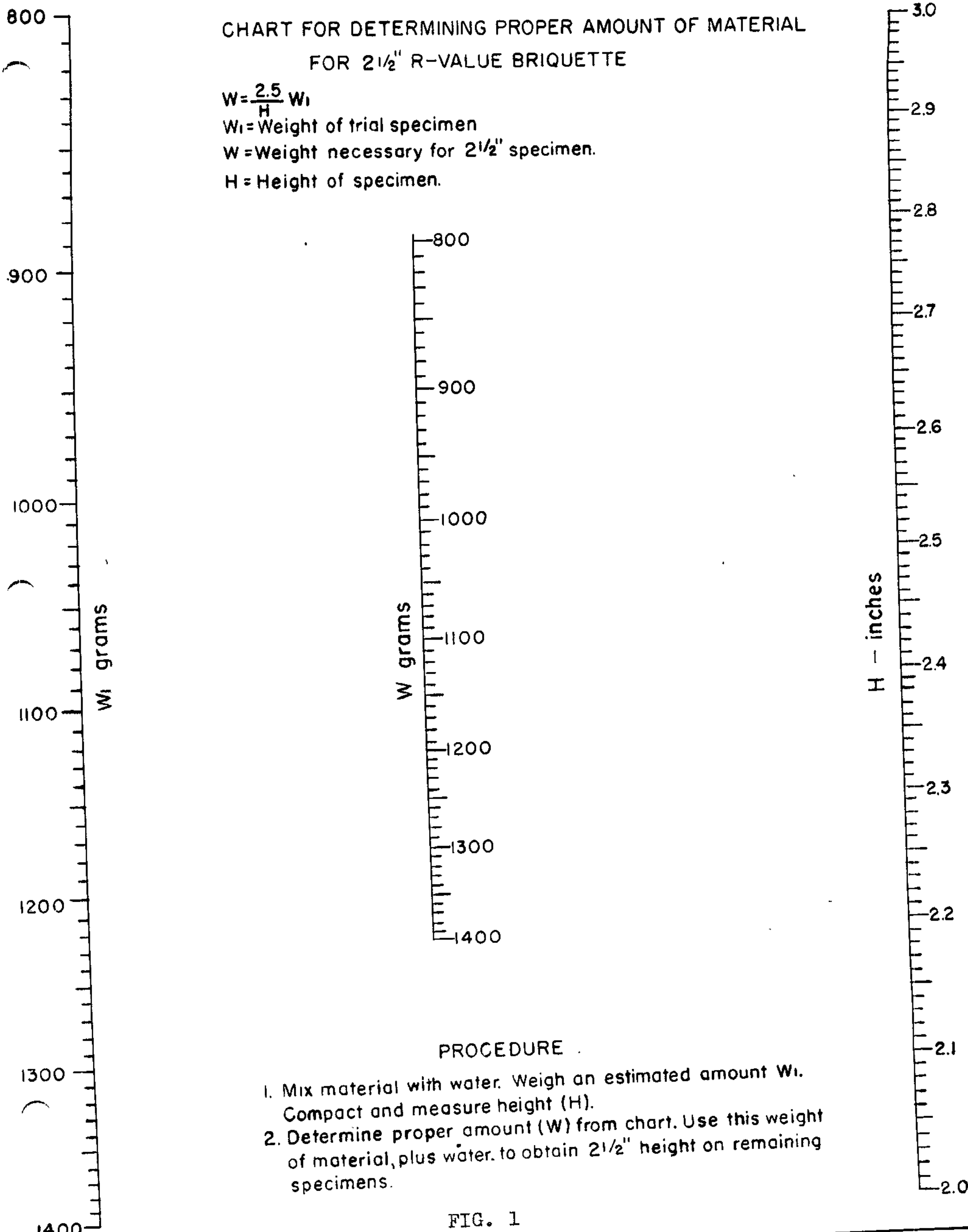
CHART FOR DETERMINING PROPER AMOUNT OF MATERIAL FOR 2½" R-VALUE BRIQUETTE

$W = \frac{2.5}{H} W_1$

W_1 = Weight of trial specimen

W = Weight necessary for 2½" specimen.

H = Height of specimen.



PROCEDURE

1. Mix material with water. Weigh an estimated amount W_1. Compact and measure height (H).
2. Determine proper amount (W) from chart. Use this weight of material, plus water, to obtain 2½" height on remaining specimens.

FIG. 1

Test Method No. 2-52

STANDARD METHOD OF COMPACTION FOR MATERIALS TO BE TESTED FOR "R" VALUE

Scope

1. This compaction method covers all materials that are used in the design of Flexible Pavements.

Apparatus

2. (a) Mechanical Kneading Compactor

(b) Compactor Accessories:

4" x 5" Steel Molds, mold holder, 20" feeder trough, spatula, rubber discs and phosphor bronze perforated discs

(c) Basket Fabrication Equipment

(d) Testing Press

Procedure ("R" Value)

3. (a) Place mold in mold holder that has a 4" disc of 1/8" thick rubber cemented to plate. Adjust mold for 1/8" clearance beneath lower edge, clamp in place.

Place 4" dia. cardboard disc into mold on top of rubber disc. Put mold funnel in place and position the assembled mold holder on compactor turntable, locking it on studs.

(b) Place well mixed sample in feeder trough, distributing the loose material evenly along the full length.

(c) Start compactor and adjust air pressure so that approximately 350 lbs. per square inch compaction pressure will be applied to the material.

(d) Using spatula formed to fit the feeder trough, push the material in the lower three inches of the trough into the mold to fill the bottom. Push the remainder of the sample into the mold in 20 equal parts using one part for each blow of the compactor. Allow ten additional blows to level and seat the material. Raise compacting foot and clean. Place rubber disc 4" dia. 1/8" thick on top of specimen.

(e) Lower compactor foot and immediately increase air pressure to a previously determined gauge reading. (Normal range = 21 - 24 psi.) On compactors that are so equipped, the green indicator light will flash on when the exact foot pressure of 350 psi. is reached.

(f) Apply 100 tamps to the specimen.

4. (a) Clays and clean sands may require lower compaction pressures. In these cases use the greatest compaction pressure possible, but do not allow the foot to penetrate over 1/4" into the surface of the specimen after all the material is in the mold.

5. (a) If free water should appear around the bottom of the mold during compaction, stop the compactor immediately and note the number of tamps.

(b) If the surface is left uneven by the action of the tamping foot, level the tamped surface with a 1-1/2 inch diameter flat ended compaction rod.

6. (a) Some granular materials are very difficult to handle without damage and may require a paper basket to keep the specimen intact.

Baskets prevent falling out of the mold and prevent crumbling when the specimen is transferred from the mold to the stabilometer. They are designed to restrain the specimen as little as possible during the stabilometer test. For that reason very few staples are used in constructing them.

(b) When compacting a specimen in a basket place all of the soil in the mold before lowering the foot. The mold should be kept upright after removal from the compactor so that the specimen will not fall out.

(c) The decision whether to use baskets on a given material must be based on experience. They should not be used if they are not needed. If baskets are not used and the specimen breaks up while being transferred into the stabilometer, the fact may not be apparent at the time, but it will result in too high stabilometer pressure readings and excessive displacement readings. Both of these errors tend to lower the "R" value, with the result that the "R" values on the sample will be too low and a group of three tests will be erratic with respect to one another. When this happens the test must be repeated using baskets.

(d) Procedure for making baskets.

Materials: Basket making device equipped with 1/2 inch masking tape. Strips of notched paper. Phosphor - bronze perforated discs. The discs are the same as those used for the exudation pressure test.

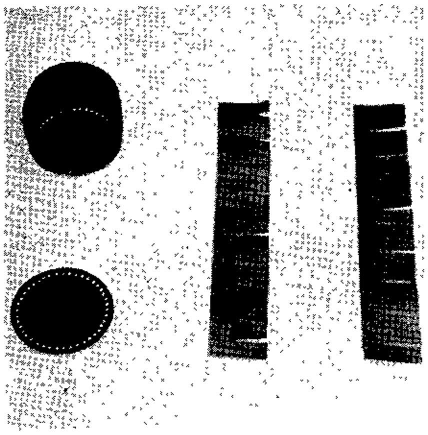
Procedure: (See the attached illustrations)

1. Staple ends of first piece of paper together. Overlap the ends to the first cut in the paper. Uncut edge is toward the stapler.

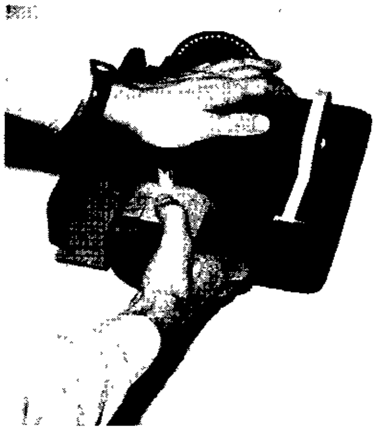
2. Rotate the paper slightly to offset the staple and slide toward stapler so that uncut edge is 2-1/2 inches from edge of wood. Two or more nails driven part way in will serve to position the paper. Place the second paper over the first with the cut edge toward the stapler, the uncut edge flush with the edge of the wood and the cuts on the two papers offset.

3. Place two more staples at third points to tie the papers together. A total of only four staples are used in the entire basket. Any more than this will confine the specimen unnecessarily.

4. Tape an exudation pressure disc in place to form the bottom.

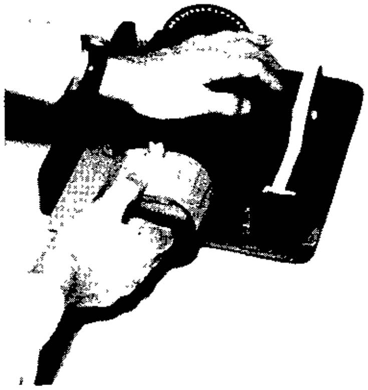


Basket and Parts



Step #1

Step #2



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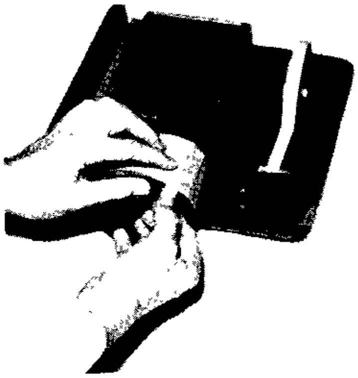

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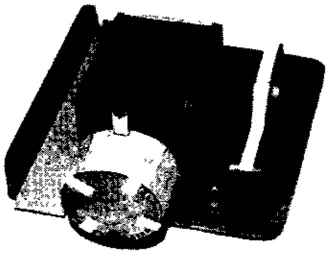

Completed Basket

Test Method No. 3-52

DETERMINATION OF EXUDATION PRESSURE

Scope

1. This method of determining the Exudation Pressure is intended for use in the fabricating of "R" value test specimens of Untreated Subgrade materials, Bases, Basement Soils, Cement Treated Bases and Lime Treated Bases.

Apparatus

2. The apparatus shall consist of the following:

   (a) Moisture Exudation Indicating Device

   (b) Phosphor Bronze, Disc, Perforated edge, 4" dia. 28 gauge

   (c) Filter Paper, 4" dia.

   (d) 10,000 lb. capacity testing press.

Procedure

3. (a) Place Phosphor Bronze Disc directly on tamped surface of specimen in mold followed by a single piece of filter paper.

(b) Invert mold with sample so that the filter paper is on the bottom and place mold on the contact plate of the moisture exudation indicator making sure that it is centered firmly against both spring posts.

Place contact plate with sample mold on platen of press centering assembly to insure even loading.

Turn Moisture Exudation Indicator switch on. When mold is clean and in the correct position the center indicator light will be on.

(c) Force the sample down in the mold to contact plate, either by hand pressure or by using the press.

(d) Apply load at the rate of 2000 lbs. per minute until five of the six outer lights are on. The vertical load in lbs. per sq. inch when the fifth light goes on is taken as the exudation pressure.

If three outer lights are on and free moisture is visible around bottom of mold, the load in lbs. per sq, inch at this moment is taken as the exudation pressure.

(e) If the exudation pressure is found to be less than 100 or more than 800 lbs. per sq. inch the sample should be discarded.

(f) In the case of a basket sample, do not invert the sample prior to placing on contact plate.

Note:

The batteries in the Moisture Exudation Indicating Device must be replaced every 3 months to insure efficient operation.

Test Method No. 4-52

METHOD OF TEST FOR DETERMINING EXPANSION PRESSURE OF SUBGRADE MATERIALS

Scope

1. This method of test covers a procedure for determining the Expansion Pressure of Subgrade materials by obtaining the amount of pressure exerted by a saturated sample due to the addition of free water while holding the volume practically constant.

Apparatus

2. (a) Expansion Pressure Apparatus

   (b) 1/10,000" Dial Assembly, Allen wrench

   (c) Proving Ring (Headquarters Laboratory)

Procedure for Calibration

3. (a) Place dial assembly in position on top bar of Expansion Pressure frame. The single bearing end must rest on adjustment plug.

(b) Place brass plate with 3/4" dia. ball bearing in center hold on turntable.

Place Proving Ring (indentation on ball) in Expansion Pressure frame, centering small ball on Proving Ring under Expansion Pressure Dial Contact.

(c) Rotate turntable up until Proving Ring Dial reads zero. Set adjustment plug so that Expansion Pressure Dial reads zero.

(d) Increase pressure in steps of .0010" from 0 to .010" on Expansion Pressure Dial. The Expansion Pressure Dial must check the Proving Ring Dial within a tolerance of ± .0002" at every point.

(e) If the dials do not check within the above tolerance, loosen the top frame bar and adjust the position of the shims until the desired check is obtained.

Note - Keep top bar clean and polished. Calibrate instruments bi-monthly.

Procedure (Testing)

4. (a) Place dial assembly in position on top bar of expansion pressure frame. The single bearing end must rest on the adjustment plug.

(b) Using an Allen wrench raise or lower the adjustment plug so that the large dial indicator is on .0090".

(c) Place perforated brass plate with rod on top of sample.

(d) Place mold on turntable.

Seat perforated brass plate on specimen with pressure applied from fingers.

(e) Turn table up until the large dial indicator is on zero.

(f) Read and record height for density determination.

(g) Pour approximately 200 ml. of water on specimen in mold and allow to stand, undisturbed, for 16 hours or more.

(h) Read and record dial reading. Remove mold with specimen, and drain off excess water.

(i) Take gross and tare weights for density determination.

Test Method No. 5-52

METHOD OF TEST FOR DETERMINING STABILITY OR STABILOMETER "R" VALUE BY MEANS OF STABILOMETER

Scope

1. This method of test covers the procedure for determining Resistance Value "R", by means of the Stabilometer. The Stabilometer measures the transmitted horizontal pressure (P_h) that is developed in a test specimen by applying a given vertical pressure (P_v).

Apparatus

2. (a) Stabilometer and accessories

(b) Testing Press, 20,000 pound capacity, minimum

Calibration Procedure

3. (a) Adjust bronze nut on base of Stabilometer so that an effective height of 2.4" is obtained when the Stabilometer shell is in position on the base. The effective height is defined as that depth of the test specimen which acts against the liquid phase of the Stabilometer. The "ideal" specimen is 2.5" high and has an effective height of 2.4"

(b) With dummy specimen in place apply a vertical load of 1000 pounds. Turn the pump to a pressure of exactly five pounds per square inch. Adjust the turns indicator dial to zero. Turn pump handle at approximately two turns per second until the Stabilometer dial reads 100 pounds per square inch. The turns indicator dial shall read $2.00 \pm .04$ turns. If it does not, the air in the cell must be adjusted. Remove air or add air by means of the rubber bulb and repeat the displacement measurement after each air change until the proper number of turns is obtained. Release horizontal and vertical pressures and remove brass dummy specimen. Stabilometer is now ready for testing specimens.

4. (a) Force specimen to be tested into Stabilometer. Specimen shall be well seated on top of base. Place follower on top of specimen, adjust pump to give a horizontal pressure of exactly five pounds per square inch. Adjust the testing machine to give a constant movement of 0.05" per minute and apply the vertical load to the test specimen.

Note: Hydraulic presses must be run several minutes before oil warms sufficiently to maintain a constant speed.

(b) ("R" Value) Samples

Record the Stabilometer gauge reading when the vertical pressure is 80 and 160 pounds per square inch. For a 4" specimen, this is at applied vertical loads of 1000 and 2000 pounds.

5. (a) Stop the vertical load when it reaches 2000 pounds. Reduce the vertical pressure to 1000 pounds and lock testing press at this point. Open Stabilometer valve (if used) and turn pump so that the horizontal pressure is exactly 5 psi. Set turns indicator dial to zero. Turn pump handle at approximately two turns per second until the Stabilometer gauge reads 100 psi.

The number of turns indicated on dial are recorded as the displacement of the specimen. The turn indicator dial reads in .001 inches with each 0.1 inch equal to one turn. Thus, a reading of 0.250 inches indicates that 2.50 turns were made with the displacement pump. This measurement is known as the displacement of the specimen.

6. (a) The Stabilometer "R" Value is then calculated from the following formula:

$$R = 100 - \frac{100}{\frac{2.5}{D}\left(\frac{P_v}{P_h} - 1\right) + 1}$$

Where P_v = 160 psi

D = Turns Displacement Reading

P_h = Horizontal Pressure (Stabilometer Gauge at P_v = 160 psi.)

The attached Stabilometer "R" value chart (Fig. 2) is normally used to solve the above formula.

7. (a) Every attempt should be made to fabricate test specimens having an over-all height between 2.4" and 2.6". However, if for some reason this is not possible, the Stabilometer should be adjusted and the "R" value corrected as indicated on the accompanying chart (Fig. 3)

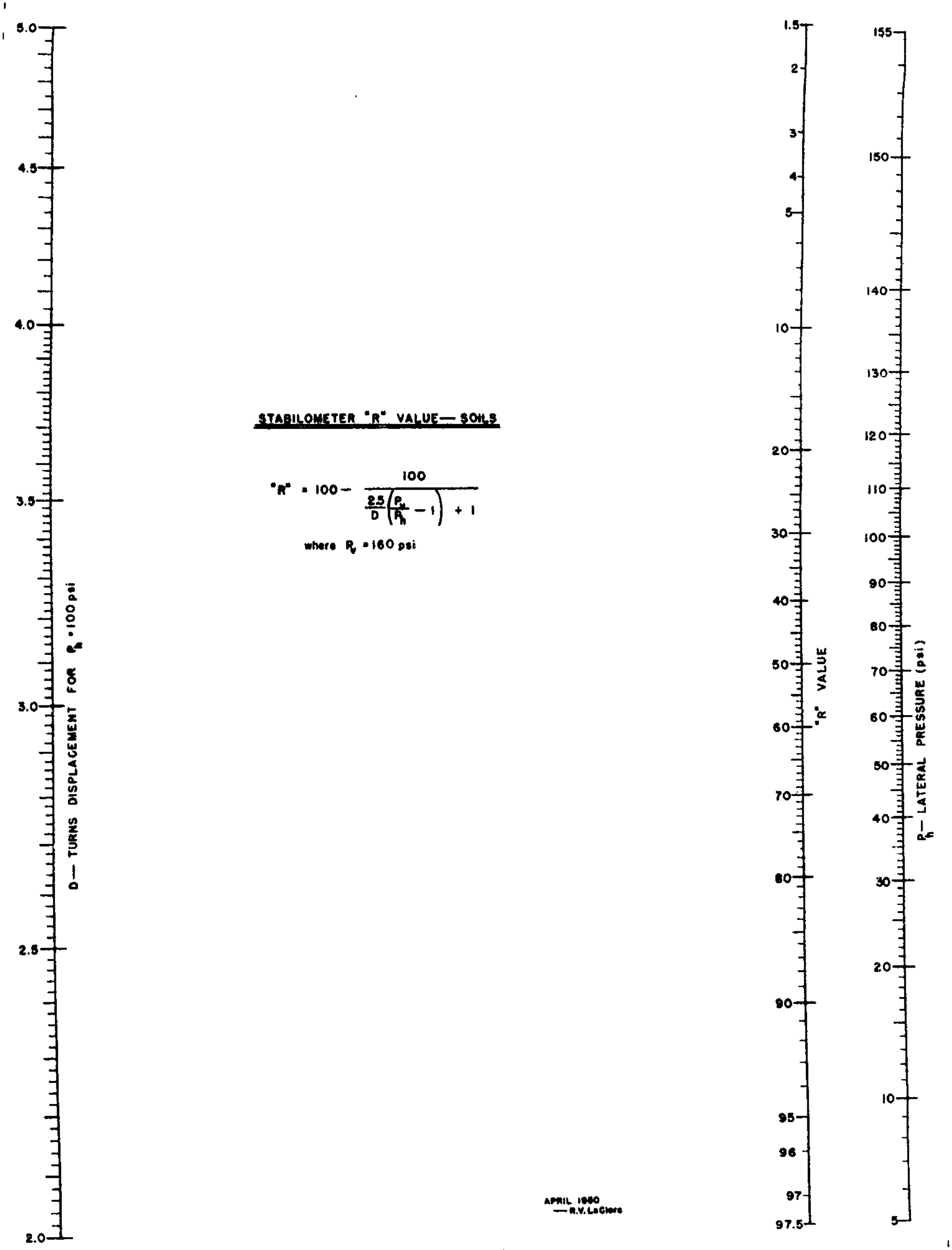

FIG. 2

FORM T 382

STATE OF CALIFORNIA DIVISION OF HIGHWAYS

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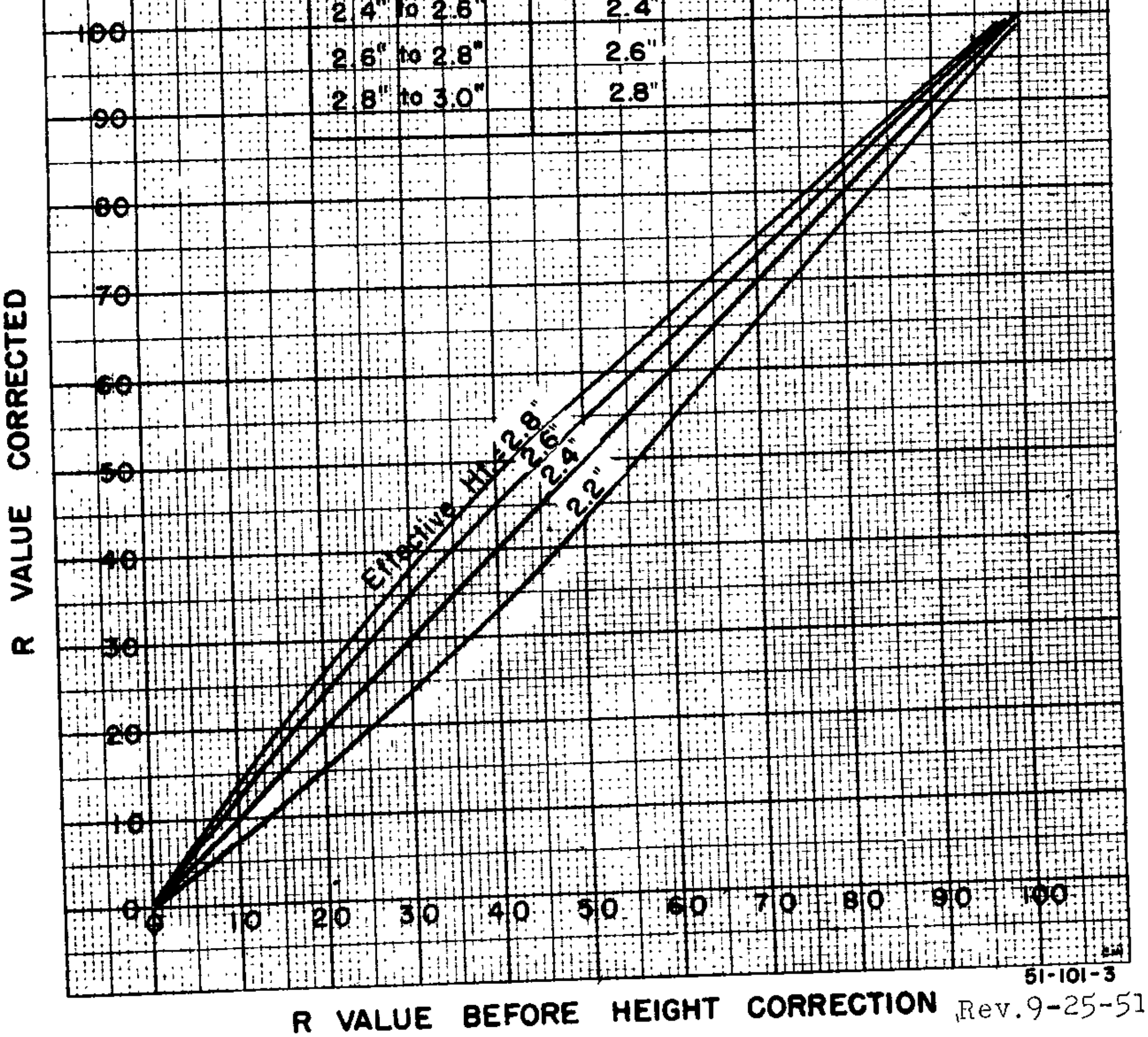
CHART FOR CORRECTING "R" VALUES TO EFFECTIVE SPECIMEN HEIGHT OF 2.40"

HEIGHT CORRECTION SHOULD BE MADE USING THE TABLE AND CHART BELOW.

EXAMPLE: OVERALL HEIGHT OF 2.74", EFFECTIVE HEIGHT SET AT 2.6" R(UNCORRECTED) = 30; R(CORRECTED) = 35.

OVERALL SPECIMEN HEIGHT	EFFECTIVE HT.
2.2" to 2.4"	2.2"
2.4" to 2.6"	2.4"
2.6" to 2.8"	2.6"
2.8" to 3.0"	2.8"



Rev.9-25-51

FIG. 3

METHOD OF COMPUTING DENSITIES FROM HEIGHT AND WEIGHT OF SPECIMEN

A. "R" Value specimens

$$\text{Dry Weight per cu. ft.} = \frac{30.3\, W_w}{(100+M)H}$$

Where:

W_w = Wet weight of specimen in grams after expansion pressure test, but before the Stabilometer test.

Drain the excess water from the samples and then weigh the samples in the tared mold.

M = Percentage of moisture on dry weight basis. Use entire briquette after Stabilometer test has been performed.

Determine moisture content by weighing before and after drying in a tared pan. Dry to constant weight at 230°F. Overnight will be sufficient time if specimen is broken up.

H = Height of specimen in inches, as measured in expansion pressure devices.

METHOD OF CALCULATING DESIGN THICKNESS

On the work card (Form T-361-51) enter the test data, including (1) percent of water added, (2) compactor pressure, (3) exudation pressure, (4) height of briquette, (5) wet weight of briquette, (6) moisture content, (7) dry density, (8) "R" value and (9) expansion pressure, and any other pertinent data for each of the specimens tested.

Knowing the Cohesiometer Value of the cover material and the estimated traffic index for the road, by means of the attached Design Chart (Chart II) determine and record the "thickness indicated by Stabilometer" corresponding with the "R" value of each specimen.

By means of the Expansion Pressure Thickness Chart (Fig. 4) determine and record the thickness indicated by expansion pressure for each of the specimens. Assume the cover to weigh 130 pounds per cubic foot except in special investigations where more accurate information is available.

Next on reverse side of work card Form T-361-51, plot "thickness indicated by Stabilometer" against "thickness indicated by expansion pressure".

Also on the same chart plot thickness indicated by Stabilometer against exudation pressure.

Note the thickness value at which the first curve crosses the 45 degree dotted line and the thickness value at which the second curve crosses the 400 pound per square inch exudation pressure line. The design thickness is then taken as the greater of these two values and the "R" value at equilibrium is determined from the design thickness. The design chart is used for this purpose. The example work card illustrates how to do this.

The first line, labeled "water added %", is used to show the amount of water added to the specimens. The card should read "water added ml." This information is used for preparing additional test specimens in case they are needed.

The compactor pressure of 21 psi. was the air pressure which gave 350 psi. pressure on the tamper foot. This value will vary between 21 and 24 psi. depending on the tamper calibration.

Some clays cannot be tamped at full pressure. The actual air pressure used should be recorded here.

The expansion pressure in psi. was determined by multiplying the expansion pressure dial readings shown on the specimen tickets by a conversion factor to convert to pressure in pounds per square inch. The equipment is adjusted to have a factor of 0.04 when the dial reading is in ten thousandths of an inch. In the example the readings were 31, 12 and 0; which give expansion pressure of 1.24, 0.48 and 0 psi. as shown on the card. These values may be determined from the attached chart.

The two graphs for determining the "R" Value at equilibrium are drawn in the space provided on the back of the card. In the example shown the curve for exudation pressure vs thickness by Stabilometer gives a design thickness of 13-1/2 inches. The curve for thickness by expansion pressure vs thickness by Stabilometer gives a design thickness of 11 inches. The final value taken as the design thickness must be the greater of the two, or 13-1/2 in. The "R" value at equilibrium is the value which corresponds to 13-1/2 inches of cover on the design chart. This value was found to be 39.

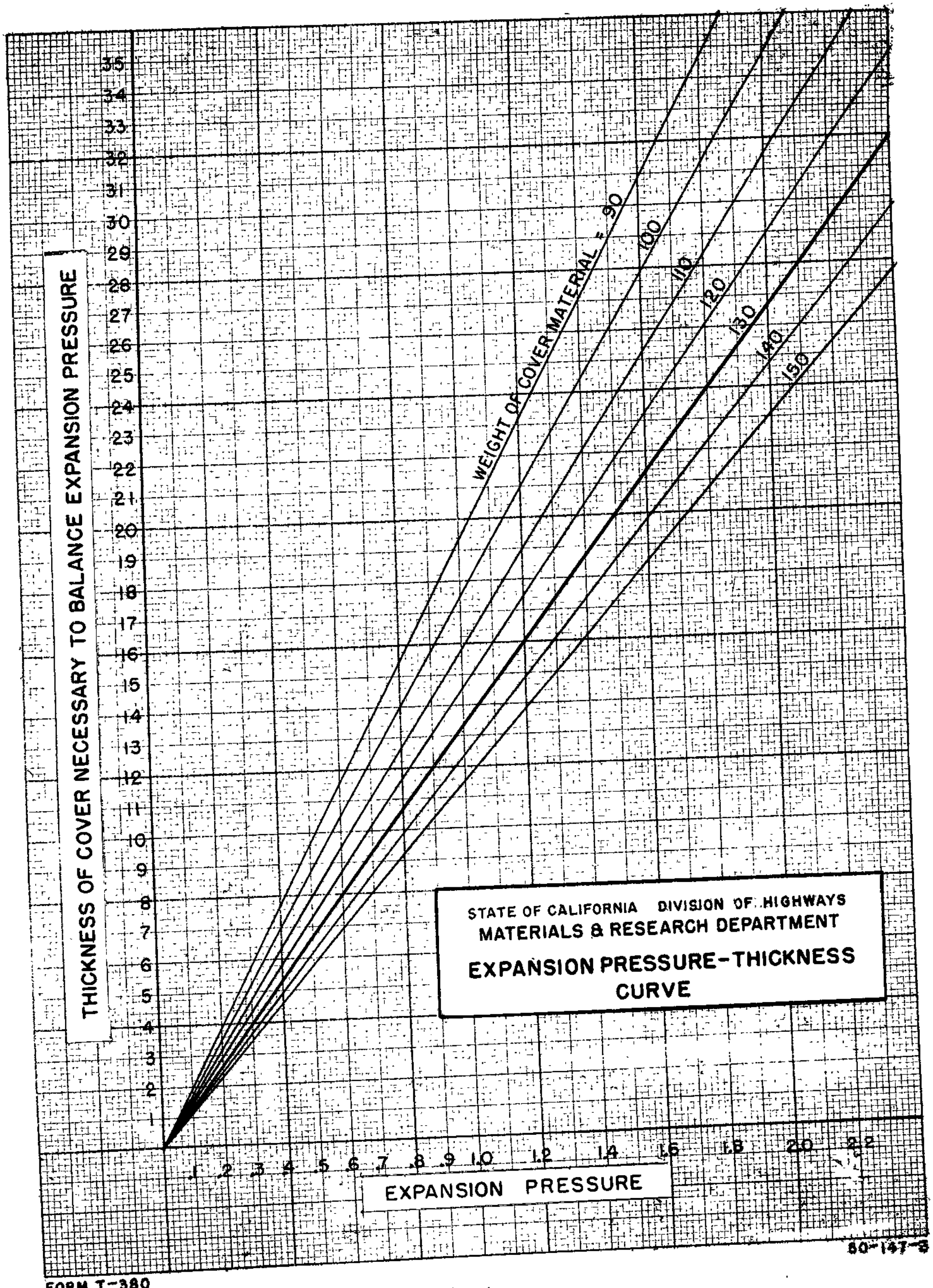

THICKNESS OF COVER NECESSARY TO BALANCE EXPANSION PRESSURE
WEIGHT OF COVER MATERIAL = 90
100
110
120
130
140
150
EXPANSION PRESSURE
STATE OF CALIFORNIA DIVISION OF HIGHWAYS
MATERIALS & RESEARCH DEPARTMENT
EXPANSION PRESSURE-THICKNESS CURVE
80-147-3
FORM T-380

FIG. 4

CALCULATIONS FOR COMBINING MATERIAL TO MEET SPECIFICATIONS

Procedure

1. (a) Single Samples

To compute the "as used" grading, increase to 100% passing the size on which the sample is scalped and increase the percent passing other sizes in the same proportion.

For example a sample has 90% passing 3/4", 80% passing 3/8", and 70% passing #4. This sample would be scalped on 3/4" and the "as used" grading would be:

Passing 3/4" $100\% = 100$

Passing 3/8" $\frac{100}{90} \times (80) = 89$

Passing #4 $\frac{100}{90} \times (70) = 78$

The percentage of material passing other screen sizes should be computed in a like manner.

On the back of the work card place the weight of each size for a 1000 gm. sample. This is done by multiplying the percent of each size as used by 10. For the example above, the weights would be:

		1000 gm. Sample		1200 gm. Sample
3/4 - 3/8	(100 - 89) x 10 =	110 gm	+ 20% =	132
3/8 - 4	(89 - 78) x 10 =	110 gm	+ 20% =	132
4 - dust	(78 - 0) x 10 =	780 gm	+ 20% =	936

2. (a) Combined Samples

Two or more different materials may be combined, but the computations are the same. Label the proper columns on Form T-361 with the test numbers of the samples to be combined. Opposite the largest size in any of the samples place the percentages of the samples to be used. In any given column the percentage passing the other sizes will be reduced by the same proportion as the first size.

(b) In the case of a sample being combined with its crushed oversize the grading of the uncrushed portion needs no adjustment. The sum of the percentages passing any size gives the total percent passing in the combination. After the grading of the combination is computed scalp on 3/4" or 1" in the usual way. Note that the material is scalped after combining and not before.

To compute the batching weights in a scalped combination break down the percentages in the "as used" column into components furnished by the different samples and figure weights as before.

For example, combine samples #1 and #2 using 20% of Sample #2.

	As Received					As Used
Sieve Size	#1	80% #1	#2	20% #2	Comb.	Scalp on 3/4"
1"	100	80		20	100	
3/4"	90	72	100	20	92	100
3/8"	80	64	95	19	83	90
#4	70	56	90	18	74	80

Compute Components of the percentage as used

Sieve Size	#1	#2	Check
3/4"	$\frac{100}{92} \times 72 = 78$	$\frac{100}{92} \times 20 = 22$	78 + 22 = 100
3/8"	$\frac{100}{92} \times 64 = 70$	$\frac{100}{92} \times 19 = 21$	70 + 21 = 91
#4	$\frac{100}{92} \times 56 = 61$	$\frac{100}{92} \times 18 = 20$	61 + 20 = 81

Check the sum of the components against the "as used" column. They may disagree by 1% because fractions have been rounded off.

Finally compute the weight of each size needed to produce the combined sample.

Sieve Size	#1	#2
3/4 - 3/8	(78 - 70) X 10 = 80	(22 - 21) X 10 = 10
3/8 - #4	(70 - 61) X 10 = 90	(21 - 20) X 10 = 10
#4 dust	(61 - 0) X 10 = 610	(20 - 0) X 10 = 200

Note that the test specimen will actually contain 78% of sample #1 instead of 80%. This is because the scalping removed some of sample #1 and none of sample #2.

(c) Adjusting Gradings to fit specifications

This usually applies to combinations and is done by adjusting the percentages of the component samples by trial and error.

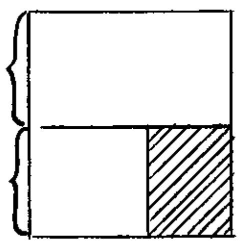
Adjustment may also be made by wasting a portion of the coarse or a portion of the fines in a sample. This method is as follows:

Adjustment of Gradings
By Wasting a Portion of the Samples

To waste a portion of passing #4:

Ret. #4

Pass. #4



W

Consider a unit amount of material
Let W = proportion to be wasted
P_1 = proportion passing #4 originally
P_2 = proportion passing #4 finally

$$P_2 = \frac{P_1 - W}{1 - W} \text{ from which } W = \frac{P_1 - P_2}{1 - P_2}$$

Example:

Sieve Size	Given % Passing	Specifications
3/4	100	95-100
3/8	90	
#4	70	55-65
#8	55	

To meet specifications it is necessary to reduce the amount of passing #4 material. Assuming that 60% is desired, then

$$W = \frac{.70 - .60}{1 - .6} = \frac{.1}{.4} = .25 \text{ or } 25\% \text{ of total sample}$$

The new grading will be

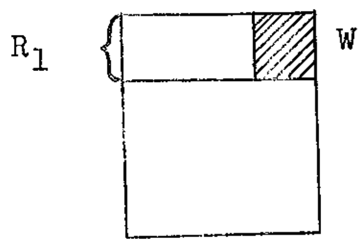
$$\text{Passing \#8} = \frac{60}{70} \times (55) = 47$$

$$\text{Retained } 3/8 = \frac{100-60}{100-70} \times (100-90) = \frac{40}{30} \times (10) = 13$$

$$\text{Passing } 3/8 = 100 - 13 = 87\%$$

Note that the new grading of the coarse material is computed by adjusting the percentages retained.

To waste a portion of retained #4:



Consider a unit amount of the material
Let W = proportion wasted
R_1 = Proportion retained #4 originally
R_2 = Proportion retained #4 finally
P_1 = Proportion passing #4 originally
P_2 = Proportion passing #4 finally

$$R_2 = \frac{R_1 - W}{1 - W} \quad \text{from which } W = \frac{R_1 - R_2}{1 - R_2} = \frac{P_2 - P_1}{P_2}$$

Example: Given the following grading:

Size	% Passing
3/4	100
3/8	90
#4	70
#8	40

It is necessary to waste enough retained #4 to increase the passing #4 to 80%

Substituting into the above equation, $R_1 = 100-70 = 30$, $R_2 = 20$

$$W = \frac{.30 - .20}{1 - .20} = \frac{.1}{.8} = .125$$ or <u>12.5%</u> of total

$$\text{or } W = \frac{80 - 70}{80} = \frac{10}{80} = 12.5\%$$

The new grading will be:

Passing #8 = $\frac{80}{70} \times (40) =$ <u>46%</u>

Retained 3/8" = $\frac{20}{30} \times (10) = 6.7$

Passing 3/8" 100 - 6.7 = 93%

Form T 361 51

LABORATORY RECORD OF UNTREATED MATERIAL

TEST No. *51-994* DIST. *VII* CO. *LA* RTE. *60* SEC. *LA* CONT. No. *51-7VC31-P* DATE REC'D *Mar. 8, 1951*

INSTRUCTIONS ______ DATE COMPLETED *Mar. 16, 1951*

APPROVED BY *G.S.*

DATE REPORTED *Mar. 16, 1951*

				Sieve	As Received	Ret Crushed	% Used	Specif. Limits Sought
				1½	100			
				2½				
				1	99			
				¾	99		100	
				½				
				⅜	97		98	
				4	96		97	
				8	92		93	
				16	86		87	
				30	81		82	
				50	74		75	
				100	67		68	
				200	60		61	
				Wash	51		52	
				5µ	19		19	
				1µ	7		7	

Grading Analysis

GRADING AS USED WAS OBTAINED BY COMBINING SAMPLE

% by Wt.	% by Vol.	Test No	Field No	Description

Test Specimen	A	B	C	D	E	F	G	H
Water Added %	14.8	15.7	18.8					
Compactor Pressure P.S.I.	21	21	21					
Exudation Pressure P.S.I.	600	450	170					
Height of Briquette	2.48	2.50	2.54					
Wet Weight of Briquette	1009	1013	996					
Moisture Content %	22.3	22.9	26.2					
Density Lb. per Cu. Ft.	102	100	94					
Expansion Pressure P.S.I.	1.24	0.48	0					
Stabilometer Ph at 1000 Lbs	39	46	60					
2000 Lbs	68	82	133					
Displacement	3.00	3.15	3.20					
R-Value	53	43	14					
Thick. Indicated by Stab. Inches	9.8	12.5	20.1					
Thick. Indicated by E.P. Inches	16.5	6.4	0					

SP. GR. FINES

SP. GR. COARSE

P.R.A. CLASSIF.

L.L. P.L.

P.I.

PETROLOGICAL CLASSIF

SAND EQUIVALENT *11*

TYPE OF SUBBASE

TYPE OF BASE *8" URB*

TYPE OF SURFACE *4" PMS*

COHESION VALUE *375*

TRAFFIC INDEX *9*

R-VALUE AT EQUIL. *39*

INDICATED MINIMUM THICK. OF COVER FOR ABOVE CONDITIONS *13.5*

LABORATORY COMMENTS

Moisture content as received = 7.4%

State of California
Department of Public Works
Division of Highways
MATERIALS AND RESEARCH DEPARTMENT
Sacramento, California

June 27, 1952

FNH/18

To All District Engineers
of the Division of Highways

Attention District Materials Engineers

Gentlemen:

Attached is a copy of Test Method No. 9-52 for performing the Sand Equivalent Test. It supersedes the tentative method dated September 1, 1950.

The only major change in the revised method is in the manner of calculating the sand equivalent value. If the sand equivalent is below the specified value, it is now necessary to perform two additional tests and to report the average of the three results as the sand equivalent value.

F. N. Hveem

F. N. HVEEM
Materials & Research Engr.

Attach.
GBS:mg

SAND EQUIVALENT TEST

Scope

1. This test is intended to serve as a rapid field test to show the relative amounts of plastic fines in graded aggregates and soils.

Apparatus

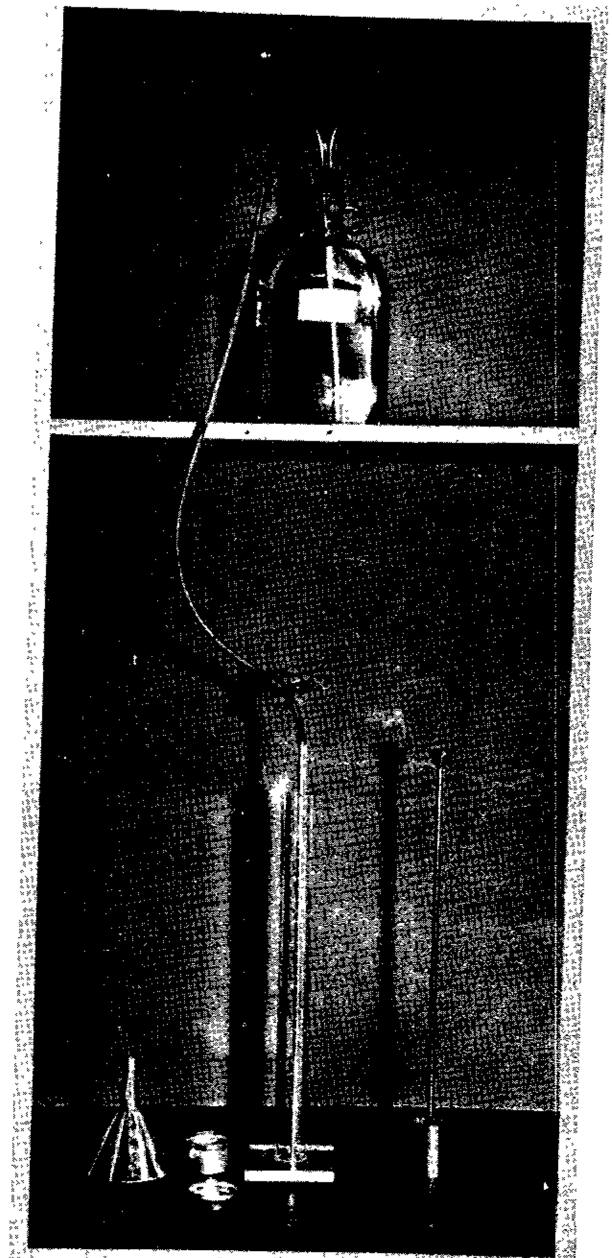
2.(a) A transparent graduated measuring cylinder having an internal diameter of 1-1/4 inches, a height of about 17 inches, and graduations up to 15 inches by tenths, beginning at the bottom.

(b) An irrigator tube made of 1/4 inch outside diameter brass or copper tubing. One end is closed to form a wedge shaped point. Two holes (drill size 60) are drilled laterally through the flat side of the wedge near the point.

(c) A one gallon bottle with siphon assembly consisting of a two-hole stopper and a bent copper tube. The bottle is placed three feet above the working table.

(d) A length of 3/16 inch rubber tubing with a pinch clamp for shutting off the flow. This tubing is used to connect the irrigator tube to the siphon assembly.

(e) A weighted foot consisting of a metal rod 18 inches long having at the lower end a one inch diameter conical foot. The foot has three small centering screws to center it loosely in the cylinder. A cap to fit the top of the cylinder fits loosely around the rod and serves to center the top of the rod in the cylinder. A weight is attached to the top end of the rod to give an assembly weight of one kilogram.



(f) A 3 ounce size measuring can (88 ml capacity).

(g) A wide mouth funnel for transferring soil into the cylinder.

Test No. ...

WEIGHT SAMPLE	1000 gr.				1200 gr.			
Test No.								
1"								
1"-3/4								
3/4-1/2								
1/2-3/8	20				24			
3/8-4	10				12			
4-Dust	970				1164			

REMARKS

Spec
A
B
C
D
E
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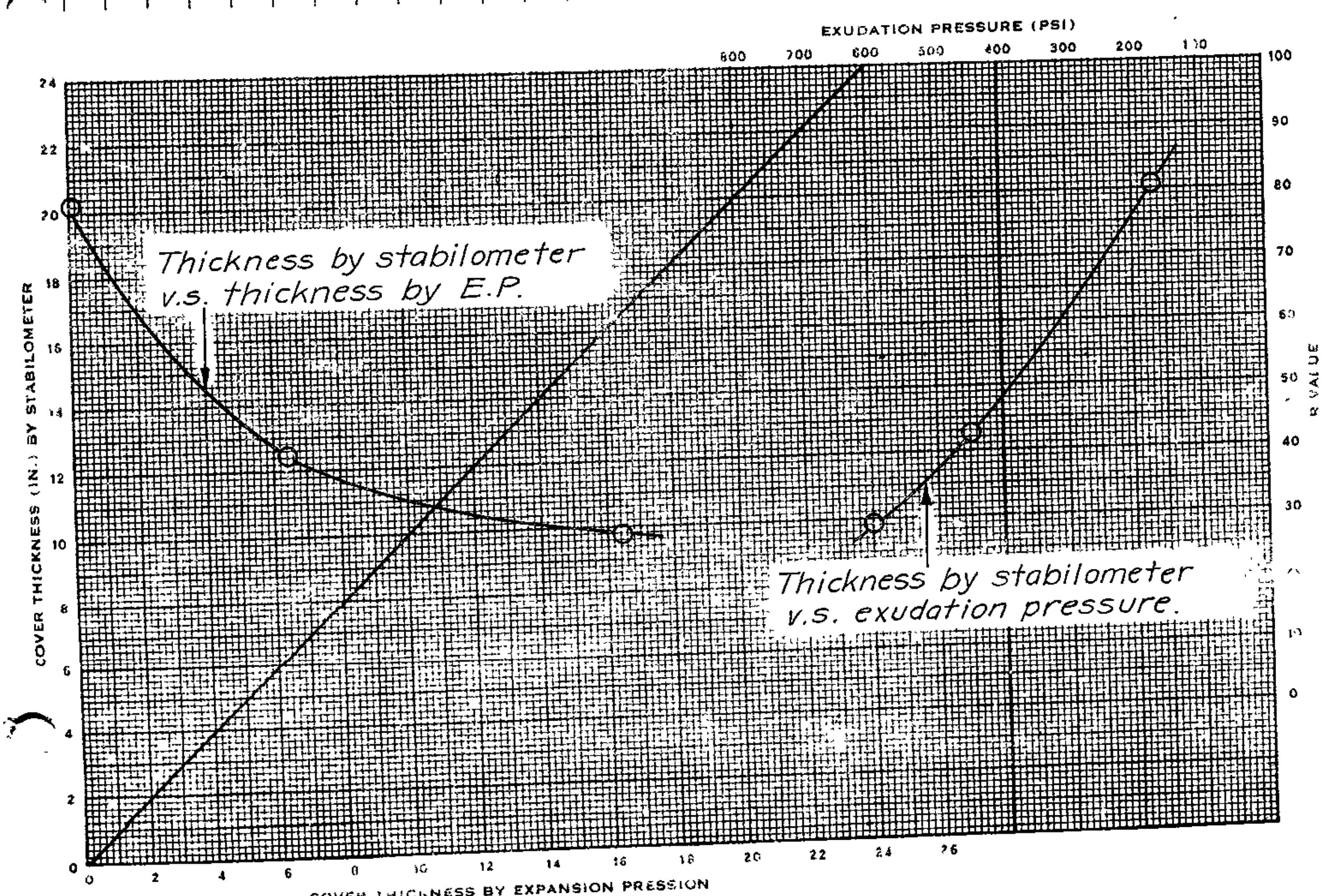
H



(h) Stock solution

454 grams (1 lb.) tech. anhydrous calcium chloride
2050 grams (1640 ml) U.S.P. glycerine
47 grams (45 ml) formaldehyde (40 volume solution)

Dissolve the calcium chloride in 1/2 gallon of water. Cool and filter through Whatman No. 12 or equal filter paper. Add the glycerine and formaldehyde to the filtered solution, mix well, and dilute to one gallon. The water may be distilled or good quality tap water.

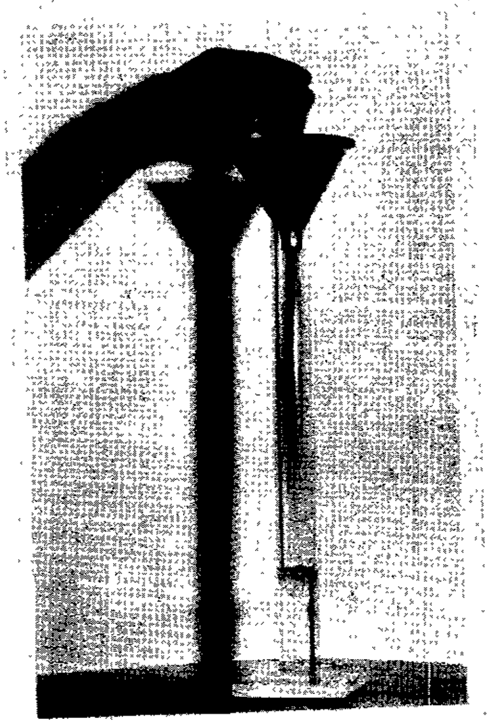
(i) Working Solution.

Dilute 88 ml of the stock solution to one gallon with tap water. The graduated cylinder filled to 4.4 inches contains the required 88 ml. Questionable water may be tested by comparing results of sand equivalent tests on identical samples using solutions made with the questionable water and with distilled water.

Procedure

3.(a) Preparation of Sample.

The material used in the test is the portion of the sample passing the #4 sieve. Therefore, if the sample contains coarse rock it must be screened on a #4 sieve and the lumps of finer material must be broken down. If the original sample is not damp it should be dampened with water before screening. If the coarse aggregate carries a coating that is not removed by the screening operation, dry the coarse aggregate and rub it between the hands, adding the resulting dust to the fines.

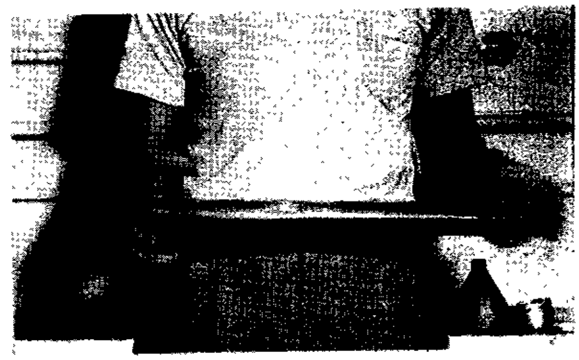


(b) Start the siphon by blowing into the top of the solution bottle through a short piece of tubing while the pinch clamp is open. The apparatus is now ready for use.

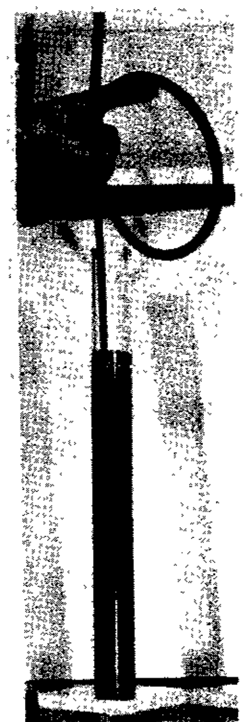
(c) Siphon the working solution into the cylinder to a depth of four inches.

(d) Pour one measuring can full of the prepared soil sample into the cylinder. One can full amounts to about 110 grams of average loose material. Tap the bottom of the cylinder firmly on the heel of the hand several times to dislodge any air bubbles and to aid in wetting the sample. Allow to stand for 10 minutes.

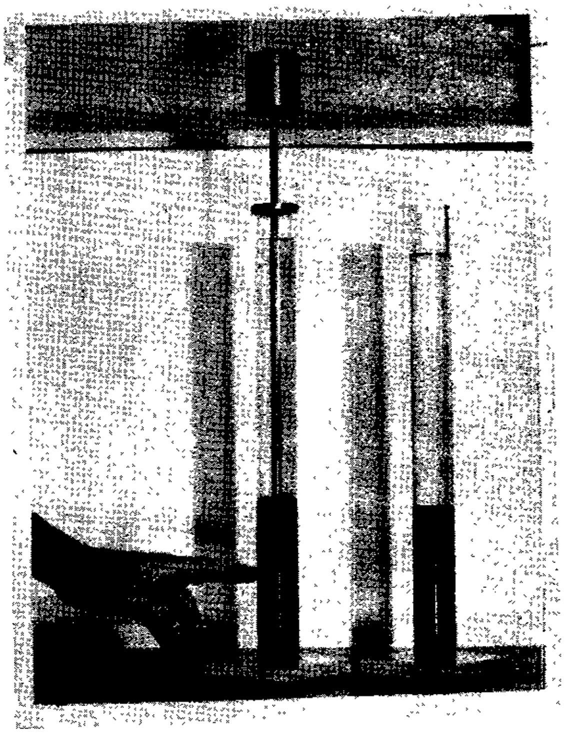
(e) At the end of the 10 minute period stopper the cylinder and shake vigorously from side to side, holding in a <u>horizontal</u> position as illustrated. Make 90 cycles in about 30 seconds, using a "throw" of about 8 inches. A cycle consists of a complete back and forth motion. To successfully shake the sample at this speed, it will be necessary for the operator to shake with the forearms only, relaxing the body and shoulders.



(f) Remove the stopper and insert the irrigator tube. Rinse down the sides, then insert the tube to the bottom of the cylinder. Wash the clayey material upward out of the sand by applying a gentle stabbing action with the tube while revolving the cylinder slowly. When the liquid level rises to 15 inches raise the irrigator tube slowly without shutting off the flow so that the liquid level is maintained at about 15 inches while the tube is being withdrawn. Regulate the flow just before the tube is entirely withdrawn and adjust the final level to 15 inches. Allow to stand undisturbed for exactly 20 minutes. Any vibration or movement of the cylinder during this time will interfere with the normal settling rate of the suspended clay and will cause an erroneous result.



(g) At the end of the 20 minute period record the level of the top of the clay suspension. Read to the nearest 0.1 inch.



(h) Gently lower the weighted foot into the cylinder until it comes to rest on the sand. Twist the rod slightly without pushing down until one of the centering screws can be seen. Record the level at the center of the screw.

(i) Calculate the sand equivalent by using the following formula:

$$SE = \frac{\text{Reading at top of sand}}{\text{Reading at top of clay}} \times 100$$

If the sand equivalent value is less than the specified value, perform two additional tests on the same material and take the average of the three as the sand equivalent.

(j) To empty the cylinder, stopper and shake up and down in an inverted position until the sand plug is disintegrated, then empty immediately. Rinse twice with water. Do not expose plastic cylinders to direct sunlight any more than is necessary.