MAXIMUM DENSITY AND OPTIMUM MOISTURE OF SOILS METHODS C & D

(A Modification of AASHO T 99, Methods C & D)

Scope

1. **Method C** shall be used only on volcanic cinders and light porous material containing less than 50% of material retained on the No. 4 sieve.

Method D shall be used only on volcanic cinders and light porous materials containing more than 50% and less than 60% of material retained on the No. 4 sieve. If the material contains more than 60% retained on the No. 4 sieve, report the sieve analysis with a note stating the density is not determinable due to excess material retained on the No. 4 sieve.

Apparatus

2. The apparatus shall consist of the following:

(a) 4.0-in. proctor mold (for Method C) having a capacity of 1/30 (.0333) cu. ft. with internal diameter of 4.0 ±.005 in. and a height of 4.584 ±.005 in.

(b) 6.0-in. proctor mold (for Method D) having a capacity of 1/13.33 (0.075) cu. ft., with internal diameter of 6.0 ±0.005 in. and a height of 4.584 ±0.005 in. (See Fig. 1.)

(c) A hand rammer or mechanical compactor of 2-in. diameter, having a flat circular face and weighing 5.5 lb.

(d) Steel straightedge 12" or longer, having one beveled edge.

(e) Balance, capacity 20 kg. sensitive to 1 g.

(f) Drying oven, operating range 110° ±5° C.

(g) Miscellaneous mixing tools and pans.

Sample

3. Enough material should be on hand to make five compacted samples.

Approximately 13,000 g. for Method C.

Approximately 25,000 g. for Method D.

(These weights may have to be adjusted depending on the type of material.)

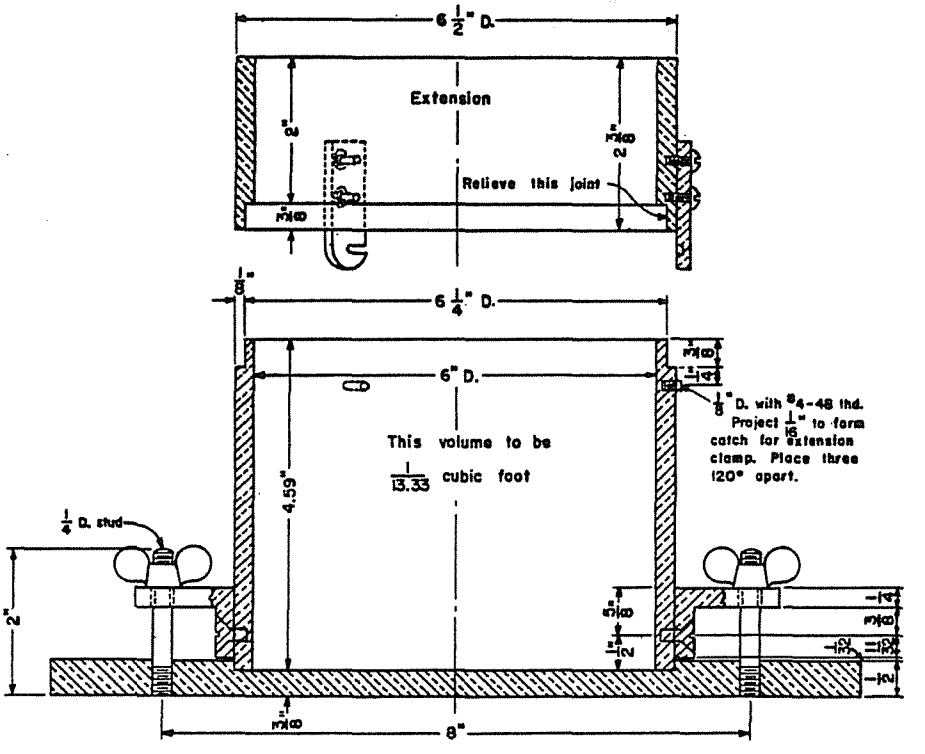

FIGURE 1
Cylindrical Mold, 6.0-in., for Soil Tests

(a) A sieve analysis, (ARIZ 201 and 203) must be run to determine the proportion of rock.

Samples which contain approximately 100% passing the ¾" sieve shall be prepared in accordance with the folowing procedure:

A uniform sample of approximately 15,000 g. so as to obtain not less than five compaction samples or test charges, shall be used. The sample shall be separated by means of a mechanical sample splitter into equal portions of approximately the desired weight. With some practice the charges can be obtained by using **only** the splitter. The operator shall not add to or take away from any portion by scooping with the hand or other means, as this may cause segregation.

(b) Samples containing rock retained on the ¾" sieve shall be processed in the following manner:

The material retained on the ½", ⅜", ¼", and No. 4 sieves shall be stored in separate containers during the sieve analysis procedure. Rock retained on the ¾" sieve shall not be used, but its percentage shall be distributed proportionately among the sieves mentioned above. Table I shows a coarse sieve analysis which required adjusting, shows the adjusted percentages, and also shows the material to build up a 2200 g. charge. Essentially the same procedure shall be followed to build a 5000 g. charge in the case of Method D. These weights may require adjustment if the charge is too large.

(c) The adjusted % retained values are found by dividing each of the percentages retained on the ½", ⅜", ¼" and No. 4 (from Table I), by the total percentage of material coarser than No. 4, x 10, and adding these quotients to the respective sieves below the ¾", i.e., $7 \div 36 = 1.9 = 2$; $8 \div 36 = 2.2 = 2$; and $12 \div 36 = 3.3 = 3$. The final correction should total 100%.

(d) Use the "adjusted % Ret." values to build up the compaction charges of 2200 g. each, i.e.,

$$\frac{2200 \times 9}{100} = 198 \text{ g. of } ½"$$

rock needed (Table I). The accumulative total is for weighing the charge as follows:

1. Weigh out the first size (½") into the balance scoop (198 g. in Table I), then set the weights at 374 g. (198 + 176) and add the ⅜" rock until the instrument balances. Next set the weights at 638 g., (374 + 264) and add the ¼" rock until the instrument again comes to balance. Continue in this manner until the charge weighing 2200 g. is built up. Weigh out 5 such charges and save them in separate pans.

Mixing

4. The amount of water that will be required for a sample is variable and requires some experience on the part of operator, but the following general rule may be of help. Add 4% water to the sample and mix thoroughly; when mixing is complete, pick up a handful of dirt and squeeze it, then open the hand, let the dirt fall, and immediately blow the breath upon the open hand. If the hand feels cool, but not cold, another 2% water shall be added, thoroughly mixed, and the squeeze and blow test repeated. Continue to add 2% portions of water, and check, until the feeling of coolness changes to cold. At this point, gather the material into a compact pile and cover it with a slightly damp cloth to inhibit drying. Record the total percentage of water added.

Compaction

5. Compact the material as follows:

(a) Place approximately ⅓ of the mixed material in the mold, moving the scoop around the top of the mold to insure even distribution of the material. Tamp the material lightly with the end of the hand rammer,

TABLE 1

Sieve No.	% Ret.	Adjusted % Ret.	Wt. in Grams (2200 gram sample)	Accumulative Total
2"	0			
1½"	2			
1"	3			
¾"	4	0		
½"	7	9 (7+2)	198	198
⅜"	6	8 (6+2)	176	374
¼"	9	12 (9+3)	264	638
#4	6	8 (6+2)	176	814
Pass #4	63	63	1386	2200
TOTAL	100	100	2200	

NOTE: *No change is made in the percentage of pass No. 4 material; this is always used at the same percentage in which it occurred in the original sample.*

or with the knuckles if the mechanical rammer is used.

(b) Compact this first layer with the rammer falling through a distance of 12 inches, moving the rammer to a different place each time so the whole surface is covered.

Method "C" requires 25 blows per layer.

Method "D" requires 56 blows per layer.

(c) Add another ⅓ portion of the dampened material and compact it as before.

(d) Add and compact the third and final layer. This last layer, when compacted, should extend up into the extension collar a short distance.

(e) Place the mold in the mixing pan and remove the collar so as to not crack or crumble the compacted specimen, then strike off the top of the specimen even with the top of the mold, using the steel straightedge. If any holes are left as rocks are scraped out, these holes shall be filled with fine material and smoothed off.

Calculations

6. The samples are weighed and calculations are as follows:

(a) Remove the base, wipe away any dirt from the mold and weigh the sample and mold to the nearest gram. Record the weight on the work card.

(b) Subtract the weight of the mold to obtain the wet weight of the sample in grams.

(c) Calculate the wet Density (D_w) in pounds per cu. ft. as follows:

Method C

D_w = wet wt. x 0.06614
= 1607 g. x 0.06614 = 106.3 lb./cu. ft.

$$\text{Where } 0.06614 = \frac{1}{\text{Vol. of 4" mold x 453.6 g./lb.}}$$

Method D

D_w = wet wt. x 0.02939
= 3617 g. x 0.02939 = 106.3 lb./cu. ft.

$$\text{Where } 0.02939 = \frac{1}{\text{Vol. of 6" mold x 453.6 g./lb.}}$$

(d) The approximate dry density of the sample (D_a) may be calculated as follows:

$$D_a = \frac{D_w}{100 + \%\text{ water added}} \times 100$$

Example:

Wet Density, D_w = 106.3 lb./cu. ft.
% Water added = 14
$D_a = \frac{106.3}{114} \times 100$ = 93.2 lb./cu. ft.

NOTE: *These densities are approximate only and will be corrected when final moisture results are obtained.*

The approximate dry density is useful in deciding how much water to add in later trial batches. For instance, if the 14% water in the example, shown on the previous page, gave a density of 93.2 lb. per cu. ft., and a later increase to 16% gave the same density of 93.2 lb. per cu. ft., then the next trial to be run should be dropped to 12% water. (This was tried and resulted in a compaction of 92.1 lb. per cu. ft., giving a curve which rose from 12% to 14% and fell away at 16%.) One or two additional samples with either 10% or 18% water added should be compacted, to aid in establishing the curve. By carefully observing the approximate dry density of the compacted samples, the operator should be able to vary the moisture content as the test proceeds so that when the final results are plotted a curve will result that rises to a peak and then recedes.

Moisture Determination

7. The percentage of moisture in the compacted samples is determined as follows:

(a) Break the compacted sample into small pieces, being careful to **lose none.** Dry the sample in an oven at 110° ±5° C to constant weight, and record the weight.

NOTE: *The "Speedy" Method is not applicable for moisture determinations.*

(b) Calculate the moisture content as follows:

$$\%\text{ Moisture} = \frac{W_w - W_d}{W_d} \times 100$$

Where:

W_w = weight of wet soil, g.
W_d = weight of dry soil, g.

Example:

$$\%\text{ Moisture} = \frac{322\text{ g.} - 286\text{ g.}}{286\text{ g.} - 22\text{ g.}} \times 100$$

$$= \frac{36\text{ g.}}{264\text{ g.}} \times 100 = 13.6\%$$

(c) The dry density in lb. per cu. ft. for each sample is calculated as follows:

$$D = \frac{D_w}{100 + \%\ \text{moisture}} \times 100$$

Where:

D = dry density of soil, lb./cu. ft.
D_w = wet density of soil, lb./cu. ft.

Example:

$$D = \frac{106.3\ \text{lb./cu. ft.}}{113.6} \times 100 = 93.6\ \text{lb./cu. ft.}$$

Maximum Density and Optimum Moisture

8. The optimum moisture is determined as follows:

(a) The results of all samples are plotted on graph paper, using the percentage of moisture as the horizontal axis and the dry weight per cubic foot as the vertical axis.

(b) Draw a curve through the resulting points. The peak of the curve represents the "Maximum Density", in pounds per cubic foot, and the percentage of water at the peak represents the "Optimum Moisture Content" necessary to produce maximum density when compacted under these conditions.

Figure 2 gives a typical example of the calculations involved.

METHOD "C & D" PROCTOR

EXAMPLE OF CALCULATIONS FOR ARIZ-226

a	b	c	d	e	f	g	h	i
Approx. % Water Added	Wet Weight of Mold & Soil(gm	Weight of Mold (gm.)	Wet weight of Soil (gm.)	Factor	Wet Density lb./cu. ft.	Approx. Dry Density lb./cuft.	Actual % Water Added	Actual Dry Density lb./cuft.
			(b-c) = d		(dxe) = f	$\frac{f}{100+a} \times 100 = g$	(From Moisture Chart Below)	$\frac{f}{100+h} \times 100 = i$
10	3335	1820	1515	0.06614	100.2	91.1	10.3	90.8
12	3380	1820	1560	0.06614	103.2	92.1	11.9	92.2
14	3427	1820	1607	0.06614	106.3	93.2	13.6	93.6
16	3455	1820	1635	0.06614	108.1	93.2	16.2	93.0
18	3453	1820	1633	0.06614	108.0	91.5	18.1	91.4
			(Factor for Method "D" = 0.02939)					

MOISTURE CHART

a	j	k	l	h
Approx. % Water Added	Wet Weight (gm.)	Dry Weight (gm.)	Weight Water (j-k)=l	Water Added $\frac{l}{k} \times 100 = h$
10	300	272	28	10.3
12	300	268	32	11.9
14	300	264	36	13.6
16	300	258	42	16.2
18	300	254	46	18.1

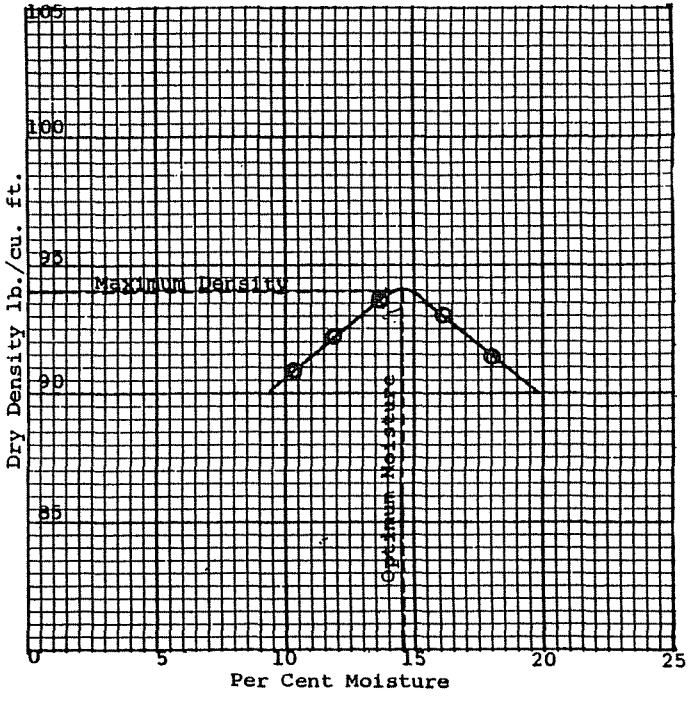

Fig. 2.