ADOT
Infrastructure Delivery and Operations

ARIZ 225d
November 13, 2019
(17 Pages)

MAXIMUM DRY DENSITY AND OPTIMUM MOISTURE OF SOILS BY PROCTOR METHOD A

(A Modification of AASHTO Designation T 99)

1. SCOPE

1.1 This test method describes the procedure for determining the maximum dry density and optimum moisture content for a soil by the Proctor Method A. Some materials may be more appropriately tested by Arizona Test Method 245, "Maximum Dry Density and Optimum Moisture of Soils by Proctor Alternate Method D ".

1.2 Method A may be used for all maximum dry density and optimum moisture content determinations except for volcanic cinders or light porous material on which the specific gravity cannot be determined with consistency or when the moisture absorption for the coarse aggregate is greater than 4.0%.

1.3 Method A may be used except when greater than 50% (60% for Aggregate Base) of the material is retained on the No. 4 sieve.

1.4 An example is provided in Figure 2 for the calculations and determinations referenced herein.

1.5 This test method may involve hazardous materials, operations, and equipment. This test method does not purport to address all of the safety problems associated with its use. It is the responsibility of whomever uses this test method to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

1.6 See Appendix A1 of the Materials Testing Manual for information regarding the procedure to be used for rounding numbers to the required degree of accuracy.

2. APPARATUS

2.1 Requirements for the frequency of equipment calibration and verification are found in Appendix A3 of the Materials Testing Manual.

2.2 4 inch proctor mold having a capacity of approximately 1/30 cubic foot, with an internal diameter of 4.000 plus 0.024 or minus 0.016 inches and a height of 4.584 plus 0.005 or minus 0.008 inches. The mold shall have a nominal wall thickness of 1/4 inch. It shall be equipped with an extension collar approximately 2-3/8 inches high. A baseplate as shown in Figure 1 shall be provided.

2.3 A hand or mechanical rammer weighing 5.50 $\pm$ 0.02 pounds, having a flat face, and equipped with a suitable arrangement to control the height of drop to a free fall of 12 $\pm$ 0.06 (1/16) inches above the elevation of the soil. The rammer face shall be circular with a diameter of 2.000 plus 0.010 or minus 0.015 inches. If a mechanical apparatus is used, it must be monitored through the ADOT proficiency sample program and maintain a rating of 3 or better based on the results of testing ADOT and AMRL proficiency samples.

2.4 Hard steel straightedge, at least 10 inches in length. It shall have one beveled edge, and at least one longitudinal surface (used for final trimming) shall be plane within 0.01 inch per 10 inches (0.1 percent) of length with the portion used for trimming the soil.

2.5 Scale or balance capable of measuring the maximum weight to be determined, accurate to at least one gram.

2.6 Scale or balance capable of measuring the maximum weight to be determined, accurate to at least 0.1 gram.

2.7 Oven capable of maintaining a temperature of 230 $\pm$ 9 °F.

2.8 No. 4 and 3 inch sieves conforming to the requirements of ASTM E11.

2.9 Miscellaneous mixing tools and pans.

2.10 Sample Extruder (optional) consisting of a jack, lever, frame, or other device for extruding the compacted sample from the mold.

3. CALIBRATION OF MOLD

3.1 Molds shall be calibrated in accordance with APPENDIX A of this procedure.

4. SAMPLE

4.1 Enough soil material shall be provided from the field to make five compacted specimens. A minimum sample size of 20,000 grams (approximately 45 lbs.) is normally required.

4.2 If the soil sample is damp when received from the field, dry it until it becomes friable under a trowel. Drying may be in air or by use of a slow fan or other drying apparatus such that the temperature of the sample does not exceed 140 °F.

4.3 Thoroughly break up the aggregations in such a manner as to avoid reducing the natural size of individual particles.

4.4 Weigh out an approximate 20,000 gram sample of representative soil. Record the weight of the sample, and sieve the material over a No. 4 sieve. If the percentage of coarse aggregate or rock retained on the No. 4 sieve is not already known from gradation testing, save any material retained on the No. 4 sieve and weigh. Calculate the percent of coarse aggregate or rock particles retained on the No. 4 sieve according to the following equation:

$$PR4 = \frac{WR4}{WT} \times 100$$

Where:
- PR4 = Percentage of coarse aggregate or rock particles retained on the No. 4 sieve
- WR4 = Weight of coarse aggregate or rock particles retained on the No. 4 sieve
- WT = Total weight of material sieved

4.5 If "PR4" is greater than 50% (60% for Aggregate Base), Alternate Method D, Arizona Test Method 245, shall be used to determine the maximum dry density. If "PR4" is less than or equal to 50% (60% for Aggregate Base), blend material passing the No. 4 sieve thoroughly and proceed to Section 5 of this test method. If a specific gravity and absorption determination, in accordance with AASHTO T 85, is to be made for the plus No. 4 material, save an adequate amount of this material, otherwise, discard it.

5. PROCEDURE

5.1 From the thoroughly blended passing No. 4 material from Subsection 4.5, split out 5 representative approximate 2500 gram samples.

5.2 Select one sample and thoroughly mix with sufficient water to dampen it to approximately three percentage points below optimum moisture content.

Note: If desired, an additional three samples may be mixed at this time with approximate moisture contents of 1% below optimum, 1% over optimum, and 3% over optimum. The moisture in each of these samples shall be retained by covering with a damp cloth or being sealed in air tight containers until they are compacted. One of the five samples should be retained for future use since it is necessary to have at least two points defined on each side of the moisture-density curve.

5.3 Heavy clay soils or materials which tend to break down, or those in which it is difficult to incorporate water, shall require approximately 12 hours for uniform moisture absorption to be achieved. This shall be accomplished by preparing separate samples for each increment of water to be added, and then placing and sealing these samples in air tight containers for the 12-hour period.

5.4 Form a specimen by compacting the prepared soil in the four inch mold (with extension collar attached) in three equal layers to give a total compacted depth of about 5 inches. Compact each layer with 25 uniformly distributed blows from the rammer, dropping free from a height of 12 inches. While each layer is being compacted, the remainder of material shall be in a pan covered by a damp cloth. During compaction, the mold shall rest firmly on a dense, uniform, rigid and stable foundation.

Note: Each of the following has been found to be a satisfactory base on which to rest the mold during compaction of the soil: A block of concrete, weighing not less than 200 lbs., supported by a stable foundation; a sound concrete floor; and for field application, such surfaces as found in concrete box culverts, bridges, and pavements.

5.5 When compacting granular, free-draining materials, at moisture contents which are at or above optimum, the mold shall be prepared by first sealing the bottom of the mold with waterproofing grease. All excess grease shall be wiped from the mold and baseplate.

5.6 Following compaction, carefully remove the extension collar. It may be necessary to use a follower to retain the soil in the mold while removing the collar to prevent damage or disturbance of the soil below the top of the mold. Carefully trim the compacted soil even with the top of the mold by means of the straightedge. If any voids are created during trimming, these shall be filled with fine material and smoothed off. Determine the weight of compacted specimen and mold. Determine the wet density, "WD", of the compacted soil by the following:

$$WD = \frac{M1 - M2}{VM \times 453.6 \text{ (grams/lb.)}}$$

Where: WD = Wet density of compacted soil, lb./cu. ft.
M1 = Weight of compacted specimen and mold, grams
M2 = Weight of the mold, grams
VM = Volume of the mold, cu. ft. (See Section 3 of this procedure.)

5.7 The estimated dry density, "ED", of the compacted soil may be calculated and recorded to the nearest 0.1 lb./cu. ft. as follows:

$$ED = \frac{WD}{\text{(Approx. \% of water added)} + 100} \times 100$$

Where: ED = Estimated dry density of compacted soil, lb./cu. ft.
WD = Wet density of compacted soil, lb./cu. ft.

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

5.8 The estimated dry density is useful in deciding how much water to add in later trial batches, if the procedure described in the note following Subsection 5.2, for initially preparing three additional samples with varying moisture contents is not utilized. By carefully observing the estimated 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 moisture-density results are plotted, a curve will result that rises to a peak and then falls away.

5.9 Remove the material from the mold and slice vertically through the center. Take a representative minimum 300 gram sample from the full length and width of one of the cut faces. Weigh immediately, and dry to a constant weight in an oven at 230 ± 9 °F to determine the moisture content in accordance with AASHTO T 265. Record the weight of wet soil to the nearest 0.1 gram as "WW", and record the weight of oven dry soil to the nearest 0.1 gram as "DW".

5.10 For granular, free-draining materials, the moisture content shall be determined using the entire compacted proctor specimen. Determine the weight of wet soil, "WW", by subtracting the weight of the mold, "M2", from the weight of compacted specimen and mold, "M1". Record the weight of wet soil, "WW", and the weight of oven dry soil, "DW", to at least the nearest gram. All clinging material shall be removed from the inside of the mold and included with the specimen. To facilitate drying, the specimen may be broken up and spread out in a large pan, being careful to not lose any soil particles.

5.11 Select another of the samples which was split in Subsection 5.1, and if not already done, thoroughly mix with water in sufficient amount to increase the moisture content by approximately two percentage points.

5.12 Repeat the procedure in Subsections 5.3 through 5.10 for the sample at each moisture content, as necessary to establish a moisture-density curve which rises to a peak and then falls away.

6. CALCULATIONS

6.1 Calculate percent moisture and record to the nearest 0.1 percent by the following:

$$\%\ \text{Moisture} = \frac{\text{WW - DW}}{\text{DW}} \times 100$$

Where: WW = weight of wet soil, grams
DW = weight of oven dry soil, grams

6.2 Calculate dry density and record to the nearest 0.1 lb./cu. ft. by the following:

$$DD = \frac{WD}{\%\ Moisture + 100} \times 100$$

Where: DD = Dry density of compacted soil, lb./cu. ft.
WD = Wet density of compacted soil, lb./cu. ft.

7. MOISTURE-DENSITY RELATIONSHIP

7.1 The percent moisture and corresponding dry density for each of the compacted soil specimens shall be plotted on the graph provided on the proctor density test form shown in Figure 3. For a good plot, the majority of the graph is utilized. Normally, three increments on the horizontal axis shall equal one percent of moisture, and three increments on the vertical axis shall equal one lb./cu. ft. of dry density. If another number of increments other than three is utilized, the number of increments for one percent moisture and one lb./cu. ft. dry density shall always be the same.

7.2 On each side of the maximum density curve, at least two points should be utilized to form two straight lines. The intersection point of these two lines defines the peak point of the density-moisture content relationship, or the maximum density and optimum moisture content for the soil. In general it will be found that higher unit mass soils assume steeper slopes with high maximum dry densities at low optimum moisture contents, while the lower unit mass soils assume flatter, more gently sloped lines with high optimum moisture contents and low maximum dry densities. Figure 4 gives examples of moisture-density plots which show the different slopes associated with different maximum dry density ranges.

7.3 Optimum moisture content - The percent moisture content corresponding to the peak (intersection point of the two lines) of the moisture-density curve shall be termed the "optimum moisture content", and shall be reported as "OM" to the nearest 0.1 percent.

7.4 Maximum dry density - The dry density at optimum moisture content corresponding to the peak (intersection point of the two lines) of the moisture-density curve shall be termed the "maximum dry density", and shall be reported as "MD" to the nearest 0.1 lb./cu. ft.

Note: The optimum moisture and maximum dry density determinations above are for the material passing the No. 4 sieve. When testing field samples for comparison to proctor optimum moisture and maximum dry density, a correction to the proctor optimum moisture and maximum dry density must be made, in accordance with ARIZ 227, for the percent rock which the field sample contains.

8. REPORT

8.1 Record the moisture and density data on the laboratory test form along with the laboratory number, material source and type, and other information required. A blank laboratory test form is provided in Figure 3.

APPENDIX A

CALIBRATION OF PROCTOR MOLDS

1. CALIBRATION

1.1 Molds shall be calibrated at least once a year, or sooner if there is reason to question the accuracy of the calibration.

1.2 Lightly coat the bottom of the mold with a waterproofing grease. (Dow Corning High Vacuum Grease, or similar, has proven satisfactory for this application.) For split molds, waterproofing grease is also necessary on the edges of the split mold halves which join together.

1.3 Fit mold into baseplate and secure snugly into place.

1.4 Wipe excess grease from the mold and the baseplate.

1.5 Record weight of baseplate, empty mold, and glass plate to at least the nearest 0.1 gram.

Note: An example which illustrates the recording of calibration data and calculations is shown in Figure 5. Figure 6 is a blank calibration form.

1.6 With the mold and baseplate assembly on a flat and level surface fill the mold with distilled water at room temperature 77 ± 9 °F.

1.7 Determine and record the temperature of the water to the nearest one degree Fahrenheit.

1.8 With a small rod, remove any air bubbles that may be clinging to the sides or bottom of the mold. Add additional water to completely fill the mold, using a glass plate in such a way to ensure accurate filling of the mold, eliminating air bubbles and excess water. Check bottom of mold to assure there is no leakage.

1.9 Dry the base plate, glass and outside of mold with a dry, absorbent cloth. Care must be taken to not lose water from inside of mold during drying. Record weight of baseplate, mold filled with water, and glass plate to at least the nearest 0.1 gram.

APPENDIX A - (Continued)

1.10 Determine the weight of water to fill mold by subtracting the weight of baseplate, empty mold, and glass plate from the weight of the baseplate, mold filled with water, and glass plate.

1.11 For the temperature of the water, determine its corresponding unit weight from the table below.

Temperature	**Unit Weight of Water**
Temp °F	**lbs/cu. Ft.**
68	62.315
69	62.308
70	62.301
71	62.293
72	62.285
73	62.277
74	62.269
75	62.261
76	62.252
77	62.243
78	62.234
79	62.225
80	62.216
81	62.206
82	62.196
83	62.186
84	62.176
85	62.166
86	62.155

1.12 Calculate the volume of the mold, in cu. ft., as shown on the calibration form in Figures 5 and 6, and record to the nearest four decimal places.

1.13 Thoroughly clean grease from the mold and base plate. On the mold, record the identification of the mold, the date of calibration, and the volume of the mold.

1.14 Documentation of the calibration data shall be kept on file.

2. REQUIRED DOCUMENTATION

2.1 Record of weights, temperatures, and calculations required in the calibration procedure.

2.2 Identification of mold.

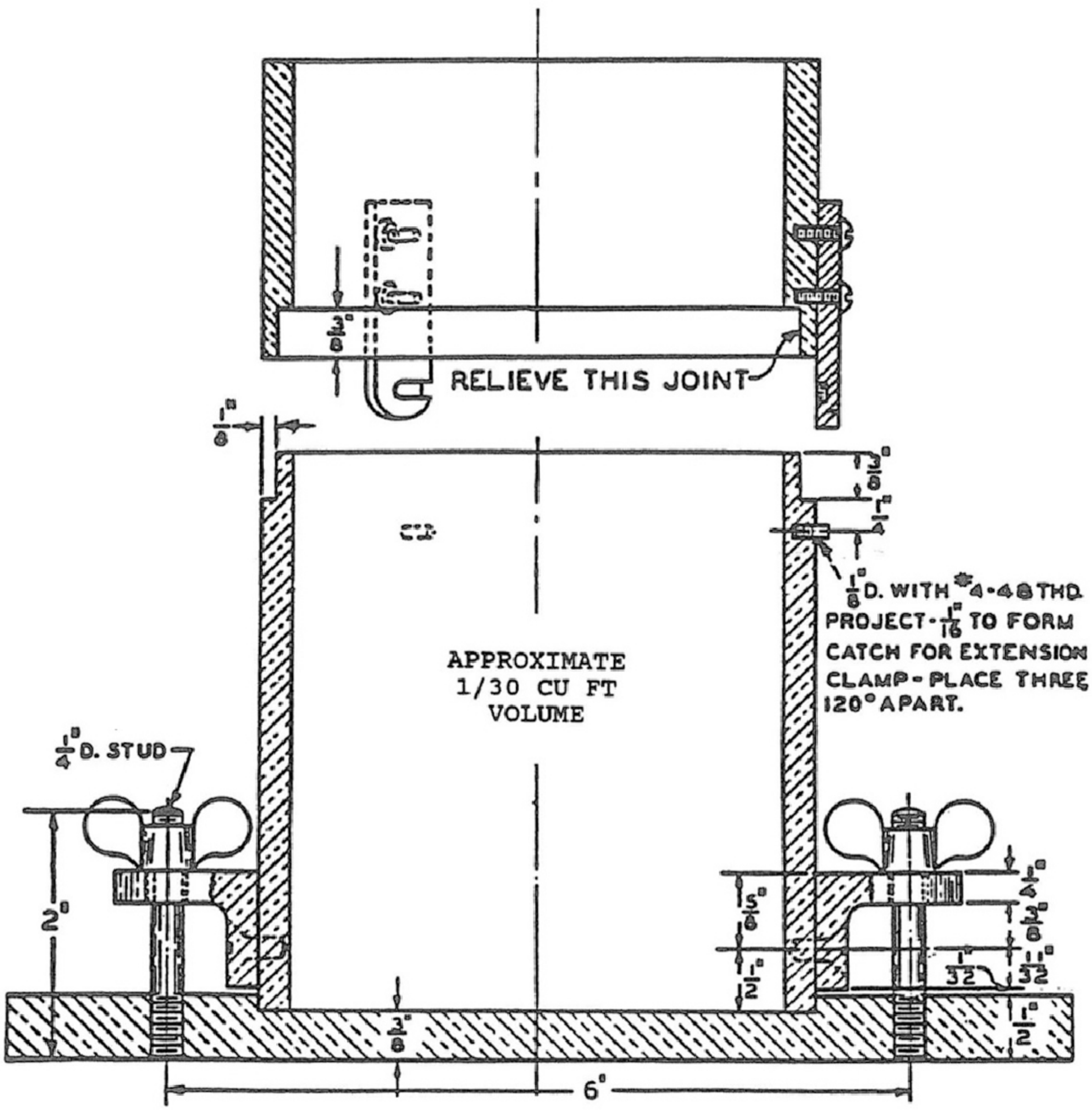
2.3 Date of calibration.

2.4 Volume of the mold.

2.5 Operator performing calibration.

2.6 Supervisor check of calibration data.

2.7 Date of calibration expiration.



CYLINDRICAL MOLD, COLLAR,
AND BASEPLATE
(4 INCH MOLD)

FIGURE 1

Arizona Department of Transportation
METHOD A or **ALTERNATE METHOD D** PROCTOR DENSITY
(Arizona Test Method 225 or 245)

TRACS No: H999901C Lab No: ______ Rec'd Date: 08/15/2015
Source and Type of Material: ______
Proctor Method Used: **Method A** ✓ or **Alternate Method D** ______
Test Operator and Date: ______ Supervisor and Date: ______

Weight of Mold = **M2** = 1970 grams | Volume of Mold = **VM** = 0.0336 cu. ft. | **a** = VM x 453.6 = 15.2410

b	M1	c	WD	ED	WW	DW	d	e	DD
					Moisture Determination				
Approx % of water Added	Wt. of Sample and Mold	Wet Wt. of Sample M1 - M2	Wet Density lb/ cu ft c / a	Est. Dry Density WD x 100 / b + 100	Wet Wt. of Moisture Sample	Dry Wt. of Moisture Sample	Wt. of Water WW - DW	Percent Moisture d x 100 / DW	Dry Density lb/cu ft WD x 100 / e + 100
11	3884	1914	125.6	113.2	354.6	318.9	35.7	11.2	112.9
13	3955	1985	130.2	115.2	320.1	283.8	36.3	12.8	115.4
15	3995	2025	132.9	115.6	410.6	356.7	53.9	15.1	115.5
17	3986	2016	132.3	113.1	344.6	293.8	50.8	17.3	112.8

METHOD A

WT = 21556 WR4 = 4462

PR4 = WR4 / WT x 100 = 21 %

ALTERNATE METHOD D

WT = ______ WR 3/4 = ______

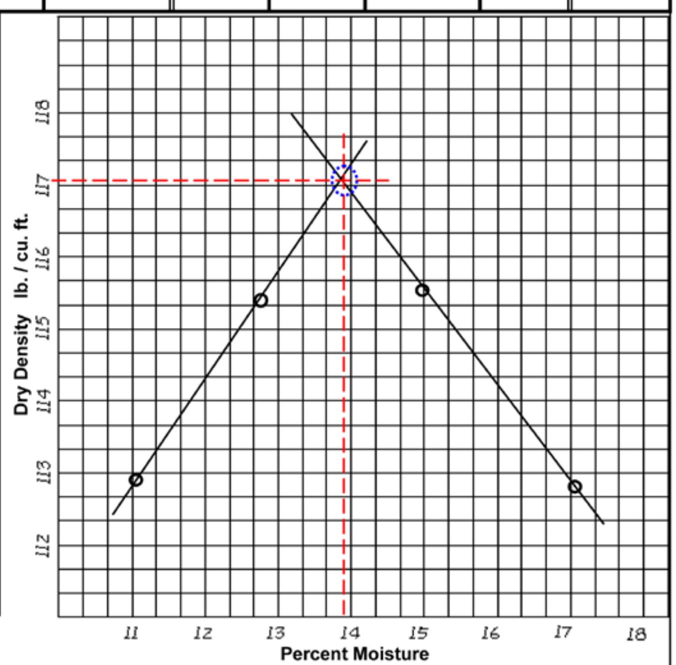
PR 3/4 = WR 3/4 / WT x 100 = ______ %

Coarse Aggregate Bulk Oven Dry Specific Gravity: 2.476

Coarse Aggregate Absorption: 1.83 %

OPTIMUM MOISTURE CONTENT = OM = 13.9 %

MAXIMUM DRY DENSITY (lb. / cu. ft.) = MD = 117.1



Remarks: ______

44-1002 Rev 11/15

FIGURE 2

Arizona Department of Transportation
METHOD A or **ALTERNATE METHOD D** PROCTOR DENSITY
(Arizona Test Method 225 or 245)

Project No: ____________ Lab No : ____________ Rec'd Date: ____________

Source and Type of Material : ____________

Proctor Method Used : **Method A** ____________ or **Alternate Method D** ____________

Test Operator and Date : ____________ Supervisor and Date: ____________

Weight of Mold = **M2** = ______ grams	Volume of Mold = **VM** = ______ cu. ft.	a = VM x 453.6 = ______

b	M1	c	WD	ED	Moisture Determination: WW	DW	d	e	DD
Approx % of water Added	Wt. of Sample and Mold	Wet Wt. of Sample **M1 - M2**	Wet Density lb/ cu ft **c** / **a**	Est. Dry Density WD x 100 / **b** + 100	Wet Wt. of Moisture Sample	Dry Wt. of Moisture Sample	Wt. of Water **WW - DW**	Percent Moisture **d** x 100 / **DW**	Dry Density lb/cu ft **WD** x 100 / **e** + 100

METHOD A

WT = ______ WR4 = ______

PR4 = WR4 / WT x 100 = ______ %

ALTERNATE METHOD D

WT = ______ WR 3/4 = ______

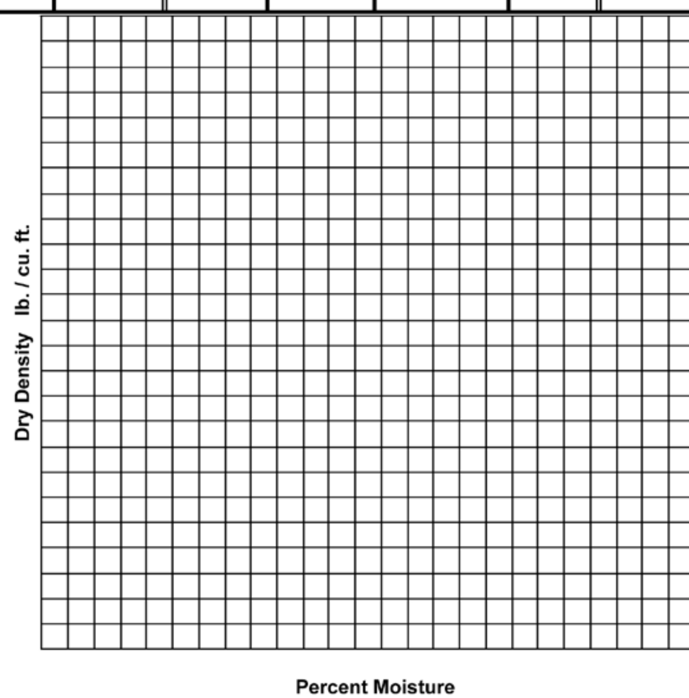
PR 3/4 = WR 3/4 / WT x 100 = ______ %

Coarse Aggregate Bulk Oven Dry Specific Gravity : ______

Coarse Aggregate Absorption : ______ %

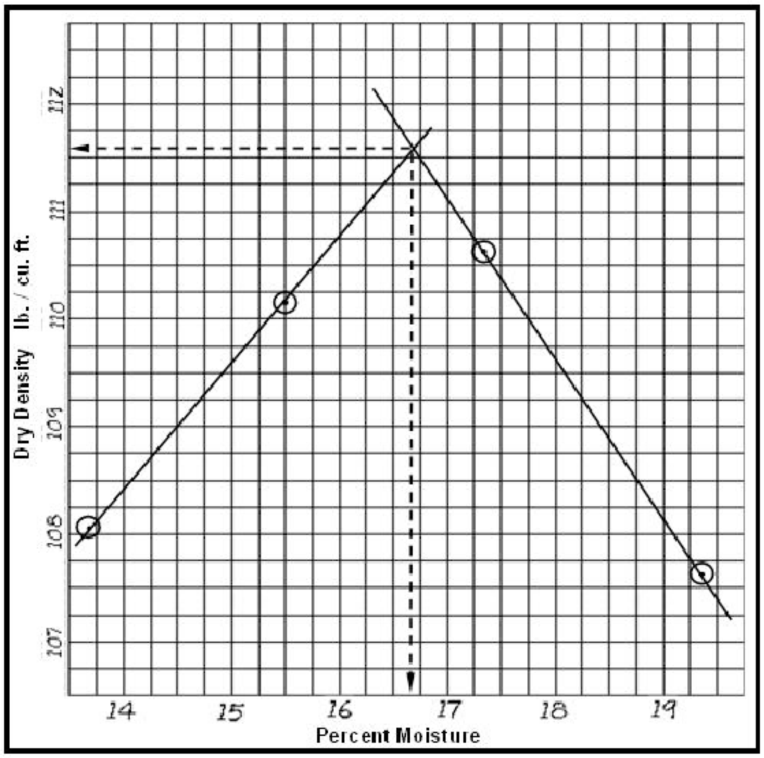
OPTIMUM MOISTURE CONTENT = OM = ______ %

MAXIMUM DRY DENSITY (lb. / cu. ft.) = MD = ______



Remarks : ____________

FIGURE 3



CLAYEY SAND

% Moisture	Dry Density
13.7	108.1
15.5	110.2
17.3	110.6
19.4	107.6

Maximum Density = 111.6 lb/cu ft
Optimum Moisture = 16.7%

FINE CLAY

% Moisture	Dry Density
21.2	94.5
22.3	95.8
25.2	95.1
27.8	93.1

Maximum Density = 96.7 lb/cu ft
Optimum Moisture = 23.1%

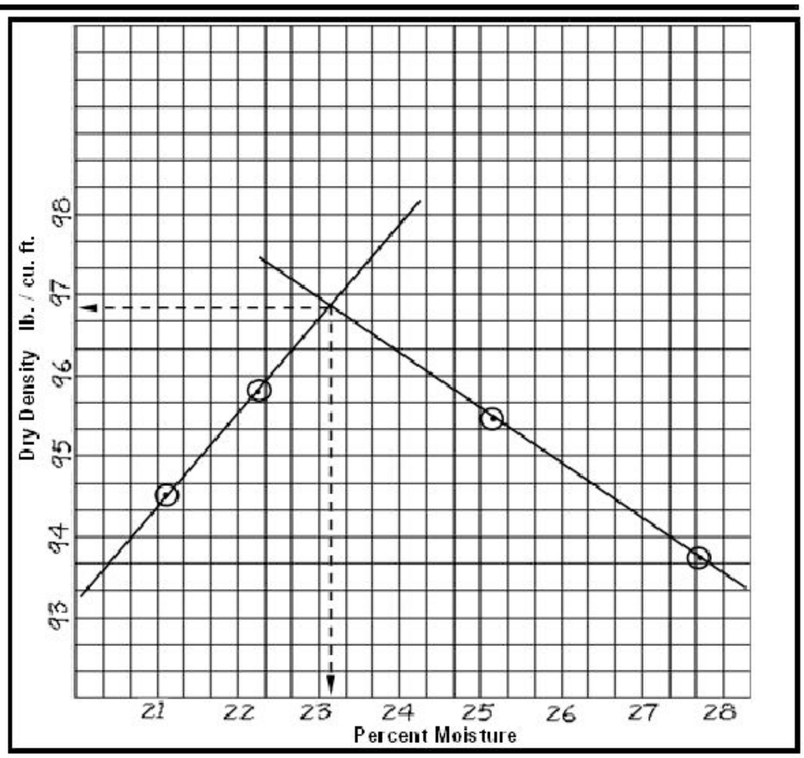


FIGURE 4

ARIZONA DEPARTMENT OF TRANSPORTATION

CALIBRATION OF PROCTOR MOLD
ARIZ 225 Appendix A

__✓__ Four Inch Mold ______ Six Inch Mold Mold I. D. #: __4A__

Calibration Date: __08/15/15__ Calibration Expiration Date: __08/15/16__

Temperature of water used for Calibration: __73__ ° F

Unit Weight of Water: __62.277__ lb. /cu. ft.

Test Operator: __Joe Tester__ Supervisor and Date: __Joe Supervisor 08/17/15__

Weight of Baseplate, Empty Mold, and Glass Plate (grams)	Weight of Baseplate, Mold Filled with Water, and Glass Plate (grams)	Weight of Water to Fill Mold (grams)
4458.7	5407.9	949.2

$$V = \left[\begin{array}{c}\text{Volume of}\\ \text{Mold}\\ \text{(cu. ft.)}\end{array}\right] = \frac{\text{Weight of Water to Fill Mold (grams)}}{\left[\begin{array}{c}\text{Unit Weight}\\ \text{of Water}\\ \text{(lb. / cu. ft.}\end{array}\right] \times [453.6\ \text{(grams / lb.)}]}$$

$$V = \frac{(\ 949.2\ )}{(\ 62.277\ ) \times (\ 453.6\ )} = 0.0336 \text{ cu. ft.}$$

0.033601371

REMARKS: ______________________________

Unit Weight of Water Table

Temp °F	lbs/cu. Ft.	Temp °F	lbs/cu. Ft.
68	62.315	77	62.243
69	62.308	78	62.234
70	62.301	79	62.225
71	62.293	80	62.216
72	62.285	81	62.206
73	62.277	82	62.196
74	62.269	83	62.186
75	62.261	84	62.176
76	62.252	85	62.166
		86	62.155

FIGURE 5

ARIZONA DEPARTMENT OF TRANSPORTATION

CALIBRATION OF PROCTOR MOLD
ARIZ 225 Appendix A

______ Four Inch Mold ______ Six Inch Mold Mold I. D. #: ____________

Calibration Date: ____________ Calibration Expiration Date: ____________

Temperature of water used for Calibration: ________ ° F

Unit Weight of Water: ____________ lb. /cu. ft.

Test Operator: ____________________ Supervisor and Date: ____________________

Weight of Baseplate, Empty Mold, and Glass Plate (grams)	Weight of Baseplate, Mold Filled with Water, and Glass Plate (grams)	Weight of Water to Fill Mold (grams)

$$V = \begin{bmatrix}\text{Volume of} \\ \text{Mold} \\ \text{(cu. ft.)}\end{bmatrix} = \frac{\text{Weight of Water to Fill Mold (grams)}}{\begin{bmatrix}\text{Unit Weight} \\ \text{of Water} \\ \text{(lb. / cu. ft.}\end{bmatrix} \text{X} \left[453.6 \text{ (grams / lb.)}\right]}$$

$$V = \frac{(\qquad\qquad\qquad)}{(\qquad\qquad) \text{ X } (\qquad\qquad)} = \underline{\qquad\qquad} \text{ cu. ft.}$$

REMARKS: ____

Unit Weight of Water Table

Temp °F	lbs/cu. Ft.
68	62.315
69	62.308
70	62.301
71	62.293
72	62.285
73	62.277
74	62.269
75	62.261
76	62.252

Temp °F	lbs/cu. Ft.
77	62.243
78	62.234
79	62.225
80	62.216
81	62.206
82	62.196
83	62.186
84	62.176
85	62.166
86	62.155

FIGURE 6