EXPERIMENT 9

MOISTURE-DENSITY RELATION (COMPACTION) TEST

Purpose:

This laboratory test is performed to determine the relationship between the moisture content and the dry density of a soil for a specified compactive effort. The compactive effort is the amount of mechanical energy that is applied to the soil mass. Several different methods are used to compact soil in the field, and some examples include tamping, kneading, vibration, and static load compaction. This laboratory will employ the tamping or impact compaction method using the type of equipment and methodology developed by R. R. Proctor in 1933, therefore, the test is also known as the Proctor test.

Two types of compaction tests are routinely performed: (1) The Standard Proctor Test, and (2) The Modified Proctor Test. Each of these tests can be performed in three different methods as outlined in the attached Table 1. In the Standard Proctor Test, the soil is compacted by a 5.5 lb hammer falling a distance of one foot into a soil filled mold. The mold is filled with three equal layers of soil, and each layer is subjected to 25 drops of the hammer. The Modified Proctor Test is identical to the Standard Proctor Test except it employs, a 10 lb hammer falling a distance of 18 inches, and uses five equal layers of soil instead of three. There are two types of compaction molds used for testing. The smaller type is 4 inches in diameter and has a volume of about 1/30 ft^3 (944 cm^3), and the larger type is 6 inches in diameter and has a volume of about 1/13.333 ft^3 (2123 cm^3). If the larger mold is used each soil layer must receive 56 blows instead of 25 (See Table 1).

Table 1 Alternative Proctor Test Methods

	Standard Proctor ASTM 698			Modified Proctor ASTM 1557		
	Method A	Method B	Method C	Method A	Method B	Method C
Material	≤20% Retained on No.4 Sieve	>20% Retained on No.4 ≤20% Retained on 3/8" Sieve	>20% Retained on No.3/8" <30% Retained on 3/4" Sieve	≤20% Retained on No.4 Sieve	>20% Retained on No.4 ≤20% Retained on 3/8" Sieve	>20% Retained on No.3/8" <30% Retained on 3/4" Sieve
For test sample, use soil passing	Sieve No.4	3/8" Sieve	¾" Sieve	Sieve No.4	3/8" Sieve	¾" Sieve
Mold	4" DIA	4" DIA	6" DIA	4" DIA	4" DIA	6" DIA
No. of Layers	3	3	3	5	5	5
No. of blows/layer	25	25	56	25	25	56

Note: Volume of 4" diameter mold = 944 cm^3 , Volume of 6" diameter mold = 2123 cm^3
(verify these values prior to testing)

Standard Reference:

ASTM D 698 - Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbs/ft^3 (600 KN-m/m^3))

ASTM D 1557 - Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbs/ft^3 (2,700 KN-m/m^3))

Significance:

Mechanical compaction is one of the most common and cost effective means of stabilizing soils. An extremely important task of geotechnical engineers is the performance and analysis of field control tests to assure that compacted fills are meeting the prescribed design specifications. Design specifications usually state the required density (as a percentage of the “maximum” density measured in a standard laboratory test), and the water content. In general, most engineering properties, such as the strength, stiffness, resistance to shrinkage, and imperviousness of the soil, will improve by increasing the soil density.

The optimum water content is the water content that results in the greatest density for a specified compactive effort. Compacting at water contents higher than (wet of) the optimum water content results in a relatively dispersed soil structure (parallel particle orientations) that is weaker, more ductile, less pervious, softer, more susceptible to shrinking, and less susceptible to swelling than soil compacted dry of optimum to the same density. The soil compacted lower than (dry of) the optimum water content typically results in a flocculated soil structure (random particle orientations) that has the opposite characteristics of the soil compacted wet of the optimum water content to the same density.

Equipment:

Molds, Manual rammer, Extruder, Balance, Drying oven, Mixing pan, Trowel, #4 sieve, Moisture cans, Graduated cylinder, Straight Edge.


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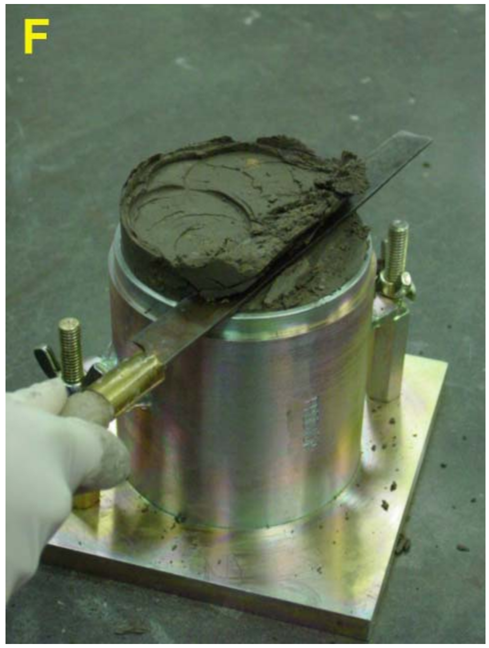
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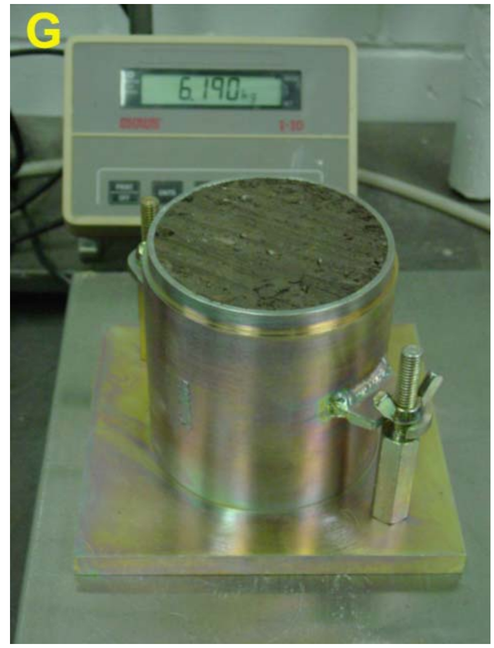
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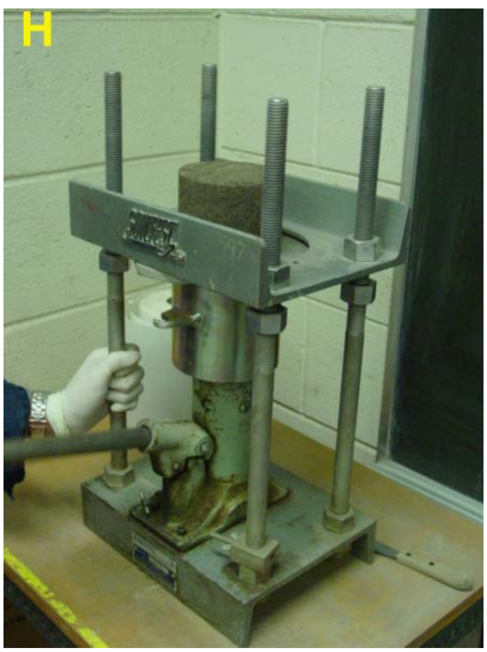
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Test Procedure:

(1) Depending on the type of mold you are using obtain a sufficient quantity of air-dried soil in large mixing pan. For the 4-inch mold take approximately 10 lbs, and for the 6-inch mold take roughly 15 lbs. Pulverize the soil and run it through the # 4 sieve.

(2) Determine the weight of the soil sample as well as the weight of the compaction mold with its base (without the collar) by using the balance and record the weights.

(3) Compute the amount of initial water to add by the following method:

(a) Assume water content for the first test to be 8 percent.

(b) Compute water to add from the following equation:

$$\text{water to add (in ml)} = \frac{(\text{soil mass in grams})8}{100}$$

Where "water to add" and the "soil mass" are in grams. Remember that a gram of water is equal to approximately one milliliter of water.

(4) Measure out the water, add it to the soil, and then mix it thoroughly into the soil using the trowel until the soil gets a uniform color (See Photos B and C).

(5) Assemble the compaction mold to the base, place some soil in the mold and compact the soil in the number of equal layers specified by the type of compaction method employed (See Photos D and E). The number of drops of the rammer per layer is also dependent upon the type of mold used (See Table 1). The drops should be applied at a uniform rate not exceeding around 1.5 seconds per

drop, and the rammer should provide uniform coverage of the specimen surface. Try to avoid rebound of the rammer from the top of the guide sleeve.

(6) The soil should completely fill the cylinder and the last compacted layer must extend slightly above the collar joint. If the soil is below the collar joint at the completion of the drops, the test point must be repeated. (Note: For the last layer, watch carefully, and add more soil after about 10 drops if it appears that the soil will be compacted below the collar joint.)

(7) Carefully remove the collar and trim off the compacted soil so that it is completely even with the top of the mold using the trowel. Replace small bits of soil that may fall out during the trimming process (See Photo F).

(8) Weigh the compacted soil while it's in the mold and to the base, and record the mass (See Photo G). Determine the wet mass of the soil by subtracting the weight of the mold and base.

(9) Remove the soil from the mold using a mechanical extruder (See Photo H) and take soil moisture content samples from the top and bottom of the specimen (See Photo I). Fill the moisture cans with soil and determine the water content.

(10) Place the soil specimen in the large tray and break up the soil until it appears visually as if it will pass through the # 4 sieve, add 2 percent more water based on the original sample mass, and re-mix as in step 4. Repeat steps 5 through 9 until, based on wet mass, a peak

value is reached followed by two slightly lesser compacted soil masses.

Analysis:

(1) Calculate the moisture content of each compacted soil specimen by using the average of the two water contents.

(2) Compute the wet density in grams per cm^3 of the compacted soil sample by dividing the wet mass by the volume of the mold used.

(3) Compute the dry density using the wet density and the water content determined in step 1. Use the following formula:

$$\rho_d = \frac{\rho}{1+w}$$

where: w = moisture content in percent divided by 100, and ρ = wet density in grams per cm^3.

(4) Plot the dry density values on the y-axis and the moisture contents on the x-axis. Draw a smooth curve connecting the plotted points.

(5) On the same graph draw a curve of complete saturation or “zero air voids curve”. The values of dry density and corresponding moisture contents for plotting the curve can be computed from the following equation:

$$w_{sat} = \left(\frac{\rho_w}{\rho_d} - \frac{1}{G_s}\right) \times 100$$

or

$$\rho_d = \frac{\rho_w}{\left(\frac{w}{100} + \frac{1}{Gs}\right)}$$

where:

ρ_d = dry density of soil grams per cm^3

G_s = specific gravity of the soil being tested (assume 2.70 if not given)

ρ_w = density of water in grams per cm^3 (approximately1 g/cm^3)

w_{sat} = moisture content in percent for complete saturation.

Example Calculations:

G_s=2.7 (assumed)

ρ_w=1.0 g/cm^3

Assumed w_{sat}%	Calculated ρ_d (g/cm^3)
8	2.22
10	2.13
12	2.04
14	1.96
16	1.89
18	1.82

(6) Identify and report the optimum moisture content and the maximum dry density. Make sure that you have recorded the method of compaction used (e.g., Standard Proctor, Method A) on data sheet.

EXAMPLE DATA

Moisture-Density (Compaction) Test

Data Sheets

Test Method: Standard Proctor, Method A (ASTM 698)

Date Tested: October 05, 2002

Tested By: CEMM315 Class, Group A

Project Name: CEMM315 Lab

Sample Number: Bag-1, 2'-6'

Visual Classification of Soil: Gray silty clay, trace fine sand, low plasticity, moist, CL

Water Content Determination:

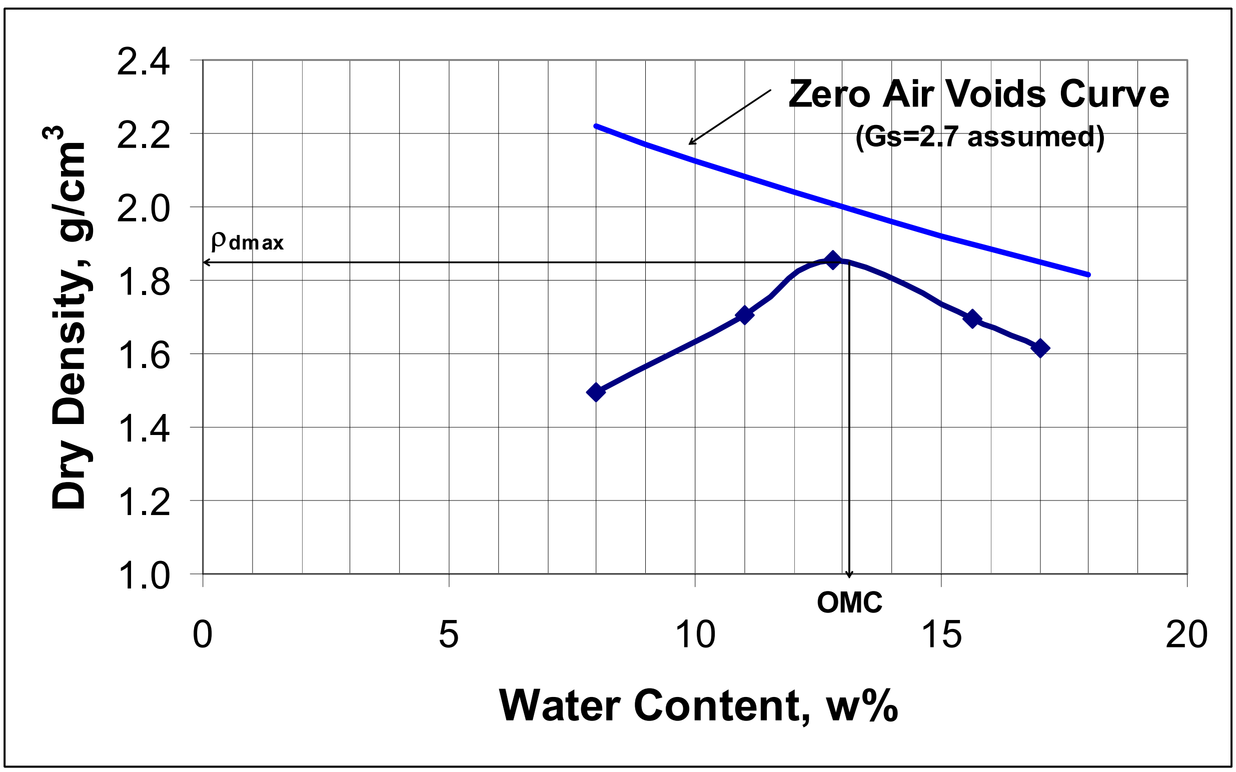
Compacted Soil - Sample no.	1		2		3	
Water content - Sample no.	1A	1B	2A	2B	3A	3B
Moisture can number - Lid number	1	2	3	4	5	6
M_C = Mass of empty, clean can + lid (grams)	7.78	7.83	7.71	7.9	7.5	7.9
M_{CMS} = Mass of can, lid, and moist soil (grams)	11.78	11.05	10.71	11 . 1	10.7	12 .0
M_{CDS} = Mass of can, lid, and dry soil (grams)	11.48	10.81	10.41	10.75	10.3	11.52
M_S = Mass of soil solids (grams)	3.70	2.98	2.7	2.85	2.84	3.62
M_W = Mass of pore water (grams)	0.29	0.24	0.30	0.35	0.40	0.53
w = Water content, w%	7.9	8.1	11 . 1	10.9	12.5	13.1

Compacted Soil - Sample no.	4		5		6	
Water content - Sample no.	4A	4B	5A	5B	6A	6B
Moisture can number - Lid number	7	8	9	10		
M_C = Mass of empty, clean can + lid (grams)	8.1	7.6	7.7	7.65		
M_{CMS} = Mass of can, lid, and moist soil (grams)	11. 1	10.2	10.3	10.33		
M_{CDS} = Mass of can, lid, and dry soil (grams)	10.70	9.84	10.02	9.92		
M_S = Mass of soil solids (grams)	2.60	2.24	2.32	2.27		
M_W = Mass of pore water (grams)	0.40	0.35	0.4	0.39		
w = Water content, w%	15.3	16.0	17. 1	17.6		

Density Determination:

Mold Volume=944 cm^3

Compacted Soil - Sample no.	1	2	3	4	5	6
w = Assumed water content, w%	10	12	14	16	18	
Actual average water content, w%	8.0	11.0	12.8	15.65	17	
Mass of compacted soil and mold (grams)	3457.2	3721.2	3909.0	3782.5	3715.2	
Mass of mold (grams)	1933	1933	1976.0	1849.5	1782.2	
Wet mass of soil in mold (grams)	1524.2	1788.2	2176	2149	2082	
Wet density, ρ , (g/cm^3)	1.615	1.894	2.093	1.959	1.888	
Dry density, ρ_d , (g/cm^3)	1.50	1.71	1.86	1.69	1.61	



Optimum Moisture Content = 13.1 %

Maximum Dry Density = 1.87 g/cm^3

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Moisture-Density (Compaction) Test

Data Sheets

Test Method:

Date Tested:

Tested By:

Project Name:

Sample Number:

Visual Classification of Soil:

Water Content Determination:

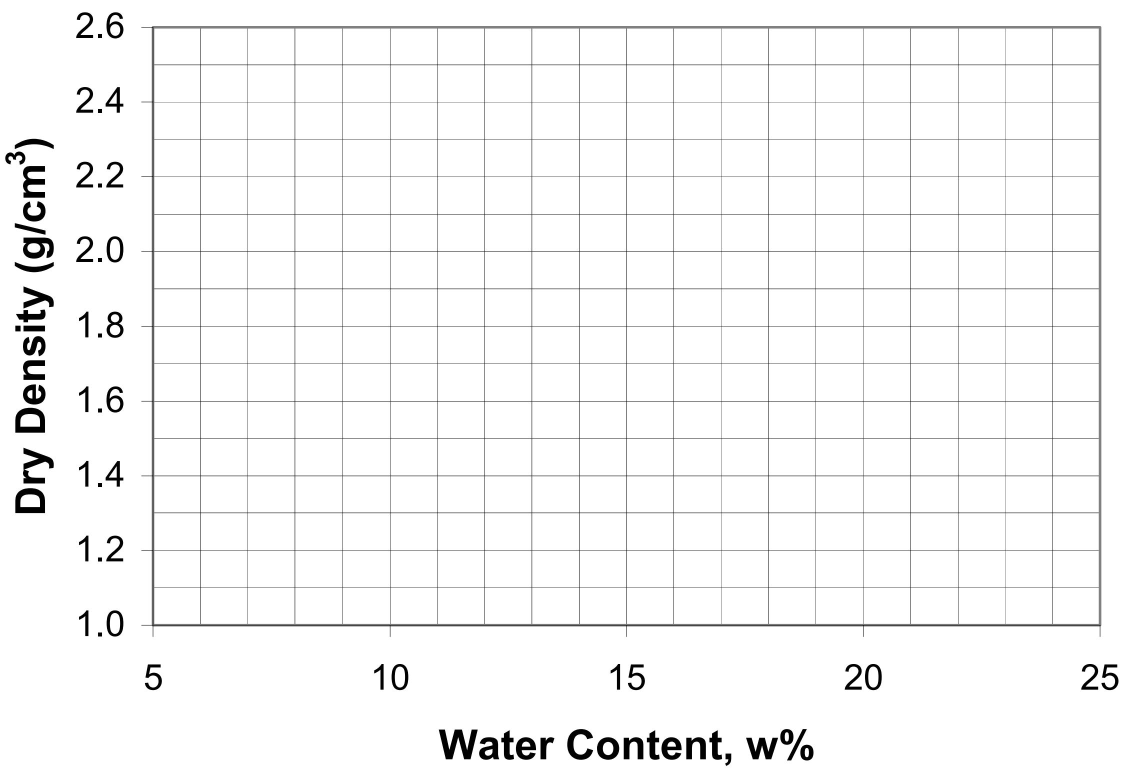
Compacted Soil - Sample no.	1		2		3	
Water content - Sample no.	1A	1B	2A	2B	3A	3B
Moisture can number - Lid number						
M_C = Mass of empty, clean can + lid (grams)						
M_{CMS} = Mass of can, lid, and moist soil (grams)						
M_{CDS} = Mass of can, lid, and dry soil (grams)						
M_S = Mass of soil solids (grams)						
M_W = Mass of pore water (grams)						
W = Water content, w%						

Compacted Soil - Sample no.	4		5		6	
Water content - Sample no.	4A	4B	5A	5B	6A	6B
Moisture can number - Lid number						
M_C = Mass of empty, clean can + lid (grams)						
M_{CMS} = Mass of can, lid, and moist soil (grams)						
M_{CDS} = Mass of can, lid, and dry soil (grams)						
M_S = Mass of soil solids (grams)						
M_W = Mass of pore water (grams)						
W = Water content, w%						

Density Determination:

Volume of mold=

Compacted Soil - Sample no.	1	2	3	4	5	6
w = Assumed water content, w%						
Actual average water content, w%						
Mass of compacted soil and mold (grams)						
Mass of mold (grams)						
Wet mass of soil in mold (grams)						
Wet density, ρ , (kg/m^3)						
Dry density, ρ_d , (kg/m^3)						



Optimum Moisture Content = _________________ %

Maximum Dry Density = ___________________ g/cm^3