SECTION 7

RELATIVE DENSITY TEST

References

- ASTM D 4253 - Standard Test Method for Maximum Index Density and Unit Weights of Soils and Calculations of Relative Density.
- ASTM D 4254 - 16 - Standard Test Method for Minimum Index Density and Calculation of Relative Density
- Bowles, Joseph E., Engineering Properties of Soils and Their Measurement (4th Edition)
- Lambe, T.W., Soil Testing for Engineers.
- ASTM D 6026 - 06 – using Significant Digits in Geotechnical Data

General Discussion

This test is performed to determine the state of density of cohessionless, free-draining soils with respect to its maximum and minimum densities using a vibrating table. Relative Density and percent compaction are commonly used for evaluating the state of compactness of a given soil mass. The engineering properties, such as shear strength, compressibility, and permeability, of a given soil depend on the level of compaction.

The relative density of a soil is the ratio expressed as a percentage, of the difference between the maximum index void ratio of a cohessionless, free-draining soil; to the difference between its maximum and minimum index void ratios.

The necessary formula for relative density determination is as follows:

$$\text{Relative Density, } \quad D_r = \frac{e_{max} - e}{e_{max} - e_{min}}$$

Where, e_{max} = void ratio in loosest state

e_{min} = void ratio in densest state

e = void ratio in natural state

Since void ratios are difficult to obtain (they require specific gravity G_s of the soil) the equation form usually used for D_r is,

$$D_r = \left(\frac{\gamma_d - \gamma_{d\,min}}{\gamma_{d\,max} - \gamma_{d\,min}}\right)\left(\frac{\gamma_{d\,max}}{\gamma_{d\,min}}\right)$$

Where, γ_{dmax} = maximum laboratory dry density

γ_{dmin} = minimum laboratory dry density

γ_d = field or in situ soil density

Therefore, the following three components of relative density is to be determined:

a. Minimum dry unit weight, γ_{dmin}.
b. Maximum dry unit weight, γ_{dmax}.
c. Field dry unit weight, γ_d.

Equipment

Figure 7-1 shows the equipment used for relative density test. The list of the equipment is as following:

- Vibrating Table
- Mold Assembly consisting of standard mold
- Guide sleeves
- Surcharge base plate
- Surcharge weights
- Surcharge base plate hand
- Dial indicator gage
- Scoop
- Straightedge
- Balance

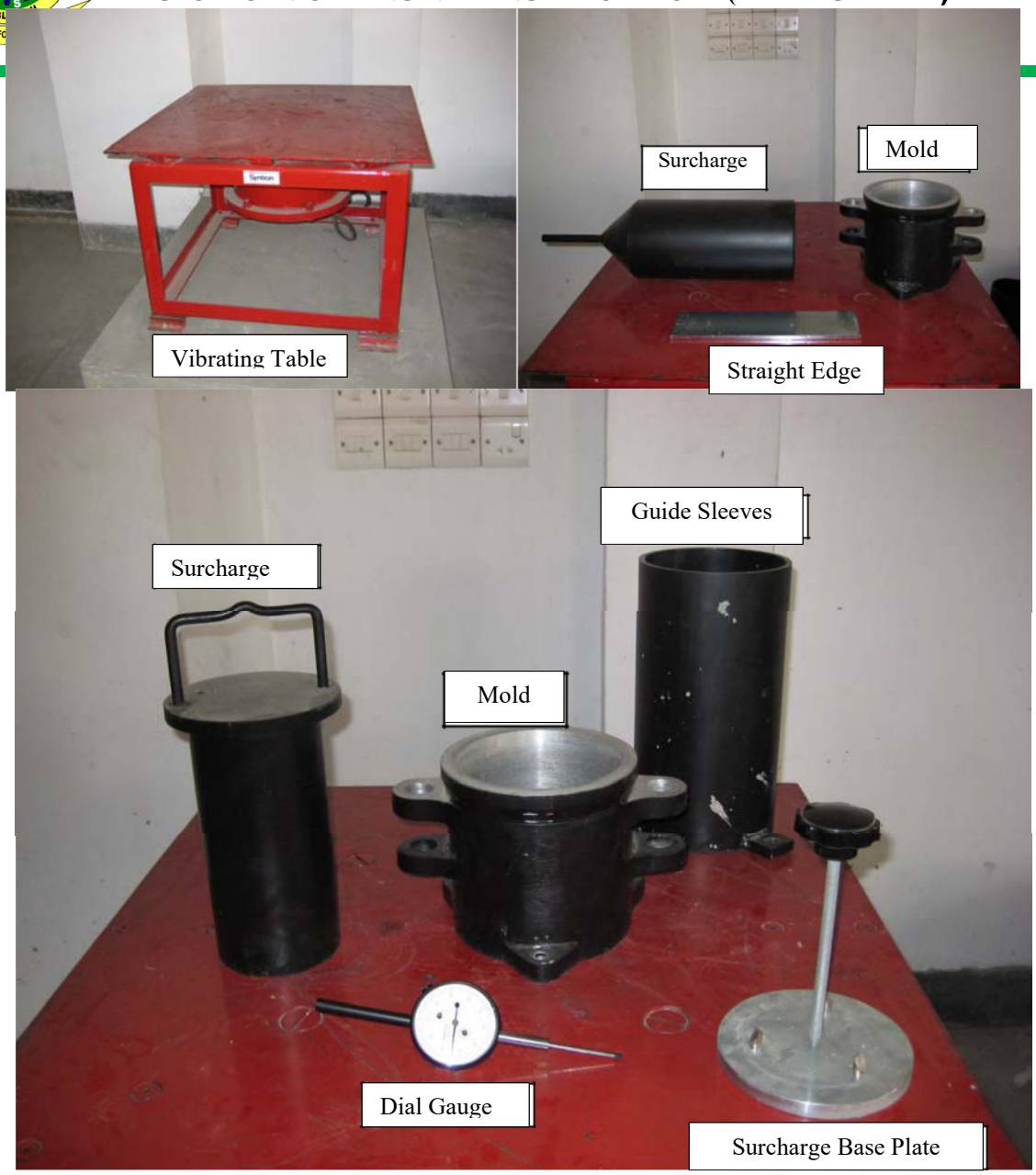


Figure 7-1: Equipment Used for Relative Density Test.

Test Procedure

Loosest Condition.

a. The weight of the empty mold (W_0) should be determined and recorded. Also the dimensions of the mold should be determined to calculate the calibrated volume of the mold, V_m.

b. The mold should be filled with the soil (approximately 0.5 inch to 1 inch above the top of the mold) as loosely as possible by pouring the soil using a scoop or pouring device (funnel). The diameter of the spout (outlet of funnel) should be ½ inch. Spiraling motion should be just sufficient to minimize particle segregation.

c. The excess soil should be trimmed off to level with the top by carefully trimming the soil surface with a straight edge.

d. The weight of the mold and soil (W_1) should be determined and recorded.

Densest Condition.

a. The mold should be filled with soil. The sides of the mold may be struck a few times using a metal bar or rubber hammer to settle the soil so that the surcharge base-plate can be easily placed into position and there is no surge of air from the mold when vibration is initiated.

b. The surcharge base plate should be placed on the surface of the soil and it must be twisted slightly several times so that it is placed firmly and uniformly in contact with the surface of the soil. Then the surcharge plate handle should be removed.

c. The mold should be attached to the vibrating table.

d. The initial dial reading should be determined by inserting the dial indicator gauge holder in each of the guide brackets with the dial gage stem in contact with the rim of the mold (at its center) on the both sides of the guide brackets. Six sets of dial indicator readings should be obtained, three on each side of each guide bracket. The average of these readings is the initial dial gauge reading, R_i. Record Ri to the nearest 0.001 in. (0.025 mm).

e. The guide sleeve should be firmly attached to the mold and lower the appropriate surcharge weight [14 kN/m^2 or 2 lb/in^2] onto the surcharge base plate.

f. The mold assembly and soil specimen should be vibrated for 8 minutes at a frequency of 3600 cycles/sec and amplitude of 1/40 inches.

g. After the vibration, the dial indicator gage readings should be determined and recorded as in Step (d). The average of these readings is the final dial gage reading, R_f.

h. The surcharge base-plate should be removed from the mold and the mold should be detached from the vibrating table.

j. The weight of the mold and soil (W_2) should be determined and recorded. Also, the thickness of the surcharge base-plate, T_p should be determined.

Data Analysis

Minimum Dry Unit Weight, γ_{dmin} or Loose Unit Weight.

a. Volume of the mold, V_m determination:

(1) Height of the mold = H_m inch.

(2) Diameter of the mold = d inch

(3) Volume of the empty mold, $V_m = \pi/4 \times d^2/144 \times H_m/12$ ft^3

b. Weight of soil, W_{s1} determination:

(1) Weight of empty mold, W_0 lb.

(2) Weight of loose soil + mold, W_1 lb.

(3) Weight of soil, $W_{s1} = (W_1 - W_0)$ lb.

c. Minimum Dry Unit Weight, $\gamma_{dmin} = W_{s1}/V_m$ pcf.

Maximum Dry Unit Weight, γ_{dmax} or Dense Unit Weight

a. Volume of the tested dry soil, V_s determination:

(1) Diameter of the mold = d inch.

(2) Height of the mold, H_m inch

(3) Initial dial reading, R_i

(4) Final dial reading, R_f

(5) Thickness of base plate, T_p

(6) Subsidence Height, $H = \{(R_f - R_i) \times 0.001 + T_p\}$ inch

(7) Volume of the soil sample, $Vs = \pi/4 \times d^2/144 \times H_m/12$ ft^3

b. Weight of soil, W_{s2} determination:

(1) Weight of empty mold, W_0 lb.

(2) Weight of dense soil + mold, W_2 lb.

(3) Weight of soil, $W_{s2} = (W_2 - W_0)$ lb.

c. Maximum Dry Unit Weight, $\gamma_{dmax} = W_{s2}/V_s$ pcf.

Field Dry Unit Weight, γ_d.

A sample collection container of specific shape (known dimension) whose weight is known is inserted into the soil. Measures to be taken to create least possible disturbances. Soil sample is collected to the full volume of the container. Additional soil has to be removed with the help of trimmer and care has to be taken not to give extra pressure to fill the container. The soil sample along with the container is put in the oven for drying. Oven dry sample is then weighted to get the dry weight of the sample. As the volume of the container represents the volume of soil, so the field dry unit weight γ_d can be determined.

Significant Figures

1. The value of relative density should be expressed to the nearest 0.1.

WORKED OUT EXAMPLE

Relative Density Test

Test Serial No.: **07**
Date Tested: **January 15, 2009**

Tested By: _____

Project Name: **Hatirjheel Project**

Location : **Behind Sonargaon Hotel**

Sample Number: **S-1, Embankment Top**.

Visual Classification of Soil: **Fine Sand to silty sand**.
Job No: **3** Sample Depth: **0 ft**.
Height of Mold: **6. 1″** Diameter of Mold: **6″** Thickness of Base Plate: **0.5″**
Area of Mold: **0.1963 ft$_2$** Volume of Mold: **0.0998 ft^3**

LOOSEST STATE

No. of Obsn	Wt. of mold + Soil, W_1 in lb	Wt. of mold, W_0 in lb	Wt. of Soil, W_{s1} in lb	Vol of Soil, V_m in ft^3	Min Dry Density, γ_{dmin} in pcf	Avg. Density, pcf	Min Dry γ_{dmin} in pcf
1.	16.4252	7.744	8.6812	0.0998	86.99		
2.	16.1	7.68	8.42	0. 0998	84.17		84.65
3.	16.07	7.67	8.4	0.0998	84.17		
4.	16.038	7.7264	8.3116	0.0998	83.28		

DENSEST STATE

No. of Obsn.	Wt. mold Soil, W_2 (lb)	of Wt. of + mold, W_0 (lb)	Wt. of Soil, W_{s2} (lb)	Initial Dial Reading, R_i (inch)	Final Dial Reading, R_f (inch)	Subsidence Height, $H = (R_f - R_i) * 0.001$ + Thickness of Base Plate, T_p (inch)	Vol of Soil, $V_s=(\pi d^2/4)*(H_m-H)$ (ft^3)	MaxDry Density (pcf)	Avg. Max Dry Density, γ_{dmax} (pcf)
1.	16.432	7.744	8.688	100	200	0.6	0.08997	96.57	96.28
2.	16.09	7.68	8.410	140	-110	0.75	0.0875	96.11	
3.	16.083	7.67	8.413	63	307	0.744	0.0876	96.04	
4.	16.083	7.726	8.357	100	400	0.8	0.0867	96.39	

If the field dry unit weight, γ_d is determined to be 92 pcf (say). Then,

The relative density,

$$D_r = \frac{\gamma_d - \gamma_{d\min}}{\gamma_{d\max} - \gamma_{d\min}} \times \frac{\gamma_{d\max}}{\gamma_d}$$

$$= \frac{92 - 84.65}{96.28 - 84.65} \times \frac{96.28}{92}$$

$$= \frac{7.35}{11.63} \times 1.04652$$

$$= 0.6614$$

$$= 66.1\%$$