RELATIVE DENSITY OF SOIL

1. Objective: Porosity of a soil depends on the shape of grain, uniformity of grain size and condition of sedimentation. Hence porosity itself does not indicate whether a soil is in loose or dense state. This information can only be obtained by comparing the porosity or void ratio of the given soil with that of the same soil in its loosest and densest possible state and hence the term, relative density is introduced.

Relative density is the measure of compactness of cohesion less soil. Relative density or density index is the ratio of the difference between the void ratios of a cohesionless soil in its loosest state and existing natural state to the difference between its void ratio in the loosest and densest states.

Relative density is an arbitrary character of sandy deposit. In real sense, relative density expresses the ratio of actual decrease in volume of voids in a sandy soil to the maximum possible decrease in the volume of voids i.e how far the sand under investigation can be capable to the further densification beyond its natural state. Determination of relative density is helpful in compaction of coarse grained soils and in evaluating safe bearing capacity in case of sandy soils. For very dense gravelly sand, it is possible to obtain relative density greater the one. This means that such natural dense packing could not be obtained in the laboratory.

$$\textbf{Relative Density} = (e_{max} - e)/ (e_{max} - e_{min})$$

Where,

- e_{max} = void ratio of coarse grained soil (cohesionless) in its loosest state.
- e_{min} = void ratio of coarse grained soil (cohesionless) in its densest state.
- e = void ratio of coarse grained soil (cohesionless) in its natural existing state in the field.

We have,

$$e = V_V/ V_S$$

$$Y_d = G\, Y_W/(1+e)$$

Therfore, $\mathbf{e = G\, Y_W/ (Y_d - 1)}$. So, "e" is inversely proportional to "Y_d"

2. Apparatus Required:

Fig. 1: Relative Density Apparatus

The Apparatus consists of (a) Cushioned steel vibrating deck 75X75 cm size, R.P.M : 3600 ; under a 11 kg load. (b) Two cylindrical metallic moulds, 3000 cc and 15000 cc conforming to requirements given in IS: 10837-1984. (c) 10 mm thick surcharge base plate with handle separately for each mould. (d) Surcharge weights, one for each size having a weight equal to 140 gms / sq.cm. conforming to requirements given in IS: 10837-1984. (e) Guide sleeves with clamps for each mould separately. (f) Calibration bar 75X300X3 mm.

Fig. 2: Mixing Pan

Suitable size are 60 x 90 cm and 10 cm deep and 40 x 40 cm and 5 cm deep.

Fig. 3: Weighing Scale

Portable platform scale, 100 kg capacity with sensitivity of 20 g in accordance with IS: 1435-l960.

3. Reference: IS 2720(Part 14):1983 Methods of test for soils: Determination of density Index (Relative Density) of Cohesionless Soil (First revision). Reaffirmed- Dec 2015.

4. Procedure:

A. Calibration of mould

a. Measure inside diameter of mould at different depths using a bore gauge and take the average.

b. Keep the mould on a flat surface or flat plate. Measure the height at different positions and take the average (accuracy = 0.025 mm). Volume of the 3000 cm^3 mould should be calculated to the nearest 3 cm^3 and that of 15000 cm^3 mould to the nearest 30 cm^3.

c. Calculate the volume and fill the mould with distilled water till over flowing takes place. The temperature of the water should be measured and the mass in grams of the water filling the mould should be determined. The volume of the mould should be calculated in cubic centimetres by multiplying the mass of water by the volume of water per gram at the measured temperature.

d. The thickness of the surcharge base plate and the calibration bar should be measured to 0.025 mm using a micrometer. The calibration bar should then be placed across a diameter of the mould along the axis of the guide brackets. The dial gauge holder should be inserted in each of the guide brackets on the mould with the dial gauge stem on top of the calibration bar and on the axis of the guide brackets. The dial gauge holder should be placed in the same position in the guide brackets each time by means of matchmarks on the guide brackets and the holder.

e. Six dial gauge readings should be obtained, three on the left side and three on the right side, and these six readings averaged. The initial dial reading should be computed by adding together the surcharge base plate thickness and the average of the six dial gauge readings and subtracting the thickness of the calibration bar. The initial dial reading is constant for a particular mould and surcharge base plate combination.

B. Preparation of the Sample:

A representative sample of soil should be selected. The mass of soil sample to be taken depends upon the maximum size of particle in the soil as given in Table 1.

Maximum size of the soil particle (mm)	Mass of Soil Sample required (kg)	Pouring Device to be used in Test for the determination of minimum density	Size of Mould to be used (cm^3)
75	45	Shovel or extra-large scoop	15000
37.5	12	Scoop	3000
19.0	12	Scoop	3000
9.50	12	Pouring Device (25 mm dia. Spout)	3000
4.75	12	Pouring Device (12 mm dia. Spout)	3000

Table 1: Mass of the Soil Sample to be taken for the Test

The soil sample should be dried in an oven at a temperature of 105 to 110°C. The soil sample should be pulverized without breaking the individual soil particles and sieved through the requited sieve.

a) Minimum Density:

The pouring device and mould should be selected according to the maximum size of particle as indicated in Table 1. The mould should be weighed and the mass recorded. Oven-dry soils should be used.

Soil containing particles smaller than 9.50 mm should be placed as loosely as possible in the mould by pouring the soil through the spout in a steady stream. The spout should be adjusted so that the height of free fall of the soil is always 25 mm. While pouring the soil, the pouring device should be moved in a spiral motion from the outside towards the centre to form a soil layer of uniform thickness without segregation. The mould should be filled approximately 25 mm above the top and levelled with top by making one continuous pass with the steel straightedge. If all excess matter is not removed, an additional continuous pass should be made. Great care shall be exercised to avoid jarring the mould during the entire pouring and trimming operation. The mould and the soil should be weighed and the mass recorded.

Soil containing particles larger than 9.50 mm should be placed by means of a large scoop (or shovel) held as close as possible to and just above the soil surface to cause the material to slide rather than fall into the previously placed soil. If necessary, large particles may be held by hand to prevent them from rolling off the scoop. The mould should be filled to overflowing but not more than 25 mm above the top. The surface of the soil should be levelled with the top of the mould using the steel straightedge (and the fingers, if necessary) in such a way that any slight projections of the larger particles above the top of the mould shall approximately balance the larger voids in the surface below the top of the mould. The mould and the soil should be weighed and the mass recorded.

$$\text{Volume of mould} = V \text{ (cc)}$$

$$\text{Mass of dry soil} = M_S \text{ (g)}$$

$$\boldsymbol{(\gamma_d)_{min} = M_S/V} \text{ (g/cc)}$$

$$\boldsymbol{e_{max} = G\,\gamma_W/\,(\gamma_d)_{min} - 1}$$

b) Maximum Density:

The guide sleeve should be assembled on top of the mould and the clamp assemblies tightened so that the inner surfaces of the walls of the mould and the sleeve are in line. The lock nuts on the two set screws equipped with them should be tightened. The third clamp should be loosened, the guide sleeve removed, the empty mould weighed and its mass recorded.

The mould should then be filled with the thoroughly mixed oven-dry soil by the procedure explained in Para 2 and Para 3 above. The mould filled for the determination of minimum density may also be used for this test.

The guide sleeves should be attached to the mould and the surcharge base plate should be placed on the soil surface. The surcharge weight should then be lowered on the base-plate using the hoist in the case of the 15000 cm^3 mould.

The mould should be fixed to the vibrator deck for assembly. The vibrator control should be set at maximum amplitude and the loaded soil specimen should be vibrated for 8 minutes.

The surcharge weight and guide sleeves should be removed from the mould. The dial gauge readings on two opposite sides of the surcharge base plate should be obtained and the average recorded. The mould with the soil should be weighed and its mass recorded.

Volume of mould, V, cc

Mass of dry soil, M_S, g

$$\boldsymbol{(Yd)_{max} = M_S/V} \ (g/cc)$$

$$\boldsymbol{e_{min} = G\, Y_W / (Y_d)_{max} - 1}$$

c) Natural Density:

Weigh the mould with dry soil. Knowing the volume of the mould and weight of dry soil natural density, Yd, can be calculated.

$$e = GY_W/(Y_d - 1)$$

$$\boldsymbol{\text{Relative Density} = \{(e_{max} - e)/(e_{max} - e_{min})\} \times 100}$$