Some Relationship:

- Relation between **e** and **n**
  - $\frac{1}{n} = \frac{V}{V_v} = \frac{V_s+V_v}{V_v} = 1 + \frac{V_s}{V_V} = 1 + \frac{1}{e} = \frac{1+e}{e}$ **Hence,** $n = \frac{e}{1+e}$ or $e = \frac{n}{1-n}$
- Relation between **e, w, G** and **S:**
  - $w = \frac{W_w}{W_s} = \frac{\gamma_w}{\gamma_s}\frac{V_w}{V_s} = \frac{1}{G}\frac{V_w}{V_s}$ [G= $\frac{\gamma_s}{\gamma_w}$]

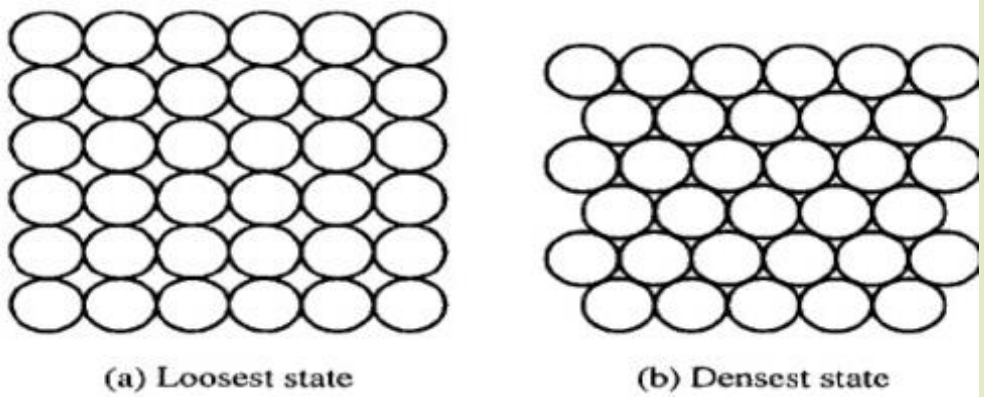
    $= \frac{1}{G} * (\frac{V_w}{V_v} * \frac{V_v}{V_s}) = \frac{1}{G} * S * e$
  - Hence: [**Se=Gw]**
- Relation between γ_t, G, e, w *and* γ_w:
  - $\gamma_t = \frac{W}{V} = \frac{W_s+W_w}{V_s+V_v} = \frac{W_s(1+{}^{W_w}/_{W_s})}{V_s(1+{}^{V_v}/_{V_s})} = \frac{\gamma_s(1+w)}{(1+e)} = \frac{G\gamma_w(1+w)}{(1+e)}$
  - $\gamma_t = \frac{G\gamma_w(1+w)}{(1+e)} = \frac{G\gamma_w(1+Se/G)}{(1+e)} = \frac{\gamma_w(G+Se)}{(1+e)}$
- Saturated Unit Weight (γ_{sat}) $= \frac{\gamma_w(G+e)}{(1+e)}$ [Since; S=1]
- Dry Unit Weight (γ_d) $= \frac{G\gamma_w}{(1+e)}$ [Since; S=0]
- Submerged Unit Weight (γ_{sub} *or* γ' = (γ_{sat} - γ_w)= $\frac{\gamma_w(G+e)}{(1+e)}$ - γ_w $= \frac{\gamma_w(G+e-1-e)}{(1+e)} = \frac{\gamma_w(G-1)}{(1+e)}$

- Relation between $\gamma_t, \boldsymbol{w}$ *and* γ_d:
  - $\gamma_t = \frac{\boldsymbol{W}}{\boldsymbol{V}} = \frac{\boldsymbol{W_s}+\boldsymbol{W_w}}{\boldsymbol{V}} = \frac{\boldsymbol{W_s}(1+\boldsymbol{W_w}/\boldsymbol{W_s})}{\boldsymbol{V}} = \gamma_d(\boldsymbol{1}+\boldsymbol{w}) \Rightarrow \gamma_d = \frac{\gamma_t}{\boldsymbol{1+w}}$
- Relation between $\gamma_d, \boldsymbol{G}, \boldsymbol{w}$ *and* $\boldsymbol{n_a}$
  - $V = \boldsymbol{V_s} + \boldsymbol{V_w} + \boldsymbol{V_a}$
  - $1 = \frac{\boldsymbol{V_s}+\boldsymbol{V_w}+\boldsymbol{V_a}}{V} = \frac{\boldsymbol{V_s}}{V} + \frac{\boldsymbol{V_w}}{V} + \frac{\boldsymbol{V_a}}{V} = \frac{\boldsymbol{V_s}}{V} + \frac{\boldsymbol{V_w}}{V} + \boldsymbol{n_a}$
  - $1 - \boldsymbol{n_a} = \frac{\boldsymbol{V_s}}{V} + \frac{\boldsymbol{V_w}}{V} = \frac{w_s/G\gamma_\omega}{V} + \frac{w_w/\gamma_\omega}{V} = \frac{\gamma_d}{G\gamma_\omega} + \frac{wW_s/\gamma_\omega}{V} = \frac{\gamma_d}{G\gamma_\omega} + \frac{w\gamma_d}{\gamma_\omega} = \frac{\gamma_d}{\gamma_\omega}\left(\frac{1}{G} + w\right)$
  - $(1 - \boldsymbol{n_a})\,\gamma_\omega = \gamma_d\left(\frac{1}{G} + w\right) = \gamma_d\left(\frac{1+wG}{G}\right)$
  - $\gamma_d = \frac{\mathbf{G}\gamma_\omega(\mathbf{1} - n_a)}{\boldsymbol{1+wG}}$
- Relation between mass specific gravity, $\boldsymbol{G_m}$ and specific gravity of soil solids, $\boldsymbol{G}$ (at dry condition):
  - Mass specific gravity (G_m) $= \frac{\gamma}{\gamma_w}$ (for dry condition, $\gamma = \gamma_d$); So, $G_m = \frac{\gamma_d}{\gamma_w}$
  - $\gamma_d = \frac{G\gamma_w}{(1+e)} \quad \Leftrightarrow \frac{\gamma_d}{\gamma_w} = \frac{G}{(1+e)}$

$$\boldsymbol{G_m} = \frac{\boldsymbol{G}}{(\boldsymbol{1}+\boldsymbol{e})}$$

Relative Density or Density Index

- The degree of denseness or looseness of natural deposits of coarse-grained soils is measured in terms of relative density, **D_r ,(I_D).**
- Relative Density, **D_r ,(I_D)** $= \frac{e_{max} - e_{nat}}{e_{max} - e_{min}} \times \mathbf{100\%}$
- e_{max} = Void ratio at loosest state;
  e_{min} = Void ratio at densest state;
  $e_{nat=}$ Void ratio at field in the natural state
- If the relative density is high, the granular soil will be dense and will have high shearing strength and low compressibility.
- In the loosest state, **D_r = 0** and in Densest state, **D_r** = 100%



Relative Density (D_r)	Classification
< 15	Very loose
15-35	Loose
35-65	Medium
68-85	Dense
>85	Very Dense

MCQ PREPARATION

1. The difference between maximum void ratio and minimum void ratio of a sand sample is 0.30. If the relative density of this sample is 66.6% at a void ratio of 0.40, then the void ratio of the sample at the loosest stage is:
   a. 0.4
   b. 0.5
   c. 0.6
   d. 0.7
2. The dry density of a soil is 1.5 g/cm^3. If the saturation water content is 50%, then its saturated density and submerged density will respectively be:
   a. 1.5 and 1.0 g/cm^3
   b. 2.0 and 1.0 g/cm^3
   c. 2.25 and 1.25 g/cm^3
   d. 2.50 and 1.50 g/cm^3
3. The Void ratio of the saturated soil is equal to the …….. of water content and specific gravity.
   a. Sum
   b. Difference
   c. Product
   d. Ratio
4. Which of the following relation is true (notations indicates usual meaning):
   a. (e+s) = (w+G)
   b. (es = wG)
   c. (e/s) = (w/G)
   d. (s+e)s = w(G+e)

5. What will be the degree of saturation of a soil sample whose specific gravity G=2.7, void ratio e=0.66 and water content w=20%?
   a. 85.88%
   b. 90.91%
   c. 81.81%
   d. 92.92%

6. A soil sample has a dry density of 18.5 kN/m^3, specific gravity of solids G as 2.7 and voids ratio of 0.6. Find the bulk unit weight of soil when the soil is 50% saturated

   a) 19.274 kN/m^3 b) 23.034 kN/m^3 **c)20.554 kN/m^3** d) 21.428 kN/m^3

7. If water content of fully saturated soil is 100%, then the void ratio of the sample is
   a. Less than the specific gravity of soil
   b. Equal to the specific gravity of soil
   c. Greater than specific gravity of soil
   d. Independent of specific gravity of soil

8. For a soil sample, the ratio of saturated unit weight to dry unit weight is equal to 1.2 and specific gravity of solids G is 2.65, then its void ratio will be _____
   a. 0.58
   b. 0.66
   c. **0.53**
   d. 0.94

9. If a soil has a void ratio of 0.64, specific gravity of solids as 2.65, then its saturated unit weight will be ______
   a. 24.5 kN/m^3
   b. 25 kN/m^3
   c. 25.5 kN/m^3
   d. **19.5 kN/m^3**

10. A soil sample is having a specific gravity of 2.60 and a void ratio of 0.78. The water content in percentage required to fully saturate the soil at that void ratio will be:
    a. 10
    b. 30
    c. 50
    d. 70

Determination of Properties of Soil

a) Determination of water content

- Oven dried method: Most common and accurate method
- Sand bath method: Field method
- Calcium carbide method: Quickest method
- Pycnometer method: Suitable method for coarse grained. This method requires values of specific gravity.

b) Determination of specific gravity

- Density bottle method: Most accurate method, and is suitable for all types of soil
- Pycnometer method: This method Is used for only coarse-grained soils

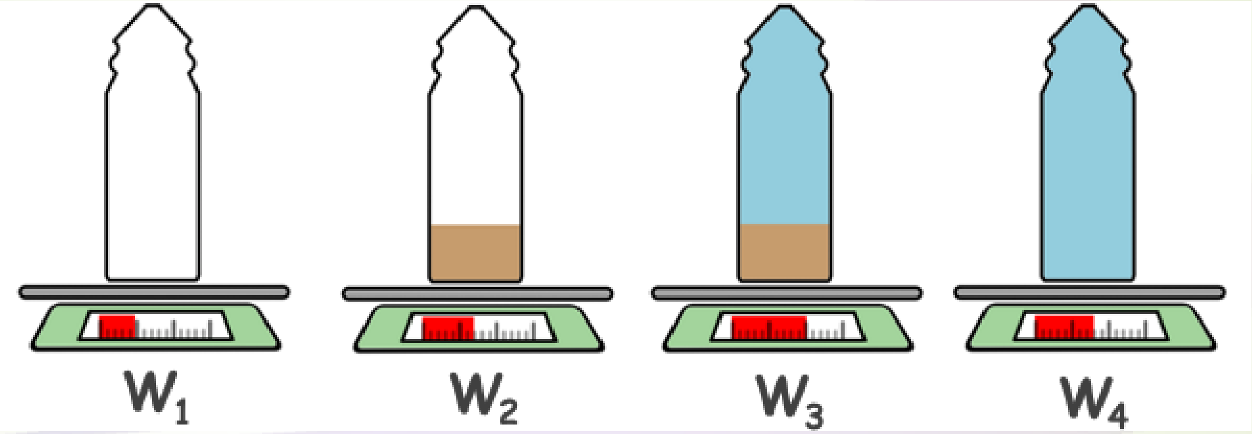
11. Accurate determination of water content, is made by:
    a. Calcium Carbide Method b. Sand Bath Method c. Alcohol Method d. **Oven Drying Method**
12. A Pycnometer is used to determine:
    a. Void Ratio
    b. Dry Density
    c. Water content
    d. Density Index
13. You are given a sample of soil containing coarse grains to determine its water content, you will use:
    a. Pycnometer
    b. Oven-Drying Method
    c. Calcium Carbide Method
    d. Alcohol Method

DETERMINATION OF SPECIFIC GRAVITY (PYCNOMETER METHOD)

Materials and Equipment:

Pycnometer of about 900 ml capacity, with a conical brass cap and screwed at its top; **Balance** sensitive to 1g, **Glass rod**, Deaired/ **Distilled Water**

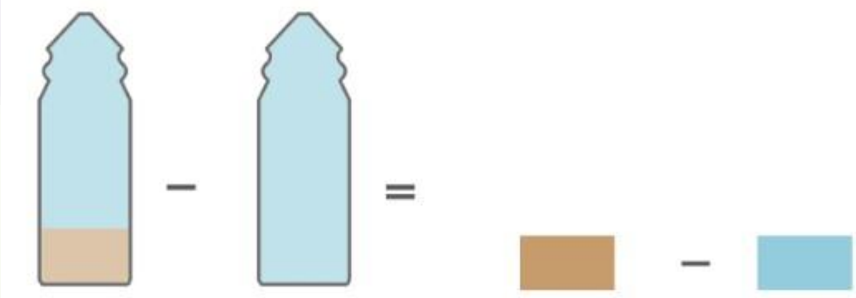
$$G_s = \frac{W_2 - W_1}{(W_2 - W_1) - (W_3 - W_4)}$$



1. W_1 = Weight of the empty, clean and dry pycnometer.
2. W_2 = Weight of pycnometer with oven-dried soil (200-400 gm)
3. W_3 = Weight of pycnometer with soil and completely filled with distilled water.
4. W_4 = Weight of pycnometer completely filled with distilled water.

$$G_S = \frac{\text{Mass of soil}}{\text{Mass of water displaced by soil}}$$

$$W_W = W_2 - W_1 - (W_3 - W_4)$$



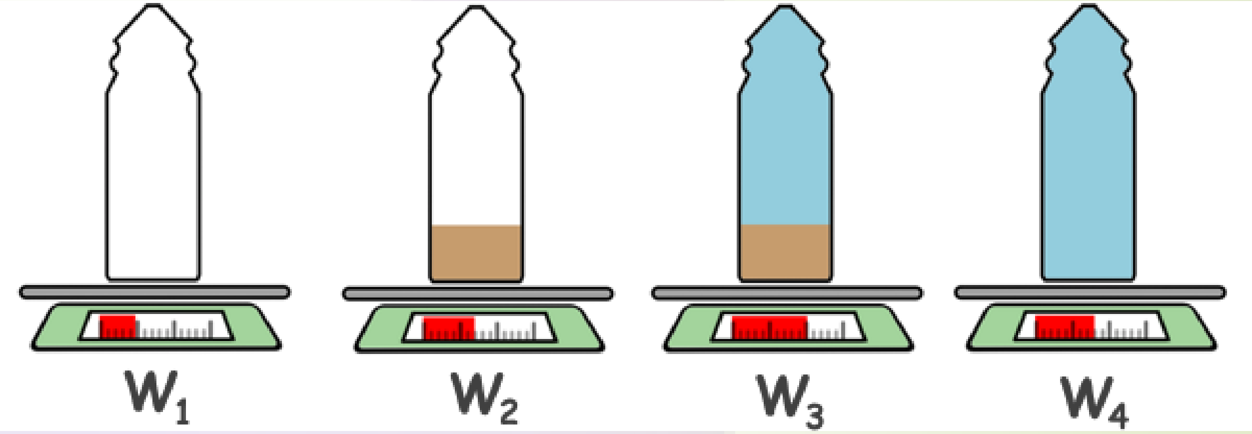
$$W_3 - W_4 = W_S - W_W$$

DETERMINATION OF WATER CONTENT (PYCNOMETER METHOD)

Materials and Equipment:

Pycnometer of about 900 ml capacity, with a conical brass cap and screwed at its top; **Balance** sensitive to 1g, **Glass rod**, Deaired/ **Distilled Water**

$$w = \left[\frac{M_2 - M_1}{M_3 - M_4}\left(\frac{G-1}{G}\right) - 1\right] \times 100$$



1. W_1 = Weight of the empty, clean and dry pycnometer.
2. W_2 = Weight of pycnometer with WET soil (200-400 gm)
3. W_3 = Weight of pycnometer with soil and completely filled with distilled water.
4. W_4 = Weight of pycnometer completely filled with distilled water.

DETERMINATION OF WATER CONTENT (OVEN DRIED METHOD)

- Oven Drying Method (Temperature of Oven 105^0 C to 110^0 C, for about 16 to 24 hours.
- Dry and clean the container. Measure the weight of the empty container **(W$_1$)**.
- Take the **moist soil sample into the container and weigh it (W$_2$).**
- The soil sample is kept in the electric **oven to dry at a temperature of 105-110** degree celsius for 24 hours.
- Finally, Record the constant **weight of perfectly dried soil sample with the container (W$_3$).**

$$w = \frac{W_2 - W_3}{W_3 - W_1}$$

Moisture Content Test/ Water content determination

- Pycnometer Method
- Oven drying Method
- Sand-bath Method
- Rapid Moisture Meter Method
- Torsion Balance Moisture Meter Method

14. An oven – dried soil is placed in a pycnometer where empty weight is 573g. The mass of pycnometer with soil is 973g. The total mass of pycnometer with water and soil inside is 1605g. The pycnometer filled with water alone has mass of 1480. The specific gravity of solids is 2.65. Its water content is ______
    a. 40.456
    b. 46.504
    c. 23.236
    d. 99.245

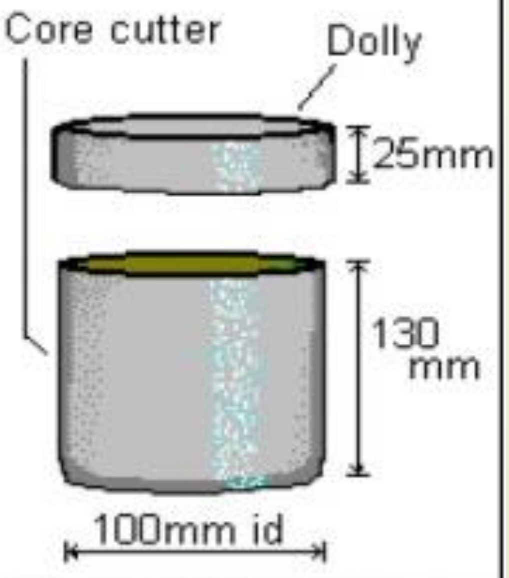
15. In a pycnometer where empty weight is 573g. The mass of pycnometer with dry soil is 973g. The total mass of pycnometer with water and soil inside is 1605g. The pycnometer filled with water alone has mass of 1480. The specific gravity of solids is……
    a. 1.45
    b. 2.45
    c. 1.65
    d. 2.65

16. A soil sample with specific gravity of solids 3 has a mass specific gravity of 2. Assuming the soil to be perfectly dry, determine the void ratio.
    a. 1.0
    b. 1.5
    c. 0.5
    d. 0.8

Determination of Field/ In-situ Density of Soil:

- Core Cutter Method
- Sand Replacement Method
- Water Displacement Method
- Pycnometer Method

Core Cutter Method



Bulk density, $\rho = \dfrac{M_2 - M_1}{V}$

Dry density, $\rho_d = \dfrac{\rho}{1 + w}$

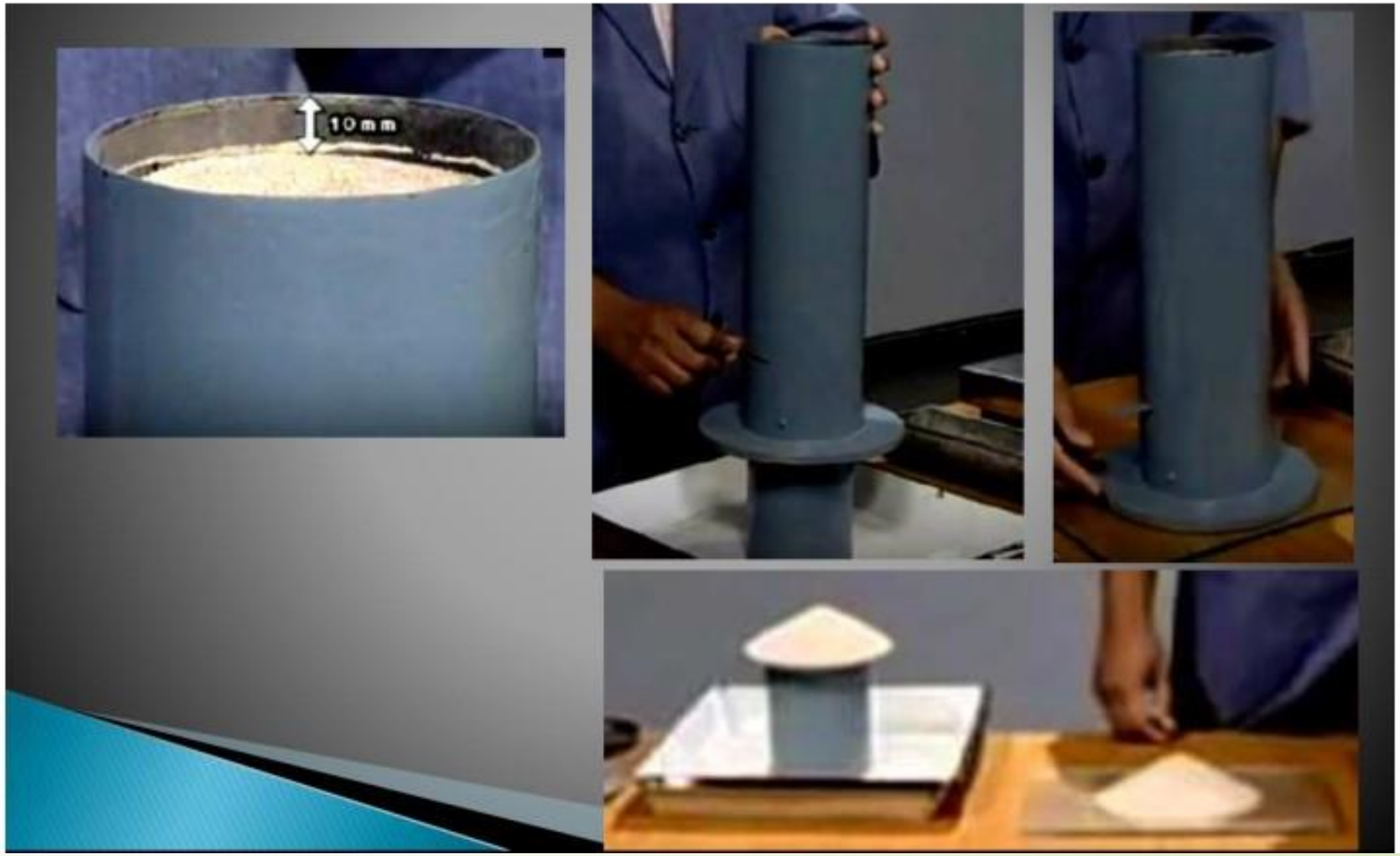
Where, w is the water content

M1 = mass or weight of empty core cutter

M2 = mass or weight of core cutter full of soil

Stage 1: Calibration of Sand Density

Sl no	Data (Calibration of Unit Weight of Sand)
1	Volume of the calibrating container, V (cm^3)
2	Weight of SPC + sand, W_1 (g) SPC=SAND POURING CYLINDER
3	Weight of sand required to fill the conical portion on a flat surface, W_2 (g)
4	Weight of SPC + sand (after filling calibrating can), W_3 (g)
5	Weight of sand required to fill the calibrating container, $W_c = (W_1 - W_2 - W_3)$ (g)
6	Unit weight of sand, $\gamma_{sand} = (W_c)/V$ (g/cm^3)



Stage 2: Measurement of Soil Density

Sl. no	Data (Determination of Density of Soil)
1	Weight of the excavated from the pit (W) (g)
2	Weight of sand + SPC, before pouring, W_1 (g)
3	Weight of SPC after filling the hole & conical portion, W_4 (g)
4	Weight of sand in the pit $W_p = (W_1 - W_4 - W_2)$ (g)
5	Volume of sand required to fill the pit $V_p = W_p/\gamma_{sand}$ (cm^3)a
6	Wet unit weight of the soil $\gamma_{wet} = W/V_p$ (g/cm^3)
7	Dry unit weight of the soil $\gamma_{dry} = \gamma_{wet}/(1+w)$ (g/cm^3) (where '**w**' is the moisture content of soil)

17. A 1000 cc core cutter weighing 946.80 gm was used to find out the in situ unit weight of an embankment. The weight of core cutter filled with soil was noted to be 2770.60 gm. Laboratory test on the sample indicated a water content of 10.45 percent. What is the dry unit weight of the sample?

    a. 1.45 gm/cc
    b. 1.55 gm/cc
    c. 1.65 gm/cc
    d. 1.75 gm/cc

18. A 1000 cc core cutter weighing 946.80 gm was used to find out the in situ unit weight of an embankment. The weight of core cutter filled with soil was noted to be 2770.60 gm. Laboratory test on the sample indicated a water content of 10.45 percent and specific gravity of solids of 2.65. What is the void ratio of the sample?

    a. 0.55
    b. 0.60
    c. 0.65
    d. 0.70

19. During sand replacement method, weight of excavated soil is 761.25g, weight of sand and cylinder is 10500 gm, weight of sand and cylinder after pouring in excavated hole and cone is 9450 gm, weight of sand and cylinder after pouring on the cone only is 9005 gm, weight of sand in calibrating can after pouring from cylinder is 1500 gm and if volume of calibrating can be 1000 cc. Determine the in-situ unit weight of soil.

    a. 1.88 gm/cc
    b. 1.98 gm/cc
    c. 2.08 gm/cc
    d. 2.18 gm/cc

c) Determination of particle size distribution

It is also called as "grain size distribution" or "mechanical analysis" which means the separation of a soil into different size fractions. It is carried in two stages:

- **Sieve analysis**

  It is useful for soil having particle size **more than 75 micron (0.075mm)** i.e., for coarse grained soils.

  As per IS, Smallest sieve size is 45 microns.

- **Sedimentation analysis**

  It is useful for particle **finer than 75 microns**, i.e., fine grained soil (silt and clay) which cannot be separated by sieving. This method is based on **Stoke's law** which is **valid for 0.2 mm to 0.0002 mm**. The sedimentation analysis is done either with the help of **hydrometer or a pipette**.

- **Hydrometer method**:

  It is used to determine the **density of soil suspension**.

  Hydrogen Peroxide (H_2O_2) is used to remove organic content.

  Hydrochloric acid of normality 0.2 N is used to remove calcium compounds.

  Sodium hexa meta-Phosphate is used as dispersing agent.

  Hydrometers are calibrated at 27^0 C.

  For other values of temperature, correction must be applied for temperature. Similarly, correction for hydrometer is also required. Correction for meniscus is always positive whereas correction for dispersing agent is always negative.

- **Pipette method**: It is the standard sedimentation method, in which suitable dispersion agents are added for proper dispersion of soil. Dispersion solution contains **7g sodium carbonate, 33g sodium hexameta phosphate and 1-liter distilled water.**

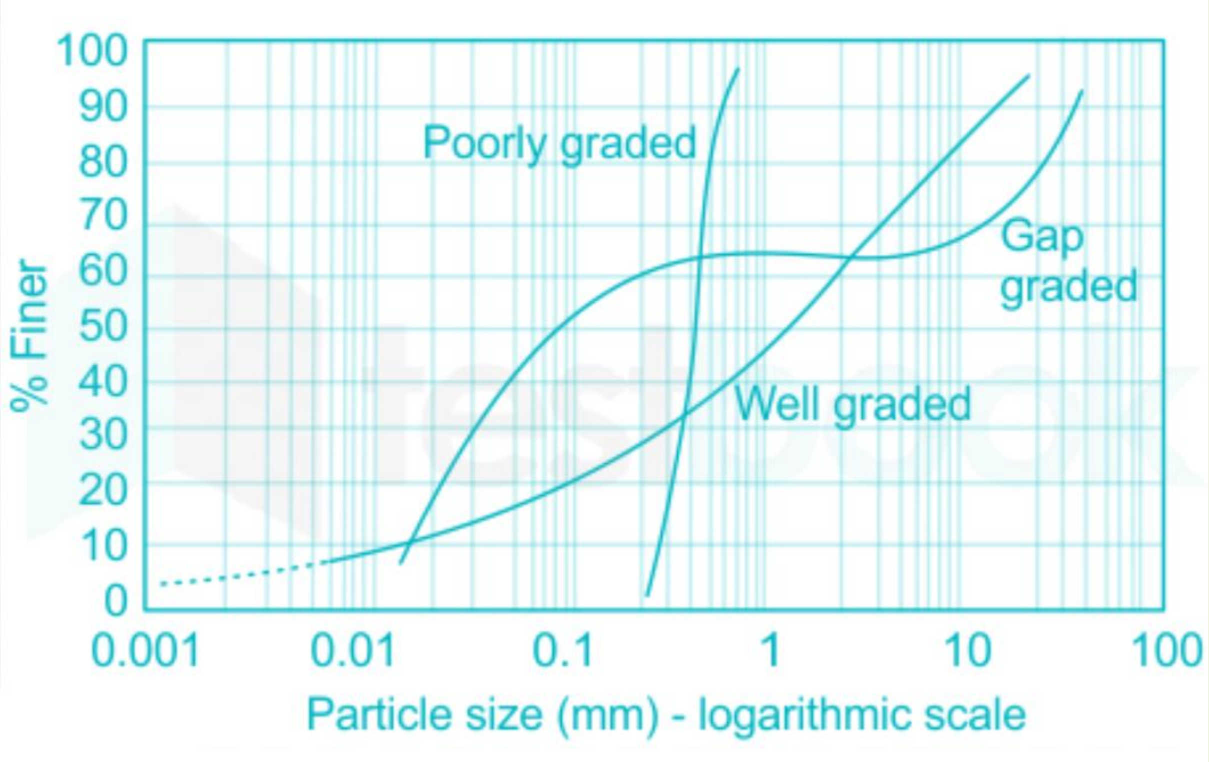
Gradation of soil:

- The curve which spreads over a large range of particle size represents well graded soil whereas those confined to narrow range of particles represents uniform or poorly graded soil. Soil in which some particles are missing which is represented by horizontal line are called gap graded soil.
- The size corresponding to 10% finer, 30% finer and 60% finer have been designated as D_{10}, D_{30} and D_{60} respectively. D_{10} is also called effective size or effective diameter.

$$Uniformity\ Coefficient\ (C_u) = \frac{D_{60}}{D_{10}}, (measures\ particle\ size\ ranges)$$

$$Coefficient\ of\ Curvature\ (C_c) = \frac{{D_{30}}^2}{D_{60} \times D_{10}}, (also\ called\ coefficient\ of\ gradation)$$

- For well graded soil, $1 < C_c < 3$.
- For well graded gravel, $C_u > 4$, and for well graded sand $C_u > 6$.
- For poorly graded (uniform) soil, C_u is nearly unity.



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1. Strokes law is used to determine:
    a. Specific gravity of soil solids
    b. Density of soil suspension
    c. Grain Size distribution of soil finer than 0.075 mm
    d. All of the above
2. The smallest sieve size according to the Indian Standard is:
    a. 0.0045 mm
    b. 0.045 mm
    c. 0.45 mm
    d. 0.154 mm
3. Sieving is not practicable for grain size smaller than about:
    a. 0.075 mm
    b. 0.095 mm
    c. 0.15 mm
    d. 0.2 mm
4. According to Indian Standard, in a 2 mm sieve:
    a. There are two holes
    b. Each sieve is circular and its diameter is 2 mm.
    c. Each sieve is a square and its side is 2 mm.
    d. There are two holes per cm length of the mesh.
5. Stroke's law does not hold good if the size of the particle is smaller than:
    a. 0.0002 mm
    b. 0.002 mm
    c. 0.02 mm
    d. 0.2 mm

ADACA

6. The effective size of the soil is:
   a. D_{10}
   b. D_{20}
   c. D_{40}
   d. D_{60}
7. The uniformity coefficient of the soil is defined as the ratio of:
   a. D_{40} to D_{10}
   b. D_{40} to D_{20}
   c. D_{50} to D_{10}
   d. D_{60} to D_{10}
8. A soil having particles of nearly the same size is known as:
   a. Uniform soil
   b. Poor soil
   c. Well Graded Soil
   d. Coarse Soil
9. A soil having uniformity coefficient more than 10, is called:
   a. Uniform Soil
   b. Poor Soil
   c. Well Graded Soil
   d. Coarse Soil
10. Which of the following statement is true for Hydrometer method of sedimentation Analysis?
    a. Correction for meniscus is always positive whereas correction for dispersing agent is always negative.
    b. Correction for meniscus and dispersing agent both are always negative.
    c. Correction for meniscus and dispersing agent both are always negative.
    d. Correction for meniscus is always negative whereas correction for dispersing agent is always positive.

Borehole Log Interpretation

Bore hole data hence should be as correctly interpreted as possible so that following conditions are met.

- No interpretation of folded strata as straight strata.
- Case of weaker soil layer laying below stronger layer should be properly studied. For this, deeper bore hole as specified in codes should be provided.
- Possibility of formation of sink holes or any other such structures underground surface should be clearly illustrated.
- It is recommended to check any dips if existing, to prevent foundation overloading and subsequent failure.
- Higher number of boreholes are drilled to eliminate the possibility of misrepresentation of bed rock. When a large boulder is reached at shallow depth, it may be misrepresented as a bed rock.
- Presence of Faults if any should be precisely studied. Rock strata would be improperly studied if the presence of faults is not taken care of.
- Soil profile and water table should be interpreted clearly.

Layer id	Depth(m)	Strip log	Lithology description
01	2.00		Quaternary surface soil...
02	10.00		Completely weathred basalt ...
03	20.00		Highly weathred basalt...
04	30.00		Moderately weathred basalt ... Slightly weathred basalt...
05	50.00		Fresh basalt, bedrock...