CMR INSTITUTE OF TECHNOLOGY
Internal Assessment Test 1 – September 2016

Sub:	Geotechnical Engineering-I				Code:	10CV54
Date: 08/ 09/ 16	Duration: 90 mins	Max Marks: 50		Sem: 5	Branch:	CIVIL

Scheme and solution to the question paper –Prepared by Dr Asha M Nair

1 a. (5)

Prove that, $S^r = \left| \dfrac{w}{\frac{\gamma_w}{\gamma_b}(1+w) - \frac{1}{G}} \right|$

Phase diagram-0.5

$\rho_b = \dfrac{\rho_w(G+wG)}{1+\frac{wG}{S}} - 2$

eS=wG -1

$S = \dfrac{w}{\left[\frac{\rho_w(1+w)}{\rho_b} - \frac{1}{G}\right]}$ **-1**

$S == \dfrac{w}{\left[\frac{\gamma_w(1+w)}{\gamma_b} - \frac{1}{G}\right]}$ **-0.5**

$e = \dfrac{V_v}{V_s}$

Assume V_s=1, then, $e = \dfrac{V_v}{1}$ or $V_v=e$

Therefore, $V=V_v+V_s= e+1$

$\rho_b = \dfrac{M}{V} = \dfrac{M_s+M_w}{1+e} = \dfrac{G\rho_w V_s+\rho_w V_w}{1+e}$
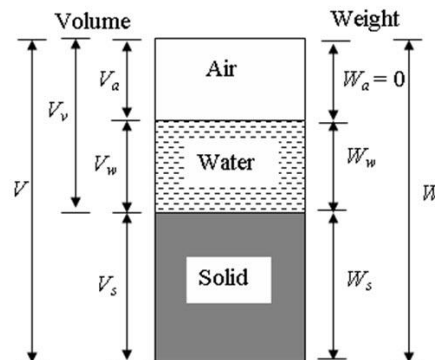
$S = \dfrac{V_w}{V_v} = \dfrac{e_w}{e}$

Or $V_w = e_w = eS$

Since $Vs=1$ and $V_w = eS$,

$\rho_b = \dfrac{M}{V} = \dfrac{M_s+M_w}{1+e} = \dfrac{G\rho_w+\rho_w eS}{1+e}$

$\rho_b = \dfrac{\rho_w(G+eS)}{1+e}$

$w = \dfrac{M_w}{M_s} = \dfrac{\rho_w V_w}{\rho_s V_s} = \dfrac{\rho_w V_w}{G\rho_w V_s} = \dfrac{eS}{G}$

Or $eS = wG$

Therefore, $\rho_b = \dfrac{\rho_w(G+wG)}{1+\frac{wG}{S}}$

$$1 + \frac{wG}{S} = \frac{\rho_w(G+wG)}{\rho_b}$$

$$\frac{wG}{S} = \frac{\rho_w(G+wG)}{\rho_b} - 1$$

$$\frac{wG}{S} = \frac{\rho_w(G+wG) - \rho_b}{\rho_b} = \frac{G\rho_w(1+w) - \rho_b}{\rho_b}$$

$$\frac{S}{wG} = \frac{\rho_b}{G\rho_w(1+w) - \rho_b}$$

$$S = \frac{wG\rho_b}{G\rho_w(1+w) - \rho_b} = \frac{wG\rho_b}{G\rho_b\left[\frac{\rho_w(1+w)}{\rho_b} - \frac{1}{G}\right]} = \frac{w}{\left[\frac{\rho_w(1+w)}{\rho_b} - \frac{1}{G}\right]}$$

Since in the given question, the expression in terms of unit weight, the above equation can be rewritten as

$$S = = \frac{w}{\left[\frac{\gamma_w(1+w)}{\gamma_b} - \frac{1}{G}\right]}$$

b. **Briefly explain the different corrections to be applied for correct hydrometer reading.** (5)

Four corrections –1.0 for listing and 4 for detailing

Basically there are four corrections for hydrometer reading

(i) Meniscus correction

(ii) Temperature correction

(iii) Dispersing agent correction

(iv) Composite correction

Meniscus correction:

Since the soil suspension is opaque, the readings are taken at upper meniscus, though they are to be taken at lower meniscus. Since the hydrometer readings increase downwards, the meniscus correction is to be added to the observed hydrometer reading.

To measure meniscus correction: distilled water is filled in a gas jar and the hydrometer readings

are taken at upper and lower meniscus. The difference in this reading gives meniscus correction.

Temperature correction (c_t):

Hydrometer is generally calibrated to a temperature of 27°C. If the temperature is greater than 27°C, the density of suspension decreases. Hence, hydrometer will be going further down. Since the hydrometer reading decreases as we go up, the measured hydrometer reading will be less than the actual hydrometer reading. Hence, correction will be positive.

Similarly, when the temperature is less than 27°C, the density of suspension increases. Hence, hydrometer will not be going down. Since the hydrometer reading increases as we go down, the measured hydrometer reading will be more than the actual hydrometer reading. Hence, correction will be negative.

To measure temperature correction:

At different time periods, along with hydrometer reading, the temperature of the suspension is also measured and its average is determined. If the difference between individual temperature reading and average temperature is not more than 2°C, this correction need not have to be applied. Else using calibration chart provided along with the supply of hydrometer can be used to determine temperature correction.

Dispersing agent correction (c_d):

When dispersing agent is added to distilled water, its density increases. Hence, hydrometer will not be going down. Since the hydrometer reading increases as we go down, the measured hydrometer reading will be more than the actual hydrometer reading. Hence, dispersing agent correction will be negative.

To measure dispersing agent correction:

Hydrometer readings are taken in pure distilled water and in distilled water containing dispersing agent. The difference between the two gives this correction

Composite correction (c_c):

The sum of all the three corrections is called as composite correction.

Therefore corrected hydrometer reading, $R'_h = R_h \pm c_m$

2 a. **What are the different structures of soil particles formed during and after deposition in fresh water?**   **(5)**
Briefly discuss their characteristics.

5 structures- explanation+fig-1×5=5

Following are the types of soil structure which have been recognized in various soil deposits

1.   Single grained structure – in case of coarse grained soil deposits (sand)

2.   Honeycomb structure – in the case of silt deposits

3.   Dispersed structure – in the case of clay deposits

4.   Coarse grained skeleton structure

5.   Cohesive matrix structure

1. **Single grained structure**

• Single-grained structure is characteristic of coarse grained soils, with a particle size greater than 0.02 mm. (see Fig-1).

• When such soils settle out of suspension in water, the particles settle independently of each other.

• The major force causing their deposition is gravitational and surface forces are too small to produce any effect.

• There will be particle-to-particle contact in the deposit. The void ratio attained depends on the relative size of grains.
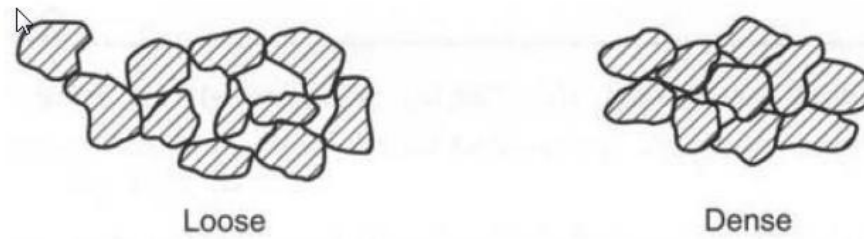
Loose   Dense

Fig. 1 Single grained structure

2. **Honeycomb structure**

• This structure can occur only in fine-grained soils, especially in silt and rock flour (0.02-0.002 mm).

• Due to the relatively smaller size of grains, besides gravitational forces, inter-particle surface forces also play an important role in the process of settling down.

• Miniature arches are formed, which bridge over relatively large void spaces. This results in the formation of a honey-comb structure, each cell of a honey-comb being made up of numerous individual soil grains.

• The structure has a large void space and may carry high loads without a significant volume change. The structure can be broken down by external disturbances like pile driving.
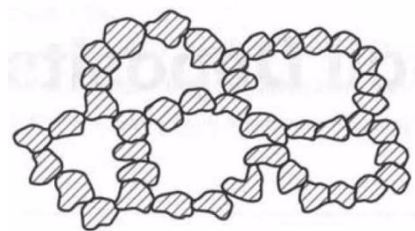
Fig-2 Honeycomb Structure

3. **Dispersed structure**

• When inter-particle repulsive forces are brought back into play either by remoulding or by the transportation process, a more parallel arrangement or reorientation of the particles occurs, as shown in Fig. 3.

• Face-to-face contacts occur for the flaky particles when these are in a dispersed state. This type of structure is common in fresh water deposits.
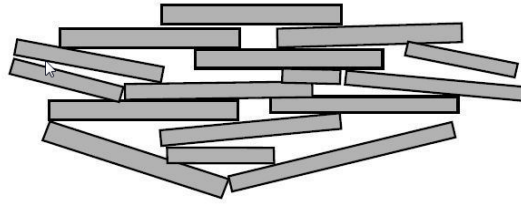
Fig-3 Dispersed Structure

4. Coarse grained skeleton structure

Here, the coarse grained particles forms the skeleton with particle to particle contact and the voids between the particles will be occupied by the fine grained particles as shown in Fig.4.
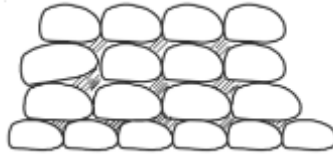

Fig-4 Coarse grained skeleton structure

5. Cohesive matrix structure

In this case the coarse grained particles will be embedded in fine grained fraction and will be prevented from having particle to particle contact. This type of structure (shown in Fig.5) is relatively more compressible compared to the more stable coarse grained skeleton structure.
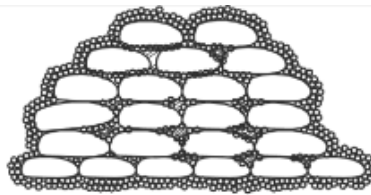

Fig-5 Cohesive matrix structure

b. Discuss 'particle size distribution curve'. Explain how the gradation of soil can be determined using this curve. **(5)**
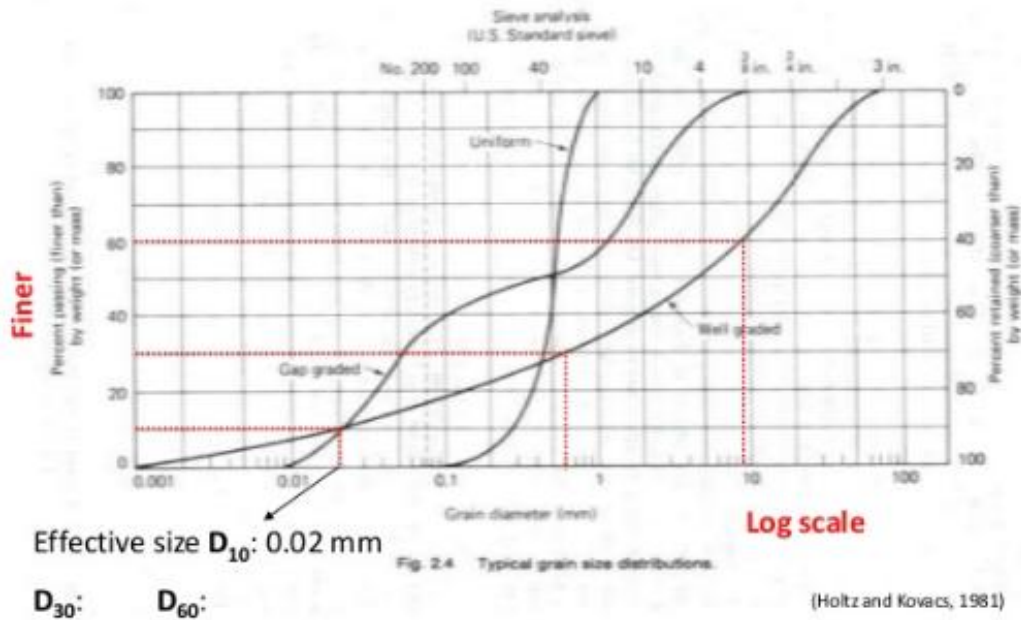
Graph- explanation-1.5

Graphs- 1.5

Cu-1

Cc-1

"Particle-size distribution curve" (or "Grain-size distribution curve") is plotted on semi-log co-ordinates, where the sieve size is on a horizontal 'logarithmic' scale, and the percentage by weight of the size smaller than a particular sieve-size is on a vertical 'arithmetic' scale. Logarithmic scales for the particle diameter gives a very convenient representation of the sizes because a wide range of particle diameter can be shown in a single plot; also a different scale need not be chosen for representing the fine fraction with the same degree of precision as the coarse fraction.

A soil is said to be "wellgraded", if it contains a good representation of various grain-sizes. If the

soil contains grains of mostly one size, it is said to be "uniform" or "poorly graded". A soil is said to be "gap-graded", if it is deficient in a particular range of particle sizes. These different gradations are shown in the figure below.

Fig. 2.4   Typical grain size distributions.

Effective size D_{10}: 0.02 mm

D_{30}: D_{60}:

(Holtz and Kovacs, 1981)

The uniformity of a soil is defined by its "Coefficient of Uniformity"

$$C_u = D_{60}/D_{10}$$

Similarly coefficient of curvature is given as $C_c = (D_{30})^2/(D_{60}.D_{10})$

where D_{60} = Particle size corresponding to 60% finer.

D_{30} = Particle size corresponding to 30% finer

and D_{10} = Particle size corresponding to 10% finer or effective size.

C_u will be less than 2 for poorly graded soils, will be greater than 4 for well graded gravels, will be greater than 6 for well graded sand.

C_c should be between 1 and 3 for well graded soil.

3 a. **An embankment is to be constructed with a void ratio of 0.73 and the quantity of embankment being 4800 m³. Three borrow pits are available for the construction of the embankment and the corresponding void ratio and the cost of transportation for 1.0 m³ of soil is given below *(next page)*. Determine the most economical borrow pit.**   **(5)**

Borrow pit	Void ratio, e	Cost/m³ in Rupees
A	0.88	28
B	1.45	19
C	1.73	22

V_s of embankment -1.5

Tabular column-3

Econmical-0.5

Void ratio of embankment $= 0.73 = \dfrac{V_v}{V_S} = \dfrac{V - V_S}{V_S} = \dfrac{4800 - V_S}{V_S}$

$V_s = 2774.57 \text{ m}^3$

$$e = \dfrac{V - V_s}{V_S} \ or \ V = (1 + e) \times V_s$$

Pit	Void ratio	V	Cost/m^3	Total Cost, Rs
A	0.88	5216.19	28	146053.32
B	1.45	6797.7	19	129156.3
C	1.73	7574.58	22	166640.76
Economical pit is B				

3 b. **State Stoke's law. Pertaining to soil sedimentation, list the assumptions and limitations of Stoke's law.** **(5)**

Law – 1

Assumptions -0.5×4=2

Limitations -0.5×4=2

Stoke's law states that a sphere settling in a viscous medium of infinite extent experience a viscous drag which is directly proportional to its settling velocity/ terminal velocity, viscosity of the medium and radius of the sphere. The terminal velocity of the sphere is directly proportional to the shape of the sphere and its weight.

Sl No	Parameter	Assumptions	Limitations
1	Shape	Shape of the sphere is assumed as spherical	This is not true. All particles are not spherical
2	Medium	Medium is of infinite extent	Its false. Medium is of finite extent
3	Interference	There is no interference between particles	Particle interference will effect settling velocity.
4	Particle size	Is applicable to all particle sizes	Particles greater than 0.2 mm cause turbulence and particles less than 0.002 mm will cause Brownian movement
5	Soil type	Can be used for all soils	Cannot be used for chalky soils because of pre-treatment

4 a. **Explain the following with respect to clay mineral (i) Cation exchange capacity (ii) Isomorphous substitution.** **(5)**

Cation exchange capacity (2.5)

Isomorphous substitution (2.5)

Cation exchange capacity/base exchange capacity

In the presence of polar fluids like water, clay develops negative charges. Cations Na^+, K^+ or Mg^{2+} or H^+ ions move to the surface of the negatively charged particles and form what is known as the adsorbed layer. The H+ ions can be replaced by other cations such as Na, K or Mg. These cations enter the adsorbed layers and constitute what is termed as an adsorption complex. The process of

replacing cations of one kind by those of another in an adsorption complex is known as base exchange and the cations that can be replaced by other ions is called as exchangeable ions.

Base exchange capacity is expressed in terms of milliequivalent per 100 gm of soil which is equal to 6×10^{20} electronic charges.

Isomorphous substitution

If one atom in basic unit of clay mineral is replaced by another atom, it is called as isomorphous substitution. As a result of this the negative charge of the clay mineral increases. For example, when one silicon atom in a tetrahedron is replaced by aluminium atom, there will be a deficiency of unit positive charge per atom. Similar is the effect when Magnesium replaces aluminium from the clay mineral.

b. **The moisture content of an undisturbed sample of clay belonging to a volcanic region is 265% under** **(5)** **100% saturation. The specific gravity of the solids is 2.5. The dry unit weight is 16.5 kN/m³. Determine (i) Saturated unit weight (ii) Submerged unit weight and (iii) Void ratio.**

(i)Saturated unit weight - (1.5)

(ii) Submerged unit weight and (1.5)

(iii) Void ratio (2)

Given: w=2.65 ; S=1; G=2.5; γ_d = 16.5 kN/m³

$$\gamma_d = \frac{\gamma}{1+w} = \frac{\gamma_{sat}}{1+w}$$

Or $\gamma_{sat} = \gamma_d (1 + w) = 16.5 \times (1 + 2.65) = 60.225$ kN/m³

$\gamma_{sub} = \gamma_{sat} - \gamma_w = 60.225 - 9.81 = 50.415 \ kN/m3$

$$\gamma_d = \frac{G\gamma_w}{1 + e}$$

Or $e = \frac{2.5 \times 9.81}{16.5} - 1 = 0.486$

5 **Define diffused double layer. With the aid of schematic diagrams distinguish between principal clay** **(10)** **minerals viz. Kaolinite, Montmorillonite and Illite.**

Diffused double layer- explanation+ fig – 2 + 0.5 = 2.5

Minerals- 3 Nos -2×3=6

Fig – 0.5×3=1.5

Diffused double layer:

Clay particles have negative charge by virtue of isomorphous substitution. This negative charge on the surface of the clay particle, therefore, attracts cations or positive (hydrogen) ends of the water molecules. This attractive force decreases with the increase in the distance of the water molecule

from the surface. The electrically attracted water that surrounds the clay particle is known as the diffused double-layer of water. The water located within the zone of influence is known as the adsorbed layer as shown in Fig. 5a. Near the surface of the particle the water has the property of a solid. At the middle of the layer it resembles a very viscous liquid and beyond the zone of influence, the properties of the water become normal.
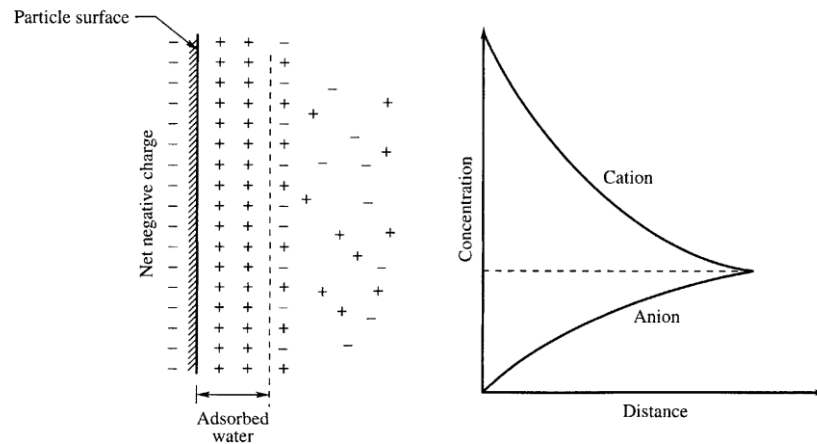

Fig. 5a Diffused double layer developed around clay

Kaolinite

|	
➤ The thickness of the layer is about 7 A° (one angstrom = 10~8 cm) thick. ➤ The kaolinite mineral is formed by stacking silica sheets and gibbsite sheets one above the other. ➤ The sheets are held to each other by hydrogen bonding. ➤ The mineral is therefore, stable, and water cannot enter between the sheets to expand the unit cells. ➤ In the kaolinite mineral there is a very small amount of isomorphous substitution.	
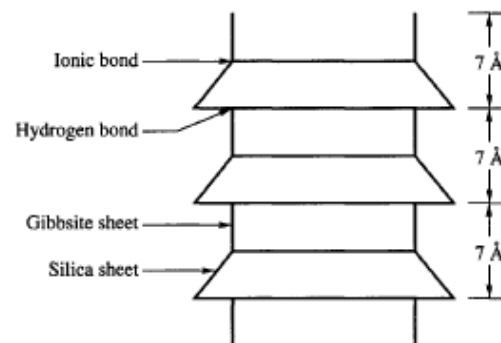
Montmorillonite mineral

> The silica and gibbsite sheets are combined in such a way that the tips of the tetrahedrons of each silica sheet and one of the hydroxyl layers of the octahedral sheet form a common layer.

> The thickness of the silica-gibbsite-silica unit is about 10 A°.

> In stacking these combined units one above the other, oxygen layers of each unit are adjacent to oxygen of the neighbouring units with a consequence that there is a very weak bond and an excellent cleavage between them.

> Water can enter between the sheets, causing them to expand significantly and thus the structure can break into 10 A° thick structural units.
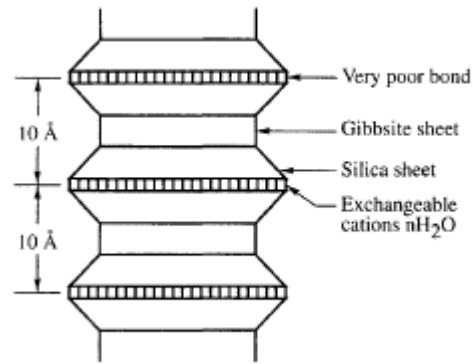
> Soils containing a considerable amount of montmorillonite minerals will exhibit high swelling and shrinkage characteristics.

> In montmorillonite, there is isomorphous substitution of magnesium and iron for aluminium.

Illite mineral

> Here silicon atoms are replaced by aluminum atoms and the resultant charge deficiency is balanced by potassium ions.

> The link between dfferent structural unit is through non-exchangeable K^+ ions and not through water.

> The bonds with the K^+ ions are weaker than the hydrogen bonds, but stronger than the water bond of montmorillonite.

> Illite, therefore, does not swell as much in the presence of water as does montmorillonite.
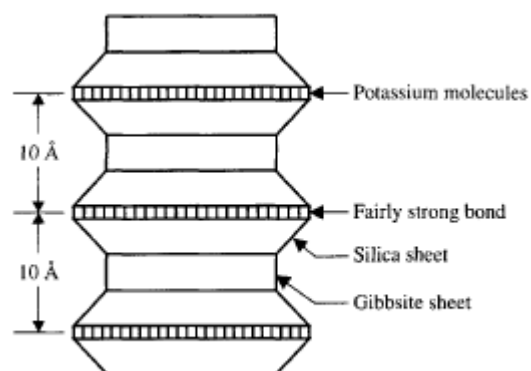
6 **With the help of phase diagram differentiate between the following:** **(10)**

      (i) **Voids ratio and porosity**
      (ii) **Water content and degree of saturation**
      (iii) **Absolute/true specific gravity and apparent specific gravity**
      (iv) **Air content and percentage air voids**
      (v) **Bulk density and dry density**

Each item -2
5 items - 2×5=10

i	Void ratio , $e = \dfrac{V_v}{V_s}$ Expressed as a decimal, Can be greater than 1	Porosity , $n = \dfrac{V_v}{V}$ Expressed as a percentage, Will be less than 1
ii	Water content, $w = \dfrac{M_w}{M_s}$ It's a mass relationship, Expressed as a percentage Can be greater than 1 also	Degree of saturation, $S = \dfrac{V_w}{V_v}$ It's a volume relationship, Expressed as a percentage Will be less than 1.
iii	Absolute/true specific gravity $= \dfrac{\rho_s}{\rho_w}$ It is defined as the mass of dry soil in air to mass of equal volume of water (excluding voids from solids volume) at 4°C)	Apparent specific gravity $= \dfrac{\rho}{\rho_w}$ It is defined as the mass of substance in air to mass of equal volume of water (including voids from solids volume) at 4°C) This will be greater than absolute specific gravity
iv	Air content , $a_c = \dfrac{V_a}{V_v}$ Expressed as a percentage, Cannot be greater than 1	Percentage air voids , $n_a = \dfrac{V_a}{V}$ Expressed as a percentage, Cannot be greater than 1
v	Bulk density, $\rho = \dfrac{M}{V}$ It's a mass -volume relationship, Unit is gm/cc or kg/m^3	Dry density, $\rho_d = \dfrac{M_s}{V}$ It's a mass -volume relationship, Unit is gm/cc or kg/m^3