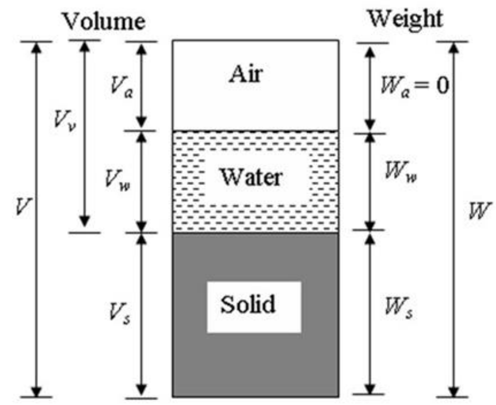
# Internal Assessment Test 1 Solutions – Mar. 2018

| SUB: BASIC GEOTECHNICAL ENGINEERING | Sub Code: 15CV45 | Branch: CIVIL |
|---|---|---|

| | | |
|---|---|---|
| 1 (a) | **With the help of phase diagram define the following (a)Void ratio (b) Air content (c) Water content (d) Submerged unit weight** | [06] |
| | **Each item = 1.25×4**<br>**Fig - 1** | |

| | |
|---|---|
| **a) Void ratio**<br>Void ratio, $e = \frac{V_v}{V_s}$<br>It's a volume relationship. Expressed as a number.<br>Can be less than 1, =1 or more than 1. | **d) Submerged unit weight**<br>It is defined as submerged weight per unit volume. Submerged weight,<br>$\gamma_{sub} = \frac{W_{sub}}{V} = \gamma_{sat} - \gamma_w$ |
| **b) Air content**<br>Aircontent $a_c = \frac{V_a}{V_v}$<br>It's a volume relationship. Expressed as percentage and used as decimal in equations.<br>Will be less than 1.<br>**c) Water content**<br>Water content, $w = \frac{M_w}{M_s}$<br>It's a mass relationship. Expressed as a percentage. Can be greater than 1 also |  |



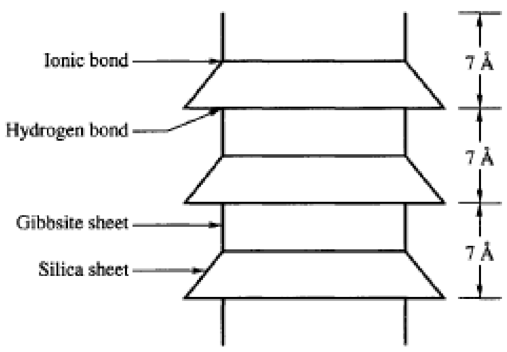
| | | |
|---|---|---|
| (b) | **List the different types of clay minerals commonly found in soils. Briefly explain Kaolinite and Montmorillonite mineral.** | [07] |
| | **Each item = 2.5×2**<br>**Fig - 2** | |

**Kaolinite mineral**

- 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.
- In the kaolinite mineral there is a very small amount of isomorphous substitution.

**Characteristics**

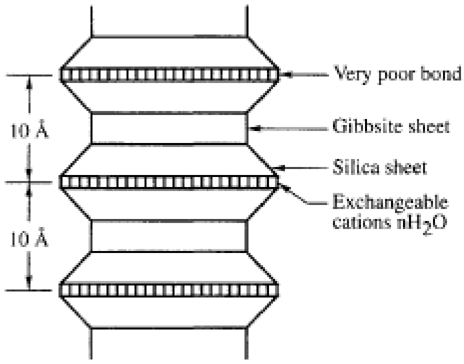
- The sheets are held to each other by hydrogen bonding.
- The mineral is therefore, stable, and water cannot enter between the sheets to expand



the unit cells.

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




**Characteristics**

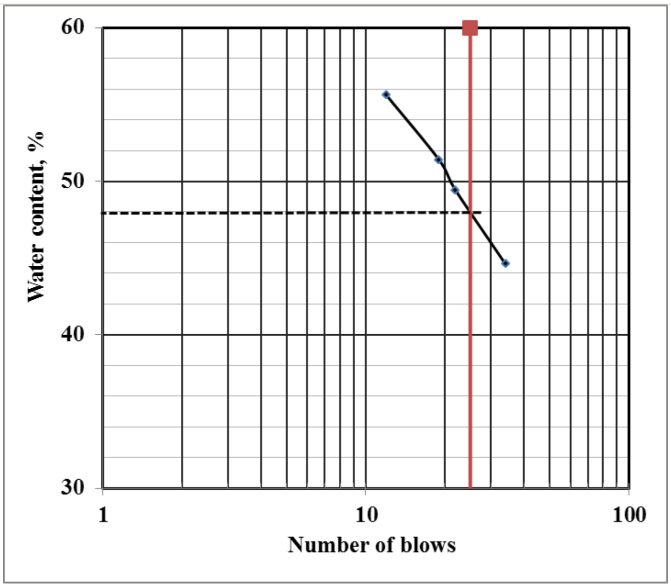
- Soils containing a considerable amount of montmorillonite minerals will exhibit high swelling and shrinkage characteristics.

**(c)** **The results of a liquid limit test are given below:** [07]

| No.of blows | 34 | 22 | 19 | 12 |
|---|---|---|---|---|
| Water Content (%) | 44.6 | 49.4 | 51.4 | 55.6 |

**If the natural water content is 28%, The plastic limit of the soil is 23%. Plot the flow curve and determine (i) Liquid limit (ii) Plasticity index (iii) Flow index (iv) Toughness index and (v) Consistency index.**

**Each item = 1×5**
**Graph - 2**




Liquid limit = 48%

Plasticity index = 48-23 = 25%

Flow index = $\frac{51-46}{log10\ (30-20)} = 28.4\%$

Toughness index = $\frac{25}{28.4} = 0.88$

| | | |
|---|---|---|
| | Consistency index = $\frac{48-28}{25} = 80\%$ | |
| 2 (a) | **State Stoke's law. Pertaining to soil sedimentation, list the assumptions and limitations of Stoke's law.** | [05] |
| | **Statement -2**<br>**Assumptions -2**<br>**Limitations- 3** | |

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 |

(b) Considering soil as a three phase system, derive the relationship, $\gamma_d = \frac{G\gamma_w}{1+e}$. [05]

Phase diagram – 1

$\rho_b = \frac{G\rho_w+\rho_w eS}{1+e}$ **-2**

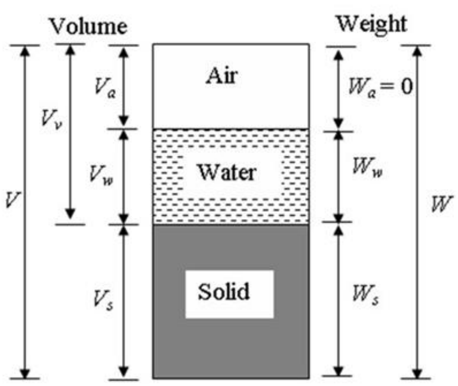
$\rho_d = \frac{G\rho_w}{1+e}$ **-1**

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

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

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

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




$\rho_b = \frac{M}{V} = \frac{M_s+M_w}{1+e} = \frac{G\rho_w V_s+\rho_w V_w}{1+e}$

$S = \frac{V_w}{V_v} = \frac{e_w}{e}$

Or $V_w = e_w = eS$

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

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

For an oven dried soil, S=0

Hence dry density, $\rho_d$ can be obtained as

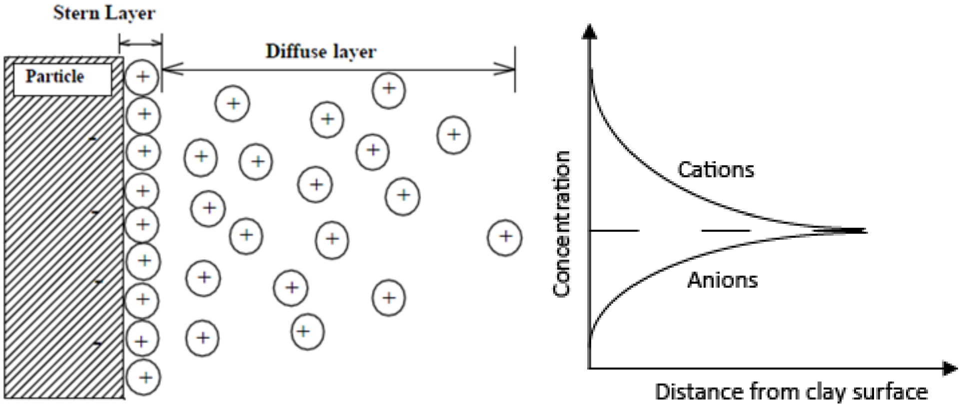
$\rho_d = \frac{G\rho_w}{1+e}$

In SI units, when $\rho_d$ becomes $\gamma_d$ and $\rho_w$ becomes $\gamma_w$

$Therefore\ \rho_d = \frac{G\rho_w}{1+e}$ becomes $\gamma_d = \frac{G\gamma_w}{1+e}$

**(c)** **With neat sketches explain electrical diffused layer.** [05]

**Fig – 2**
**Explanation-3**




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.

**3 (a)** **Briefly explain corrections to hydrometer reading.** [05]

**Each correction= 1.25×4**

To hydrometer readings mainly 4 corrections are applied

(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, $R'_h = R_h \pm c_m$

**(b)** **How many cubic meters or soil can be formed with a void ratio of 0.6 from 1000 cubic meters of soil shaving void ratio of 1.4.** [05]

**Estimation of Vs = 2.5**
**Estimation of V=2.5**

Void ratio of embankment = $1.4 = \frac{V_v}{V_s} = \frac{V - V_s}{V_s} = \frac{1000 - V_s}{V_s}$

$V_s = 416.67\ m^3$

$m^3$ of fill that can be constructed:

$$e = \frac{V - V_s}{V_s} \text{ or } V = (1+e) \times V_s == (1+0.6) \times 416.67 = 666.67\ m^3$$

**(c)** **Prove that e×S = w×G** [05]

**Fig- 1**
**Final expression-4**

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

Assume $V_s$=1, then, $e = \frac{V_v}{1}$ *or Vv=e*

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

$\rho_b = \frac{M}{V} = \frac{M_s + M_w}{1+e} = \frac{G\rho_w V_s + \rho_w V_w}{1+e}$

$S = \frac{V_w}{V_v} = \frac{e_w}{e}$

Or $V_w = e_w = eS$

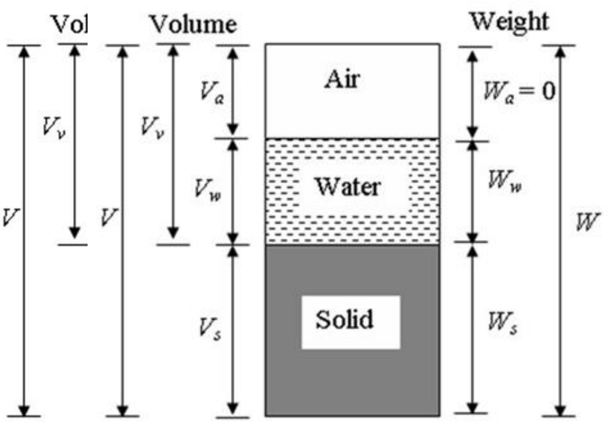
Since $Vs = 1$ and $V_w = eS$,

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

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

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

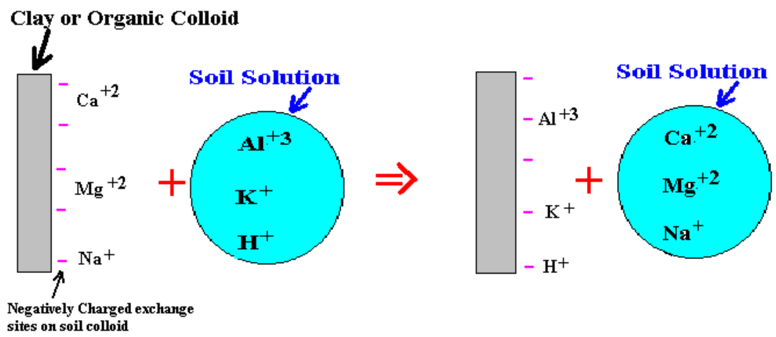
Or **eS=wG**



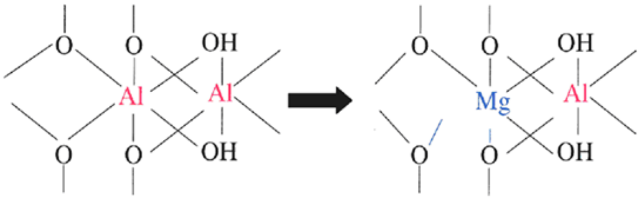

**4 (a)** **Write short note on (i) Base Exchange capacity and (ii) Isomorphous substitution by giving examples. Explain its affect on clay structure.** [05]

**Each item = 2.5×4**

(i) **Cation exchange capacity/base exchange capacity:** In the presence of polar fluids like water, clay develops negative charges. Cations Na+, K+ or Mg2+ 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. 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 $6\times10^{20}$ electronic charges. Negative charge is high for soils containing Montomorillonite minerals.




**(ii) 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 aluminum from the clay mineral. Owed to isomorphous substitution, the negative charge of clay increases.

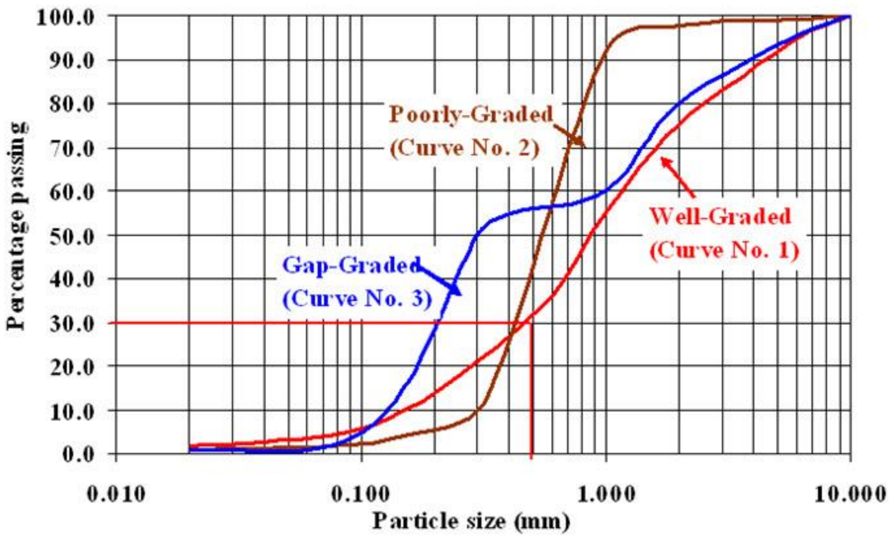



**(b)** **With the help of particle size distribution curve, explain the terms (i) Well Graded (ii) Uniformly graded and (iv) Gap graded distributions. Explain how the gradation of soil can be determined using the particle size distribution curve.** [05]

Fig – 3

Cu and Cc - 2

A soil is said to be "well graded", if it contains a good representation of various grain-sizes. This is represented by Curve No 1 in the graphical representation below. If the soil contains grains of mostly one size, it is said to be "uniform" or "poorly graded" and is represented by Curve No 2 in the graphical representation below. A soil is said to be "gap-graded", if it is deficient in a particular range of particle sizes and is represented by Curve no 3 in the graph below. All the different gradations are shown below.




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

$$C_u = \frac{D_{60}}{D_{10}}$$

Similarly coefficient of curvature is given as

$$C_u = \frac{[D_{30}]^2}{[D_{60} \times D_{10}]}$$

where D60 = Particle size corresponding to 60% finer.

D30 = Particle size corresponding to 30% finer

and D10 = Particle size corresponding to 10% finer or effective size.

Cu 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. Cc should be between 1 and 3 for well graded soil

**(c)** **The moisture content of an undisturbed sample of clay belonging to a volcanic region is 265% under 100% saturation. The specific gravity of the solids is 2.5. The dry unit weight is** [05]

| | | |
|---|---|---|
| | **16.5 kN/m3. Determine (i) Saturated unit weight (ii) Submerged unit weight and (iii) Void ratio.** | |
| | Saturated unit weight - 2<br>Submerged unit weight -1<br>Void ratio -2 | |

**Given :**

w=265% = 2.65

S=1

G=2.5

$\gamma_d$ = 16.5 kN/m$^3$

$\gamma_w$ = 10 kN/m$^3$

**Solution:**

$$\gamma_{sat} = \left[\frac{G+e}{1+e}\right]\gamma_w$$

eS=wG

e×1 =2.65×2.5

**e== 6.625**

$$\gamma_{sat} = \left[\frac{2.5+6.625}{1+6.625}\right] \times 10$$

$\boldsymbol{\gamma_{sat}}$ **= 11. 97 kN/m$^3$**

$\boldsymbol{\gamma_{sub} == \gamma_{sat} - \gamma_w}$ **= 11.97-10 = 1.97 kN/m$^3$**