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CMRIT — CMR INSTITUTE OF TECHNOLOGY, BENGALURU. ACCREDITED WITH A+ GRADE BY NAAC

# Internal Assessment Test 1 – November 2021

| Sub: | BASIC GEOTECHNICAL ENGINEERING | | | | | Sub Code: | 18CV54 | Branch: | CIVIL |
|---|---|---|---|---|---|---|---|---|---|
| Date: | 12.11.2021 | Duration: | 90 min's | Max Marks: | 50 | Sem / Sec: | VA | | OBE |

**Answer all questions. Question numbers should be correctly entered.**
**Assume any missing data suitably. Provide neat sketches wherever necessary**

| | | | MARKS | CO | RBT |
|---|---|---|---|---|---|
| 1 | (a) | With the help of a three phase diagram explain (a) Void ratio b) Porosity (c) Degree of saturation (d) Water content. | [06] | CO1 | L2 |
| | (b) | With the usual denominations derive the relationship: $\gamma_d = \frac{G\gamma_w.(1-n_a)}{1+wG}$ | [06] | CO1 | L3 |
| | (c) | A sample of soil has a volume of 1000 cc and a weight of 17.2 N. the specific gravity of soil solid is 2.60. If dry unit weight is 15.5 kN/m$^3$, determine the water content, void ratio, submerged unit weight and degree of saturation. | [08] | CO1 | L4 |
| 2 | (a) | List and explain the various soil structures. | [06] | CO1 | L2 |
| | (b) | Explain electrical diffused double layer and adsorbed water with neat sketches. | [06] | CO1 | L2 |
| | (c) | Describe the three principal clay minerals with neat sketches. | [08] | CO1 | L3 |
| 3 | (a) | An oven dried soil weighing 1.854 N is placed in a pycnometer. The total weight of the pycnometer along with soil and water is 15.51 N. the pycnometer along with water alone weighs 14.34 N. Determine the specific gravity of soil. | [04] | CO1 | L3 |
| | (b) | Write short note on (a) Cation Exchange capacity (b) Isomorphous substitution. | [06] | CO1 | L2 |

Signature of CI     Signature of CCI     Signature of HoD

Solution for Internal Assessment Test 1 – November 2021

| | | | | | | | | | |
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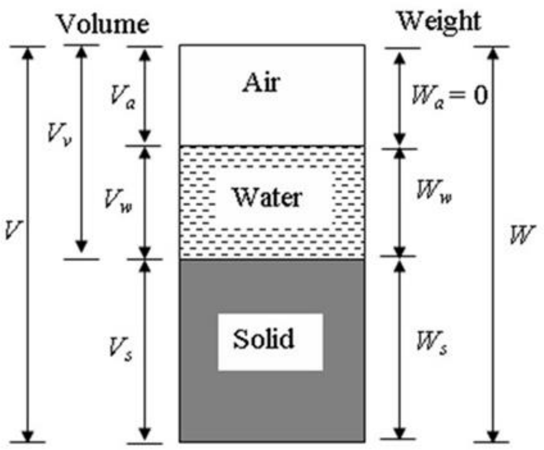
***Assume any missing data suitably. Provide neat sketches wherever necessary***

1 (d) With the help of a three phase diagram explain (a) Void ratio b) Porosity (c) Degree of saturation (d) Water content. [06] CO1 L2

Scheme: explanation of each with figure denotions – 1.5×4 = 6 marks

[06] CO1 L3




**Void ratio**

Void ratio, $\boldsymbol{e} = \frac{V_v}{V_s}$

It's a volume relationship. Expressed as a number.

Can be less than 1, =1 or more than 1.

**Porosity**

Porosity, $\boldsymbol{n} = \frac{V_v}{V}$

It's a volume relationship. Expressed as percentage and used as decimal in equations.

Can be less than 1.

**Degree of saturation**

Degree of saturation, $\boldsymbol{S} = \frac{V_w}{V_v}$

It's a volume relationship, expressed as a percentage. Will be less than 1.

**Water content**

Water content, $w = \frac{M_w}{M_s}$

It's a mass relationship. Expressed as a percentage. Can be greater than 1 also.

(e) With the usual denominations derive the relationship:

$$\gamma_d = \frac{G\gamma_w.(1-n_a)}{1+wG}$$

**Phase diagram – 1**

**Derivation - 5**

$$\boldsymbol{V = V_a + V_w + V_s}$$

**Dividing throughout by V**

$$\boldsymbol{1 = \frac{V_a}{V} + \frac{V_w}{V} + \frac{V_s}{V}}$$

$$\boldsymbol{1 = \frac{V_a}{V} + \frac{M_w}{\rho_w.V} + \frac{M_s}{\rho_s.V}}$$

$$\boldsymbol{1 = \frac{V_a}{V} + \frac{w.M_s}{\rho_w.V} + \frac{M_s}{\rho_s.V}}$$

$$\boldsymbol{1 - n_a = \frac{w.\rho_d}{\rho_w} + \frac{\rho_d}{G.\rho_w}}$$

$$\boldsymbol{1 - n_a = \frac{\rho_d}{\rho_w}\left(w + \frac{1}{G}\right)}$$

$$\boldsymbol{\rho_d = \frac{G.\rho_w(1-n_a)}{1+wG}}$$

| | | | |
|---|---|---|---|
| (f) A sample of soil has a volume of 1000 cc and a weight of 17.2 N. the specific gravity of soil solid is 2.60. If dry unit weight is 15.5 kN/m$^3$, determine the water content, void ratio, submerged unit weight and degree of saturation. | [08] | CO1 | L4 |

Unknown = 2×4 = 8

$$Unit\ weight = \frac{17.2}{10^{-3}} = 17.2\ kN/m^3$$

$$Dry\ Unit\ weight = 15.5\ kN/m^3$$

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

$$15.5 = \frac{17.2}{1+w}$$

$$w = 10.96\%$$

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

$$15.5 = \frac{2.6 \times 9.81.}{1+e}$$

$$e = 0.645$$

$$eS = wG$$

$$S = 44.17\%$$

$$\boldsymbol{\rho_{sat} = \frac{\gamma_w(G+eS)}{1+wG}}$$

$$\boldsymbol{\gamma_{sat} = \frac{9.81(2.6 + 0.645 \times 1)}{1 + 0.1096 \times 2.6}}$$

$$\boldsymbol{\gamma_{sat} = 24.77}\ kN/m^3$$

$$Submerged\ Unit\ weight = (24.77 - 9.81)\ kN/m^3$$
$$Submerged\ Unit\ weight = 14.96\ kN/m^3$$

| | | | | | |
|---|---|---|---|---|---|
| 2 | (a) | List and explain the various soil structures. | [06] | CO1 | L2 |

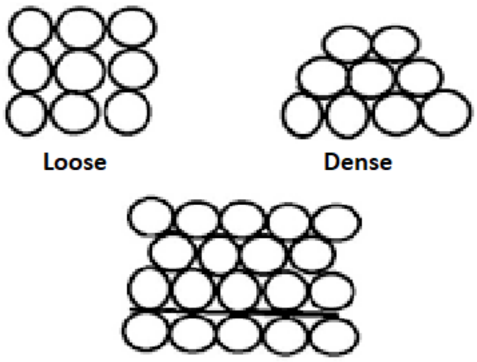
Atleast 4 structure with figures– 1.5×4 = 6

Geometrical arrangement of soil particles with respect to one another is known as soil structure. The different soil structures include

1. Single grained structure
2. Honey comb structure
3. Flocculated structure
4. Dispersed structure
5. Coarse grained skeleton
6. Clay-matrix structure

**Single grained structure**

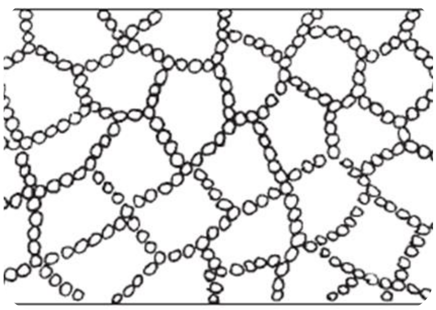
- Single-grained structure is characteristic of coarse grained soils, with a particle size greater than 0.02 mm.
- Gravitational forces predominate the surface forces and hence grain to grain contact results.
- The deposition may occur in a loose state, with large voids or in a dense state, with less of voids.



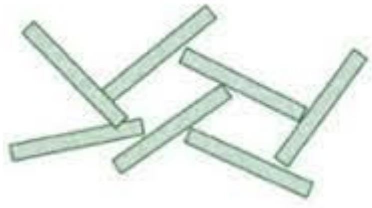

Single Grained Structure

**Honey comb structure**

- This structure can occur only in fine-grained soils, especially in silt and rock flour.
- 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.

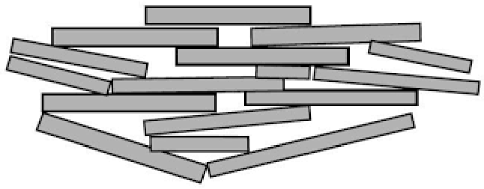


**Flocculated structure**



- They have large surface area and electrical forces are important in such soils.
- They have a negative charge on the surface and a positive charge on the edges.
- Interparticle contact develops between positively charged edges and negatively charged faces resulting in a flocculated structure.
- This structure is caused due to the net attractive force between the particles.
- Very fine particles or particles of colloidal size (< 0.001 mm) may be in a flocculated or dispersed state.
- Clay settling out in salt water solution have flocculent structure than in fresh water solution. This is because salt is an electrolyte.
- They will be light in weight and have high void ratio and water content.
- They are insensitive to vibrations.

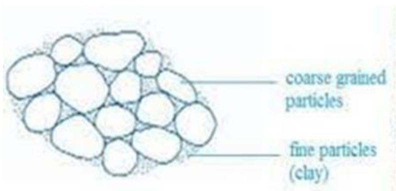
**Dispersed structure**



- 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.
- Remolding converts edge to face orientation to face to face orientation.
- This is because repulsive forces prevail between particles.

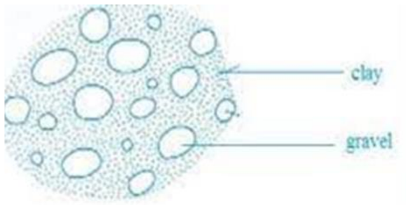
**Coarse grained skeleton**

- It is a composite structure which is formed when the bulky cohesionless paticles are large compared to fine grained clayey particles.
- Bulky grains form a skeleton and the space occupied by the clayey particles is known as binders
- A coarse grained skeleton can take heavy load without much deformations. However, when the structure is disturbed, load is transferred from coarse grained particles to clayey particles and the support and stability of soil gets reduced




**Clay-matrix structure**

- Here the amount of clay particle is very large compared to coarse grained particles.
- Clay forms a matrix in which bulky grains appear floating without touching one another. They have the properties same as that of clay.



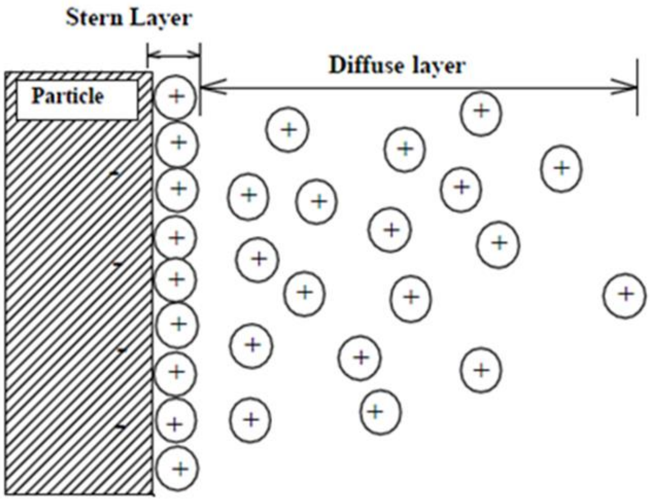

(b) Explain electrical diffused double layer and adsorbed water with neat sketches. [06] CO1 L2

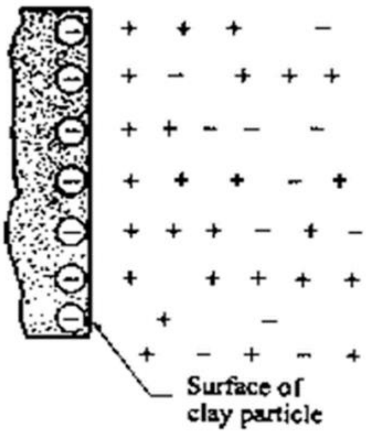
Explanation – 3 marks

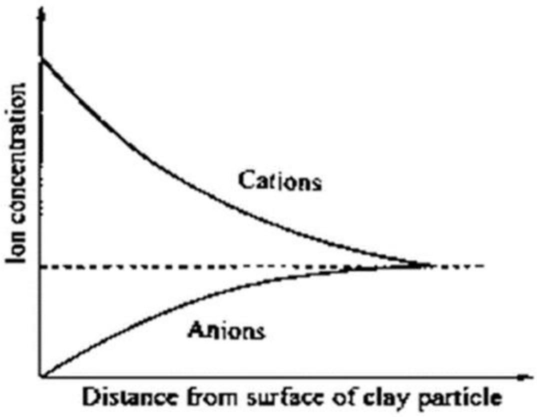
Values – 1

Figures - 2

Clay minerals have a charge. Edges generally have a positive charge and faces have a negative charge. Charges in clay minerals are due to the grouping and arrangement of ions. Because of this negative charge clay particles attract cations such as potassium, calcium, sodium etc. from the moisture present in the soil to reach an electrically balanced equilibrium. Charges in clay are due to high surface area to volume ratio. The net effect of forces decreases exponentially with increase in distance from the clay particle surface. This zone




of influence of clay charge is called as diffuse double layer. The total thickness of diffuse double layer is about 400 A⁰ out of which 10 A⁰ is held tightly to the clay surface. This tightly held layer is called as stern layer. The water held in the double layer is called as adsorbed layer or oriented water.

(c) Describe the three principal clay minerals with neat sketches. [08] CO1 L3

Kaolinite – 2 Other two minerals – 3 marks each

**Kaolinite**

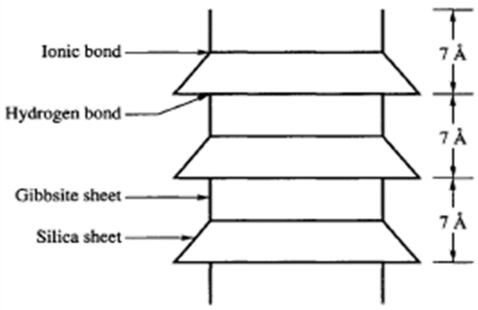
- The thickness of the layer is about 7 A° (one angstrom = 10~8 cm) thick.
- The sheets are held to each other by hydrogen bonding.
- The mineral is therefore, stable, and water cannot enter between the sheets to expand the unit cells.
- In the kaolinite mineral there is a very small amount of isomorphous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

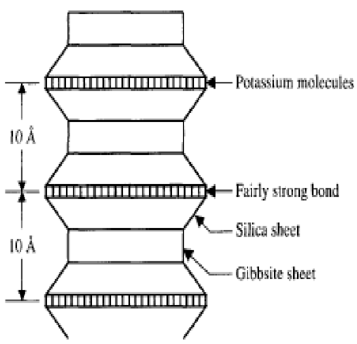
**Montmorillonite a**

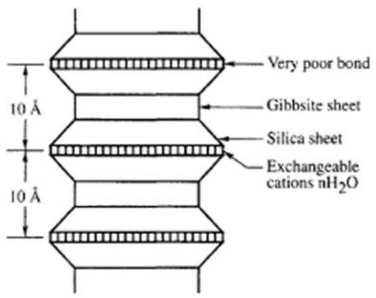
- The thickness of the silica-gibbsite-silica unit is about 10 A°.
- In stacking these combined units one above the other, there is a very weak bond and an excellent cleavage between them.
- Water can enter between the sheets, causing them to expand significantly and thus the structure can break into 10 A° thick structural units.
- In montmorillonite, there is isomorphous substitution of magnesium and iron for aluminium.

**Illite**

- The thickness of the silica-gibbsite-silica unit is about 10 A°.
- Some of the silicons in silica sheet are replaced aluminum atoms and the resultant charge deficiency is balanced by potassium ions.
- The link between different structural unit is through non-exchangeable K+ ions and not through water.




3 (a) An oven dried soil weighing 1.854 N is placed in a pycnometer. The total weight of the pycnometer along with soil and water is 15.51 N. the pycnometer along with water alone weighs 14.34 N. Determine the specific gravity of soil. [04] CO1 L3

Equation +Value = 2+2

$$G = \frac{1.854}{1.854 - (15.51 - 14.34)} = 2.71$$

(b) Write short note on (a) Cation Exchange capacity (b) Isomorphous substitution. [06] CO1 L2

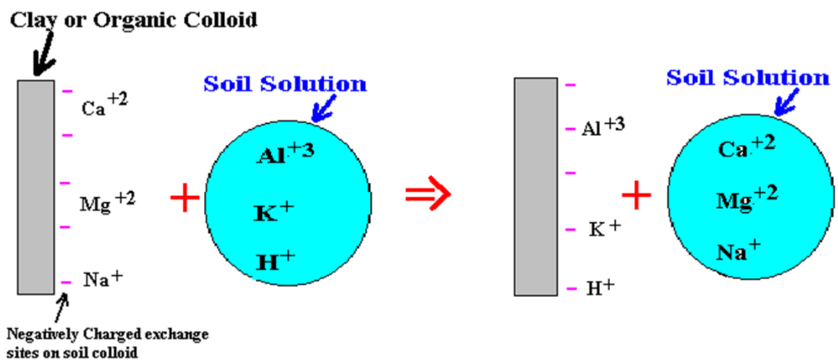
Each one explanation 2 marks + 1 mark for figures

(a) Cation Exchange capacity

The cations attracted to the negatively charged surface of the soil particles are not strongly attracted. These cations can be replaced by other ions called as exchangeable ions. The soil particles and the exchangeable ions make the system neutral. Base exchange capacity is the capacity of the clay particles to change cation adsorbed on the surface. Base exchange capacity is expressed in terms of total number of positive charges adsorbed on the surface per 100 g of soil. It is expressed as milliequivalent (meq) which is equal to $6\times10^{20}$ electronic charges. Thus 1 meq per 100 g means that 100 g of material can exchange $6\times10^{20}$ electronic charges if the ions are monovalent. If its divalent cation, 100 g of material can exchange 3×1020 electronic charges.

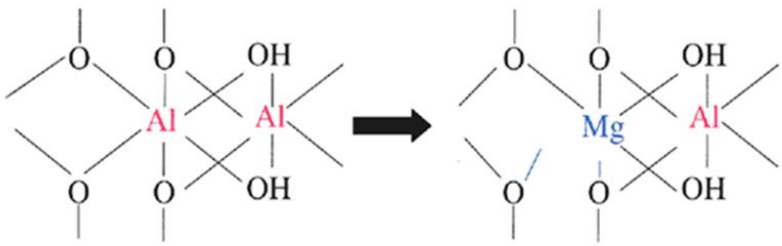
The affinity of attraction is as follows:

$Al^{3+} > Ca^{2+} > Mg^{2+} > NH_4^{4+} > H^{+} > Na^{+} > Li^{+}$




(b) Isomorphous substitution

If one atom in a basic unit is replaced by another atom, it is called as isomorphous substitution. For eg: Silicon atom in a tetrahedral unit will be substituted by an Aluminum atom or magnesium replacing aluminum in octahedral unit and so on. Silicon atom has four positive charge and aluminum has three positive charges. If Silicon is replaced by aluminum, there will be a deficiency of one positive charge. Hence isomorphous



causes an increase in the negative charge of an atom because of the reduction in positive charge.

Signature of CI    Signature of CCI    Signature of HoD