# SOIL MECHANICS - I
# (CIVL 2202)

**Time Allotted : 3 hrs** **Full Marks : 70**

***Figures out of the right margin indicate full marks.***

***Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.***

***Candidates are required to give answer in their own words as far as practicable.***

## Group – A
## (Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) The height of capillary rise of water above the ground water table in a homogeneous bed of sand ($w$ = 10%, $G$ = 2.67, $C$ = 0.5 cm$^2$) having an effective size of 0.12mm is given by
(a) 62.5 cm (b) 52.5 cm (c) 42.5 cm (d) 72.5 cm

(ii) The volume of water that will flow through a cylindrical soil sample ($k$ = 0.01 mm/sec) of 8 cm diameter and 12 cm height in a day under a constant head of 65 cm is
(a) 13.5 litres (b) 23.5 litres (c) 26.0 litres (d) 19.5 litres

(iii) Flow lines and equipotential lines intersect with each other at an angle of
(a) 120° (b) 60° (c) 90° (d) 30°

(iv) If $B$ is the width of footing, then the significant depth is equal to
(a) 1.75$B$ (b) $B$ (c) 1.25$B$ (d) 1.5$B$

(v) A sand sample is 50% saturated and has a bulk density of 1.75t/m$^3$. The specific gravity of solids is 2.65. The critical hydraulic gradient is given by
(a) 0.96 (b) 0.92 (c) 0.86 (d) 1.04

(vi) The limitation of sedimentation analysis is that Brownian movement takes place and particles size computed from Strokes' law gives erroneous results when particle size is
(a) < 0.0002 mm (b) < 0.002 mm
(c) > 0.0002 mm (d) > 0.002 mm.

(vii) A soil sample has % sand = 40%, % fines =15 ; $I_p$ = 6, the soil is classified as per IS classification as,
(a) Silty Gravel (GM) (b) Silty and clayey gravel (GM-GC)
(c) Silty sand (SM) (d) Silty and Clayey sand (SM-SC)

(viii) For soils containing gypsum or organic matter maximum oven drying temperature for water content determination should be,
(a) 40°- 60°C (b) 80°-100°C
(c) 60°- 80°C (d) 105°-110°C.

(ix) In a vane shear, the blades, after insertion into soil, are rotated at the rate of
(a) 0.1°/sec (b) 0.6° /sec (c) 0.1° /min (d) 0.6°/min

(x) The corrected cross-sectional area at failure ($A_f$) can be obtained from original cross-sectional are ($A_0$) in an unconfined compression test using the relation
(a) $A_f = A_0/(1-\epsilon_l)$ (b) $A_f = A_0(1-\epsilon_l)$
(c) $A_f = A_0/(1-\epsilon_v)$ (d) $A_f = [V_o/(1+\epsilon_v)]/[l_o/(1\pm\epsilon_l)]$.

## Group – B

2. (a) For constructing an embankment, the soil is transported from a borrow area using a truck which can carry 6 $m^3$ of soil at a time. With the following details, determine the number of truck loads of soil required to obtained 100 $m^3$ of compacted earth-fill and the volume of borrow pit.

| Property | Borrow area | Truck (loose) | Field (compacted) |
|---|---|---|---|
| Bulk Density | 16.6 kN/$m^3$ | 11.5 kN/$m^3$ | 18.2 kN/$m^3$ |
| Water content (%) | 8 % | 6 % | 14% |

(b) Laboratory test on a sample of soil gave the following results:
(i) Natural water content = 24%
(ii) Liquid limit = 62%
(iii) Plastic limit = 28%
(iv) Percentage of particles less than 2μ = 23%
Determine the liquidity index and activity number

(c) Write short notes on flocculent and dispersed structures.

**7 + 2 + 3 = 12**

3. (a) The results of laboratory tests conducted on two soils A and B are as follows:

| | Soil A | Soil B |
|---|---|---|
| % passing 0.075 mm sieve | 14 | 75 |
| % passing 4.75 mm sieve | 92 | 100 |
| ($D_{10}$) mm | 0.14 | - |
| ($D_{30}$) mm | 0.33 | - |
| ($D_{60}$) mm | 1.00 | - |
| Liquid limit | 16 | 58 |
| Plastic limit | 8 | 14 |

Classify the two soils as per the Indian Standard Classification.

(b) An undisturbed saturated specimen of clay has a volume of 18.5 cc and a mass of 30.2 g. On the oven drying, the mass reduces to 18.0 g. The volume of dry specimen as determined by displacement of mercury is 9.98 cc. Determine shrinkage limit, specific gravity, shrinkage ratio and volumetric shrinkage.

(c) In a hydrometer analysis, particles of different sizes were mixed to form a uniform suspension of volume 1000 $cm^3$. It is required to determine the time required for the fall of all the particles of sizes ranging from 0.05 mm to 0.001 mm and also the time required for the coarsest of the particles to fall. The depth of fall is 20 cm. The other data available are G= 2.7 and $\mu = 8.1 \times 10^{-3}$ poises.

**5 + 4 + 3 = 12**

## Group – C

4. (a) A pumping test was carried out in the field in order to determine the average coefficient of permeability of a 18 m thick sand layer. The ground water table was located at a depth of 2.2 m below the ground level. A steady state was reached when the discharge from the well was 21.5 lit/sec. At this stage the drawdown in the test well was 2.54 m, while the drawdowns in two observation wells situated at 8 m and 20 m from the test well were found to be 1.76 m and 1.27 m, respectively. Determine co-efficient of permeability of the sand layer in 'm/day', radius of influence of the test well in 'm' and effective size of the sand particle i.e. $D_{10}$ in 'mm'. [Assume $C$ = 100 $cm^{-1}sec^{-1}$]

(b) At a particular site (Figure 1) lies a layer of fine sand 8 m thick below the ground surface and having a void ratio of 0.7. The ground water table is at a depth of 4 m below ground surface. The average degree of saturation of the sand above the capillary fringe is 50%. The soil is saturated due to capillary action to a height of 2.0 m above the ground water table level. Considering the effect of porosity, calculate the effective pressures at fringe level, ground water table level and at depth of 6 m below the ground level. [Given: $G$ = 2.65]

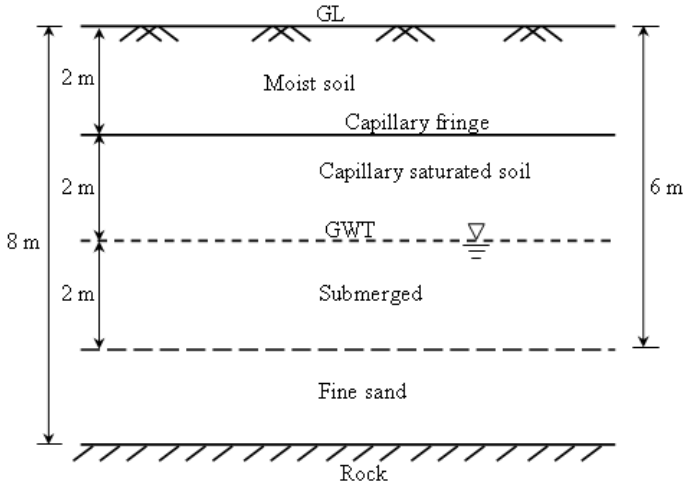


***Fig.1***

(c) A single row of sheet piles (Figure 2) is driven upto a depth of 4 m in a bed of clean sand having a co-efficient of permeability of 0.002 cm/sec. An impermeable layer of very stiff clay exists at a depth of 10 m below the ground level GL. The sheet pile wall has to retain water upto 4 m above GL. The height of water level on the downstream side is 0.5 m. The length of the last element is 1.1 m. Determine (i) Quantity of seepage loss considering unit width of the sheet piles, (ii) Piezometric heads at points A, B, and C, (iii) Exit gradient and (iv) Factor of safety against piping. [Given: $G$ = 2.67, $e$ = 0.95].

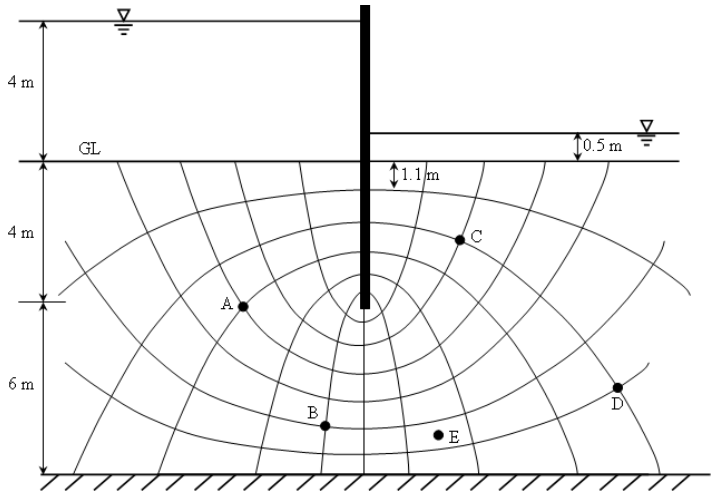


***Fig.2***

**3 + 3 + 6 = 12**

5. (a) The data given below relate to two falling head permeability tests performed on two different soil samples: (a) stand pipe area = 4 cm$^2$, (b) sample area = 28 cm$^2$, (c) sample height = 5 cm, (d) initial head in the stand pipe = 100 cm, (e) final head = 20 cm, (f) time required for the fall of water level in test 1, $t$ = 500 sec, (g) for test 2, $t$ = 15 sec. Determine the value of coefficient of permeability for each of the two test samples. If these two types of soils form adjacent layers in a natural state with flow (i) in the horizontal direction, and (ii) in the vertical direction, determine the equivalent coefficient of permeability for both the cases by assuming that the thickness of each layer is equal to 150 cm.

(b) At a site (Figure 3) the subsoil consists of a 8 m thick layer of dry sand ($G$ = 2.65, $e$ = 0.85, $D_{10}$ = 0.14 mm) which is underlain by a 6 m thick clay layer ($G$ = 2.75, $w$ = 22%) below which there exists a thick layer of rock. The water table is located at a depth of 6 m below the ground level. Neglecting the effect of porosity, determine effective pressures at the ground level, at ground water table level, at the level of capillary rise and at the bottom of sand layer. [Assume $C$ = 0.5 cm$^2$]

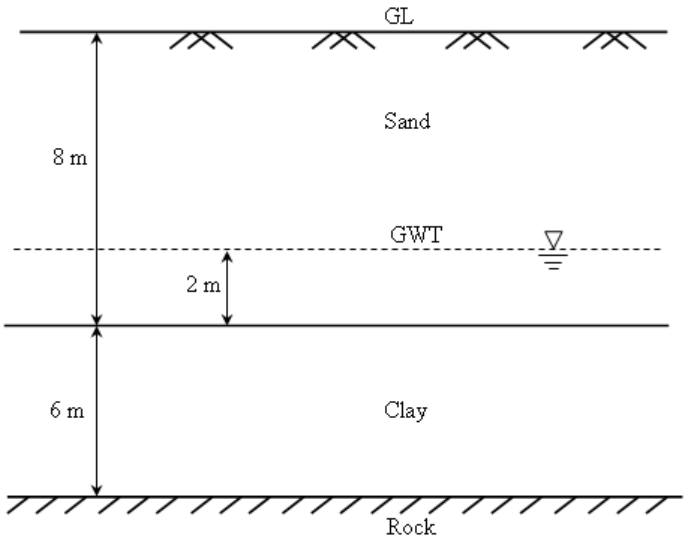


***Fig.3***

(c) A sheet pile wall (Figure 4) is driven into a silty soil having co-efficient of permeability of 0.5 × 10$^{-6}$ cm/sec. The length of the last element is 3.45 m. Find the pore pressure at points B, C, F and H.

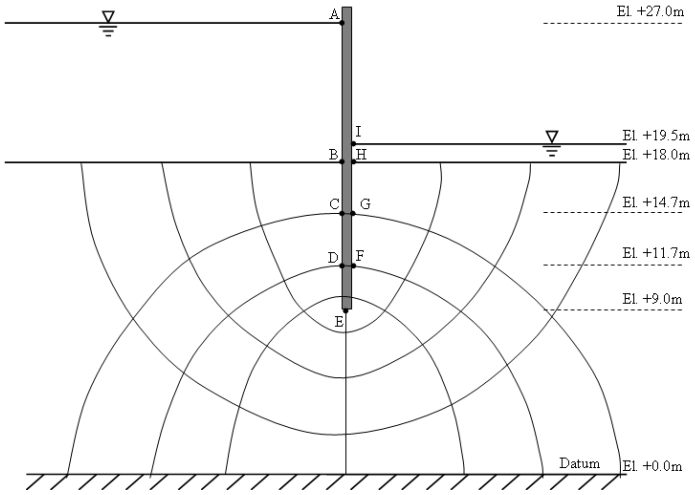


*Fig.4*

**4 + 4 + 4 = 12**

## Group – D

6. (a) A rectangular raft of size 30 m × 12 m founded at a depth of 2.5 m below the ground surface is subjected to a uniform pressure of 150 kPa. Assume the centre of the area is the origin of the coordinates (0,0) and the corners have the coordinates (6,15). Calculate the stresses at a depth of 20 m below the foundation level by the methods of Boussinesq and Westergaard at coordinates of (0,0), (6,15) and (10,25). Neglect the effect of foundation depth on stresses.

   (b) What are isobar and significant depth?

   (c) A ring footing of external diameter 8 m and internal diameter 4 m rests at a depth of 2 m below ground surface. It carries a load intensity of 150 kN/m$^2$. Using the following table, find the vertical stress at depths of 2 m, 4 m and 8 m along the axis of the footing below the footing base. Neglect the effect of excavation on the stress.

| $\sigma_z/q$ | $R/z$ | $\sigma_z/q$ | $R/z$ |
|---|---|---|---|
| 0.00 | 0.000 | 0.80 | 1.387 |
| 0.10 | 0.270 | 0.90 | 1.908 |
| 0.20 | 0.401 | 0.92 | 2.094 |
| 0.30 | 0.518 | 0.94 | 2.351 |
| 0.40 | 0.637 | 0.96 | 2.748 |
| 0.50 | 0.766 | 0.98 | 3.546 |
| 0.60 | 0.917 | 1.00 | ∞ |
| 0.70 | 1.110 | – | – |

**6 + 3 + 3 = 12**

7. (a) Three parallel strip footings (Figure 5) 3 m wide each and 5 m apart centre to centre transmit contact pressures of 200, 150 and 100 kN/m$^2$, respectively. Calculate the vertical stress due to the combined loads beneath the centres of each footing i.e. at points A, B and C at a depth of 3 m below the base. Assume the footings are placed at a depth of 2 m below the ground surface. Use Boussinesq's equation for line loads.

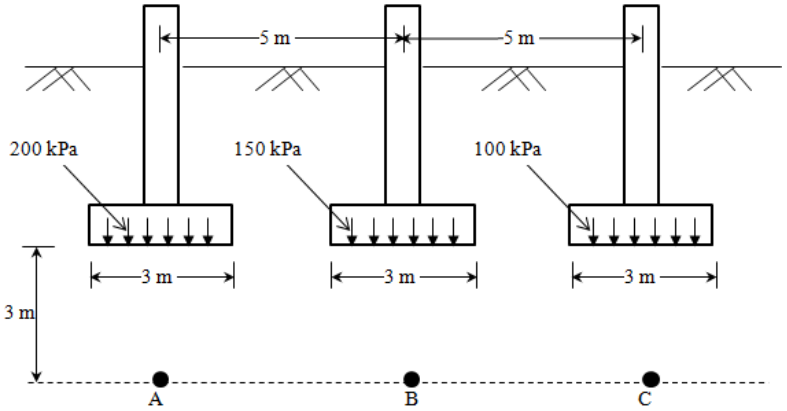


*Fig.5*

(b) A 3 m high embankment is to be constructed (Figure 6). If the unit weight of the soil used in the embankment is 19.0 kN/m$^3$, calculate the vertical stress due to the embankment loading at points $P_1$, $P_2$ and $P_3$ using Figure 7 for influence co-efficient given with the problem.

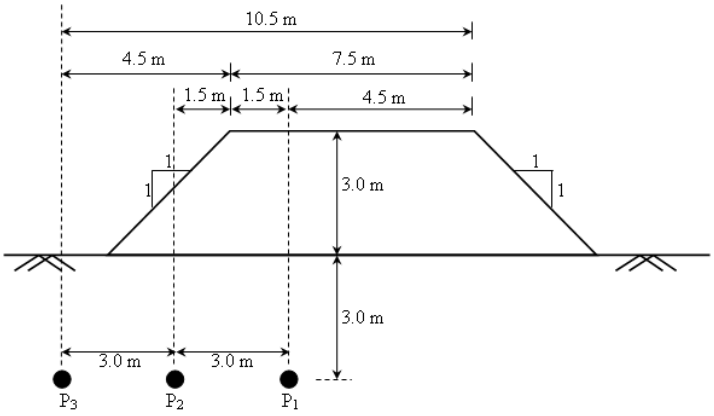


*Fig.6*

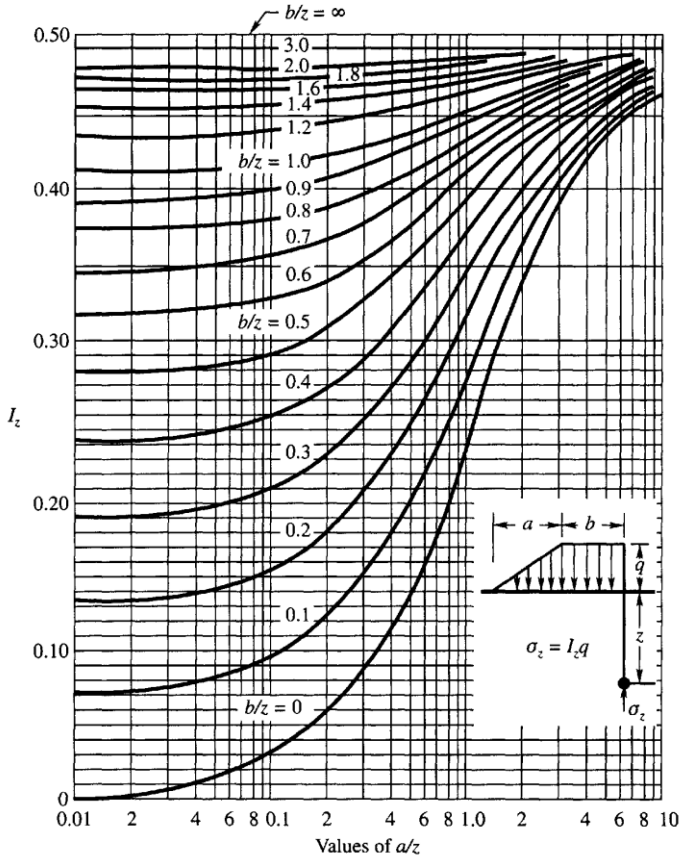


*Fig.7*

**6 + 6 = 12**

## Group – E

8 (a) A vane, 11.25 cm long and 7.5 cm in diameter, was pressed into soft clay at the bottom of a bore hole. Torque was applied to cause failure of soil. The shear strength of clay was found to be 37 kN/m$^2$. Determine the torque that was applied.

(b) Unconsolidated undrained triaxial tests were carried out on the three identical specimens of partly saturated clay. The following results were obtained:

| Sample no. | Cell pressure (kPa) | Deviator stress at failure (kPa) |
|---|---|---|
| 1 | 50 | 81.7 |
| 2 | 100 | 101.3 |
| 3 | 150 | 113.6 |

Determine the shear parameters of the soil (i) graphically (ii) analytically.

(c) For loose and dense sands, draw the following typical diagrams:
(i) Deviator stress with linear strain,
(ii) Volumetric strain with linear strain, Discuss them.

**2 + 7 + 3 = 12**

9. (a) A soil sample is initially subjected to a cell pressure of 100 kPa. Draw stress paths for the loading conditions when
(i) The cell pressure is kept constant and the major principal stress is increased to 200 kPa.
(ii) Both the cell pressure and major principal stress are increased to 300kPa.
(iii) Major principal stress is maintained constant and cell pressure is increased to 200 kPa.

(b) A direct shear test was performed on a dry sand sample with a normal stress of 150 kPa. Failure occurred when the applied shear stress reached 65 kPa.
(i) Draw the Mohr circle to represent the stress condition at failure.
(ii) Determine the magnitude of the principle stresses.
(iii) Find the directions of the principle planes.

(c) Describe advantages of triaxial test over direct shear test.

**3 + 6 + 3 = 12**

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