Internal Assessment Test 3 Solutions – May. 2018

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

Answer Question 1 compulsorily and answer any two from Questions 2, 3 and 4 MARKS

1 (a)	What are the factors affecting permeability?	[06]
	Any 6 – 6 marks	

In soils, the interconnected pores provide passage for water. A large number of such flow paths act together, and the average rate of flow is termed the coefficient of permeability, or just permeability. It is a measure of the ease that the soil provides to the flow of water through its pores.

The different factors affecting permeability are

(a) Particle size
(b) Structure of soil mass
(c) Shape of particles
(d) Void ratio
(e) Properties of water
(f) Degree of saturation
(g) Adsorbed water
(h) Impurities in water

For a laminar flow, coefficient of permeability of soil can be given as

$$k = C\left[\frac{\gamma_w}{\mu}\right]\left[\frac{e^3}{1+e}\right]D2$$

This expression can be used to explain the different factors affecting permeability.

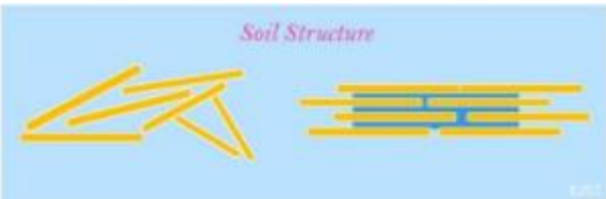
i. **Particle size:**

Coefficient of permeability varies approximately as the square of the grain size. It depends on the effective diameter of the grain size i.e., D_{10}.

$K=CD_{10}^2$

ii. Structure of soil mass:

The coefficient C, takes into account the shape of flow passage. The size of flow passage depends upon the structural arrangement. For the same void ratio, the permeability is more in case of flocculated structure as compared to dispersed structure.



iii. **Shape of particles**

Angular particles have greater specific surface area as compared to rounded particles. For the same void ratio, angular particles are less permeable than those with rounded particles as the permeability is inversely proportional to specific surface.

iv. **Void ratio**

$$k \propto \frac{e^3}{1+e}$$

Greater the void ratio, greater is the permeability.

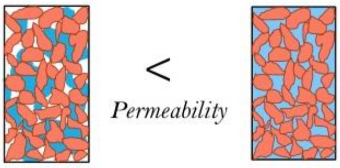
v. **Properties of water**

$$k \propto \frac{\gamma_w}{\mu}$$

Coefficient of permeability is directly dependent on unit weight of water and inversely proportional to its viscosity. Since viscosity is dependent upon temperature, coefficient of permeability is dependent upon temperature.

vi. **Degree of saturation**

Presence of air in soil causes blockage to the flow of water. So if the soil is not saturated, coefficient of permeability decreases.



vii. **Adsorbed water**

Fine grained soils have a layer of adsorbed water around it and this will not mover under gravity. It causes an obstruction to flow passage. Thus coefficient of permeability decreases with presence of adsorbed water.

viii. Impurities in water

Foreign matter has a tendency to block the flow passage and reduce the effective voids. Thus coefficient of permeability decreases if impurities are present in water.

(b) The triaxial test was carried out on soil samples gave the following results: [07]

Confining pressure, kN/m^2	50	100	150
Deviator stress kN/m^2	76	132	186
Pore pressure kN/m^2	150	186	83

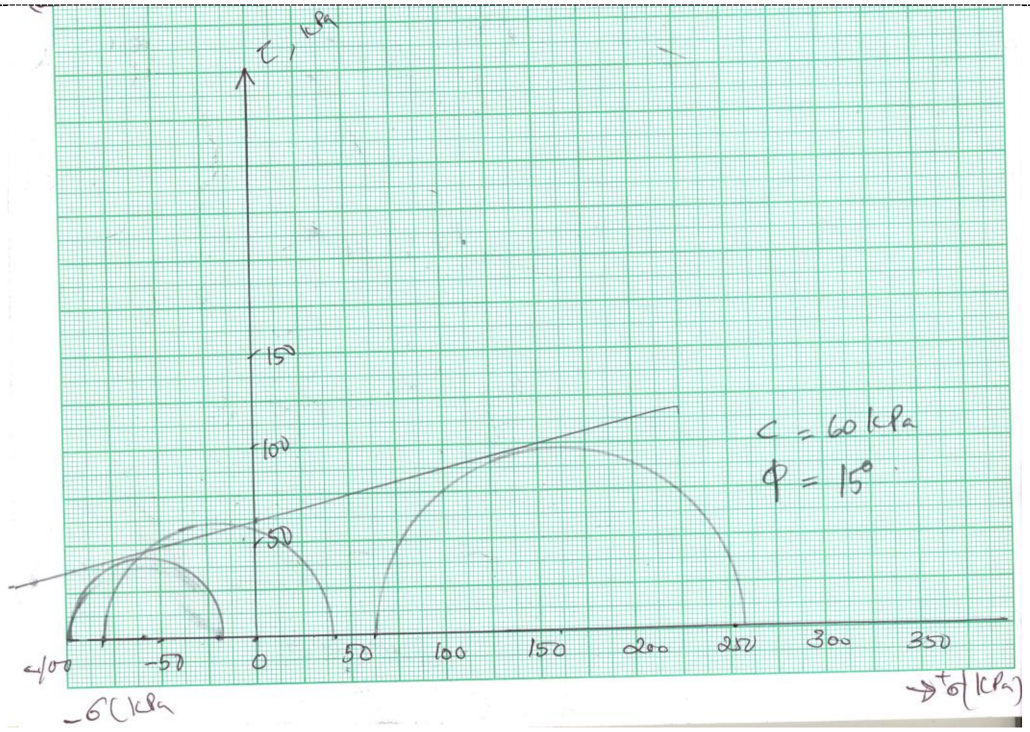
Plot Mohr's circle and obtain ***effective*** shear parameters

Calculation – 2 marks

Mohr circle – 4 marks

C and phi- 1 mark

σ3	50	100	150
σ1	126	232	336
σ3'	-100	-86	67
σ1	-24	46	253



Shear parameters are c'=60 kPa

Φ'= 15°

(c) What are the characteristics of flow nets? [07]

With a neat sketch, explain the method of locating the phreatic line for a homogenous earth dam with horizontal filter.

Characteristics- 2 marks

Construction of phreatic line figure – 3marks

Explanation -2 marks

Graphical form of solutions to Laplace equation for two-dimensional seepage can be presented as flow nets. Two orthogonal sets of curves form a flow net:

- Equipotential lines connecting points of equal total head h
- Flow lines indicating the direction of seepage down a hydraulic gradient

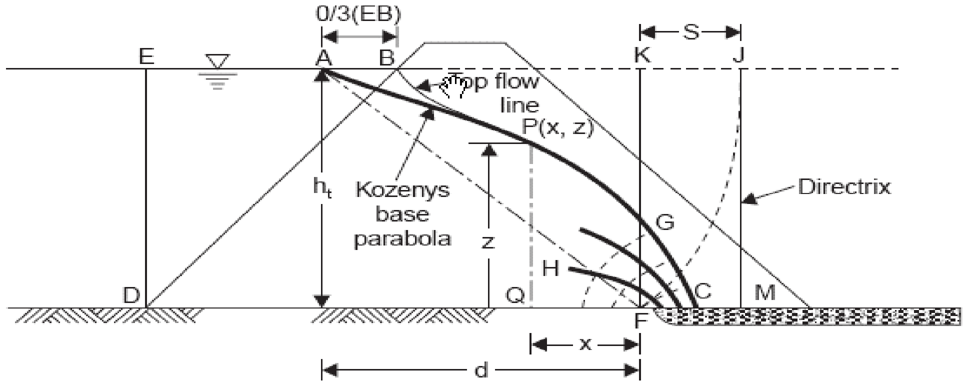
Flow Lines are the paths which water particle follow in the course of seepage. Water flows from the point of higher head to low head.

Equipotential lines are the lines formed by joining the points of same head or potential on the flow lines.

Properties of Flow net:

- Flow lines and equal potential lines intersect each other at 90 degrees.
- The areas bounded by the flow lines and equal potential lines form approximate squares.
- Flow nets must satisfy the boundary conditions of flow field.
- Quantity of water flowing through each flow channel is the same.
- The potential drop in any two consecutive equal potential lines is same/constant.
- Flow lines and equal potential lines are smooth curves.

- Flow lines do show refraction at the interface between two soils having different coefficient of permeability.



(2) Locate the point A, using BA = 0.3 (BE). A will be the starting point of the Kozeny parabola.

(*ii*) With A as centre and AF as radius, draw an arc to cut the water surface (extended) in J. The vertical through J is the directrix. Let this meet the bottom surface of the dam in M.

(*iii*) The vertex C of the parabola is located midway between F and M.

(*iv*) For locating the intermediate points on the parabola the principle that it must be equidistant from the focus and the directrix will be used. For example, at any distance *x* from F, draw a vertical and measure QM. With F as center and QM as radius, draw an arc to cut the vertical through Q in P, which is the required point on the parabola.

(*v*) Join all such points to get the base parabola. The portion of the top flow line from B is sketched in such that it starts perpendicular to BD, which is the boundary equipotential and meets the remaining part of the parabola tangentially without any kink. The base parabola meets the filter perpendicularly at the vertex C.

2 (a)	Explain briefly UU, CU and CD tests	[05]
	UU, CU and CD – 2+2+1	

In shear tests, there are basically three stages:

(1) Saturation stage
(2) Consolidation stage
(3) Shearing stage

In saturation stage, to simulate the weakest condition, the soil is saturated. This is called as saturation stage.

In consolidation stage, the excess pore water pressure developed in the sample is may be allowed to drain off. If the excess pore water pressure is drained off , it is called as consolidated sample, designated as C. If the excess pore water pressure is not made to dissipate, it is called as unconsolidated sample, designated as U

During shearing stage, within the saturated sample, pore water pressure is developed on application of deviator stress. If the excess pore water pressure developed in the sample is made to drain off it is called as drained test, designated as D. If the excess pore water pressure developed in the sample is made to not allowed to drain, pore water pressure develops and it is called as undrained test, designated as U. in undrained test, pore water pressure measurement is involved.

UU tests- Unconsolidated Undrained test: This is the quickest test, because neither consolidation is involved or drainage is involved. It is appropriate for immediate safety of foundations and structures resting on clays where the permeability is low. It is also applicable to determine embankment stability where immediate rapid drawdown can occur.

Long term stability of slopes, embankments and earth supporting structures in cohesive soils require the use of effective strength parameters. Hence on such soils, tests are conducted with pore water pressure measurements or drainage measurements.

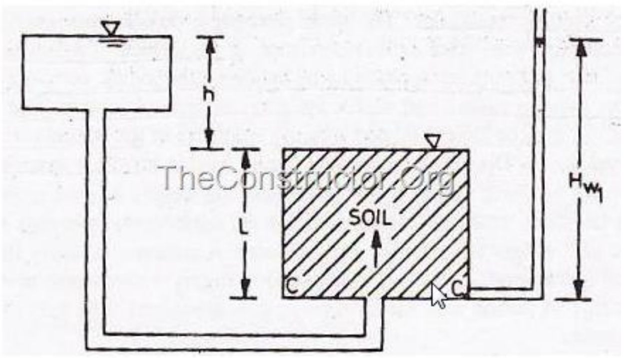
CU tests- Consolidated Undrained test- Generally for soils with low permeability, to evaluate long term stability, CU tests are conducted wherein no pre water pressure measurements are involved.

CD tests- Consolidated Drained test- Generally for granular soils with high permeability, to evaluate long term stability, CD tests are conducted wherein drainage is involved.

(b) Define quick sand condition. Derive an expression for critical hydraulic gradient. [05]

Definition -1
Figure- 2
Derivation-2

The effective stress is reduced due to upward movement of flow of water. When the head causing upward flow is increased, a stage is reached when the effective stress is reduced to zero. The condition so developed is known as quick sand condition.



From the above figure

$\sigma' = \sigma - u$

$\sigma' = \gamma_{sat} L - \gamma_w H_{w1}$

$\sigma' = \gamma_{sat} L - \gamma_w h - \gamma_w L$

$\sigma' = \gamma_{sub} L - \gamma_w h$

When effective stress becomes equal to 0, $\sigma' = \gamma_{sub} L - \gamma_w h$ or

$h/L = \gamma_{sub} / \gamma_w$ ______________________________ (1)

$\gamma_{sub} = \gamma_{sat} - \gamma_w$ ________________________ (2)

But $\gamma_{sat} = \frac{\gamma_w (G+eS)}{1+e} = \frac{\gamma_w (G+e)}{1+e}$

Therefore, $\gamma_{sub} = \gamma_{sat} - \gamma_w$

$\gamma_{sub} = \frac{\gamma_w(G+e)}{1+e} - \gamma_w = \frac{\gamma_w[G+e-1-e]}{1+e} = \frac{\gamma_w(G-1)}{1+e}$ ____________(3)

Substituting (3) in (1) $\frac{h}{L} = \frac{\gamma_{sub}}{\gamma_w} = \frac{\gamma_w(G-1)}{1+e} \times \frac{1}{\gamma_w} = \frac{(G-1)}{1+e} = i_c$

This ic is called as critical hydraulic gradient.

(c) Explain vane shear test with sketch. [05]

A vane 11.25 cm long, and 7.5 cm in diameter was pressed into soft clay at the bottom of a borehole. 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.

Explanation – 3

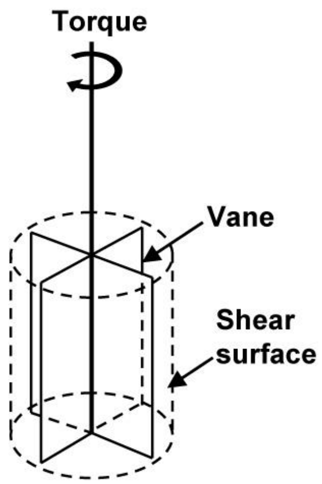
Problem -2

The vane shear test is a shear test that can be used in both laboratory as well in field to determine the shear strength of fully saturated clays. The test is relatively simple, quick, and provides a cost-effective way of estimating the soil shear strength.

The vane shear test apparatus consists of a four-blade stainless steel vane attached to a steel rod that will be pushed into the ground. The height of vane is usually twice its overall widths and is often equal to 10 cm or 15 cm.

The test starts by pushing the vane and the rod vertically into the soft soil. The vane is then rotated at a slow rate of 6° to 12° per minute. The torque is measured at regular time intervals and the test continues until a maximum torque is reached and the vane rotates rapidly for several revolutions.

At this time, the soil fails in shear on a cylindrical surface around the vane. The rotation is usually continued after shearing and the torque is measured to estimate the remoulded shear strength.



$$Undrained\ shear\ strength, \quad C_u = \frac{T}{\pi[D^2H + D^3]}$$

Where T is the torque in kgcm
D is the overall diameter of the vane in cm
H is the height of vane in cm

$$c_u = \frac{T}{\pi d^2\left[\frac{H}{2} + \frac{d}{6}\right]}$$

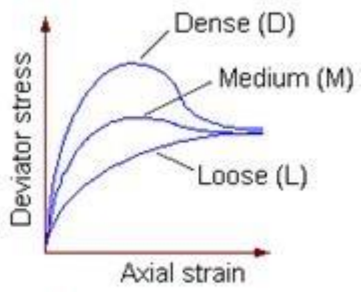
	$$37 = \frac{T}{\pi \times 0.075^2 \left[\frac{0.1125}{2} + \frac{0.075}{6}\right]}$$ $$c_u = 45\ Nm$$	
3 (a)	Explain the factors affecting shear strength of soils.	[05]
	Any 5 factors – 5 marks	

The principal factors effecting the shearing strength of cohesion less soil are

1) Shape of particles: Angular particles will always develop higher shear resistance when compared to rounded particles.

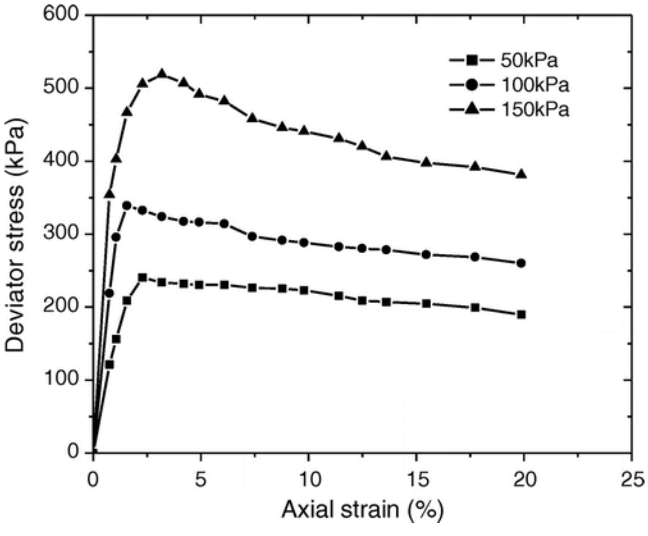
2) Gradation: Well graded soil particles will develop higher shear resistance than poorly or uniformly graded soils.

3) Denseness: Typical plot of deviator stress versus axial strain for dense and loose soils are as shown below:



As the denseness of soil increases, the soils strain softening behaviour whereas for loose soils, it exhibit a strain hardening behaviour.

4) Confining pressure: Higher the confining pressure higher will be the deviator stress as seen in figure below:



The graph presents the variation of deviator stress for 3 different confining pressures: 50, 100 and 150 kPa.

5) Deviator stress: As the deviator stress increases, particles will be subjected to crushing. This will reduce the shear resistance of soils.

6) Vibration and repeated loading: vibrations and repeated loading intend to reduce the shear strength of soil.

7) Type of minerals: The shear resistance of soil is dependent upon the clay mineral.

8) Capillary moisture: Capillary moisture provides apparent cohesion and increases effective shear parameters. This infact increases shear resistance of the soil.

9) Strain rate. The faster a soil specimen is sheared (i.e., a fast strain rate), the higher will be the value of the undrained shear strength

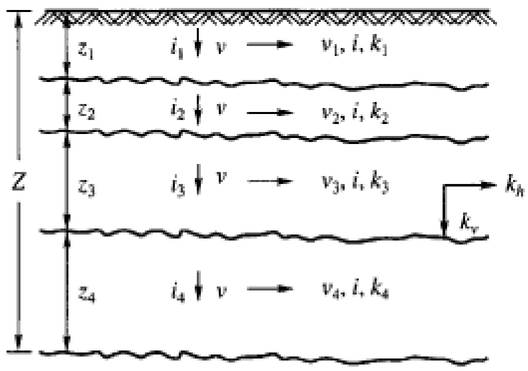
9) Clay content: Higher the clay content higher will be the cohesion of the sample.

10) Stress history: the behaviour of Overconsoldiated clay is similar to dense sand and that of normally consolidated clay, it will be similar to loose sand.

(b) Derive expression for average permeability of stratified soils when flow is perpendicular to the direction of stratification. [05]

Figure – 2

Derivation – 3 marks



<u>Flow perpendicular to bedding planes</u>

In this case $Q = Q_1 = Q_2 = Q_3 = Q_4$

or $v = v_1 = v_2 = v_3 = v_4$

$$k_v \times i = k_1 \times i_1 = k_2 \times i_2 = k_3 \times i_3 = k_4 \times i_4$$

or $i_1 = \frac{k_v \times i}{k_1};\ i_2 = \frac{k_v \times i}{k_2};\ i_3 = \frac{k_v \times i}{k_3};\ i_4 = \frac{k_v \times i}{k_4};$

or Total head loss = sum of head loss in each layer

$$h = i \times z$$

$h = h_1 + h_2 + h_3 + h_4$

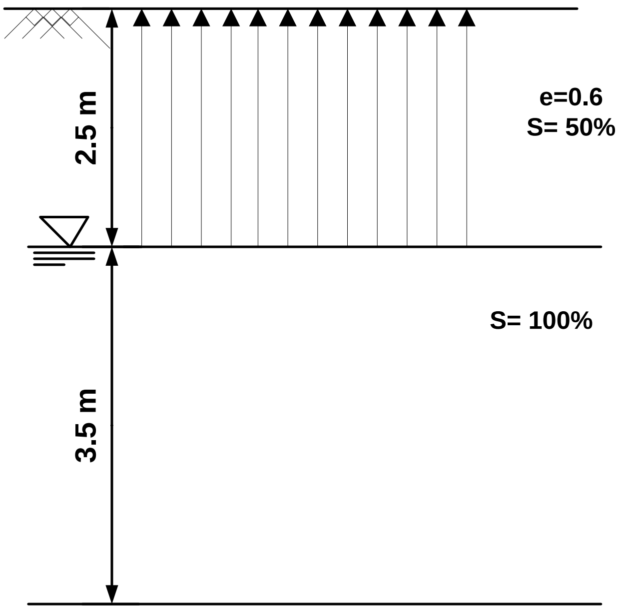
or $i \times Z = \frac{k_v \times i}{k_1} \times z_1 + \frac{k_v \times i}{k_2} \times z_2 + \frac{k_v \times i}{k_3} \times z_3 + \frac{k_v \times i}{k_4} \times z_4$

$$Z = k_v \left[\frac{z_1}{k_1} + \frac{z_2}{k_2} + \frac{z_3}{k_3} + \frac{z_4}{k_4}\right]$$

$$Or\ k_v = \frac{Z}{\left[\frac{z_1}{k_1} + \frac{z_2}{k_2} + \frac{z_3}{k_3} + \frac{z_4}{k_4}\right]}$$

(c) A uniform soil deposit has a void ratio 0.6 and specific gravity of 2.65. The natural ground water is at 2.5 m below natural ground level. Due to capillary moisture, the average degree of saturation above ground water table is 50%. Determine the neutral pressure, total pressure and effective pressure at a depth of 6 m. Draw a neat sketch. [05]

Determination of densities and figure -2
Computation -2 marks
Pressure diagram- 1

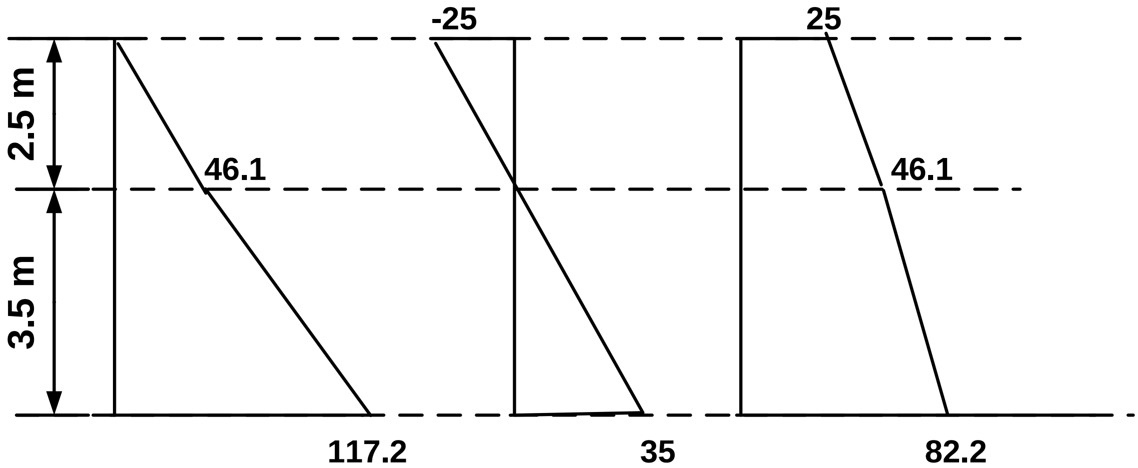


$$\gamma_b = \frac{\gamma_w(G+eS)}{1+e}$$

$$For\ top\ 2.5\ m,\ \gamma_b = \frac{10(2.65+0.6\times0.5)}{1+0.6} = 18.44\ kN/m^3$$

$$For\ next\ 3.5\ m,\ \gamma_b = \frac{10(2.65+0.6\times1)}{1+0.6} = 20.31\ kN/m^3$$

Depth below ground surface	σ, kPa	u, kPa	σ’, kPa
Z=0	0	=-10×2.5 =- 25	25
Z=2.5m	=18.44×2.5 = 46.1	=0	=46.1
Z=3.5m	=46.1+20.31×3.5 = 117.2	=10×3.5 =35	=117.2-35=82.2



4 (a)	Explain the terms (i) sensitivity of clay (ii) Neutral stresses	[05]
	Sensistivity -3 Neutral stresses - 2	

Sensitivity

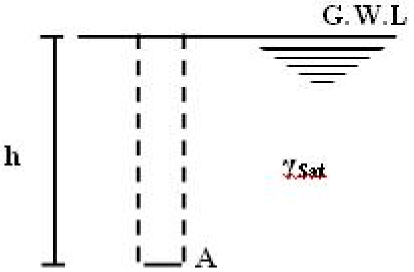
Sensitivity is the measure of loss of strength with remoulding. Sensitivity, St is defined as the ratio of unconfined compressive strength of clay in undisturbed state to unconfined compressive strength of same clay in remoulded state at unaltered water content.

$$S_t = \frac{q_{u(undisturbed)}}{q_{u(remoulded)}}$$

S. No	Classification
1-4	Normal
4-8	Sensitive
8-15	Extra-sensitive
>15	Quick

Neutral stresses

Consider a soil mass as shown in figure below. Assume that water table is at ground surface.



In this case, the total pressure exerted by the soil column over A= $\sigma = \gamma_{sat}h$

Since ground water table is at ground surface, pore water pressure, $u = \gamma_w h$

Pressure exerted on soil grains, $\sigma' = \gamma_{sat}h - \gamma_w h = \gamma_{sub}h$

In the presence of water, the pressure sustained by soil grains decreases, and hence effective stress decreases.

Effective stress: The stress carried by the solid particles or the solid portion of the soil is known as effective stress.

Pore water pressure/ neutral stress: The stress carried by the pore water is known as pore water pressure.

Total stress: The compressive stress at a point which may or may not consists of geostatic stresses and induced stresses, is carried partially by the solid portion of the soil and partially by the pore water. Geotechnical engineers call this stress total stress because it is the sum of stresses carried by these two portion of the soil i.e solid portion and pore water.

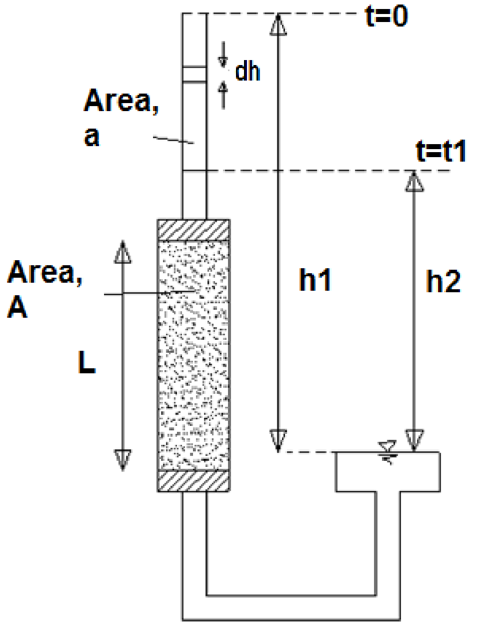
(b)	List the merits of triaxial shear test over direct shear test.	[05]
	Any 5 merits – 5 marks	

Direct shear tests are generally suitable for cohesionless soils except fine sands and silts whereas triaxial tests are suitable for all types of soils and tests.

Advantages of triaxial test over direct shear test

- The stress distribution across the soil sample is more uniform in a triaxial test as compared to a direct shear test.
- Measurement of volume changes are accurate in triaxial test.complete state of stress condition is known only at failure. The conditions prior to failure are indeterminate and, therefore, the mohr circle cannot be drawn.
- Complete state of stress is known at all stages during the triaxial test, whereas stresses at failure are known in direct shear test.
- In case of triaxial shear, the sample fails along a plane on which the combination of normal and shear stress gives the maximum angle of obliquinity of the resultant with the normal, whereas in the case of direct shearm the sample is sheared only on one horizontal plane which may not be the actual failure plane.
- Control on the drainage conditions is very difficult in direct shear test whereas it is easy in triaxial test.
- The measurement of pore water pressure is not possible in direct shear test whereas it is possible in triaxial test.
- The side walls of the shear box cause lateral restraint on the specimen and do not allow it to deform laterally. But in triaxial tests, the latex membrane makes the specimen flexible in lateral directions too.

(c)	Derive an expression to obtain coefficient of permeability under falling head condition. A sample in a variable head permeameter is 8 cm in diameter and 10 cm high. The permeability of the sample is estimated to be 10 × 10–4 cm/s. If it is desired that the head in the stand pipe should fall from 24 cm to 12 cm in 3 min., determine the size of the standpipe which should be used.	[05]
	Derivation +figure – 3 Problem -2	



$$dQ = -adh = Ak\frac{h}{L}dt$$

Integrating,

$$\int_{h1}^{h2} -adh = Ak\int_0^t dt.\ \frac{h}{L}$$

$$\int_{h1}^{h2} -\frac{dh}{h} = \frac{Ak}{aL}\int_0^t dt$$

$$-ln\frac{h2}{h1} = \frac{Akt}{aL}$$

$$ln\frac{h1}{h2} = \frac{Akt}{aL}$$

$$2.303.\, log\frac{h1}{h2} = \frac{Akt}{aL}$$

$$k = 2.303\ \frac{aL}{At}\ log\frac{h1}{h2}$$

$$k = \frac{2.303.\, aL}{At} log_{10}\left[\frac{h1}{h2}\right]$$

$$10 \times 10^{-6} = \frac{2.303.\times (\pi/_4) \times d^2 \times 0.1}{(\pi/_4) \times 0.08^2 \times 3 \times 60} log_{10}\left[\frac{0.24}{0.12}\right]$$

a = 1.305 ×10^{-4} m^2

d = 0.0129 m or 1.29 cm

Signature of CI **Signature of CCI** **Signature of HoD**