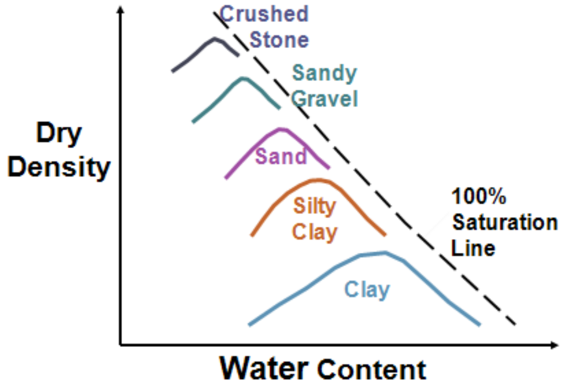
Solution - Internal Assessment Test V –February 2022

1	(a) Explain the factors affecting compaction.	[06]
	Any 4 factor with sketches - 4	

The factors which affect the degree of compaction are given below.

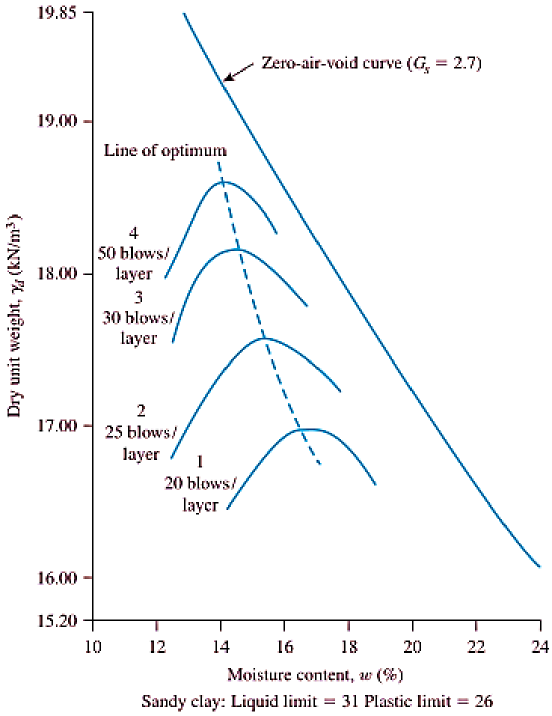
1. Type of soil

Normally, heavy clays, clays & silts offer higher resistance to compaction where as sandy soils and coarse grained or gravelly soils are amenable for easy compaction.



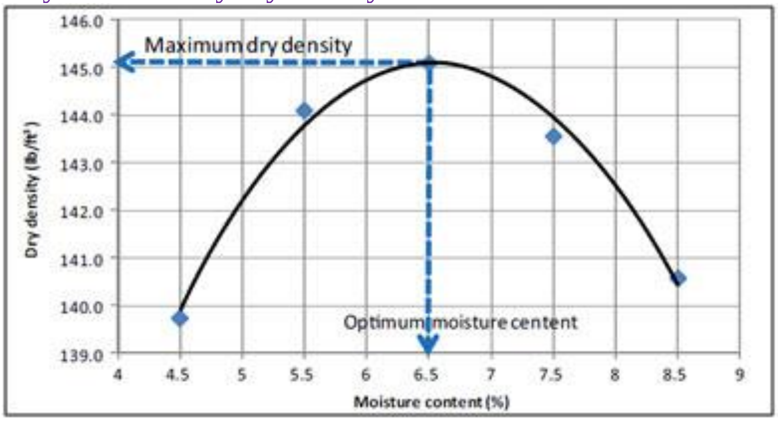
2. Amount of compaction

This is dependent on the type of compacting equipment, layer thickness, layer lifts, roller passes etc. Greater the compactive effort, greater will be the compaction energy, greater will be the extent of compaction. Type of compaction equipment to be used is mainly dependent upon the type of soil to be compacted.



3. Moisture content/ water content

Proper control of moisture content in soil is necessary for achieving desired density. Maximum density with minimum compacting effort can be achieved by compaction of soil near its OMC (optimum moisture content). Relative compaction is the ratio of field dry density to laboratory dry density.



4. Type of compaction/ methods of compaction

Types of Compaction

- **Vibration**
- **Impact**
- **Kneading**
- **Pressure**

Static or Vibratory

For example, Sheepfoot roller can be used for silty soil or clayey soil; Pneumatic tyred roller can be used for Sands, gravel, silty soil, clayey soils

5. Admixtures

Addition of admixtures like flyash, granulated blast furnace slag, cement, lime, gypsum when added to problematic soils, improve its compaction characteristics.

Soil Stabilization Using Admixtures

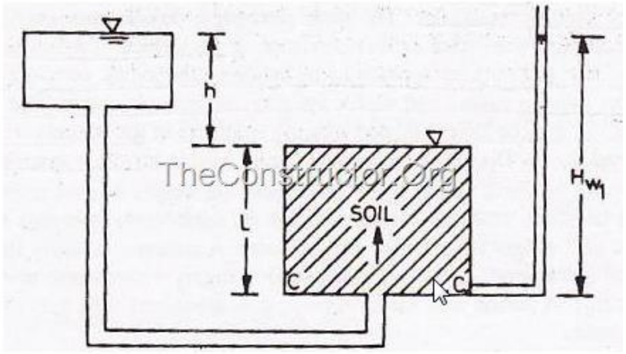
- Admixtures
  - Lime (quick lime/CaO, hydrated lime/$Ca(OH)_2$)
  - Cement
  - Flyash, cement kiln dust (CKD)

- To improve mechanical/mechanistic (strength & deformation) properties of soils
- Also, to control frost-heave and swelling
- Reduces Plasticity Index & increases strength over time

(b) Define quick sand condition. Derive an expression for critical hydraulic gradient. [06]

Definition – 1
Derivation - 5

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

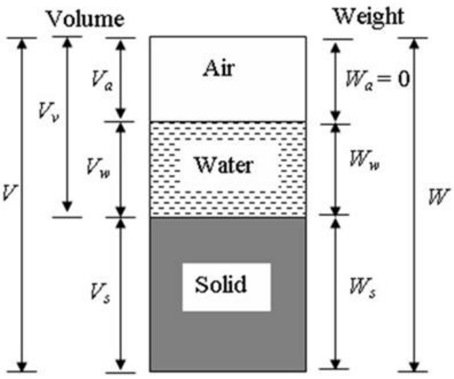
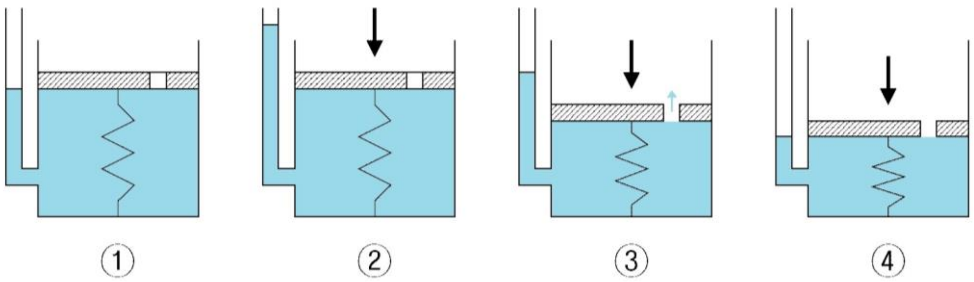
(c) List the merits of triaxial shear test over direct shear test. [08]

Any 5 points @ 1.5 marks/each

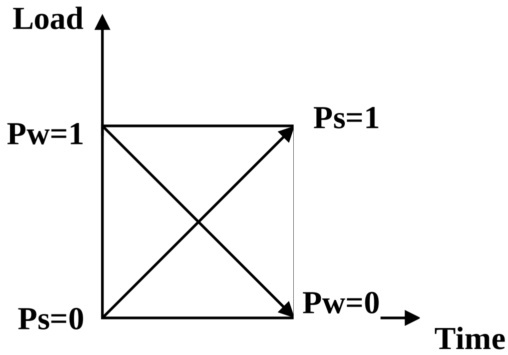
Direct shear tests are generally suitable for cohesionless soils except fine sands and silts whereas triaxial tests are suitable for all types of soils and tests.

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.	
2	(a) Considering soil as a three-phase system, derive the relationship, $\gamma_d = \frac{G\gamma_w}{1+e}$.	[06]
	Figure -2 Derivation - 4	
	$e = \frac{V_v}{V_s}$ 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, ρ_d can be obtained as $\rho_d = \frac{G\rho_w}{1+e}$ In SI units, when ρ_d becomes γ_d and ρ_w becomes γ_w $Therefore\ \rho_d = \frac{G\rho_w}{1+e}$ becomes $\gamma_d = \frac{G\gamma_w}{1+e}$	
	(b) Explain mass spring analogy of consolidation of soils.	[06]
	Spring analogy – Fig – 2 Explanation - 4	
	The consolidation process is often explained with an idealized system composed of a spring, a container with a hole in its cover, and water.  In this system, the spring represents the compressibility or the structure itself of the soil, and the water which fills the container represents the pore water in the soil. ➢ The container is completely filled with water, and the hole is closed. (Fully saturated soil)	

- A load of 1 kN is applied onto the cover, while the hole is still unopened. At this stage, only the water resists the applied load. (Development of excessive pore water pressure)
- As soon as the hole is opened, water starts to drain out through the hole and the spring shortens. (Drainage of excessive pore water)
- After some time, the drainage of water no longer occurs. Now, the spring alone resists the applied load. (Full dissipation of excessive pore water pressure. End of consolidation)



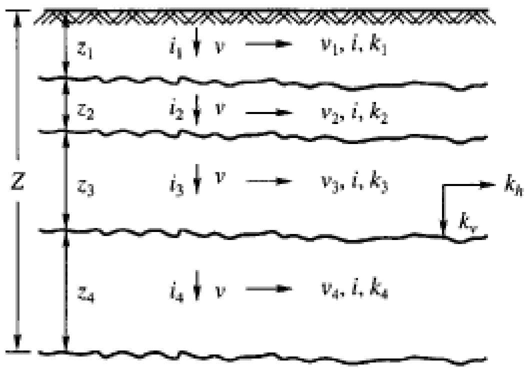
(c) Derive expression for average permeability of stratified soils when flow is parallel and perpendicular to the direction of stratification. [08]

Flow parallel – 4
Flow perpendicular - 4

When a soil deposit consists of a number of horizontal layers having different permeabilities, the average value of permeability can be obtained separately for both vertical flow and horizontal flow, as **k_V** and **k_H** respectively.

Consider a stratified soil having 3 horizontal layers of thickness **z_1, z_2, z_3 and z_3** with coefficients of permeability **k_1, k_2, k_3 and k_4**.

Flow parallel to bedding planes



In this case discharge $kiA=Q= Q_1+Q_2+Q_3+Q_4$

But head causing flow remains same; i.e., hydraulic gradient remains same.

$k_H \times i \times Z \times 1$

$$= k_1 \times i \times z_1 \times 1 + k_2 \times i \times z_2 \times 1 + k_3 \times i \times z_3 \times 1 + k_4 \times i \times z_4 \times 1$$

Or

$$k_H \times Z = k_1 \times z_1 + k_2 \times z_2 + k_3 \times z_3 + k_4 \times z_4$$

Or

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

Flow perpendicular to bedding planes

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

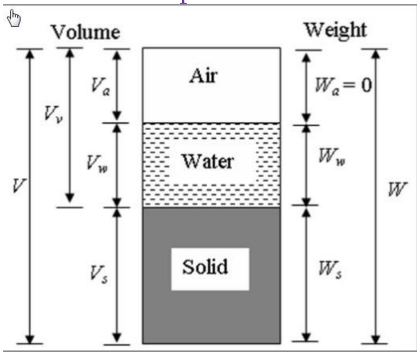
$$Z = k_v \left[\frac{z_1}{k_1} + \frac{z_2}{k_2} + \frac{z_3}{k_3} + \frac{z_4}{k_4}\right]$$

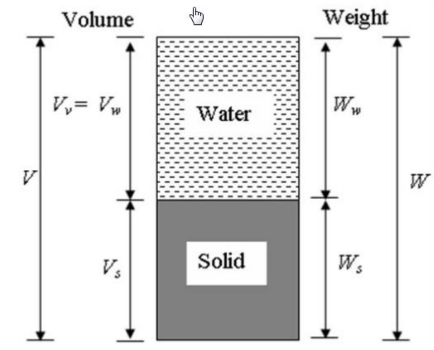
Or $k_v = \frac{Z}{\left[\frac{z_1}{k_1} + \frac{z_2}{k_2} + \frac{z_3}{k_3} + \frac{z_4}{k_4}\right]}$

3	(a) Differentiate between compaction and consolidation.	[5]
	5 differences with sketch - 5	

Sl No	Compaction	Consolidation
1	Compaction is the process by which solid soil particles are packed more closely together by mechanical means.	Consolidation is the process by which soil particles are packed more closely together under the application of static loading
2	It is achieved through reduction of air voids.	It is achieved through gradual drainage of water from soil pores.
3	It is a rapid and artificial process. Applicable to cohesive and cohesionless soils.	It is a gradual and natural process. In some soils it takes many years. Applicable to cohesive soils

4	Proper compaction of soil is achieved at optimum moisture content.	Consolidation is strictly applicable for saturated or nearly saturated clays or soils with low permeability.
5	Soil exists in three phases before and after compaction	Soil exists in two phases before and after consolidation





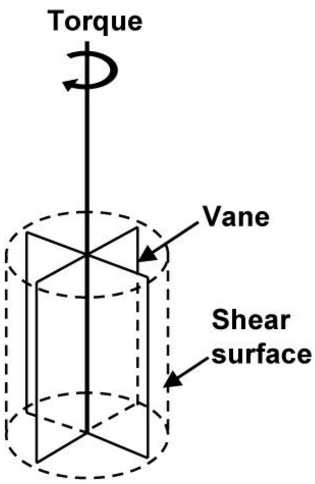
	(b) Explain vane shear test with sketch.	[5]
	Sketch – 1 Equation -1 Explanation with Sensitivity - 3	

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.



	$Undrained\ shear\ strength,\qquad c_u = \dfrac{T}{\pi d^2\left[\dfrac{H}{2}+\dfrac{d}{6}\right]}$ 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	

Signature of CI   Signature of CCI   Signature of HoD