UNIT-I

SOIL CLASSIFICATION AND COMPACTION

Nature of soil – phase relationships – Soil description and classification for engineering purposes, their significance – Index properties of soils - BIS Classification system – Soil compaction – Theory, comparison of laboratory and field compaction methods – Factors influencing compaction behaviour of soils.

1. What is meant by degree of saturation?

The degree of saturation is defined as the ***ratio of volume of water (V_w) to the volume of voids (V_v)***.

$$S = \frac{V_w}{V_v} \times 100$$

2. List various factors affecting the compaction. (A/M'17, N/D'17)

Following the different factors affecting compaction of soil:

(i) Water content (ii) Amount of compaction (iii) Types of soil (iv) Methods of soil compaction

3. What do you mean by water content in a soil sample? (A/M'11)

By definition the water content (w) is the ratio of the weight (or mass) of the water and the solids, $w = W_w / W_s$.

4. Define Porosity of a given soil sample. (A/M'11) (N/D'13)

Porosity of the soil (n) is defined as the ratio of volume of voids (V_v) to the total volume of soil sample (V). It is expressed as **$n = V_v/V \times 100\%$**

5. Define Void Ratio. (N/D'10) (N/D'13) (N/D'11)

Voids ratio of the soil (e) is defined as the ratio of volume of voids (V_v) to the volume of solids (V_s). Then it is expressed as, **$e = V_v / V_s \times 100\ \%$**

6. Write about Consistency limits or Atterberg Limits. (N/D'12)

Liquid Limit: (N/D'10) (N/D'11) (N/D '17)

The moisture content or water content, in percent, at which the transition from plastic to liquid state is the *liquid limit*.

Plastic Limit:

The moisture content at the point of transition from semisolid to plastic state is the *plastic limit.*

Shrinkage Limit:

The moisture content or water content, in percent, at which the transition from semi solid to solid state takes place, is defined as the *shrinkage limit*.

7. Define Air content and percentage air content in soil. (M/J'16)

Air content (a_c) is the ratio of the volume of air (V_a) to the volume of voids. $a_c = \frac{V_a}{V_V}$

Percentage air voids (n_a) is the ratio of the volume of air to the total volume. $n_a = \frac{V_a}{V} x\,100 = n\ x\ a_c$

8. State whether the following statement is true or false. The efficiency of compaction improves with increase in compaction effort. (N/D'15)

True. The compaction effort increases the density and reduces the voids of the soil mass.

9. Distinguish between Residual soil and Transported soil. (A/M'12)

Residual Soil	Transported Soil
Formed by weathering of rocks may remain in position at the place of region.	Transported from the place of origin by various agencies such as wind, water, ice, gravity, etc
Degree of disintegration may vary greatly throughout a residual soil mass.	A high degree of alteration of particle shape, size, and texture as also sorting of the grains occurs during transportation and deposition.
Three zones (i) upper zone (ii) intermediate zone (iii) partially weathered zone	Types (i) Alluvial soils (ii) Aeoline soils (iii) Glacial soils (iv) Lacustrine soils (v) Marine soils.

10. Give the relationship between γ_{sat}, G, e, γ_w (A/M'12)

The Phase relationships between various terms are saturated unit weight (γ_{sat}), Specific gravity (G), Void ratio (e) and Unit weight of water (γ_w) is given by

$$\text{Saturated unit weight } (\gamma_{sat}) = \frac{(G+e)\gamma w}{1+e}$$

11. Write any two engineering classification system of soil.

Soils with similar properties may be classified into groups and subgroups based on their engineering behavior

(i) American Association of State Highway Officials (AASHTO)

(ii) Unified Soil Classification System (USCS)

12. What are the laboratory methods of determination of water content? (N/D'13)

The method for the determination of water content, recommended by the Indian Standards Institution (I.S.I.), is set out in "IS: 2720 (Part-II)–1973, Methods of Test for soils-Part II) Determination of Moisture content", and is based on oven-drying of the soil sample.

The following methods will be given here:

(i) **Over-drying method (Most accurate method)**

(ii) Pycnometer method

(iii) Rapid moisture Tester method.

13. What do you understand from grain size distribution?

The range of sizes of particles in the soil and the percentage of particles in each of these size ranges can be known from grain-size distribution.

Grain-size distribution curves of soils primarily indicate the type of the soil, the history and stage of its deposition, and the gradation of the soil.

14. Define plasticity index, flow index and liquidity index. (Nov/Dec 2014)

Plasticity index' (PI or I_p) is the range of water content within which the soil exhibits plastic properties; that is, it is the difference between liquid and plastic limits.

$$\mathbf{PI\ (or\ I_p) = (LL - PL) = (w_L - w_P)}$$

When the plastic limit cannot be determined, the material is said to be non-plastic (NP). Plasticity index for sands is zero.

Liquidity index (LI or IL)' or '**Water-plasticity ratio**' is the ratio of the difference between the natural water content and the plastic limit to the plasticity index:

$$\textbf{LI (or } I_L\textbf{)} = \frac{(w-wp)}{Ip}$$

If IL = 0, w = PL; IL = 1, w = LL; IL > 1, the soil is in liquid state.IL < 0, the soil is in semi-solid state and is stiff.

15. What are the methods available for determination of in-situ density?

Two important methods for the determination of the in-situ unit weight are being given:

(i) Sand-replacement method.

(ii) Core-cutter method.

16. Define effective size of particle in sieve analysis.

The properties of granular or coarse-grained soils have been related to particle diameters. The particular diameter in actual spheres that would cause the same effect as a given soil, and opined that the diameter for which 10% was finer would give this equivalence.

It is effective diameters, D_e, of the soil particles. Thus, $D_{10} = D_e$. The effective diameter is also termed the "Effective Size" of the soil. It is this size that is related to permeability and capillarity. D_{10} may be easily determined by reading-off from the grain-size distribution curve for the soil.

17. A compacted sample of soil with a bulk unit weight of 19.62 kN/m^2 has a water content of 15 percent. What are its dry density, degree of saturation and air content? Assume G=2.65. (A/M'10)

Given: $\gamma_=$ 19.62 kN/m^{2,} w = 15 %, G= 2.65

Solution: Dry unit weight $\gamma_d = \gamma/(1+w) = 19.62/(1+0.15) \rightarrow \gamma_d = 17.06$ kN/m^3

and also dry unit weight, $\gamma_d = G.\gamma_w/(1+e)$, Then, $(1+e) = G.\gamma_w/\gamma_d = 2.65 \times 9.81 / 17.06 = 1.524$, Void ratio, e = 0.524, Degree of saturation, S= w.G/e = 0.15 x 2.65/0.524 = 0.7585

Degree of saturation, S = 75.85 %

18. Define sieve analysis and sedimentation analysis and what the necessity of these two analysis? (N/D'12)

Sieve analysis is the mechanical analysis where the particle sizes of above 0.075mm is analyzed. A series of sieves having different-size openings are stacked with the larger sizes over the smaller one. The weight of material retained on each sieve is converted to a percentage of the total sample.

Sedimentation analysis: The soil particles less than 75–μ size can be further analyzed for the distribution of the various grain-sizes of the order of silt and clay is 'sedimentation analyses or 'wet analyses.

The main purposes of these two analyses are to classify the soil according to their grain sizes and to determine the particle size characteristics.

19. Derive the relationship between void ratio and porosity. (N/D'13) (A/M'16)

Relationship between Porosity and void ratio

(i) $n = \frac{V_v}{V} = \frac{V - V_s}{V}$

$= 1 - \frac{V_s}{V} = 1 - \frac{W_s}{G\gamma_w \cdot V}$

$n = 1 - \frac{W_d}{G\gamma_w \cdot V}$

(ii) $e = \frac{V_v}{V_s} = \frac{V - V_s}{V_s} = \frac{V}{V_s} - 1 = \frac{V G \gamma_w}{W_s} - 1$

$e = \frac{V \cdot G \cdot \gamma_w}{W_d} - 1$ $\quad n = \frac{V_v}{V}, \quad e = \frac{V_v}{V_s}$

$1/n = \frac{V}{V_v} = \frac{V_s + V_v}{V_v} = \frac{V_s}{V_v} + \frac{V_v}{V_v} = 1/e + 1 = \frac{1+e}{e}$

$n = \frac{e}{1+e}$ (or) $e = \frac{n}{1-n}$

20. If the volume of voids is equal to the volume of solids in a soil sample, find the void ratio and porosity. (N/D'09)

Volume of voids (V_v) = Volume of Solids (V_s)

Void ratio e = V_v/V_s, e = 1

Then, Porosity n = e/ (1+e) = 1/(1+1)= 0.5

21. Define Activity of Clay.

Activity (A)' is defined as the ratio of plasticity index to the percentage of clay-sizes:

$$A = I_p / c$$

Where, I_p=Plasticity index and c is the percentage of clay sizes, *i.e.*, of particles of size less than 0.002 mm.

Activity can be determined from the results of the standard laboratory tests such as the wet analysis, liquid limit and plastic limit

22. Dry clay has a mass of 30 g and volume of 15cc, find its shrinkage limit if the specific gravity of solids is 2.65. (A/M'13)

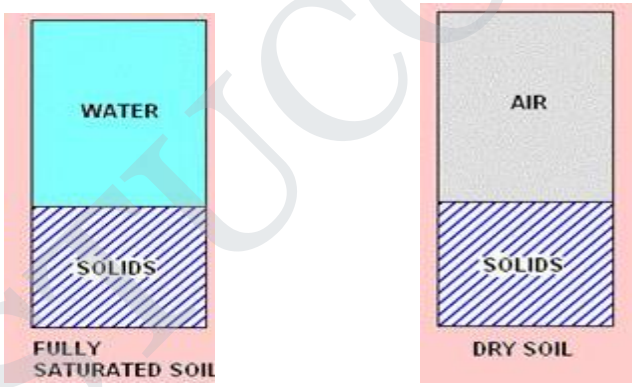
Shrinkage Limit of the soil specimen w_{su} = (V/W-(1/G))*100 = ((15/30)-(1/2.65))*100

= 12.264 %

23. If the liquidity index of a soil is zero. Find its consistency index. (A/M'13)

When the Liquidity index (LI) is zero, then Consistency index is 1. That is the clay is stiff.

24. Draw the phase diagram for dry soil and saturated soil. (N/D '16, A/M'17) (A/M '14)



25. List any four equipments/methods available for field compaction of soil. (N/D'16) (A/M'15) (A/M'14)

1. Smooth Wheeled Steel Drum Rollers
2. Pneumatic Tyred Rollers
3. Sheep foot Rollers
4. Impact Rollers
5. Vibrating Rollers
6. Hand Operated vibrating plate & rammer compactors

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UNIT II

SOIL WATER AND WATER FLOW

Soil water – static pressure in water - Effective stress concepts in soils – capillary stress – Permeability measurement in the laboratory and field pumping in pumping out tests – factors influencing permeability of soils – Seepage – introduction to flow nets – Simple problems.(sheet pile and weir)

1. List out the forms of Soil water. (N/D'10) (A/M'12) (A/M'13) (N/D'11)

Soil water may be in the forms of (i) Free water or Gravitational water and (ii) Held water.

(i) ***Gravitational water*** - (*a*) free water (bulk water) and (*b*) Capillary water.

Free water may be further distinguished as (*i*) Free surface water and (*ii*) Ground water.

(ii) ***Held water*** is that water which is held in soil pores or void spaces because of certain forces of attraction. It can be further classified as

(a) Structural water and (*b*) Absorbed water- Hygroscopic water and Film Moisture

2. State the name of the methods of finding field permeability. (N/D '10) (N/D'11) (N/D'17)

The following are the methods used in the field to determine permeability.

1. Pumping out of wells and 2. Pumping into wells

3. What is capillary rise, capillary moisture and capillarity? (A/M'11) (N/D'12)

The phenomenon in which water rises above the ground water table against the pull of gravity, but is in contact with the water table as its source, is referred to as 'Capillary rise' The water associated with capillary rise is called 'capillary moisture'. The phenomenon by virtue of which a liquid rises in capillary tubes is, in general, called 'capillarity'.

4. Define Darcy's Law. (A/M'10) (N/D'16) (A/M'14)

Darcy's law states that for laminar flow conditions in a saturated soil, the rate of flow or the discharge per unit time is proportional to the hydraulic gradient.

$$q = K_i A, \qquad V = q/A = k_i$$

Where,

q = discharge per unit time, A = Total cross-sectional area of soil mass perpendicular to the Direction of flow, i = hydraulic gradient, k = Darcy's Coefficient of permeability

v = Velocity of flow, or average discharge velocity.

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5. List out the methods of drawing flow nets. (A/M'12)

The following methods are available for the determination of flow nets:

1. Graphical solution by sketching, 2. Mathematical or analytical methods
3. Numerical analysis, 4. Models, 5. Analogy methods

All the methods are based on Laplace's equation.

6. What is meant by total stresses, neutral stresses and effective stresses? (N/D'12, 14)

Total stress is either due to self-weight of the soil or due to external applied forces or due to both, at any point inside a soil mass is resisted by the soil grains as also by water present in the pores or void spaces in the case of a saturated soil.

Neutral stress is defined as the stress carried by the pore water and it is the same in all directions when, there is static equilibrium since water cannot take static shear stress. This is also called '**pore water pressures**' and is designated by u. This will be equal to $\gamma_w . z$ at a depth z below the water table :

$$u = \gamma_w . z$$

Effective stress is defined as the difference between the total stress and the neutral stress; this is also referred to as inter granular pressure and is denoted by:

$$\sigma' = \sigma - u$$

The above equation is the '***Effective Stress Equation***'. **(N/D'13) (A/M'13)**

7. Define seepage.

Seepage is the flow of water under gravitational forces in a permeable medium. The flow is generally laminar.

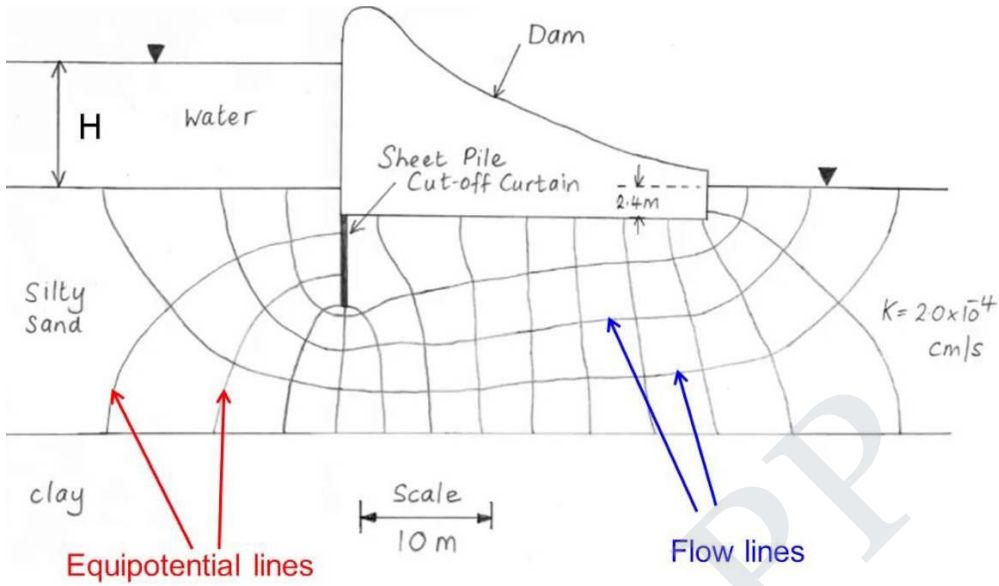
8. What are methods available for determination of k for a soil sample?

(i) Constant Head permeability test (ii) Falling Head Permeability Test (iii) Horizontal Capillary Test.

9. Define Flow net. What are the uses of flow nets? (N/D'15) (N/D'17)

A Flow net is a graphical representation of two-dimensional seepage and consists of two groups of curves of flow lines and equipotential lines.

Uses: (i) Estimation of seepage losses from reservoirs (ii) Determination of uplift pressures below dams (iii) Checking the possibility of piping beneath dams.



10. What are the factors affecting permeability/hydraulic conductivity? (M/J'16)

The following soil characteristics have influence on permeability:

1. Grain-size, 2. Void ratio, 3. Composition, 4. Fabric or structural arrangement of particles, 5. Degree of saturation, 6. Presence of entrapped air and other foreign matter.

11. Differentiate between discharge velocity and seepage velocity? (N/D'16) (N/D'15) (A/M'14)

Seepage is the flow of a fluid through soil pores with excess in pressure in soil mass. The actual velocity of water flowing through the voids is termed as **seepage velocity**. The flow of water through a certain length of soil sample with a cross section is termed as **discharge velocity** or superficial velocity.

12. Write about critical hydraulic gradient. (M/J'16)

A hydraulic gradient is supposed to exist between two points if there exists a difference in the 'hydraulic head' at the two points. By hydraulic head is meant the sum of the position or datum head and pressure head of water.

It is given by **i=h/L = (G-1)/(1+e)**

13. What is the critical gradient of a sand deposit of specific gravity = 2.65 and void ratio = 0.5?

Given data:

G = 2.65, e = 0.50, Critical hydraulic gradient, $i_c = (G - 1)/ (1 + e) = (2.65 - 1)/ (1+0.5)$

$= (1.65)/ (1.5)$, i_c = **1.1**

14. Define free water and held water.

Free water: Water that is free to move through a soil mass under the influence of gravity is known as free water.

Held water: Held water is the part of water held in soil pores by some forces existing within the pores: such water therefore is not free to move under gravitational forces.

15. Define structural, adsorbed and capillary water.

Structural water: Structural water is the water chemically combined in the crystal structure of the soil mineral and can be removed only by breaking the structure.

Adsorbed water: Adsorbed water, also termed as the hygroscopic water (or) the contact moisture (or) surface bound moisture. It is the part which the soil particles freely adsorb from atmosphere by the physical forces of attraction and is hold by the force of adhesion.

Capillary water: Water held in the interstices of soil due to capillary forces is called capillary water.

16. Compute the maximum capillary tension for a tube 0.05 mm in diameter.

Solution:

The maximum capillary height at 4o C is given by $h_{c,\max} = 0.3084/d = 0.3084/0.005$

$= 61.7\ cm = 0.617\ m$

Capillary tension = $(h_c)_{max} * \gamma_w = 0.617 \times 9.81 = 6.05 \times kN/m^3$

17. Define surface tension. (A/M'11)

The upward movement of water through the voids of soil mass due to the capillary rise is known as Surface tension.

18. What are the assumptions made in construction of flow nets? (N/D'14)

- A submerged permeable soil boundary is an equipotential line.
- The boundary between permeable and impermeable soil materials is a flow line.

19. What is mean by quick sand condition? (N/D'13)

The sudden increase in volume of sand due inclusion of water pressure into the soil and there will loss of shear strength considerable amount is said to be quick sand condition.

UNIT –III
STRESS DISTRIBUTION AND SETTLEMENT

Stress distribution - soil media – Boussinesq theory - Use of Newmark's influence chart – Components of settlement — Immediate and consolidation settlement – Terzaghi's one dimensional consolidation theory – computation of rate of settlement. - √t and log t methods–e-log p relationship - Factors influencing compression behavior of soils.

1. **What are the assumptions of Boussinesq Equations?**
   - The soil mass in homogeneous, that is all its constituent parts or elements are similar and it has identical properties at every point in it in identical directions.
   - The soil mass is isotropic, that is it has identical elastic properties in all directions through any point of it.
   - The soil mass is semi-infinite, that is it extends infinitely in all directions below a level surface.

2. **Define isobar. (N/D'11) (A/M'11)**

   An isobar is a curved or contour connecting all points below the ground surface of equal vertical pressure.

3. **Define pressure bulb or Stress isobar. (A/M'09, 16)**

   The zone in a loaded soil mass bounded by an isobar of given vertical pressure intensity is called a pressure bulb.

4. **Write down the Boussinesq equations of vertical pressure due to concentrated load. (N/D'12, 16)**

$$\sigma_z = \frac{3Q}{2\pi z^2}\left[\frac{1}{1+\left(\frac{r}{z}\right)^2}\right]^{5/2}$$

Q = point load

z = depth of stress acting

r = distance from the axis of load

5. **Write an equation of vertical pressure in uniformly loaded rectangular area?**

$$\sigma_z = q\left[1 - \frac{1}{\left[1+(a/z)^2\right]^{3/2}}\right]$$

6. **Define Influence Value. (Nov 2013)**

Newmarks chart consists of number of circles and sectors. Total elements for a nine circle chart will be 200. It is denoted by N. The value of 1/N (i.e., 1/200 or 0.005) is said to be the 'influence value' (or 'influence factor') for the chart. Each mesh may thus be understood to represent an influence area.

7. **What is the principle behind the Newmark's influence chart? (A/M'17)**

Newmark's Influence Chart is an illustration used to determine the vertical pressure at any point below a uniformly loaded flexible area of soil of any shape. This method, like others, was derived by integration of Boussinesq's equation for a point load.

The equation and chart needed to apply Newmark's method is based entirely on the principles of the **theory of elasticity**.

8. **Write about immediate settlement or elastic settlement of soil.**

The settlement which occurs immediately on application of the foundation load. Such immediate settlement in the case of partially saturated soils is primarily due to the expulsion of gases and to the elastic compression and rearrangement of particles.

The immediate settlement of a flexible foundation, according to Terzaghi (1943), is given by:

$$S_i = q \,.\, B\left(\frac{1-\nu^2}{E_s}\right).\, I_t$$

where S_i = immediate settlement at a corner of a rectangular flexible foundation of size $L \times B$,

B = Width of the foundation, q = Uniform pressure on the foundation, Es = Modulus of elasticity of the soil beneath the foundation, ν = Poisson's ratio of the soil.

9. **Define consolidation and write its stages. (N/D'11) (A/M'16)**

The process of gradual compression due to the expulsion of pore water under steady pressure is referred to as 'Consolidation'. This is a time dependent phenomenon, especially occurs in clays.

(i) Primary consolidation (ii) Secondary consolidation (iii) Tertiary compression

10. What are the factors which influence the compression behavior of soil? (N/D'15)

The compressibility of a soil depends on the

(i) Structural arrangement of the soil particles,

(ii) Degree to which adjacent particles are bonded, in fine-grained soils.

(iii) Pressure on the soil.

11. Define coefficient of consolidation and compression index. (A/M'17)

The ***coefficient of consolidation*** combines the effect of permeability and compressibility characteristics on volume change during consolidation. Its units can be shown to be mm^2/s or L^2T^{-1}. It is given by

$$c_v = \frac{k}{\gamma_w \cdot m_v}$$

Where, c_v is known as the "Coefficient of consolidation". k is the permeability of soil in the direction of flow, γ_w = unit weight of water, m_v =modulus of volume change.

Compression Index (C_c):

The ratio of decreasing void ratio for increasing pressure, is called the 'Compression index'

$$C_c = \frac{(e - e_0)}{\log_{10} \frac{\bar{\sigma}}{\bar{\sigma}_0}}$$

Where e and e_0 =natural and initial void ratio, σ and σ_0= actual pressure and initial pressure.

12. Define secondary consolidation. (A/M'13) (N/D'14)

After reduction of ***all excess hydrostatic pressure to zero***, some compression of soil mass takes place at a ***very slow rate*** is termed as secondary consolidation.

13. Define coefficient of compressibility. (N/D'13)

The coefficient of compressibility is defined as the decrease in voids per unit increase in pressure.

$$\mathbf{a_v} = \frac{(eo - e)}{\sigma' - \sigma o'}$$

14. Write any four assumptions of Terzaghi's theory of one dimensional consolidation. (A/M'10)

1. The soil is homogeneous (k_z is independent of z).

2. The soil is completely saturated (S = 100%).
3. The soil grains and water are virtually incompressible (γ_w is constant and volume change of soil is only due to change in void ratio).
4. The compression is one-dimensional (u varies with z only).

15. Define isochrones.(A/M'09)

In a consolidation curve of a soil, the hydrostatic excess pressure will be maximum at the the middle and it is zero at the top and bottom. The distribution of the hydrostatic excess pressure with depth is sinusoidal at other instants of time, as shown by dotted lines. These curves are called "Isochrones".

16. Explain the method of estimating the vertical stress using Newmark's chart. (A/M'10) (N/D'15)

A series of values is assigned for the ratio σ_z/q, such as 0, 0.1, 0.2... 0.9, and 1.00, a corresponding set of values for the relative radii, a/z, may be obtained. If a particular depth is specified, then a series of concentric circles can be drawn. Influence value can be taken as (1/N), where N = No. of elements in the chart.

$$\sigma_z = I.\ N.\ q, \text{ where } I = \text{influence value of the chart.}$$

17. List out the uses of Influence charts in soil mechanics. (A/M'12)

- Many loaded areas have to be drawn; alternatively, many influence charts have to be drawn.
- For each different depth, counting of the influence meshes must be done. Considerable amount of guesswork may be required in estimating the influence units partially covered by the loaded area.
- It can be used for loaded area of any shape and that it is relatively rapid. This makes it attractive.
- This is applicable to a semi-infinite, homogeneous, isotropic and elastic soil mass (and not for a stratified soil).

18. Differentiate between Compaction and Consolidation. (A/M'12)

Compaction	Consolidation
Expulsion of pore air	Expulsion of pore water
Soil involved is partially saturated	Fully saturated soil

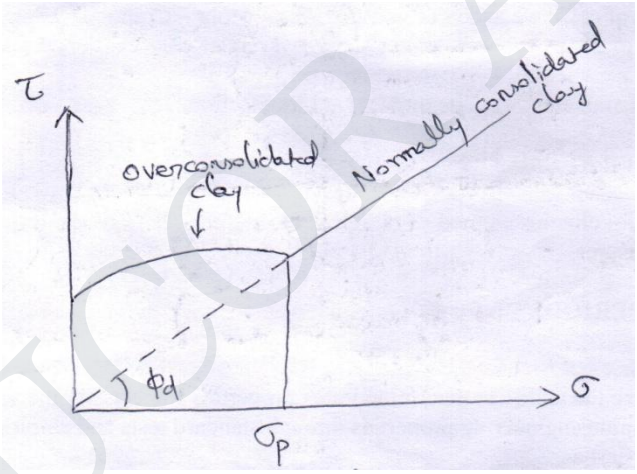
Applies to cohesive as well as cohesionless	Applies to cohesive soils only soils
Dynamic loading is commonly applied	Static loading is commonly applied

19. Define normally consolidated clay and over consolidated clay. (N/D'12) (A/M'15)

A soil for which the ***existing effective stress is the maximum***, to which it has ever been subjected in its stress history, is said to be '***normally consolidated***'.

A soil is said to be '***over consolidated***' if the present effective stress in it has been exceeded sometime during its stress history.

20. Draw the consolidation curves for normally consolidated clay and over consolidated clay. (A/M'12, 14)



Pre consolidation Pressure diagram

UNIT- IV
SHEAR STRENGTH

Shear strength of cohesive and cohesion less soils – Mohr – Coulomb failure theory –Measurement of shear strength, direct shear – Tri-axial compression, UCC and Vane shear tests –Pore pressure parameters – cyclic mobility – Liquefaction.

1. **What is shear strength? (A/M'11) (N/D'07)**
   Shear strength may be defined as the resistance to shearing stresses and a consequent tendency for shear deformation. It is the most important of its engineering properties. Shearing strength of a soil is the most difficult to comprehend in view of the multitude of factors known to affect it.

2. **What are the factors that influence shear strength?**
   (1) Resistance due to the interlocking of particles.
   (2) Frictional resistance between the individual soil grains, which may be sliding friction, rolling friction, or both.
   (3) Adhesion between soil particles or 'cohesion'.

3. **What is principle plane and principle stress?**
   A 'Principal plane' is defined as a plane on which the stress is wholly normal, or one which does not carry shearing stress. There are three principal planes at any point in a stressed material. The normal stresses acting on these principal planes are known as the 'principal stresses'.

4. **What are shear strength parameters? (A/M'16)**
   The parameters are (i) Void ratio, e_f at failure, (ii) Effective normal stress on the failure plane, at failure, (iii) Cohesion, (iv) Angle of internal friction

5. **Mention any four laboratory methods to measure the shear strength of soil. (N/D'11)**
   1. Direct Shear Test
   2. Tri-axial Compression Test
   3. Unconfined Compression Test
   4. Laboratory Vane Shear Test

6. **Define Sensitivity of Soils (N/D'11)**
   If the strength of an undisturbed sample of clay is measured and its strength is again measured after remolding at the same water content to the same dry density, a reduction in strength is

often observed. This is an important phenomenon which is quantitatively characterized by'Sensitivity', defined as follows:

$$\text{Sensitivity, } S_t = \frac{\text{Unconfined compression strength, undisturbed}}{\text{Unconfined compression strength, remolded}}$$

7. Write down the Coulomb's expression for shear strength. (A/M'11) (A/M'16 & 17)

The shear strength of the soil is given by $\boldsymbol{\tau = c + \sigma \tan \varphi}$

τ = shear strength of soil, c= cohesive strength of soil, σ = vertical pressure and φ = angle of internal friction.

8. Explain in brief Mohr-Coulomb theory. (N/D'12) (A/M'10)

The Mohr-Coulomb theory of shearing strength of a soil, first propounded by Coulomb (1976) and later generalized by Mohr, is the most commonly used concept. The functional relationship between the normal stress on any plane and the shearing strength available on that plane was assumed to be linear by Coulomb; thus the following is usually known as Coulomb's law:

$$\mathbf{s = c + \sigma \tan \varphi}$$

9. What is strength envelope?

Mohr circles have the shear stress and the normal stress. The shear stress is drawn as the circle the tangent to that circle is termed as strength envelope.

10. What do you know about undrained and drained test?

In drained tests the drainage during the performance of test is allowed and hence there is no pore water pressure. But in case of undrained test the water is not allowed during the load application and hence there will be presence of hydrostatic pressure.

11. What are the field tests to determine shear strength test?

Field Tests

1. Vane Shear Test
2. Penetration Test

12. What are the different types of shear test based on drainage conditions? (A/M'10,14)

- Unconsolidated undrained Tests (UU-test)
- Consolidated undrained tests (CU test)
- Consolidated Drained tests (CD test)

13. What are the factors that affect shear strength of cohesion less soils?

The shearing strength of cohesion less soils depend primarily upon the angle of internal friction which itself is dependent upon a number of factors including the normal pressure on the failure plane. The sand is saturated or dry and also by the nature of stresses considered—total or effective.

14. What are the merits and demerits of triaxial test? (A/M'17)

The following are the significant points of **merit** of triaxial compression test:

- Failure occurs along the weakest plane unlike along the predetermined plane in the case of direct shear test.
- Complete control of the drainage conditions is possible with the triaxial compression test; this would enable one to simulate the field conditions better.

Demerits:

Test is slightly complicated when compared to other strength tests.

15. What are the different types of failure of a tri-axial compression test specimen

(a) Brittle failure (b) Semi-plastic failure (c) Plastic failure

16. Give the expression to find shear strength by vane shear test (A/M'13)

Shear Strength of soil by means of laboratory vane shear test, $\mathbf{s = T/\pi D^2 (H / 2 + D/ 6)}$

17. State the principle of direct shear test. (A/M'12)

Two types of application of shear are possible—one in which the shear stress is controlled and the other in which the shear strain is controlled.

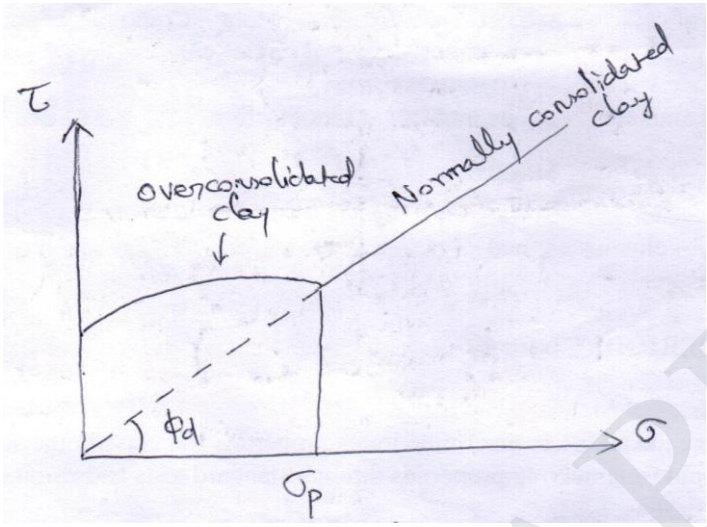
18. What is the effect of pore pressure in shear strength of Soil? (A/M'12)

Pore water pressures play an important role in determining the strength of soil. ***The change in pore water pressure due to change in applied stress*** is characterized by dimensionless coefficients, called 'Pore pressure coefficients' or 'Pore pressure parameters.

19. In a drained tri-axial test, "the failure plane is the plane of maximum shear stress". Say True or False. Justify (M/J'09) (N/D'13)

True. In Drained tests since there is no pore water pressure, the total stress is same as the effective stress and the failure is due to the shear stress and it is maximum.

20. Draw the strength envelope for saturated clay under drained and undrained conditions. (A/M'12, 15)



Drained tests in triaxial compression on a remoulded saturated clay sheared under cell pressure equal to the consolidation pressure

21. Define Stress path. (A/M'12, 14, 16)

A ''Stress–Path'' is a curve or a straight line which is the **locus of a series of stress points** depicting the changes in stress in a test specimen during loading or unloading or in a soil element in-situ forces of nature. The stress path represents the **change in horizontal stress** as the **pore pressure changes**. The relationship between the initial and present state of these two factors is known as the stress path (Q). The co-ordinates of the points on the stress path are

$$\left(\frac{\sigma_1+\sigma_3}{2}\right) \text{ and } \left(\frac{\sigma_1-\sigma_3}{2}\right)$$

22. The diameter of all the Mohr's circles drawn at failure for the results of a triaxial test performed on a soil is the same and equal to 200 kPa to a scale. Find the shear strength parameters. (A/M'13,09)

Given: c= 200 kPa, φ = 45 °, we know that, s = c + σ tan φ

s= 200 tan 45°

Hence s= 200 kPa

23. Write down any four advantages of direct shear test. (A/M'13) (N/D'17,14)

The direct shear test is a relatively simple test. Quick drainage, i.e., quick dissipation of pore pressures is possible since the thickness of the specimen is small.

24. Define Critical Void Ratio.

At large strains both initially loose and initially dense specimens attain nearly the same void

ratio, at which further strain will not produce any volume changes. Such a void ratio is usually referred to as the 'Critical Void Ratio'.

25. Define Liquefaction and State the effects on structural stability due to liquefaction. (N/D'16, 15)

The ***sudden loss of shear strength due sudden increase in moisture content of soil*** developed due to any impact or vibration is termed as Liquefaction of soil. It leads to structural damage of structures like differential settlement, cracks or even sudden collapse.

26. What do you meant by Thixotropy? (N/D'17)

When clays with a flocculent structure are used in construction, these may lose some strength as a result of remoulding. With passage of time, however, the strength increases, though not back to the original value. This phenomenon of ***strength loss-strength gain***, with ***no change in volume or water content***, is called 'Thixotropy'.

UNIT V
SLOPE STABILITY

Slope failure mechanisms – Types - infinite slopes – finite slopes – Total stress analysis for saturated clay – Fellenius method - Friction circle method – Use of stability number - slope protection measures.

1. What are the factors leading to the failure of slopes? (A/M'16)

The factors leading to the failure of slope may be classified in to two categories.

a) The factors which cause an increase in the shear stresses, seepage pressure.

b) The factors which cause a decrease in the shear stresses. This is due to increase in water content, Increase in pore water, weathering, Intense Rain-Fall, Water-Level Change, Seepage Water Flow,

Volcanic Eruption, Earthquake Shaking, Human activity

2. What do you know about Infinite slope? (A/M'10) (N/D'12)

An Infinite slope is very large in extent and is theoretically infinite and the properties of the soil will be same at identical points.

3. What do you mean by Finite Slope? (A/M'10) (N/D'17, 12)

A Finite slope is limited in extent and the properties of the soil will not be same at identical depths. So that the slip surface may be curved.

4. Define Depth factor.

The depth at which the ledge or strong material occurs may be expressed in terms of a depth factor n_d which is defined as, $\mathbf{n_d = D/H}$

Where, D - depth of ledge below the top of the embankment, H = height of slope above the toe.

5. What are the types of slip surface in a Finite slope?

1. Planar failure surface 2. Circular failure surface 3. Non circular failure surface

6. What are the different methods used for analysis of finite slope.

1. Culmann's method of planar failure surface **2**. Swedish circle method (slip circle method)

3. Friction circle method **4**. Bishop's method

7. Define critical surface of failure. (M/J'12)

The critical failure surface for a given slope can be determined by comparing factor of safety of several trial slip surfaces. The slip surface that has the lowest factor of safety is considered to be the critical failure surface.

8. Write down the assumptions made in the analysis of slope?

(i) The stress is assumed to be two dimensional.
(ii) Coulomb equation for shear strength is applicable and parameters and Φ are known.
(iii) Seepage pressure was estimated from the assumed seepage conditions and water levels.
(iv) The conditions of plastic failure are assumed to be satisfied along the critical surface.

9. What are the three forces acting in circular failure while analyses through friction circle method? (A/M'16)

- Cohesive force (C) developed along the slip surface
- Reaction (R) on the slip surface
- Self Weight of the soil mass (W)

10. What do you mean by slide? (A/M'11)

The failure of a mass of soil located beneath a slope a called a slide.

11. Define Taylor's Stability number. (A/M'14, 13)

The force causing instability is the weight of the wedge which is equal to unit weight γ and the area of the wedge which is proportional to the square of the height H. It is a dimensionless quantity.

$$S_n = C'/F_c\gamma H$$

S_n =Stability number, C' = unit cohesion, F_c – Factor of safety, γ - unit weight, H – Height of the slope

12. What are the different factors of safety used in stability analysis of slopes? (N/D'13)

1. Factor of safety with respect to cohesion assuming to be fully mobilized.
2. Factor of safety with respect to friction assuming to be fully mobilized.
3. Factor of safety with respect to shear strength
4. Factor of safety with respect to height.

13. Write down the formula for calculating factor of safety with respect to cohesion. (N/D'17, 10)

$$F_c = C/c_m \text{ (Assuming friction to be fully mobilized)}$$

F_c – Factor of safety with respect to cohesion, C – Ultimate cohesion, c_m – mobilized cohesion

14. Write down the formulae for calculating factor of safety with respect to friction? (N/D'17, 11)

$$F_\varphi = \tan\varphi / \tan\varphi_m \text{ (assuming cohesion to be fully mobilized)}$$

φ - ultimate angle of shearing resistance, φ_m – mobilised angle of shearing resistance.

15. What do you mean by sudden or rapid draw down? (N/D'11)

The sudden decrease in the water table level in an earth dam or an embankment which leads to loss of shear strength and makes the slope instable is sudden or rapid draw down.

16. What do you mean by Tension crack? (M/J'12)

When slip is imminent in a cohesive soil there will always develop a tension crack at the top surface of the slope along which no shear resistance can develop, it occurs in the tension zone of the slope, and the depth of the tension crack is given by $\mathbf{h_c = 2c/\gamma}$

17. List out any two slope protection methods. (N/D'12)

(i) Construction of retaining walls, (ii) Providing deep site drainage, (iii) Planting of trees

18. What is the maximum depth of a vertical cut which is just stable in a purely cohesive soil of Unconfined compressive strength of 40 kPa and the unit weight of 19 kN/m^3? (M/J'09)

Given: UCC q= 40 kN/m^2; c= q/2 = 40/2 = 20 kN/m^2, γ= 19 kN/m^3

Depth of Tension crack $h_c = 2c/\gamma = 2X20/19 = 2.10$m

19. Say True or False and justify your answer, In the case of c-φ soil, the slope failure of an infinite slope never takes place if the angle of the slope and the angle of the internal friction of the soil is equal. (M/J'09)

True. It is an equilibrium condition. Hence the slope will remain stable

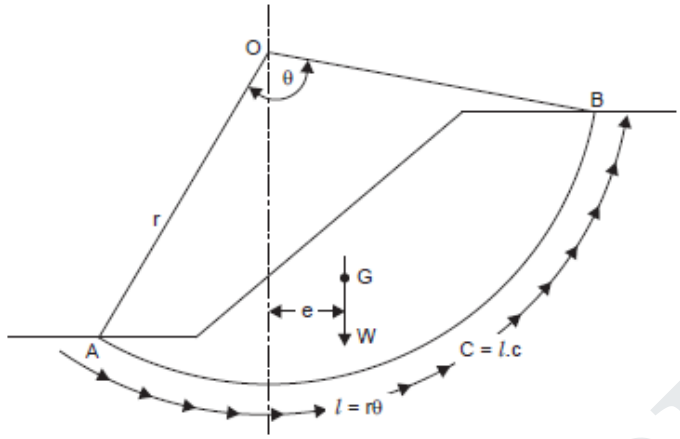
20. Find the factor of safety if the angle of the slope is 30°and the angle of internal friction is 36°

F= tanϕ/tanβ = tan36/tan30 = 0.7265/0.5773, F = 1.258

21. Compare Finite slope and infinite slope. (N/D'16, 12) (A/M'14)

Infinite Slopes	Finite Slopes
Slopes with larger height and indefinite base and top width	Slopes with defined height and a top width
Failure tends to occur only along a plane parallel to the surface	stability of finite slopes involves possible slip surface, equilibrium of the forces acting on this surface
Natural side slopes of a hill	The inclined faces of earth dams, embankments, and excavations.

23. Draw a slip circle for a failure plane in a slope and show the forces involved. (N/D'16)



where AB= slope, G= Centre of gravity, W= weight of wedge, C=cohesion mobilized, e= eccentricity, O=centre of rotation, θ= angle of slip surface (rotation), r= radius of slip circle.

24. Sketch the different types of slope failures. (N/D'14, 13) (A/M'17, 15, 13, 11)

Based on its Layout

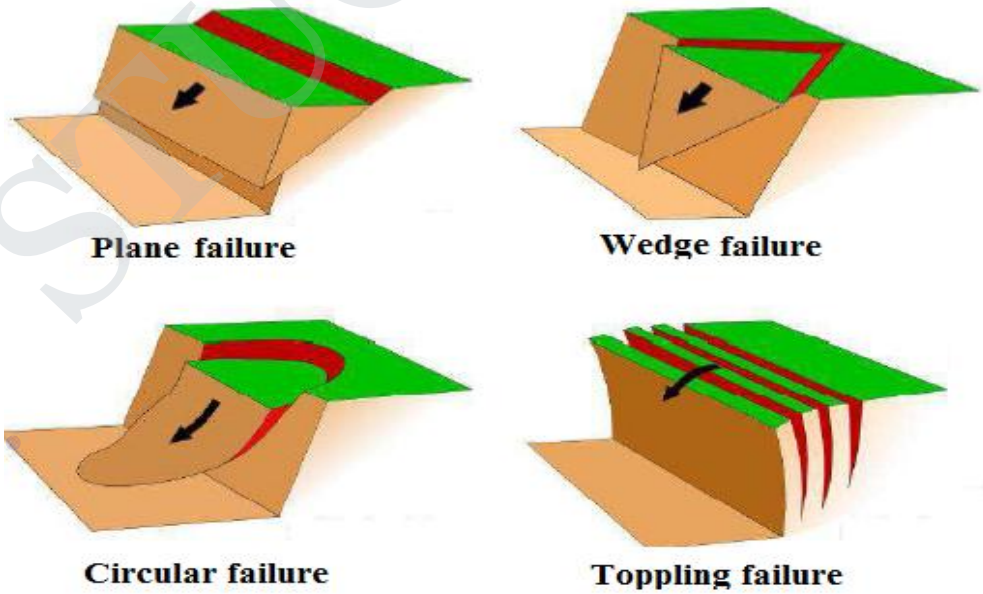
Face (Slope) Failure: This type of failure occurs when the slope angle (β) is large and when the soil at the toe portion is strong.

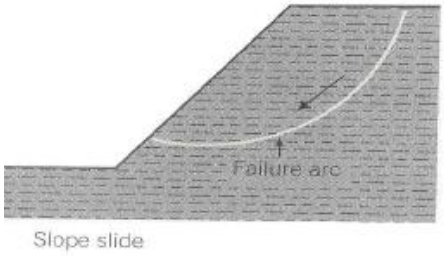
Toe Failure: In this case the failure surface passes through the toe. This occurs when the slope is steep and homogeneous.

Base Failure: In this case the failure surface passes below the toe. This generally occurs when the soil below the toe is relatively weak and soft.

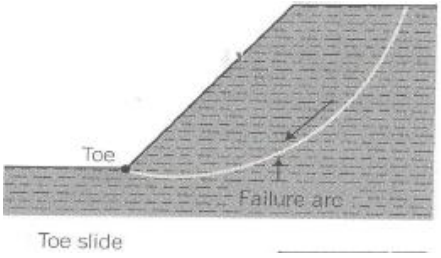
Based on movement of soil mass

(i) Plane failure (ii) Wedge failure (iii) Circular failure (iv) Toppling failure

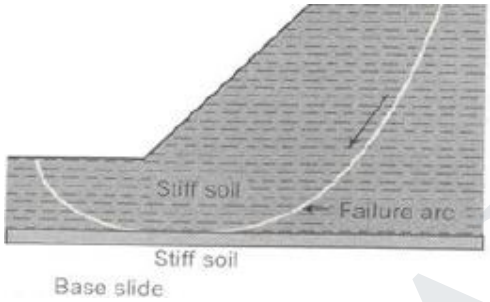




Face failure



Toe failure



Base failure