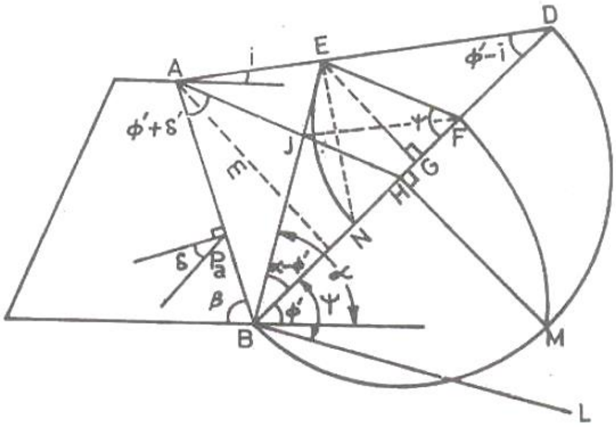
APPLIED GEOTECHNICAL ENGINEERING					
Internal Assessment Test III – July 2022 Solution					
1	(a) Describe Rehbann's graphical method of finding active earth pressure on a retaining wall with the help of a neat sketch.	[07]	CO3	L3
	Fig – 2 Explanation - 5			

Rehbann gave a graphical method for the determination of the total active pressure according to Coulomb's theory. This is based on Poncelet's solution and hence its also known as Poncelet's method.



The step-by step procedure of this graphical method is as follows:

1. Line BD is drawn at an angle ϕ' to the horizontal.
2. Line BL is drawn at an angle ψ with the line BD, is known as the earth pressure line. The angle ψ is equal to β – δ.
3. A semi circle BMD is drawn on BD as diameter.
4. Line AH is drawn parallel to B, intersecting line BD at H. A perpendicular HM is drawn at H, intersecting the semi-circle at M.
5. With B as centre and BM as radius, arc MF is drawn, intersecting BD at F. the line FE is drawn parallel to BL, intersecting the ground surface at E.
6. With F as centre and FE as radius, an arc is drawn to intersect BD at N. the line BE represents the critical failure plane.
7. The total active pressure P_a is given by
   $P_a = \gamma.(\,area\ of\ triangle\ NEF)$
   $P_a = \gamma.\left(\frac{1}{2} \times NF \times x\right)$
   Where x is the perpendicular distance EG between E and BD

	(b) An embankment 10 m high is inclined at an angle of 36° to the horizontal. A stability analysis by the method of slices gives the following forces per running meter: Σ Shearing forces = 450 kN; Σ Normal forces = 900 kN; Σ Neutral forces = 216 kN. The length of the failure arc is 27 m. Laboratory tests on the soil indicate the effective values c′ and φ′ as 20 kN/m^2 and 18° respectively. Determine the factor of safety of the slope with respect to shearing strength.	[07]	CO3	L3
	Identification of values, equation, substitution, answer – 3+1+3			

$$Factor\ of\ Safety = \frac{\left(C'\hat{L} + (\sum N - \sum U) \times tan\emptyset'\right)}{\sum T}$$

$$Factor\ of\ Safety = \frac{(20 \times 27 + (900 - 216) \times tan18)}{450}$$

$$Factor\ of\ Safety = 1.69$$

	(c) What is a pile foundation? Explain its classification based in load transfer.	[06]	CO5	L2

Pile foundations are deep foundation which are used to transfer to the superimposed loads to firm stratum below.

Classification of piles with respect to load transmission and functional behavior are:

- End bearing piles (point bearing piles)
- Friction piles (cohesion piles)
- Combination of friction and cohesion piles

End bearing piles

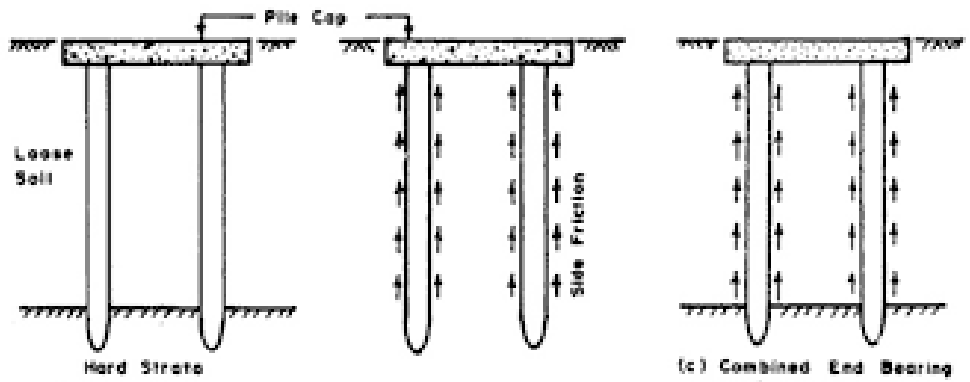
These piles transfer their load on to a firm stratum located at a considerable depth below the base of the structure and they derive most of their carrying capacity from the penetration resistance of the soil at the toe of the pile. Even in weak soil a pile will not fail by buckling and this effect need only be considered if part of the pile is unsupported, i.e. if it is in either air or water.

Friction or cohesion piles

Carrying capacity is derived mainly from the adhesion or friction of the soil in contact with the shaft of the pile. These piles transmit most of their load to the soil through skin friction. This process of driving such piles close to each other in groups greatly reduces the porosity and compressibility of the soil within and around the groups. Therefore piles of this category are sometimes called compaction piles.

Combination of friction piles and cohesion piles

An extension of the end bearing pile when the bearing stratum is not hard, such as firm clay. The pile is driven far enough into the lower material to develop adequate frictional resistance.



(a) End Bearing Pile (b) Friction Pile (c) Combined End Bearing and Friction Pile

2	(a) Explain friction circle method for analysis of slopes.	[07]	CO3	L3
	Fig + Explanation +force triangle – 2+4+1			

Friction circle method if used for stability analysis of slopes made of homogenous soils. Here, slip surface is considered as an arc of a circle. Following is the step by step procedure:

For dry soil

1. Forces acting on the wedge on the sliding wedge AEBD are
   - Weight (W) of the sliding wedge
   - Cohesive force C developed along the slip surface AEB
   - Reaction R on the slip surface
2. The reaction R is inclined at an angle ϕm to the normal to the slip surface. As the direction of normal changes R also changes.
3. With centre as O, a small circle is drawn. This circle is called as friction circle and is radius is $rSin\phi_m$.
4. All lines which are tangent to the friction circle makes an angle ϕ_m with the normal to the slip surface. These lines represent the direction of the combined normal and mobilised frictional forces on the slip surfaces. Thus, the reaction R is tangential to the friction circle.
5. With these forces, a force triangle can be constructed.
6. The cohesive force $C_m = c_m L_a$, where c_m is the mobilised cohesion and L_a is the length of the circular arc.
7. The force acting along the circular arc can be replaced to the force C, acting the chord AB whose length is L_c. Line of action of this force is determined by taking moments about the centre of rotation.

$$c_m.L_a.r = c_m.L_c.a$$

$$a = \frac{L_a}{L_c}.r$$

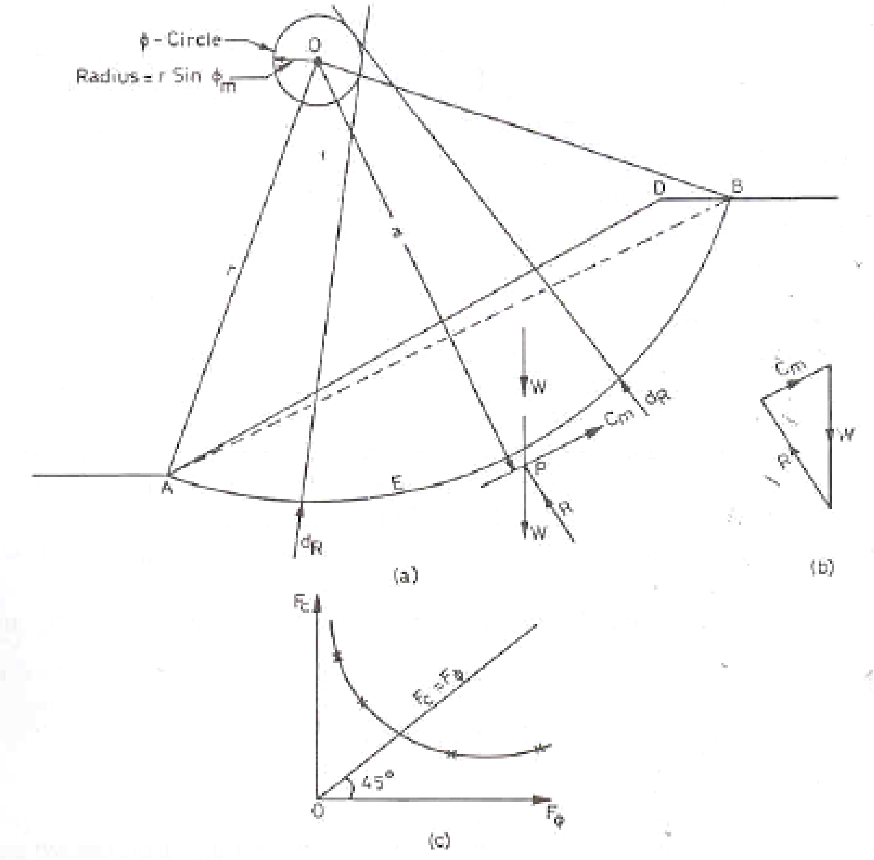
   Since L_a, length of arc is greater than L_c, a will be greater than r
8. Intersection of the weight W and cohesive force establishes a point P which reaction R must act. Direction R is obtained by drawing a line tangential to the ϕ circle.
9. The forced C_m and R can be determined by the force triangle. Force triangle is presented in (b).
10. Factor of safety with reference to F_c cohesion, is given as

$$F_c = \frac{c}{c_m}$$

11. Factor of safety with respect to angle of friction F_ϕ

$$F_\emptyset = \frac{tan\emptyset}{tan\emptyset_m}$$

12. A curve is plotted between F_ϕ and F_c is plotted and the Factor of Safety with respect to shear strength is obtained by drawing a line at an angle of 45^o which Fc = Fϕ = Fs



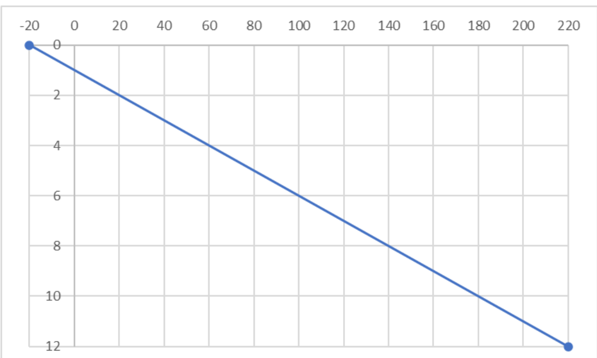
(b) A retaining wall with a smooth vertical back retains a purely cohesive fill. Height of wall is 12 m. Unit weight of fill is 20 kN/m^3. Cohesion is 1 N/cm^2. What is the total active Rankine thrust on the wall? At what depth is the intensity of pressure zero and where does the resultant thrust act?	[07]	CO3	L3
k_a, σ_z, pressure distribution, critical depth, thrust, point of action – each item 1 mark			

For a purely cohesive soil, ϕ = 0

$$k_a = \frac{1 - Sin0}{1 + Sin0} = 1$$

$$\sigma_z = k_a.\gamma z - 2c\sqrt{k_a}$$

z	Vertical stress	
0	$-2 \times 10\sqrt{1}$	-20
5	$1 \times 20 \times 12 - 20$	220



$$\frac{20}{220} = \frac{z_c}{12 - z_c}$$

$$20 \times 12 - 20z_c = 220z_c$$

$$z_c = 1m$$

$$Active\ thrust = 0.5 \times 11 \times 220$$
$$= 1210\ kN\ acting\ at\ a\ depth\ of\ 3.67\ from\ bottom$$

(c) Explain causes of slope failure.	[06]	CO3	L2
Atleast 6 different causes – 6 × 1 = 6			

The basic criterion to achieve a stable slope is to ensure that the shear strength of the soil is higher than the shear stress that may cause the failure. Following are the ways that can affect the stability of slopes :

1. The decrease in the shear strength of the soil.
2. The increase in the shear stress that ultimately causes the failure of soil.

1. Causes for decrease in shear strength:

1.1 Increase in Pore Water Pressure

The frequent increase in the groundwater table and upward seepage, as an outcome of uncommonly heavy rains, are the most common reasons for increased pore water pressure. Mostly, the clayey soils have a very low permeability index. Thus, the change in shear strength of clayey soil determines the long-term stability of the slope while in case of sandy soils, the short term stability needs to be evaluated.

1.2 Cracking

Cracks appear as an outcome of tension in the soil at the ground surface that goes beyond the tensile strength of the soil. Therefore, as the tensile strength of soil reduces, the shear strength on crack-plane also reduces.

1.3 Swelling

Highly plastic and over-consolidated clay easily swells when it comes in contact with water.

1.4 Decomposition of Clayey Rock Fills

Compacted clayey rock fills when in contact with groundwater or seepage water, disintegration of compacted fill occurs which can result in chunks of clay particles. These chunks of clayey particles then swell into the open spaces within the fill, causing a reduction in the shear strength of soil, and making the fill unstable.

a. Creep

Under sustained loading, the highly plastic clays undergo constant deformation. The impact of creep is worsened under cyclic loads such as freezing, thawing, wetting, and drying conditions.

1.6 Leaching

As the water seeps through the voids of the soil, the chemical and mechanical properties of soil start undergoing modifications. This process is known as leaching.

1.7 Strain Softening

In a stress-strain curve of brittle soils, when the critical stress reaches the peak, the shear strength of brittle soils reduces with more constant strain. This type of stress-strain behavior makes a progressive failure, thus creating a path for slope failure.

1.8 Weathering

The process in which rocks and soils lose their strength due to the modifications in physical, chemical, and mechanical properties by external agents such as water, wind, temperature change, etc. is known as weathering.

1.9 Cyclic loading

Under the impact of cyclic loads, the bond between the soil particles may break, and the pore water pressure might increase, resulting in the loss of strength.

2. **Increase in Shear Stress of Soil**

The factors through which shear stresses can be increased are discussed below:

2.1 Loads at the Top of the Slope

If the ground at the top of a slope is loaded, the shear stress needed for equilibrium of the slope will be more.

2.2 Water Pressure in Fractures

A slope can become unstable if fractures at the top of a slope are filled with water. The pressure created due to water in the fractures loads the soil and increases the shear stresses.

2.3 Due to an Increase in Soil Weight

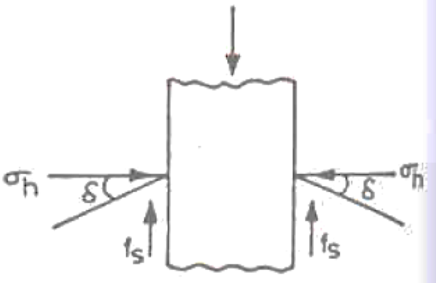
	Seepage into the soil within a slope can increase the water content of the soil, thereby increasing its weight. If this increase in weight is considerable, specifically with the combination of other forces, it can lead to slope failure. 2.4 Excavation Excavation that makes a slope steeper will increase the shear stress in the soil within the slope and reduce stability. The disintegration of soil by a stream at the base of a slope has the same result. 2.5 Drop in Water Level at the Base of a Slope External water pressure acting on the face of the slope provides a stabilizing result. Rather, the slope will become unstable if the water content reduces by increasing shear stress. When this level drops quickly, and the pore pressures within the slope are not reduced in accordance with the drop in the water level outside, the slope will be less stable. This phenomenon is known as the rapid drawdown condition and is important for the design of partially submerged slopes. 2.6 Earthquakes In the event of an earthquake, slopes are subjected to vertical and horizontal velocities that result in cyclic variations in stresses within the slope. This increases them above their static values for brief durations, lasting for seconds or fractions of a second.			
3	(a) Explain static formula to estimate pile load carrying capacity.	[05]	CO5	L2
	End resistance + friction resistance Sand + clay + figure – 2 + 2 + 1 = 5			
	$\boldsymbol{Q_u = Q_p + Q_s}$ $\boldsymbol{Q_p = q_p A_p}$ $\boldsymbol{Q_s = f_s A_s}$ $\boldsymbol{Q_p\ is\ the\ resistance\ of\ the\ pie\ tip}$ $\boldsymbol{Q_p\ is\ the\ shaft\ resistance\ developed\ by\ friction\ of\ the\ pie\ tip}$ In sand: $\boldsymbol{Q_u = Q_p + Q_s}$ $\boldsymbol{q_p = \overline{q} N_q + 0.4 \gamma B N_\gamma}$ $\boldsymbol{\overline{q} -\ effective\ vertical\ pressure\ at\ pile\ tip}$ **N_γ and N_q are bearing capacity factors** **B – pie tip width or diameter, m** **In driven piles:**			

$q_p = \bar{q}N_q$

$\sigma_h = k\bar{\sigma}_v$

$f_s = k\bar{\sigma}_v.\tan\delta$

$$Q_u = \bar{q}N_qA_p + \sum_{i=1}^{n} K(\bar{\sigma}_v)_i.\tan\delta.(A_s)_i$$



In Clayey soil

$Q_u = Q_p + Q_s$

$Q_p = cN_cA_p$

Pile Material	δ	*K* (*loose sand*)	*K* (*dense sand*)
Steel	20°	0.50	1.0
Concrete	0.75 ϕ	1.0	2.0
Timber	0.67 ϕ	1.5	4.0

$N_c = 9$

$Q_s = \alpha\bar{c}A_s$

(b)	An embankment is inclined at an angle of 35° and its height is 15 m. The angle of shearing resistance is 15° and the cohesion intercept is 200 kN/m^2. The unit weight of soil is 18.0 kN/m^3. If Taylor's stability number is 0.06, find the factor of safety with respect to cohesion.	[05]	CO3	L3
	Expression + calculation – 2+3 = 5			

$$S_n = \frac{c}{F_c\gamma_{sat}H}$$

$$0.06 = \frac{200}{F_c \times 18 \times 15}$$

$F_c = 12.34$

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