USN

15CV53

Fifth Semester B.E. Degree Examination, Dec.2019/Jan.2020
Applied Geotechnical Engineering

Time: 3 hrs. Max. Marks: 80

Note: Answer any FIVE full questions, choosing one full question from each module.

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

Module-1

1 a. What is subsurface exploration? What are objectives of soil exploration? **(08 Marks)**
b. What are Geophysical methods? Explain seismic refraction method with neat sketch. **(08 Marks)**

OR

2 a. List and explain different types of samplers used in soil sampling. **(08 Marks)**
b. What are the methods available for dewatering? Explain dewatering by well point system. **(08 Marks)**

Module-2

3 a. Derive the expressions for vertical stress and shear by using Boussinesq's theory. Also write expression for Westerguard's theory. **(08 Marks)**
b. What is Newmark's influence chart and also describe construction procedure for Newmarks's influence chart. **(08 Marks)**

OR

4 a. What are the types of settlement? Explain them with equations. **(08 Marks)**
b. A soft, normally consolidated clay layer 18 m thick. The natural water content, saturated unit weights specific gravity and liquid limit are 45%, 18 kN/m^3, 2.70 and 63% respectively. The vertical stress increment at centre of the layer due to the foundation load is 9 kN/m^2. The ground water level is at the surface of the clay layer. Determine the settlement of the foundation. **(08 Marks)**

Module-3

5 a. Define with neat sketch At rest, Active and Passive earth pressure. **(06 Marks)**
b. A retaining wall, 8 m high with a smooth vertical back, retains a clay backfill with $C' = 15$ kN/m^2, $\phi' = 15°$ and $\gamma = 18$ kN/m^3. Calculate the total active thrust on the wall assuming that tension cracks may develop to the full theoretical depth. **(10 Marks)**

OR

6 a. Explain the causes for slope failure and also list the type of slope failures. **(08 Marks)**
b. A 7m deep canal has side slope of 1:1. The properties of soil are $C_u = 20$ kN/m^2, $\phi_u = 15°$, $e = 0.9$ and $G = 2.75$. If Taylor's stability number is 0.108, determine the factor of safety with respect to cohesion when canal runs full. Also find the factor of safety in case of sudden draw down, if the Taylor's stability number for this condition is 0.137. **(08 Marks)**

22°

Module-4

7 a. Write a note on standard penetration test and its corrections. **(08 Marks)**
b. Define safe bearing capacity, safe bearing pressure and allowable bearing pressure and also write expressions for the same. **(08 Marks)**

CBCS SCHEME

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b. Define safe bearing capacity, safe bearing pressure and allowable bearing pressure and also write expressions for the same. **(08 Marks)**

OR

8 a. Discuss the effect of ground water table on bearing capacity of soil. (08 Marks)

b. A square footing 2.5m × 2.5m is built on homogenous bed of sand of density 19 kN/m^3 and having an angle of shearing resistance of 36°. The depth of foundation is 1.5m below ground surface. Calculate safe load that can be applied on the footing with factor of safety 3. Take bearing capacity factors as $N_c = 27$, $N_q = 30$ and $N\gamma = 35$. (08 Marks)

Module-5

9 a. Explain the types of piles and also mention their uses. (08 Marks)

b. 200 mm diameter, 8 m long piles are used as foundation for column in a uniform deposit of medium clay (q_u = 100 kN/m^2). The spacing between the piles is 500mm. There are 9 piles in the ground arranged in a square pattern. Calculate the ultimate pile load capacity of the group. Assume adhesion factor = 0.9. (08 Marks)

OR

10 Write short notes on :

a. Piles in granular soils (04 Marks)

b. Settlement of pile group (04 Marks)

c. Negative skin friction (04 Marks)

d. Pile load tests. (04 Marks)

* * * * *

QUESTION PAPER SOLUTION

Q1.a. Sub surface exploration is investigation of soil below the ground level to obtain necessary information about th soil.

The objectives of site investigation is

1) To provide relaible, specific & detailed information about the soil & ground water condition of site which may be required for a safe and economic design & execution of engineering work.

2) An exploration of region should yield precise information about

a) Order of occurenc & extent of soil & rock strata

b) nature & engineering properties of soil & rock formation

c) Location of ground water & its variation.

3) An exploration should also give information like

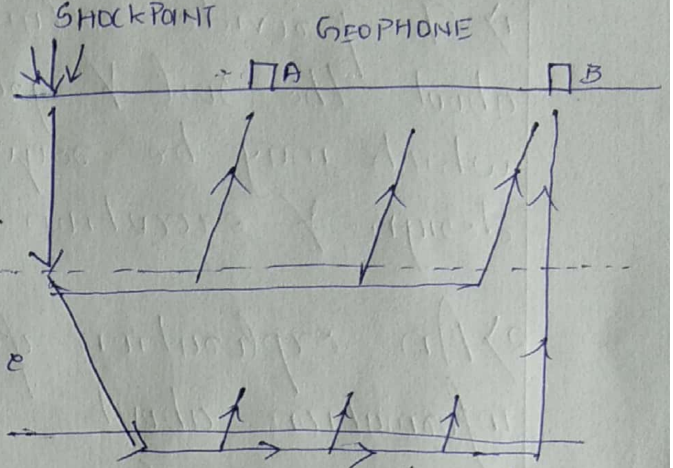
a) environmental problems

b) Identify potential problems concerning adjacent property

c) Ensure safety of surrounding existing structure.

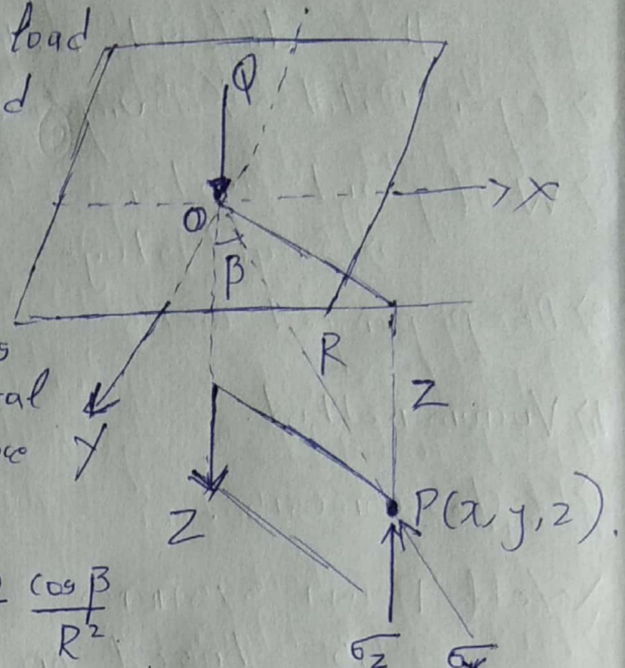
Q1.b. Geophysical methods involve technique of determining underground materials by measuring some property of the material. They are mostly done from the ground surface using non-destructive techniques.

SEISMIC REFRACTION METHOD.



* Shock waves are created by exploding charges or striking a plate with hammer at shockpoint.
* Radiating shockwaves are picked up by geophones, where the time of travel is recorded.
* Either a no of geophones are arranged along a line or shock point is moved away from geophone to produce shockwave at given intervals.
* Some waves called primary waves travel directly from shakpoint to geophone.
* If subsoil comprises 2 or more layers some of primary waves travel downwards to lower layer & gets refracted at the interfere.
* If underlying layer is dense, the refracted waves travel much faster. They emerge again & reach th geophone.

Q2a. Let Q be a point load acting at point 'O' on ground surface which is taken as origin of X, Y & Z axes.



Consider pnt 'P' in the soil mass having coordinates x, y & z and radial horizontal distance 'r' & vertical distance 'z' from point 'O'.

Polar radial stress, $\sigma_r = \frac{3}{2}\frac{Q}{\pi}\frac{\cos\beta}{R^2}$

Where $R = \sqrt{x^2+y^2+z^2}$ & $\cos\beta = z/R$, $r = \sqrt{x^2+y^2}$.

$$\sigma_z = \sigma_r \cos^2\beta = \frac{3}{2}\frac{Q}{\pi}\frac{\cos^3\beta}{R^2} \Rightarrow \sigma_z = \frac{3}{2}\frac{Q}{\pi}\frac{Z^3}{R^5}$$

$$\Rightarrow \sigma_z = \frac{3}{2}\frac{Q}{\pi}\frac{Z^3}{\left(\sqrt{x^2+y^2+z^2}\right)^5} = \frac{3}{2}\frac{Q}{\pi}\frac{Z^3}{(r^2+z^2)^{5/2}} = K_B\frac{Q}{Z^2}.$$

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

According to Westergaard's theory

$$\sigma_z = \frac{Q}{\pi Z^2}\frac{\sqrt{(1-2\mu)(2-2\mu)}}{\left[(1-2\mu)/(2-\mu) - (r/z)^2\right]^{3/2}}.$$

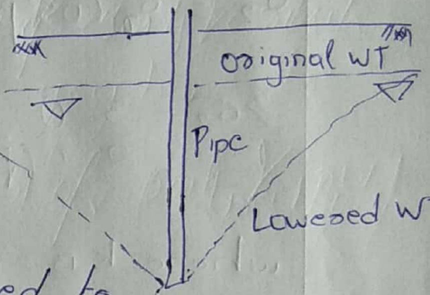
Q2b The different methods of dewatering are.

1) Open Ditches & Sumps
2) Well point system
   i) Single stage   ii) Multiple stage.
3) Deep pumped wells
4) Vacuum method.
5) Electro osmosis.

Well POINT SYSTEM.

is based on gravity flow involving installation of well point.

A well point is a perforated pipe about 0.5 to 1m long & 5 to 8cm in diameter covered by cylindrical wire gauge screen.



A conical steel drive point is attached to the lower end of pipe to allow jetting of water to pass through it.

Points are placed in a row or ring & riser pipes are attached through a common header pipe to a special well point.

Well point is inserted into th ground by water jets.

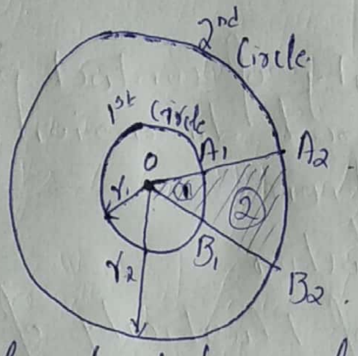
The gap formed b/w riser pipe & well point is filled with coarse sand.

Suction pump used in the system has a capacity of bringing water to the surface from a minimum depth of 6m.

Well points are generally spaced b/w 1 to 2m.

Q3b Newmark's chart is a more accurate method of determining th vertical stress at any point under a uniformly loaded area of any shape.

The chart consisting of no of circles & radiating lines is so prepared that th influence of each area unit is the same at centre of circle.



· Let a uniformly loaded circular area of radius r_1 cm be divided into 20 sectors.

If 'q' is the intensity of loading, σ_z is vertical stress at depth 'z' below the centre of area, each unit such as OA_1B_1 exerts a pressure $= \sigma_z/20$ at the centre.

$$\sigma_z/20 = q/20\left[1 - \left\{\frac{1}{1+(r_1/z)^2}\right\}^{3/2}\right] = i_f\, q$$

If 'i_f' can be made = arbitrarily fixed value say 0.005 we have $q/20\left[1 - \left\{\frac{1}{1+(r_1/z)^2}\right\}^{3/2}\right] = 0.005\, q$.

Selecting $z = 5$ cm (say), the value of r_1 from above eqn. comes out as 1.35 cm.

Hence O^le of radius, $r_1 = 1.35$ cm is drawn & divided into 20 equal areas, each area unit will exert a pressure $= 0.005\, q$ at depth of 5 cm.

Let radius of 2nd concentric O^le be r_2. By extending 20 radial lines space b/w 2 concentric O^le is divided into 20 units. $A_1A_2B_1B_2$ is such unit.

Total pressure due to OA_1B_1 & $A_1A_2B_2B_1$ at depth $z = 5$ cm below centre is $2 \times 0.005\, q$.

Q4a. The different types of settlement are
1) Immediate settlement.
2) Primary Consolidation settlement.
3) Secondary settlement.

Immediate settlement is given by

$$S_i = qB\frac{(1-\mu^2)}{E_s} I_w$$

where, q = intensity of contact pressure.
B = Least Lateral dimension of footing.
μ = Poisson's ratio
I_w = Influence factor
E_s = Modulus of Elasticity of soil.

Primary consolidation settlement is given by

$$S_c = \frac{C_c}{1+e_0} H \log_{10}\left[\frac{\sigma_0 + \Delta\sigma}{\sigma_0}\right]$$

H → Thickness of clay layer.
C_c → Compression Index.
e_0 → Initial voids ratio
σ_0 → Initial effective overburden pressure.
$\Delta\sigma$ → Average pressure increment due to foundation load in clay layer.

Q4b. Given, $H = 18m$ $w = 18\%$ $G = 2.7$.
$\gamma_{sat} = 18 \, kN/m^3$ $w_L = 63\%$ $\Delta\sigma = 9 \, kN/m^2$.

$\sigma_0 = \gamma' z$
$= (\gamma_{sat} - \gamma_w) z = (18 - 9.81) \times (18/2)$

$\therefore \sigma_0 = 73.71 \, kN/m^2$.

$e_0 = wG$
$= 0.18 \times 2.7 = 1.22$.

$$S_c = \frac{C_c}{1+e_0} H \log_{10}\left(\frac{\sigma_0 + \Delta\sigma}{\sigma_0}\right).$$

$C_c = 0.009(w_L - 10)$.
$= 0.009(63 - 10) = 0.477$.

$$\therefore S_c = \frac{0.477}{1+1.22} \times 18 \times \log\left[\frac{73.71 + 9}{73.71}\right]$$

$S_c = 0.194 m$
$= 194 mm$.

Q5a. ~~In the~~

Earth pressure at Rest

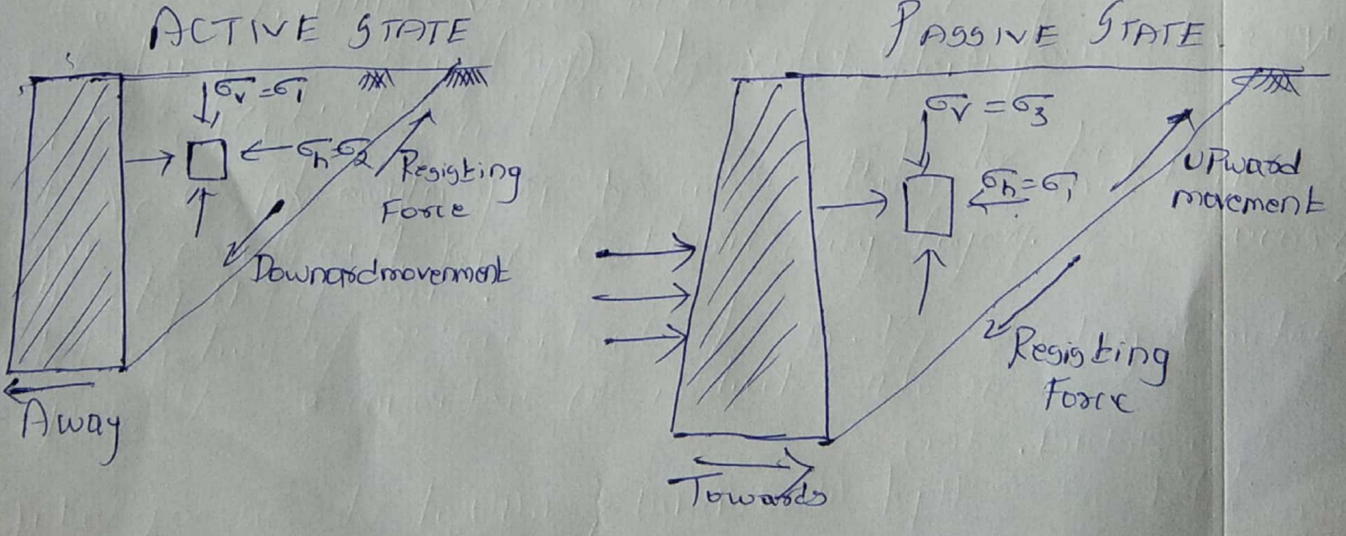
In the natural state, soil at any depth 'z' below the ground surface is not subjected to any lateral strain due to infinite extent of soil mass all around in horizontal plane. The element is in a condition of rest. The pressure exerted on RW in such state is Earth pressure at rest 'P_0'.

ACTIVE Earth Pressure.

During active state, th wall moves away from backfill & a certain portion of backfill located immediately behind the wall breaks away from the rest of the soil.
This results is decrease in earth. This decrease continue upto a point where EP does not decrease beyond this point even if there is further movement of wall. This minimum pressure is called Active EP.

PASSIVE Earth pressure.

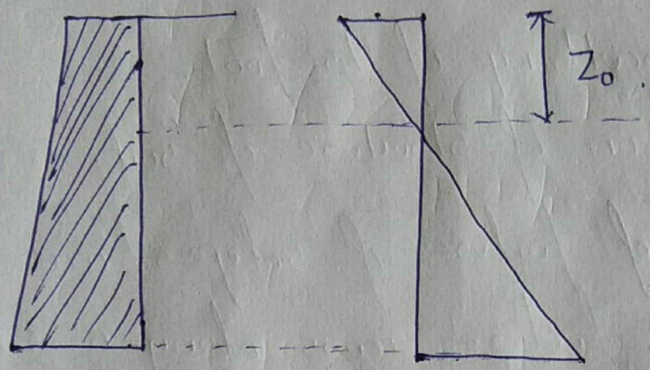
When wall moves towards the fill the EP increases because shearing resistance builds up in directions towards the fill. The pressure reaches maximum point & after this even if there is movement of wall, pressure does not increase. This maximum EP is called Passive EP.



Q5b

Given, $H = 8m$ $C = 15 kN/m^2$ $\phi = 15°$

$\gamma = 18 kN/m^3$



$$K_a = \frac{1-\sin\phi}{1+\sin\phi} = \frac{1-\sin 15}{1+\sin 15} = \frac{1-0.259}{1+0.259} = 0.774$$

$$Z_0 = \frac{2c}{\gamma\sqrt{K_a}} = \frac{2\times 15}{18\times\sqrt{0.774}} = \frac{30}{18\times 0.88} = 1.89m$$

Total active thrust, P_a

$$P_a = \frac{1}{2}\gamma H^2 \cot^2\alpha - 2c \cdot H \cot\alpha \quad \left[\alpha = 45 + \frac{\phi}{2} = 52.5°\right]$$

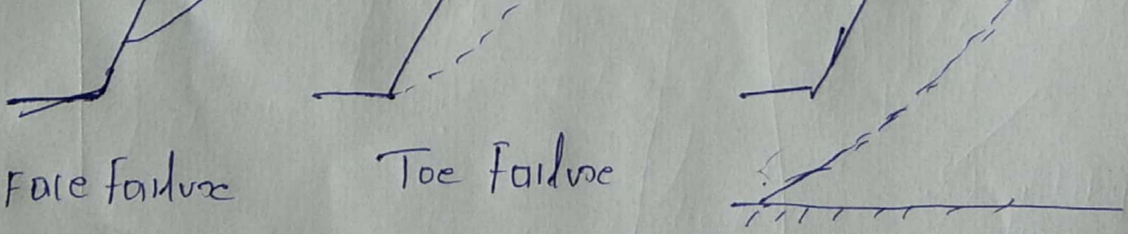
$$= \frac{1}{2}\times 18\times 8^2 \times \cot 52.5 - 2\times 15\times 8\times \cot 52.5$$

$$= 55.26 \times 8 - 184.08$$

$$= 258 kN/m$$

Q6a. The causes of failure of slope are.
1) Action of gravitational forces.
2) Seepage forces within the soil.
3) Excavation or undercutting of its foot.
4) Gradual Disintegration of structure of soil.

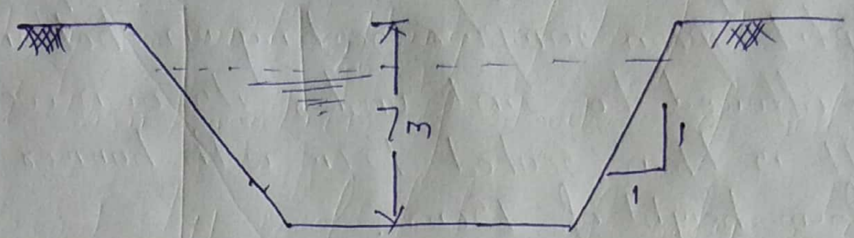
Different types of failures of slopes are.
1) SLOPE FAILURE :- If failure occurs along a surface of sliding that intersects th slope at or above its toe, it is called slope failure.
a) Slope failure: is called as FACE failure if the arc passes above the toe.
b) Slope failure is called as TOE failure if the arc passes through the toe.
2) BASE failure: If soil beneath the toe of the slope is weak the failure occurs along a surface that passes at some distance below the toe of slope. Such type of failure is called as BASE FAILURE.



SLOPE FAILURE.   BASE FAILURE

Q6b.

Given, $H = 7m$, $C = 20\,kN/m^2$ $\phi = 15^\circ$ $e = 0.9$
$G = 2.75$, $S_n = 0.108$ (for full canal)



$$\gamma_{sat} = \frac{G+e}{1+e}\gamma_w = \frac{2.75+0.9}{1+0.9} \times 9.81 = 18.84\,kN/m^3$$

$$\gamma' = \gamma_{sat} - \gamma_w = 18.84 - 9.81 = 9.04\,kN/m^3.$$

i) When Canal is Full.

$$F_c = \frac{c}{\gamma' H S_n} = \frac{20}{9.04 \times 7 \times 0.108} = \frac{20}{6.83}$$

$\therefore F_c = 2.92$

ii) Sudden Drawdown.

$S_n = 0.137$

$$F_c = \frac{c}{\gamma_{sat} H S_n} = \frac{20}{18.84 \times 7 \times 0.137} = \frac{20}{18.07}$$

$F_c = 1.107$.

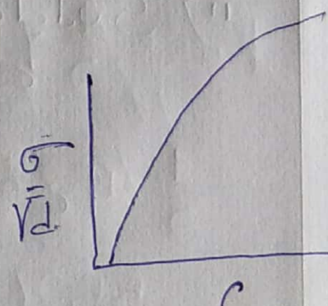
Q7a. Standard penetration test (SPT) is performed in a clean hole, 50 to 150mm diameter.

A casing or drilling mud is used to support sides of wall.

- Split spoon sampler resting on bottom of bore hole is allowed to sink under its own weight.
- It is then seated 15 cm with hammer blows falling from height of 75cm.
- The sampler is further driven by 30cm blows
- No of blows required to affect each 15cm penetration is recorded
- 1st 15cm of drive is seating drive.
- Total blows required for 2nd and 3rd 15cm of penetration is termed as penetration resistance 'N'.
- If sampler is driven < 45 cm, then penetration resistance shall be for last 30cm of penetration.
- Entire sampler may sometimes sink under its own weight when very soft sub soil is encountered.
- Under such condition it may not be necessary to give any blow to be sampler & SPT value be indicated as zero.

1) Correction for overburden (C_N)

Corrected value, $N_0 = C_N N$.



2) Correction due to Dilatancy

applied if soil consists of fine sand & silt below water table for $N > 15$.

$$N_e = 15 + (N_0 - 15)$$

Correction for overburden is always applied first.

Q7b

SAFE BEARING ~~PRESSURE~~: (SBC; q_s)

Maximum pressure which th soil can carry safely without risk of shear failure is called safe bearing capacity.

$$q_s = q_{ns} + \gamma D = \frac{q_{nf}}{F} + \gamma D.$$

SAFE BEARING PRESSURE.

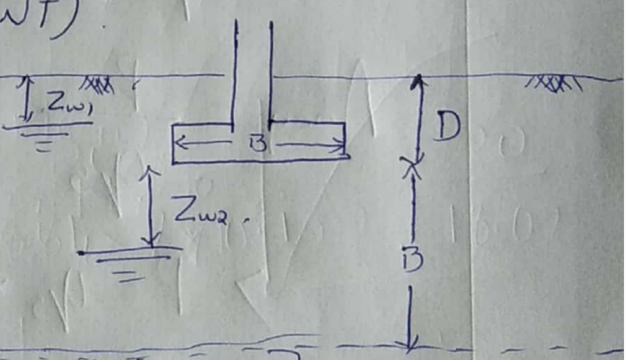
is the intensity of loading that will cause a permissible settlement or specified settlement for th structure.

ALLOWABLE BEARING CAPACITY/PRESSURE (q_a)

is the net loading intensity at which neither the soil fails in shear nor there is excessive settlement detrimental to the structure.

Q.8a. Effect of water Table(WT)

When WT is above (D+B) depth from ground level its effect should be considered & γ' should be used for soil above WT.



$R_{w1} = 0.5\left[1 + \frac{Z_{w1}}{D}\right]$. $R_{w2} = 0.5\left[1 + \frac{Z_{w2}}{B}\right]$.

WT at GL: $Z_{w1} = 0$ $R_{w1} = 0.5$ $R_{w2} = 0.5$.

WT at Foundation $Z_{w1} = D$ $R_{w1} = 1$ $Z_{w2} = 0$ $R_{w2} = 0.5$.

WT at $Z_w = B$ $R_{w1} = 1$ $Z_{w2} = B$ $R_{w2} = 1$

WT at depth $> (D+B)$ $R_{w1} = 1$ $R_{w2} = 1$.

Q8b. Given, $B = 2.5m$ $\gamma = 19 \, kN/m^3$ $\phi = 36°$

$D = 1.5m$ $F = 3$ $N_q = 27$ $N_\gamma = 35$

$c = 0$ ∴ sand soil.

$$q_{nf} = \gamma D(N_q - 1) S_q + \frac{1}{2} \gamma B N_\gamma S_\gamma.$$

For square footing $S_q = 1$ and $S_\gamma = 0.8$

$$\therefore q_{nf} = 19 \times 1.5 (27-1) \times 1 + \frac{1}{2} \times 19 \times 2.5 \times 35 \times 0.8$$

$$= 741 + 665$$

$$\therefore q_{nf} = 1406 \, kN/m^2.$$

$$q_s = \frac{q_{nf}}{F} + \gamma D = \frac{1406}{3} + 19 \times 1.5.$$

$$\therefore q_s = 497.1667 \, kN/m^2.$$

$$A_{req} = \frac{P}{q_s}$$

$$\Rightarrow P = q_s \times A = 497.167 \times (2.5 \times 2.5)$$

$$\therefore P = 3107.29 \, kN.$$

Q9a. CLASSIFICATION based on FUNCTION :

1) End Bearing Pile :- used to transfer load through water or soft soil to a hard stratum.

2) Friction Piles :- used to transfer load in soils such as sand.

3) Compaction piles :- used to compact loose granular soil thus increasing their bearing capacity.

4) Tension piles :- anchor down the structure subjected to uplift due to hydrostatic pressure due to overturning moment.

5) Anchor piles :- provides anchorage against horizontal pull from sheet piling.

6) Fender Piles :- used to protect water front structures against impact from ships or other floating objects.

7) Sheet piles :- used to reduce seepage under hydraulic structure

8) Batter Piles :- used to resist large horizontal forces.

CLASSIFICATION BASED ON MATERIALS

1) CONCRETE PILES

a) PRECAST PILES   b) CAST IN-SITU PILES.

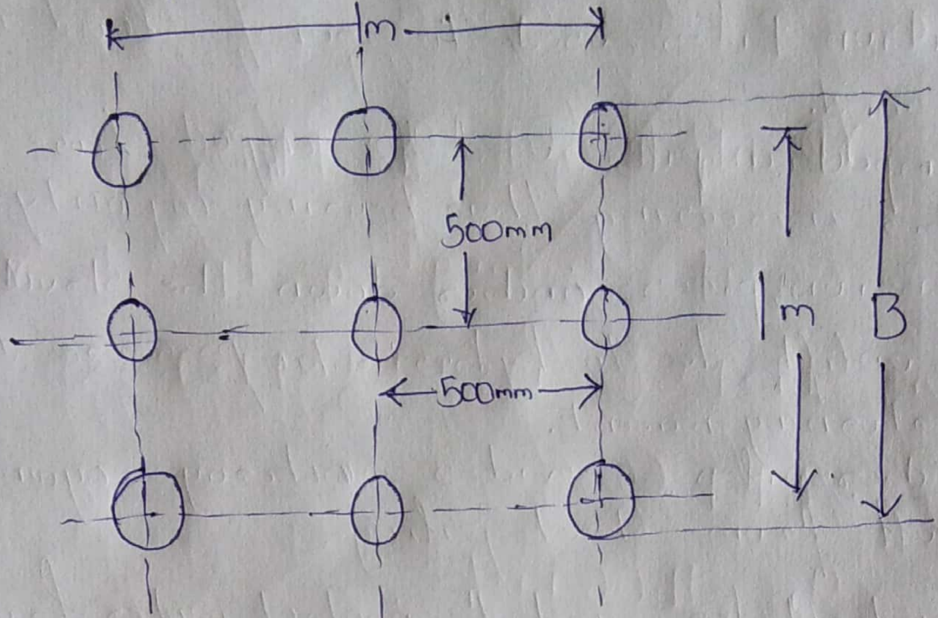
Precast Piles are used for maximum design load of about 80 tonnes.

Cast In-situ Piles are used for maximum design load of 75 tonnes.

Q9b.

Given, diameter = 200mm L = 8m.

$q_u = 100 \, kN/m^2$ $m = 0.9$.



$B = 500 \times 2 + 2 \times 200/2 = 1200 = 1.2m$.

$c = q_u = 100 \, kN/m^2$.

$A_s = (\pi d)L = \pi(0.2) \times 8 = 5.0272 \, m^2$.

a) Piles failing individually.

$Q_u = n(m c A_s)$

$= 9 \times (0.9 \times 100 \times 5.0272)$

$= 4072.03 \, kN/m^2$.

b) Piles failing as group.

$Q_{ug} = c(4BL) = 100(4 \times 1.2 \times 8)$

$\therefore Q_{ug} = 3840 \, kN/m^2$.

Lesser of both values, $Q_u = 3840 \, kN/m^2$.

~~Safe load, Qs = 1/3840~~

Q10. a) PILES in GRANULAR SOIL.

The ultimate load capacity of piles for granular soil is given by

$$Q_u = Q_{up} + Q_{us} = A\left(\frac{1}{2} D \gamma N_\gamma + P_o N_q\right) + \sum_{i=1}^{n} K_i P_{oi} \tan \delta_i A_{si}$$

The first term gives end bearing resistance and second term gives skin friction resistance.

$A_p \rightarrow$ c/s area of pile (m^2)

$D \rightarrow$ Diameter of pile.

$\gamma \rightarrow$ effective unit wt of soil at pile tip

N_γ and $N_q \rightarrow$ Bearing Capacity factors.

P_o = effective overburden pressure at pile tip

K_i = co-efficient of earth pressure

δ = angle of wall friction b/w pile & soil.

A = surface area of pile shaft.

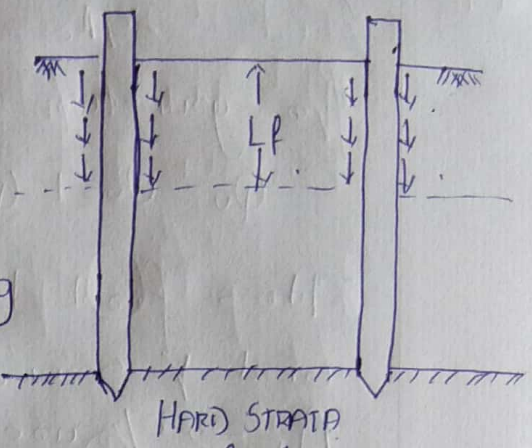
b) SETTLEMENT OF PILE GROUP.

in clay is determined on the assumption that the clay contained between the top of piles & their lower third point is incompressible & that th load is applied to the soil at the lower third point to be uniformly distributed at lower third point & is assumed to spread at an angle of 30° with th vertical.

The soil below lower 3rd point is divided into no. of layers to calculate initial stress (σ_0) at centre of layer & additional stress due to piles ($\Delta\sigma$)

c) NEGATIVE SKIN FRICTION.

It is a downward drag acting on pile due to downward movement of surrounding compressible soil relative to the pile.



This happens when th surrounding compressible soil has been recently filled or formed.

As the soil consolidates, th earth fill moves downwards, developing friction forces on th perimeter of pile which tend to carry th pile farther into the ground.

PILE LOAD TESTS

can be performed either on working pile or on a test pile.

Test load is applied with help of hydraulic jack.

Reaction of the jack is borne by a loading platform

Load is applied in equal increment of about 1/5th of the estimated allowable load.

Settlements are recorded with the help of 3 dial gauges placed over test plate.

Each load increment is kept for a sufficient time till rate of settlement is < 0.02mm per hour.

Test piles are loaded until ultimate load is reached.

Results are plotted in th form of Load-settlement curves.

Ultimate load is obtained from these curves.