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Soil

C_u & C_c : D_{10}, D_{30}, D_{60}

① * For particle size distribution curve D_{10}, D_{30} and D_{60} value is 0.15mm, 0.17mm and 0.27mm, Find uniformity coefficient and co-efficient of gradation.

Soln: Coefficient of Uniformity,

$$\boxed{C_u = \frac{D_{60}}{D_{10}}} = \frac{0.27}{0.15} = 1.8$$

Coefficient of Gradation,

$$\boxed{C_c = \frac{D_{30}^2}{D_{60} \times D_{10}}} = \frac{0.17^2}{0.27 \times 0.15} = 0.71$$

(Ans)

② * DNCC-2016

$D_{10} = 0.0162$ mm, $D_{30} = 0.1018$ mm, $D_{60} = 0.577$,

Find the coefficient of uniformity.

Soln:

$$\boxed{C_u = \frac{D_{60}}{D_{10}}} = \frac{0.577}{0.0162} = 35.62$$

(Ans)

①, ②, ⑥ → এই প্রকার serial

⑥ * PGCB-2019

Grain size distribution of a soil are given below, find the uniformity co-efficient and the co-efficient of curvature and find out if the soil is well graded?

Particle size (mm)	% finer	
0.4	60	$= D_{60}$
0.2	30	$= D_{30}$
0.05	10	$= D_{10}$

Soln: Uniformity co-efficient,

$$\boxed{C_u = \frac{D_{60}}{D_{10}}} = \frac{0.4}{0.05} = 8$$

Coefficient of curvature,

$$\boxed{C_c = \frac{D_{30}^2}{D_{60} \times D_{10}}} = \frac{0.2^2}{0.4 \times 0.05} = \cancel{0.2}\ 2$$

As, $C_u > 6$ and $1 \leq C_c \leq 3$,

So, the soil is well graded (Ans)

Hints: $C_u > 6$ = Well Graded Sand

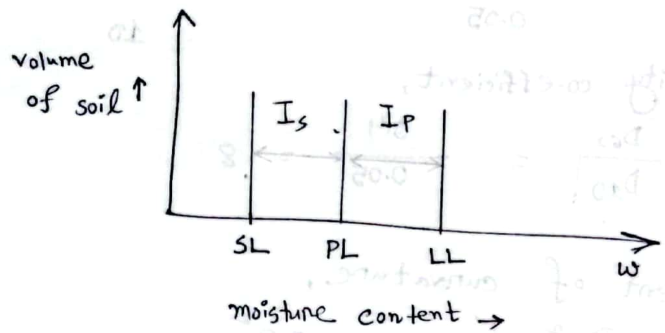
$C_u < 6$ = well Graded Gravel.

Consistency of soil:

Formula

Water Add. করার $\xrightarrow{\text{(swell)}}$ soil $\Longrightarrow$ water বের করার (Shrink)

Atterberg Limit :



Index Properties:

$$LL = PL + I_p$$

$$PL = SL + I_s$$

Clayey soil ⇒ Consistency

Sandy soil ⇒ Relative Density

- Plasticity Index, $I_p = LL - PL$

  Shrinkage Index, $I_s = PL - SL$

- Liquidity Index, $I_L = \dfrac{w - PL}{LL - PL}$

  $$\Rightarrow I_L = \frac{w - PL}{I_p}$$

- Liquid Limit, $LL = w \left(\dfrac{N}{25}\right)^{0.121}$

~~Important Notes:~~

(8) * The values of liquid limit, plastic limit and water contents are ~~20%~~ 50%, 20% and 40%, Determine plasticity index and liquidity Index.

[BUET MSc-2019]

Soln:

$LL = 50\%$

$PL = 20\%$

$\omega = 40\%$

Plasticity Index, $\boxed{I_P = LL - PL}$

$= 50\% - 20\% = 30\%$

Liquidity Index, $\boxed{I_L = \dfrac{\omega - PL}{LL - PL}}$

$= \dfrac{40-20}{50-20} = 0.667$

(Ans)

* 8.2) A soil have $LL = 72$, $PL = 18$. Classify the soil by USCS system.

Plasticity chart A-Line, $I_P = 0.73\,(LL-10)$.

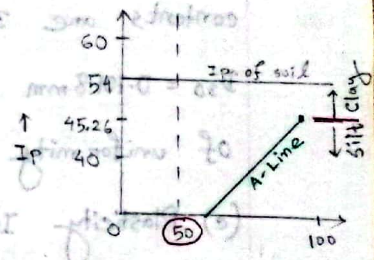
[BADC-2020]

soln:

Plasticity Index, $I_P = LL - PL$

$= 72 - 18$

$= 54\%$.



And, From Chart line,

$I_P = 0.73\,(LL-10)$

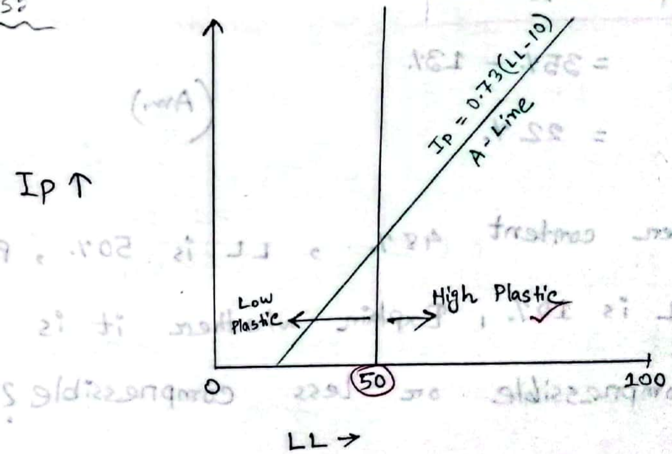
$= 0.73\,(72-10)$

$= 45.26\%$.

The soil is above A-Line and $LL > 50\%$,

So the soil is CH. (High plasticity inorganic clay).

Hints:



(4) * The values of liquid limit, plastic limit and water contents are 35%, 13% and 40%, $D_{10} = 0.0162$ mm, $D_{30} = 0.1018$ mm, $D_{60} = 0.577$. Find (a) The coefficient of uniformity. (b) coefficient of curvature and (c) Plasticity Index. [PGCB-2018]

Solⁿ:

$$\boxed{C_u = \frac{D_{60}}{D_{10}}} = \frac{0.577}{0.0162} = 35.62$$

$$\boxed{C_c = \frac{D_{30}^2}{D_{60} \times D_{10}}} = \frac{(0.1018)^2}{0.577 \times 0.0162} = 1.11$$

$$\boxed{I_p = LL - PL}$$

$= 35\% - 13\%$

$= 22\%$. (Ans)

(6) * Water content 48%, LL is 50%, PL is 30%, SL is 10%, Explain whether it is soft compressible or less compressible?

MES-2015

$\omega = 48$
$LL = 50$
$PL = 30$
$SL = 10$

I_L close to 1 (or 0.9) = Soft compressible clay

I_L close to 0 (or 0.1) = very stiff

Solⁿ: Liquid Index, $\boxed{I_L = \frac{\omega - PL}{LL - PL}}$

$$= \frac{48 - 30}{50 - 30}$$

$= 0.9$

So, the clay is soft compressible. (Ans)

(9) * The natural moiture content is 32%, LL is 60% and PL is 27%. Determine I_p of the soil and comment about the nature of the soil.

Solⁿ: $\boxed{I_p = LL - PL} = 60\% - 27\% = 33\%$.

The nature can be judged by determining I_L.

$$\boxed{I_L = \frac{\omega - PL}{LL - PL}}$$

$$= \frac{32 - 27}{60 - 27} = 0.15$$

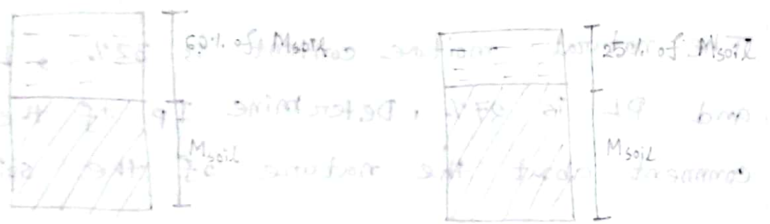
Since the value of ~~soil~~ I_L is close to 0, the nature of soil is very stiff.

(soil এর nature জানতে I_L বের করতে হয়)

GTCL-2018

(8) * Clay sample has atterberg Limits: LL = 60, PL = 40, SL = 25, The sample shrink from 15 cm^3 to 9.57 cm^3, when the moisture content is decreased from LL to SL. What is the dry specific gravity of the clay sample?

Soln.:



At Liquid Limit   At Shrinkage Limit

Now, Difference of Volume = Diffence of water mass

$\Rightarrow$ $15 - 9.57 = 60\% \times M_{soil} - 25\% \times M_{soil}$

$\Rightarrow$ $5.43 \ cm^3 = 0.35 \times M_{soil}$

$\therefore M_{soil} = 15.51 \ g$ 1 cm^3 water = 1 g.

Now, Mass of water at Liquid Limit = 60% × M_{soil}

$= 0.6 \times 15.51$

$= 9.306 \ g$

volume of water at LL = 9.306 cm^3

$\therefore$ Volume of soil at LL = $15 - 9.306 = 5.7 \ cm^3$
$= V_{soil}$

$$\rho = \frac{M}{V} = \frac{M_{soil}}{V_{soil}} = \frac{15.51}{5.7}$$
$$= 2.72$$

$\therefore$ Dry specific gravity, $G_s = \frac{\rho}{\rho_w} = \frac{2.72}{1} = 2.72$

(Ans.)

Hints:

$\rho_w = 1 \ gm/cc$

$\therefore$ 1 cm^3 water = 1 gm water

$$LL = \omega \times \left(\frac{N}{25}\right)^{0.121}$$

* In a Liquid limit test: moisture content = 70% at 10 blows and moisture content = 20% at 100 blows. What is the LL of the soil?

Soln:

$$LL_1 = \omega_1 \times \left(\frac{N_1}{25}\right)^{0.121}$$

$$= 70 \times \left(\frac{10}{25}\right)^{0.121}$$

$$= 62.7\%$$

$$LL_2 = \omega_2 \times \left(\frac{N_2}{25}\right)^{0.121}$$

$$= 20 \times \left(\frac{100}{25}\right)^{0.121}$$

$$= 23.7\%$$

$\therefore$ LL of soil $= LL_1 - LL_2$

$= 62.7\% - 23.7\%$

$= 39\%$ (Ans.)

q_u & c_u ; $\tau = c + \sigma \tan\phi$:

50 *** The unconfined compressive strength is 120 KN/m². Find undrained shear strength.
[WASA-2017, EGCB-2020, BCMCL-2020, APSCL-2020]

Soln: Unconfined compressive strength, $q_u = 120$ KN/m²

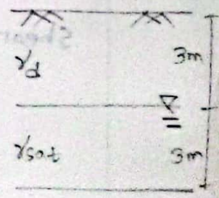
Undrained shear strength, $\boxed{C_u = \frac{q_u}{2}}$

$$= \frac{120}{2}$$

$= 60$ KN/m² (Ans)

* A 6m sand layer having properties, $\gamma_{sat} = 20$ KN/m³, $\gamma_d = 15$ KN/m³. Water table is 3m below the ground level. If cohesion and angle of internal friction is 52 KPa and 36°, determine the shear strength of the sand.

BR Powergen -2019



Soln: Normal stress, $\boxed{\sigma = \gamma_d \times h_1 + (\gamma_{sat} - \gamma_w) h_2}$

$\sigma = 15 \times 3 + (20 - 9.81) \times 3$

$= 75.57$ KN/m²

Shear strength,

$\boxed{\tau = c + \sigma \tan\phi}$

$= 52 + 75.57 \times \tan 36°$

$= 106.9$ KN/m² (Ans.)

$C = 52$ KPa $= 52$ KN/m²

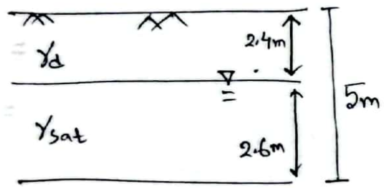
$\phi = 36°$

$\boxed{\gamma' = \gamma_{sat} - \gamma_w}$

37 * BPDB-2018

A sand layer having properties $\gamma_d = 16\ KN/m^3$, $\gamma_{sat} = 18\ KN/m^3$, $G_s = 2.6$, $\varphi = 36°$. Water table is 2.4 m below the ground level. Determine shear strength at a depth of 5m from its base.

Soln:



$\gamma' = \gamma_{sat} - \gamma_w$

Here, $C = 0\ KN/m^2$ = Not given

Normal stress, $\sigma = h_1 \times \gamma_d + h_2 \times \gamma'$

$$\boxed{\sigma = \gamma_d \times h_1 + (\gamma_{sat} - \gamma_w) h_2}$$

$= 2.4 \times 16 + 2.6 \times (18 - 9.81)$

$= 59.69\ KN/m^2$

Shear strength, $\boxed{\tau = C + \sigma \tan\varphi}$

$= 0 + 59.69 \times \tan 36°$

$= 43.37\ KN/m^2$ (Ans.)

38 * From a direct shear test, the value of normal stress of two sample is found 100 & 200 Kip/ft². The value of shear stress of Two sample is 80 & 120 Kip/ft² respectively. What is the value of c & φ value? [Combined Bank-2020]

Soln: Normal stress, $\sigma_1 = 100$ Kip/ft²

$\sigma_2 = 200$ Kip/ft²

Shear stress, $\tau_1 = 80$ Kip/ft²

$\tau_2 = 120$ Kip/ft²

Now, $\boxed{\tau_1 = C + \sigma_1 \tan\varphi}$

$\Rightarrow 80 = C + 100 \tan\varphi$ ——— (i)

$\boxed{\tau_2 = C + \sigma_2 \tan\varphi}$

$\Rightarrow 120 = C + 200 \tan\varphi$ ——— (ii)

solveing (i) & (ii), $C = 40$ Kip/ft²

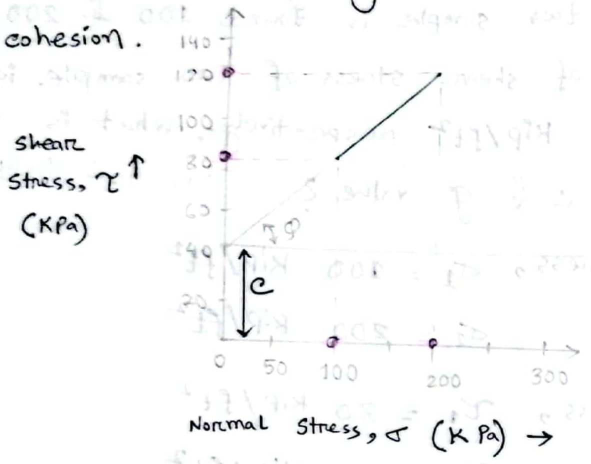
Calculator

$\tan\varphi = \frac{2}{5}$

$\therefore \varphi = 21.80°$ (Ans.)

২৭ * Find the internal angle of friction and cohesion.

GTCL-2018



Soln:

$\tan\phi = \frac{\text{লম্ব}}{\text{ভূমি}} = \frac{120-80}{200-100} = 0.4$

$\therefore \phi = \tan^{-1}(0.4) = 21.80°$

Now, $\boxed{\tau_1 = c + \sigma_1 \tan\phi}$

$\Rightarrow 80 = c + 100 \times \tan(21.80°)$

$\therefore c = 40$ KPa (Ans)

২৮ **** A sample of dry sand was tested in direct shear apparatus under a normal load of 36 kg. The sample failed under a shearing load of 58 lb. The sample size was 2" x 2". What is the angle of internal friction?

GTCL-16, SGCL-17, BWDB-18, NHA-20

Dry Sand, $c = 0$

$\because$ Cohesionless.

Soln.

Normal load = 36 kg

$= 36 \times 2.204$ lb

$\therefore$ $\boxed{\text{Normal stress, } \sigma = \frac{\text{Normal Load}}{\text{Area}}}$

$= \frac{36 \times 2.204}{2 \times 2} = 19.84$ psi

Shear load = 58 lb

$\therefore$ $\boxed{\text{Shear stress, } \tau = \frac{\text{Shear load}}{\text{Area}}}$

$= \frac{58}{2 \times 2} = 14.5$ psi

Now, $\boxed{\tau = c + \sigma \tan\phi}$

$\Rightarrow 14.5 = 0 + 19.84 \times \tan\phi$

$\therefore \phi = 36.16°$ (Ans.)

২৮ * What is shear strength in terms of effective stress on a plane within a saturated soil mass at a point where the total normal stress is 295 KPa and the pore water pressure 120 KPa ? $c' = 12$ KPa and $\varphi' = 30°$,

Soln: Effective stress, $\boxed{\sigma' = \sigma - u}$

= Normal stress − Pore water pressure

$= 295 - 120$

$= 175$ KPa

Shear strength, $\tau = c + \sigma \tan\varphi$

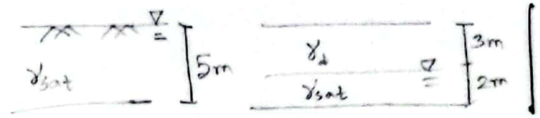
Here, $\boxed{\tau' = c' + \sigma' \tan\varphi'}$ ← Saturated soil

$= 12 + 175 \times \tan 30°$

$\tau' = 113.04$ KPa (Ans.)

***

২৯ * Properties of soil layer are $c = 15\ kN/m^2$, $\varphi = 30°$, $e = 0.6$, $G = 2.7$, Determine the shear strength of the soil along a horizontal plane at a depth of 5m in soil layer,



$\gamma_w = 9.81\ kN/m^3$

~~S = 1 when full saturated~~

if (i) water table is at the ground surface and (ii) water table is at a depth of 3m from the ground surface. [37th BCS]

Soln: Dry Unit wt, $\boxed{\gamma_d = \frac{G_s \gamma_w}{1+e}}$

$= \frac{2.7 \times 9.81}{1 + 0.6} = 16.55\ kN/m^3$

Saturated Unit wt., $\gamma_{sat} = \cancel{\frac{(G_s + Se)\gamma_w}{1+e}}$

$\gamma_{sat} = \frac{(G_s + e)\gamma_w}{1+e}$

$= \frac{(2.7 + \cancel{1} \times 0.6) 9.81}{1 + 0.6} = 20.23\ kN/m^3$

(i) WT at ground surface:

Normal stress, $\boxed{\sigma = h \times \gamma'}$, $= h \times (\gamma_{sat} - \gamma_w)$

$= 5 \times (20.23 - 9.81)$

$= 52.1\ kN/m^2$

$\boxed{\text{Shear stress, } \tau = c + \sigma \tan\varphi}$

$= 15 + 52.1 \times \tan 30° = 45.08\ kN/m^2$

(ii) WT is at Depth of 3m from Ground:

$\boxed{\sigma = h_1 \times \gamma_d + h_2 \times \gamma'}$ $= 3 \times 16.55 + 2 \times (20.23 - 9.81)$

$= 70.49\ kN/m^2$

Shear Strength, $\boxed{\tau = c + \sigma \tan\varphi}$ $= 15 + 70.49 \tan 30°$

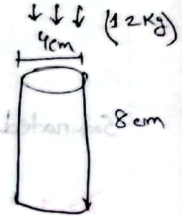
$= 55.69\ kN/m^2$ (Ans.)

২৮ * In an unconfined compression test sample of clay 8 cm long and 4 cm diameter fails under a load 12 Kg at 7% strain (ε). Calculate the un-drained shear strength of clay taking in account that the effect of change in cross-section of sample.

BPDB-2015

Soln:

Strain, $\varepsilon = 7\% = 0.07$



Initial cross section area,

$$\boxed{A_o = \frac{\pi}{4} d^2} = \frac{\pi}{4} \times 4^2 = 12.57 \text{ cm}^2$$

Cross section area after strain,

$$\boxed{A = \frac{A_o}{1-\varepsilon}} = \frac{12.57}{1-0.07} = 13.51 \text{ cm}^2$$

Unconfined compressive strength,

$$\boxed{q_u = \frac{\text{Load}}{\text{Area}}} = \frac{12}{13.51} = 0.88 \text{ Kg/cm}^2$$

Undrained shear strength,

$$\boxed{C_u = \frac{q_u}{2}} = \frac{0.88}{2} = 0.44 \text{ Kg/cm}^2$$

(Ans)

২৮.৩ * A lateral pressure in a tri-axial compression test in a cohesive soil gave the following results: Angle of shearing resistance $\varphi = 17.5$ degree, cohesion, $C = 3$ Kg/cm² and Total axial stress at failure, $\sigma_1 = 18$ Kg/cm². Determine the lateral pressure, $\sigma_3 = ?$

Soln:

$$\boxed{\begin{aligned} \sigma_1 &= \sigma_3 \tan^2\alpha + 2C \tan\alpha \\ \Rightarrow \sigma_1 &= \sigma_3 \tan^2\left(45^\circ + \frac{\varphi}{2}\right) + 2C \tan\left(45^\circ + \frac{\varphi}{2}\right) \end{aligned}}$$

$$\Rightarrow 18 = \sigma_3 \times \tan^2\left(45 + \frac{17.5}{2}\right) + 2 \times 3 \times \tan\left(45 + \frac{17.5}{2}\right)$$

$$\therefore \sigma_3 = 5.278 \text{ Kg/cm}^2$$

$\therefore$ Lateral pressure, $\sigma_3 = 5.278$ Kg/cm²

(Ans)

SPT : Std. Penetration Test :

১৯

**** In SPT test for each 15 cm penetration needs 10, 15 and 20 SPT value. Calculate N value.
[EGCB-2020, BCMCL-2020, APSCL-2020, BGDCL-2021]

Soln: SPT 'N' value = 2nd Penetration + 3rd Penetration

$= 15 + 20$

$= 35$ (Ans.)

২০ * HED-2020

প্রতি ৬ inch পর পর ধারাবাহিক Penetration এর জন্য blow লাগে 4, 6, 8 টি ; তাহলে SPT এর value কত ?

Soln: SPT value $= 6 + 8 = 14$. (Ans)

২১ ** In a SPT test, For 15cm successive 5m penetration, SPT values are 8, 10 and 12 respectively. Calculate Field Penetration Number.

Soln: Field Penetration Number, $N = 10 + 12$

$= 22$ (Ans)

Bearing Capacity of Footing :

= Pressure
= Stress
= load per Area

Concept

① Square footing = Spread Footing :

$$q_u = 1.3\, c\, N_c + q\cdot N_q + 0.4\, \gamma B N_\gamma$$

② Strip footing = Continuous footing
= Wall footing :

$$q_u = c\, N_c + q\, N_q + 0.5\, \gamma B\, N_\gamma$$

③ Mat footing = Raft Foundation :

$$q_u = c\, N_c \left(1 + \frac{0.2\,B}{L}\right)\left(1 + \frac{0.4\,D_f}{B}\right)$$

$$= 5.14\, c \left(1 + \frac{0.2\,B}{L}\right)\left(1 + \frac{0.4\,D_f}{B}\right)$$

Bearing Capacity = Effect of Cohesion + Effect of Surface + Effect of Soil wt. in Shear zone

$$\Rightarrow q_u = c N_c + q N_q + 0.5\, \gamma B N_\gamma$$

(For Strip Footing)

$\gamma_{soil} = 18\ KN/m^3$

Square footing or Spread footing

(22) * DESCO-2015

Using Terzaghi equation, find the bearing capacity of a footing. Necessary data is given. Footing size 2m X 2m and having the depth of foundation is 1m, if take c-φ soil, $c = 18\ KN/m^2$, $\varphi = 35°$, $N_c = 57.7$, $N_q = 14.4$, $N_\gamma = 42.4$.

Soln:

$B \times B = 2m \times 2m$ (Square Footing) $\boxed{q = \gamma D_f} = 18 \times 1 = 18\ KN/m^2$

$D_f = 1m$ $\qquad \gamma_{soil} = 18\ KN/m^3$

For Square footing, Bearing capacity,

$$\boxed{q_u = 1.3\ c\ N_c + q\ N_q + 0.4\ \gamma B\ N_\gamma}$$

$$= 1.3 \times 18 \times 57.7 + 18 \times 14.4 + 0.4 \times 18 \times 2 \times 42.4$$

$$= 2219.94\ KN/m^2 \qquad \text{(Ans.)}$$

(20) * BCPCL-2016

A square footing 2m x 2m rests on a c-φ soil, with its base at 5m below the ground surface. Calculate the allowable bearing capacity using a factor of safety 3. The soil has following parameters $\gamma_{sat} = 20.4\ KN/m^2$, $\varphi = 20°$, $c = 20 KPa$ and the value of $N_c = 14.83$, $N_q = 6.40$, $N_\gamma = 5$.

Soln: $B = 2m$, $D_f = 5m$

$\boxed{q = \gamma D_f} = 20 \times 5 = 100\ KN/m^2$

$[\gamma = 20\ KN/m^3 \approx C]$

Now, Bearing capacity for Square footing,

$$\boxed{q_u = 1.3\ C\ N_c + q\ N_q + 0.4\ \gamma B N_\gamma}$$

$$= 1.3 \times 20 \times 14.83 + 100 \times 6.40 + 0.4 \times 20 \times 2 \times 5$$

$$= 1105.58\ KN/m^2 \qquad \text{(Ans.)}$$

$$q_{allow} = \frac{q_u}{F.S.}$$

$$= \frac{1105.58}{3}$$

$$= 368.53\ KN/m^2$$

BCIC - 2017

(28) * A 4m X 4m square footing has its base at 3m below the ground level. Unit weight of the soil is 18 KN/m³. Find the allowable bearing capacity of the soil if $C = 35$ KPa, $N_c = 9$, $N_q = 2$, $N_\gamma = 1$ and use factor of safety 3.

Soln: Bearing capacity for square footing,

$$\boxed{q_u = 1.3\, c N_c + q N_q + 0.4\, \gamma B N_\gamma}$$

$$= 1.3 \times 35 \times 9 + (3 \times 18) \times 2 + 0.4 \times 18 \times 4 \times 1$$

$$= 546.3 \text{ KN/m}^2$$

$\gamma = 18$ KN/m³

$D_f = 3$m

$\therefore \boxed{q = \gamma D_f}$

$= 18 \times 3$

Allowable bearing capacity,

$$\boxed{q_{allow} = \frac{q_u}{\text{Factor of Safety}}}$$

$$= \frac{546.3}{3}$$

$$= 182.1 \text{ KN/m}^2$$ (Am.)

G_s of soil = 2.65

(26) * A 3m X 3m spread footing with a depth of 1.5m is to be placed on a homogenous clay layer having $C = 30$ KN/m², NMC = 20% and $e = 50\%$, Determine the gross allowable load capacity if factor of safety is 2. [SGFCL - 2017]

Soln: $B = 3$m, $D_f = 1.5$m

NMC = ω = 20% = 0.2

$e = 50\% = 0.5$

Unit wt of soil (γ_{Bulk}), $\boxed{\gamma = \frac{G_s \gamma_w (1+\omega)}{1+e}}$

$$= \frac{2.65 \times 9.81 \times (1 + 0.2)}{1 + 0.5}$$

$$= 20.79 \text{ KN/m}^3$$

For Pure clay soil,

$\phi = 0°$, $N_c = 5.14$, $N_q = 1$, $N_\gamma = 0$

$$\therefore \boxed{q_u = 1.3\, c N_c + q N_q + 0.4\, \gamma B N_\gamma}$$

$$= 1.3 \times 30 \times 5.14 + (20.79 \times 1.5) \times 1 + 0.4 \times 20.79 \times 3 \times 0$$

$$= 365.285 \text{ KN/m}^2$$

$\boxed{q = \gamma \times D_f}$

$= 20.79 \times 1.5$

[P.T.O.]

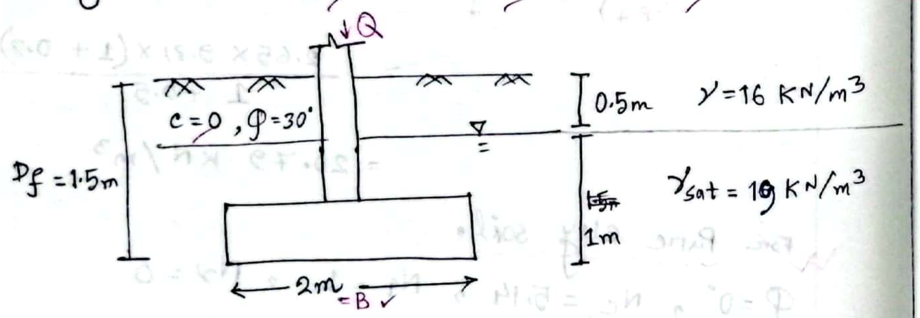
$\therefore$ Gross allowable load capacity,

$$q_a = \frac{q_u}{F.S.} = \frac{365.285}{2} = 182.64\ KN/m^2$$

(Ans)

(26) * 40th BCS

A square footing is shown in figure. Determine the gross allowable load that the footing can carry. Use Terzaghi's bearing capacity equation for general shear failure. Given, factor of safety $=3$, $N_c = 30$, $N_q = 18$, $N_\gamma = 15$.



Soln:

$\boxed{\gamma' = \gamma_{sat} - \gamma_w}$
$= 19 - 9.81$
$= 9.19\ KN/m^3$

$\boxed{q = \gamma h_1 + \gamma' h_2} = 16 \times 0.5 + 9.19 \times 1$
$= 17.19\ KN/m^2$
= Effective surcharge

$B = 2m$, $D_f = 1.5m$ | $\gamma = \gamma'$

$c = 0$, $\phi = 30°$

Ultimate bearing capacity,

$$\boxed{q_u = 1.3\ C\ N_c + q\ N_q + 0.4\ \gamma' B\ N_\gamma}$$

$= 1.3 \times 0 \times 30 + 17.19 \times 18 + 0.4 \times 9.19 \times 2 \times 15$

$= 419.7\ KN/m^2$

Allowable bearing capacity,

$$\boxed{q_a = \frac{q_u}{F.S.}} = \frac{419.7}{3} = 139.9\ KN/m^2$$

$\therefore$ Allowable Load, $\boxed{Q_a = q_a \times (B \times B)}$
$= 139.9 \times (2 \times 2)$
$= 559.6\ KN$

(Ans)

$q = \frac{Q}{A}$

$\boxed{Q = q \times A}$

Hints:

Load = Stress × Area
= Bearing Capacity × Footing Base Area.

Strip footing or, Continuous footing or, Wall footing:

(29) * Determine the Ultimate bearing capacity of a strip footing of 1m is laid at a depth 0.5m, Water table is at 8m below the ground level. Given, $c = 30\ kN/m^2$, $\gamma = 16\ kN/m^3$, $N_c = 17$, $N_q = 12$, $N_\gamma = 5$, [PGCB-2019]

Soln: Ultimate bearing capacity of Strip footing,

$$\boxed{q_u = cN_c + qN_q + 0.5\,\gamma B N_\gamma}$$

$$= 30\times17 + (16\times0.5)\times12 + 0.5\times16\times1\times5$$

$$= 646\ kN/m^2.$$

(Ans)

$\boxed{q = \gamma D_f}$

$= 16\times0.5$

$B = 1m$

(28) * Determine the ultimate bearing capacity of a strip footing 1.2m wide and having the depth of foundation is 1.5m. Take for C-soil, $c = 30\ kN/m^2$, $\gamma = 20\ kN/m^3$, $\phi = 0°$, $N_c = 5.14$, $N_q = 1$, $N_\gamma = 2.4$, [DESCO-2015]

Soln: $B = 1.2\ m$

$D_f = 1.5m$

$\boxed{q = \gamma D_f} = 20\times1.5 = 30\ kN/m^2$

For Strip footing,

$$\boxed{q_u = cN_c + qN_q + 0.5\,\gamma B N_\gamma}$$

$$= 30\times5.14 + 30\times1 + \cancel{0.5\times20\times1.2\times2.4}\ 0$$

$$= 184.2\ kN/m^2$$

(Ans)

For c- soil & $\phi = 0$;

3rd Part = 0

$\therefore 0.5\gamma B \cancel{N_\gamma}^{0} = 0$

$N_\gamma = (N_q - 1)\times\tan(1.4\phi)$

২৭

** Determine the Ultimate bearing capacity of a continuous footing having 1.2m width and the depth of foundation is 0.9m, Take for c-soil, $c = 20\ kN/m^2$, $\gamma = 17.2\ kN/m^3$, $N_c = 17.69$, $N_q = 7.44$, $N_\gamma = 3.64$,

[APSCL-2020, BCMCL-2020]

Soln:

$B = 1.2\ m$

$D_f = 0.9\ m$

$\boxed{q = \gamma D_f} = 17.2 \times 0.9 = 15.48\ kN/m^2$

For strip footing,

$\boxed{q_u = c N_c + q N_q + 0.5 \gamma B N_\gamma}$

$= 20 \times 17.69 + 15.48 \times 7.44 + 0.5 \times 17.2 \times 1.2 \times 3.64$

$= 506.54\ kN/m^2$ (Ans.)

২৭.১

$\tan 20 = 0.364$

$\therefore \cot 20 = \frac{1}{\tan 20} = 2.747$

* [EGCB-2020] Determine the Ultimate bearing capacity of the continuous footing 1.2 m wide and having the depth of footing is 0.8 m, Unit weight of soil is $\gamma = 17.79\ kN/m^3$, Cohesion $C = 9.6\ kN/m^2$, $\varphi = 20°$, Ground water table is far more than footing.

Soln:

$\boxed{N_q = e^{\pi \tan\varphi} \tan^2\left(45 + \frac{\varphi}{2}\right)}$

$= e^{\pi \tan 20} \tan^2\left(45 + \frac{20}{2}\right) = 6.4$

$\boxed{N_c = (N_q - 1) \cot\varphi}$

$= (6.4 - 1) \times \cot 20 = 14.84$

$\boxed{N_\gamma = (N_q - 1) \tan(1.4\varphi)}$

$= (6.4 - 1) \times \tan(1.4 \times 20) = 2.87$

For Continuous footing,

$B = 1.2m$

$D_f = 0.8m$

$q = \gamma D_f$

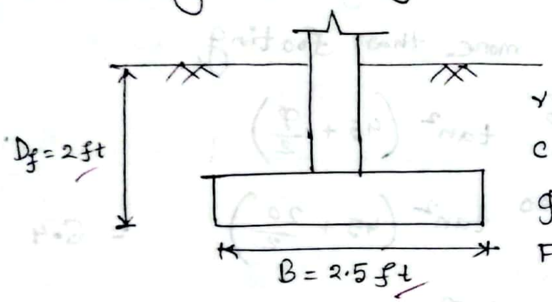
$= 17.79 \times 0.8$

$q_u = c N_c + q N_q + 0.5 \gamma B N_\gamma$

$= 9.6 \times 14.84 + (17.79 \times 0.8) \times 6.4 + 0.5 \times 17.79 \times 1.2 \times 2.87$

$= 264.07\ kN/m^2$ (Ans.)

(৬) * A continuous footing is shown in the fig below,
33th BCS Using Terzaghi's bearing capacity factor, determine the gross allowable $\boxed{\text{load per unit area}}$ (q_{all}) that the footing can carry.



$\gamma = 115\ lb/ft^3$
$c = 400\ lb/ft^2$
$\phi = 25°$
$FOS = 4$

Given, $\phi = 25°$, $N_c = 25.13$, $N_q = 12.72$, $N_\gamma = 8.34$,

Soln: $\boxed{q = \gamma D_f} = 115 \times 2 = 230\ lb/ft^2$

For Continous footing,

$$\boxed{q_u = c N_c + q N_q + 0.5 \gamma B N_\gamma}$$

$= 400 \times 25.13 + 230 \times 12.72 + 0.5 \times 115 \times 2.5 \times 8.34$

$= 14176.45\ lb/ft^2$

Gross allowable load per unit area,

$q_a = \boxed{q_{all} = \frac{q_u}{FOS}} = \frac{14176.45}{4} = 3544.11\ lb/ft^2$ (Ans)

stress = capacity

(৭) * A strip footing of 1m, $q_u = 50$ KPa,
Wasa - 2017
$N_c = 9$, $\gamma = 18\ KN/m^2$, $N_q = 2$, $N_\gamma = 1$.
Calculate the Ultimate Bearing capacity.

Soln: [এখানে, q_u থেকে কেবল C_u বা c হিসাবে করতে হবে। q_u হিসেবে যা Given সেটা আলাদা আর Bearing capacity, q_u আলাদা বিষয়।]

$\boxed{c = C_u = \frac{q_u}{2}} = \frac{50}{2} = 25$ KPa

$\boxed{q = \gamma D_f} = 18 \times 0.5 = 9\ KN/m^2$

এখানে, $D_f = 0.5$ m
D_f দেওয়া না থাকলে $\boxed{D_f = \frac{B}{2}}$ ধরিতে হবে।

For Strip footing,

$$\boxed{q_u = c N_c + q N_q + 0.5 \gamma B N_\gamma}$$

$= 25 \times 9 + 9 \times 2 + 0.5 \times 18 \times 1 \times 1$

$= 252\ KN/m^2$ (Ans)

02.01

TGTDCL-2018

* A strip footing carrying a load of 340 KN/m which is located at EGL. Water table is located at EGL. $\gamma_{sat} = 21\ KN/m^3$, Width of footing = 2m and depth of water = 1m, FS = 3, Ultimate pressure is 530 KN/m^2. Use $q_n = q_u - \gamma D_f$. Prove that the size of footing is safe.

Soln:

$\gamma' = \gamma_{sat} - \gamma_w = 21 - 9.81 = 11.19\ KN/m^3$

$D_f = 1\,m$, $B = 2m$, $q_u = 530\ KN/m^2$

Net Ultimate Bearing capacity,

$q_n = q_u - \gamma D_f$

$q_n = q_u - \gamma' D_f$ ~~= 530 × 1~~ $= 530 - (11.19 \times 1)$

$= 518.81\ KN/m^2$

Allowable, $q_a = \frac{q_n}{FOS} = \frac{518.81}{3} = 172.93\ KN/m^2$

Applied pressure, $q_{ap} = \frac{340}{2} = \frac{\text{Carrying Load}}{B}$

$= 170\ KN/m^2$

Here, $q_a > q_{ap}$; Hence the footing size is safe.

[Proved]

Concept:

$q_a = q_{allow}$ = Allowable bearing capacity

$q_{ap} = q_{apply}$ = Applied pressure

$q_n = q_{net}$ = Net Ultimate bearing capacity

$q_u = q_{ultimate}$ = Ultimate bearing capacity.

$q_{allow} > q_{apply}$ is OK.

$q_{allow} = q_a = \frac{q_n}{F.S.}$

$q_{apply} = q_{ap} = \frac{\text{Carrying Load}}{\text{Width, } B}$

$C = C_u$

Mat footing or, Raft Foundation

(67)* Determine the net ultimate bearing capacity of a mat foundation measuring 20m × 8m on a saturated clay with $C_u = 85$ KN/m², $\phi = 0$ and $D_f = 1.5$ m.

$20m \times 8m = L \times B$

Soln: $$\boxed{q_{net(u)} = 5.14 \times C\left(1 + \frac{0.2B}{L}\right)\left(1 + \frac{0.4D_f}{B}\right)}$$

$$= 5.14 \times 85\left(1 + \frac{0.2 \times 8}{20}\right)\left(1 + \frac{0.4 \times 1.5}{8}\right)$$

$$= 507.24 \text{ KN/m}^2$$ (Ans.)

(69)* If a mat foundation 10m × 10m and depth of foundation 1.5m. Undrained cohesion 75 KPa. FOS 2.5, Bearing capacity factor 5.14, unit weight of soil, $\gamma = 18$ KN/m³. What is the net bearing capacity?

[LGD - 2018]

Soln: $L \times B = 10m \times 10m$

$D_f = 1.5$ m, $N_c = 5.14$

Undrained Cohesion, $C_u = 75$ KPa

For Mat Foundation,

$$\boxed{q_{net(u)} = C_u \cancel{N_c}^{5.14}\left(1 + \frac{0.2B}{L}\right)\left(1 + \frac{0.4D_f}{B}\right)}$$

$$= 75 \times 5.14\left(1 + \frac{0.2 \times 10}{10}\right)\left(1 + \frac{0.4 \times 1.5}{10}\right)$$

$$= 490.356 \text{ KN/m}^2$$ (Ans.)

(68)* BUET MSc - 2017

For a fully compensated mat foundation, find the depth of foundation. Given, Area = 20 m × 30 m. Unit wt of soil, $\gamma = 20$ KN/m³, Q = Load = 6000 KN.

Soln: For a fully compensated mat foundation,

$$\boxed{D_f = \frac{Q}{A\gamma}}$$

$$= \frac{6000}{(20 \times 30) \times 20} \qquad \frac{KN}{m^2 \times KN/m^3}$$

$$= 0.5 \text{ m}$$ (Ans.)

(02) **** BIFPCL-15, BCIC-16, MPL-17, JOCL-18

Find the allowable bearing capacity of a raft foundation of 10m X 10m and depth of foundation is 5m below the ground level. Undrained cohesion of soil is 40 KN/m² and bearing capacity factor Nc is 5.14, consider factor of safety 2.

Soln:

$L \times B = 10\,m \times 10\,m$, $FS = 2$

$D_f = 5\,m$, $N_c = 5.14$

Undrained cohesion of soil, $C_u = 40\ KN/m^2$

For raft foundation,

$$\boxed{q_{net(u)} = C_u N_c \left(1 + \frac{0.2B}{L}\right)\left(1 + \frac{0.4 D_f}{B}\right)}$$

$$= 40 \times 5.14 \left(1 + \frac{0.2 \times 10}{10}\right)\left(1 + \frac{0.4 \times 5}{10}\right)$$

$$= 294.83\ KN/m^2$$

$$\boxed{q_{allow} = \frac{q_{net(u)}}{F.S.}} = \frac{294.83}{2} = 147.41\ KN/m^2$$

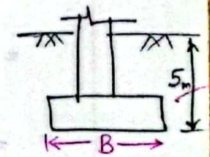
(Ans)

$C = C_u = C'$

Design Type Math

(04) *

A square footing is carrying a gross mass of 30000 Kg. Using a factor of safety is 3. Determine the size of footing. $\phi = 30°$, $N_c = 30.14$, $N_q = 18.40$, $N_\gamma = 15.67$, $C' = 0$, $\gamma = 18.15\ KN/m^3$



Soln:

$\boxed{q = \gamma D_f} = 18.15 \times 5 = 90.75\ KN/m^2$

For Square footing,

$$\boxed{q_u = 1.3\,C N_c + q\,N_q + 0.4\,\gamma B\,N_\gamma}$$

$$= 1.3 \times 0 \times 30.14 + 90.75 \times 18.40 + 0.4 \times 18.15 \times B \times 15.67$$

$q_u = 1669.8 + 113.76 \times B$ ——— (i)

$Q = 30000$ kg
$= 30000 \times 9.81$ N
$= \frac{30000 \times 9.81}{1000}$ KN
$= 294.3$ KN

Again,

$$\boxed{q_a = \frac{Q}{B \times B}}$$

$$\Rightarrow \boxed{\frac{q_u}{F.S.} = \frac{Q}{B \times B}}$$

$\Rightarrow q_u = \frac{294.3 \times 3}{B \times B}$ ——— (ii)

(i) & (ii) $\Rightarrow$ $\frac{294.3 \times 3}{B \times B} = 1669.8 + 113.76 \times B$

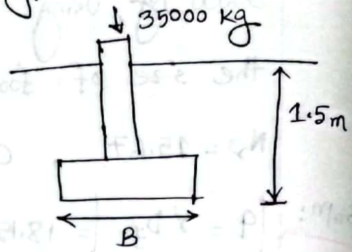
$\therefore B = 0.71\ m$

Ans: $\boxed{B \times B = 0.71\,m \times 0.71\,m}$

06.21

BWDB-2019

* A square footing carry a gross mass of 35000 kg column load. If the factor of safety is 3, Determine the width of footing.



Soln: Column load,

$Q = 35000$ kg

$= \frac{35000 \times 9.81}{1000}$ KN

$= 343.35$ KN

$\gamma = 18$ KN/m^3

$c = 5$ KPa

$\phi = 30^\circ$

$q = \gamma D_f = 18 \times 1.5 = 27$ KN/m^2

Now,

$N_q = e^{\pi \tan\phi} \tan^2\left(45 + \frac{\phi}{2}\right)$

$= e^{\pi \tan 30} \times \tan^2\left(45 + \frac{30}{2}\right) = 18.40$

$N_c = (N_q - 1) \cot\phi = 30.14$

$N_\gamma = (N_q - 1) \tan(1.4\phi) = 15.66$

$q_u = 1.3\, c N_c + q N_q + 0.4 \gamma B N_\gamma$

$= 1.3 \times 5 \times 30.14 + 27 \times 18.40 + 0.4 \times 18 \times B \times 15.66$

$\Rightarrow q_u = 692.71 + 112.75 \times B$ ——— (i)

Again, $q_a = \frac{Q}{B \times B}$

$\Rightarrow \frac{q_u}{F.S.} = \frac{Q}{B \times B}$

$\Rightarrow q_u = \frac{343.35 \times 3}{B \times B}$ ——— (ii)

(i) & (ii) $\Rightarrow$

$\frac{343.35 \times 3}{B \times B} = 692.71 + 112.75\, B$

$\Rightarrow B = 1.12$ m (Am.)

$\therefore$ Footing size $= B \times B = 1.12\text{m} \times 1.12\text{m}$

Pile ; Friction Pile and Group Pile :

(69) *** PGCL-14, WRGCL-14, MES-15.

Calculate the ultimate capacity of 24" diameter pile with an embedment length of 30' is saturated clay. Given the unconfined strength of clay and adhesion factor are 25 Psi and 0.8 (α_2) respectively.

Soln: Pile Dia, $D = 24''$, $N_c = 9$ মুখস্ত

Pile length, $L = 30' = 30 \times 12'' = 360''$

Unconfined strength of clay, $q_u = 25$ psi

$\therefore \boxed{C_u = \frac{q_u}{2}} = \frac{25}{2} = 12.5$ psi

Adhesion capacity, $\alpha_2 = 0.8$

Now, Ultimate pile capacity, Q_u = Skin friction, Q_{SF} + End Bearing, Q_{EB}

$$\Rightarrow Q_u = \alpha_2 C_u A_{(surface)} + C_u N_c A_{(Bottom)}$$

$$\boxed{Q_u = \alpha_2 C_u (\pi D L) + C_u N_c \left(\frac{\pi}{4} D^2\right)}$$

$$= 0.8 \times 12.5 \times (3.1416 \times 24 \times 360) + 12.5 \times 9 \times \left(\frac{\pi}{4} \times 24^2\right)$$

$$= 322328 \text{ lb}$$

$$= 322.33 \text{ Kip} \quad \text{(Ans.)}$$

\# Hints: Dia given, so circular pile.

Driven Pile : $N_c = 5.14$

Cast-in-situ : $N_c = 9$

(70) *** DPDC-14, BWDB-16, PGCL-17, MPA-19

Calculate the ultimate load bearing capacity of a 25 ft long and 24" diameter pile which is embedded in clayey soil. Co-efficient of adhesion = 0.5, unconfined compression strength = 2000 psf.

Soln: Ultimate load bearing capacity of pile, Q_u = ?

$L = 25'$ ~~$= 25 \times 12'' = 300''$~~ , $N_c = 9$

$D = 24'' = 2'$, Coefficient of Adhesion, $\alpha_2 = 0.5$,

Unconfined comp. strength, $q_u = 2000$ psf

$\therefore \boxed{C_u = \frac{q_u}{2}} = \frac{2000}{2} = 1000$ psf

Now, $Q_u = Q_{SF} + Q_{EB}$

$$\boxed{Q_u = \alpha_2 C_u (\pi D L) + C_u N_c \left(\frac{\pi}{4} D^2\right)}$$

$$\cancel{= 0.5 \times 1000 \times (\pi \times 24 \times 300) + 1000 \times 9 \times \left(\frac{\pi}{4} \times 24^2\right)}$$

$$= 0.5 \times 1000 \times (\pi \times 2 \times 25) + 1000 \times 9 \left(\frac{\pi}{4} \times 2^2\right)$$

$$= 106814.4 \text{ lb}$$

$$= 106.81 \text{ Kip} \quad \text{(Ans.)}$$

\# **** Concept: Pile ⇒

$C_u \rightarrow$ psi	;	D & $L \rightarrow$ inch
$C_u \rightarrow$ psf	;	D & $L \rightarrow$ ft
$C_u \rightarrow$ KN/m²	;	D & $L \rightarrow$ m,

(৭৯) * BPDB-2015

Concrete pile of 24″ diameter embedded in clay, unconfined compression strength of soil is 4 Ksf and embed length of pile 30 ft. Calculate ultimate load carrying capacity of pile if adhesive friction between clay and pile is 0.45, unit wt of clay 100 lb/ft³ and water table exists at ground.

No use

Solⁿ: Dia, $D = 24'' = 2'$, $N_c = 9$

$q_u = 4$ Ksf $\therefore \boxed{C_u = \frac{q_u}{2}} = 2$ ksf

Length, $L = 30'$, $\gamma_{clay} = 100$ lb/ft³

Adhesive friction betⁿ clay & pile, $\alpha_2 = 0.45$

$$Q_u = Q_{SF} + Q_{EB}$$

$$\boxed{Q_u = \alpha_2 C_u (\pi D L) + C_u N_c \left(\frac{\pi}{4} D^2\right)}$$

$$= 0.45 \times 2 \times (\pi \times 2 \times 30) + 2 \times 9 \times \left(\frac{\pi}{4} \times 2^2\right)$$

$$= 226.195 \text{ Kip}$$

(Ans.)

Hints: যেহেতু $C_u \rightarrow$ Ksf, তাই $Q_u \rightarrow$ Kip হবে, যদি $C_u \rightarrow$ Psf, তখন $Q_u \rightarrow$ lb হবে।

$\alpha = \alpha_2$

(80) * NHA-2020

A nine pile group consisting of 600 mm diameter concrete pile was cast in situ in a soil whose unconfined compressive strength is 80 KN/m². Each pile is 15 m long. Using a reduction factor $\alpha = 0.5$, and factor of safety is 3, Calculate allowable skin friction of single pile.

Solⁿ: Dia, $D = 600$ mm $= 0.6$ m

$q_u = 80$ KN/m² ; $\boxed{C_u = \frac{q_u}{2}} = 40$ KN/m²

$L = 15$ m , FOS $= 3$

Reduction factor, $\alpha = 0.5 = \alpha_2$

Now, Skin friction of a single pile,

$$\boxed{Q_{SF} = \alpha_2 C_u (\pi D L)}$$

$$= 0.5 \times 40 \times (\pi \times 0.6 \times 15)$$

$$= 565.49 \text{ KN}$$

$$\therefore \boxed{Q_{SF\,(Allow)} = \frac{Q_{SF}}{\text{Factor of safety}}}$$

$$= \frac{565.49}{3} = 188.49 \text{ KN}$$

(Ans.)

[PGCB-2015, DNCC-2016, GTCL-2016, SGCL-2017, ERL-2017, BWDB-2018, BIWTA-2019]

(81) *** ** *

A nine pile group consisting of 18" diameter concrete pile was cast in situ in a clayey soil whose unconfined compressive strength is 1000 lb/ft^2. Each pile is 60 ft long and the pile spacing is 2.5 times the pile diameter. Using an adhesion factor $\alpha = 0.5$ and factor of safety is 3, Calculate allowable skin friction of single pile.

No wise

Soln.: Dia, $D = 18'' = 1.5'$

Cast in situ, $N_c = 9$, $FoS = 3$

$q_u = 1000 \ lb/ft^2$ $\therefore \boxed{C_u = \frac{q_u}{2}} = 500$ psf

Length, $L = 60$ ft, $\alpha = 0.5 = \alpha_2$

pile spacing, $S = 2.5 D$

Skin friction for single pile,

$$\boxed{\begin{aligned} Q_{SF} &= \alpha_2 \, C_u \, A_{(surface)} \\ &= \alpha_2 \, C_u \, (\pi D L) \end{aligned}}$$

$= 0.5 \times 500 \times (\pi \times 1.5 \times 60)$

$= 70686$ lb

$= 70.686$ Kip

Allowable skin friction,

$$\boxed{Q_{SF(Allow)} = \frac{Q_{SF}}{\text{Factor of Safety}}}$$

$= \frac{70.686}{3}$

$= 23.56$ Kip (Am.)

(82) *

Determine the capacity of the Driven pile into clay, the embedded length of pile is 30' and unconfined comp. strength is 25 Psi. Adhesion capacity is 0.8, Diameter of pile is 24",

Soln.: $q_u = 25$ psi, $\boxed{C_u = \frac{q_u}{2}} = 12.5$ Psi

$\boxed{\text{For Driven pile, } N_c = 5.14.}$

$L = 30' = 30 \times 12'' = 360''$; $D = 24''$

Now, $Q_u = Q_{SF} + Q_{EB}$

$$\boxed{Q_u = \alpha_2 \, C_u \, (\pi D L) + C_u N_c \left(\frac{\pi}{4} D^2\right)}$$

$= 0.8 \times 12.5 \times (\pi \times 24 \times 360) + 12.5 \times 5.14 \times \left(\frac{\pi}{4} \times 24^2\right)$

$= 300500$ lb

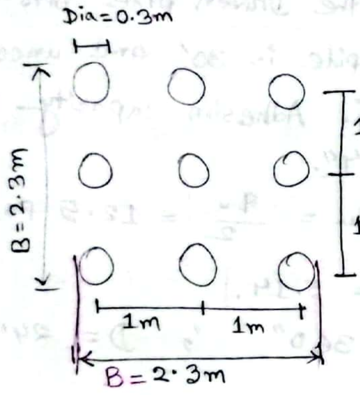
$= 300.5$ Kip (Am.)

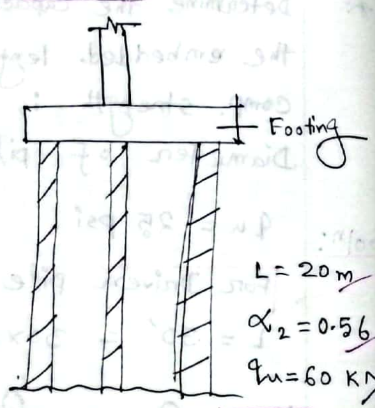
(8)

** 27th BCS

Group Pile

A pile group consists of a 9 friction pile in cohesive soil (clay) as shown in figure. The dia of each pile is 0.3m and centre to centre distance of two piles is 1m. Compute the Ultimate design capacity of the "Group of Pile"?





$L = 20m$

$\alpha_2 = 0.56$

$q_u = 60\ KN/m^2$

$\boxed{C_u = \frac{q_u}{2}} = 30\ KN/m^2$

Soln: (i) Individual Action:

(i) $\boxed{Q_u = N \times [\alpha_2 C_u (\pi D L) + C_u N_c (\frac{\pi}{4} D^2)]}$

Skin Friction, $Q_{SF} = \alpha_2 C_u A_{surf}$

$= \alpha_2 C_u (\pi D L)$

$= 0.56 \times 30 \times (\pi \times 0.3 \times 20)$

$= 316.67$ KN

End Bearing, $Q_{EB} = C_u N_c A_{(Top\ circle)}$

$N_c = 9$

$= C_u N_c (\frac{\pi}{4} D^2)$

$= 30 \times 9 \times (\frac{\pi}{4} \times 0.3^2)$

$= 19.1$ KN

$\therefore$ Total Pile capacity, $Q_u = n \times (Q_{SF} + Q_{EB})$

$= 9 \times (316.67 + 19.1)$

$= 3021.93$ KN

(ii) Group Action:

$Q_u = Q_{SF} + Q_{EB}$

(ii) $\Rightarrow \boxed{Q_u = \alpha_2 C_u (4BL) + C_u N_c (B \times B)}$

$= 1 \times 30 \times (4 \times 2.3 \times 20) + 30 \times 9 \times (2.3 \times 2.3)$

$= 6948.3$ KN

Let, $\alpha_2 = 1$ (Group Act.)

FOS = 3 for pile.

$\therefore Q_u = 3021.93$ KN [(i) ও (ii) এর মধ্যে minimum নিবে]

$\therefore \boxed{Q_{allow} = \frac{Q_u}{\text{Factor of Safety}}} = \frac{3021.93}{3} = 1007.31$ KN (Ans)

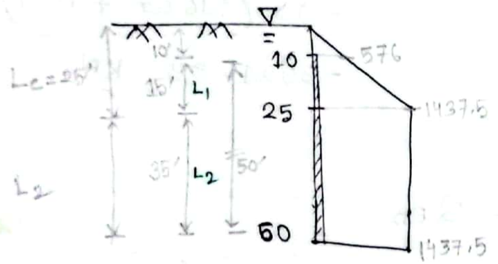
Hints: এখানে individual & group Action হতে উত্তর চাইলে যেটা Ans হবে, তখন minimum টা নিতে হবে না,

RCC Pile

8.0.8 * BWDB-2014

Determine the skin friction capacity of a cast-in-situ bored RCC pile of diameter 20″ and length 50′ in homogeneous sand layer. The top of pile is at 10 ft below the ground surface. Unit weight at saturated condition 120 pcf and angle of internal friction 30°, GWT is at the ground surface.

Soln:



Dia, D = 20″ = 1.67′

Length, L = 50′

γ_{sat} = 120 pcf

φ = 30°

Now, $K_o = 1 - \sin\varphi = 1 - \sin 30° = 0.5$ (At Rest)

$\tan\delta = \tan(0.75\varphi) = \tan(0.75 \times 30°) = 0.414$

Critical depth, $L_c = 15D = 15 \times 1.67 = 25'$

Stress at 10′ depth from surface, $\sigma_1 = \gamma' h_1 = (120 - 62.4) \times 10$
$= 576$ psf

stress at 25′ depth from surface, $\sigma_2 = \gamma' h_2 = (120 - 62.4) \times 25$
$= 1437.5$ psf

$\sigma_1' = \frac{\sigma_1 + \sigma_2}{2} = \frac{576 + 1437.5}{2} = 1006.75$ (Trapezoidal zone)

$\sigma_2' = \sigma_2 = 1437.5$

Skin friction capacity of RCC pile,

$Q_{SF} = Q_{SF(1)} + Q_{SF(2)}$

$$\boxed{Q_{SF} = (\pi D L_1) K_o \sigma_1' \tan\delta + (\pi D L_2) K_o \sigma_2' \tan\delta}$$

$= \pi D K_o \tan\delta (\sigma_1' L_1 + \sigma_2' L_2)$

$= \pi \times 1.67 \times 0.5 \times 0.414 \times (\cancel{576 \times} 1006.75 \times 15 + 1437.5 \times 35)$

$= 71040.62$ lb

~~= 70.94 kip~~

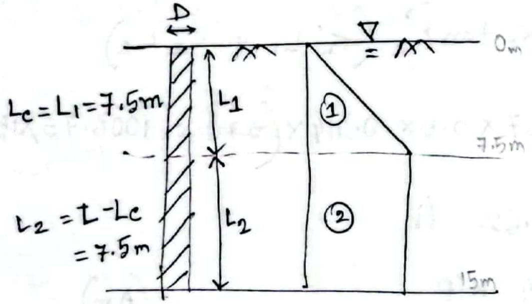
$= 71.040$ kip (Ans)

Pull out capacity of RCC pile

80.2 *

Estimate the pull out capacity of a Cast-in-situ bored concrete pile of dia 500mm and length 15m. Pile installed in a homogeneous sand deposit, If density is 18 kN/m^3 and angle of internal friction is 30°. Water table is at Ground surface.

Soln:



$\gamma_{sat} = 18\ kN/m^3$

$\therefore \gamma' = \gamma_{sat} - \gamma_w$

$= 18 - 9.81$

$\gamma' = 8.19\ kN/m^3$

$\phi = 30°$

Here,

Dia, $D = 500mm = 0.5m$

Length, $L = 15m$

$L_c = 15D = 15 \times 0.5 = 7.5m$

$\therefore L_1 = L_c = 7.5m$

$L_2 = L - L_c = 15 - 7.5 = 7.5m$

$K_o = 1 - \sin\phi = 1 - \sin 30° = 0.5$ (At Rest)

$\tan\delta = \tan(0.75\phi) = \tan(0.75 \times 30°) = 0.414$

Stress at 7.5m, $\sigma_1 = \frac{1}{2}\gamma' h_1 = \frac{1}{2} \times 8.19 \times 7.5 = 30.71\ kN/m^2$

Stress at 15m, $\sigma_2 = \gamma' h_2 = 8.19 \times 7.5 = 61.43\ kN/m^2$

Here, $\sigma_1 = \sigma_1'$ & $\sigma_2 = \sigma_2'$

$Q_{wt} = \gamma_{conc} \times A_{(Entire)}$

$= \gamma_{conc} \times \left(\frac{\pi}{4} D^2 L\right)$

$= 24 \times \left(\frac{\pi}{4} \times 0.5^2 \times 15\right) = 70.69\ kN$

Now, Pull out capacity of Concrete pile,

$Q_{Pull} = Q_{wt} + Q_{SF(1)} + Q_{SF(2)}$

$$\boxed{Q_{pull} = Q_{wt} + (\pi D L_1) K_o \sigma_1' \tan\delta + (\pi D L_2) K_o \sigma_2' \tan\delta}$$

$= Q_{wt} + \pi D K_o \tan\delta\ (\sigma_1' L_1 + \sigma_2' L_2)$

$= 70.69 + \pi \times 0.5 \times 0.5 \times 0.414 \times (30.71 \times 7.5 + 61.43 \times 7.5)$

$= 295.39\ kN$ (Ans.)

Settlement :

(8b) * The initial void ratio of a 5m thick clay layer is 1.1, If the difference of void ratio is 0.3 than find out the settlement. [BUET MSc-2018]

Solⁿ: $e_0 = 1.1$ = Initial void ratio

Difference of void ratio, $\Delta e = 0.3$

Thickness of Clay layer, $H = 5m$

$$\boxed{\text{settlement, } S = \frac{\Delta e}{1+e_0} \times H}$$

$$= \frac{0.3}{1+1.1} \times 5$$

$$= 0.714\ m \quad \text{(Ans)}$$

(8c) * The initial void ratio of a 5m thick underlying saturated clay layer is 1.4, Due to the weight of a super imposed embankment the void ratio of clay layer decrease from 1.4 to 1.1, Determine the consequent settlement of that clay layer. [DPDC-2019]

Solⁿ: $e_0 = 1.4$ $\quad \Delta e = 1.4 - 1.1 = 0.3$

$H = 5m$

$$\text{Settlement, } \boxed{S = \frac{\Delta e}{1+e_0} * H}$$

$$= \frac{0.3}{1+1.4} \times 5 = 0.625 m \quad \text{(Ans.)}$$

(8d) ** A clay stratum 5m thick has initial void ratio of 1.5 and the effective overburden pressure of 120 KN/m², when the sample is subjected to an increased pressure of 120 KN/m² the void ratio reduces to 1.44, Determine the coefficient of volume compressibility and the final settlement of the stratum.

35th BCS

Solⁿ: $H = 5m$, $e_0 = 1.5$

Effective overburden pressure, $\Delta\sigma = 120\ KN/m^2$

Reduction of void ratio, $\Delta e = 1.5 - 1.44 = 0.06$

Co-efficient of volume compressibility,

$$\boxed{m_v = \frac{\Delta e}{\Delta\sigma(1+e_0)}} = \frac{0.06}{120 \times (1+1.5)} = 2 \times 10^{-4}\ m^2/KN$$

[P.T.O.]

Settlement, $\boxed{S = \frac{\Delta e}{1+e_o} \times H}$

$= \frac{0.06}{1+1.5} \times 5$

$= 0.12$ m (Am.)

(89) * 2m deep clay layer, coefficient of volume compressibility is 0.02 cm²/kg. Effective pressure increases from 2 to 4 kg/cm², what is the settlement of the clay layer? [NPCBL - 2017]

Soln: ✓ $H = 2m$ = clay layer thickness $= 200cm$

✓ $m_v = 0.02$ cm²/kg

✓ pressure increase, $\Delta\sigma = 4-2 = 2$ kg/cm²

Settlement, $\boxed{S = m_v H \Delta\sigma}$

$= 0.02 \times 2 \times 200$ $\left(\frac{cm^2}{kg} \times cm \times \frac{kg}{cm^2}\right)$

$\cancel{= 0.08}$

$= 8$ cm (Am.)

(88) * Determine the coefficient of volume change if the settlement is 5cm for 7.5m clay layer having increasing pressure of 80 kg/cm². [CPGCBL-2018]

Soln: Coefficient of volume change, $m_v = ?$

✓ Settlement, $S = 5$ cm

✓ layer thickness, $H = 7.5m = 750$ cm

✓ Pressure increase, $\Delta\sigma = 80$ kg/cm²

Settlement, $\boxed{S = m_v \cdot H \cdot \Delta\sigma}$

$\Rightarrow 5 = m_v \times 750 \times 80$

$\therefore m_v = 8.33 \times 10^{-5}$ cm²/kg (Am.)

(87) * ← [Same Math (89)] NPCBL-2017

A clay layer of 2m thick has $m_v = 0.02$ cm²/kg. If effective stress increase $= 2$ kg/cm², what is the settlement of clay layer?

Soln: ✓ $m_v = 0.02$ cm²/kg, ✓ $H = 2m = 200cm$, ✓ $\Delta\sigma = 2$ kg/cm²

Settlement, $\boxed{S = m_v \cdot H \cdot \Delta\sigma}$

$= 0.02 \times 200 \times 2$ $\left(\frac{cm^2}{kg} \times cm \times \frac{kg}{cm^2}\right)$

$= 8$ cm (Am.)

৬০ * A clay layer 5m depth has a settlement of 7.5cm, Find the coefficient of volume change if effective overburden pressure increase 20 KN/m² due to construction of a building. [CBGCBL – 2018]

Soln: Layer depth, $H = 5m = 500\ cm$

Settlement, $S = 7.5\ cm = 0.075\ m$

Coefficient of volume change, $m_v = ?$

Effective overburden pressure, $\Delta\sigma = 20\ KN/m^2$

$$\boxed{S = m_v \cdot H \cdot \Delta\sigma}$$

$$\Rightarrow 0.075 = m_v \times 5 \times 20$$

$$\Rightarrow m_v = \frac{0.075}{5 \times 20} \qquad \frac{m}{m \times KN/m^2}$$

$$\therefore m_v = 7.5 \times 10^{-4}\ m^2/KN \quad \text{(Ans.)}$$

Consolidation settlement

৬১ * Compute consolidation settlement of a 2.5m thick clay layer due to an increase of 30 KN/m² pressure at the mid ht. of the layer, If vertical stress at the mid ht of layer is 130 KN/m². Given, $e_o = 0.8$, Compression index, $C_c = 0.28$, [WRGCL-2014]

Soln: Consolidation settlement, $S_c = ?$

Layer thickness, $H = 2.5m$

Pressure increase, $\Delta\sigma = 30\ KN/m^2$ at mid ht

Vertical stress, $\sigma_o = 130\ KN/m^2$ at mid ht

$e_o = 0.8$; Compression index, $C_c = 0.28$,

Now, Consolidation settlement,

$$\boxed{S_c = \frac{C_c H}{1+e_o} \log \frac{\sigma_o + \Delta\sigma}{\sigma_o}}$$

$$= \frac{0.28 \times 2.5}{1 + 0.8} \log \frac{130 + 30}{130}$$

$$= 0.035\ m \quad \text{(Ans.)}$$

$S_c \rightarrow H \rightarrow$

Hints: S_c এর একক হবে H এর একক, $H \rightarrow m$ তাই $S_c \rightarrow m$ এ,

(62) [PGCB-2015, GTCL-2016, SGCL-2017, ERL-2017, BWDB-2018, NHA-2020]

*** Compute consolidation settlement of a 2.5m thick clay layer due to an increase of 30 KN/m² pressure at the mid ht of the layer, If vertical stress at the mid ht of layer is 40 KN/m². The value of initial void ratio is 0.7 and compression index is 0.28,

Solⁿ: Clay layer thickness, $H = 2.5m$

Pressure increase, $\Delta\sigma = 30\ KN/m^2$ (mid ht)

Vertical stress, $\sigma_0 = 40\ KN/m^2$ (mid ht)

$e_0 = 0.7$; Compression index, $C_c = 0.28$,

Consolidation Settlement,

$$\boxed{S_c = \frac{C_c H}{1+e_0} \log \frac{\sigma_0 + \Delta\sigma}{\sigma_0}}$$

$$= \frac{0.28 \times 2.5}{1+0.7} \log \frac{40+30}{40}$$

$$= 0.1\ m \quad \text{(Ans.)}$$

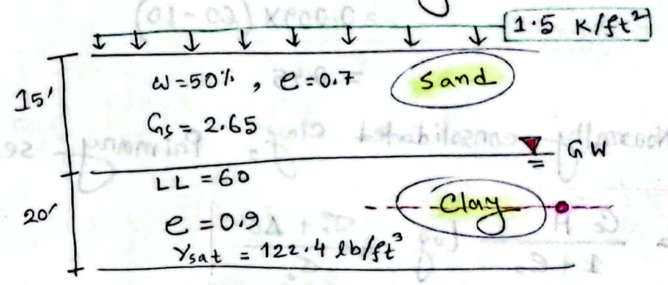
$\sigma_0 \Rightarrow$ mid ht of clay $\left(\frac{h_2}{2}\right)$

$S_c \Rightarrow$ Full ht of clay (H)

(63)

PGCB-2018

* Determine the primary settlement of the clay layer. The soil is normally consolidated.



$\boxed{\gamma' = \gamma_{sat} - \gamma_w}$ $= (122.4 - 62.4)$

Solⁿ: For Sand layer, (γ_{BULK})

$$\boxed{\gamma = \frac{G_s \gamma_w (1+\omega)}{1+e}}$$

$$= \frac{2.65 \times 62.4 \times (1+0.5)}{1+0.7}$$

$$= 145.9\ lb/ft^3$$

Existing Pressure at mid ht of clay,

$$\boxed{\sigma_0 = \gamma h_1 + \gamma' \frac{h_2}{2}}$$

$$= 145.9 \times 15 + (122.4 - 62.4) \times \frac{20}{2}$$

$$= 2784.5\ lb/ft^2$$

$$= 2.785\ K/ft^2$$

Over burden pressure, $\Delta\sigma = 1.5\ K/ft^2$

[P.T.O.]

$e_o = e = 0.9$ [Figure] clay layer

Compression Index, $\boxed{C_c = 0.009 \times (LL - 10)}$

$= 0.009 \times (60 - 10)$

$= 0.45$

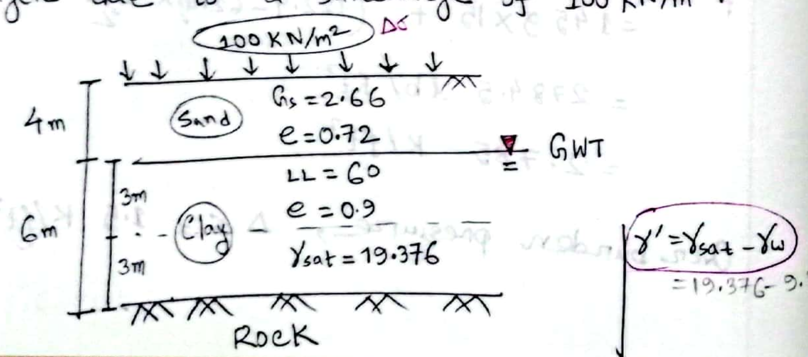
For Normally consolidated clay, Primary settlement,

$$\boxed{S_c = \frac{C_c H}{1 + e_o} \log \frac{\sigma_o + \Delta\sigma}{\sigma_o}} \quad \text{(clay layer)}$$

$$= \frac{0.45 \times 20}{1 + 0.9} \log \frac{2.7845 + 1.5}{2.7845}$$

$= 0.887$ ft (Ans.)

A soil profile shown in fig. Calculate the settlement due to primary consolidation for the 6m clay layer due to a surcharge of 100 kN/m².



$\gamma' = \gamma_{sat} - \gamma_w$
$= 19.376 - 9.81$

$\gamma_w = 9.81$ kN/m³
$\gamma_w = 62.4$ lb/ft³

Soln: For Sand, $\boxed{\gamma = \frac{G_s \gamma_w}{1 + e}}$

$$= \frac{2.66 \times 9.81}{1 + 0.72} = 15.17 \text{ kN/m}^3$$

For clay, $\boxed{\sigma_o = \gamma h_1 + \gamma' \times \frac{h_2}{2}}$ (mid ht.)

$$= 15.17 \times 4 + (19.376 - 9.81) \times \frac{6}{2}$$

$= 89.378$ kN/m²

Over-burden pressure, $\Delta\sigma = 100$ kN/m²

Compression Index, $\boxed{C_c = 0.009 \, (LL - 10)}$

$= 0.009 \times (60 - 10) = 0.45$

Now, Settlement due to primary consolidation,

$$\boxed{S_c = \frac{C_c H}{1 + e_o} \log \frac{\sigma_o + \Delta\sigma}{\sigma_o}} \quad \text{(clay layer)}$$

$$= \frac{0.45 \times 6}{1 + 0.9} \log \frac{89.378 + 100}{89.378}$$

$= 0.463$ m (Ans.)

38.2

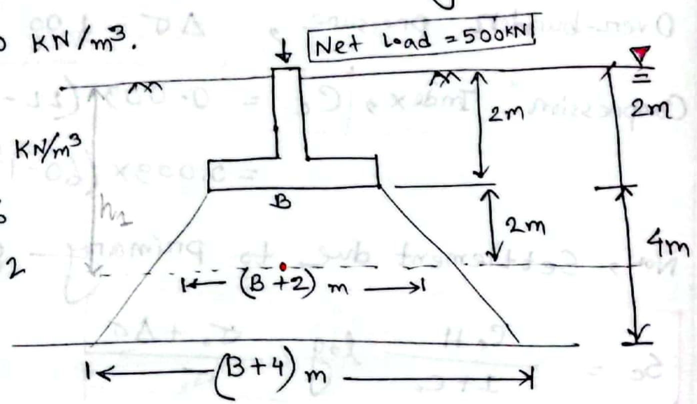
* A square footing is to be established in a clayey soil at a depth of 2m. Where water table has risen upto the ground level as shown in fig. Determine the width of footing if it is permitted to settle by 120 mm for the given data. Assume that the net load given is a constant and that the same is dispersed into clay as shown.

$\gamma_w = 10$ KN/m³.

$\gamma_{sat} = 19.3$ KN/m³

$C_c = 0.36$

$e_o = 0.92$



Solⁿ: Let, size of footing = B X B

Width of ~~footing~~ spread at the depth below footing = B + 2

$\therefore$ Stress, $\Delta\sigma = \dfrac{500}{(B+2)^2}$ KN/m² ——— (i)

Given, $S_c = 120$ mm $= 0.12$m

$C_c = 0.36$, $e_o = 0.92$

$H = 4$m, $\gamma_w = 10$ KN/m³

Stress at mid ht, under footing $\sigma_o = \gamma' h_1 = (\gamma_{sat} - \gamma_w) \times h_1$

$= (19.3 - 10) \times 4$

$\sigma_o = 37.2$ KN/m²

Now,

$$S_c = \frac{C_c H}{1+e_o} \log \frac{\sigma_o + \Delta\sigma}{\sigma_o}$$

$$\Rightarrow 0.12 = \frac{0.36 \times 4}{1 + 0.92} \log \frac{37.2 + \Delta\sigma}{37.2}$$

$\therefore \Delta\sigma = 16.57$ KN/m²

(i) থেকে, $16.57 = \dfrac{500}{(B+2)^2}$

$\Rightarrow$ ~~3.4~~ $B = 3.49$ m (Ans.)

Consolidation

(Q2) * PGCL-2017

A 3m thick layer (Double drainage) of saturated clay under a surcharge loading underwent 90% Primary consolidation in 75 days. Find the coefficient of consolidation of clay for the pressure range.

Soln: For Double drainage, $H = \frac{\text{thickness}}{2} = \frac{3m}{2} = 1.5m$

% of primary consolidation, $U = 90\% > 60\%$

$\therefore \boxed{T_v = 1.781 - 0.933 \log (100 - U\%)}$

$= 1.781 - 0.933 \log (100-90)$

$= 0.848$

~~Again~~ time, $t = 75$ day

$= 75 \times 24 \times 3600$ sec

$= 6.48 \times 10^6$ sec

Again,

Time factor, $T_v = \frac{C_v t}{H^2}$

Coefficient of Consolidation

$\cancel{\text{...}}$, $\boxed{C_v = \frac{T_v H^2}{t}} = \frac{0.848 \times 1.5^2}{6.48 \times 10^6} \frac{m^2}{s}$

$= 2.94 \times 10^{-7}$ m^2/s

$= 2.94 \times 10^{-3}$ cm^2/s

(Ans)

(Q3) * 30th BCS

Time required to reach 50% consolidation for a soil of 3cm thick tested in a consolidometer under single drainage condition was 30 minutes. Determine the time required for the same soil of 4m thick to reach the same degree of consolidation, it has double drainage paths.

Soln: First Case: (Single Drainage)

$U = 50\% < 60\%$, $\therefore \boxed{T_v = \frac{\pi}{4}\left(\frac{U}{100}\right)^2} = \frac{\pi}{4}\left(\frac{50}{100}\right)^2$

$= 0.196$

$H = 3cm$; time, $t_{50} = 30$ minutes

$= 0.5$ hr

Coefficient of consolidation,

$\boxed{C_v = \frac{T_v H^2}{t_{50}}} = \frac{0.196 \times 3^2}{0.5} = 3.528\ cm^2/hr$

Second Case: (Double Drainage)

$H = \frac{\text{thickness}}{2} = \frac{4m}{2} = 2m = 200\ cm$

time, $t = \frac{T_v H^2}{C_v} = \frac{0.196 \times 200^2}{3.528}$

$= 2222.22$ hr

(Ans.)

$\gamma_w = 1\ gm/cm^3$
$= 1\times10^{-3}\ kg/cm^3$

(63) * In a laboratory consolidation test, the void ratio of the sample reduced from 0.85 to 0.73 as the pressure was increased from 1 to 2 kg/cm². If the coefficient of permeability of soil be 3.3×10^{-4} cm/sec, Determine the coefficient of volume change and co-efficient of consolidation.

Soln: Reduction of void ratio, $\Delta e = 0.85 - 0.73 = 0.12$

Pressure increase, $\Delta\sigma = 2-1 = 1\ cm^2/kg$

Coefficient of permeability, $K = 3.3\times10^{-4}$ cm/sec

Now, Coefficient of Volume Change,

$$m_v = \frac{\Delta e}{\Delta\sigma(1+e_0)}$$

$$= \frac{0.12}{1\ (1+0.85)} = 0.065\ cm^2/kg$$

Coefficient of consolidation,

$$c_v = \frac{K}{m_v\ \gamma_w} = \frac{3.3\times10^{-4}}{0.065\times(1\times10^{-3})} \quad \frac{cm/sec}{(cm^2/kg)\times(kg/cm^3)}$$

$$= 5.07\ cm^2/sec$$

(Ans)

(64) * In a consolidation test, the void ratio of specimen which was 1.068 under the effective pressure of 214 KN/m², changed to 0.994 when the pressure was increased to 429 KN/m². Calculate the coefficient of compressibility, Compression index and the coefficient of volume compressibility. Find the settlement of foundation resting on above type of clay, if thickness of layer is 8m and pressure increase 10 KN/m².

Soln: $e_0 = 1.068$, $\sigma_0 = 214\ KN/m^2$, $e = 0.994$, $\sigma = 429\ KN/m^2$

$\Delta e = e_0 - e = 0.074$, $\Delta\sigma = \sigma - \sigma_0 = 215\ KN/m^2$

Coefficient of compressibility, $a_v = \frac{\Delta e}{\Delta\sigma}$

$$= \frac{0.074}{215}$$

$$= 3.442\times10^{-4}\ m^2/KN$$

Compression Index, $C_c = \frac{\Delta e}{\log\left(\frac{\sigma}{\sigma_0}\right)}$

$$= \frac{0.074}{\log\left(\frac{429}{214}\right)} = 0.245$$

$H = 8m$

[P.T.O]

Coefficient of volume change,

$$m_v = \frac{\Delta e}{\Delta\sigma\,(1+e_o)} = \frac{0.074}{215\times(1+1.068)}$$

$$= 1.664\times10^{-4} \quad m^2/KN$$

Settlement, $S_c = \frac{C_c H}{1+e_o}\log\frac{\sigma_o+\Delta\sigma}{\sigma_o}$

when $\Delta\sigma = 10\ KN/m^2$

$$= \frac{0.245\times8}{1+1.068}\log\frac{214+\cancel{215}\,10}{214}$$

$$= 0.0188\ m \qquad \text{(Ans.)}$$

(20) * A strata of normally consolidated clay of thickness 10ft is drained on one side only. It has a hydraulic conductivity of $K = 1.863\times10^{-8}$ in/sec and a coefficient of volume compressibility, $m_v = 8.6\times10^{-4}$ in²/lb. Determine the ultimate compression of the stratum by assuming a uniformly distributed load of 5250 lb/ft² and also determine the time required for 20% and 80% consolidation.

$\gamma_w = 62.4\ lb/ft^3$

$$= \frac{62.4}{12\times12\times12}\ \frac{lb}{in^3} = 3.61\times10^{-2}\ lb/in^3$$

Solⁿ: Ultimate compression,

$$S_c = m_v\ H\ \Delta\sigma$$

$$= (8.6\times10^{-4})\times(10\times12)\times\left(\frac{5250}{12^2}\right) \quad \left(\frac{in^2}{lb}\times in\times\frac{lb}{in^2}\right)$$

$$= 3.763\ in$$

For 20% consolidation, $T_v = \frac{\pi}{4}\left(\frac{U}{100}\right)^2$

$$= \frac{\pi}{4}\left(\frac{20}{100}\right)^2 = 0.0314$$

For 80% Consolidation,

$$T_v = 1.781 - 0.933\log(100-U)$$

$$= 1.781 - 0.933\log(100-80) = 0.567$$

Coefficient of consolidation, $C_v = \frac{K}{m_v\,\cancel{K}\,\gamma_w}\ \left(\frac{in/sec}{\frac{in^2}{lb}\times\frac{lb}{in^3}}\right)$

$$\Rightarrow C_v = \frac{1.863\times10^{-8}}{(8.6\times10^{-4})\times(3.61\times10^{-2})} = 6\times10^{-4}\ in^2/sec$$

Time required for 20% consolidation,

$$t_{20} = \frac{T_v H^2}{C_v} = \frac{(0.0314)\times(10\times12)^2}{(6\times10^{-4})\times\underbrace{(60\times60\times24)}_{\text{sec to day}}} = 8.72\ \text{days}$$

Time required for 80% consolidation,

$$t_{80} = \frac{T_v H^2}{C_v} = \frac{(0.567)\times(10\times12)^2}{(6\times10^{-4})\times60\times60\times24} = 157.5\ \text{days.}$$

(Ans)