DETAILS EXPLANATIONS

1. (A) (i) Sensitivity(S_t) of a soil indicates its weakening due to remoulding. It is defined as the ratio of the undisturbed strength to the remoulded strength at the same water content.

$$S_t = \frac{(q_u)_{undisturbed}}{(q_u)_{remoulded}}$$ where,

$(q_u)_{undisturbed}$ = Unconfined compressive strength of undisturbed clay.

$(q_u)_{remoulded}$ = Unconfined compressive strength of remoulded clay.

Extra-Sensitive and quick soil for which sensitivity is (8 - 15) and >15 respectively are not suitable soils.

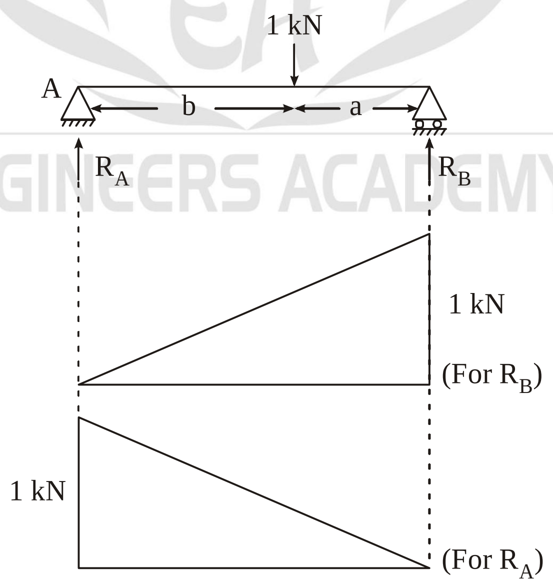
(ii) ***(a) Specific-Yield :***

The specific yield of an unconfined aquifer is the ratio of volume of water which will flow under saturated condition due to gravity effect to the total volume (v).

(b) Specific-Retention :

The specific retention of an unconfined aquifer is the ratio of volume of water retained against gravity effect to the total volume of aquifer.

(B)



Load is moving from 'B' to 'A'.

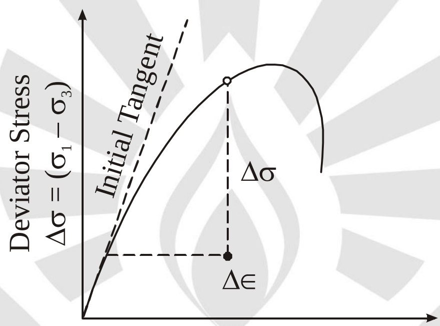
$$R_B \cdot l = l.b$$
$$R_B = b/l$$
$$R_A = 1 - R_B = \frac{a}{l}$$

(C) Elastic Properties of Soil

Modulus of Elasticity : *(Elastic Modulus)*

The Elastic modulus of soil is obtained from the deviator stress-strain curve. The undrained modulus, E_u is obtained from the undrained triaxial test data while the drained modulus, E_d is obtained from the drained test conditions.

Deviator stress-strain curve for triaxial shear-test.



Since the curve is non-linear one. So for such a curve, two types of modulus can be defined namely tangent modulus and secant modulus.

$$\text{Tangent modulus} = \frac{d(\sigma_1 - \sigma_3)}{d \in_E}$$

$$\text{Secant modulus} = \frac{\Delta(\sigma_1 - \sigma_3)}{\Delta \in_E}$$

If 'S_u' is the undrained strength of soil. Then.

(i) For a normally consolidated sensitive clay

$$E_u = (200 \text{ to } 500)S_u$$

(ii) For a normally over consolidated clay

$$E_u = (750 \text{ to } 1200)S_u$$

(iii) For a heavily consolidated clay

$$E_u = (1500 \text{ to } 2000)S_u$$

Possion's Ratio

It is defined as the ratio of lateral strain to axial strain in triaxial compression test.

$$\mu = \frac{\epsilon_3}{\epsilon_1}$$

Possion's Ratio is not a constant for a soil but is dependent on the stress and strain levels.

Value of 'μ' ranges from 0 to 0.5 for soils. For saturated soils, it is close to 0.5 and for dry soils, close to '0'.

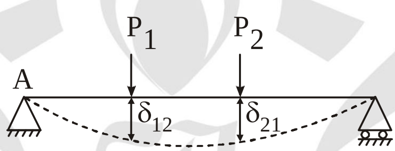
Shear Modulus :

The shear modulus 'G' is defined as the ratio of shear-stress to shear strain and can be determined from the following relationship.

$$G = \frac{E}{2(1+\mu)}$$

The above discussion on elastic properties is relevant for static conditions. For dynamic conditions, the elastic properties are evaluated from cyclic load tests and other special tests.

2. **(A)**



According to Maxwell's Reciprocal - Theorem.

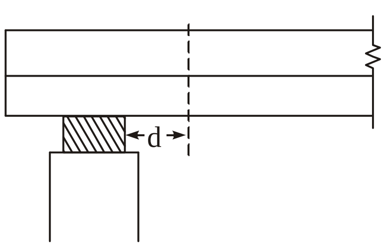
$$\delta_{12} = \delta_{21}$$

Where δ_{12} = deflection in direction (2) due to applied load in direction (1).

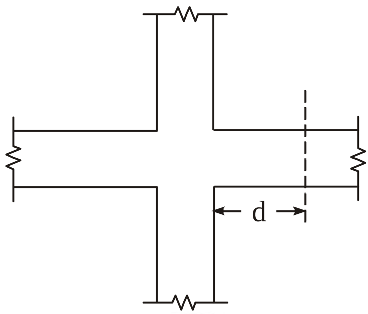
δ_{21} = deflection in direction (1) due to applied load in the direction (2).

(B) A section which is most prone to be failed in shear is called the critical section for shear.

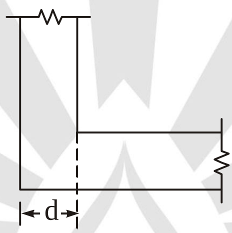
(i) For a simply supported beam



(ii) For Intermediate Beam



(iii) For water tanks etc.

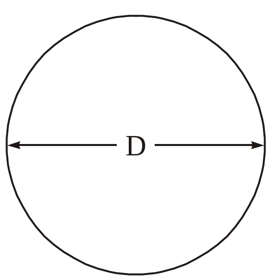


3.(A) ***General Requirements of lacings:***

- Radius of gyration about the axis perpendicular to the plane of lacing and radius of gyration in the plane of lacing.
- The lacing system should not be varied through the length of strut as far as practiable.
- The single-laced system on opposite sides on the main components should preferably in the same direction so that one can be the shadow of the other.

(B) Shape-factor $= \dfrac{\text{Plastic Section Modulus}}{\text{Elastic Section Modulus}}$

Shape-factor $= \dfrac{Z_p}{Z_e}$



Plastic-modulus $(Z_p) = \frac{A}{2}(\bar{y}_1 + \bar{y}_2)$

$$Z_P = \frac{\pi}{8}D^2\left(\frac{2D}{3\pi} + \frac{2D}{3\pi}\right)$$

$$Z_P = \frac{D^3}{6}$$

Elastic Section modulus

$$Z_e = \frac{\pi}{32}D^3$$

∴ Shape-factor

$$\frac{Z_p}{Z_e} = \frac{(D^3/6)}{(\pi D^3/32)}$$

Shape-factor $= \frac{32}{6\pi} = 1.7$

4. p_t = Percentage of tension reinforcement

$$p_t = \frac{4\times(\pi/4)\times 25^2}{300\times 500}\times 100\% = 1.309\%$$

For M20 concrete

p_t	$\tau_C (N/mm^2)$
1.25	0.67
1.50	0.72

$$\tau_C = \frac{0.72-0.67}{1.50-1.25}(1.309-1.25)+0.67$$

$$\tau_C = 0.6818 \text{ N/mm}^2$$

and $\tau_{C_{max}} = 2.8 \text{ N/mm}^2$

Nominal shear-stress

$$\tau_V = \frac{V_u}{B.d} = \frac{250\times 10^3}{300\times 500} = 1.67 \text{ N/mm}^2$$

$$\tau_V < \tau_{C_{max}}$$

$$\tau_V > \tau_C$$

Design Shear force

$$V_S = (\tau_V - \tau_C)B.d$$

$$V_S = (1.67 - 0.68) \times 300 \times 500$$

$$V_S = 148000 \text{ N}$$

Shear Resistance for a series of bent-up bars at different cross sections.

$$V_{sb} = 0.87 f_y A_{Sb} \sin\alpha$$
$$= 0.87 f_y A_{sb} \sin\alpha$$
$$V_{sb} = 0.87 \times 250 \times 2 \times \frac{\pi}{4} \times 20^2 \sin 45^o$$
$$V_{sb} = 96632.92 \text{ N}$$

But the shear-resistance of the bentup bars cannot exceed 0.5 times the design shear force

$$= 0.5 \times 148000 = 74000 \text{ N.}$$

So, Providing → 6 mm-2legged stirrups.

$$A_{sv} = 2\times\frac{\pi}{4} \times 6^2 = 56.55 \text{ mm}^2$$
$$S_v = \frac{0.87 f_y A_{sv} d}{V_s}$$
$$= \frac{0.87\times250\times56.55\times500}{74000}$$
$$S_v = 83.10 \text{ mm}$$

So, Spacing = 83.10 mm

Check for maximum spacing :

(i) 300 mm

(ii) 0.75 d = 0.75 × 500 = 375 mm

(iii) $S_v \geq \frac{0.87 f_y A_{sv}}{0.4b} = \frac{0.87\times250\times56.55}{0.4\times300}$

$$= 102.40 \text{mm}$$

So, provide spacing 80 mm.

5. For solid column let diameter be 'D_s' and external diameter of hollow column b 'D_e'.

Since both columns have same cross-sectional area.

$$\frac{\pi}{4}\left[D_e^2 - \left(\frac{2}{3}D_e\right)^2\right] = \frac{\pi}{4}D_S^2$$

$$\frac{\sqrt{5}}{3}D_e = D_S$$

Buckling strength means Euler's critical load required.

So, Buckling-Strength of solid column

$$P_1 = \left(\frac{\pi^2 EI}{L_{eff}^2}\right)_1 = \frac{\pi^2 E(\pi D_S^4 / 64)}{(0.5L)^2}$$

$$P_1 = \frac{4\pi^2 E D_S^4}{64L^2}$$

$$P_1 = \frac{\pi^2 E D_S^4}{16}$$

and Buckling strength of hollow column

$$P_2 = \left(\frac{\pi^2 EI}{L_{eff}^2}\right)_2 = \frac{\pi^2 E(\pi / 64)(D_e^4 - D_i^4)}{(0.5L)^2}$$

$$P_2 = \frac{4\pi^2 E}{64L^2}\left[D_e^4 - \left(\frac{2}{3}D_e\right)^4\right]$$

$$P_2 = \frac{4\pi^2 E}{64}\left[\left(\frac{3D_s}{\sqrt{5}}\right)^4 - \left(\frac{2}{3} \times \frac{3}{\sqrt{5}} D_S\right)^4\right]$$

Since $D_e = \frac{3}{\sqrt{5}} D_S$

$$P_2 = \frac{\pi^2 E}{16}\left[\frac{81 D_S^4}{25} - \frac{16 D_S^4}{25}\right]$$

$$P_2 = \frac{\pi^2 E}{16}\left[\frac{81-16}{25}\right] D_S^4 = \frac{\pi^2 E}{16}\left(\frac{65}{25} D_S^4\right)$$

∴ Ratio of buckling-strengths

$$\frac{P_1}{P_2} = \frac{25}{65} = \frac{5}{13}$$

6. For the layer of 5 m thickness, U = 50%, t = 1 year and S_{ct} = 80

Since $S_{ct} = u_t S_F$

$$S_f = \frac{8}{0.5} = 16 \text{ cm}$$

Hence for 25 m thick layer

$$S_f = 16 \times \frac{25}{5} = 80 \text{ cm} \qquad (\because S_f \propto H_0)$$

From equation

$$T_V = \frac{C_v.t}{d^2}$$

$$T_V = \left.\frac{C_v t}{H^2}\right| d = H$$

$$\frac{t_1}{t_2} = \frac{H_1^2}{H_2^2}$$

For 5 m thick layer t_{50} = 1 year

Hence for 25 m thick layer,

$$t_{50} = 1 \times \left(\frac{25}{5}\right)^2 = 25 \text{ years}$$

For 25 m thick layer,

$$\frac{(T_V)_1}{(T_V)_2} = \frac{t_1}{t_2}$$

Also, Since

$$T_V = \frac{\pi}{4} U^2 \text{ for } U < 60\%$$

$$\frac{U_1^2}{U_2^2} = \frac{(T_V)_1}{(T_V)_2} = \frac{t_1}{t_2}$$

U_1 = 50% for t_1 = 25 year

For t_2 = 1 year

$$U_2^2 = U_1^2 \times \frac{t_2}{t_1} = 0.5^2 \times \frac{1}{25} = 0.01$$

U_2 = 0.1

$S_{Ct} = US_F$

$$S_{Ct} = 0.1 \times 80 = 8 \text{ cm}$$

$$t_2 = 4 \text{ years}$$

$$U_2^2 = U_1^2 \frac{t_2}{t_1} = 0.5^2 \times \frac{4}{25} = 0.04$$

$\because \quad U_2 = 0.2$

$\therefore \quad S_{Ct} = 0.2 \times 80 = 16 \text{ cm}$

7. Since $K = \dfrac{Ql}{Ath}$

$$A = \text{Area} = \pi\frac{D^2}{4} = \pi \times \frac{(7.5)^2}{4}$$

$$= 44.18 \text{ cm}^2$$

$\therefore \quad K = \dfrac{626 \times 18}{44.18 \times 60 \times 24.7}$

$$= 1.72 \times 10^{-1} \text{ cm/sec}$$

Discharge-Velocity

$$V = ki = 1.72 \times 10^{-1} \times \frac{24.7}{18}$$

$$= 2.36 \times 10^{-1} \text{ cm/sec}$$

Seepage velocity

$$V_s = \frac{V}{n} = \frac{2.36 \times 10^{-1}}{0.44}$$

$$= 5.36 \times 10^{-1} \text{ cm/sec}$$

For $n_1 = 44\%$

$e_1 = 0.97$

$$\frac{e_1^3}{1+e_1} = 0.275$$

For $n_2 = 39\%$

$e_2 = 0.64$

$$\frac{e_2^3}{1+e_2} = 0.16$$

At 25°C, Viscosity of water μ_1 = 8.95 mili-poise. At 20°, η_2 = 10.09 milipose.

Considering that,

$$k_1 : k_2 = \frac{r_{w1}}{\eta_1} : \frac{r_{w2}}{\eta_2}$$; Neglecting effect on r_w.

$$k_1 : k_2 = \frac{1}{\eta_1} : \frac{1}{\eta_2}$$

$$k_{20^\circ C} = 1.72 \times 10^{-1} \times \frac{8.95}{10.09}$$

$$= 1.526 \times 10^{-1} \text{ cm/sec}$$

At e = 0.79

Now considering that,

$$k_1 : k_2 = \frac{e_1^3}{1+e_1} : \frac{e_2^3}{1+e_2}$$

$k_{20^\circ C}$ at e = 0.64 is equal to

$$1.526 \times 10 \times \frac{0.16}{0.275} = 8.88 \times 10^{-2} \text{ cm/sec}$$

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