BITS-PILANI HYDERABAD CAMPUS

CIVIL ENGINEERING DEPARTMENT

FOUNDATION ENGINEERING (CE F313)

COMPREHENSIVE EXAMINATION 2022-23

NAME: ____ ID: ________________________

PART A (Closed Book)

Full Marks: 20 **Time: 30 minutes**

Fill in the blanks with words / phrases and return it within 30 minutes. Each correct answer carries 1 mark.

1. The caisson foundation which is open at top and closed at bottom is called ____________________ caisson.
2. Lacey's silt factor is a function of ________________________ of soil particles.
3. The action of negative skin friction on the pile is to _____________________ the allowable load on the pile.
4. _____________________ is the liquid (apart from water) used in free swell test of expansive soils.
5. The depth correction factor for calculating the settlement of a shallow foundation founded on the ground level is ________________________.
6. The artificial drains used to accelerate consolidation process in clayey soils are known as ____.
7. A soil medium may be approximated by a series of closely spaced independent elastic springs. This theory is suggested by __________________________ .
8. The lower wedge shaped part of the well steining which protects the cutting edge is known as ___________________.

9. ______________________ is a waste material which can be used in place of cement in ground improvement in order to reduce the emission of greenhouse gases.

10. The boundary where the velocity of shear waves drops to 0 is known as ________________.

11. When operating frequency and natural frequency of a machine are same, the condition is known as __________________________.

12. Consider a door that uses a spring to close the door once open. It will return to closed position as quickly as possible without oscillating if the damping condition is _______________________________.

13. If the soil below the toe of a slope is relatively weak and soft and the slope is flat, the critical slip circle is expected to pass through the _______________ of the slope.

14. In order to avoid installation damage, the geosynthetic is generally placed at a minimum distance of _____________ meters from the ground level.

15. In Terzaghi's method of analysis of bearing capacity of shallow foundations, the failure surface extends till the base of the foundation / ground level (tick the correct option).

16. With respect to a $c - \varphi$ soil in an infinite slope, the factor of safety of the slope does not depend on the height of soil in the slope. The statement is True / False (tick the correct option).

17. Driven piles have the advantage of compacting the adjacent soil mass for __________________________ type of soils.

18. The pile foundations which are inclined at an angle to the vertical are known as __________________________ piles.

19. __________________________ is the clay mineral present in black cotton soil responsible for its swell / shrink properties.

20. ____________________________ is an example of a natural geosynthetic.

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PART B (Closed Book)

Full Marks: 60 **Time: 2 hours 30 minutes**

Answer all questions. Any data, if assumed, should be clearly stated. Separate marks are allotted for each step.

Solve the following questions: **[10 nos. x 6 marks = 60]**

1. A retaining wall of height 10m with clay backfill is shown in Fig. 1 (not to scale). Weight of the retaining wall is 5000 kN per meter acting at 3.3m from the toe of the retaining wall. The interface friction angle between the base of the retaining wall and the base soil is 20°. The depth of clay in front of the retaining wall is 2m. The properties of the clay backfill and the clay placed in front of the retaining wall are same. Consider development of tension cracks. Using Rankine's active earth pressure theory, determine the factor of safety against sliding and overturning failures of the retaining wall. Ignore adhesion at the base of the wall. Draw proper earth pressure diagrams.

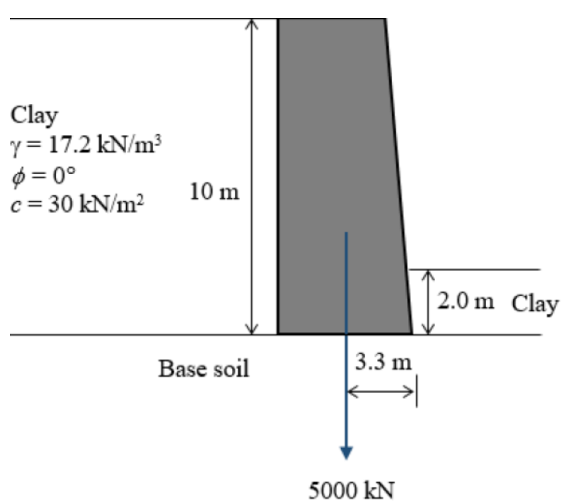

Fig. 1

2. A retaining wall of height H retains a cohesionless soil reinforced with steel strips. A highway runs on top of the retaining wall, which exerts a surcharge load of ` per unit length. The water table is at the ground level. The saturated unit weight and internal angle of friction of the backfill soil are γ_{sat} and φ respectively. The steel strips are placed at a horizontal spacing of S_H. The steel strip has ultimate yield strength of f_y, width w and thickness t. The interface friction angle between backfill soil and steel strip is δ. The factors of safety against breakage and pull out are FS_B and FS_P.

Derive the expressions of vertical spacing S_v and effective length L_E. Show proper steps and earth pressure diagrams.

3. A circular raft foundation of 20m diameter and 1.6m thick is founded at 2m below the ground surface for a tank that applies a load of 35000 kN on a sandy soil with Young's Modulus 30 MPa and Poisson's Ratio of 0.3. Considering the raft as rigid, what is the elastic settlement (in mm) of the foundation? Apply the necessary correction factors.

Given, Rigidity correction factor = 0.8
Pore water pressure correction factor = 0.85

4. A concrete pile of 400 mm diameter and 9 m length was driven in a uniform deposit of sand having angle of internal friction 36° and saturated unit weight of 19 kN/m^3. Consider interface friction angle between sand and pile material as 25° and average lateral earth pressure coefficient as 1. The water table is at the ground level. Unit weight of water = 10 kN/m^3.

Estimate safe load capacity of the pile with a factor of safety of 2.50.

5. Calculate the settlement of a (4 x 3) pile group having a superstructure load intensity of 200 kN/m^2 acting on top of the pile cap. The length of the piles is 8m, diameter 200mm and centre to centre spacing of 500mm. The pile group is embedded in a normally consolidated clay layer of 12 m thickness having γ_{sat} = 20 kN/m^3, liquid limit = 40% and initial void ratio (e_0) = 1.05. The water table is at the ground level. Unit weight of water = 10 kN/m^3. Show the distances with proper diagrams.

6. A steel pipe straight pile of 50 cm outside diameter and a wall thickness of 2 cm is driven is driven to a depth of 15m into a silty sand having relative density 40% and a friction angle of 35°. The water table is at the ground level. The dry and saturated unit weights of the silty sand are 16.5 kN/m^3 and 19.3 kN/m^3 respectively. The elastic modulus of steel is 210 GPa. A lateral load of 300 kN is acting at a distance of 2m above ground level. Compute the deflection at 1m depth from ground level.

7. A multi-storeyed building is to be constructed in stiff clay having undrained cohesion value of 150 kN/m^2. It is proposed to use a drilled pier of length 23m, diameter 2m, bell height 1.3m and base diameter of bell 4.5m. Determine the ultimate load and allowable load with a FS = 2.5. Consider $\alpha = 0.55$. Ignore surcharge.

What would be the ultimate load if all parameters are same, but the pile is a straight pile and not a belled one?

8. A slope of height 8m and slope 2.5H: 1V is constructed in a saturated homogenous clay having saturated and dry unit weights of 20 kN/m^3 and 18 kN/m^3 respectively and cohesion of 32 kN/m^2. Before development of tension cracks, the critical slip circle subtends an angle of 112° and a radius of 16m at the centre (O). The area of the failure zone is estimated to be 125 m^2 and the perpendicular distance from the centre is 3.75m. The vertical distance between ground level and point O is 3m. Unit weight of water = 10 kN/m^3.

After development of tension cracks, the angle subtended at the centre by the critical slip circle reduces by 12°, with the radius remaining same. The area of the failure zone reduces to 120 m^2 and the perpendicular distance from the centre become 3.25m.

Determine the factor of safety against immediate shear failure along the critical slip circle (a) ignoring tension cracks, (b) allowing development of tension cracks without water, (c) allowing development of tension cracks filled with water.

9. (i) State the major difference between a sand drain and a prefabricated vertical drain.

(ii) Name 2 chemical admixtures which can be used to stabilize expansive soils.

(iii)Define free swell index.

10. (i) Differentiate between active and passive isolation.

(ii) Differentiate between undertuned and overtuned design of machine foundations.

(iii) Differentiate between hypocenter and epicenter.

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Relevant Formulae

1)
$$FS_{sliding} = \frac{c_a B + V \tan\delta + P_p}{F_H}$$
$$FS_{overturning} = \frac{M_R}{M_O}$$

2) Depth of tensile crack $= z_0 = \dfrac{2c}{\gamma\sqrt{K_A}}$

3) For cohesive soil, active earth pressure $p_A = \gamma z K_A - 2c\sqrt{k_A}$

4) $$S_e = qB\frac{\left(1-\upsilon^2\right)}{E} I_f \times RF \times DF$$

5)
For $28^\circ < \phi < 36.5^\circ$, $\dfrac{L_c}{d} = 5 + 0.24\left(\phi - 28^\circ\right)$

For $36.5^\circ < \phi < 42^\circ$, $\dfrac{L_c}{d} = 7 + 2.35\left(\phi - 36.5^\circ\right)$

6) $\varphi_2 = \dfrac{\varphi_1 + 40^\circ}{2}$ for driven piles

7)
For cohesionless soil, $Q_u = \left(q_0 N_q\right) A_b + \left(\bar{q}_o \bar{k}_s \tan\delta\right) A_s$

For cohesive soil, $Q_u = \left(c_b N_c + \gamma L\right) A_b + \left(\alpha \bar{c}\right) A_s$

8) Compression Index $C_c = 0.009(LL - 10)$

9) $$S_c = \frac{C_c}{1+e_o} \mathrm{H} \log \frac{\bar{\sigma}_o + \Delta\bar{\sigma}}{\bar{\sigma}_o}$$

10) $$y = A_y \frac{P_t T^3}{EI} + B_y \frac{M_t T^2}{EI}$$

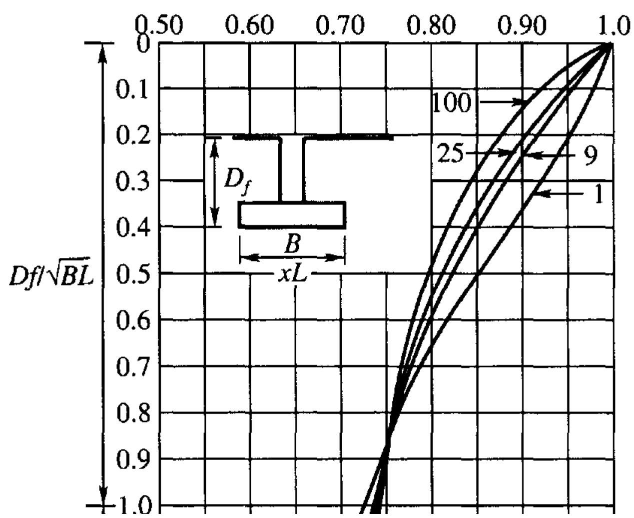
11) $$T = \left[\frac{EI}{n_h}\right]^{\frac{1}{n+4}}$$

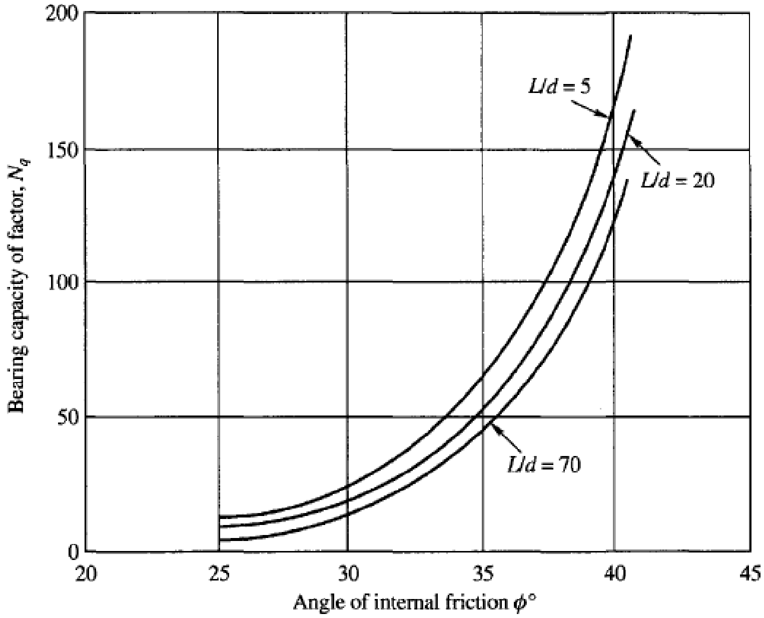
12) Factor of Safety for a finite slope is

$$FS = \frac{cR^2\theta}{W\,\bar{x}}$$

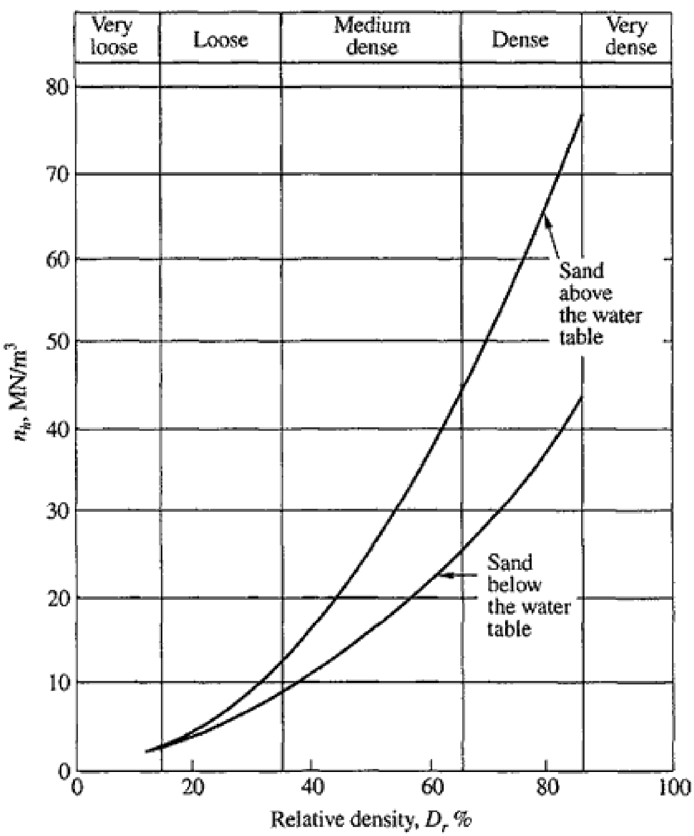
Table 13.4 Influence factor I_f (Bowles, 1988)

Shape	I_f (average values) Flexible footing	Rigid footing
Circle	0.85	0.88
Square	0.95	0.82
Rectangle	1.20	1.06
L/B = 1.5	1.20	1.06
2.0	1.31	1.20
5.0	1.83	1.70
10.0	2.25	2.10
100.0	2.96	3.40





Berezantsev's bearing capacity factor, N_q (after Tomlinson, 1986)



Z	A_y	A_s	A_m	A_v	A_p
0.0	2.435	–1.623	0.000	1.000	0.000
0.1	2.273	–1.618	0.100	0.989	–0.227
0.2	2.112	–1.603	0.198	0.966	–0.422
0.3	1.952	–1.578	0.291	0.906	–0.586
0.4	1.796	–1.545	0.379	0.840	–0.718
0.5	1.644	–1.503	0.459	0.764	–0.822
0.6	1.496	–1.454	0.532	0.677	–0.897
0.7	1.353	–1.397	0.595	0.585	–0.947
0.8	1.216	–1.335	0.649	0.489	–0.973
0.9	1.086	–1.268	0.693	0.392	–0.977
1.0	0.962	–1.197	0.727	0.295	–0.962
1.2	0.738	–1.047	0.767	0.109	–0.885
1.4	0.544	–0.893	0.772	–0.056	–0.761
1.6	0.381	–0.741	0.746	–0.193	–0.609
1.8	0.247	–0.596	0.696	–0.298	–0.445
2.0	0.142	–0.464	0.628	–0.371	–0.283
3.0	–0.075	–0.040	0.225	–0.349	0.226
4.0	–0.050	0.052	0.000	–0.016	0.201
5.0	–0.009	0.025	–0.033	0.013	0.046

Z	B_y	B_s	B_m	B_v	B_p
0.0	1.623	–1.750	1.000	0.000	0.000
0.1	1.453	–1.650	1.000	–0.007	–0.145
0.2	1.293	–1.550	0.999	–0.028	–0.259
0.3	1.143	–1.450	0.994	–0.058	–0.343
0.4	1.003	–1.351	0.987	–0.095	–0.401
0.5	0.873	–1.253	0.976	–0.137	–0.436
0.6	0.752	–1.156	0.960	–0.181	–0.451
0.7	0.642	–1.061	0.939	–0.226	–0.449
0.8	0.540	–0.968	0.914	–0.270	–0.432
0.9	0.448	–0.878	0.885	–0.312	–0.403
1.0	0.364	–0.792	0.852	–0.350	–0.364
1.2	0.223	–0.629	0.775	–0.414	–0.268
1.4	0.112	–0.482	0.668	–0.456	–0.157
1.6	0.029	–0.354	0.594	–0.477	–0.047
1.8	–0.030	–0.245	0.498	–0.476	0.054
2.0	–0.070	–0.155	0.404	–0.456	0.140
3.0	–0.089	0.057	0.059	–0.0213	0.268
4.0	–0.028	0.049	0.042	0.017	0.112
5.0	0.000	0.011	0.026	0.029	–0.002