UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
(ONLINE)
SEMESTER II
SESSION 2020/2021

COURSE NAME	:	ADVANCED FOUNDATION ENGINEERING
COURSE CODE	:	MFA 10303
PROGRAMME	:	MFA
EXAMINATION DATE	:	JULY 2021
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS. **OPEN BOOK EXAMINATION**

THIS QUESTION PAPER CONSISTS OF **FIFTEEN (15)** PAGES

Q1 (a) Construction of foundations is important in providing a stable and safe structures. Construction on soft soil will be a difficult task for engineers to build foundations for buildings. This can be solved by firstly simulating the conditions in software analysis. Based on your knowledge, construct the procedure in modeling the foundation construction in the Plaxis finite element software aided with appropriate figures. Your answer should consist of the selection of suitable soil parameters, structures, boundary condition, initial condition, mesh and stage construction and expected results of the model.

(10 marks)

(b) Define ultimate bearing capacity.

(2 marks)

(c) List **TWO (2)** characteristic of shallow foundation

(2 marks)

(d) A rigid square footing is used under a three storey building with a size of 1.5 m x 1.5 m. The load from the structure imposes a soil pressure of (q_o) 200 kN/m^2 on the soil. The depth (D_f) of the foundation is 1 m below the surface. The poisson ratio (μ) and elastic modulus (E_s) of the soil is 0.4 and 11000 kN/m^2. The thickness (H) of the soil layer is 5m. Calculate the elastic settlement at the center of the foundation using the theory of elasticity.

(11 marks)

Q2 (a) Explain in detail with the aid of sketches **SIX (6)** conditions that require pile foundations.

(6 marks)

(b) Working in construction sites requires fundamental knowledge in civil engineering. Explain in detail on how can the load carrying capacity of a single pile be assessed in the field.

(5 marks)

(c) A site investigation report shown in **Table Q2(c)** is used to assist in estimating the load capacity of a bored pile. A 14 m bored pile with 1 m diameter is used for the proposed structure. Based on the information from the site investigation report, calculate the allowable load capacity of the pile with a factor of safety of 2.

(14 marks)

Q3 (a) State the lateral earth pressure theories available and discuss in detail the major differences between the two theories.

(4 marks)

(b) **Figure Q3(b)** shows the construction of a newly developed housing project at a hillside that was badly affected by a recent landslide. Hypothesize **THREE (3)** possible causes in which triggered this geotechnical problem with suitable illustration.

(6 marks)

(c) In order to avoid anymore slope failures at the location as seen in **Figure Q3(b)**, a mechanically stabilised retaining wall using metallic strips is constructed at a backfill as shown in **Figure Q3(c)**. The reinforced wall is 8-m-high and has a granular backfill. The properties of the reinforcement are as follows:

Vertical spacing = 1.2m
Horizontal Spacing = 1.5m
Width of reinforcement = 150mm
Yield of breaking strength of tie material = 300MN/m^2
Soil – tie friction angel = 25°
Factor of safety against tie pullout = 3
Factor of safety against tie breaking = 3
corrosion rate of the galvanized
Steel to be 0.025 mm/year and the life span of the structure to be 100 years

Determine:

i) The required thickness of ties.

(6 marks)

ii) The required maximum length of ties.

(9 marks)

Q4 (a) Discuss **THREE (3)** purposes of designing appropriate machine foundation.

(5 marks)

(b) Discuss **TWO (2)** common factors influencing stress-deformation and strength characteristics of cohesive soil under cyclic loading.

(4 marks)

(c) A single cylinder engine is mounted on a concrete foundation block of the dimension 5.5m x 2.5m x 0.75m (length x width x thickness). The soil below the foundation is a pure clay with a unit weight of 16 kN/m^3, shear modulus of 16,500 kN/m^2, concrete unit weight of 25 kN/m^3 and Poisson's ratio of 0.33. A' is assumed to be 0.20.
The specification of the engine is as follows:

Weight of the machine = 22.00 kN
Primary force , F_p = 9.00 kN
Secondary force , F_s = 3 kN
Operating speed = 2000 rpm

Calculate:

(i) Total force acted on the soil surface due to the mass of foundation block and machine.

(3 marks)

(ii) Radius of loading area, ro for the foundation.

(3 marks)

(iii) Mass ratio, b for the foundation.

(3 marks)

(iv) Resonance frequency, f_{res} for the system.

(3 marks)

(v) Amplitude of vibration for the system.

(4 marks)

END OF QUESTIONS

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Table Q1(d)i: Variation of F_1 with m' and n'

	m'									
n'	1.0	1.2	1.4	1.6	1.8	2.0	2.5	3.0	3.5	4.0
0.25	0.014	0.013	0.012	0.011	0.011	0.011	0.010	0.010	0.010	0.010
0.50	0.049	0.046	0.044	0.042	0.041	0.040	0.038	0.038	0.037	0.037
0.75	0.095	0.090	0.087	0.084	0.082	0.080	0.077	0.076	0.074	0.074
1.00	0.142	0.138	0.134	0.130	0.127	0.125	0.121	0.118	0.116	0.115
1.25	0.186	0.183	0.179	0.176	0.173	0.170	0.165	0.161	0.158	0.157
1.50	0.224	0.224	0.222	0.219	0.216	0.213	0.207	0.203	0.199	0.197
1.75	0.257	0.259	0.259	0.258	0.255	0.253	0.247	0.242	0.238	0.235
2.00	0.285	0.290	0.292	0.292	0.291	0.289	0.284	0.279	0.275	0.271
2.25	0.309	0.317	0.321	0.323	0.323	0.322	0.317	0.313	0.308	0.305
2.50	0.330	0.341	0.347	0.350	0.351	0.351	0.348	0.344	0.340	0.336
2.75	0.348	0.361	0.369	0.374	0.377	0.378	0.377	0.373	0.369	0.365
3.00	0.363	0.379	0.389	0.396	0.400	0.402	0.402	0.400	0.396	0.392
3.25	0.376	0.394	0.406	0.415	0.420	0.423	0.426	0.424	0.421	0.418
3.50	0.388	0.408	0.422	0.431	0.438	0.442	0.447	0.447	0.444	0.441
3.75	0.399	0.420	0.436	0.447	0.454	0.460	0.467	0.458	0.466	0.464
4.00	0.408	0.431	0.448	0.460	0.469	0.476	0.484	0.487	0.486	0.484
4.25	0.417	0.440	0.458	0.472	0.481	0.484	0.495	0.514	0.515	0.515
4.50	0.424	0.450	0.469	0.484	0.495	0.503	0.516	0.521	0.522	0.522
4.75	0.431	0.458	0.478	0.494	0.506	0.515	0.530	0.536	0.539	0.539
5.00	0.437	0.465	0.487	0.503	0.516	0.526	0.543	0.551	0.554	0.554
5.25	0.443	0.472	0.494	0.512	0.526	0.537	0.555	0.564	0.568	0.569
5.50	0.448	0.478	0.501	0.520	0.534	0.546	0.566	0.576	0.581	0.584
5.75	0.453	0.483	0.508	0.527	0.542	0.555	0.576	0.588	0.594	0.597
6.00	0.457	0.489	0.514	0.534	0.550	0.563	0.585	0.598	0.606	0.609
6.25	0.461	0.493	0.519	0.540	0.557	0.570	0.594	0.609	0.617	0.621
6.50	0.465	0.498	0.524	0.546	0.563	0.577	0.603	0.618	0.627	0.632
6.75	0.468	0.502	0.529	0.551	0.569	0.584	0.610	0.627	0.637	0.643
7.00	0.471	0.506	0.533	0.556	0.575	0.590	0.618	0.635	0.646	0.653
7.25	0.474	0.509	0.538	0.561	0.580	0.596	0.625	0.643	0.655	0.662
7.50	0.477	0.513	0.541	0.565	0.585	0.601	0.631	0.650	0.663	0.671
7.75	0.480	0.516	0.545	0.569	0.589	0.606	0.637	0.658	0.671	0.680
8.00	0.482	0.519	0.549	0.573	0.594	0.611	0.643	0.664	0.678	0.688
8.25	0.485	0.522	0.552	0.577	0.598	0.615	0.648	0.670	0.685	0.695
8.50	0.487	0.524	0.555	0.580	0.601	0.619	0.653	0.676	0.692	0.703
8.75	0.489	0.527	0.558	0.583	0.605	0.623	0.658	0.682	0.698	0.710
9.00	0.491	0.529	0.560	0.587	0.609	0.627	0.663	0.687	0.705	0.716
9.25	0.493	0.531	0.563	0.589	0.612	0.631	0.667	0.693	0.710	0.723
9.50	0.495	0.533	0.565	0.592	0.615	0.634	0.671	0.697	0.716	0.719
9.75	0.496	0.536	0.568	0.595	0.618	0.638	0.675	0.702	0.721	0.735
10.00	0.498	0.537	0.570	0.597	0.621	0.641	0.679	0.707	0.726	0.740
20.00	0.529	0.575	0.614	0.647	0.677	0.702	0.756	0.797	0.830	0.858
50.00	0.548	0.598	0.640	0.678	0.711	0.740	0.803	0.853	0.895	0.931
100.00	0.555	0.605	0.649	0.688	0.722	0.753	0.819	0.872	0.918	0.956

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Table Q1(d)ii: Variation of F_2 with m' and n'

Table 7.3 Variation of F_2 with m' and n'

n'	m' 1.0	1.2	1.4	1.6	1.8	2.0	2.5	3.0	3.5	4.0
0.25	0.049	0.050	0.051	0.051	0.051	0.052	0.052	0.052	0.052	0.052
0.50	0.074	0.077	0.080	0.081	0.083	0.084	0.086	0.086	0.0878	0.087
0.75	0.083	0.089	0.093	0.097	0.099	0.101	0.104	0.106	0.107	0.108
1.00	0.083	0.091	0.098	0.102	0.106	0.109	0.114	0.117	0.119	0.120
1.25	0.080	0.089	0.096	0.102	0.107	0.111	0.118	0.122	0.125	0.127
1.50	0.075	0.084	0.093	0.099	0.105	0.110	0.118	0.124	0.128	0.130
1.75	0.069	0.079	0.088	0.095	0.101	0.107	0.117	0.123	0.128	0.131
2.00	0.064	0.074	0.083	0.090	0.097	0.102	0.114	0.121	0.127	0.131
2.25	0.059	0.069	0.077	0.085	0.092	0.098	0.110	0.119	0.125	0.130
2.50	0.055	0.064	0.073	0.080	0.087	0.093	0.106	0.115	0.122	0.127
2.75	0.051	0.060	0.068	0.076	0.082	0.089	0.102	0.111	0.119	0.125
3.00	0.048	0.056	0.064	0.071	0.078	0.084	0.097	0.108	0.116	0.122
3.25	0.045	0.053	0.060	0.067	0.074	0.080	0.093	0.104	0.112	0.119
3.50	0.042	0.050	0.057	0.064	0.070	0.076	0.089	0.100	0.109	0.116
3.75	0.040	0.047	0.054	0.060	0.067	0.073	0.086	0.096	0.105	0.113
4.00	0.037	0.044	0.051	0.057	0.063	0.069	0.082	0.093	0.102	0.110
4.25	0.036	0.042	0.049	0.055	0.061	0.066	0.079	0.090	0.099	0.107
4.50	0.034	0.040	0.046	0.052	0.058	0.063	0.076	0.086	0.096	0.104
4.75	0.032	0.038	0.044	0.050	0.055	0.061	0.073	0.083	0.093	0.101
5.00	0.031	0.036	0.042	0.048	0.053	0.058	0.070	0.080	0.090	0.098
5.25	0.029	0.035	0.040	0.046	0.051	0.056	0.067	0.078	0.087	0.095
5.50	0.028	0.033	0.039	0.044	0.049	0.054	0.065	0.075	0.084	0.092
5.75	0.027	0.032	0.037	0.042	0.047	0.052	0.063	0.073	0.082	0.090
6.00	0.026	0.031	0.036	0.040	0.045	0.050	0.060	0.070	0.079	0.087
6.25	0.025	0.030	0.034	0.039	0.044	0.048	0.058	0.068	0.077	0.085
6.50	0.024	0.029	0.033	0.038	0.042	0.046	0.056	0.066	0.075	0.083
6.75	0.023	0.028	0.032	0.036	0.041	0.045	0.055	0.064	0.073	0.080
7.00	0.022	0.027	0.031	0.035	0.039	0.043	0.053	0.062	0.071	0.078
7.25	0.022	0.026	0.030	0.034	0.038	0.042	0.051	0.060	0.069	0.076
7.50	0.021	0.025	0.029	0.033	0.037	0.041	0.050	0.059	0.067	0.074
7.75	0.020	0.024	0.028	0.032	0.036	0.039	0.048	0.057	0.065	0.072
8.00	0.020	0.023	0.027	0.031	0.035	0.038	0.047	0.055	0.063	0.071
8.25	0.019	0.023	0.026	0.030	0.034	0.037	0.046	0.054	0.062	0.069
8.50	0.018	0.022	0.026	0.029	0.033	0.036	0.045	0.053	0.060	0.067
8.75	0.018	0.021	0.025	0.028	0.032	0.035	0.043	0.051	0.059	0.066
9.00	0.017	0.021	0.024	0.028	0.031	0.034	0.042	0.050	0.057	0.064
9.25	0.017	0.020	0.024	0.027	0.030	0.033	0.041	0.049	0.056	0.063
9.50	0.017	0.020	0.023	0.026	0.029	0.033	0.040	0.048	0.055	0.061
9.75	0.016	0.019	0.023	0.026	0.029	0.032	0.039	0.047	0.054	0.060
10.00	0.016	0.019	0.022	0.025	0.028	0.031	0.038	0.046	0.052	0.059
20.00	0.008	0.010	0.011	0.013	0.014	0.016	0.020	0.024	0.027	0.031
50.00	0.003	0.004	0.004	0.005	0.006	0.006	0.008	0.010	0.011	0.013
100.00	0.002	0.002	0.002	0.003	0.003	0.003	0.004	0.005	0.006	0.006

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Table Q1(d)iii: Variation of I_f with D_f/B, B/L and μ

		B/L		
μ_s	D_f/B	0.2	0.5	1.0
0.3	0.2	0.95	0.93	0.90
	0.4	0.90	0.86	0.81
	0.6	0.85	0.80	0.74
	1.0	0.78	0.71	0.65
0.4	0.2	0.97	0.96	0.93
	0.4	0.93	0.89	0.85
	0.6	0.89	0.84	0.78
	1.0	0.82	0.75	0.69
0.5	0.2	0.99	0.98	0.96
	0.4	0.95	0.93	0.89
	0.6	0.92	0.87	0.82
	1.0	0.85	0.79	0.72

Table Q2(c): Site investigation soil information

Depth (m)	Length of each layer (m)	Soil parameters given	Soil Description
0 - 5	5	γ = 17.8 kN/m^2 ϕ = 28° s_u = 28 kPa OCR = 1	Soft Clay
5 - 10	5	γ = 18.8 kN/m^2 ϕ = 24° s_u = 60 kPa OCR = 4	Stiff Clay
10 - 13	3	γ = 19 kN/m^2 ϕ = 28° s_u = 70 kPa OCR = 4	Stiff Clay
13 – 15	2	N_{60} = 28	Sand
15 – 17	2	N_{60} = 33	Sand
17 - 20	3	N_{60} = 31	Sand

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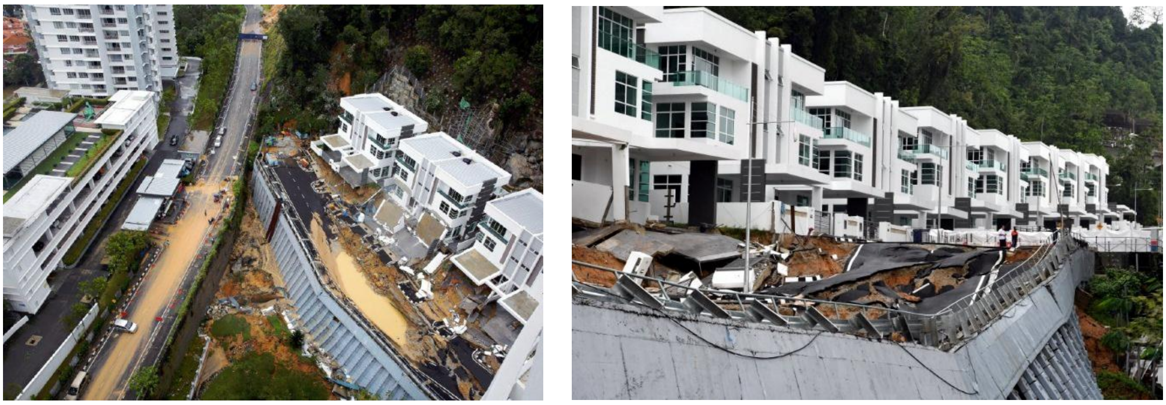

Figure Q3(b): Landslide problems

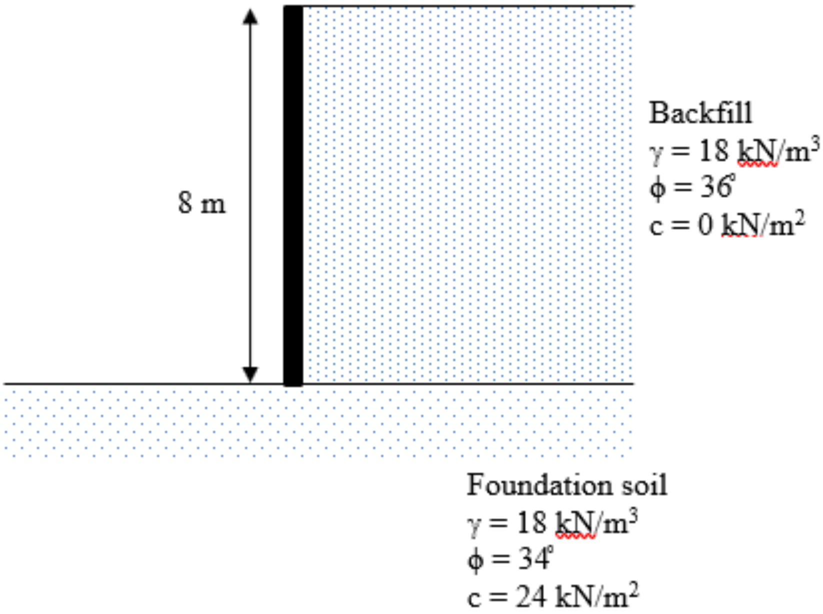

Figure Q3(c): Retaining wall

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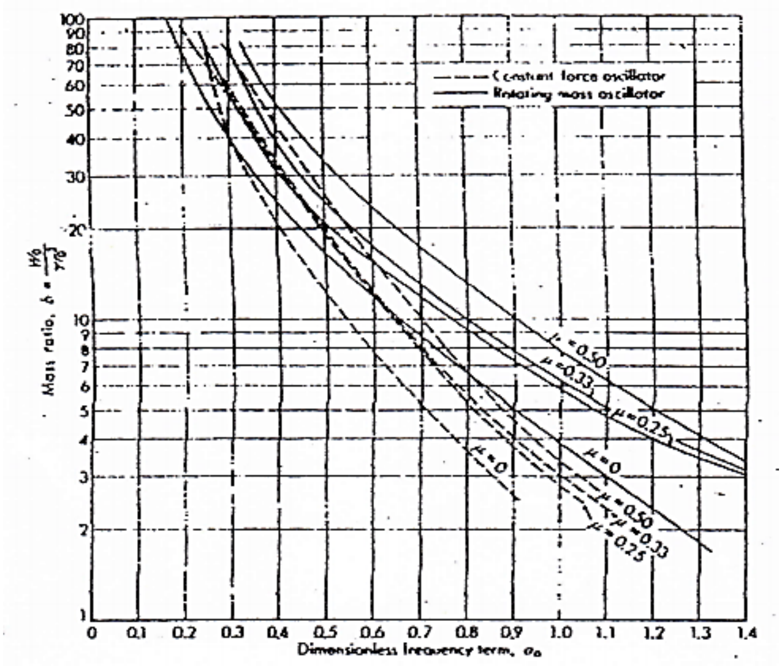

Figure Q4(c): Frequency factor vs mass-ratio relationship for several vaues of Poisson's ratio

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Factor of safety

$$q_{all} = \frac{q_u}{FS} \qquad q_{all(\text{net})} = \frac{q_u - \gamma D_f}{FS}$$

$$\bar{q} = D_1\gamma + D_2(\gamma_2 - \gamma_w) \qquad \bar{q} = \gamma D_f$$

$$\bar{\gamma} = \gamma' + \frac{d}{B}(\gamma - \gamma')$$

Meyerhof's general bearing capacity

$$q_u = c'N_c F_{cs} F_{cd} F_{ci} + \bar{q} N_q F_{qs} F_{qd} F_{qi} + \tfrac{1}{2}\bar{\gamma} B N_\gamma F_{\gamma s} F_{\gamma d} F_{\gamma i}$$

$$F_{cs} = 1 + \frac{B}{L}\cdot\frac{N_q}{N_c} \qquad F_{qs} = 1 + \frac{B}{L}\tan\phi' \qquad F_{\gamma s} = 1 - 0.4\left(\frac{B}{L}\right)$$

$$F_{ci} = F_{qi} = \left(1 - \frac{\beta^\circ}{90^\circ}\right)^2 \qquad F_{\gamma i} = \left(1 - \frac{\beta}{\phi'}\right)^2$$

$$\frac{D_f}{B} \le 1 : \phi' = 0^\circ$$

$$F_{cd} = 1 + 0.4\left(\frac{D_f}{B}\right) \qquad F_{qd} = 1 \qquad F_{\gamma d} = 1$$

$$\frac{D_f}{B} \le 1 : \phi' > 0^\circ$$

$$F_{cd} = F_{qd} - \frac{1 - F_{qd}}{N_c \tan\phi'} \qquad F_{qd} = 1 + 2\tan\phi'(1 - \sin\phi')^2 \frac{D_f}{B} \qquad F_{\gamma d} = 1$$

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cont.

Meyerhof's general bearing capacity

$$\frac{D_f}{B} > 1 : \phi' = 0°$$

$$F_{cd} = 1 + 0.4\tan^{-1}\left(\frac{D_f}{B}\right) \qquad F_{qd} = 1 \qquad F_{\gamma d} = 1$$

$$\frac{D_f}{B} > 1 : \phi' > 0°$$

$$F_{cd} = F_{qd} - \frac{1 - F_{qd}}{N_c \tan\phi'} \qquad F_{qd} = 1 + 2\tan\phi'(1 - \sin\phi')^2\tan^{-1}\left(\frac{D_f}{B}\right) \qquad F_{\gamma d} = 1$$

One way eccentricity

$$B' = B - 2e \quad \& \quad L' = L \qquad L' = L - 2e \quad \& \quad B' = B$$

Elastic settlement for shallow foundations

$$I_s = F_1 + \frac{2 - \mu_s}{1 - \mu_s}F_2$$

$$S_{e(Flex)} = q_o(\alpha B')\frac{1 - \mu_s^2}{E_s} I_s I_f$$

Primary consolidation settlement for shallow and pile foundations

normally consolidated clays

$$S_c = \frac{C_c H_c}{1 + e_o}\log\frac{\sigma'_o + \Delta\sigma'_{av}}{\sigma'_o}$$

Over consolidated clays

$$\sigma'_o + \Delta\sigma'_{av} < \sigma'_c : S_c = \frac{C_s H_c}{1 + e_o}\log\frac{\sigma'_o + \Delta\sigma'_{av}}{\sigma'_o}$$

$$\sigma'_o < \sigma'_c < \sigma'_o + \Delta\sigma'_{av} : S_c = \frac{C_s H_c}{1 + e_o}\log\frac{\sigma'_c}{\sigma'_o} + \frac{C_c H_c}{1 + e_o}\log\frac{\sigma'_o + \Delta\sigma'_{av}}{\sigma'_c}$$

average increase in pressure

$$\Delta\sigma'_{av} = \tfrac{1}{6}(\Delta\sigma'_{\text{top}} + 4\Delta\sigma'_{\text{middle}} + \Delta\sigma'_{\text{bottom}}) \qquad \Delta\sigma'_o = q_o I_c$$

$$m_1 = L/B \qquad n_1 = z/(B/2)$$

Site investigations

$$A_R = \frac{D_2^2 - D_1^2}{D_1^2} \times 100\% \qquad R_R = RQD = \frac{L_{\text{recovered}}}{L_{\text{total}}} \times 100\%$$

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Mat foundations

$$q_{net} = \frac{N_{60}}{0.08}\left[1 + 0.33\left(\frac{D_f}{B}\right)\right]\left[\frac{S_e}{25}\right] \leq 16.63 N_{60}\left[\frac{S_e}{25}\right]$$

$$q = \frac{Q}{A} \pm \frac{M_y x}{I_y} \pm \frac{M_x y}{I_x}$$

$$I_x = \left(\frac{1}{12}\right) B L^3$$

$$I_y = \left(\frac{1}{12}\right) L B^3$$

$$M_x = Q e_y$$

$$M_y = Q e_x$$

$$x^i = \frac{Q_1 x_1' + Q_2 x_2' + Q_3 x_3' + ..}{Q}$$

$$e_x = x' - \frac{B}{2}$$

$$y^i = \frac{Q_1 y_1' + Q_2 y_2' + Q_3 y_3' + ..}{Q}$$

$$e_y = y' - \frac{B}{2}$$

Pile Foundation

Point Bearing

Meyerhof

Sand $Q_p = A_p q' N_q^* \leq A_p q_l$

$q_l = 0.5 p_a N_q^* \tan\phi'$

Clay $Q_p = 9 c_u A_p$

Vesic

Sand $Q_p = A_p q_p = A_p \bar{\sigma}_o' N_\sigma^*$

Clay $Q_p = A_p q_p = A_p c_u N_c^*$

Coyle and Castello

Sand $Q_p = q' N_q^* A_p$

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For Drilled Shaft/ Bored Pile Frictional Resistance

$\alpha_u = 0.5; \quad \frac{s_u}{p_a} \leq 1.5$

$f_s = \alpha_u s_u \leq 380\ kPa$

For Drilled Shaft/ Bored Pile Point Bearing

$$f_b = 57.5N_{60}; \quad f_b \leq \ 2900(kPa); \ \frac{L}{D} \geq 10$$

$$f_b = 57.5N_{60}; \quad f_b \leq \ 290L(kPa); \ \frac{L}{D} < 10$$

Frictional Resistance

Sand $Q_s = \Sigma p\Delta L f$

$f = K\sigma_o' tan\delta'$

$\delta = 0.8\phi$

Clay

α method, $Q_s = \Sigma \alpha c_u p\Delta L$

λ method, $Q_s = pLf_{av}$

$f_{av} = \lambda(\bar{\sigma}_o' + 2c_u)$

β method $Q_s = \Sigma f p\Delta L$

$f = \beta\sigma_o'$

Correlation with Cone penetration

$Q_p = A_p q_c$

$q_p = q_c$

$Q_s = \Sigma p\Delta L f$

$f = \alpha' f_c$

$f_c = Frictional\ resistance$

Correlation with SPT

$Q_p = A_p q_p$

$q_p = 0.4p_a N_{60} \frac{L}{D} \leq 4p_a N_{60}$

$Q_s = pLf_{av}$

$f_{av} = 0.02p_a N_{60}$

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Conventional retaining walls

Rankine active and passive pressure

$$P_a = \tfrac{1}{2} K_a \gamma_1 H^2 \qquad P_a = \tfrac{1}{2} K_a \gamma_1 H^2 + qK_a H$$

$$P_v = P_a \sin\alpha^\circ \qquad P_h = P_a \cos\alpha^\circ$$

$$P_p = \tfrac{1}{2} K_p \gamma_2 D^2 + 2c_2' \sqrt{K_p} D$$

$$K_a = \tan^2\left(45^\circ - \tfrac{1}{2}\phi_1'\right) \qquad K_p = \tan^2\left(45^\circ + \tfrac{1}{2}\phi_2'\right)$$

Factor of safety against overturning

$$FS = \frac{\Sigma W_i X_i}{\Sigma P_{a_i} z_{a_i}} = \frac{\Sigma(A_i \times \gamma_i) X_i}{\Sigma P_{a_i} z_{a_i}}$$

$$FS = \frac{\gamma_{n+i} A_{n+i} x_{n+i} + \mathrm{K} + \gamma_n A_n x_n}{P_a \cos\alpha (H'/3)}$$

Factor of safety against sliding

$$FS = \frac{\Sigma V \tan\left(\tfrac{2}{3}\phi_2'\right) + \tfrac{2}{3} B c_2' + P_p}{P_a \cos\alpha}$$

Retaining walls with geotextile and geogrid reinforcement

$$\sigma_o' = \sigma_{o_1}' + \sigma_{o_2}' \qquad \sigma_{o_1}' = \gamma_1 z$$

$$\sigma_{o_2}' = \frac{qa'}{a' + z} \text{ for } z \le 2b' \qquad \sigma_{o_2}' = \frac{qa'}{a' + \tfrac{1}{2} z + b'} \text{ for } z > 2b'$$

$$FS_B = \frac{w f_y}{\sigma_a' S_V S_H} \qquad F_R = 2 L_e w \sigma_o' \tan\phi_\mu'$$

$$\sigma_a' = \sigma_{a_1}' + \sigma_{a_2}' \qquad \sigma_{a_1}' = \gamma_1 z K_a$$

$$\sigma_{a_2}' = M\left[\frac{2q}{\pi}(\beta - \sin\beta\cos 2\alpha)\right] \qquad M = 1.4 - \frac{0.4b'}{0.14H} \ge 1$$

$$FS_P = \frac{2 L_e w \sigma_o' \tan\phi_\mu'}{\sigma_a' S_V S_H} \qquad L = \frac{H - z}{\tan(45^\circ + \tfrac{1}{2}\phi_1')} + \frac{FS_P \sigma_a' S_V S_H}{2 w \sigma_o' \tan\phi_\mu'}$$

overturning factor of safety

$$FS = \frac{M_R}{M_O} = \frac{(W_1 x_1 + W_2 x_2 + \ldots + qa')\left(b' + \tfrac{1}{2} a'\right)}{P_a z_a}$$

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sliding factor of safety

$$FS = \frac{F_R}{F_d} = \frac{(W_1x_1 + W_2x_2 + \ldots + qa')[\tan(\phi_1')]}{P_a}$$

bearing capacity factor of safety

$$FS = \frac{q_{ult}}{\sigma'_{o_H}} = \frac{c_2'N_c + \frac{1}{2}\gamma_2 L_2 N_\gamma}{\gamma_1 H + \sigma'_{o_2}}$$

Galvanized Steel-Strip Reinforcement

$$T_{max} = \sigma_{a(\max)} S_v S_H$$

$$\sigma_{a(\max)} = \gamma_1 H tan^2(45 - \frac{\phi_1}{2})$$

$$t = \frac{\left[\gamma_1 H tan^2(45 - \frac{\phi_1}{2}) S_v S_H\right] FS_{(B)}}{w f_y}$$

$$L = \frac{(H - z)}{\tan(45 - \frac{\phi_1}{2})} + \frac{FS_{(p)}\gamma_1 z K_a S_v S_H}{2w\gamma_1 z tan\phi_\mu}$$

Equations Machine Vibrations

$$W_o = W_b + W_m$$

$$r_o = \sqrt{\left(\frac{Area}{\pi}\right)}$$

$$b = \frac{W_o}{\gamma\, r_o^3}$$

$$f_{res} = \frac{a_o}{2\pi\, r_o}\sqrt{\frac{Gg}{\gamma}}$$

$$F = (F_p + F_s)\left(\frac{f_{res}}{f_o}\right)^2$$

$$F = 2\, me\, \omega_{res}^2$$

$$N' = N\left(\frac{f_o}{f_{res}}\right)^2$$

$$W_e = 2me$$

$$X = N\left(\frac{f_o}{f_{res}}\right)^2\left(\frac{W_e}{W_o}\right)$$