UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2021/2022

COURSE NAME	:	FOUNDATION ENGINEERING
COURSE CODE	:	BFC 43103
PROGRAMME CODE	:	BFF
EXAMINATION DATE	:	JULY 2022
DURATION	:	3 HOURS
INSTRUCTION	1.	ANSWER **ALL** QUESTIONS IN **PART A** AND **TWO (2)** QUESTIONS IN **PART B.**
	2.	THIS FINAL EXAMINATION IS AN **ONLINE** ASSESSMENT AND CONDUCTED VIA **CLOSED BOOK.**
	3.	STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

THIS QUESTION PAPER CONSISTS OF **SIXTEEN (16)** PAGES

PART A

Q1 (a) Identify how piles are classified according to the method of installation and function.
(5 marks)

(b) The variation of N_{60} with depth in a granular soil deposit is as shown in **Table Q1(b)**. A rectangular concrete pile 7.5 m long (0.5 m x 0.5 m in cross section) is driven into the sand and fully embedded in the soil. For the proposed site, given: Design load = 1112.1 kN, FOS = 3.0, P_a = 100 kN/m^2 and L_{pile} = 7.5 m.

(i) Design Q_p by using data given in **Table Q1(b)**
(6 marks)

(ii) Design Q_s by using data given in **Table Q1(b)**
(5 marks)

(iii) Estimate the allowable bearing capacity Q_{all} of the pile
(3 marks)

(iv) Predict the elastic settlement of the pile based on the situation.
(6 marks)

Q2 (a) The backfill used in the construction of the retaining wall has expansive behaviour. These materials swell significantly when in contact with water during rainfall and floods, resulting in large lateral pressure on the retaining wall. As a geotechnical engineer, propose **TWO (2)** methods to maintain the stability of the retaining wall.
(6 marks)

(b) The proposed design of the cantilever retaining wall will be constructed on clay soil as shown in **Figure Q2 (b).** The backfill is a coarse grained soil and inclined at 8°. The live load from a rural main road is 15 kN/m^2 .The ground water level is located 2 m below the base.

(i) Evaluate the stability of the retaining wall in terms of overturning
(6 marks)

(ii) Design the stability of the retaining wall in terms of bearing capacity.
(5 marks)

(iii) Evaluate the factor of safety against sliding of the proposed retaining structure.
(5 marks)

(iv) If the factor of safety against sliding is less than 1.5, propose **THREE (3)** suitable methods to increase the stability against sliding.

(3 marks)

PART B

Q3 (a) Due to high loading of traffic, the local government is planning to widen the federal road from Batu Pahat to Air Hitam in the near future. The Design Department of JKR is requested to propose ground improvement works that needs to be carried out in advance before commencement of the road widening project.

(i) The use of PVD together with surcharge load was proposed by the designer. Explain the working principles and details of this ground improvement technique with the illustration of relevant sketches.

(6 marks)

(ii) Discuss any **TWO (2)** disadvantages of using this technique when compared to soil replacement method.

(4 marks)

(b) Cement stabilization was proposed by the designer. Briefly discuss any **TWO (2)** advantages and **TWO (2)** disadvantages compared to the mechanical stabilization method using roller.

(8 marks)

(c) Evaluate whether dynamic compaction using tamper is suitable in this case. Based on the desk study, the soil formation at the proposed site is comprised of quaternary marine deposit.

(7 marks)

Q4 (a) A new building will be constructed at Taman Seri Indah area. For foundation, the consultant engineer has suggested to use a shallow foundation instead of deep foundation. Compare the difference between shallow foundation and deep foundation. Use sketches to support your answer.

(5 marks)

(b) The consultant engineer suggested to build a bungalow house with one floor at Elmina area. A 2.0 m wide strip foundation is placed in sand at 1.0 m depth. The properties of the sand are: γ = 19.5 kN/m^3 , c = 0, and ϕ'= 34^0. Determine the maximum wall load that the foundation can carry, with a factor of safety of 3.0.

(8 marks)

(c) You anticipate the foundation for a proposed highway bridge will consist of end bearing piles driven through the overlying soils to bedrock. However, you are not certain the location of the bedrock.. You wish to obtain at least an approximate idea of the depth to bedrock before you begin drilling the exploratory borings. Propose plan of work to obtain the data needed

(12 marks)

Q5 (a) The road between Ayer Hitam and Batu Pahat had to be restricted due to the collapse of a 9-meter high soil slope. Mr. Ahmad recommended the cantilever sheet pile retaining structure as a method of stabilising the failing soil slope. Based on your experience,

(i) Write comment on Mr. Ahmad's selection of a retaining structure idea.

(4 marks)

(ii) Propose the suitable type of retaining structure, with a diagram to ensure the stability of the supported soil.

(5 marks)

(iii) Discuss the factors that should be considered while selecting a retaining structure.

(3 marks)

(b) (i) Explain in detail with the aid of sketches on what condition does pile foundations need to be used.

(5 marks)

(ii) A 12 m prestressed concrete pile 450 mm square is installed in a clay with water table at 5 m depth as shown in **Figure Q5(b)**. The upper clay layer is 5 m thick, with a unit weight (γ) of 17.4 kN/m^3. The lower clay layer has a unit weight (γ) of 18.1 kN/m^3. Determine the allowable pile capacity (Q_{all}) with factor of safety of 2 by using the simplest method.

(8 marks)

-END OF QUESTIONS-

FINAL EXAMINATION

SEMESTER / SESSION : SEM II 2021/2022 PROGRAMME CODE : BFF
COURSE NAME : FOUNDATION ENGINEERING COURSE CODE : BFC 43103

Table Q1(b): The SPT value for the proposed site

Depth of Soil Layer (m)	**Description**	**SPT (N_{60})**
0.0 – 1.50	Top soil, dark brown clayey silty sand	11
1.50 – 1.95	Medium dense with traces of gravel	11
3.00 – 3.45	Light greyish brown, silty sand	47
4.50 – 4.95	Greyish brown silty sand with some gravel	8
6.00 – 6.45	Medium dense silty sand	19
7.50 – 7.95	Medium grey silty sand with some gravel	31
9.00 – 9.33	Very dense silty sand	50
10.50 – 10.82	Very dense silty sand	50
12.00 – 12.32	Very dense silty sand	50
13.50 – 13.79	Very dense silty sand	50
15.00 – 15.445	Very dense silty sand	50
16.50 – 16.82	Very dense silty sand	50
18.00 – 18.32	Very dense silty sand	50

FINAL EXAMINATION

SEMESTER / SESSION : SEM II 2021/2022
COURSE NAME : FOUNDATION ENGINEERING
PROGRAMME CODE : BFF
COURSE CODE : BFC 43103

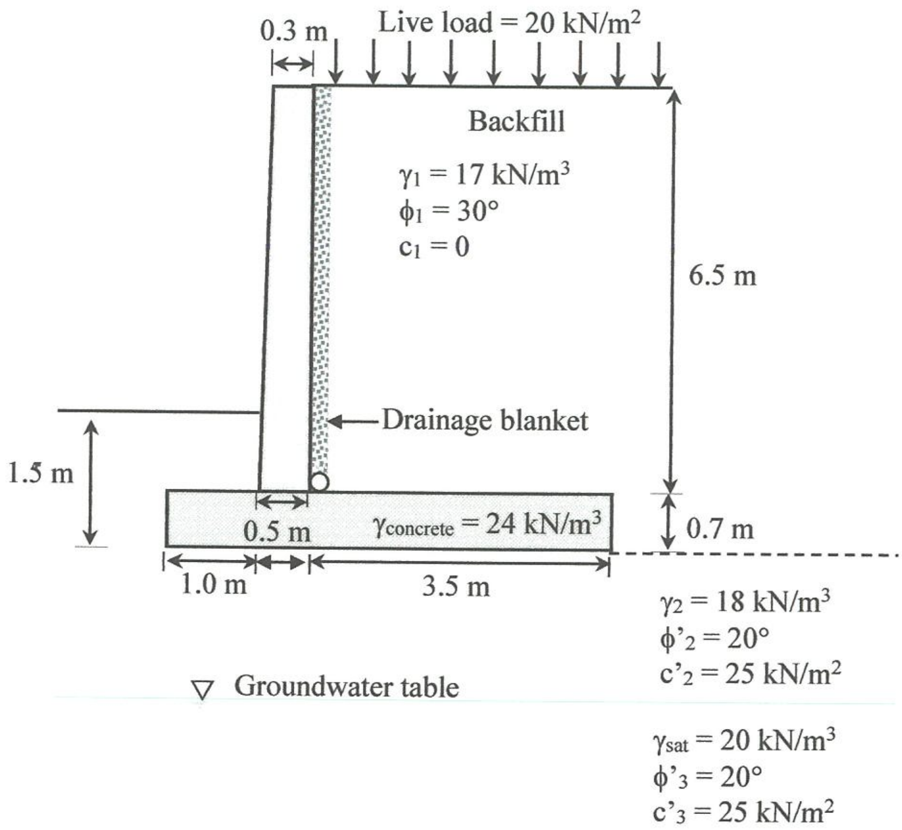

FIGURE Q2(b): Cantilever gravity retaining wall

FINAL EXAMINATION

SEMESTER / SESSION : SEM II 2021/2022
COURSE NAME : FOUNDATION ENGINEERING
PROGRAMME CODE : BFF
COURSE CODE : BFC 43103

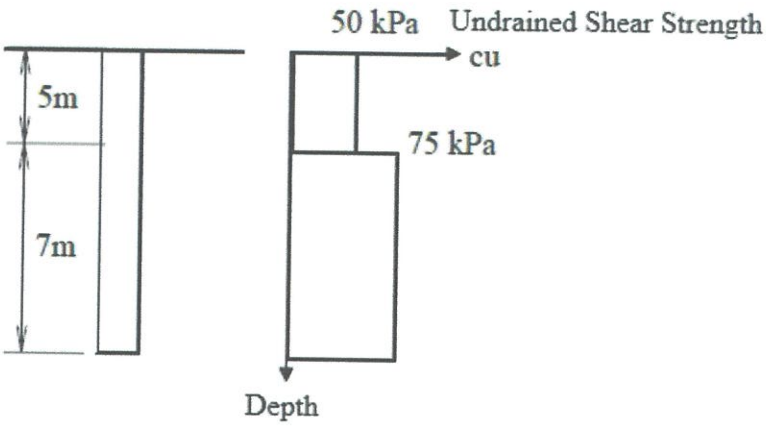

FIGURE Q5 (b) : Undrained shear strength

FINAL EXAMINATION

SEMESTER / SESSION : SEM II 2021/2022
COURSE NAME : FOUNDATION ENGINEERING
PROGRAMME CODE : BFF
COURSE CODE : BFC 43103

TABLE 1 : Terzaghi Bearing Capacity factor

ϕ'	N_c	N_q	N_γ^a	ϕ'	N_c	N_q	N_γ^a
0	5.70	1.00	0.00	26	27.09	14.21	9.84
1	6.00	1.10	0.01	27	29.24	15.90	11.60
2	6.30	1.22	0.04	28	31.61	17.81	13.70
3	6.62	1.35	0.06	29	34.24	19.98	16.18
4	6.97	1.49	0.10	30	37.16	22.46	19.13
5	7.34	1.64	0.14	31	40.41	25.28	22.65
6	7.73	1.81	0.20	32	44.04	28.52	26.87
7	8.15	2.00	0.27	33	48.09	32.23	31.94
8	8.60	2.21	0.35	34	52.64	36.50	38.04
9	9.09	2.44	0.44	35	57.75	41.44	45.41
10	9.61	2.69	0.56	36	63.53	47.16	54.36
11	10.16	2.98	0.69	37	70.01	53.80	65.27
12	10.76	3.29	0.85	38	77.50	61.55	78.61
13	11.41	3.63	1.04	39	85.97	70.61	95.03
14	12.11	4.02	1.26	40	95.66	81.27	115.31
15	12.86	4.45	1.52	41	106.81	93.85	140.51
16	13.68	4.92	1.82	42	119.67	108.75	171.99
17	14.60	5.45	2.18	43	134.58	126.50	211.56
18	15.12	6.04	2.59	44	151.95	147.74	261.60
19	16.56	6.70	3.07	45	172.28	173.28	325.34
20	17.69	7.44	3.64	46	196.22	204.19	407.11
21	18.92	8.26	4.31	47	224.55	241.80	512.84
22	20.27	9.19	5.09	48	258.28	287.85	650.67
23	21.75	10.23	6.00	49	298.71	344.63	831.99
24	23.36	11.40	7.08	50	347.50	415.14	1072.80
25	25.13	12.72	8.34				

FINAL EXAMINATION

SEMESTER / SESSION : SEM II 2021/2022 PROGRAMME CODE : BFF
COURSE NAME : FOUNDATION ENGINEERING COURSE CODE : BFC 43103

TABLE 2: Meyerhof's bearing capacity factor

ϕ'	N_c	N_q	N_γ	ϕ'	N_c	N_q	N_γ
0	5.14	1.00	0.00	26	22.25	11.85	12.54
1	5.38	1.09	0.07	27	23.94	13.20	14.47
2	5.63	1.20	0.15	28	25.80	14.72	16.72
3	5.90	1.31	0.24	29	27.86	16.44	19.34
4	6.19	1.43	0.34	30	30.14	18.40	22.40
5	6.49	1.57	0.45	31	32.67	20.63	25.99
6	6.81	1.72	0.57	32	35.49	23.18	30.22
7	7.16	1.88	0.71	33	38.64	26.09	35.19
8	7.53	2.06	0.86	34	42.16	29.44	41.06
9	7.92	2.25	1.03	35	46.12	33.30	48.03
10	8.35	2.47	1.22	36	50.59	37.75	56.31
11	8.80	2.71	1.44	37	55.63	42.92	66.19
12	9.28	2.97	1.69	38	61.35	48.93	78.03
13	9.81	3.26	1.97	39	67.87	55.96	92.25
14	10.37	3.59	2.29	40	75.31	64.20	109.41
15	10.98	3.94	2.65	41	83.86	73.90	130.22
16	11.63	4.34	3.06	42	93.71	85.38	155.55
17	12.34	4.77	3.53	43	105.11	99.02	186.54
18	13.10	5.26	4.07	44	118.37	115.31	224.64
19	13.93	5.80	4.68	45	133.88	134.88	271.76
20	14.83	6.40	5.39	46	152.10	158.51	330.35
21	15.82	7.07	6.20	47	173.64	187.21	403.67
22	16.88	7.82	7.13	48	199.26	222.31	496.01
23	18.05	8.66	8.20	49	229.93	265.51	613.16
24	19.32	9.60	9.44	50	266.89	319.07	762.89
25	20.72	10.66	10.88				

FINAL EXAMINATION

SEMESTER / SESSION	: SEM II 2021/2022	PROGRAMME CODE	: BFF
COURSE NAME	: FOUNDATION ENGINEERING	COURSE CODE	: BFC 43103

TABLE 3 : Variation of α

$\frac{c_u}{p_a}$	α
≤ 0.1	1.00
0.2	0.92
0.3	0.82
0.4	0.74
0.6	0.62
0.8	0.54
1.0	0.48
1.2	0.42
1.4	0.40
1.6	0.38
1.8	0.36
2.0	0.35
2.4	0.34
2.8	0.34

Note: p_a = atmospheric pressure
≈ 100 kN/m^2 or 2000 lb/ft^2

FINAL EXAMINATION

SEMESTER / SESSION : SEM II 2021/2022
COURSE NAME : FOUNDATION ENGINEERING
PROGRAMME CODE : BFF
COURSE CODE : BFC 43103

List of formula

SOIL IMPROVEMENT AND GROUND MODIFICATION

$$S_{c(p)} = \frac{C_c H_c}{1+e_o}\log\frac{\sigma_o' + \Delta\sigma_{(p)}'}{\sigma_o'}$$

$$S_{c(p+f)} = \frac{C_c H_c}{1+e_o}\log\frac{\sigma_o' + \left[\Delta\sigma_{(p)}' + \Delta\sigma_{(f)}'\right]}{\sigma_o'}$$

$$U = \frac{\log\left[\dfrac{\sigma_o' + \Delta\sigma_{(p)}'}{\sigma_o'}\right]}{\log\left[\dfrac{\sigma_o' + \Delta\sigma_{(p)}' + \Delta\sigma_{(f)}'}{\sigma_o'}\right]}$$

$$T_v = \frac{c_v t}{H_c^{\,2}}$$

For U%: 0% to 60%; $T_v = \frac{\pi}{4}\left(\frac{U\%}{100}\right)^2$

For U% > 60%;
$T_v = 1.781 - 0.931\log(100 - U\%)$

$$U = \frac{\log\left[1 + \dfrac{\Delta\sigma_{(p)}'}{\sigma_o'}\right]}{\log\left[1 + \dfrac{\Delta\sigma_{(p)}'}{\sigma_o'}\left(1 + \dfrac{\Delta\sigma_{(f)}'}{\sigma_{(p)}'}\right)\right]}$$

SITE INVESTIGATION

$$A_R(\%) = \frac{D_o^2 - D_i^2}{D_i^2}(\%)$$

$$N_{corrected} = C_N * N_{field}$$

$$C_N = 0.77\log_{10}\frac{1915}{p_o'}$$

$$N_{60} = \frac{N\eta_H\eta_B\eta_S\eta_R}{60}$$

where
N_{60} = Standard penetration number, corrected for field conditions.
η_H = Hammer Effiency (%)
η_B = Correction for borehole diameter
η_S = Sampler correction
η_R = Correction for rod length

Variation of η_B

Diameter (mm)	η_B
60 – 120	1
150	1.05
200	1.15

Variation of η_S

Rod lenght (mm)	η_B
Standard sampler	1.0
With liner for dense sand and clay	0.8
With liner for loose sand	0.9

Schmertmann's (1975) theory

$$\phi = \tan^{-1}\left[\frac{N_{60}}{12.2 + 20.3\left(\frac{\sigma_0'}{P_a}\right)}\right]^{0.34}$$

where, σ_0'= effective overburden pressure (kPa) = γH
P_a = atmospheric pressure

FINAL EXAMINATION

SEMESTER / SESSION	: SEM II 2021/2022	PROGRAMME CODE	: BFF
COURSE NAME	: FOUNDATION ENGINEERING	COURSE CODE	: BFC 43103

SHALLOW FOUNDATIONS

Modification of Bearing Capacity Equations for Water Table

Case I for water within $0 \leq D_1 \leq D_f$;	Case II for water within $0 \leq d \leq B$;	Case III when the water table is located so that $d \geq B$, the water will have no effect on the ultimate bearing capacity.
$q = D_1\gamma_{dry} + D_2(\gamma_{sat} - \gamma_w)$ $\gamma' = \gamma_{sat} - \gamma_w$	$q = D_1\gamma_{dry}$ $\bar{\gamma} = \gamma' + \frac{d}{B}(\gamma_{dry} - \gamma')$	

$$q_u = c'N_cF_{cs}F_{cd}F_{ci} + qN_qF_{qs}F_{qd}F_{qi} + \tfrac{1}{2}\gamma BN_\gamma F_{\gamma s}F_{\gamma d}F_{\gamma i}$$

Shape Factor

$F_{cs} = 1 + \frac{B}{L}\cdot\frac{N_q}{N_c}$	$F_{qs} = 1 + \frac{B}{L}\tan\phi$	$F_{\gamma s} = 1 - 0.4\frac{B}{L}$

Depth Factor

$D_f/B \leq 1, for\ \phi = 0$		
$F_{cd} = 1 + 0.4(D_f/B)$	$F_{qd} = 1$	$F_{\gamma d} = 1$
$D_f/B \leq 1, for\ \phi > 0$		
$F_{cd} = F_{qd} - \frac{1 - F_{qd}}{N_c tan\phi'}$	$F_{qd} = 1 + 2tan\phi'(1 - sin\phi')^2\frac{D_f}{B}$	$F_{\gamma d} = 1$
$D_f/B > 1, for\ \phi = 0$		
$F_{cd} = 1 + \underbrace{0.4\ tan^{-1}(D_f/B)}_{radians}$	$F_{qd} = 1$	$F_{\gamma d} = 1$
$D_f/B > 1, for\ \phi > 0$		
$F_{cd} = F_{qd} - \frac{1 - F_{qd}}{N_c tan\phi'}$	$F_{qd} = 1 + 2\tan\phi'(1 - sin\phi')^2\underbrace{tan^{-1}(\frac{D_f}{B})}_{radians}$	$F_{\gamma d} = 1$

where L is the length of the foundation and L>B.

Inclination Factor

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

β is the inclination of the load on the foundation with respect to vertical

Eccentric Loading in Shallow Foundations

FINAL EXAMINATION

SEMESTER / SESSION	: SEM II 2021/2022	PROGRAMME CODE	: BFF
COURSE NAME	: FOUNDATION ENGINEERING	COURSE CODE	: BFC 43103

$q_{max} = \frac{Q}{BL} \pm \frac{6M}{B^2L}$	$e = \frac{M}{Q}$
$q_{max} = \frac{4Q}{3L(B-2e)}$	$FS = \frac{Q_{ult}}{Q}$

FINAL EXAMINATION

SEMESTER / SESSION	: SEM II 2021/2022	PROGRAMME CODE	: BFF
COURSE NAME	: FOUNDATION ENGINEERING	COURSE CODE	: BFC 43103

SHALLOW FOUNDATIONS

$$q'_u = c'N_cF_{cs}F_{cd}F_{ci} + qN_qF_{qs}F_{qd}F_{qi} + \tfrac{1}{2}\gamma' B' N_\gamma F_{\gamma s}F_{\gamma d}F_{\gamma i}$$

One Way Eccentric Loading in Shallow Foundations

Method 1:

$$B' = B - 2e$$
$$L' = L$$
$$q'_u = c'N_cF_{cs}F_{cd}F_{ci} + qN_qF_{qs}F_{qd}F_{qi} + \tfrac{1}{2}\gamma' B' N_\gamma F_{\gamma s}F_{\gamma d}F_{\gamma i}$$
$$Q_{ult} = q'_u B' L'$$

Method 2:

$$Q_{ult} = B\left[c'N_{c(e)} + qN_{q(e)} + \frac{1}{2}\gamma B N_{\gamma(e)}\right]$$
$$Q_{ult} = BL\left[c'N_{c(e)}F_{cs(e)} + qN_{q(e)}F_{qs(e)} + \frac{1}{2}\gamma B N_{\gamma(e)}F_{\gamma s(e)}\right]$$
$$F_{cs(e)} = 1.2 - 0.025\frac{L}{B}$$
$$F_{qs(e)} = 1.00$$
$$F_{\gamma s(e)} = 1.0 + \left(\frac{2e}{B} - 0.68\right)\frac{B}{L} + \left[0.43 - \left(\frac{3}{2}\right)\left(\frac{e}{B}\right)\right]\left(\frac{B}{L}\right)^2$$

Method 3:

$$R_k = 1 - \frac{q_{u(eccentric)}}{q_{u(centric)}}$$
$$R_k = a\left(\frac{e}{B}\right)^k$$
$$q_{u(eccentric)} = q_{u(centric)}\left(1 - R_k\right)$$
$$q_{u(centric)} = qN_qF_{qd} + \tfrac{1}{2}\gamma B N_\gamma F_{\gamma d}$$
$$Q_{ult} = Bq_{u(eccentric)}$$

Primary Consolidation Settlement for Normally Consolidated Clays

$$S_{c(p)} = \frac{C_cH_c}{1+e_o}\log\frac{\sigma'_o + \Delta\sigma'_{av}}{\sigma'_o}, \text{ for 2:1 method } \Delta\sigma'_{(1)} = \frac{Q_g}{(L_g+z_1)(B_g+z_1)}$$

Primary Consolidation Settlement for OverConsolidated Clays

for $\sigma'_o + \Delta\sigma'_{av} < \sigma'_c$

$$S_{c(p)} = \frac{C_sH_c}{1+e_o}\log\frac{\sigma'_o + \Delta\sigma'_{av}}{\sigma'_o}$$

for $\sigma'_o < \sigma'_c < \sigma'_o + \Delta\sigma'_{av}$

$$S_{c(p)} = \frac{C_sH_c}{1+e_o}\log\frac{\sigma'_c}{\sigma'_o} + \frac{C_cH_c}{1+e_o}\log\frac{\sigma'_o + \Delta\sigma'_{av}}{\sigma'_c}$$

Average Increase in Pressure

$$\Delta\sigma'_{av} = \tfrac{1}{6}\left(\Delta\sigma'_{top} + 4\Delta\sigma'_{medium} + \Delta\sigma'_{bottom}\right), \ \Delta\sigma'_{top/middle/bottm} = q_o I_c$$
$$m_1 = \frac{L}{B}, n_1 = \frac{z}{(B/2)}$$

FINAL EXAMINATION

SEMESTER / SESSION : SEM II 2021/2022
COURSE NAME : FOUNDATION ENGINEERING
PROGRAMME CODE : BFF
COURSE CODE : BFC 43103

LATERAL EARTH PRESSURE AND RETAINING WALLS

$$K_a = \tan^2\left(45 - \frac{\phi}{2}\right)$$

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

$$L_3 = \frac{\sigma'_2}{\gamma'(K_p - K_a)}$$

$$\sigma'_5 = (\gamma L_1 + \gamma' L_2)K_p + \gamma' L_3(K_p - K_a)$$

$$A_1 = \frac{\sigma'_5}{\gamma'(K_p - K_a)}$$

$$A_2 = \frac{8P}{\gamma'(K_p - K_a)}$$

$$A_3 = \frac{6P\left[2\bar{z}\gamma'(K_p - K_a) + \sigma'_5\right]}{\gamma'^2(K_p - K_a)^2}$$

$$A_4 = \frac{P\left[6\bar{z}\sigma'_5 + 4P\right]}{\gamma'^2(K_p - K_a)^2}$$

$$L_4^4 + A_1L_4^3 - A_2L_4^2 - A_3L_4 - A_4 = 0$$

$$\sigma'_4 = \sigma'_5 + \gamma' L_4(K_p - K_a)$$

$$\sigma'_3 = L_4(K_p - K_a)\gamma'$$

$$L_5 = \frac{\sigma'_3 L_4 - 2P}{\sigma'_3 + \sigma'_4}$$

$$K_{p(design)} = \frac{K_p}{FS}$$

$$S_V = \frac{T_{all}}{\gamma_1 z K_a [FS_{(B)}]}$$

$$L = \frac{H - z}{\tan\left(45 + \frac{\phi'_1}{2}\right)} + \frac{S_V K_a [FS_{(B)}]}{2\tan\phi'_F}$$

$$l_l = \frac{S_V K_a [FS_{(P)}]}{4\tan\phi'_F}$$

$$v = \sqrt{\frac{E}{\left(\frac{\gamma}{g}\right)}\frac{(1-\mu)}{(1-2\mu)(1+\mu)}}$$

$$Z_1 = \frac{1}{2}\sqrt{\frac{v_2 - v_1}{v_2 + v_1}}x_c$$

$$z_2 = \frac{1}{2}\left[T_{i2} - 2Z_1\frac{\sqrt{v_3^2 - v_1^2}}{v_3 v_1}\right]\frac{v_3 v_2}{\sqrt{v_3^2 - v_2^2}}$$