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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2021/2022

COURSE NAME	:	ADVANCED FOUNDATION ENGINEERING
COURSE CODE	:	MFA 10303
PROGRAMME	:	MFA
EXAMINATION DATE	:	JANUARY / FEBRUARY 2022
DURATION	:	3 HOURS
INSTRUCTION	:	1. ANSWER **ALL QUESTIONS** 2. THIS FINAL EXAMINATION IS AN **ONLINE** ASSESSMENT AND CONDUCTED VIA **CLOSE BOOK**

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

Q1 (a) Plaxis is a finite element software that assists engineers in all sorts of geotechnical engineering problems. Explain in detail on what are the capabilities does the Plaxis software can bring to benefit geotechnical engineers.

(9 marks)

(b) A careful study of the site indicates that there is a clay soil layer with a rigid rock layer underlying it. A shallow foundation of 1.5m x 1.5 was built in the clay layer where the bottom of the foundation is at 2 meters from the ground surface. The rock layer is located 10 meters below the bottom of the foundation. The load per unit area (q_o) of the foundation is 150 kN/m^2. The soil is clay where it has an undrained shear strength (c_u) of 200kN/m2, with an OCR of 2 and plasticity index (PI) of 45. Estimate the elastic settlement of the foundation with reference to **Figure Q1(b)i** and **Figure Q1(b)ii**.

(7 marks)

(c) A mat foundation was used for a building that was constructed on a soft soil. In order to have a stable structural design of a mat foundation, the reaction of the column loads needs to be analysed. **Figure Q1(c)** shows all the loadings from the column of the structure. All loads are factored loads according to ACI 381-11 (2011). With that, calculate the soil pressures at A, B, C, and D.

(9 marks)

Q2 (a) **Figure Q2(a)** shows a collapsed building that occurred in China. It seems that the structure collapsed due to foundation failure. Based on your observations, explain in detail the possibilities that caused the failure.

(9 marks)

(b) Based on the problem that occurred as shown in **Figure Q2(a)**, justify your strategies as a geotechnical engineer on the steps of how would you avoid the problem to occur.

(9 marks)

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

(7 marks)

Q3 (a) Discuss the difference in terms of its mechanism between a cantilever retaining structure and a mechanically stabilised earth retaining structure.

(4 marks)

(b) A basement needs to be constructed under a building and therefore deep excavation works are being done in a layer of clay soil. With that, a 17 m deep braced excavation in clay was designed as shown in **Figure Q3(b).** The unit weight (γ) and cohesion (c) of the soil are 17.5 kN/m^3 and 35 kN/m^2 respectively. The center-to-center spacing of struts in the plan is 10 m and the allowable flexural stress of the sheet pile material, σ_{all} is 200 x 10^3 kN/m^2.

(i) Illustrate the earth pressure envelope.

(4 marks)

(ii) Analyze the loads in the struts A, B and C.

(6 marks)

(c) 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:

Vs = 1.2m
Hs = 1.5m
Width of reinforcement = 150mm
fy = 300 MN/m^2
$\phi_\mu = 25$
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.

(5 marks)

ii) The required maximum length of ties.

(6 marks)

Q4 **(a)** For an appropriate design of a foundation under dynamic loading, there are two parameters that must comply with the design requirement. Justify what are these two parameters.

(4 marks)

(b) Foundations that need to support dynamic loadings are due to machine vibrations. Explain in detail the type and characteristics of machines that cause dynamic loading on foundations.

(6 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, a 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

Dertemine:

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

(ii) The radius of the 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) The amplitude of vibration for the system.
(3 marks)

- END OF QUESTIONS -

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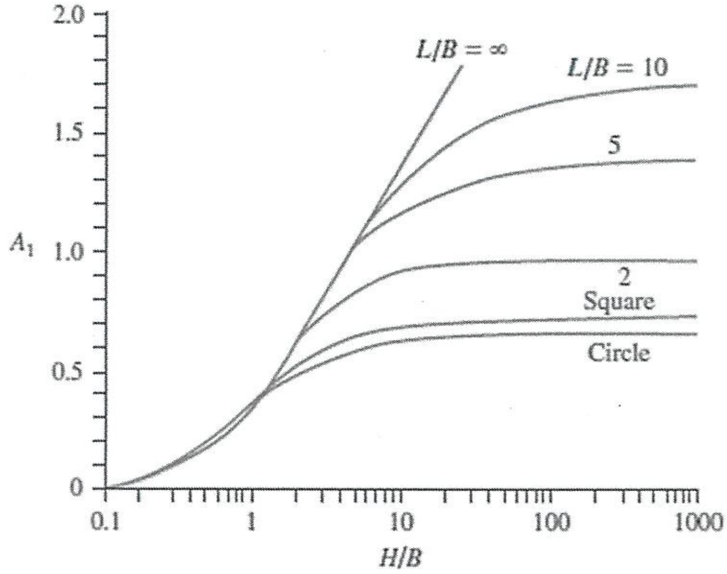

Figure Q1(b)i: Relationship of A_1 and H/B

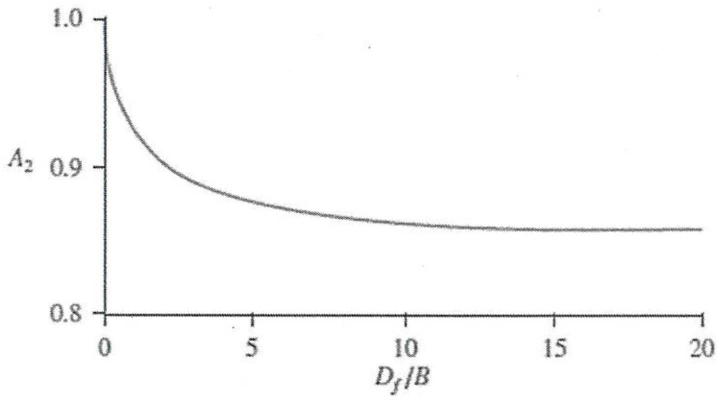

Figure Q1(b)ii: Relationship of A_2 and D_f/B

Table Q1(b): Range of β for saturated clay

Plasticity Index	β				
	OCR = 1	OCR = 2	OCR = 3	OCR = 4	OCR = 5
<30	1500–600	1380–500	1200–580	950–380	730–300
30 to 50	600–300	550–270	580–220	380–180	300–150
>50	300–150	270–120	220–100	180–90	150–75

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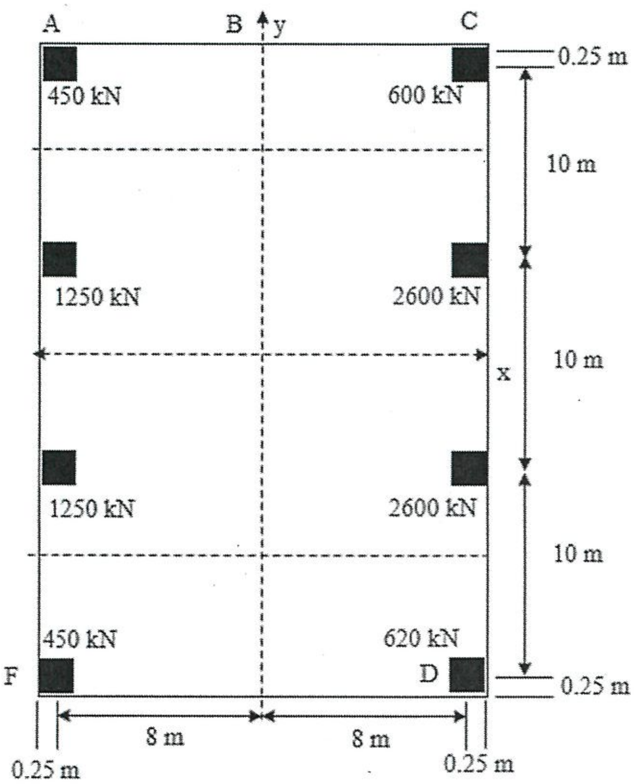

Figure Q1(c): Plan view of the sturcture

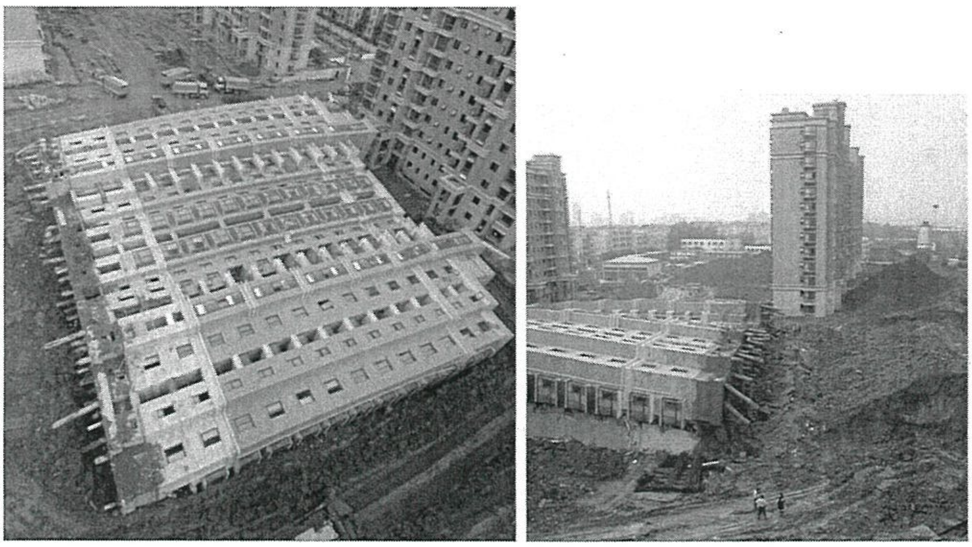

Figure Q2(a): Foundation problem

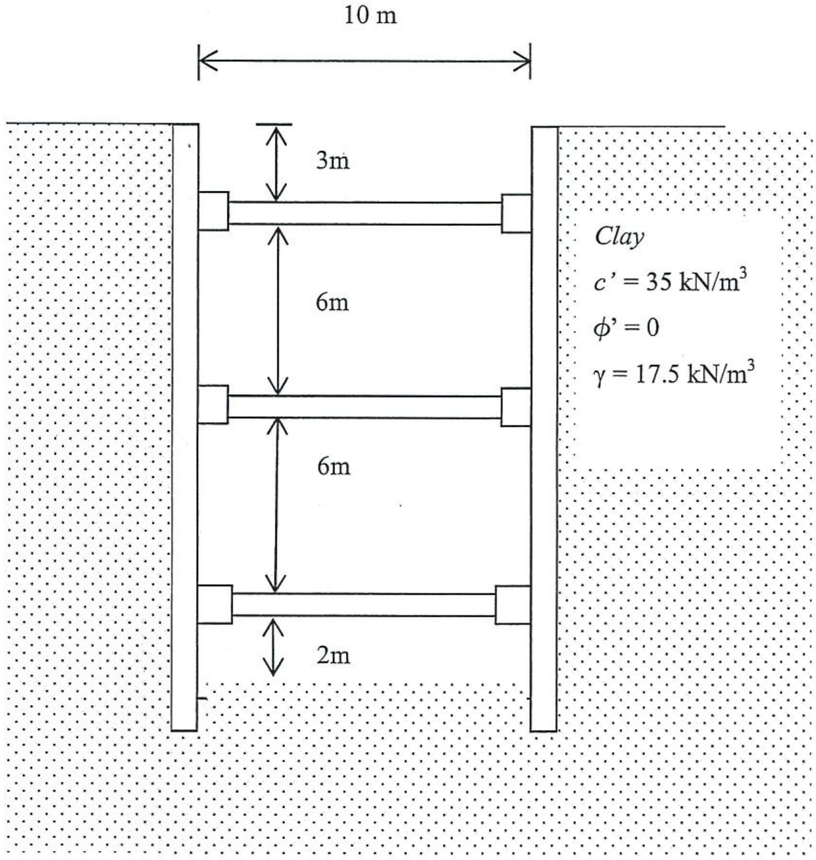

Figure Q3(b): Struts

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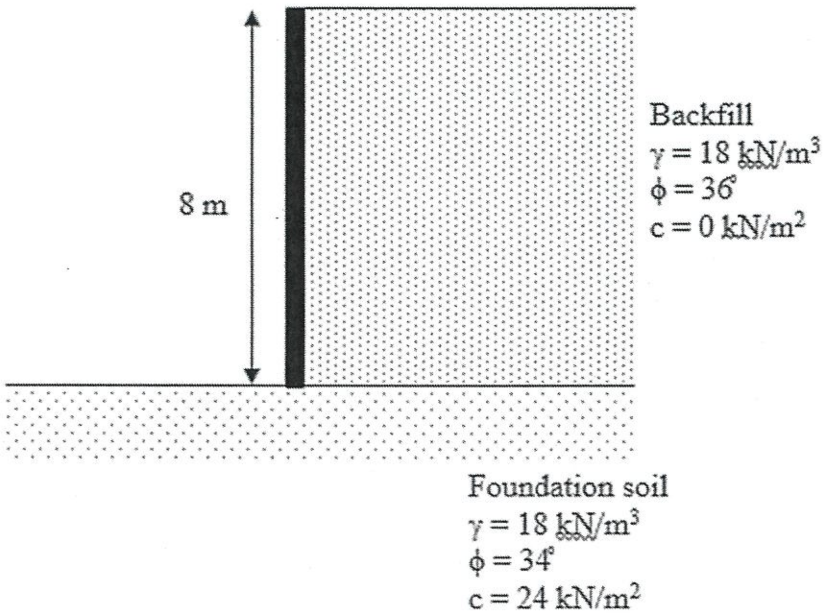

Figure Q3(c): Retaining wall

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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

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

Elastic settlement

$$S_e = A_1 A_2 \frac{q_o B}{E_s}$$

$$E_s = \beta c_u$$

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

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

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

Site investigations

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

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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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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

$Q_p = A_p q_p$

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

$Q_s = pLf_{av}$

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

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Conventional retaining walls

Rankine active and passive pressure

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

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

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

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

Factor of safety against overturning

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

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

Factor of safety against sliding

$$FS = \frac{\Sigma V \tan\left(\tfrac{2}{3}\phi_2'\right) + \tfrac{2}{3}Bc_2' + P_p}{P_a \cos\alpha}$$

Retaining walls with geotextile and geogrid reinforcement

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

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

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

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

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

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

overturning factor of safety

$$FS = \frac{M_R}{M_O} = \frac{(W_1x_1 + W_2x_2 + \ldots + qa')\left(b' + \tfrac{1}{2}a'\right)}{P_a z_a}$$

sliding factor of safety

$$FS = \frac{F_R}{F_d} = \frac{(W_1 x_1 + W_2 x_2 + \ldots + qa')[\tan(\phi_1')]}{P_a}$$

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

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

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

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

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

Equations Machine Vibrations

$$W_o = W_b + W_m$$

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

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

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

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

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

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

$$W_e = 2me$$

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

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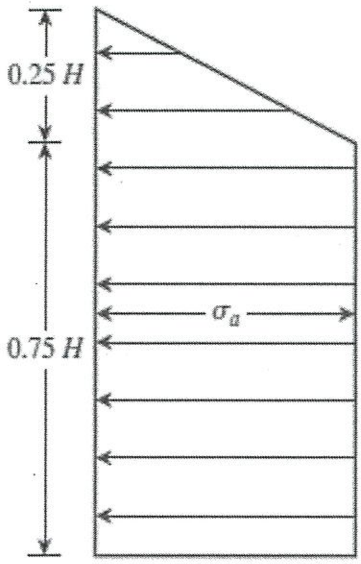
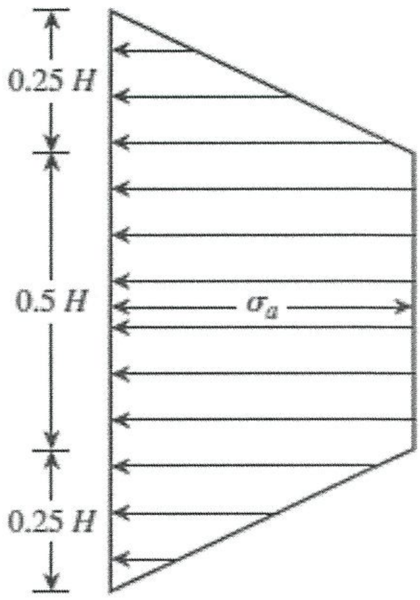
Equations needed for Q4



Peck's (1969) apparent-pressure envelope for cuts in soft to medium clay



Peck's (1969) apparent-pressure envelope for cuts in stiff clay

$$\sigma_a = 0.65\gamma H K_a$$

$$\sigma_a = \gamma H \left[1 - \left(\frac{4c}{\gamma H}\right)\right]$$

$$\sigma_a = 0.2\gamma H \text{ to } 0.4\gamma H$$

and

$$\sigma_a = 0.3\,\gamma\,H$$

$$S = \frac{M_{max}}{\sigma_{all}}$$