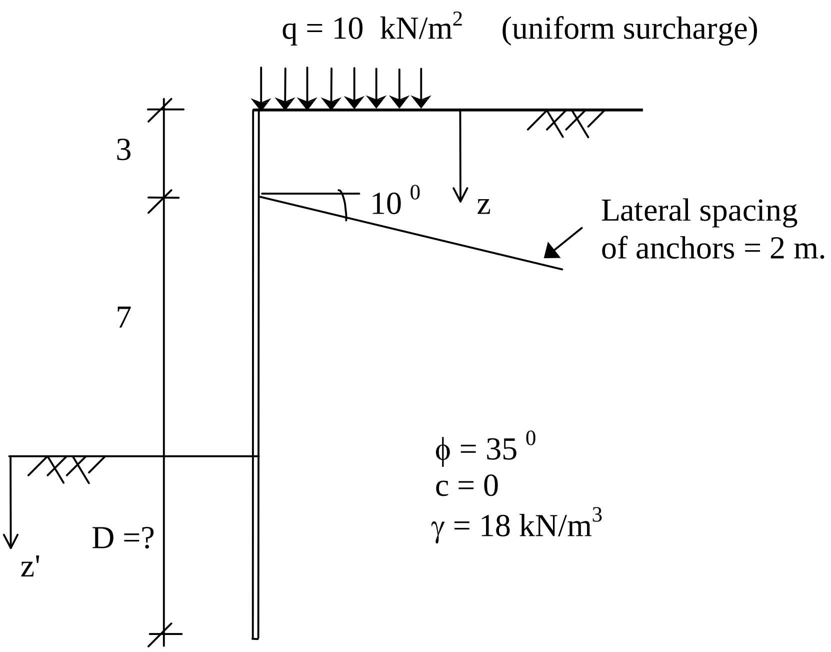
P1. ANCHORED SHEET PILE WALL

Question:

An anchored sheet-pile wall is constructed as shown in the figure below. By using Rankine's Earth Pressure Theory and free earth support method, determine:

a. Depth of penetration.
b. Axial anchor force if center to center spacing of two successive anchors is 2 meters.
c. Maximum bending moment in the sheet pile.



Solution:

$$K_a = \tan^2(45 - \frac{\phi}{2}) = \tan^2(45 - \frac{35}{2}) = 0.27$$

$$K_p = \frac{1}{K_a} = 3.69$$

Active Pressure:

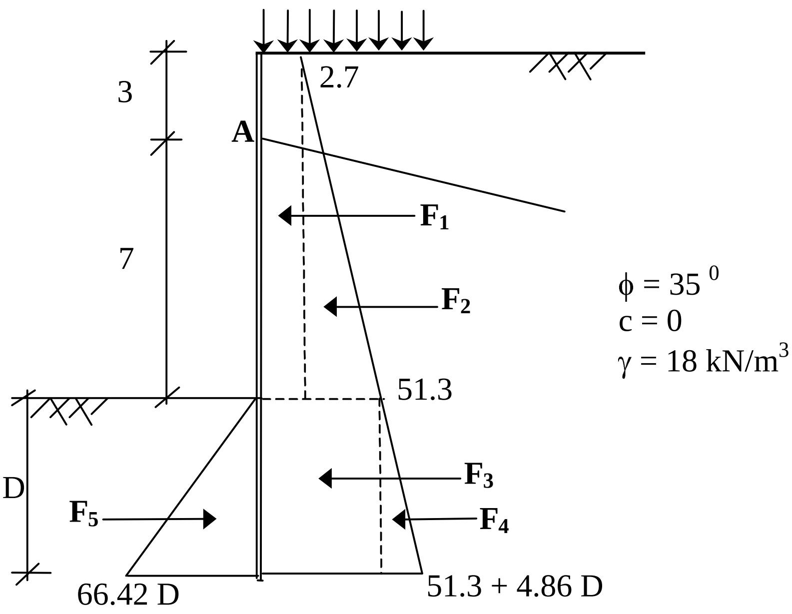
$$P_a = (\gamma z + q).K_a - 2.c.\sqrt{K_a}$$

z = 0 m	p_a = 10 x 0.27 = 2.7 kPa
z = 10 m	p_a = (10 x 18 + 10) x 0.27 = 51.3 kPa
z = 10 + D	p_a = [(10 + D) x 18 + 10] x 0.27 = 51.3 + 4.86 D kPa

Passive Pressure:

$$P_p = (\gamma z + q).K_p + 2.c.\sqrt{K_p}$$

z' = 0 m	p_p = 0 kPa
z' = D m	p_p = 18 x D x 3.69 = 66.42 D kPa



Force (kN/m)	Moment arm about point A (m)	Moment, $\mathbf{M_A}$ (kN.m / m)
$F_1 = 2.7 \times 10 = 27$	2	54
$F_2 = (51.3-2.7) \times 10 \times 0.5 = 243$	3.67	889.38
$F_3 = 51.3 \times D = 51.3\ D$	7 + D/2	$359.1\ D + 25.6\ D^2$
$F_4 = 4.86\ D \times D \times 0.5 = 2.43\ D^2$	7 + 2D/3	$17.01\ D^2 + 1.62\ D^3$
$- F_5 = 66.42\ D \times D \times 0.5 = -33.21\ D^2$	7 + 2D/3	$-232.47\ D^2 - 22.14\ D^3$

$\Sigma F_H = 270 + 51.3\ D - 30.78\ D^2$

$\Sigma M_A = 0$

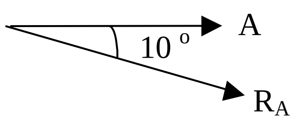
$\Sigma M_A = 943.38 + 359.1\ D - 189.86\ D^2 - 20.52\ D^3 = 0$ $\Rightarrow D = 2.80$ m.

a) Depth of penetration : 1.2 x 2.80 = 3.36 m.

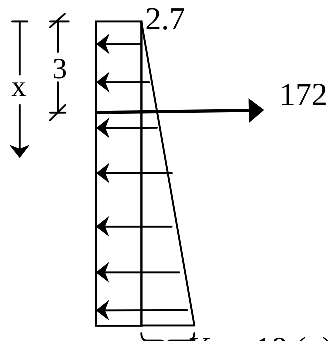
b) Anchor Force : $\Sigma H = 0$ (force equilibrium)

$\Sigma H = 270 + 51.3\ (2.80) - 30.78\ (2.80)^2 - A = 0$ $\Rightarrow A = 172$ kN / m

$R_A = (A / \cos 10) \times 2 = 350$ kN (2 m is the lateral spacing of anchors)



c) Max. Bending Moment : (when shear , V= 0)



$\gamma z K_a = 18 (x) (0.27)$

To find the location of $M_{max,}$ determine the point at which shear force is equal to 0

2.7 (x) + [18.(x).(0.27)].(x).0.5 - 172 = 0

$$2.7\,x + 2.43\,x^2 - 172 = 0 \qquad x = 7.88\text{ m (distance from top)}$$

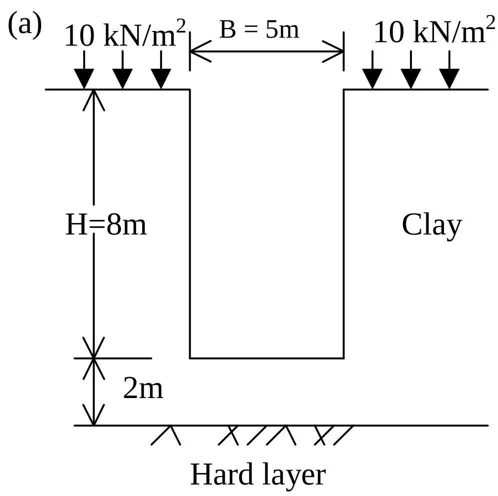
M_{max} = 2.7 (7.88) (7.88 / 2) + 18 (7.88)(0.27) (7.88 / 2) (7.88 / 3) – 172 (7.88 - 3)

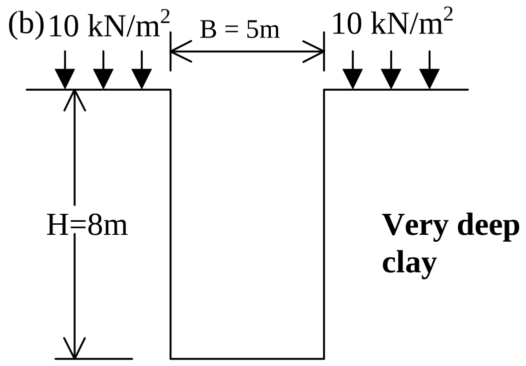
M_{max} = 359.24 kN.m / m

P2. BRACED CUTS

Question:

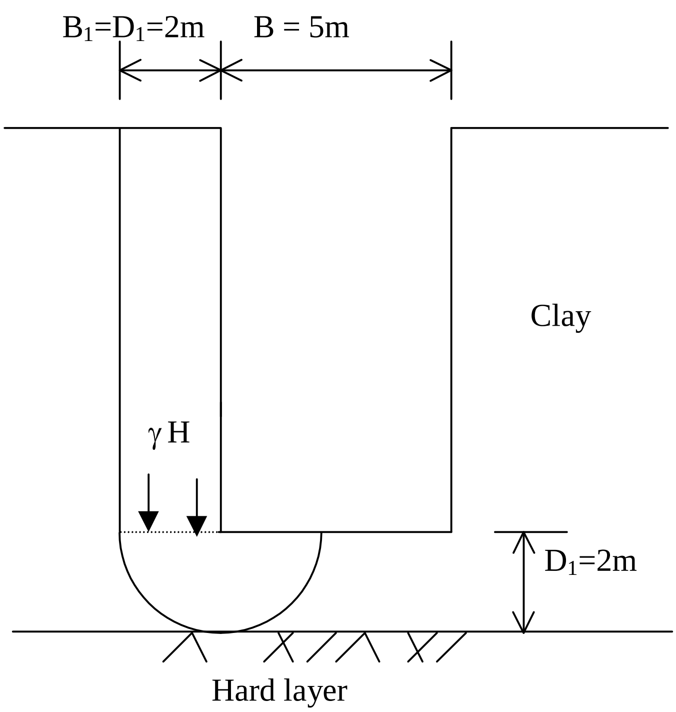
For the very long braced systems shown in the figures (a) and (b), when c_u=40 kN/m^2, ϕ_u=0, γ=19 kN/m^3, and there is no water, what is the factor of safety of the bottom against heave?

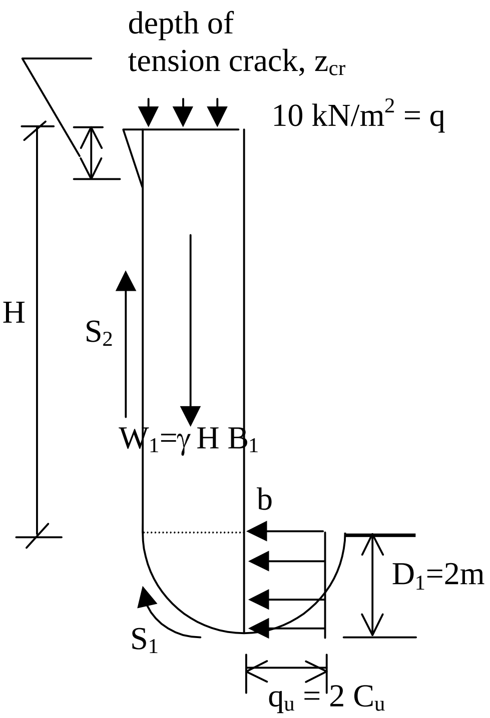




Solution:

(a)





Depth of tension crack;

$$P_{active} = (\gamma z + q)K_a - 2C_u\sqrt{K_a}$$

$\phi = 0° \longrightarrow K_a = 1$

$$p_{active} = (\gamma z + q) - 2C_u = 0$$

$$(\gamma z + q) = 2C_u$$

$$z_{cr} = \frac{2C_u - q}{\gamma}$$

For ; C_u = 40 kPa ; q=10 kPa
γ = 19 kN/m^3

$$z_{cr} = \frac{2C_u - q}{\gamma} = \frac{2x40 - 10}{19} = \frac{70}{19} = 3.68m$$

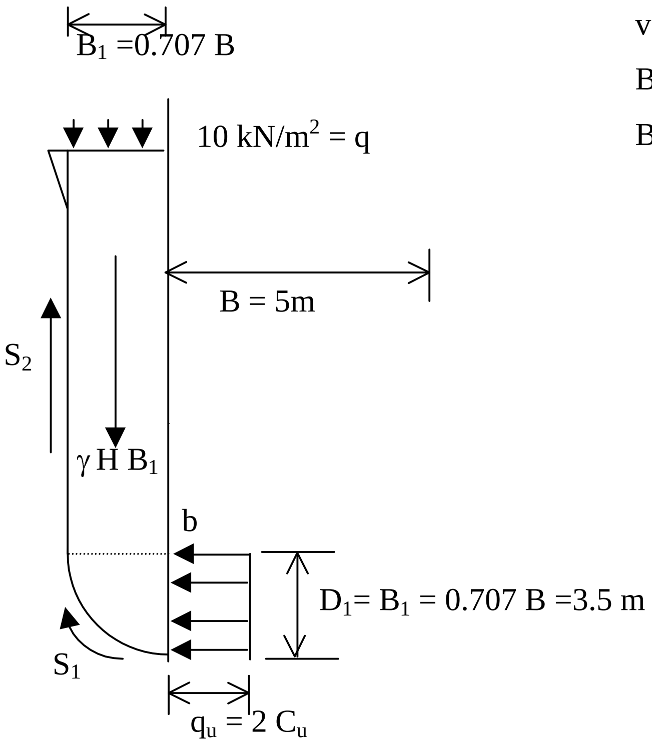
For ; $B_1 = D_1$ = 2m
$q_u = 2\ C_u$ = 2x40 = 80 kPa
H = 8m ; γ = 19 kN/m^3

taking moment about b;

Force (kN/m)	Moment arm (m), about point b	Moment, $\mathbf{M_b}$ (kN.m / m)
$S_1 = (0.5x\pi xB_1)xCu = (0.5x\pi x2)x40 = 125.60$	B_1=2	251.20
$S_2 = (H-z_{cr})xC_u$ = (8-3.68)x40= 172.80	B_1=2	345.60
$P_1 = q_uxB_1=2xC_uxB_1$=2x40x2=160	0.5xB_1=1	160
$W_1 = \gamma xHxB_1$=19x8x2=304	0.5xB_1=1	-304
$W_2 = qxB_1$=10x2=20	0.5xB_1=1	-20

$$FS = \frac{251.20 + 345.60 + 160}{304 + 20} = 2.34$$

(b)



very deep clay;

$B_1 = 0.707\ B$

$B_1 = 0.707 \times 5 = 3.5$ m

For ; $B_1 = D_1 = 3.5$ m

$q_u = 2\ C_u = 2x40 = 80$ kPa

$H = 8m$; $\gamma = 19$ kN/m^3

taking moment about b;

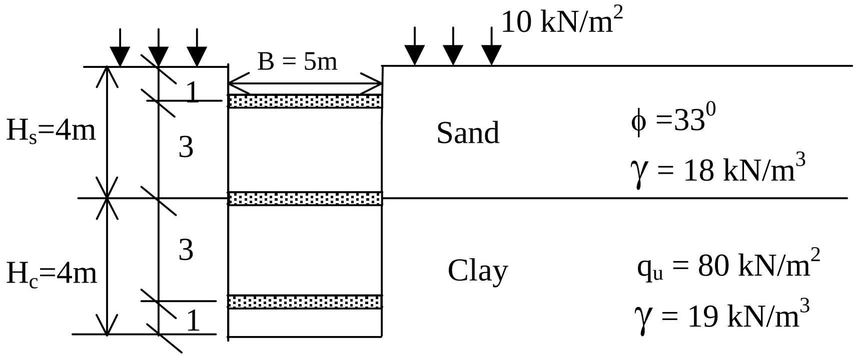
Force (kN/m)	Moment arm (m), about point b	Moment, $\mathbf{M_b}$ (kN.m / m)
$S_1 = (0.5x\pi xB_1)xCu= (0.5x\pi x3.5)x40=219.80$	B_1=3.5	769.30
$S_2 = (H-z_{cr})xC_u = (8-3.68)x40= 172.80$	B_1=3.5	604.80
$P_1 = q_uxB_1=2xC_u\ xB_1=2x40x3.5=280$	$0.5xB_1$=1.75	490
$W_1 = \gamma xHxB_1=19x8x3.5=532$	$0.5xB_1$=1.75	-931
$W_2 = qxB_1=10x3.5=35$	$0.5xB_1$=1.75	-61.25

$$FS = \frac{769.30 + 604.80 + 490}{931 + 61.25} = 1.88$$

P3. BRACED CUTS

Question;

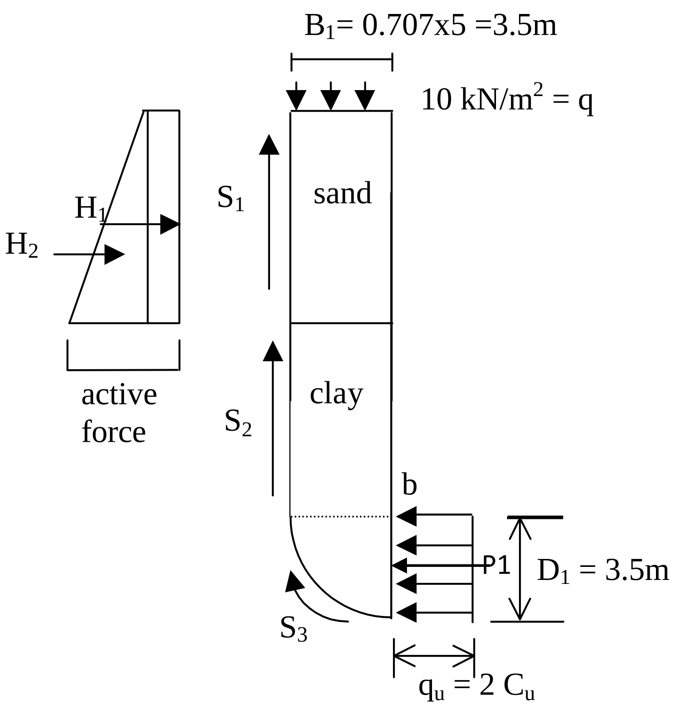
Determine the factor of safety of the bottom against heave for the very long braced system shown below (hint: make reasonable assumptions).



Solution;

For sand, consider active earth pressure, not earth pressure at rest, because of some lateral displacement during excavation.

$K_a = \tan^2(45 - \phi/2) = \tan^2(45 - 33/2)$
$K_a = 0.29$



z = 0 $p_a = 10 \times 0.29 = 2.9$ kPa

z = 4 $p_a = (10 + 4 \times 18) \times 0.29 = 23.8$ kPa

$H_1 = 2.9 \times 4 = 11.6$ kN/m

$H_2 = (23.8 - 2.9) \times 4 \times (1/2) = 41.8$ kN/m

$\Sigma = 53.4$ kN/m

Force (kN/m)	Moment arm about point A (m)	Moment, $\mathbf{M_A}$ (kN.m / m)
$S_1 = \sigma_n \tan\phi = 53.4 \times \tan 33 = 35$	3.5	122.5
$S_2 = 4\ C_u = 4 \times 40 = 160$	3.5	560
$S_3 = 0.5 x \pi x B_1 x C_u = 0.5 x \pi x 3.5 x 40 = 220$	3.5	770
$P_1 = 80x3.5 = 280$	1.75	490
$W_1 = 4x18x3.5=252$	1.75	-441
$W_2 = 4x19x3.5=266$	1.75	-465.5
$W_3 = 10x3.5=35$	1.75	-61.25

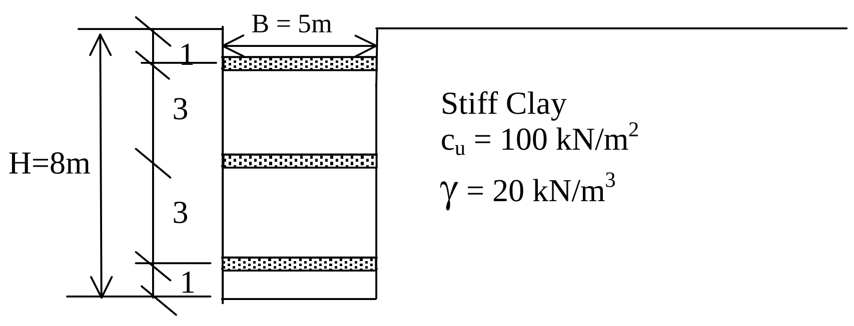
$$FS = \frac{122.5 + 560 + 770 + 490}{441 + 465.5 + 61.25} = 2.0$$

P4. BRACED CUTS

Question:

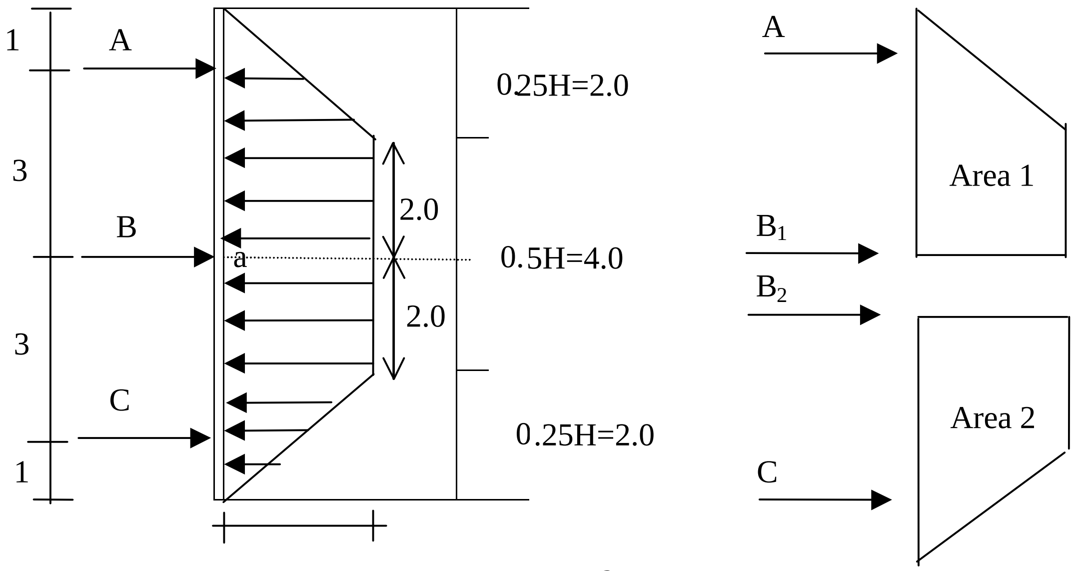
Find the strut loads for each level for the long braced system given below.

Horizontal struts are spaced at every 5 m. No ground water.



Solution;

- for strut loads, the earth pressure distribution is



$0.3\gamma_t$ H =0.3x20x8=48 kN/m^2 per linear meter

area 1 ⟶ 2.0x48x(1/2) + 2.0x48 = 144 kN/m

area 2 ⟶ 2.0x48 + 2.0x48x(1/2) = 144 kN/m

taking moment wrt. point a;

⟶ 3.0 A = 2.0 x 48 x (2.0 / 2) + 2.0 x 48 x (1/2) x (2.0 /3 + 2.0)

A = 74.7 kN/m

B_1 = 144 – 74.7 = 69.3 kN/m

⟶ 3.0 C = 2.0 x 48 x (2.0 / 2) + 2.0 x 48 x (1/2) x (2.0 /3 + 2.0)

C = 74.7 kN/m

B_2 = 144 – 74.7 = 69.3 kN/m

spacing

Strut loads; A = 74.7x 5 = 373.5 kN

B = (69.3 + 69.3) x 5 = 693 kN

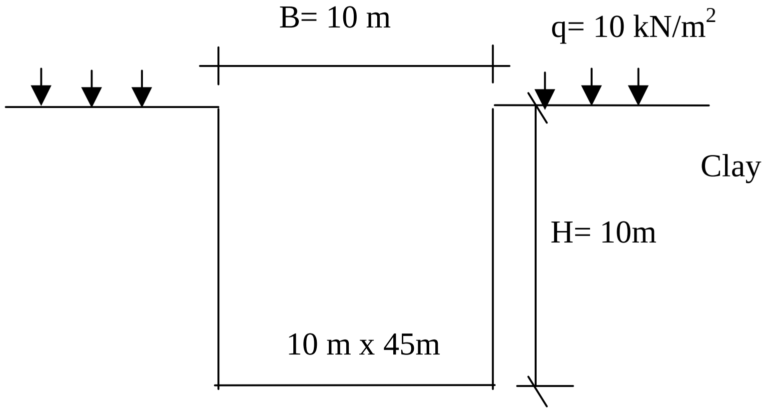
C = 74.7 x 5 = 373.5 kN

P5. BRACED CUTS

Question;

For a braced system constructed in a 10 m deep rectangular excavation in a clay, when length L= 45m ; width B= 10m ; surcharge q= 10kN/m^2 ; unit weight γ = 19 kN/m^2 and unconfined compressive strength q_u= 80 kN/m^2 ; and there is no water, what is the factor of safety at the bottom against heave?

Solution;



If the excavation is not very long $(L/B \leq 10)$ ⟶ square, rectangular or circular exc.

Assumption ⟶ braced cut is a deep footing

$$F.S. = \frac{N_c C_u}{(\gamma H + q)} = \frac{N_c q_u}{2(\gamma H + q)} = \frac{\text{ultimate bearing capacity}}{\text{applied load}}$$

N_c : bearing capacity factor

(from Fig 4.6, pp 73 of Lecture Notes)

H/B= 10 / 10 = 1 $\quad$ N_c (square) = 7.7

$N_{c\,(rect)}$ = (0.84 + 0.16 B/ L) N_c (square)

= (0.84 + 0.16 x 10 / 45) x 7.7

= 6.8

$$FS = \frac{6.8x40}{(19x10 + 10)} = 1.36$$