

Гипотеза Энергообла

МЕХАНИКА ТЛА - ЗАДАЧИ

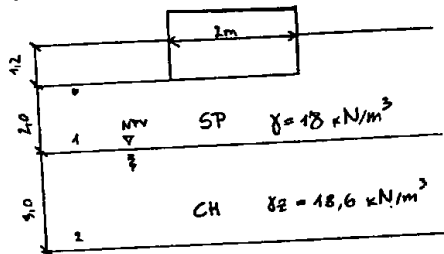
Zadatak 1 - Vežbe

Fleksibilna temeljna stopa dimenzija $2 \times 4 \text{ m}$, opterećen je koncentrisanom silom $G = 1600 \text{ kN}$.

Sloj SP: $M_v = 17000 \text{ kN/m}^2$ $\gamma = 18 \text{ kN/m}^3$

Sloj CH: $M_v = 3000 \text{ kN/m}^2$ $\gamma_z = 18,6 \text{ kN/m}^3$

odrediti stanje srednje tačke temeljne stope.



$$\gamma_w = 9,807 \text{ kN/m}^3$$

$$\gamma' = \gamma_z - \gamma_w \Rightarrow \gamma' = 18,6 - 9,807 \Rightarrow \gamma' = 8,793 \text{ kN/m}^3$$

Neto kontaktni napon (z_n)

$$z_n = \frac{G}{b \cdot L} - \gamma \cdot D_f \Rightarrow z_n = \frac{1600}{2 \cdot 4} - 18 \cdot 1,2 \Rightarrow z_n = 178,4 \text{ kN/m}^2$$

Početni efektivni napon (p_0')

$$z_0 = 0,0 \text{ m} \quad p_{0,0}' = \gamma \cdot D_f \Rightarrow p_{0,0}' = 18 \cdot 1,2 \Rightarrow p_{0,0}' = 21,6 \text{ kN/m}^2$$

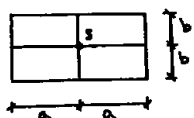
$$z_1 = 2,0 \text{ m} \quad p_{0,1}' = p_{0,0}' + \gamma \cdot (z_1 - z_0) \Rightarrow p_{0,1}' = 21,6 + 18 \cdot 2 \Rightarrow p_{0,1}' = 57,6 \text{ kN/m}^2$$

$$z_2 = 5,0 \text{ m} \quad p_{0,2}' = p_{0,1}' + \gamma' \cdot (z_2 - z_1) \Rightarrow p_{0,2}' = 57,6 + 8,793 \cdot 3 \Rightarrow p_{0,2}' = 83,979 \text{ kN/m}^2$$

Prirastak vertikalnih napona ($\Delta \sigma_z'$)

Štirnbrener - za fleksibilni temelj

$$I = \left(\frac{a}{b}, \frac{z}{b} \right) \quad \Delta \sigma_z' = 2 I \cdot z_n$$



$$a = \frac{L}{2} \Rightarrow a = 2 \text{ m}$$

$$b = \frac{B}{2} \Rightarrow b = 1 \text{ m}$$

$$\Delta \sigma_z' = 4 I \cdot z_n$$

$$z_0 = 0,0 \text{ m} \quad \frac{a}{b} = \frac{2}{1} \Rightarrow \frac{a}{b} = 2 \quad \frac{z}{b} = \frac{0}{1} \Rightarrow \frac{z}{b} = 0 \quad I_0 = 0,25 \Rightarrow \Delta \sigma_{z,0}' = 4 \cdot 0,25 \cdot 178,4 \Rightarrow \Delta \sigma_{z,0}' = 178,4 \text{ kN/m}^2$$

$$z_1 = 2,0 \text{ m} \quad \frac{a}{b} = 2 \quad \frac{z}{b} = \frac{2}{1} \Rightarrow \frac{z}{b} = 2 \quad I_1 = 0,12 \Rightarrow \Delta \sigma_{z,1}' = 4 \cdot 0,12 \cdot 178,4 \Rightarrow \Delta \sigma_{z,1}' = 85,632 \text{ kN/m}^2$$

$$z_2 = 5,0 \text{ m} \quad \frac{a}{b} = 2 \quad \frac{z}{b} = \frac{5}{1} \Rightarrow \frac{z}{b} = 5 \quad I_2 = 0,0323 \Rightarrow \Delta \sigma_{z,2}' = 4 \cdot 0,0323 \cdot 178,4 \Rightarrow \Delta \sigma_{z,2}' = 23,049 \text{ kN/m}^2$$

Konačni vertikalni napon (σ_z')

$$z_0 = 0,0 \text{ m} \quad \sigma_{z,0}' = p_{0,0}' + \Delta \sigma_{z,0}' \Rightarrow \sigma_{z,0}' = 21,6 + 178,4 \Rightarrow \sigma_{z,0}' = 200 \text{ kN/m}^2$$

$$z_1 = 2,0 \text{ m} \quad \sigma_{z,1}' = p_{0,1}' + \Delta \sigma_{z,1}' \Rightarrow \sigma_{z,1}' = 57,6 + 85,632 \Rightarrow \sigma_{z,1}' = 143,232 \text{ kN/m}^2$$

$$z_2 = 5,0 \text{ m} \quad \sigma_{z,2}' = p_{0,2}' + \Delta \sigma_{z,2}' \Rightarrow \sigma_{z,2}' = 83,979 + 23,049 \Rightarrow \sigma_{z,2}' = 107,028 \text{ kN/m}^2$$

VERTIKALNE DEFORMACIJE (ϵ_z)

$$z_0 = 0,0 \text{ m}$$

$$\epsilon_{z,0} = \frac{\Delta \bar{\sigma}_{z,0}}{M_v} \Rightarrow \epsilon_{z,0} = \frac{178,4}{17000} \Rightarrow \epsilon_{z,0} = 0,0105$$

$$z_1 = 2,0 \text{ m}$$

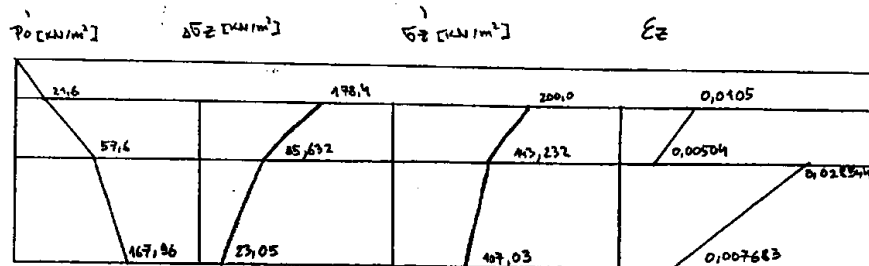
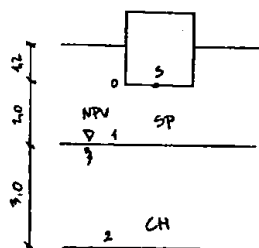
$$\epsilon_{z,1}^G = \frac{\Delta \bar{\sigma}_{z,1}^G}{M_v} \Rightarrow \epsilon_{z,1}^G = \frac{85,632}{17000} \Rightarrow \epsilon_{z,1}^G = 0,00504$$

$$z_1 = 2,0 \text{ m}$$

$$\epsilon_{z,1}^D = \frac{\Delta \bar{\sigma}_{z,1}^D}{M_v} \Rightarrow \epsilon_{z,1}^D = \frac{85,632}{3000} \Rightarrow \epsilon_{z,1}^D = 0,028544$$

$$z_2 = 5,0 \text{ m}$$

$$\epsilon_{z,2} = \frac{\Delta \bar{\sigma}_{z,2}}{M_v} \Rightarrow \epsilon_{z,2} = \frac{23,049}{3000} \Rightarrow \epsilon_{z,2} = 0,007683$$



SLEGANJE (s)

$$s = \int_0^z \epsilon_z dz$$

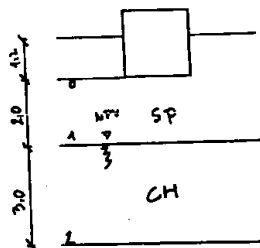
$$s = \frac{1}{2} \cdot (0,0105 \cdot 2 + 0,00504 \cdot 2 + 0,028544 \cdot 3 + 0,007683 \cdot 3) \Rightarrow s = 0,06088 \text{ m} \Rightarrow s = 6,088 \text{ cm} \Rightarrow s \approx 7 \text{ cm}$$

Zadatak 2 - Vežbe

Kružna temelja stopa dimenzija $2 \times 4 \text{ m}$, opterećena je silom $Q = 1600 \text{ kN}$.

- Sloj SP $z_0 = 0$ $z_c = 3000 \text{ kN/m}^2$
 $z_1 = 2.0$ $z_c = 5000 \text{ kN/m}^2$

- Sloj CH $C_c = 0.45$ $C_k = 0.103$ $G_{15} = 2.7$
 Teren je pre građena objekta bio opterećen sa nasipom visine 2 m i $\gamma = 18 \text{ kN/m}^3$



$\gamma = 18 \text{ kN/m}^3$

$\gamma_z = 18.6 \text{ kN/m}^3$

$\gamma' = \gamma_z - \gamma_w \Rightarrow \gamma' = 18.6 - 9.807 \Rightarrow \gamma' = 8.793 \text{ kN/m}^3$

Neto kontaktni napon (z_n)

$z_n = \frac{Q}{B \cdot L} - \gamma \cdot D_f \Rightarrow z_n = \frac{1600}{2 \cdot 4} - 18 \cdot 1.2 \Rightarrow z_n = 178.4 \text{ kN/m}^2$

Početni efektivni napon (p_0')

$z_0 = 0.0 \text{ m}$ $p_{0,0}' = \gamma \cdot D_f \Rightarrow p_{0,0}' = 18 \cdot 1.2 \Rightarrow p_{0,0}' = 21.6 \text{ kN/m}^2$

$z_1 = 2.0 \text{ m}$ $p_{0,1}' = p_{0,0}' + \gamma(z_1 - z_0) \Rightarrow p_{0,1}' = 21.6 + 18 \cdot 2 \Rightarrow p_{0,1}' = 57.6 \text{ kN/m}^2$

$z_2 = 5.0 \text{ m}$ $p_{0,2}' = p_{0,1}' + \gamma'(z_2 - z_1) \Rightarrow p_{0,2}' = 57.6 + 8.793 \cdot 3 \Rightarrow p_{0,2}' = 83.979 \text{ kN/m}^2$

PRIRAŠTAJ VERTIKALNIH
 Početni efektivni napon ($\Delta \sigma_z'$)

Kani $I = \left(\frac{L}{B}, \frac{z}{B} \right)$ $\Delta \sigma_z' = I \cdot z_n$

$z_0 = 0.0 \text{ m}$ $\frac{L}{B} = \frac{4}{2} = 2$ $\frac{z}{B} = 0$ $I_0 = 1.0 \Rightarrow \Delta \sigma_{z,0}' = 1 \cdot 178.4 \Rightarrow \Delta \sigma_{z,0}' = 178.4 \text{ kN/m}^2$

$z_1 = 2.0 \text{ m}$ $\frac{L}{B} = 2$ $\frac{z}{B} = 1$ $I_1 = 0.31 \Rightarrow \Delta \sigma_{z,1}' = 0.31 \cdot 178.4 \Rightarrow \Delta \sigma_{z,1}' = 55.304 \text{ kN/m}^2$

$z_2 = 5.0 \text{ m}$ $\frac{L}{B} = 2$ $\frac{z}{B} = 2.5$ $I_2 = 0.11 \Rightarrow \Delta \sigma_{z,2}' = 0.11 \cdot 178.4 \Rightarrow \Delta \sigma_{z,2}' = 19.624 \text{ kN/m}^2$

Konačni vertikalni napon (σ_z')

$z_0 = 0.0 \text{ m}$ $\sigma_{z,0}' = p_{0,0}' + \Delta \sigma_{z,0}' \Rightarrow \sigma_{z,0}' = 21.6 + 178.4 \Rightarrow \sigma_{z,0}' = 200 \text{ kN/m}^2$

$z_1 = 2.0 \text{ m}$ $\sigma_{z,1}' = p_{0,1}' + \Delta \sigma_{z,1}' \Rightarrow \sigma_{z,1}' = 57.6 + 55.304 \Rightarrow \sigma_{z,1}' = 112.904 \text{ kN/m}^2$

$z_2 = 5.0 \text{ m}$ $\sigma_{z,2}' = p_{0,2}' + \Delta \sigma_{z,2}' \Rightarrow \sigma_{z,2}' = 83.979 + 19.624 \Rightarrow \sigma_{z,2}' = 103.603 \text{ kN/m}^2$

VERTIKALNE DEFORMACIJE (ϵ_z)

Tačka 0

$z = 0,0 \text{ m}$

$$q_c = 3000 \text{ kN/m}^2$$

$$C = 1,5 \cdot \frac{q_c}{p_{0,0}} \Rightarrow C = 1,5 \cdot \frac{3000}{21,6} \Rightarrow C = 208,333$$

$$\epsilon_{z,0} = \frac{1}{C} \ln \left(\frac{p_{0,0} + \Delta \sigma_{z,0}}{p_{0,0}} \right) \Rightarrow \epsilon_{z,0} = \frac{1}{208,333} \cdot \ln \left(\frac{200}{21,6} \right) \Rightarrow \epsilon_{z,0} = 0,0107$$

Tačka 1

$z_1 = 2,0 \text{ m}$

$$q_c = 5000 \text{ kN/m}^2$$

$$C = 1,5 \cdot \frac{q_c}{p_{0,1}} \Rightarrow C = 1,5 \cdot \frac{5000}{57,6} \Rightarrow C = 130,20833$$

$$\epsilon_{z,1}^G = \frac{1}{C} \ln \left(\frac{p_{0,1} + \Delta \sigma_{z,1}^G}{p_{0,1}} \right) \Rightarrow \epsilon_{z,1}^G = \frac{1}{130,20833} \cdot \ln \left(\frac{112,904}{57,6} \right) \Rightarrow \epsilon_{z,1}^G = 0,0051687$$

Tačka 1

$z_1 = 2,0 \text{ m}$

$$p_{c,1} = (h_u + D_f) \cdot \gamma + h_{ucl} \cdot \gamma \Rightarrow p_{c,1} = (2 + 1,2) \cdot 18 + 2 \cdot 18 \Rightarrow p_{c,1} = 93,6 \text{ kN/m}^2$$

$$\text{USLOV I} \quad \sigma_{z,1} \geq p_{c,1} \geq p_{0,1} \Rightarrow 112,904 \geq 93,6 \geq 57,6 \Rightarrow \textcircled{+}$$

$$e = \frac{\sigma_s}{\sigma_d} - 1 = \frac{G_s \sigma_w}{\sigma_d} - 1$$

$$e_0 = \frac{G_s \cdot \gamma_w - \gamma_z}{\gamma_z - \gamma_w} \Rightarrow e_0 = \frac{2,7 \cdot 9,807 - 18,6}{18,6 - 9,807} \Rightarrow e_0 = 0,896$$

$$e_0 = 0,4236$$

$$\epsilon_{z,1}^D = \frac{C_R}{1+e_0} \cdot \log \frac{p_{c,1}}{p_{0,1}} + \frac{C_c}{1+e_0} \cdot \log \frac{\sigma_{z,1}}{p_{c,1}}$$

$$\epsilon_{z,1}^D = \frac{0,09}{1+0,896} \cdot \log \frac{93,6}{57,6} + \frac{0,45}{1+0,896} \cdot \log \frac{112,904}{93,6} \Rightarrow \epsilon_{z,1}^D = 0,02934$$

Tačka 2

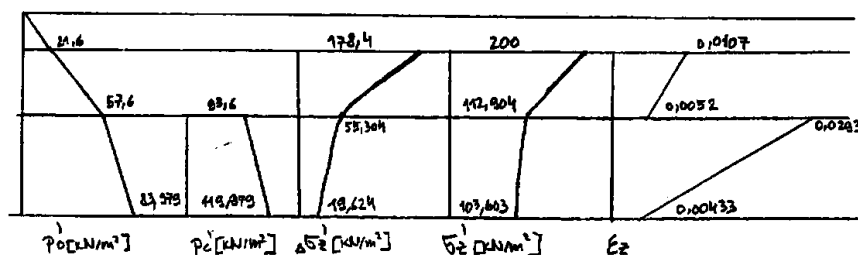
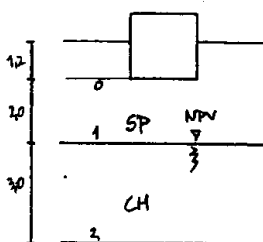
$z_2 = 5,0 \text{ m}$

$$p_{c,2} = p_{c,1} + \gamma \cdot (z_2 - z_1) \Rightarrow p_{c,2} = 93,6 + 8,793 \cdot 3 \Rightarrow p_{c,2} = 119,979 \text{ kN/m}^2$$

$$\text{USLOV I} \quad \sigma_{z,2} \geq p_{c,2} \geq p_{0,2} \Rightarrow 103,603 \geq 119,979 \geq 83,979 \Rightarrow \textcircled{+}$$

$$\text{USLOV II} \quad \sigma_{z,2} \leq p_{c,2}$$

$$\epsilon_{z,2} = \frac{C_R}{1+e_0} \cdot \log \frac{\sigma_{z,2}}{p_{0,2}} \Rightarrow \epsilon_{z,2} = \frac{0,09}{1+0,896} \cdot \log \frac{103,603}{83,979} \Rightarrow \epsilon_{z,2} = 0,00433$$



SLEGANJE (S)

$$S = \int_0^z \epsilon_z dz \Rightarrow S = \frac{1}{2} \cdot (0,0107 \cdot 2 + 0,0052 \cdot 2 + 0,0293 \cdot 3 + 0,00433 \cdot 3) \Rightarrow S = 0,0663 \text{ m} \Rightarrow S \approx 6,6 \text{ cm}$$

Zadatak 3.

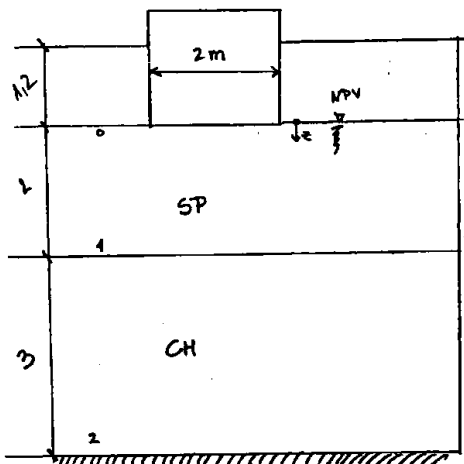
15. JUN. 2007

A

KRUTA TEMELJNA STOPA DIMENZIJA 2x4m KAO NA SLICI, OPTEREĆENA JE CENTRALNOM VERTIKALNOM SILOM $Q = 1200 \text{ kN}$. IZRAČUNATI SLEGANJE TEMELJA RAČUNAJUĆI NAPONE I SPECIFIČNE DEFORMACIJE NA NIVOIMA 0, 1, 2. PARAMETRI TLA SU:

- Sloj SP: $\gamma = 18,0 \text{ kN/m}^3$; $\delta_z = 20 \text{ kN/m}^3$; $M_v = 18000 \text{ kN/m}^2$
- Sloj CH: $e_0 = 0,8$; $C_c = 0,30$; $C_r = 0,06$; $G_s = 2,7$; $OCR = 1,5$

Kanijeva metoda



$$\gamma_w = 9,807 \text{ kN/m}^3$$

$$\delta'_1 = \delta_z - \gamma_w \Rightarrow \delta'_1 = 20 - 9,807 \Rightarrow \delta'_1 = 10,193 \text{ kN/m}^3$$

$$\sigma_s = G_s \cdot \sigma_w = 2,7 \cdot 9,807 = 26,48$$

$$\delta_s = 27,46 \text{ kN/m}^3$$

$$\delta'_2 = \frac{\gamma_s + e_0 \cdot \delta_w}{1 + e_0} - \gamma_w \Rightarrow \delta'_2 = \frac{27,46 + 0,8 \cdot 9,807}{1 + 0,8} - 9,807 \Rightarrow$$

$$\delta'_2 = 9,291 \text{ kN/m}^3$$

Neto kontaktni napon (q_n)

$$q_n = \frac{Q}{B \cdot L} - \gamma \cdot D_f \Rightarrow q_n = \frac{1200 \text{ kN}}{2,4 \text{ m} \cdot 4 \text{ m}} - 18 \cdot \frac{\text{kN}}{\text{m}^3} \cdot 1,2 \text{ m} \Rightarrow q_n = 128,4 \frac{\text{kN}}{\text{m}^2}$$

Početni efektivni vertikalni naponi ($p_{0,i}$)

$$z_0 = 0 \text{ m} \quad p_{0,0} = \gamma \cdot D_f \Rightarrow p_{0,0} = 18 \cdot 1,2 \Rightarrow p_{0,0} = 21,6 \text{ kN/m}^2$$

$$z_1 = 2 \text{ m} \quad p_{0,1} = p_{0,0} + \delta'_1 (z_1 - z_0) \Rightarrow p_{0,1} = 21,6 + 10,193 \cdot 2 \Rightarrow p_{0,1} = 41,986 \text{ kN/m}^2$$

$$z_2 = 5 \text{ m} \quad p_{0,2} = p_{0,1} + \delta'_2 (z_2 - z_1) \Rightarrow p_{0,2} = 41,986 + 9,291 \cdot 3 \Rightarrow p_{0,2} = 69,859 \text{ kN/m}^2$$

Prirastak vertikalnih napona ($\Delta \sigma'_z$)

$$\text{Kani} \quad I = I\left(\frac{z}{B}, \frac{z}{L}\right) \quad \Delta \sigma'_z = I \cdot q_n$$

$$z_0 = 0 \text{ m} \quad \frac{z}{B} = \frac{0}{2} = 0 \quad \frac{z}{L} = 0 \quad I_0 = 1,0 \quad \Rightarrow \Delta \sigma'_{z,0} = 1 \cdot 128,4 \Rightarrow \Delta \sigma'_{z,0} = 128,4 \text{ kN/m}^2$$

$$z_1 = 2 \text{ m} \quad \frac{z}{B} = 1 \quad \frac{z}{L} = 0,5 \quad I_1 = 0,31 \quad \Rightarrow \Delta \sigma'_{z,1} = 0,31 \cdot 128,4 \Rightarrow \Delta \sigma'_{z,1} = 39,804 \text{ kN/m}^2$$

$$z_2 = 5 \text{ m} \quad \frac{z}{B} = 2,5 \quad \frac{z}{L} = 1,25 \quad I_2 = 0,11 \quad \Rightarrow \Delta \sigma'_{z,2} = 0,11 \cdot 128,4 \Rightarrow \Delta \sigma'_{z,2} = 14,124 \text{ kN/m}^2$$

Konačni vertikalni napon (σ'_z)

$$\sigma'_{z,0} = p_{0,0} + \Delta \sigma'_{z,0} \Rightarrow \sigma'_{z,0} = 21,6 + 128,4 \Rightarrow \sigma'_{z,0} = 150 \text{ kN/m}^2$$

$$\sigma'_{z,1} = p_{0,1} + \Delta \sigma'_{z,1} \Rightarrow \sigma'_{z,1} = 41,986 + 39,804 \Rightarrow \sigma'_{z,1} = 81,79 \text{ kN/m}^2$$

$$\sigma'_{z,2} = p_{0,2} + \Delta \sigma'_{z,2} \Rightarrow \sigma'_{z,2} = 69,859 + 14,124 \Rightarrow \sigma'_{z,2} = 83,983 \text{ kN/m}^2$$

$$p_c' = OCR \cdot p_0'$$

$$p_{c,1}' = 1,5 \cdot p_{0,1}' \Rightarrow p_{c,1}' = 1,5 \cdot 41,886 \Rightarrow p_{c,1}' = 62,979 \text{ kN/m}^2$$

$$p_{c,2}' = 1,5 \cdot p_{0,2}' \Rightarrow p_{c,2}' = 1,5 \cdot 69,859 \Rightarrow p_{c,2}' = 104,785 \text{ kN/m}^2$$

VERTIKALNE DEFORMACIJE (ϵ_z)

TAČKA 0

$$z = 0 \text{ m} \quad \epsilon_{z,0} = \frac{\Delta s_{z,0}'}{M_v} \Rightarrow \epsilon_{z,0} = \frac{128,4}{18000} \Rightarrow \epsilon_{z,0} = 0,00713$$

TAČKA 1

$$z = 2 \text{ m} \quad \epsilon_{z,1} = \frac{\Delta s_{z,1}'}{M_v} \Rightarrow \epsilon_{z,1} = \frac{39,804}{18000} \Rightarrow \epsilon_{z,1} = 0,00221$$

TAČKA 1

$z = 2 \text{ m}$

$$\text{USLOV I} \quad \sigma_{z,1}' \geq p_{c,1}' \geq p_{0,1}' \Rightarrow 81,79 \geq 62,979 \geq 41,886 \Rightarrow \text{ⓐ} \Rightarrow$$

$$\epsilon_{z,1} = \frac{C_\alpha}{1+e_0} \cdot \log \frac{p_{c,1}'}{p_{0,1}'} + \frac{C_\alpha}{1+e_0} \cdot \log \frac{\sigma_{z,1}'}{p_{c,1}'}$$

$$\epsilon_{z,1} = \frac{0,06}{1+0,9} \cdot \log \frac{62,979}{41,886} + \frac{0,3}{1+0,9} \cdot \log \frac{81,79}{62,979} \Rightarrow$$

$$\Rightarrow \epsilon_{z,1} = 0,006292706 + 0,017921754 \Rightarrow \epsilon_{z,1} = 0,0242 \rightarrow 0,02348 \text{ m}$$

TAČKA 2

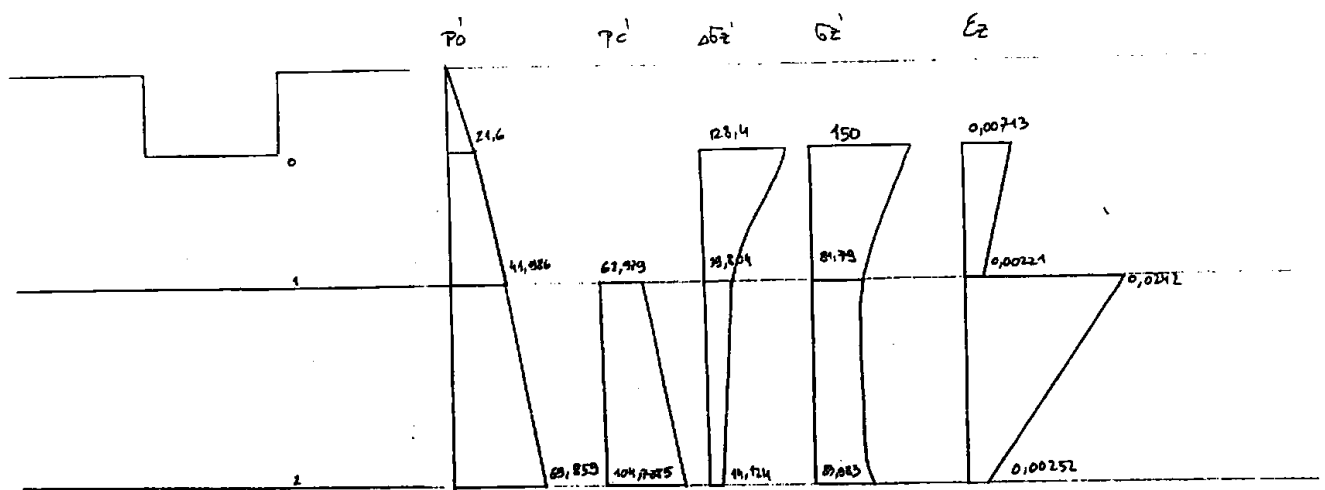
$z = 5 \text{ m}$

$$\text{USLOV I} \quad \sigma_{z,2}' \geq p_{c,2}' \geq p_{0,2}' \Rightarrow 83,933 \geq 104,785 \geq 69,859 \Rightarrow \text{ⓑ} \Rightarrow$$

$$\text{USLOV II} \quad \sigma_{z,2}' \leq p_{c,2}' \Rightarrow \text{ⓐ}$$

$$\epsilon_{z,2} = \frac{C_\alpha}{1+e_0} \cdot \log \frac{\sigma_{z,2}'}{p_{0,2}'}$$

$$\epsilon_{z,2} = \frac{0,06}{1+0,9} \cdot \log \frac{83,933}{69,859} \Rightarrow \epsilon_{z,2} = 0,00252$$



SLĖGIANĖ

$$S = \int \epsilon z dz$$

$$S = \frac{1}{2} \cdot (0.00713 \cdot 2 + 0.00221 \cdot 2 + 0.0242 \cdot 3 + 0.00252 \cdot 3) \Rightarrow S = \frac{1}{2} \cdot (0.09884) \Rightarrow$$

$$\Rightarrow S = 0.04942 \text{ m} \Rightarrow S = 4.942 \text{ cm}$$

Zadatak 3 JANUAR 2008

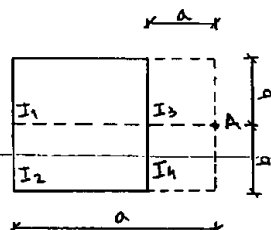
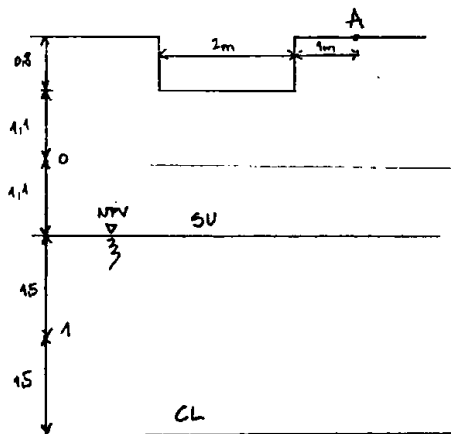
Temelj dimenzija 2x2 m opterećuje tlo bruto kontaktom naponom od 200 kN/m^2 .

Izračunati sleganje tačke A računajući napone i specifične deformacije u tačkama 0 i 1.

Podaci o tlu:

- Sloj SU $\gamma = 21 \text{ kN/m}^3$ $M_v = 10 \text{ MN/m}^3$
- Sloj CL $\gamma_z = 20 \text{ kN/m}^3$ $c_z = 0,06$ $OCR = 2$ $e_0 = 0,96$

Štajnerova metoda



$$\gamma' = \gamma_z - \gamma_w \Rightarrow \gamma' = 20 - 9,807 \Rightarrow \gamma' = 10,193 \text{ kN/m}^3$$

$$q_n = q - \gamma D_f \Rightarrow q_n = 200 - 0,8 \cdot 21 \Rightarrow q_n = 183,2 \text{ kN/m}^2$$

$$p_{0,0} = \gamma \cdot D_f \Rightarrow p_{0,0} = 21 \cdot 0,8 \Rightarrow p_{0,0} = 16,8 \text{ kN/m}^2$$

$$p_{0,0} = p_{0,0} + \gamma \cdot (z_0 - z_1) \Rightarrow p_{0,0} = 16,8 + 21 \cdot (1,9 - 0,8) \Rightarrow p_{0,0} = 39,99 \text{ kN/m}^2$$

$$p_{0,1} = p_{0,0} + \gamma \cdot 1,1 + \gamma' \cdot 1,5 \Rightarrow p_{0,1} = 39,99 + 21 \cdot 1,1 + 10,193 \cdot 1,5 \Rightarrow p_{0,1} = 78,38 \text{ kN/m}^2$$

Štajnerova $I = I \left(\frac{a}{b}, \frac{z}{b} \right)$ $\Delta \bar{\sigma}_z = (2I_1 - 2I_3) \cdot q_n$

$$\begin{aligned} z_0 &= 1,1 \text{ m} & \frac{a}{b} &= \frac{3}{1} = 3 & \frac{z}{b} &= 1,1 \Rightarrow I_{0,1} = I_{0,2} = 0,195 \\ & & \frac{a}{b} &= \frac{1}{1} = 1 & \frac{z}{b} &= 1,1 \Rightarrow I_{0,3} = I_{0,4} = 0,162 \end{aligned} \Rightarrow \Delta \bar{\sigma}_{z,0} = (2 \cdot 0,195 - 2 \cdot 0,162) \cdot 183,2 \Rightarrow \Delta \bar{\sigma}_{z,0} = 12,10 \text{ kN/m}^2$$

$$\begin{aligned} z_1 &= 3,7 \text{ m} & \frac{a}{b} &= \frac{3}{1} = 3 & \frac{z}{b} &= 3,7 \Rightarrow I_{1,1} = I_{1,2} = 0,0667 \\ & & \frac{a}{b} &= \frac{1}{1} = 1 & \frac{z}{b} &= 3,7 \Rightarrow I_{1,3} = I_{1,4} = 0,03167 \end{aligned} \Rightarrow \Delta \bar{\sigma}_{z,1} = (2 \cdot 0,0667 - 2 \cdot 0,03167) \cdot 183,2 \Rightarrow \Delta \bar{\sigma}_{z,1} = 12,83 \text{ kN/m}^2$$

$$\bar{\sigma}_{z,0} = p_{0,0} + \Delta \bar{\sigma}_{z,0} \Rightarrow \bar{\sigma}_{z,0} = 39,99 + 12,10 \Rightarrow \bar{\sigma}_{z,0} = 52,09 \text{ kN/m}^2$$

$$\bar{\sigma}_{z,1} = p_{0,1} + \Delta \bar{\sigma}_{z,1} \Rightarrow \bar{\sigma}_{z,1} = 78,38 + 12,83 \Rightarrow \bar{\sigma}_{z,1} = 91,21 \text{ kN/m}^2$$

Tačka 0

$$z_0 = 1,1 \text{ m}$$

$$\epsilon_{z,0} = \frac{\Delta \bar{\sigma}_{z,0}}{M_v} \Rightarrow \epsilon_{z,0} = \frac{12,10}{10\,000} \Rightarrow \epsilon_{z,0} = 0,00121$$

Tačka 1

$$z = 3,7 \text{ m}$$

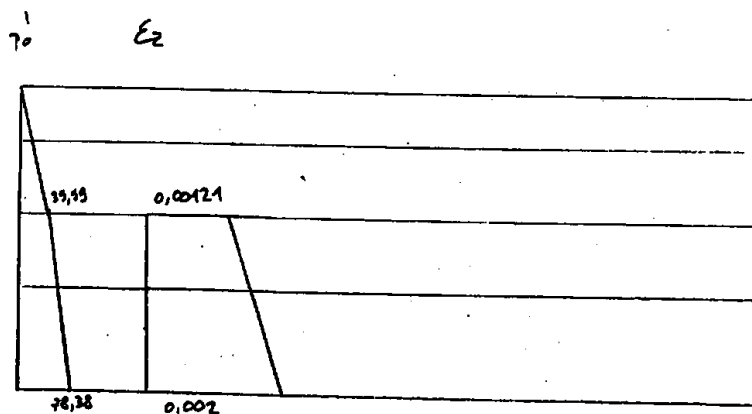
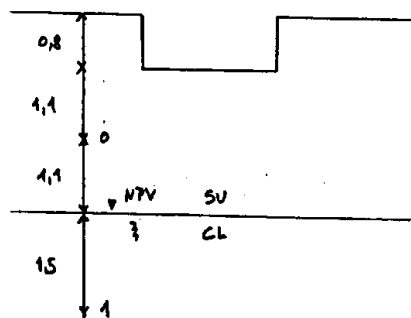
$$p_{c,1} = \text{OCR} \cdot p_{0,1} \Rightarrow p_{c,1} = 2 \cdot 78,38 \Rightarrow p_{c,1} = 156,76 \text{ kN/m}^2$$

$$\text{USLOV I} \quad \bar{\sigma}_{z,1} \geq p_{c,1} \geq p_{0,1} \Rightarrow 91,21 \geq 156,76 \geq 78,38 \Rightarrow \textcircled{1}$$

$$\text{USLOV II} \quad \bar{\sigma}_{z,1} \leq p_{c,1}$$

$$\epsilon_{z,1} = \frac{C_R}{1 + e_0} \cdot \log \frac{\bar{\sigma}_{z,1}}{p_{0,1}} \Rightarrow \epsilon_{z,1} = \frac{0,06}{1 + 0,96} \cdot \log \frac{91,21}{78,38} \Rightarrow$$

$$\Rightarrow \epsilon_{z,1} = 0,002$$



$$S = \int_0^z \epsilon_z dz$$

$$S = \frac{1}{2} \cdot (0,00121 \cdot 1,1 + 0,002 \cdot 1,5) \Rightarrow S = \frac{1}{2} \cdot 0,00836 \Rightarrow S = 0,00418 \text{ m} \Rightarrow S = 0,418 \text{ cm}$$

Zadatak 3

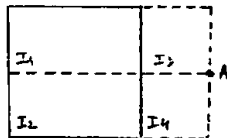
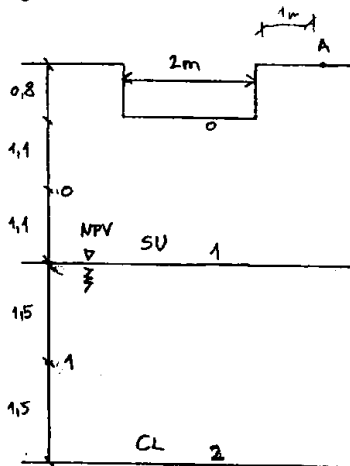
Januar 2008

Temelj dimenzija 2x2 m opterećuje tlo bruto kontaktnim naponom od 200 kN/m².
Izračunati sleganje tačke A računajući napone i specifične deformacije u tačkama 0 i 1.

Podaci o tlu:

- Sloj SU $\gamma = 21 \text{ kN/m}^3$ $M_v = 10 \text{ MN/m}^3$
- Sloj CL $\gamma_z = 20 \text{ kN/m}^3$ $C_R = 0,06$ $OCR = 2$ $C_0 = 0,96$

Štainerova metoda



$$\gamma' = \gamma_z - \gamma_{SU} \Rightarrow \gamma' = 20 - 9,807 \Rightarrow \gamma' = 10,193 \text{ kN/m}^3$$

$$q_n = q - \gamma \cdot D_f \Rightarrow q_n = 200 - 21 \cdot 0,8 \Rightarrow q_n = 183,2 \text{ kN/m}^2$$

$$p_{0,0} = \gamma \cdot D_f \Rightarrow p_{0,0} = 21 \cdot 0,8 \Rightarrow p_{0,0} = 16,8 \text{ kN/m}^2$$

$$p_{0,1} = p_{0,0} + \gamma \cdot (z_1 - z_0) \Rightarrow p_{0,1} = 16,8 + 21 \cdot 2,2 \Rightarrow p_{0,1} = 63 \text{ kN/m}^2$$

$$p_{0,2} = p_{0,1} + \gamma' \cdot (z_2 - z_1) \Rightarrow p_{0,2} = 63 + 10,193 \cdot 3 \Rightarrow p_{0,2} = 93,579 \text{ kN/m}^2$$

$$z_0 = 0 \Rightarrow \frac{a}{b} = 3 \quad \frac{z_0}{b} = 0 \Rightarrow I_1 = I_2 = 0,25$$

$$\Delta \bar{\sigma}_{z,0} = (2I_1 - 2I_2) \cdot q_n \Rightarrow \Delta \bar{\sigma}_{z,0} = 0$$

$$\frac{a}{b} = 1 \quad \frac{z_0}{b} = 0 \Rightarrow I_3 = I_4 = 0,25$$

$$z_1 = 2,2 \Rightarrow \frac{a}{b} = 3 \quad \frac{z_1}{b} = 2,2 \Rightarrow I_1 = I_2 = 0,12$$

$$\Delta \bar{\sigma}_{z,1} = (2I_1 - 2I_2) \cdot q_n \Rightarrow \Delta \bar{\sigma}_{z,1} = 17,22 \text{ kN/m}^2$$

$$\frac{a}{b} = 1 \quad \frac{z_1}{b} = 2,2 \Rightarrow I_3 = I_4 = 0,073$$

$$z_2 = 5,2 \Rightarrow \frac{a}{b} = 3 \quad \frac{z_2}{b} = 5,2 \Rightarrow I_1 = I_2 = 0,0433$$

$$\Delta \bar{\sigma}_{z,2} = (2I_1 - 2I_2) \cdot q_n \Rightarrow \Delta \bar{\sigma}_{z,2} = 9,78 \text{ kN/m}^2$$

$$\frac{a}{b} = 1 \quad \frac{z_2}{b} = 5,2 \Rightarrow I_3 = I_4 = 0,066$$

$$\bar{\sigma}_{z,0} = p_{0,0} + \Delta \bar{\sigma}_{z,0} \Rightarrow \bar{\sigma}_{z,0} = 16,8 \text{ kN/m}^2$$

$$\bar{\sigma}_{z,1} = p_{0,1} + \Delta \bar{\sigma}_{z,1} \Rightarrow \bar{\sigma}_{z,1} = 63 + 17,22 \Rightarrow \bar{\sigma}_{z,1} = 80,22 \text{ kN/m}^2$$

$$\bar{\sigma}_{z,2} = p_{0,2} + \Delta \bar{\sigma}_{z,2} \Rightarrow \bar{\sigma}_{z,2} = 93,579 + 9,78 \Rightarrow \bar{\sigma}_{z,2} = 103,359 \text{ kN/m}^2$$

$$z_0^* = 1,1 \text{ m} \quad \frac{a}{b} = 3 \quad \frac{z_0^*}{b} = 1,1 \Rightarrow I = 0,195$$

$$\Delta \bar{\sigma}_{z,0}^* = 12,10 \text{ kN/m}^2$$

$$\frac{a}{b} = 1 \quad \frac{z_0^*}{b} = 1,1 \Rightarrow I = 0,162$$

$$z_1^* = 3,7 \text{ m} \quad \frac{a}{b} = 3 \quad \frac{z_1^*}{b} = 3,7 \Rightarrow I = 0,0667$$

$$\Delta \bar{\sigma}_{z,1}^* = 12,89 \text{ kN/m}^2$$

$$\frac{a}{b} = 1 \quad \frac{z_1^*}{b} = 3,7 \Rightarrow I = 0,05467$$

VERTIKALNE DEFORMACIJE (ϵ_z)

TAŽKA 0

$$\epsilon_{z,0} = \frac{\Delta \bar{\epsilon}_{z,0}}{\mu \nu} \Rightarrow \epsilon_{z,0} = 0$$

TAŽKA 1

$$\epsilon_{z,1}^f = \frac{\Delta \bar{\epsilon}_{z,1}}{\mu \nu} \Rightarrow \epsilon_{z,1} = \frac{17,22}{10000} \Rightarrow \epsilon_{z,1} = 0,001722$$

$$p_{c,1} = \alpha_{CR} \cdot p_{0,1} \Rightarrow p_{c,1} = 2 \cdot 63 \Rightarrow p_{c,1} = 126 \text{ kN/m}^2$$

$$\bar{\sigma}_{z,1} \leq p_{c,1}$$

$$\epsilon_{z,1}^d = \frac{c_2}{1 + e_0} \cdot \log \frac{\bar{\sigma}_{z,1}}{p_{0,1}} \Rightarrow \epsilon_{z,1}^d = \frac{0,06}{1 + 0,96} \cdot \log \frac{80,22}{63} \Rightarrow \epsilon_{z,1}^d = 0,0032$$

TAŽKA 2

$$p_{c,2} = \alpha_{CR} \cdot p_{0,2} \Rightarrow p_{c,2} = 2 \cdot 93,579 \Rightarrow p_{c,2} = 187,158 \text{ kN/m}^2$$

$$\bar{\sigma}_{z,2} \leq p_{c,2}$$

$$\epsilon_{z,2} = \frac{c_2}{1 + e_0} \cdot \log \frac{\bar{\sigma}_{z,2}}{p_{0,2}} \Rightarrow \epsilon_{z,2} = \frac{0,06}{1,96} \cdot \log \frac{103,353}{93,579} \Rightarrow \epsilon_{z,2} = 0,00132$$

TAŽKA 0*

$$\epsilon_{z,0} = \frac{\Delta \bar{\epsilon}_{z,0}}{\mu \nu} \Rightarrow \epsilon_{z,0} = \frac{12,10}{10000} \Rightarrow \epsilon_{z,0} = 0,00121$$

TAŽKA 1*

$$p_{c,1} = \alpha_{CR} \cdot p_{0,1} \Rightarrow p_{c,1} = 2 \cdot 78,29 \Rightarrow p_{c,1} = 156,58 \text{ kN/m}^2$$

$$\bar{\sigma}_{z,1} \leq p_{c,1}$$

$$\epsilon_{z,1} = \frac{0,06}{1,96} \cdot \log \frac{81,12}{78,29} \Rightarrow \epsilon_{z,1} = 0,00202$$

SLEKANJE (s)

S =

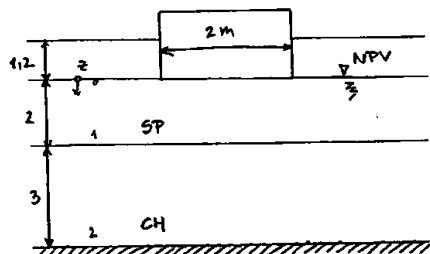
Zadatak 3

15. Jun. 2007 A

KRUTA TEMELJNA STOPA DIMENZIJA 2x4 m KAO NA SKICI, OPTEREĆENA JE CENTRALNOM VERTIKALNOM SILOM $Q = 1200$ kN. IZRAČUNATI SLEGANJE TEMELJA RAČUNAJUĆI NAPONE I SPECIFIČNE DEFORMACIJE NA NIVOIMA 0, 1, 2. PARAMETRI TLA SU:

- SLOJ SP: $\gamma = 18,0$ kN/m³, $\gamma_z = 20$ kN/m³, $M_v = 18000$ kN/m²

- SLOJ CH: $e_0 = 0,9$; $C_c = 0,30$, $C_r = 0,06$; $G_s = 2,7$; $OCR = 1,5$



$$\gamma_w = 9,807 \text{ kN/m}^3$$

$$\gamma'_1 = \gamma_z - \gamma_w \Rightarrow \gamma'_1 = 20 - 9,807 \Rightarrow \gamma'_1 = 10,193 \text{ kN/m}^3$$

$$\gamma_s = 27,46 \text{ kN/m}^3$$

$$\gamma'_2 = \frac{\gamma_s + e_0 \cdot \gamma_w}{1 + e_0} - \gamma_w \Rightarrow \gamma'_2 = \frac{27,46 + 0,9 \cdot 9,807}{1 + 0,9} - 9,807 \Rightarrow$$

$$\gamma'_2 = 9,291 \text{ kN/m}^3$$

KANJEVA METODA

NETO KONTAKTNI NAPON (z_n)

$$z_n = \frac{Q}{B \cdot L} - \gamma \cdot D_f \Rightarrow z_n = \frac{1200}{4 \cdot 2} - 18 \cdot 1,2 \Rightarrow z_n = 128,4 \text{ kN/m}^2$$

POZITIVNI EFEKTIVNI VERTIKALNI NAPONI ($P_{0,i}$)

$$z_0 = 0 \text{ m} \quad P_{0,0} = \gamma \cdot D_f \Rightarrow P_{0,0} = 18 \cdot 1,2 \Rightarrow P_{0,0} = 21,6 \text{ kN/m}^2$$

$$z_1 = 2 \text{ m} \quad P_{0,1} = P_{0,0} + \gamma'_1 (z_1 - z_0) \Rightarrow P_{0,1} = 21,6 + 10,193 \cdot (2 - 0) \Rightarrow P_{0,1} = 41,986 \text{ kN/m}^2$$

$$z_2 = 5 \text{ m} \quad P_{0,2} = P_{0,1} + \gamma'_2 (z_2 - z_1) \Rightarrow P_{0,2} = 41,986 + 9,291 \cdot (5 - 2) \Rightarrow P_{0,2} = 68,859 \text{ kN/m}^2$$

PRIRASTAK VERTIKALNIH NAPONA ($\Delta \sigma'_z$)

$$\text{Kani} \quad I = I\left(\frac{1}{B}, \frac{z}{b}\right) \quad \Delta \sigma'_z = I \cdot z_n$$

$$z_0 = 0 \text{ m} \quad \frac{1}{B} = \frac{4}{2} = 2 \quad \frac{z}{b} = 0 \quad I_0 = 1,0 \Rightarrow \Delta \sigma'_{z,0} = 1,0 \cdot 128,4 \Rightarrow \Delta \sigma'_{z,0} = 128,4 \text{ kN/m}^2$$

$$z_1 = 2 \text{ m} \quad \frac{1}{B} = 2 \quad \frac{z}{b} = 1 \quad I_1 = 0,31 \Rightarrow \Delta \sigma'_{z,1} = 0,31 \cdot 128,4 \Rightarrow \Delta \sigma'_{z,1} = 39,804 \text{ kN/m}^2$$

$$z_2 = 5 \text{ m} \quad \frac{1}{B} = 2 \quad \frac{z}{b} = 2,5 \quad I_2 = 0,11 \Rightarrow \Delta \sigma'_{z,2} = 0,11 \cdot 128,4 \Rightarrow \Delta \sigma'_{z,2} = 14,124 \text{ kN/m}^2$$

KONAČNI VERTIKALNI NAPON (σ'_z)

$$\sigma'_{z,0} = P_{0,0} + \Delta \sigma'_{z,0} \Rightarrow \sigma'_{z,0} = 21,6 + 128,4 \Rightarrow \sigma'_{z,0} = 150 \text{ kN/m}^2$$

$$\sigma'_{z,1} = P_{0,1} + \Delta \sigma'_{z,1} \Rightarrow \sigma'_{z,1} = 41,986 + 39,804 \Rightarrow \sigma'_{z,1} = 81,79 \text{ kN/m}^2$$

$$\sigma'_{z,2} = P_{0,2} + \Delta \sigma'_{z,2} \Rightarrow \sigma'_{z,2} = 68,859 + 14,124 \Rightarrow \sigma'_{z,2} = 82,983 \text{ kN/m}^2$$

$$p_c' = OCR \cdot p_0'$$

$$p_{c,1}' = 1,5 \cdot p_{0,1}' \Rightarrow p_{c,1}' = 1,5 \cdot 41,986 \Rightarrow p_{c,1}' = 62,979 \text{ kN/m}^2$$

$$p_{c,2}' = 1,5 \cdot p_{0,2}' \Rightarrow p_{c,2}' = 1,5 \cdot 69,859 \Rightarrow p_{c,2}' = 104,7885 \text{ kN/m}^2$$

VERTIKALNE DEFORMACIJE (ϵ_z)

Tačka 0

$z = 0 \text{ m}$

$$\epsilon_{z,0} = \frac{\Delta \bar{\sigma}_{z,0}}{M_v} \Rightarrow \epsilon_{z,0} = \frac{128,4}{18000} \Rightarrow \epsilon_{z,0} = 0,00713$$

Tačka 1

$z = 2 \text{ m}$

$$\epsilon_{z,1} = \frac{\Delta \bar{\sigma}_{z,1}}{M_v} \Rightarrow \epsilon_{z,1} = \frac{39,804}{18000} \Rightarrow \epsilon_{z,1} = 0,00221$$

Tačka 1

$z = 2 \text{ m}$

$$\text{USLOV I} \quad \bar{\sigma}_{z,1}' \geq p_{c,1}' \geq p_{0,1}' \Rightarrow 81,79 \geq 62,979 \geq 39,804 \Rightarrow \text{①}$$

$$\epsilon_{z,1} = \frac{C_r}{1+e_0} \cdot \log \frac{p_{c,1}'}{p_{0,1}'} + \frac{C_c}{1+e_0} \cdot \log \frac{\bar{\sigma}_{z,1}'}{p_{c,1}'}$$

$$\epsilon_{z,1} = \frac{0,06}{1+0,9} \cdot \log \frac{62,979}{41,986} + \frac{0,3}{1+0,9} \cdot \log \frac{81,79}{62,979} \Rightarrow$$

$$\Rightarrow \epsilon_{z,1} = 0,02348$$

Tačka 2

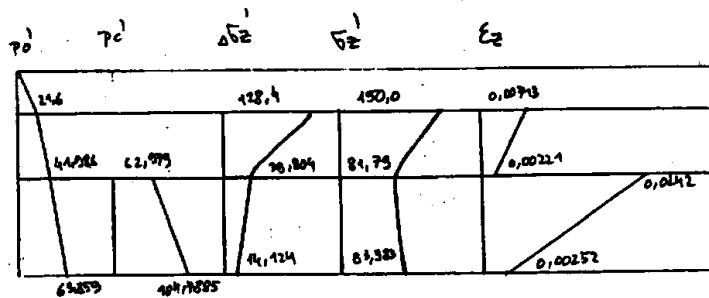
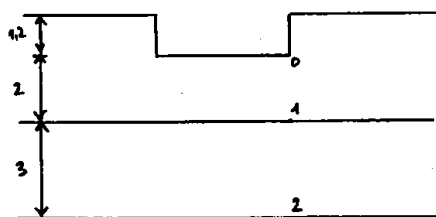
$z = 5 \text{ m}$

$$\text{USLOV I} \quad \bar{\sigma}_{z,2}' \geq p_{c,2}' \geq p_{0,2}' \Rightarrow \text{①}$$

$$\text{USLOV II} \quad \bar{\sigma}_{z,2}' \leq p_{c,2}'$$

$$\epsilon_{z,2} = \frac{C_r}{1+e_0} \cdot \log \frac{\bar{\sigma}_{z,2}'}{p_{0,2}'}$$

$$\epsilon_{z,2} = \frac{0,06}{1+0,9} \cdot \log \frac{83,983}{69,859} \Rightarrow \epsilon_{z,2} = 0,00252$$



Slučajnik ϵ

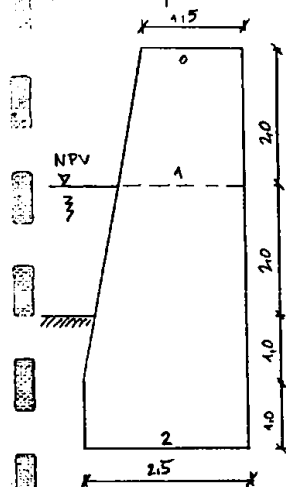
$$S = \int_0^z \epsilon_z dz$$

$$S = \frac{1}{2} \cdot (0,00713 \cdot 2 + 0,00221 \cdot 2 + 0,0242 \cdot 3 + 0,00252 \cdot 3) \Rightarrow S = \frac{1}{2} \cdot 0,09884 \Rightarrow$$

$$\Rightarrow S = 0,04942 \text{ m} \Rightarrow S = 4,942 \text{ cm}$$

Zadatak

Za potporni zid sa skice odrediti koeficijent sigurnosti protiv klizanja, ivične napone kao i prosečan napon na redukovanoj površini temeljne spojnice



$$\gamma_b = 24,0 \text{ kN/m}^3$$

$$\gamma = 17,0 \text{ kN/m}^3$$

$$\phi' = 32^\circ$$

$$\gamma_b' = \gamma_b - \gamma_w \Rightarrow \gamma_b' = 24,0 - 9,807 \Rightarrow \gamma_b' = 14,193 \text{ kN/m}^3$$

$$\gamma_z = 20,0 \text{ kN/m}^3$$

$$\gamma' = \gamma_z - \gamma_w \Rightarrow \gamma' = 20,0 - 9,807 \Rightarrow \gamma' = 10,193 \text{ kN/m}^3$$

$$\phi' = 32^\circ$$

Aktivni pritisak

$$z_1 = 2,0 \text{ m} \quad p_{o,1} = \gamma \cdot z_1 \Rightarrow p_{o,1} = 17 \cdot 2 \Rightarrow p_{o,1} = 34,0 \text{ kN/m}^2$$

$$z_2 = 6,0 \text{ m} \quad p_{o,2} = p_{o,1} + \gamma' (z_2 - z_1) \Rightarrow p_{o,2} = 34 + 10,193 \cdot 4 \Rightarrow p_{o,2} = 74,772 \text{ kN/m}^2$$

Efektivni vertikalni napon (σ_z')

$$\sigma_{z,1}' = p_{o,1} \Rightarrow \sigma_{z,1}' = 34,0 \text{ kN/m}^2$$

$$\sigma_{z,2}' = p_{o,2} \Rightarrow \sigma_{z,2}' = 74,772 \text{ kN/m}^2$$

Koeficijent aktivnog pritiska (K_a)

$$K_a = \tan^2 \left(45 - \frac{\phi'}{2} \right) \Rightarrow K_a = \tan^2 \left(45 - \frac{32}{2} \right) \Rightarrow K_a = 0,3073$$

Aktivni pritisak tla (p_a)

$$p_a = \sigma_z' \cdot K_a - 2 \cdot c' \cdot \sqrt{K_a} \Rightarrow c' = 0 \Rightarrow p_a = \sigma_z' \cdot K_a$$

$$p_{a,1} = \sigma_{z,1}' \cdot K_a \Rightarrow p_{a,1} = 34 \cdot 0,3073 \Rightarrow p_{a,1} = 10,448 \text{ kN/m}^2$$

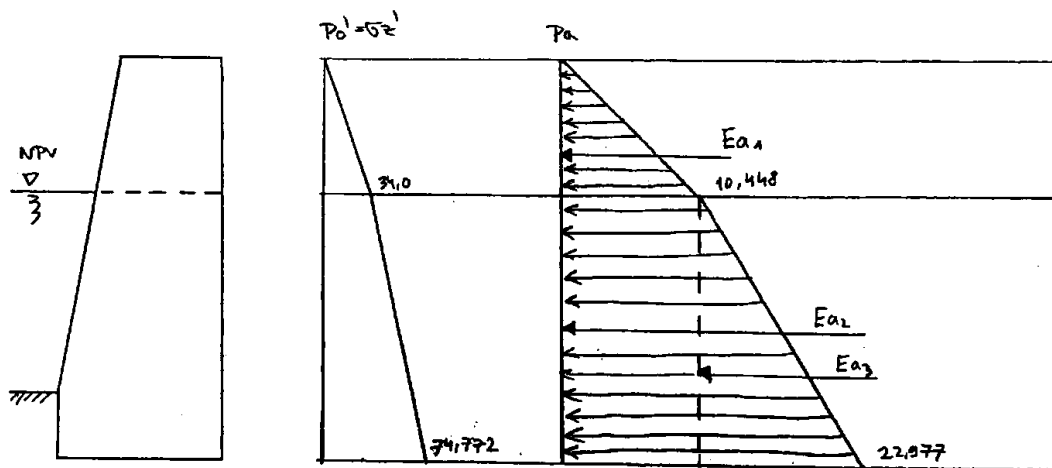
$$p_{a,2} = \sigma_{z,2}' \cdot K_a \Rightarrow p_{a,2} = 74,772 \cdot 0,3073 \Rightarrow p_{a,2} = 22,977 \text{ kN/m}^2$$

Dubina zone zatezanja u tlu

$$p_a(z_0) = \gamma \cdot z_0 \cdot K_a - 2 \cdot c' \cdot \sqrt{K_a} = 0 \Rightarrow \gamma \cdot z_0 \cdot K_a = 2 \cdot c' \cdot \sqrt{K_a} \Rightarrow z_0 = 0$$

Visina pritisnutog dela zida

$$H' = H - z_0 \Rightarrow H' = 6,0 - 0,0 \Rightarrow H' = 6,0 \text{ m}$$



- SILA AKTIVNOG PRITISKA (\vec{E}_a)

- INTENZITET

$$E_a = \int p_a \cdot dz \quad E_a = \text{površina dijagrama}$$

- Napadna tačka

$$Z_E = Z_0 + \text{TEŽIŠTE FIGURE}$$

$$E_{a1} = \frac{H_1 \cdot p_{a1}}{2} \Rightarrow E_{a1} = \frac{2 \cdot 10,448}{2} \Rightarrow E_{a1} = 10,448 \text{ kN/m}^2$$

$$Z_{E1} = Z_0 + \frac{2}{3} H_1 \Rightarrow Z_{E1} = 0 + \frac{2}{3} \cdot 2 \Rightarrow Z_{E1} = 1,333 \text{ m}$$

$$E_{a2} = H_2 \cdot p_{a1} \Rightarrow E_{a2} = 4 \cdot 10,448 \Rightarrow E_{a2} = 41,792 \text{ kN/m}^2$$

$$Z_{E2} = Z_0 + \frac{H_2}{2} \Rightarrow Z_{E2} = 2 + \frac{4}{2} \Rightarrow Z_{E2} = 4 \text{ m}$$

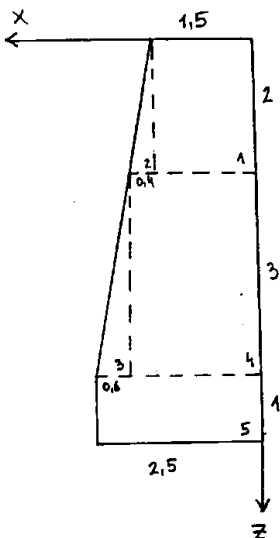
$$E_{a3} = \frac{H_2 \cdot (p_{a2} - p_{a1})}{2} \Rightarrow E_{a3} = \frac{4 \cdot (22,977 - 10,448)}{2} \Rightarrow E_{a3} = 25,058 \text{ kN/m}^2$$

$$Z_{E3} = Z_0 + \frac{2}{3} \cdot H_2 \Rightarrow Z_{E3} = 2 + \frac{2}{3} \cdot 4 \Rightarrow Z_{E3} = 4,66 \text{ m}$$

$$E_a = E_{a1} + E_{a2} + E_{a3} \Rightarrow E_a = 10,448 + 25,058 + 41,792 \Rightarrow E_a = 77,298 \text{ kN/m}^2$$

• Stabilnost zida i temelja

- Proračun težine (G) i koordinata težišta (X_G, Z_G)



F_i [m ²]	X_i	Z_i	$F_i X_i$	$F_i Z_i$
3,0	0,75	1,0	2,25	3,0
0,4	1,633	1,333	0,6532	0,533
0,9	2,10	4,00	1,890	3,60
5,7	0,95	3,50	5,415	19,95
2,5	1,25	5,50	3,125	13,75
$\Sigma F_i = 12,50$			$\Sigma = 13,33$	$\Sigma = 40,833$

$$Z:X = 5:1 \Rightarrow X = Z/5$$

$$G = \gamma b \cdot \Sigma F_i$$

$$G_1 = \gamma b \cdot F_1 \Rightarrow G_1 = 24 \cdot 3 \Rightarrow G_1 = 72 \text{ kN/m}$$

$$G_2 = \gamma b \cdot F_2 \Rightarrow G_2 = 24 \cdot 0,4 \Rightarrow G_2 = 9,6 \text{ kN/m}$$

$$G_3 = \gamma b \cdot F_3 \Rightarrow G_3 = 14,193 \cdot 0,9 \Rightarrow G_3 = 12,774 \text{ kN/m}$$

$$G_4 = \gamma b \cdot F_4 \Rightarrow G_4 = 14,193 \cdot 5,7 \Rightarrow G_4 = 80,9 \text{ kN/m}$$

$$G_5 = \gamma b \cdot F_5 \Rightarrow G_5 = 14,193 \cdot 2,5 \Rightarrow G_5 = 35,48 \text{ kN/m}$$

$$G = \Sigma G_i \Rightarrow G = 210,76 \text{ kN/m}$$

$$X_G = \frac{\Sigma F_i \cdot x_i}{\Sigma F_i} \quad Z_G = \frac{\Sigma F_i \cdot z_i}{\Sigma F_i}$$

$$X_G = \frac{13,33}{12,5} \Rightarrow X_G = 1,0664 \text{ m}$$

$$Z_G = \frac{40,833}{12,5} \Rightarrow Z_G = 3,267 \text{ m}$$

- Faktor sigurnosti protiv klizanja ($M \approx \tan \phi'$; $c_a \approx c'$)

$$F_K = \frac{S + EP}{T} \quad F_K = \frac{N \cdot M + c_a + EP}{E_a}$$

$$F_K = \frac{G \cdot \tan \phi' + c' \cdot B + EP}{E_a}$$

$$F_K = \frac{210,76 \cdot \tan 32^\circ}{77,298} \Rightarrow F_K = 1,7 \Rightarrow \text{Zadovoljen uslov } F_K > 1,5$$

* Ako se zanemaruje pasivni otpor ($EP=0$) faktor sigurnosti min dop = 1,5, u suprotnom je 2,0.

Zadatak 1

15. Jun. 2007

A

Izračunati parametre smičuće otpornosti za efektivne napone ϕ' i c' i parametre modifikovane anvelope Loma u Lembovom dijagramu uzorka ispitivanog u konsolidovano nedreniranom (CU) opitu triaksijalne kompresije. Glavni naponi i pritisci pri lomu dati su u tabeli.

Uzorak	σ_{3f} [kN/m ²]	σ_{1f} [kN/m ²]	u_f [kN/m ²]
1	200	370	120
2	400	740	240

Rešenje:

$$\phi' = ? \quad c' = ?$$

$$\alpha' = ? \quad a' = ?$$

Uzorak	$\sigma_{1f} + \sigma_{3f}$	$\sigma_{1f} - \sigma_{3f}$	$\sigma_{3f}' = \sigma_{3f} - u_f$	$\sigma_{1f}' = \sigma_{1f} - u_f$	$\sigma_{1f}' + \sigma_{3f}'$	$\sigma_{1f}' - \sigma_{3f}'$
1	570	170	80	250	330	170
2	1140	340	160	500	660	340

$$\tau_f = c' + \sigma_n \cdot \tan \phi'$$

$$\sin \phi' = \frac{(\sigma_{1f}' - \sigma_{3f}')i}{(\sigma_{1f}' + \sigma_{3f}')i + \frac{2 \cdot c'}{\tan \phi'}} \Rightarrow (\sigma_{1f}' + \sigma_{3f}') \cdot \sin^2 \phi' + 2c' \cdot \sin \phi' \cos \phi' - (\sigma_{1f}' - \sigma_{3f}') \cdot \sin \phi' = 0 \Rightarrow$$

$$\Rightarrow \begin{cases} 330 \cdot \sin^2 \phi' + 2 \cdot c' \cdot \sin \phi' \cdot \cos \phi' - 170 \cdot \sin \phi' = 0 \\ 660 \cdot \sin^2 \phi' + 2 \cdot c' \cdot \sin \phi' \cdot \cos \phi' - 340 \cdot \sin \phi' = 0 \end{cases} \xrightarrow{+} \Rightarrow$$

$$\Rightarrow 330 \cdot \sin^2 \phi' - 170 \cdot \sin \phi' = 0 \Rightarrow 330 \cdot \sin \phi' = 170 \Rightarrow \sin \phi' = 0,51515 \Rightarrow \phi' = 31^\circ$$

$$330 \cdot \sin^2 31 + 2 \cdot c' \cdot \sin 31 \cdot \cos 31 - 170 \cdot \sin 31 = 0 \Rightarrow c' = 0,021836$$

Parametri smičuće otpornosti za efektivne napone su:

$$\phi' = 31^\circ \quad c' \approx 0$$

Parametri modifikovane envelope u lemnovom dijagramu

$$t' = a' + s' \cdot \tan \alpha'$$

$$t' = \frac{\overline{b_{1t}} - \overline{b_{3t}}}{2} \quad s' = \frac{\overline{b_{1t}} + \overline{b_{3t}}}{2}$$

$$\sin \phi' = \tan \alpha' \quad c' = \frac{a'}{\cos \phi'}$$

$$\tan \alpha' = \sin \phi' \Rightarrow \tan \alpha' = \sin 31 \Rightarrow \tan \alpha' = 0,51504 \Rightarrow \alpha' = \arctg 0,51504 \Rightarrow \underline{\alpha' = 27,25^\circ}$$

$$\frac{a'}{\cos \phi'} = c' \Rightarrow \frac{a'}{\cos 31} = 0 \Rightarrow \underline{a' = 0}$$

Zadatak 2.

Januar 2008 A

U konsolidovanom nedreniranom (CU)-opitu triaksijalne kompresije na dva uzorka gline dobiveni su sledeći rezultati.

Uzorak	σ_{3f} (kN/m ²)	σ_{1f} (kN/m ²)	u_f (kN/m ²)
1	100	190	45
2	200	380	90

- (1) Izračunati parametre smičuće otpornosti za efektivne napone ϕ' i c'
 (2) Izračunati veličinu efektivnog normalnog napona i smičućeg napona koji deluju na ravan loma za uzorak 1 u stanju loma.

(1) $\tau_f = c' + \sigma_n' \cdot \tan \phi'$

Uzorak	$\sigma_{1f} + \sigma_{3f}$	$\sigma_{1f} - \sigma_{3f}$	$\sigma_{3f}' = \sigma_{3f} - u_f$	$\sigma_{1f}' = \sigma_{1f} - u_f$
1	290	90	55	145
2	580	180	110	290

$$\sin \phi' = \frac{(\sigma_{1f}' - \sigma_{3f}')}{(\sigma_{1f}' + \sigma_{3f}') + \frac{2c'}{\tan \phi'}} \Rightarrow (\sigma_{1f}' + \sigma_{3f}') \cdot \sin^2 \phi' + 2c' \sin \phi' \cos \phi' - \sin \phi' \cdot (\sigma_{1f}' - \sigma_{3f}') = 0$$

$$\begin{aligned} \text{I)} \quad & 200 \sin^2 \phi' + 2c' \sin \phi' \cos \phi' - 90 \sin \phi' = 0 \\ \text{II)} \quad & 400 \sin^2 \phi' + 2c' \sin \phi' \cos \phi' - 180 \sin \phi' = 0 \end{aligned} \quad \left. \begin{array}{l} \text{I)} \\ \text{II)} \end{array} \right\} + \Rightarrow$$

$$\Rightarrow 200 \sin^2 \phi' + 90 \sin \phi' \Rightarrow 200 \sin \phi' = 90 \Rightarrow \sin \phi' = 0,45 \Rightarrow \phi' = 26,74^\circ$$

$$200 \sin^2 \phi' + 2c' \sin \phi' \cos \phi' - 90 \sin \phi' = 0 \Rightarrow 200 \cdot \sin^2(26,74) + 2c' \cdot \sin 26,74 \cdot \cos 26,74 - 90 \sin 26,74 = 0 \Rightarrow$$

$$\Rightarrow 40,4836 + 0,804 c' - 40,495 = 0 \Rightarrow 0,804 \cdot c' = 0,0054 \Rightarrow c' = 0,0067 \approx 0 \Rightarrow c' = 0$$

$$(2) \quad \sigma_n' = \frac{\sigma_{1f}' + \sigma_{3f}'}{2} + \frac{\sigma_{1f}' - \sigma_{3f}'}{2} \cdot \cos 2\theta$$

$$\tau_f = \frac{\sigma_{1f}' - \sigma_{3f}'}{2} \cdot \sin 2\theta$$

$$\theta = 45 + \frac{\phi'}{2}$$

$$\theta = 45 + \frac{26,74}{2} \Rightarrow \theta = 58,37^\circ$$

$$\sigma_n' = \frac{(145+55)}{2} + \frac{(145-55)}{2} \cdot \cos 2 \cdot 58,37 \Rightarrow \sigma_n' = 100 + 45 \cdot \cos 116,74 \Rightarrow \sigma_n' = 79,75 \text{ kN/m}^2$$

$$\tau_f = \frac{(145-55)}{2} \cdot \sin 2 \cdot 58,37 \Rightarrow \tau_f = 45 \cdot \sin 116,74 \Rightarrow \tau_f = 40,19 \text{ kN/m}^2$$

Zadatak 2

Januar 2008

B

U konsolidovanom nedreniranom (CU) opitu triaksljalne kompresije na dva uzorka gline dobijeni su sledeći rezultati:

Uzork	σ_3 [kN/m ²]	σ_1 [kN/m ²]	u_f [kN/m ²]
1	100	210	45
2	200	420	90

- (1) Izračunati parametre smičuće otpornosti za efektivne napone ϕ' i c'
 (2) Izračunati veličinu efektivnog normalnog napona i smičućeg napona koji deluju na ravni loma za uzorak 1 u stanju loma.

Rešenje:

(1)

Uzork	$\sigma'_3 = \sigma_3 - u_f$	$\sigma'_1 = \sigma_1 - u_f$	$\sigma'_1 + \sigma'_3$	$\sigma'_1 - \sigma'_3$
1	55	165	220	110
2	110	330	440	220

$$\tau_f = c' + \sigma'_n \cdot \tan \phi'$$

$$\sin \phi' = \frac{(\sigma'_1 - \sigma'_3)_i}{(\sigma'_1 + \sigma'_3)_i + \frac{2c'}{\tan \phi'}} \Rightarrow (\sigma'_1 + \sigma'_3) \cdot \sin^2 \phi' + 2c' \sin \phi' \cos \phi' - (\sigma'_1 - \sigma'_3) \cdot \sin \phi' = 0 \Rightarrow$$

$$\begin{aligned} \text{I uzork} &\Rightarrow 220 \cdot \sin^2 \phi' + 2c' \sin \phi' \cos \phi' - 110 \sin \phi' = 0 \\ \text{II uzork} &\Rightarrow 440 \cdot \sin^2 \phi' + 2c' \sin \phi' \cos \phi' - 220 \sin \phi' = 0 \end{aligned} \quad \left. \begin{array}{l} (-) \\ (+) \end{array} \right\} \Rightarrow$$

$$\Rightarrow 220 \cdot \sin^2 \phi' - 110 \sin \phi' = 0 \Rightarrow 220 \cdot \sin \phi' = 110 \Rightarrow \sin \phi' = 0,5 \Rightarrow \phi' = 30' \Rightarrow$$

$$\Rightarrow 220 \cdot \sin^2 30 + 2 \cdot c' \cdot \sin 30 \cdot \cos 30 - 110 \cdot \sin 30 = 0 \Rightarrow$$

$$\Rightarrow 55 + 0,866 c' - 55 \Rightarrow 0,866 c' = 0 \Rightarrow c' = 0$$

$$(2) \phi = 45 + \frac{\phi'}{2}$$

$$\frac{\sigma'_1 - \sigma'_3}{2} \cdot \sin 2\phi = \tau_f$$

$$\frac{\sigma'_1 + \sigma'_3}{2} - \frac{\sigma'_1 - \sigma'_3}{2} \cdot \cos 2\phi = \sigma'_n$$

$$\phi = 45 + \frac{30}{2} \Rightarrow \phi = 60^\circ$$

$$\tau_f = \frac{110}{2} \cdot \sin 2 \cdot 60 \Rightarrow \tau_f = 55 \cdot \sin 120 \Rightarrow \tau_f = 47,631 \text{ kN/m}^2$$

$$\sigma'_n = \frac{220}{2} + \frac{110}{2} \cdot \cos 2 \cdot 60 \Rightarrow \sigma'_n = 110 + 55 \cdot \cos 120 \Rightarrow \sigma'_n = 82,5 \text{ kN/m}^2$$

Zadatak 1.

15. JUN. 2007

A

Izračunati parametre smičuće otpornosti za efektivne napone ϕ' i c' , parametre modifikovane anvelope loma u Lembovom diagramu uzorka ispitivanog u konsolidovano nedreniranom (CU) opitu triaksonalne kompresije. Glavni naponi i pritisci pri lomu dati su u tabeli.

Uzorak	σ_{3f} [kN/m ²]	σ_{1f} [kN/m ²]	u_f [kN/m ²]
1	200	370	120
2	400	740	240

Rešenje:

$$\phi' = ? \quad c' = ?$$

$$\alpha' = ? \quad a' = ?$$

Uzorak	$\sigma_{1f} + \sigma_{3f}$	$\sigma_{1f} - \sigma_{3f}$	$\sigma_{3f}' = \sigma_3 - u_f$	$\sigma_{1f}' = \sigma_1 - u_f$
1	570	170	80	250
2	1140	340	160	500

$$\tau_f = c' + \sigma_n' \cdot \tan \phi'$$

$$\sin \phi' = \frac{(\sigma_{1f}' - \sigma_{3f}')_i}{(\sigma_{1f}' + \sigma_{3f}')_i + \frac{2 \cdot c'}{\tan \phi'}}$$

$$\sin \phi' = \frac{(\sigma_{1f}' - \sigma_{3f}')_i \cdot \tan \phi'}{(\sigma_{1f}' + \sigma_{3f}')_i + \tan \phi' + 2c'} \Rightarrow \sin \phi' \cdot \frac{\sin \phi'}{\cos \phi'} \cdot (\sigma_{1f}' + \sigma_{3f}') + 2c' \cdot \sin \phi' = (\sigma_{1f}' - \sigma_{3f}')_i \cdot \frac{\sin \phi'}{\cos \phi'} \Rightarrow$$

$$\Rightarrow \sin^2 \phi' \cdot (\sigma_{1f}' + \sigma_{3f}')_i + 2c' \sin \phi' \cdot \cos \phi' = \sin \phi' \cdot (\sigma_{1f}' - \sigma_{3f}')_i \Rightarrow$$

$$\Rightarrow \sin^2 \phi' \cdot 330 + 2 \cdot c' \cdot \sin \phi' \cdot \cos \phi' - \sin \phi' \cdot 170 = 0 \quad \uparrow^{IV} \Rightarrow$$

$$\sin^2 \phi' \cdot 660 + 2 \cdot c' \cdot \sin \phi' \cdot \cos \phi' - \sin \phi' \cdot 340 = 0$$

$$\Rightarrow 330 \cdot \sin^2 \phi' - 170 \cdot \sin \phi' \Rightarrow 330 \cdot \sin \phi' = 170 \Rightarrow \sin \phi' = 0,51515 \Rightarrow \phi' = 31^\circ$$

$$\sin^2 31^\circ \cdot 330 + 2 \cdot c' \cdot \sin 31^\circ \cdot \cos 31^\circ - \sin 31^\circ \cdot 170 = 0 \Rightarrow 87,5372 + c' \cdot 0,88295 - 87,5515 = 0 \Rightarrow$$

$$\Rightarrow c' \cdot 0,88295 = 0,0143 \Rightarrow c' = 0,02486$$

Parametri smičuće otpornosti za efektivne napone su:

$$\phi' = 31^\circ \quad c' \approx 0$$

* Parametri modifikované envelope u Lembovom diagramu.

$$t' = a' + s' \cdot \tan \alpha'$$

$$t' = \frac{b_{1j}' - b_{3j}'}{2} \quad s' = \frac{b_{1j}' + b_{3j}'}{2}$$

$$\sin \phi' = \tan \alpha' \quad c' = \frac{a'}{\cos \phi'}$$

$$\tan \alpha' = \sin 31 \Rightarrow \tan \alpha' = 0,51504 \Rightarrow \alpha' = \arctg 0,51504 \Rightarrow \underline{\alpha' = 27,25^\circ}$$

$$\frac{a'}{\cos \phi} = c' \Rightarrow \frac{a'}{\cos 31} = 0 \Rightarrow \underline{a' = 0}$$

Zadatak 1.

18.01.2008 A

Zasićen uzorak gline debljine 2cm konsolidovao se u edometru nakon 20 min u relativnom iznosu od $U = 50\%$. Odrediti:

a) Koeeficijent konsolidacije gline (C_v)

b) Broj dana za koji će se sloj iste gline debljine 2m, između dva sloja peska konsolidovati u relativnom iznosu $U = 90\%$

c) Sleganje nakon vremena izračunatog pod b), ako je početni koeficijent poroznosti gline $e_0 = 1,02$, a na kraju primarne konsolidacije $e = 0,96$.

Rešenje:

$$d = 2\text{cm}$$

$$t_{50} = 20\text{ min} = 1200\text{ sec}$$

$$U = 50\%$$

$$a) C_v = ?$$

$$C_v = T_v \cdot \frac{H_d^2}{t}$$

$$H_d = \frac{1}{2} d \Rightarrow H_d = \frac{1}{2} \cdot 2\text{ cm} \Rightarrow H_d = 1\text{ cm}$$

$$* \begin{cases} U < 0,6 (60\%) \Rightarrow T_v = \frac{\pi}{4} \cdot U^2 \\ U > 0,6 (60\%) \Rightarrow T_v = -0,9332 \cdot \lg(1-U) - 0,0851 \end{cases}$$

$$U = 50\% < 60\% \Rightarrow T_v = \frac{\pi}{4} \cdot U^2 \Rightarrow T_v = \frac{\pi}{4} \cdot (0,5)^2 \Rightarrow T_v = 0,19635$$

$$C_v = T_v \cdot \frac{H_d^2}{t_{50}} \Rightarrow C_v = 0,19635 \cdot \frac{(1,01)^2}{1200} \Rightarrow C_v = 0,000163625\text{ cm}^2/\text{sec} \Rightarrow C_v = 1,63625 \cdot 10^{-4}\text{ cm}^2/\text{sec}$$

$$b) d = 2\text{ m} = 200\text{ cm}$$

$$U = 90\%$$

$$t_{90} = ?$$

$$H_d = \frac{1}{2} \cdot d \Rightarrow H_d = \frac{1}{2} \cdot 200 \Rightarrow H_d = 100\text{ cm}$$

$$U = 90\% > 60\% \Rightarrow T_v = -0,9332 \cdot \lg(1-U) - 0,0851 \Rightarrow T_v = -0,9332 \cdot \lg(1-0,9) - 0,0851 \Rightarrow$$

$$\Rightarrow T_v = 0,8481$$

$$C_v = T_v \cdot \frac{H_d^2}{t} \Rightarrow t_{90} = \frac{T_v \cdot H_d^2}{C_v} \Rightarrow t_{90} = \frac{0,8481 \cdot (100)^2}{1,63625 \cdot 10^{-4}} \Rightarrow t_{90} = 51831432,77\text{ sec} \Rightarrow$$

$$\Rightarrow t_{90} = 599,9\text{ dan} \Rightarrow t_{90} = 20\text{ meseci}$$

$$\begin{aligned}
 c) \quad t &= 20 \text{ msec} \\
 d &= 200 \text{ cm} \\
 e_0 &= 1,02 \\
 e &= 0,96 \\
 u &= 90\%
 \end{aligned}$$

$$* S_c = \frac{\Delta \bar{z} \cdot d}{M_v} \qquad \Delta \bar{z} = \gamma_w \cdot \Delta H_w \qquad M_v = \frac{C_v \cdot \gamma_w}{k}$$

$$S_c = \frac{\Delta e}{1+e_0} \cdot d \Rightarrow S_c = \frac{1,02 - 0,96}{1 + 1,02} \cdot 200 \Rightarrow S_c = 5,94 \text{ cm}$$

$$S_c(t) = S_c \cdot u(t) \Rightarrow S_c(t) = 5,94 \cdot 0,9 \Rightarrow S_c(t) = 5,346 \text{ cm}$$

Zadatak 1

22.04.2008 Grupa A

Standardni Proktorov opit zbijanja, dobijena je zavisnost između vlažnosti i zapreminske težine tla u vlažnom stanju prikazanu u tabeli.

Uzorak	1	2	3	4	5	6
$W(\%)$	6,4	8,8	11,0	14,0	16,0	18,0
$\gamma (\text{KN/m}^3)$	18,6	19,7	20,75	21,1	20,7	20,4

Specifična težina tla $\gamma_s = 2,7$

- Nacrtati zavisnost između vlažnosti (w) i zapreminske težine u suvom stanju (γ_d). Odrediti optimalnu vlažnost (w_{opt}) i maksimalnu zapreminsku težinu tla u suvom stanju (γ_{dmax}).
- Odrediti interval vlažnosti u kojem je stepen zbijanja tla RC veći od 93% pri maksimalnoj zbijenosti.
- Odrediti koeficijent poroznosti (e) i stepen zasićenja uzorka pri maksimalnoj zbijenosti.

Rešenje:

$$a) \quad \gamma_d = \frac{\gamma}{1+w}$$

$$\gamma_{d1} = \frac{18,6}{1+0,064} \Rightarrow \gamma_{d1} = 17,481 \text{ KN/m}^3$$

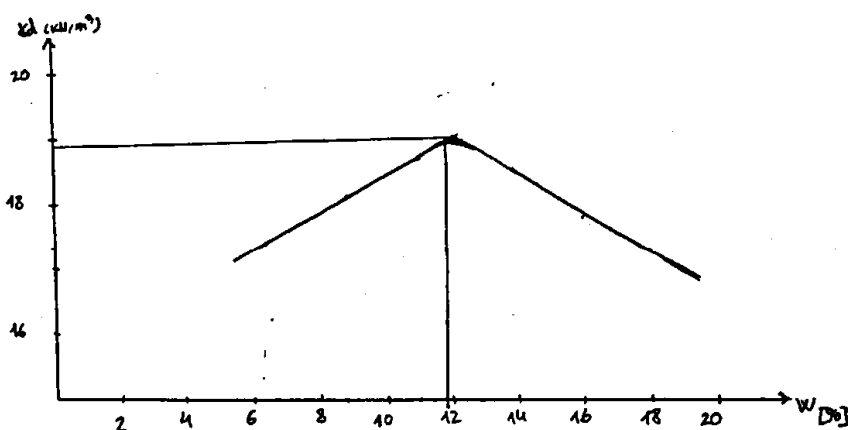
$$\gamma_{d2} = \frac{19,7}{1+0,088} \Rightarrow \gamma_{d2} = 18,11 \text{ KN/m}^3$$

$$\gamma_{d3} = \frac{20,75}{1+0,11} \Rightarrow \gamma_{d3} = 18,69 \text{ KN/m}^3$$

$$\gamma_{d4} = \frac{21,1}{1+0,14} \Rightarrow \gamma_{d4} = 18,51 \text{ KN/m}^3$$

$$\gamma_{d5} = \frac{20,70}{1+0,16} \Rightarrow \gamma_{d5} = 17,84 \text{ KN/m}^3$$

$$\gamma_{d6} = \frac{20,40}{1+0,18} \Rightarrow \gamma_{d6} = 17,29 \text{ KN/m}^3$$



$$\gamma_{dmax} = 18,8 \text{ KN/m}^3$$

$$w_{opt} = 11,8 \%$$

b) $RC > 98\%$

$$RC = \frac{\gamma_d}{\gamma_{d,max}} \Rightarrow \gamma_d > 98\% \cdot \gamma_{d,max} \Rightarrow \gamma_d = 0,98 \cdot 18,8 \Rightarrow \gamma_d = 18,424 \text{ kN/m}^3$$

sa dijagrama očitavamo W_{max} i W_{min} za koje je $\gamma_d = 18,424 \text{ kN/m}^3$

$$W_{min} = 9,1\%$$

$$W_{max} = 14,5\%$$

c) KOEFICIJENT POROZNOSTI (e)

$$e = \frac{\gamma_s}{\gamma_d} - 1$$

$$\gamma_s = G_s \cdot \gamma_w \Rightarrow \gamma_s = 2,7 \cdot 9,807 \Rightarrow \gamma_s = 26,48 \text{ kN/m}^3$$

$$e = \frac{26,48}{18,80} - 1 \Rightarrow e = 0,4085$$

STEPEN ZASIĆENJA

$$S_R = \frac{W}{W_Z} \cdot 100$$

$$W_Z = \left(\frac{\gamma_w}{\gamma_d} - \frac{\gamma_w}{\gamma_s} \right) \cdot 100 \Rightarrow W_Z = \left(\frac{9,807}{18,8} - \frac{9,807}{26,48} \right) \cdot 100 \Rightarrow W_Z = 15,13\%$$

$$S_R = \frac{11,8}{15,13} \Rightarrow S_R = 77,99 \Rightarrow S_R \approx 78\%$$

СЛЕГАНІЕ ПЛИТКИ ТЕМЕЛА

Zadatak 6.1.

- Pravougaoni temelj dimenzija $B/L = 2/4\text{ m}$, fundiran je na dubini $D_f = 1\text{ m}$

i opterećen jednolikim opterećenjem $q = 150 \frac{\text{kN}}{\text{m}^2}$.

- Teren se sastoji od sloja nisko-plastične prašine (ML) debljine 9 m ispod koje je sloj zbijenog šljunka (GV)

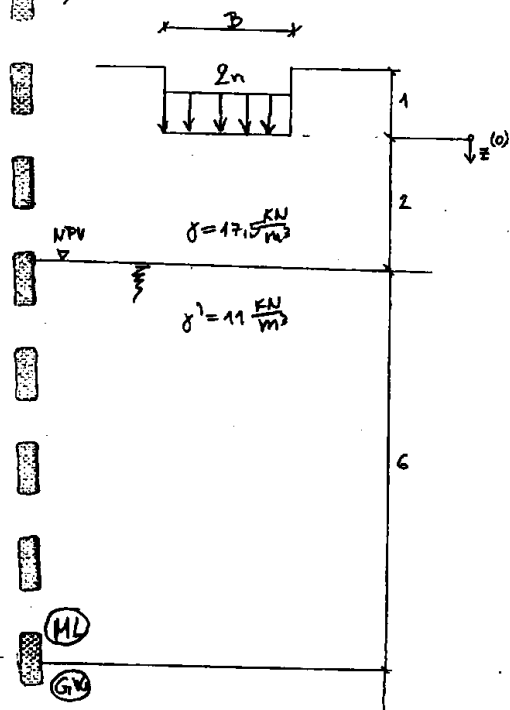
- Podzemna voda je na dubini od 3 m . Zapreminska težina tla iznad podzemne vode je $\gamma = 17,5 \frac{\text{kN}}{\text{m}^3}$, a ispod podzemne vode je $\gamma' = 11 \frac{\text{kN}}{\text{m}^3}$.

- Duž osovine temelja u tačkama na dubini $z = 0, 2, 4, 6, 8\text{ m}$ potrebno je:

a) Izračunati početne, inicijalne ili geostatičke efektivne napone

b) Izračunati prirastak vertikalnih napona metodom rasprostiranja napona pod uglom $\alpha = 0,5$; Metodom ŠTAMBRENERA ispod središnje tačke (ako je temelj savitljiv) i metodom KAVIJA (ako je temelj krut).

c) Nacrtati dijagrame vertikalnih napona ispod temelja.



Neto kontakti napon:

$$q_n = q - \gamma D_f$$

$$q_n = 150 - 17,5 \cdot 1 \Rightarrow q_n = 132,5 \frac{\text{kN}}{\text{m}^2}$$

a) POŽETNI (INICIJALNI ILI GEOSTATIZKI) EFEKTIVNI VERTIKALNI NAPONI

$$\begin{aligned}
 z_0 &= 0 \text{ m} & p_{0,0}' &= \gamma \cdot D_f \Rightarrow p_{0,0}' = 17,5 \cdot 1 \Rightarrow p_{0,0}' = 17,5 \frac{\text{kN}}{\text{m}^2} \\
 z_1 &= 2,0 \text{ m} & p_{0,1}' &= p_{0,0}' + \gamma \cdot (z_1 - z_0) \Rightarrow p_{0,1}' = 17,5 + 17,5 \cdot (2,0 - 0) \Rightarrow p_{0,1}' = 52,5 \frac{\text{kN}}{\text{m}^2} \\
 z_2 &= 4,0 \text{ m} & p_{0,2}' &= p_{0,1}' + \gamma' \cdot (z_2 - z_1) \Rightarrow p_{0,2}' = 52,5 + 11 \cdot (4 - 2) \Rightarrow p_{0,2}' = 74,5 \frac{\text{kN}}{\text{m}^2} \\
 z_3 &= 6,0 \text{ m} & p_{0,3}' &= p_{0,2}' + \gamma' \cdot (z_3 - z_2) \Rightarrow p_{0,3}' = 74,5 + 11 \cdot (6 - 4) \Rightarrow p_{0,3}' = 96,5 \frac{\text{kN}}{\text{m}^2} \\
 z_4 &= 8,0 \text{ m} & p_{0,4}' &= p_{0,3}' + \gamma' \cdot (z_4 - z_3) \Rightarrow p_{0,4}' = 96,5 + 11 \cdot (8 - 6) \Rightarrow p_{0,4}' = 118,5 \frac{\text{kN}}{\text{m}^2}
 \end{aligned}$$

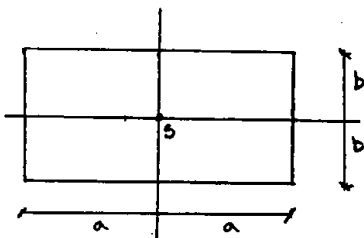
b) PRIRASTAK VERTIKALNIH NAPONA ISPOD TEMELJA METODOM RASPROSTIRANJA NAPONA pod uglom ($\tan \alpha = 0,5$).

$$\Delta \sigma_z' = \frac{B \cdot L \cdot z_n}{(B + z_n \cdot \tan \alpha) \cdot (L + z_n \cdot \tan \alpha)} \Rightarrow \tan \alpha = 0,5 \Rightarrow \Delta \sigma_z' = \frac{B \cdot L \cdot z_n}{(B + z_n)(L + z_n)} \Rightarrow$$

$$\Rightarrow \Delta \sigma_z' = \frac{2 \cdot 4 \cdot 132,5}{(2 + z)(4 + z)} \Rightarrow \Delta \sigma_z' = \frac{1060}{(2 + z)(4 + z)}$$

$$\begin{aligned}
 z_0 &= 0,0 \text{ m} & \Delta \sigma_{z,0}' &= \frac{1060}{2 \cdot 4} \Rightarrow \Delta \sigma_{z,0}' = 132,5 \frac{\text{kN}}{\text{m}^2} \\
 z_1 &= 2,0 \text{ m} & \Delta \sigma_{z,1}' &= \frac{1060}{4 \cdot 6} \Rightarrow \Delta \sigma_{z,1}' = 44,166 \frac{\text{kN}}{\text{m}^2} \\
 z_2 &= 4,0 \text{ m} & \Delta \sigma_{z,2}' &= \frac{1060}{6 \cdot 8} \Rightarrow \Delta \sigma_{z,2}' = 22,0833 \frac{\text{kN}}{\text{m}^2} \\
 z_3 &= 6,0 \text{ m} & \Delta \sigma_{z,3}' &= \frac{1060}{8 \cdot 10} \Rightarrow \Delta \sigma_{z,3}' = 13,25 \frac{\text{kN}}{\text{m}^2} \\
 z_4 &= 8,0 \text{ m} & \Delta \sigma_{z,4}' &= \frac{1060}{10 \cdot 12} \Rightarrow \Delta \sigma_{z,4}' = 8,833 \frac{\text{kN}}{\text{m}^2}
 \end{aligned}$$

* PRIRASTAK VERTIKALNIH NAPONA METODOM ŠTAINBRENERA



$$a = \frac{L}{2} \Rightarrow a = 2 \text{ m}$$

$$b = \frac{B}{2} \Rightarrow b = 1 \text{ m}$$

$$I = I\left(\frac{a}{b}, \frac{z}{b}\right) \quad \frac{a}{b} = 2$$

$$\Delta \sigma_z' = 4 \cdot I \cdot z_n \Rightarrow \Delta \sigma_z' = 4 \cdot I \cdot 132,5 \Rightarrow \Delta \sigma_z' = 530 \cdot I$$

$$\begin{aligned}
 z_0 &= 0 \text{ m} \Rightarrow \frac{z_0}{b} = 0 \Rightarrow I_0 = 0,25 \Rightarrow \Delta \sigma_{z,0}' = 530 \cdot I_0 \Rightarrow \Delta \sigma_{z,0}' = 132,5 \frac{\text{kN}}{\text{m}^2} \\
 z_1 &= 2 \text{ m} \Rightarrow \frac{z_1}{b} = 2 \Rightarrow I_1 = 0,12 \Rightarrow \Delta \sigma_{z,1}' = 530 \cdot I_1 \Rightarrow \Delta \sigma_{z,1}' = 63,6 \frac{\text{kN}}{\text{m}^2} \\
 z_2 &= 4 \text{ m} \Rightarrow \frac{z_2}{b} = 4 \Rightarrow I_2 = 0,047 \Rightarrow \Delta \sigma_{z,2}' = 530 \cdot I_2 \Rightarrow \Delta \sigma_{z,2}' = 29,91 \frac{\text{kN}}{\text{m}^2} \\
 z_3 &= 6 \text{ m} \Rightarrow \frac{z_3}{b} = 6 \Rightarrow I_3 = 0,024 \Rightarrow \Delta \sigma_{z,3}' = 530 \cdot I_3 \Rightarrow \Delta \sigma_{z,3}' = 12,72 \frac{\text{kN}}{\text{m}^2} \\
 z_4 &= 8 \text{ m} \Rightarrow \frac{z_4}{b} = 8 \Rightarrow I_4 = 0,014 \Rightarrow \Delta \sigma_{z,4}' = 530 \cdot I_4 \Rightarrow \Delta \sigma_{z,4}' = 7,42 \frac{\text{kN}}{\text{m}^2}
 \end{aligned}$$

* Priraštaj vertikalnih napona metodom Kany-a

$$I = I\left(\frac{z}{B}, \frac{z}{B}\right)$$

$$\Delta \sigma_z' = I \cdot q_n \Rightarrow \Delta \sigma_z' = 132,5 \cdot I$$

$$z_0 = 0 \text{ m} \Rightarrow \frac{z_0}{B} = 0 \Rightarrow I_0 = 1 \Rightarrow \Delta \sigma_{z,0}' = 132,5 \frac{\text{KN}}{\text{m}^2}$$

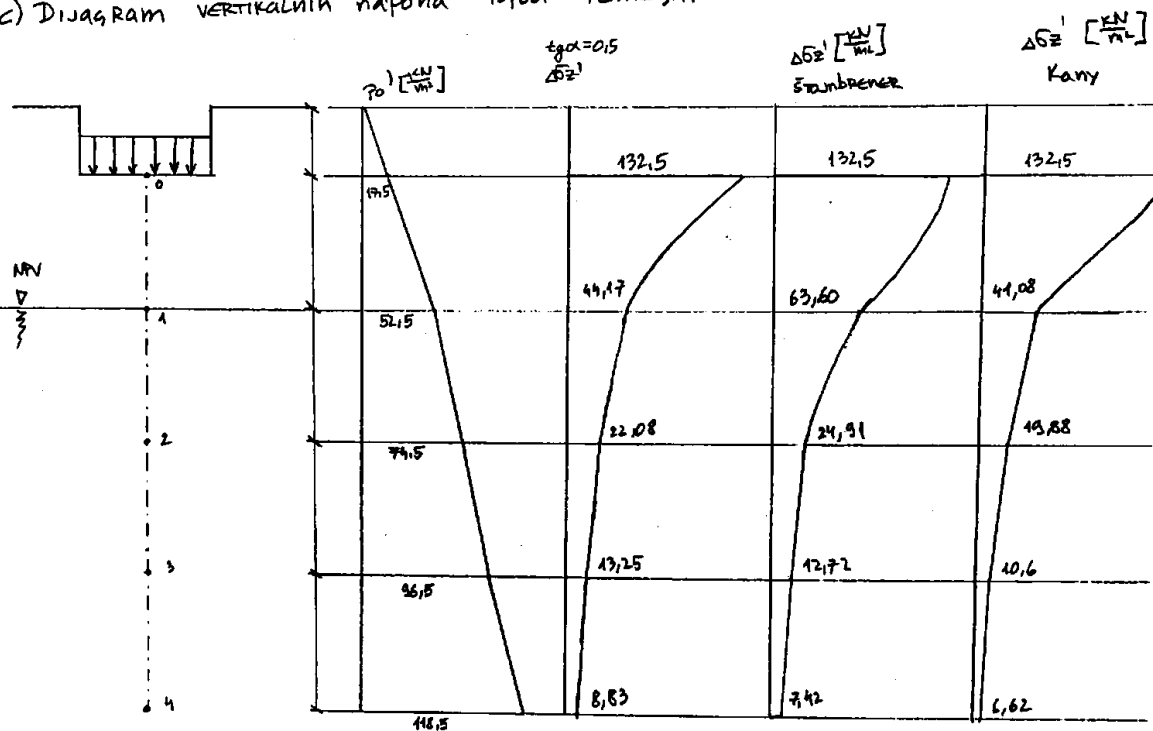
$$z_1 = 2 \text{ m} \Rightarrow \frac{z_1}{B} = 1 \Rightarrow I_1 = 0,310 \Rightarrow \Delta \sigma_{z,1}' = 41,08 \frac{\text{KN}}{\text{m}^2}$$

$$z_2 = 4 \text{ m} \Rightarrow \frac{z_2}{B} = 2 \Rightarrow I_2 = 0,150 \Rightarrow \Delta \sigma_{z,2}' = 19,88 \frac{\text{KN}}{\text{m}^2}$$

$$z_3 = 6 \text{ m} \Rightarrow \frac{z_3}{B} = 3 \Rightarrow I_3 = 0,080 \Rightarrow \Delta \sigma_{z,3}' = 10,60 \frac{\text{KN}}{\text{m}^2}$$

$$z_4 = 8 \text{ m} \Rightarrow \frac{z_4}{B} = 4 \Rightarrow I_4 = 0,005 \Rightarrow \Delta \sigma_{z,4}' = 0,62 \frac{\text{KN}}{\text{m}^2}$$

c) Diagram vertikalnih napona ispod temelja.

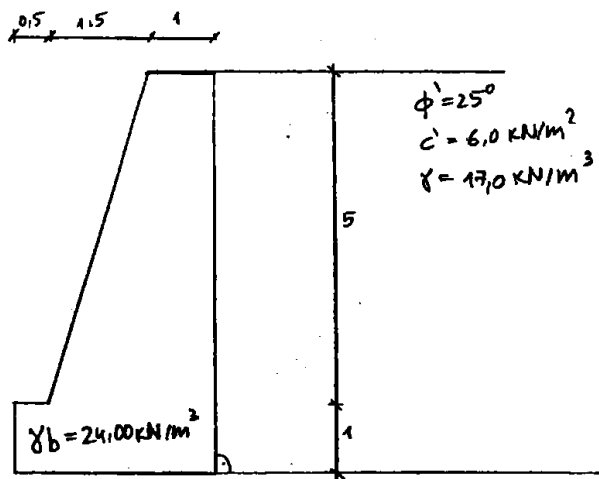


Zadatak 9.1.

Nema podzemne vode.

$$\phi' = 25^\circ \quad c' = 6 \text{ kN/m}^2 \quad \gamma = 17,0 \text{ kN/m}^3$$

- (1) Izračunati silu aktivnog pritiska tla na potporni zid po Rankine-u
- (2) Analizirati stabilnost potpornog zida protiv klizanja u temeljnoj spojnici
- (3) Odrediti nosivost tla po pravilniku, ivični i uporedni kontaktni napon.



- (1) Sila aktivnog pritiska tla

$$z = 6,0 \text{ m}$$

$$\text{Efektivni vertikalni napon: } \sigma_z' = \gamma \cdot z \Rightarrow \sigma_z' = 17 \cdot 6 \Rightarrow \sigma_z' = 102,0 \text{ kN/m}^2$$

$$\text{Koeficijent aktivnog pritiska } K_a = \tan^2(45 - \frac{\phi'}{2}) \Rightarrow K_a = \tan^2(45 - \frac{25}{2}) \Rightarrow K_a = 0,405$$

$$\text{Aktivni pritisak tla } p_a = \sigma_z' \cdot K_a - 2 \cdot c' \cdot \sqrt{K_a}$$

$$p_a = 102 \cdot 0,405 - 2 \cdot 6 \cdot \sqrt{0,405} \Rightarrow p_a = 33,67 \text{ kN/m}^2$$

Dubina zone zatezanja u tlu:

$$p_a(z_0) = \gamma \cdot z_0 \cdot K_a - 2 \cdot c' \cdot \sqrt{K_a} = 0 \Rightarrow \gamma \cdot z_0 \cdot K_a = 2 \cdot c' \cdot \sqrt{K_a} \Rightarrow$$

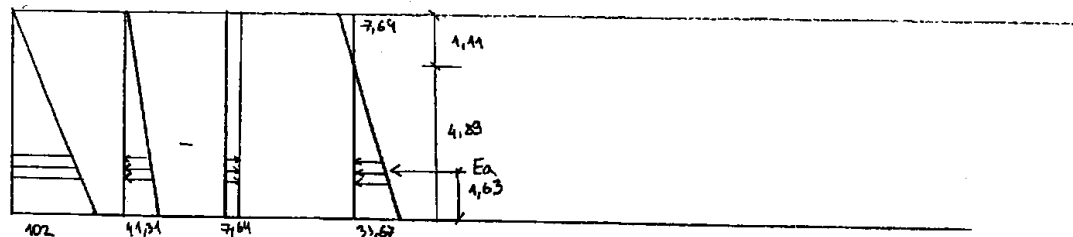
$$\Rightarrow z_0 = \frac{2 \cdot c' \cdot \sqrt{K_a}}{\gamma \cdot K_a} \Rightarrow z_0 = \frac{2 \cdot 6}{17 \cdot \sqrt{0,405}} \Rightarrow z_0 = 1,11 \text{ m}$$

Visina pritisnutog dela zida

$$H' = H - z_0 \Rightarrow H' = 6 - 1,11 \Rightarrow H' = 4,89 \text{ m}$$

DIAGRAM EFEKTIVNOG VERTIKALNOG NAPONA I AKTIVNOG PRITISKA TLA

σ_z $\sigma_z \cdot K_a$ $2 \cdot \sigma_z \cdot K_a$ P_a



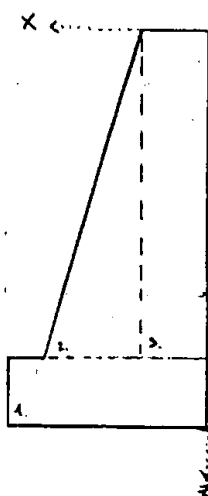
SILA AKTIVNOG PRITISKA TLA \vec{E}_a NA POTPORNI ZID

$$\text{INTENZITET SILE: } E_a = \int P_a \cdot dz \rightarrow E_a = P_a \cdot H' : 2 \Rightarrow E_a = 33.67 \cdot 4.89 : 2 \Rightarrow E_a = 82.33 \text{ kN/m}^2$$

$$\text{NAPADNA TOČKA } z_E = z_0 + H' \cdot \frac{2}{3} \Rightarrow z_E = 1.11 + \frac{2}{3} \cdot 4.89 \Rightarrow z_E = 4.37 \text{ m}$$

(2) ANALIZA STABILNOSTI POTPORNOG ZIDA

PRORAČUN TEŽINE (G) I KOORDINATE TEŽISTA (x_G, z_G)



F_i	x_i	z_i	$F_i \cdot x_i$	$F_i \cdot z_i$
$F_1 = 3 \text{ m}^2$	$x_1 = 1.5$	$z_1 = 5.5$	4.5	16.5
$F_2 = \frac{1.5 \cdot 5}{2} \Rightarrow F_2 = 3.75 \text{ m}^2$	$x_2 = 1.5$	$z_2 = 3.33$	5.63	12.5
$F_3 = 1.5 \Rightarrow F_3 = 5.00 \text{ m}^2$	$x_3 = 0.5$	$z_3 = 2.5$	2.50	12.5
$F = \sum F_i \Rightarrow F = 11.75 \text{ m}^2$			12.63	41.50

$$G = \gamma_b \cdot \sum F_i \Rightarrow G = 24 \cdot 11.75 \Rightarrow G = 282.00 \text{ kN/m}$$

$$x_G = \frac{\sum F_i \cdot x_i}{\sum F_i} \Rightarrow x_G = \frac{12.63}{11.75} \Rightarrow x_G = 1.07 \text{ m}$$

$$z_G = \frac{\sum F_i \cdot z_i}{\sum F_i} \Rightarrow z_G = \frac{41.50}{11.75} \Rightarrow z_G = 3.53 \text{ m}$$

FAKTOR SIGURNOSTI PROTIV KUZANJA U TEMELJNOJ SPOJNICI ($M \cong \tan \phi'$ $c_a \cong c'$)

$$F_k = \frac{S + E_p}{T} \quad F_k = \frac{N \cdot M + c_a + E_p}{E_a} \quad F_k = \frac{G \cdot \tan \phi' + c' \cdot B}{E_a}$$

$$F_k = \frac{282.00 \cdot \tan 25 + 6 \cdot 3}{82.33} \Rightarrow F_k = 1.80$$

AKO SE ZANEMARUJE PASIVNI OTPOR ($E_p = 0$) FAKTOR SIGURNOSTI $F_k = 1.8$ JE VEĆI OD MINIMALNO DOZVOLJENOG OTPORA OD 1.5.

(3) Proračun dozvoljenog, ivičnog i uporednog napona u temeljnoj spojnici

- Ekscentricitet rezultante opterećenja u odnosu na težište temeljne spojnice

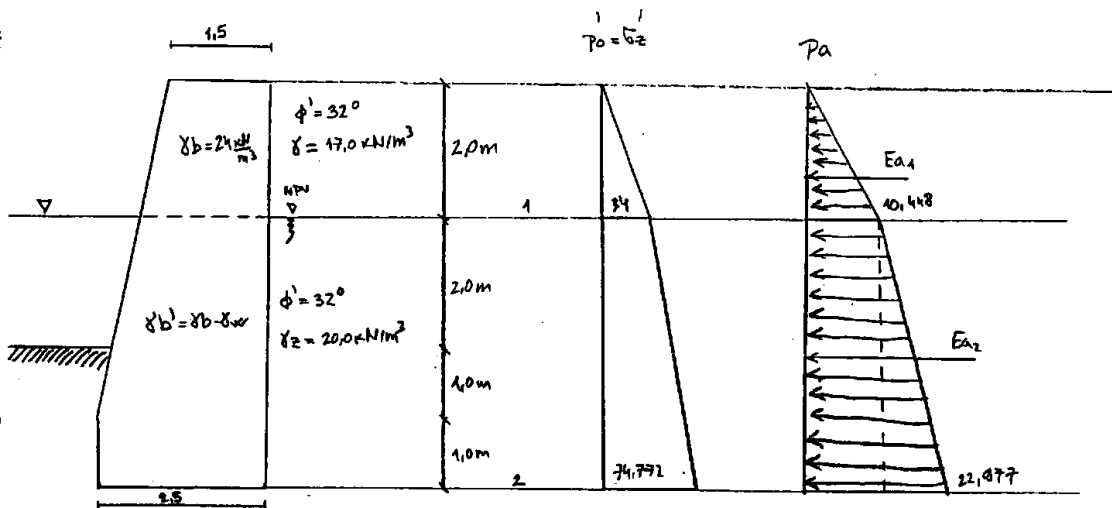
$$e_B = \frac{E_d \cdot (H - z_E) + G \cdot (X_G - B/2)}{G} \Rightarrow e_B = \frac{82,33 \cdot (6 - 4,37) + 282 \cdot (1,07 - 3/2)}{282} \Rightarrow e_B = 0,05 \text{ m}$$

- Efektivna širina temelja

$$B' = B - 2 \cdot e_B \Rightarrow B' = 3 - 2 \cdot 0,05 \Rightarrow B' = 2,90 \text{ m}$$

- Mobilisani parametri čvrstoće

Zadatak



$$\gamma_b = 24 \text{ kN/m}^3$$

$$\gamma_b' = \gamma_b - \gamma_w \Rightarrow \gamma_b' = 24 - 9.807 \Rightarrow \gamma_b' = 14.193 \text{ kN/m}^3$$

$$\gamma = 17.0 \text{ kN/m}^3$$

$$\gamma_z = 20.0 \text{ kN/m}^3$$

$$\gamma' = \gamma_z - \gamma_w \Rightarrow \gamma' = 20 - 9.807 \Rightarrow \gamma' = 10.193 \text{ kN/m}^3$$

(1) Odrediti aktivni pritisak tla na zid prema RANKINE-U

$$z_1 = 2 \text{ m} \quad p_{0,1} = \gamma \cdot z_1 \Rightarrow p_{0,1} = 17 \cdot 2 \Rightarrow p_{0,1} = 34.0 \text{ kN/m}^2$$

$$z_2 = 6 \text{ m} \quad p_{0,2} = p_{0,1} + \gamma' \cdot (z_2 - z_1) \Rightarrow p_{0,2} = 34 + 10.193 \cdot 4 \Rightarrow p_{0,2} = 74.772 \text{ kN/m}^2$$

- Efektivni vertikalni napon

$$\sigma_{z,1} = p_{0,1} \Rightarrow \sigma_{z,1} = 34 \text{ kN/m}^2$$

$$\sigma_{z,2} = p_{0,2} \Rightarrow \sigma_{z,2} = 74.772 \text{ kN/m}^2$$

- Koeficijent aktivnog pritiska

$$K_a = \tan^2 \left(45 - \frac{\phi'}{2} \right) \Rightarrow K_a = \tan^2 \left(45 - \frac{32}{2} \right) \Rightarrow K_a = \tan^2(29) \Rightarrow K_a = 0.3073$$

- Aktivni pritisak tla

$$p_a = \sigma_z' \cdot K_a - 2 \cdot c' \sqrt{K_a} \Rightarrow p_a = \sigma_z' \cdot K_a \quad * [c'=0]$$

$$p_{a,1} = \sigma_{z,1} \cdot K_a \Rightarrow p_{a,1} = 34 \cdot 0.3073 \Rightarrow p_{a,1} = 10.448 \text{ kN/m}^2$$

$$p_{a,2} = \sigma_{z,2} \cdot K_a \Rightarrow p_{a,2} = 74.772 \cdot 0.3073 \Rightarrow p_{a,2} = 22.977 \text{ kN/m}^2$$

- Dubina zone zatezanja u tlu

$$p_a(z_0) = \gamma \cdot z_0 \cdot K_a - 2 \cdot c' \sqrt{K_a} = 0 \Rightarrow \gamma \cdot z_0 \cdot K_a = 2 \cdot c' \sqrt{K_a} \Rightarrow z_0 = 0$$

- Visina pritisnutog dela zida

$$H' = H - z_0 \Rightarrow H' = 6 - 0 \Rightarrow H' = 6 \text{ m}$$

- Sila aktivnog pritiska \vec{E}_0 na potporni zid:

• Intenzitet sile:

$$E_a = \int p_a \cdot dz \quad E_a = \text{površina dijagrama}$$

• Napadna tačka

$$Z_E = Z_0 + \text{težište figure}$$

$$E_{a1} = \frac{H \cdot p_{a1}}{2} \Rightarrow E_{a1} = \frac{2 \cdot 10,448}{2} \Rightarrow E_{a1} = 10,448 \text{ kN/m}^2$$

$$Z_{E1} = Z_0 + \frac{2}{3} \cdot H_1 \Rightarrow Z_{E1} = \frac{2}{3} \cdot 2 \Rightarrow Z_{E1} = 1,333 \text{ m}$$

$$E_{a2} = H \cdot p_{a1} \Rightarrow E_{a2} = 4 \cdot 10,448 \Rightarrow E_{a2} = 41,792 \text{ kN/m}^2$$

$$Z_{E12} = Z_0 + \frac{H_1}{2} \Rightarrow Z_{E12} = 2 + \frac{2}{2} \Rightarrow Z_{E12} = 4 \text{ m}$$

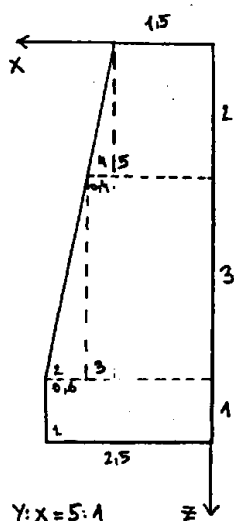
$$E_{a3} = \frac{H \cdot (p_{a2} - p_{a1})}{2} \Rightarrow E_{a3} = \frac{4 \cdot (22,977 - 10,448)}{2} \Rightarrow E_{a3} = 25,058 \text{ kN/m}^2$$

$$Z_{E13} = Z_0 + \frac{2}{3} H \Rightarrow Z_{E13} = 2 + \frac{2}{3} \cdot 4 \Rightarrow Z_{E13} = 4,66 \text{ m}$$

$$E_a = E_{a1} + E_{a2} + E_{a3} \Rightarrow E_a = 77,298 \text{ kN/m}^2$$

(2) Analizirati stabilnost zida i temelja uz zanemarivanje pasivnog otpora.

- Proračun težine (G_i) i koordinata težišta (X_i, Z_i)



$$G_i = \gamma_b \cdot \sum F_i$$

F_i [m ²]	X_i	Z_i	$F_i X_i$	$F_i Z_i$
2,5	1,25	5,5	3,125	13,75
0,9	2,10	4,00	1,89	3,60
5,7	0,95	3,5	5,415	19,95
0,4	1,633	0,666	0,6652	0,2664
3,0	0,75	1,0	2,25	3,00
		$\sum F_i = 12,5$	$\sum F_i X_i = 13,33$	$\sum F_i Z_i = 40,56$

$$G_1 = \gamma_b \cdot F_1 \Rightarrow G_1 = 14,193 \cdot 2,5 \Rightarrow G_1 = 35,4825 \text{ kN/m}$$

$$G_2 = \gamma_b \cdot F_2 \Rightarrow G_2 = 14,193 \cdot 0,9 \Rightarrow G_2 = 12,7737 \text{ kN/m}$$

$$G_3 = \gamma_b \cdot F_3 \Rightarrow G_3 = 14,193 \cdot 5,7 \Rightarrow G_3 = 80,90 \text{ kN/m}$$

$$G_4 = \gamma_b \cdot F_4 \Rightarrow G_4 = 24 \cdot 0,4 \Rightarrow G_4 = 9,60 \text{ kN/m}$$

$$G_5 = \gamma_b \cdot F_5 \Rightarrow G_5 = 24 \cdot 3,0 \Rightarrow G_5 = 72,00 \text{ kN/m}$$

$$G = \sum G_i \Rightarrow G = 210,76 \text{ kN/m}$$

$$X_G = \frac{\sum F_i \cdot x_i}{\sum F_i}$$

$$Z_G = \frac{\sum F_i \cdot z_i}{\sum F_i}$$

$$X_G = \frac{13,33}{12,50} \Rightarrow X_G = 1,0664 \text{ m}$$

$$Z_G = \frac{40,566}{12,5} \Rightarrow Z_G = 3,2453 \text{ m}$$

- Faktor sigurnosti protiv klizanja u temeljnoj spalnici ($\mu \approx \tan \phi'$; $c_a \approx c'$)

$$F_k = \frac{S + E_p}{T}$$

$$F_k = \frac{N \cdot \mu + c_a + E_p}{E_a}$$

$$F_k = \frac{G \cdot \tan \phi' + c' \cdot B + E_p}{E_a}$$

$$F_k = \frac{G \cdot \tan \phi' + c' \cdot B + E_p}{E_a} \Rightarrow F_k = \frac{210,76 \cdot \tan 32}{77,298} \Rightarrow F_k = 1,704$$

* Ako se zanemaruje pasivni otpor ($E_p = 0$) faktor sigurnosti - minimalno dozvoljeni je 1,5, u suprotnom je 2,0.

Zadovoljen je uslov jer je $F_k > 1,5$.