example_06

December 24, 2022

$z_w = 13$ (depth of watertable) $\gamma_w = 62.400$

$h_1 = 5$ (Layer 1 properties) $\gamma_1 = 100$ $\gamma_{sat1} = 110$

$\phi_1 = 26$ $c_1 = 50$

$h_2 = 10$ (layer 2 properties) $\gamma_2 = 110$ $\gamma_{sat2} = 120$

$\phi_2 = 30$ $c_2 = 0$

$h_3 = 7$ (layer 3 properties) $\gamma_3 = 120$ $\gamma_{sat3} = 130$

$\phi_3 = 34$ $c_3 = 0$

$z_0 = 0$ (at the ground surface)

$\sigma_0 = 0.000$

$u_0 = 0.000$

$\sigma'_{v_0} = \sigma_0 - u_0 = 0.000 - 0.000 = 0.000$

$z_1 = 5$ (at the first layer boundary)

$\sigma_1 = \sigma_0 + h_1 \cdot \gamma_1 = 0.000 + 5 \cdot 100 = 500.000$

$u_1 = 0.000$

$\sigma'_{v_1} = \sigma_1 - u_1 = 500.000 - 0.000 = 500.000$

$\phi_{1_r} = \text{radians}\left(\phi_1\right) = \text{radians}\left(26\right) = 0.454$

$$\text{ka}_1 = \left(\tan\left(\frac{\pi}{4} - \frac{\phi_{1_r}}{2}\right)\right)^2 = \left(\tan\left(\frac{3.142}{4} - \frac{0.454}{2}\right)\right)^2 = 0.390$$

$$\text{kp}_1 = \left(\tan\left(\frac{\pi}{4} + \frac{\phi_{1_r}}{2}\right)\right)^2 = \left(\tan\left(\frac{3.142}{4} + \frac{0.454}{2}\right)\right)^2 = 2.561$$

$$z_2 = 13 \text{ (at the groundwater table)}$$

$$\sigma_2 = \sigma_1 + (z_w - z_1) \cdot \gamma_2 = 500.000 + (13 - 5) \cdot 110 = 1380.000$$

$$u_2 = 0.000$$

$$\sigma'_{v_2} = \sigma_2 - u_2 = 1380.000 - 0.000 = 1380.000$$

$$\phi_{2_r} = \text{radians}\left(\phi_2\right) = \text{radians}\left(30\right) = 0.524$$

$$\text{ka}_2 = \left(\tan\left(\frac{\pi}{4} - \frac{\phi_{2_r}}{2}\right)\right)^2 = \left(\tan\left(\frac{3.142}{4} - \frac{0.524}{2}\right)\right)^2 = 0.333$$

$$\text{kp}_2 = \left(\tan\left(\frac{\pi}{4} + \frac{\phi_{2_r}}{2}\right)\right)^2 = \left(\tan\left(\frac{3.142}{4} + \frac{0.524}{2}\right)\right)^2 = 3.000$$

$$z_3 = 15 \text{ (at the second layer boundary)}$$

$$\sigma_3 = \sigma_2 + (h_2 - (z_w - z_1)) \cdot \gamma_{sat2} = 1380.000 + (10 - (13 - 5)) \cdot 120 = 1620.000$$

$$u_3 = (z_3 - z_w) \cdot \gamma_w = (15 - 13) \cdot 62.400 = 124.800$$

$$\sigma'_{v_3} = \sigma_3 - u_3 = 1620.000 - 124.800 = 1495.200$$

$$\phi_{2_r} = \text{radians}\left(\phi_2\right) = \text{radians}\left(30\right) = 0.524$$

$$\text{ka}_2 = \left(\tan\left(\frac{\pi}{4} - \frac{\phi_{2_r}}{2}\right)\right)^2 = \left(\tan\left(\frac{3.142}{4} - \frac{0.524}{2}\right)\right)^2 = 0.333$$

$$\text{kp}_2 = \left(\tan\left(\frac{\pi}{4} + \frac{\phi_{2_r}}{2}\right)\right)^2 = \left(\tan\left(\frac{3.142}{4} + \frac{0.524}{2}\right)\right)^2 = 3.000$$

$$z_4 = 22 \text{ (at the bottom of the soil profile)}$$

$$\sigma_4 = \sigma_3 + h_3 \cdot \gamma_{sat3} = 1620.000 + 7 \cdot 130 = 2530.000$$

$$u_4 = (z_4 - z_w) \cdot \gamma_w = (22 - 13) \cdot 62.400 = 561.600$$

$$\sigma'_{v_4} = \sigma_4 - u_4 = 2530.000 - 561.600 = 1968.400$$

$$\phi_{3_r} = \text{radians}\,(\phi_3) = \text{radians}\,(34) = 0.593$$

$$\text{ka}_3 = \left(\tan\left(\frac{\pi}{4} - \frac{\phi_{3_r}}{2}\right)\right)^2 = \left(\tan\left(\frac{3.142}{4} - \frac{0.593}{2}\right)\right)^2 = 0.283$$

$$\text{kp}_3 = \left(\tan\left(\frac{\pi}{4} + \frac{\phi_{3_r}}{2}\right)\right)^2 = \left(\tan\left(\frac{3.142}{4} + \frac{0.593}{2}\right)\right)^2 = 3.537$$

$z_0 = 0$ (at the ground surface)

$$\sigma'_{ha_0} = \mathrm{ka}_1 \cdot \sigma'_{v_0} - 2 \cdot c_1 \cdot \sqrt{\mathrm{ka}_1} = 0.390 \cdot 0.000 - 2 \cdot 50 \cdot \sqrt{0.390} = -62.487$$

$$\sigma'_{hp_0} = \mathrm{kp}_1 \cdot \sigma'_{v_0} + 2 \cdot c_1 \cdot \sqrt{\mathrm{kp}_1} = 2.561 \cdot 0.000 + 2 \cdot 50 \cdot \sqrt{2.561} = 160.033$$

$z_1 = 5$ (at the first layer boundary)

$$\sigma'_{ha_{1t}} = \mathrm{ka}_1 \cdot \sigma'_{v_1} - 2 \cdot c_1 \cdot \sqrt{\mathrm{ka}_1} = 0.390 \cdot 500.000 - 2 \cdot 50 \cdot \sqrt{0.390} = 132.744$$

$$\sigma'_{hp_{1t}} = \mathrm{kp}_1 \cdot \sigma'_{v_1} + 2 \cdot c_1 \cdot \sqrt{\mathrm{kp}_1} = 2.561 \cdot 500.000 + 2 \cdot 50 \cdot \sqrt{2.561} = 1440.569$$

$$\sigma'_{ha_{1b}} = \mathrm{ka}_2 \cdot \sigma'_{v_1} - 2 \cdot c_2 \cdot \sqrt{\mathrm{ka}_2} = 0.333 \cdot 500.000 - 2 \cdot 0 \cdot \sqrt{0.333} = 166.667$$

$$\sigma'_{hp_{1b}} = \mathrm{kp}_2 \cdot \sigma'_{v_1} + 2 \cdot c_2 \cdot \sqrt{\mathrm{kp}_2} = 3.000 \cdot 500.000 + 2 \cdot 0 \cdot \sqrt{3.000} = 1500.000$$

$z_2 = 13$ (at groundwater table)

$$\sigma'_{ha_2} = \mathrm{ka}_2 \cdot \sigma'_{v_2} - 2 \cdot c_2 \cdot \sqrt{\mathrm{ka}_2} = 0.333 \cdot 1380.000 - 2 \cdot 0 \cdot \sqrt{0.333} = 460.000$$

$$\sigma'_{hp_2} = \mathrm{kp}_2 \cdot \sigma'_{v_2} + 2 \cdot c_2 \cdot \sqrt{\mathrm{kp}_2} = 3.000 \cdot 1380.000 + 2 \cdot 0 \cdot \sqrt{3.000} = 4140.000$$

$z_3 = 22$ (at the second layer boundary)

$$\sigma'_{ha_{3t}} = \mathrm{ka}_2 \cdot \sigma'_{v_3} - 2 \cdot c_2 \cdot \sqrt{\mathrm{ka}_2} = 0.333 \cdot 1495.200 - 2 \cdot 0 \cdot \sqrt{0.333} = 498.400$$

$$\sigma'_{hp_{3t}} = \mathrm{kp}_2 \cdot \sigma'_{v_3} + 2 \cdot c_2 \cdot \sqrt{\mathrm{kp}_2} = 3.000 \cdot 1495.200 + 2 \cdot 0 \cdot \sqrt{3.000} = 4485.600$$

$$\sigma'_{ha_{3b}} = \mathrm{ka}_3 \cdot \sigma'_{v_3} - 2 \cdot c_3 \cdot \sqrt{\mathrm{ka}_3} = 0.283 \cdot 1495.200 - 2 \cdot 0 \cdot \sqrt{0.283} = 422.715$$

$$\sigma'_{hp_{3b}} = \mathrm{kp}_3 \cdot \sigma'_{v_3} + 2 \cdot c_3 \cdot \sqrt{\mathrm{kp}_3} = 3.537 \cdot 1495.200 + 2 \cdot 0 \cdot \sqrt{3.537} = 5288.720$$

$z_3 = 22$ (at the bottom of the soil profile)

$$\sigma'_{ha_4} = \mathrm{ka}_3 \cdot \sigma'_{v_4} - 2 \cdot c_3 \cdot \sqrt{\mathrm{ka}_3} = 0.283 \cdot 1968.400 - 2 \cdot 0 \cdot \sqrt{0.283} = 556.496$$

$$\sigma'_{hp_4} = \mathrm{kp}_3 \cdot \sigma'_{v_4} + 2 \cdot c_3 \cdot \sqrt{\mathrm{kp}_3} = 3.537 \cdot 1968.400 + 2 \cdot 0 \cdot \sqrt{3.537} = 6962.491$$