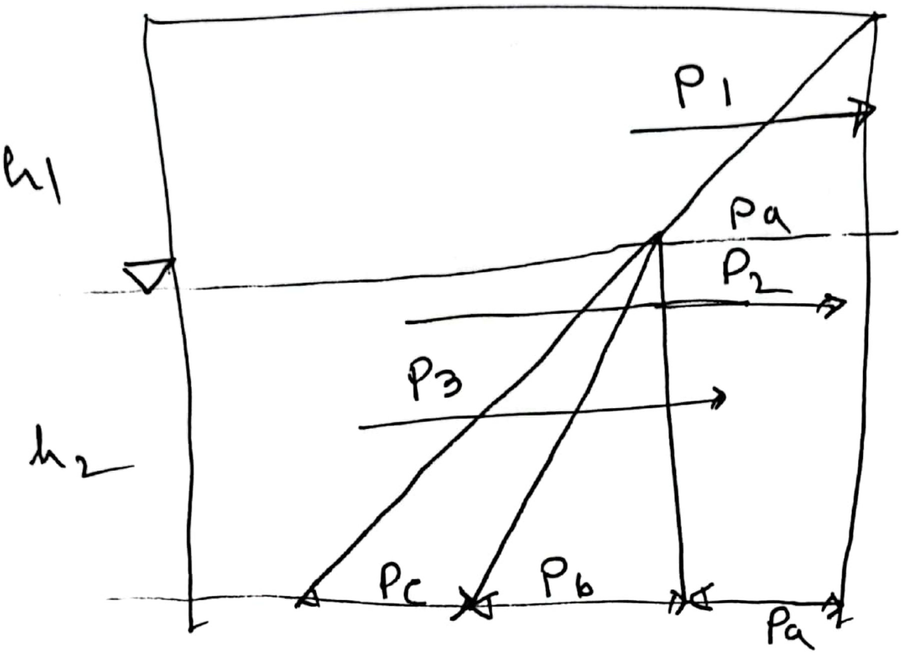
Partial submergence on

Soil lateral pressure calculation



$p_a = C_a \gamma_{m} h_1$

$p_b = C_a \gamma_{sub} h_2$

$p_c = \gamma_w h_2$

$P_1 = \frac{1}{2} p_a h_1$

$P_2 = p_a h_2$

$P_3 = \frac{1}{2} (p_b + p_c) h_2$

e.g wrt base

$h_2 = h_2 + \frac{h_1}{3} = e_1$

$h_2/2 = e_2$

$h_2/3 = e_3$

$P = P_1 + P_2 + P_3 = \frac{1}{2} p_a h_1 + p_a h_2 + \frac{1}{2}(p_b + p_c) h_2$

$= \frac{1}{2} \cancel{C_a \gamma_m h_1}$

$= \frac{1}{2} [\, p_a h_1 + p_a h_2 + p_b h_2 + p_c h_2 \,]$

$$= \frac{1}{2}\left[C_a \gamma_m h_1^2 + 2C_a \gamma_m h_1 h_2 + C_a \gamma_{sub} h_2^2 + \gamma_w h_2^2\right]$$

assume $\gamma_m = \gamma_s$

$$= \frac{1}{2}\left[C_a \gamma_s h_1^2 + 2C_a \gamma_s h_1 h_2 + C_a \gamma_{sub} h_2^2 + \gamma_w h_2^2\right]$$

$$= \frac{1}{2}\left[C_a \gamma_s h_1^2 + 2C_a \gamma_s h_1 h_2 + C_a(\gamma_s - \gamma_w) h_2^2 + \gamma_w h_2^2\right]$$

$$= \frac{1}{2}\left[C_a \gamma_s h_1^2 + 2C_a \gamma_s h_1 h_2 + C_a \gamma_s h_2^2 + \gamma_w (1 - C_a) h_2^2\right]$$

$$S_g = \frac{\gamma_s}{\gamma_w} \Rightarrow \gamma_w = \frac{1}{S_g}\gamma_s$$

$$= \frac{1}{2}\left[C_a \gamma_s h_1^2 + 2C_a \gamma_s h_1 h_2 + C_a \gamma_s h_2^2 + \frac{1}{S_g}\gamma_s (1 - C_a) h_2^2\right]$$

$$= \frac{1}{2} C_a \gamma_s \left[h_1^2 + 2h_1 h_2 + h_2^2 + \frac{1}{S_g}\left(\frac{1}{C_a} - 1\right) h_2^2\right]$$

$$SR = \frac{h_2}{h_1+h_2} \qquad h_1+h_2 = h$$

$$= \frac{h_2}{h}$$

$$\Rightarrow h_2 = SR \times h$$

$$h_1 = h - h_2$$

$$= h - SR\, h$$

$$= h(1-SR)$$

$$h_1 h_2 = (1-SR)\, SR\, h^2$$

$$P = \frac{1}{2} C_a \gamma_s \Big[(1-SR)^2 h^2 + 2(1-SR)\, SR\, h^2 + SR^2 h^2 + \frac{1}{S_g}\left(\frac{1}{C_a}-1\right) SR^2 h^2 \Big]$$

$$= \frac{1}{2} C_a \gamma_s h^2 \Big[(1-SR)^2 + 2(1-SR)\, SR + SR^2 + \frac{1}{S_g}\left(\frac{1}{C_a}-1\right) SR^2 \Big]$$

$$= \frac{1}{2} C_a \gamma_s h^2 \Big[1 - 2SR + SR^2 + 2SR - 2SR^2 + SR^2 + \frac{1}{S_g}\left(\frac{1}{C_a}-1\right) SR^2 \Big]$$

$$= \frac{1}{2} C_a \gamma_s h_1^2 \left[1 - \cancel{2SR} + \cancel{2SR} + \cancel{2SR^2} - \cancel{2SR^2} + \frac{1}{S_g}\left(\frac{1}{C_a} - 1\right) SR^2\right]$$

$$= \frac{1}{2} C_a \gamma_s h_1^2 \left[1 + \frac{1}{S_g}\left(\frac{1}{C_a} - 1\right) SR^2\right]$$

Let's assume fully unsaturated pressure as $P_0 = \frac{1}{2} C_a \gamma_s h_1^2$

$$P = P_0 \left[1 + \frac{1}{S_g}\left(\frac{1}{e_a} - 1\right) SR^2\right]$$

$$\frac{P}{P_0} = \left[1 + \frac{1}{S_g}\left(\frac{1}{e_a} - 1\right) SR^2\right]$$

Here $S_g = \frac{\gamma_s}{\gamma_w}$ $SR = \frac{h_2}{h_1 + h_2} = \frac{h_2}{h_1}$

Moment wrt base :

$$M = M_1 + M_2 + M_3$$

$$= P_1 e_1 + P_2 e_2 + P_3 e_3$$

$$= \frac{1}{2} P_a h_1 e_1 + P_a h_2 e_2 + \frac{1}{2}(P_b + P_c) h_2 e_3$$

$$= \frac{1}{2}\left[P_a h_1 e_1 + 2 P_a h_2 e_2 + P_b h_2 e_3 + P_c h_2 e_3 \right]$$

$$= \frac{1}{2}\left[C_a \gamma_m h_1 h_1 e_1 + 2 C_a \gamma_m h_1 h_2 e_2 + C_a \gamma_{sub} h_2^2 e_3 + \gamma_w h_2 h_2 e_3 \right]$$

Assume $\gamma_m = \gamma_s$

$$= \frac{1}{2}\left[C_a \gamma_s h_1^2 e + 2 C_a \gamma_s h_1 h_2 e_2 + C_a \gamma_{sub} h_2^2 e_3 + \gamma_w h_2^2 e_3 \right]$$

$$= \frac{1}{2}\left[C_a \gamma_s h_1^2 e + 2 C_a \gamma_s h_1 h_2 e_2 + C_a(\gamma_s - \gamma_w) h_2^2 e_3 + \gamma_w h_2^2 e_3 \right]$$

$$= \frac{1}{2}\left[C_a \gamma_s h_1^2 e + 2 C_a \gamma_s h_1 h_2 e_2 + C_a \gamma_s h_2^2 e_3 + (1 - C_a) \gamma_w h_2^2 e_3 \right]$$

$$= \frac{1}{2} C_a \gamma_s \left[h_1^2 e + 2 h_1 h_2 e_2 + h_2^2 e_3 + \left(\frac{1 - C_a}{C_a} \right) \frac{1}{S_g} h_2^2 e_3 \right]$$

$$= \frac{1}{2} C_a \gamma_s \left[h_1^2 e_1 + 2 h_1 h_2 e_2 + h_2^2 e_3 + \left(\frac{1}{C_a} - 1 \right) \frac{1}{S_g} h_2^2 e_3 \right]$$

$$= \frac{1}{2} C_a \gamma_s \left[h_1^2 \left(\frac{h_1}{3} + h_2 \right) + \cancel{2} h_1 h_2 \left(\frac{h_2}{\cancel{2}} \right) + h_2^2 \times \frac{h_2}{3} + \left(\frac{1}{C_a} - 1 \right) \frac{1}{S_g} h_2^2 \frac{h_2}{3} \right]$$

$$= \frac{1}{2} C_a \gamma_s \left[\frac{h_1^3}{3} + h_1^2 h_2 + h_1 h_2^2 + \frac{h_2^3}{3} + \left(\frac{1}{C_a} - 1 \right) \frac{1}{S_g} \frac{h_2^3}{3} \right]$$

$$= \frac{1}{6} C_a \gamma_s \left[\left\{ h_1^3 + 3 h_1^2 h_2 + 3 h_1 h_2^2 + h_2^3 \right\} + \left(\frac{1}{C_a} - 1 \right) \frac{1}{S_g} h_2^3 \right]$$

$$= \frac{1}{6} C_a \gamma_s \left[(h_1 + h_2)^3 + \left(\frac{1}{C_a} - 1 \right) \frac{1}{S_g} h_2^3 \right]$$

$h_1 + h_2 = h$

$h_2 = SR \times h$

$$= \frac{1}{6} C_a \gamma_s \left[h^3 + \left(\frac{1}{C_a} - 1 \right) \frac{1}{S_g} S R^3 h^3 \right]$$

$$= \frac{1}{6} C_a \gamma_s h^3 \left[1 + \left(\frac{1}{C_a} - 1 \right) \frac{1}{S_g} S R^3 \right]$$

M_0 = moment ~~of~~ due soil pressure for fully unsaturated condition

$$= \frac{1}{6} C_a \gamma_s h^3$$

$$M = M_0 \left[1 + \left(\frac{1}{C_a} - 1 \right) \frac{1}{S_g} S R^3 \right]$$

$$\frac{M}{M_0} = \left[1 + MF \right]$$

$$MF = \left(\frac{1}{C_a} - 1 \right) \frac{1}{S_g} S R^3$$