Solved Problems in:

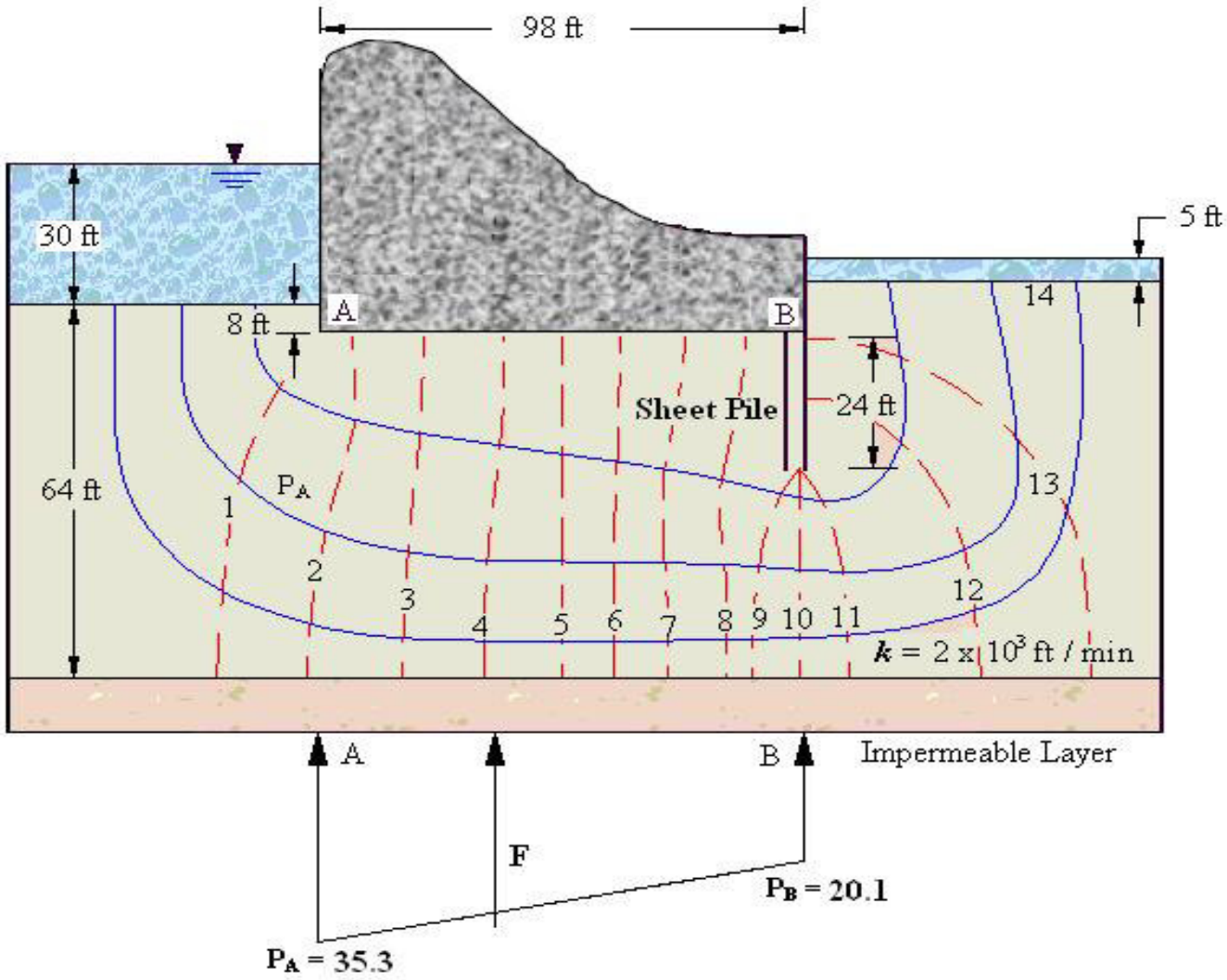
Dams and Levees

01: Uplift pressures upon a concrete levee.
02: Uplift pressures upon a concrete dam.

*Dams-01: Find the uplift pressure under a small concrete levee.

(Revision: Sept.-08)

Calculate the uplift force at the base of the weir, per foot of width. Points A and B are at the corners of the concrete levee.



Solution:

The dynamic head drop per equipotential is,

$$\Delta(\Delta h) = \frac{H_A - H_B}{N_{eq}} = \frac{30\,ft - 5\,ft}{14\ drops} = 1.8\ ft/drop$$

Pressure head at A = 30 ft + 8 ft - Δh (1.5) = 35.3 ft

Pressure head at B = 30 ft + 8 ft - Δh (10) = 20.1 ft

The uplifting force F is,

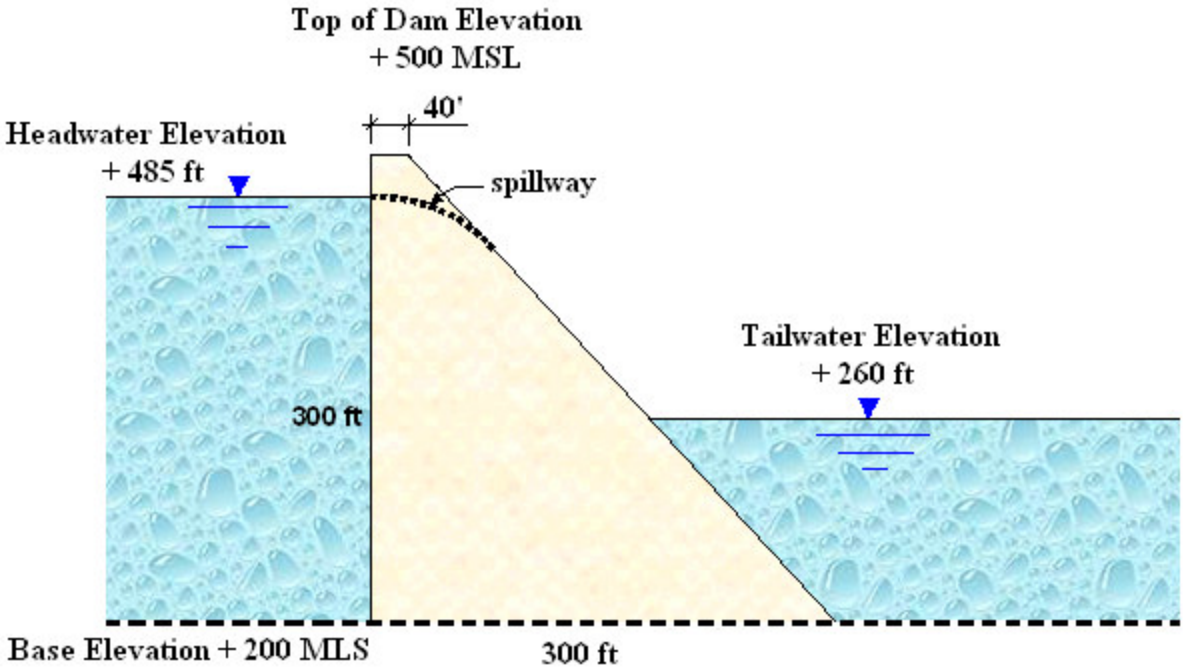
$$F = L\left(\frac{p_A + p_B}{2}\gamma_w\right) = 98'\left(\frac{35.3 + 20.1}{2}\right)(62.4)\frac{lb}{ft^3} = 169{,}000\frac{lb}{ft} = 169\ \frac{kip}{ft}$$

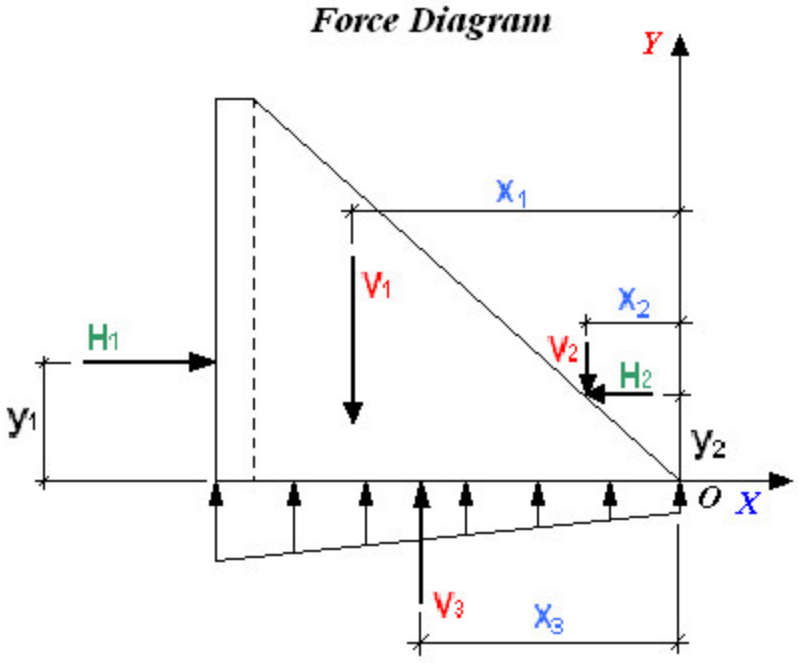
*Dams-02: Determine the uplift forces acting upon a concrete dam.

(Revision: Aug-08)

The uplift (hydrostatic) force under the concrete gravity dam shown below varies as a straight line from 67% of the headwater pressure at the heel, to 100% of the tail-water at the toe. Assume $\gamma_{Concrete} = 145\ pcf$

a) **Determine the Factor of Safety against overturning; and**
b) **Determine the FS against sliding, if the sand that underlay the dam has $\varphi = 37^{o}$.**


Top of Dam Elevation
+ 500 MSL
40'
Headwater Elevation
+ 485 ft
spillway
Tailwater Elevation
+ 260 ft
300 ft
Base Elevation + 200 MLS
300 ft


Force Diagram
Y
X1
V1
X2
V2
H2
H1
y1
y2
O
X
V3
X3

Solution:

Step 1: Determine all forces on the dam

$\Sigma F_V = 0$

$$V_1 = weight\ of\ dam = \left(0.145\frac{k}{ft^3}\right)\left((300\,ft)(40\,ft)+\left(\frac{1}{2}\right)(260\,ft)(300\,ft)\right) = 7{,}395\ kips/ft$$

$$\sum M_0 = 0$$

$$x_1,\ from\ toe\ O = \frac{(1740\ k)(280\,ft)+(5655\ k)\left(\frac{2}{3}(260\,ft)\right)}{(1740\ k+5655\ k)} = 198\ ft\ left\ of\ toe$$

$$V_2 : vertical\ weight\ of\ water\ upon\ toe\ \text{section} = 0.0624\frac{k}{ft^3}\left(\frac{1}{2}(60\,ft)(52\,ft)\right) = 97\ kips/ft$$

$$x_2,\ from\ toe\ O = \frac{1}{3}(52\,ft) = 17.3\ ft\ left\ of\ toe$$

$$H_1 : lateral\ force\ from\ headwater = \left(\frac{1}{2}0.0624\frac{k}{ft^3}\right)(285\,ft)^2 = 2{,}534\ kips/ft$$

$$y_1,\ from\ toe\ O = \frac{1}{3}(285\,ft) = 95\ ft\ above\ the\ toe.$$

$$H_2 : lateral\ force\ from\ tailwater = \left(\frac{1}{2}0.0624\frac{k}{ft^3}\right)(60\,ft)^2 = 112\ kips/ft$$

$$y_2,\ from\ toe\ O = \frac{1}{3}(60\,ft) = 20\ ft\ above\ the\ toe.$$

Step 2: The hydrostatic uplift at the base of the dam.

$$V_3 : uplift\ \ force = \frac{1}{2}(p_{LEFT}+p_{RIGHT})(300\,ft) = 2{,}534\ \ kips/ft$$

$$where\ the\ pressure\ p_{LEFT} = (0.67)\gamma_w h = 0.67(0.0624)(285\,ft) = 11.9ksf$$

$$and\ the\ pressure\ p_{RIGHT} = (1.00)\gamma_w h = 1.0(0.0624)(60\,ft) = 3.7\ \ ksf$$

$$\therefore V_3 = \frac{1}{2}(11.9+3.7)\frac{k}{ft^2}(300\,ft) = 2{,}340\ \ kips/ft$$

$$x_3,\ from\ toe\ O = \frac{\left(3.7\frac{k}{ft^2}\right)(300\,ft)\left(\frac{300\,ft}{2}\right)+\frac{1}{2}\left(11.9\frac{k}{ft^2}-3.7\frac{k}{ft^2}\right)(300\,ft)\left(\frac{2}{3}(300\,ft)\right)}{\left(3.7\frac{k}{ft^2}\right)(300\,ft)+\frac{1}{2}\left(11.9\frac{k}{ft^2}-3.7\frac{k}{ft^2}\right)(300\,ft)} = 176.3\ ft\ left\ of\ toe$$

Step 3: The factor of safety (FS) against overturning (taken about the toe),

$$FS = \frac{resisting\ moments}{overturning\ moments} = \frac{V_1x_1 + V_2x_2 + H_2y_2}{V_3x_3 + H_1y_1}$$

$$FS_{overturning} = \frac{(7395)(198)+(97)(17.3)+(112)(20)}{(2534)(95)+(2340)(176.3)} = 2.2 > 2 \quad GOOD$$

Step 4: The F.S. against sliding,

$$FS_{sliding} = \frac{resisting\ \ forces}{driving\ \ forces} = \frac{H_2+(V_1+V_2-V_3)\tan\phi}{H_1}$$

$$FS_{sliding} = \frac{(112)+(7395+97-2340)\tan 37°}{2534} = 1.58 < 2 \quad NOT\ GOOD\ ENOUGH$$