Hydraulics Structures

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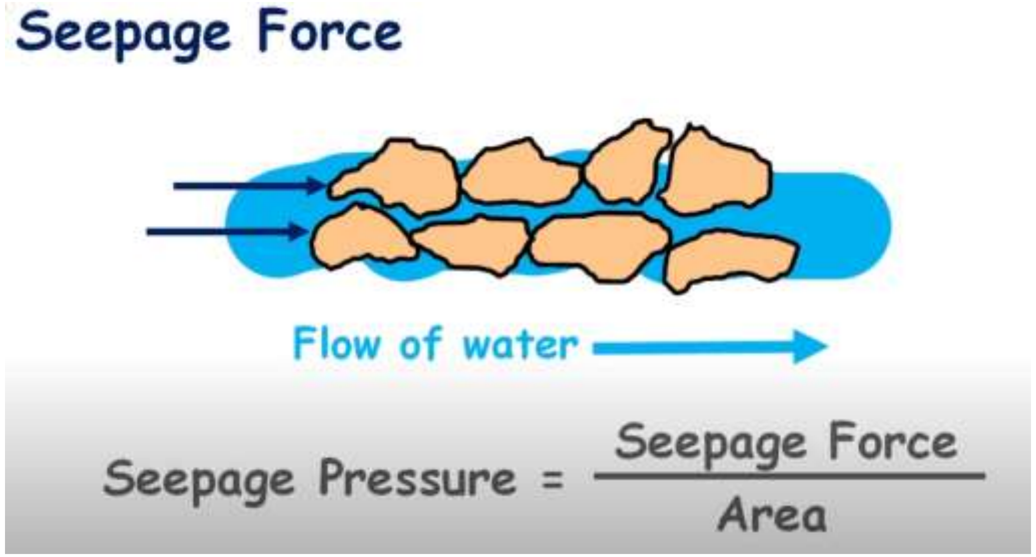
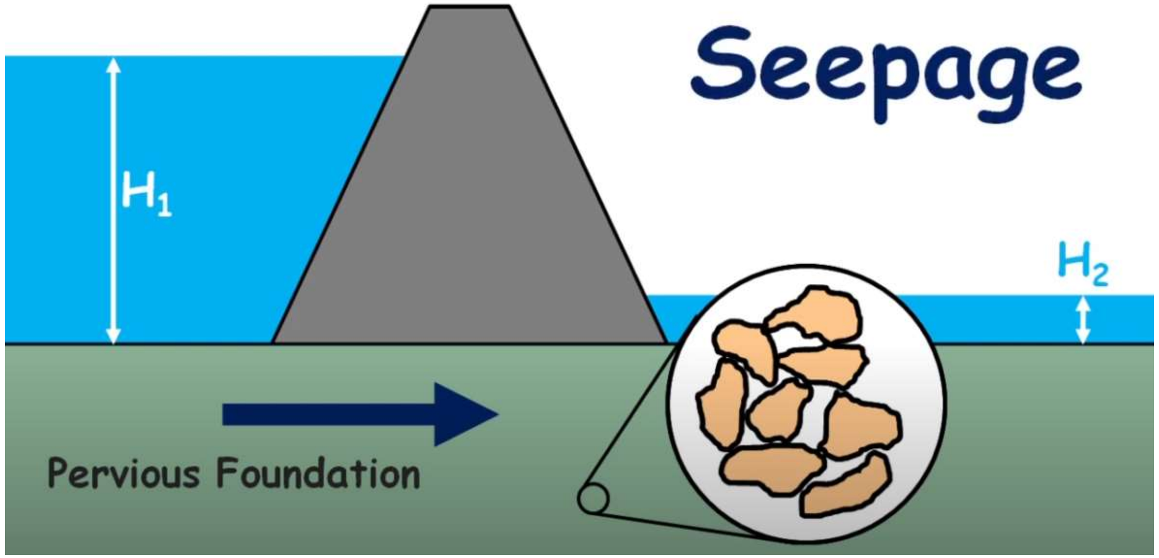
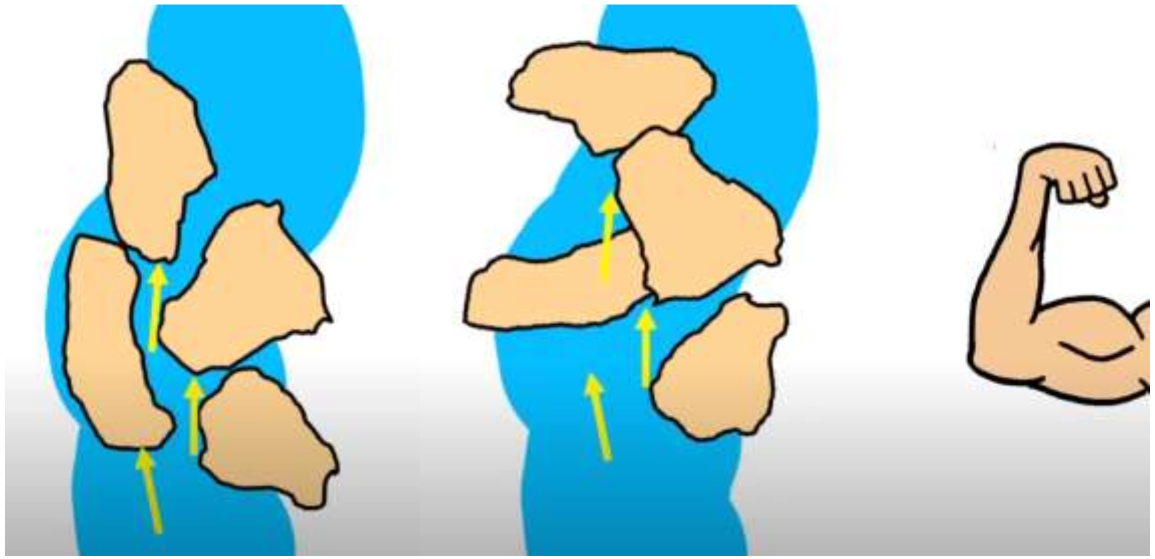
Design of Floors

Water seeps under structures causes of failure of this structure





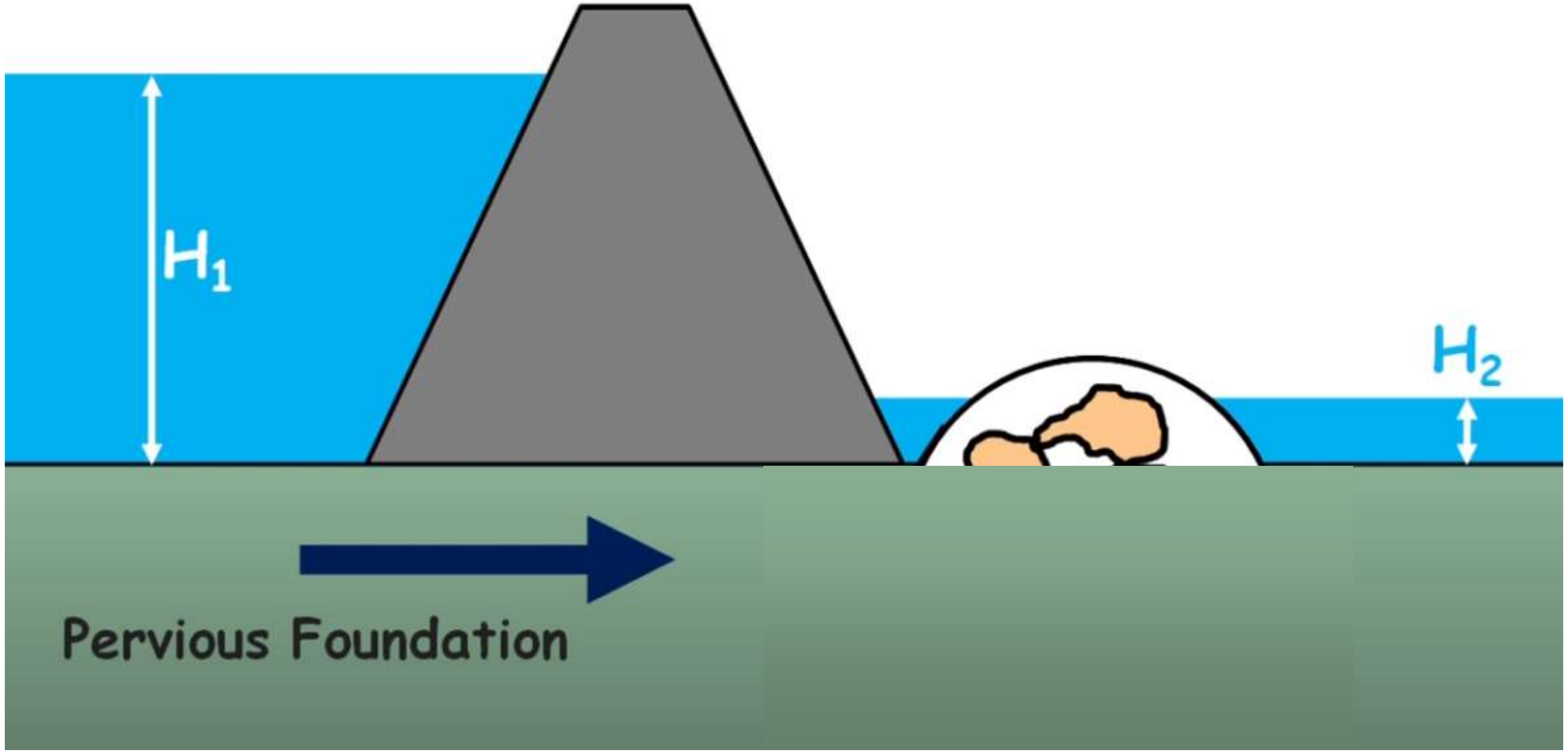


$$\text{Hydraulic Gradient } (i) = \frac{H}{L.W.}$$

Design of Floors

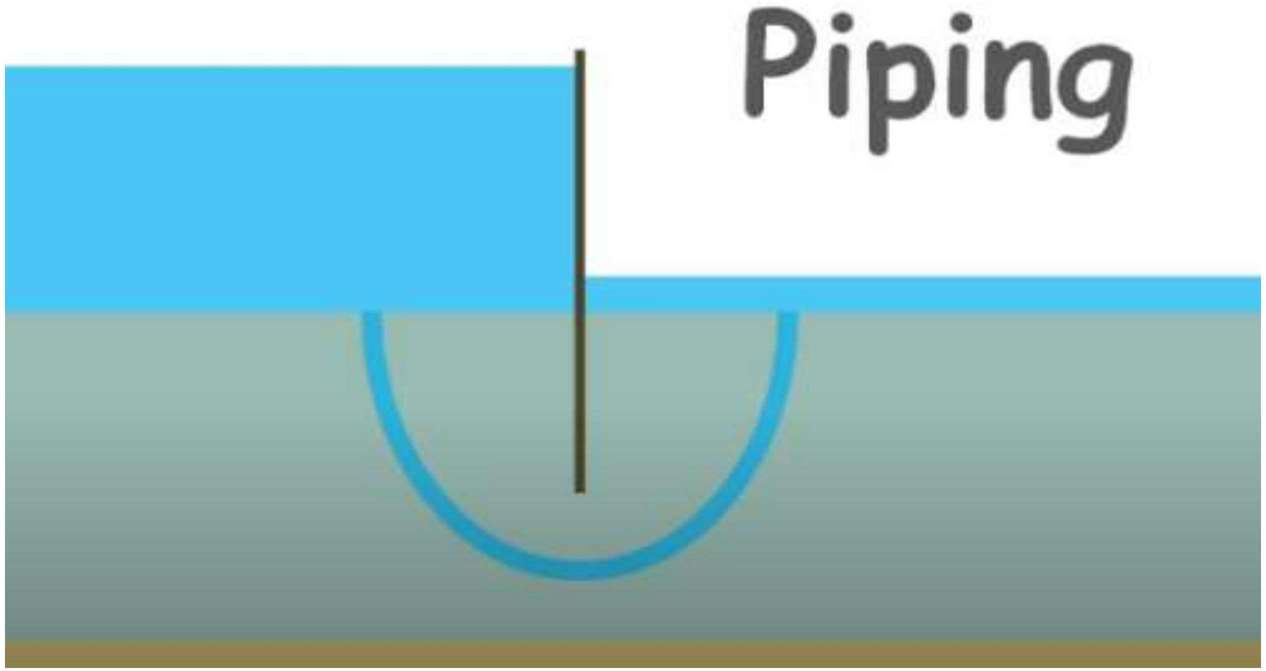
Water seeps under structures causes of failure of this structure by:

- Piping
- Rupture of the floor due to uplift pressure



<u>Failure by piping</u>

Water seeps under the base of the structure, and the flow line emerges out at the D/S end of the floor. When the exit gradient ($G.E = \frac{1}{F.S}$) exceed the specific limit (critical limit) for the soil, the surface soil starts boiling and is washing out a way to be percolating water with removed surface soil. The process of erosion causes piping.

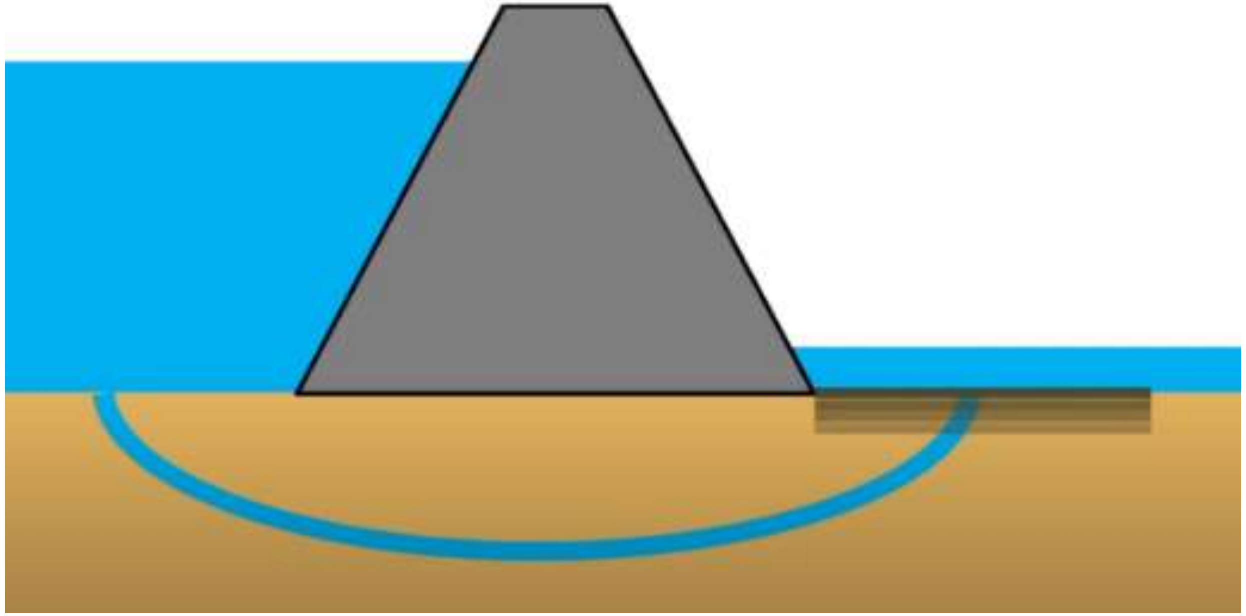


Treatments:

- Increasing the depth of sheet pile at U/S and D/S
- Increasing the length of the floor

Rupture of the floor due to uplift pressure

If the uplift pressure is counterbalanced by the concrete floor's weight above it, the floor will fail by rupturing part of this floor.



Treatments:

- Provide floor of sufficient length.
- Increase the upstream pile in order to decrease the uplift pressure.
- Increase the thickness of the floor.

$$t = \frac{h}{G-1} * \frac{4}{3}$$

Bligh's Creep Theory

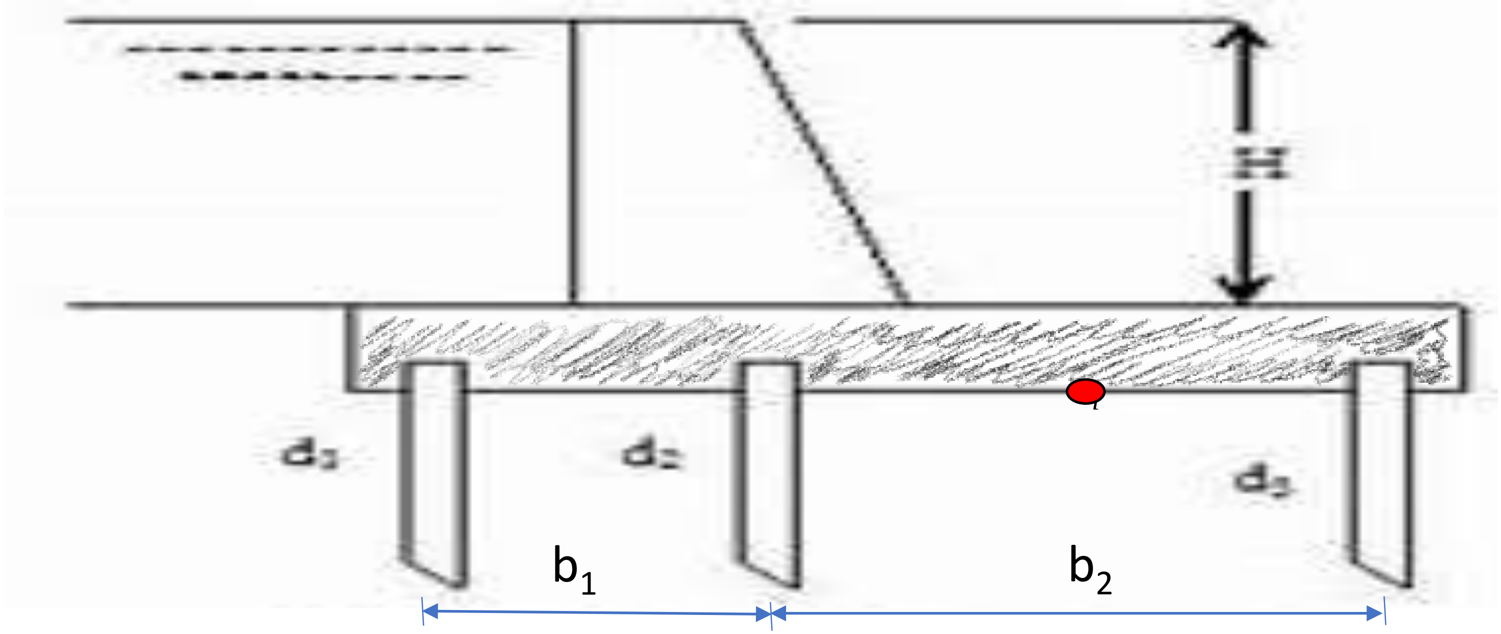
Bligh designated the length of travel as a "Creep Length" and is equal to the summation of the creep's horizontal and vertical length.

Creep line $= L.W. = 2d_1 + b_1 + 2d_2 + b_2 + 2d_3$

$= 2\,(d_1 + d_2 + d_3) + b_1 + b_2$

$= 2 * (\text{Vertical distance}) + \text{Horizontal distance}$

$$\text{Hydraulic Gradient } (i) = \frac{H}{L.W.}$$

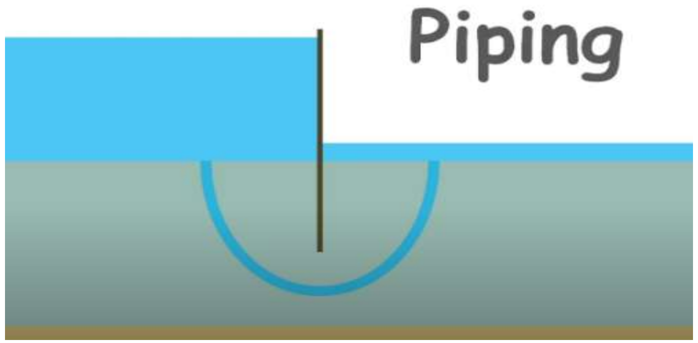


Safety Against Piping

The hydraulic gradient (i) must be kept under a safe limit in order to ensure safety against piping

$$\text{Hydraulic Gradient } (i) = \frac{H}{L.W.}$$

H = U/S Water Level – D/S Bed Level



The safe limit of soils is given in the following table:

No.	Soil type	C	Safe limit of hydraulic gradient
1	Fine sand	15	1/15
2	Coarse-grained sand	12	1/12
3	Sand mix with boulder and gravel, loam	5 - 9	1/5 - 1/9
4	Light sand and mud	8	1/8

Safety Against Uplift Pressure

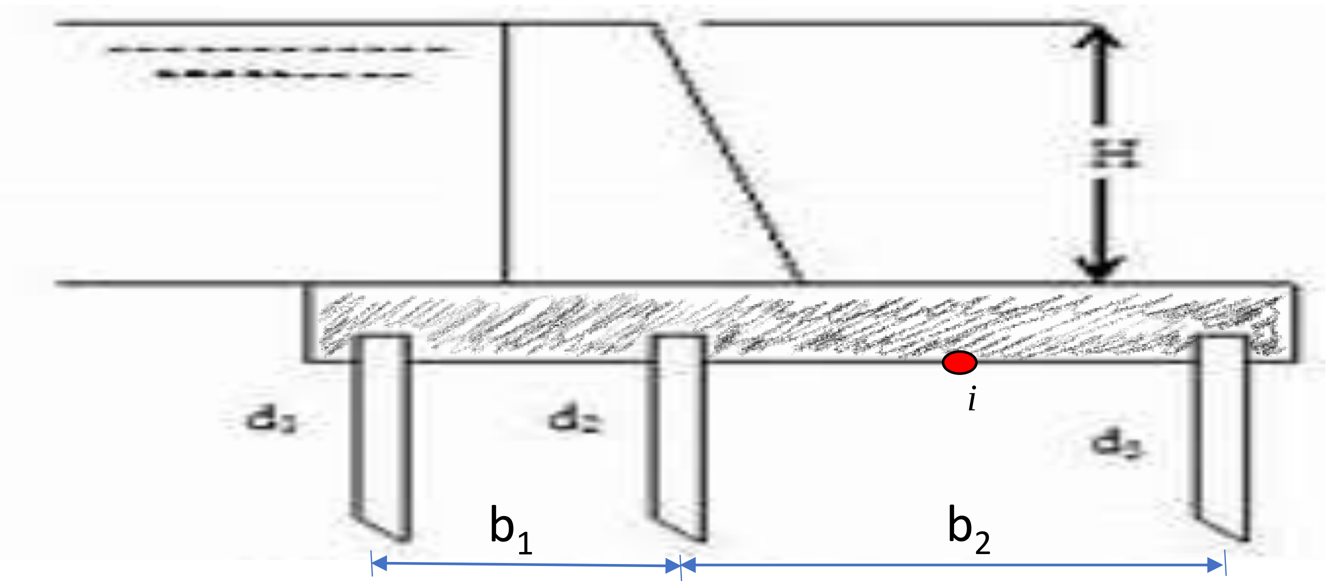
$$\text{Hydraulic Gradient } (i) = \frac{H}{L.W.}$$

$L.W. = 2d_1 + 2d_2 + 2d_3 + b_1 + b_2$

$$t = \frac{H}{G-1} * \frac{4}{3}$$

$G = 2.4\ ton/m^3$ ………For Concert

H = U/S Water Level – D/S Water Level



$$t = \frac{h_i}{G-1} * \frac{4}{3}$$

$L.W_i = 2d_1 + 2d_2 + b_1 + L$

$$h_i = H\ (1- \frac{L.Wi}{L.W})$$

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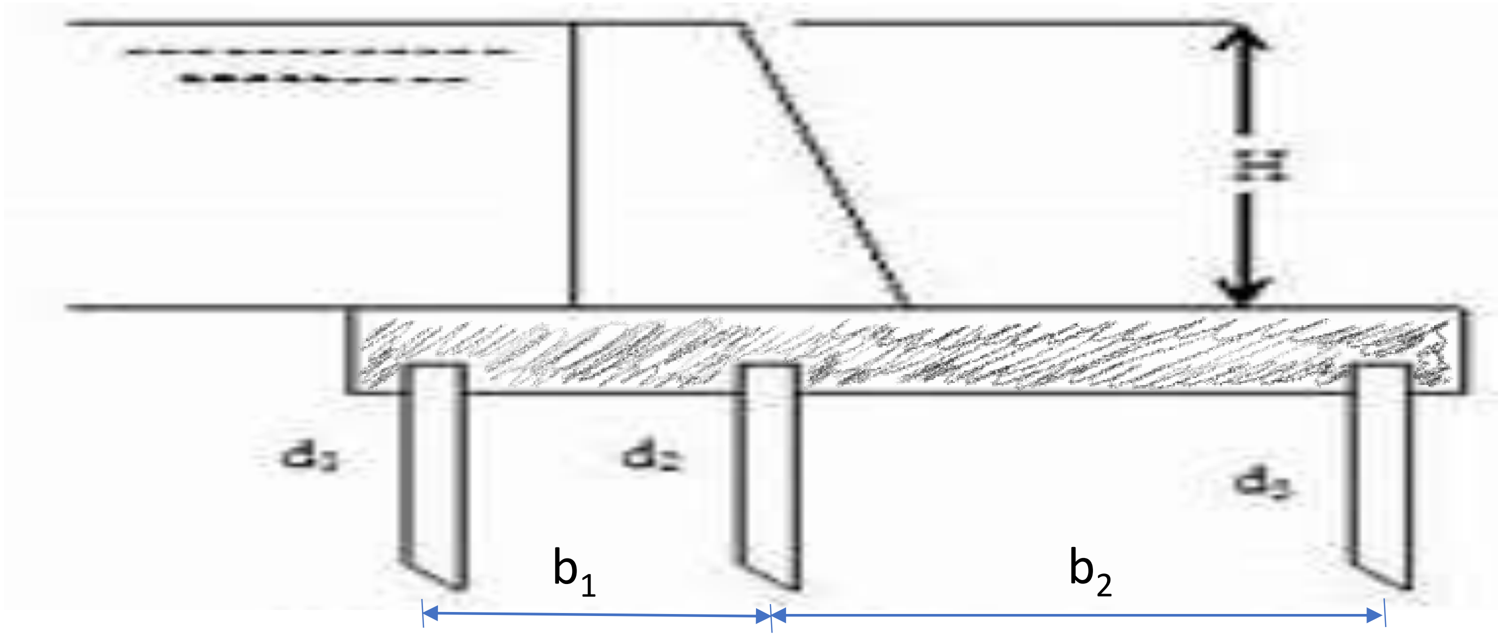
$= 2\,(d_1 + d_2 + d_3) + b_1 + b_2$

$= 2 * (\text{Vertical distance}) + \text{Horizontal distance}$

$$\text{Hydraulic Gradient } (i) = \frac{H}{L.W.}$$



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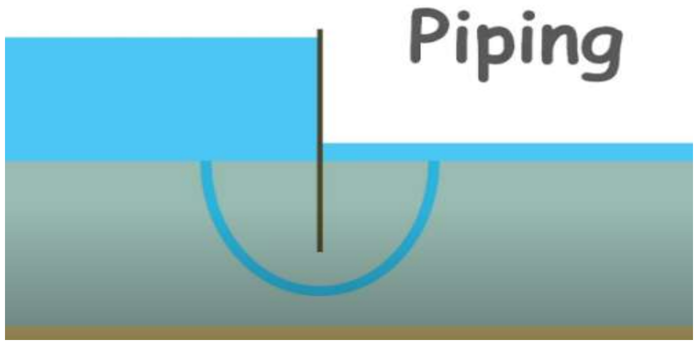

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$L.W. = 2d_1 + 2d_2 + 2d_3 + b_1 + b_2$

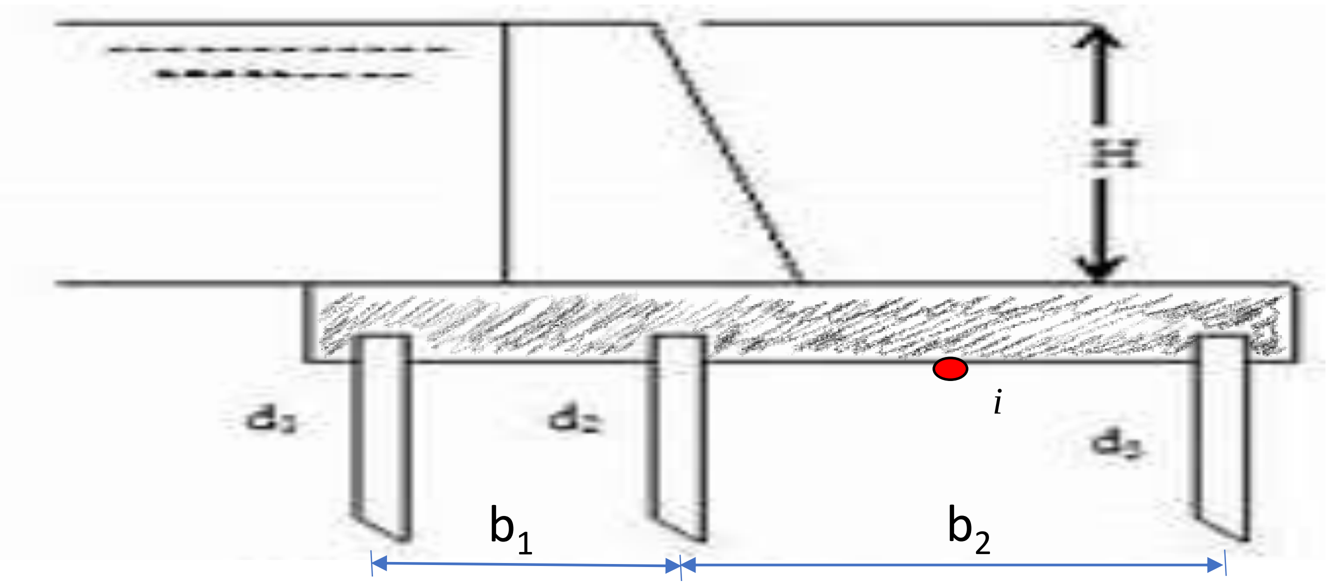
$$t = \frac{H}{G-1} * \frac{4}{3}$$

$G = 2.4$ ton/m^3 ………For Concert

$$t = \frac{h_i}{G-1} * \frac{4}{3}$$

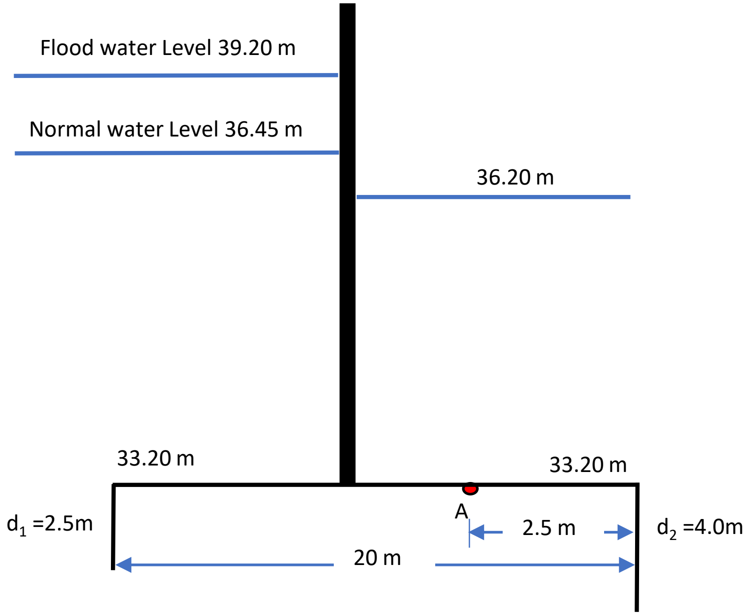
$L.W_i = 2d_1 + 2d_2 + b_1 + L$

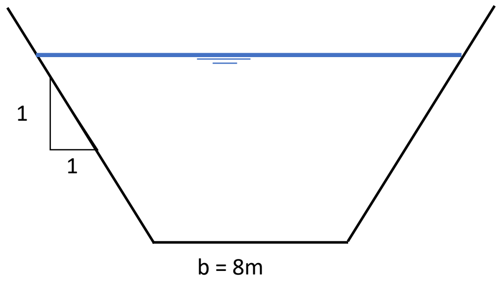
$$h_i = H\left(1 - \frac{L.Wi}{L.W}\right)$$



Example: A regulator was constructed on a canal with the following site information:

- U/S normal water level =36.45 m
- U/S flood level = 39.2 m
- D/S water level = 36.2 m
- U/S and D/S floor level = 33.2 m
- U/S and D/S bed width of the canal b = 8 m
- Side slop of the canal Z=1:1
- Manning of the canal n= 0.015
- Longitudinal slope of the canal S_o= 0.0013
- G_{conc}=2.4 ton/m^3

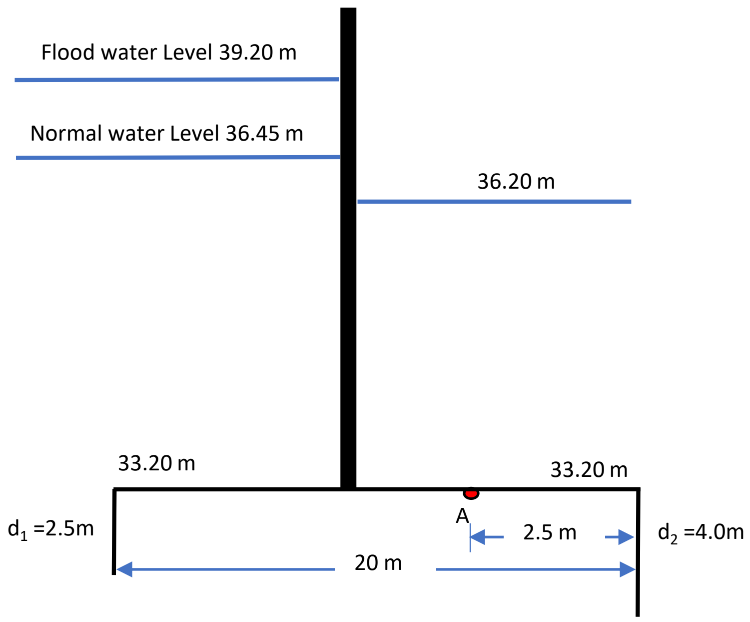


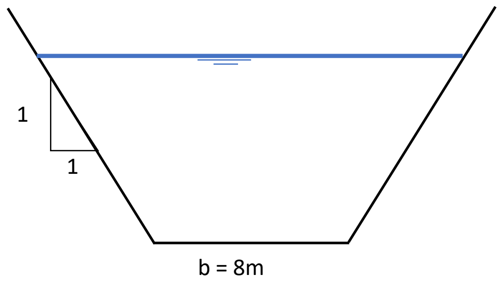


1. *Find the regulator gate width S_w*
2. The flow under the Regulator's gate is (free flow) when passing the design discharge with flood conditions. *Calculate the velocity of the flow through the gate opening*. Assume S_w= 6 m
3. *Calculate the thickness of the floor at point A using Bligh's Theory*. Assume (S_w= 6 m)
4. *Check is this structure safe against piping* if the safe limit of the Hydraulic gradient of soil under this structure is (i = 1/12)

Solution:

1. *Find the regulator gate width S_w*





$$Q = C * S_w * y_t * \sqrt{2gH_1}$$

$$Q = \frac{1}{n} A\, R^{2/3} S_o^{1/2}$$

$A = by + Zy^2$

$A = 8\ (36.45 - 33.2) + 1\ (36.45 - 33.2)^2 \longrightarrow A = 36.56\ m^2$

$P = b + 2y\sqrt{1 + Z^2}$

$P = 8 + 2\ (3.25) + \sqrt{1 + 1^2} \longrightarrow P = 17.19\ m$

$$R = \frac{A}{P} = \frac{36.56}{17.19} = 2.127\ m$$

$$Q = \frac{1}{0.015}(36.56)\ (2.127)^{2/3}(0.0013)^{1/2}$$

$Q = 45.57\ m^3/sec$

$$H_1 = \Delta H + h_v$$

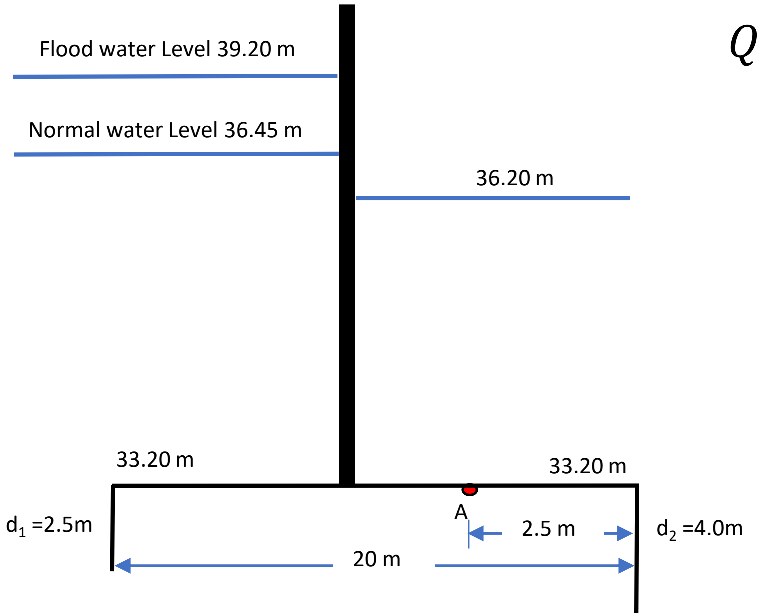
$$\Delta H = 36.45 - 36.2 = 0.25\ m$$

$$h_v = \frac{V^2}{2g} \qquad V = \frac{Q}{A} = \frac{45.57}{36.56} = 1.246\ m/sec$$

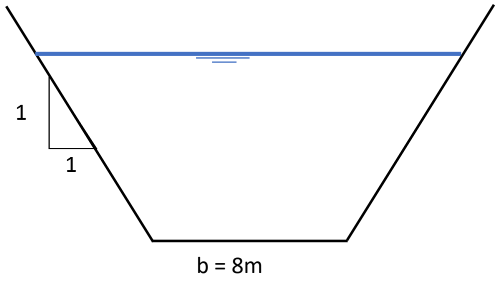
$$h_v = \frac{(1.246)^2}{19.62} = 0.079\ \text{m}$$

$$H_1 = 0.25 + 0.079 = 0.329\ m$$

$$y_t = 36.20 - 33.20 = 3m$$



$$Q = C * S_w * y_t * \sqrt{2gH_1}$$



$Q = 45.57\ m^3/sec$

$H_1 = 0.329\ m$

$y_t = 3.0\ m$

$$45.57 = (0.6 + 0.08\ S_W)\ S_W (3) \sqrt{19.62\ (0.329)}$$

$S_w = 5.673$ m

- <u>Check C</u>

$C = 0.6 + 0.08\ (5.673) > 0.92$. Thus, use C=0.92 and recalculate the new value of S_w

$$45.57 = 0.92\ S_W (3) \sqrt{19.62\ (0.329)}$$

$S_w = 6.5$ m

2. *Calculate the velocity of the flow through the gate opening. (Assume S_W= 6 m)*

For free flow, $Q = C_d * S_w * W * \sqrt{2gy_1}$

$$C_d = \frac{0.61}{(1 + 0.61\,\frac{W}{y_1})^{1/2}}$$

y_1= 39.2 – 33.2 = 6.0 m

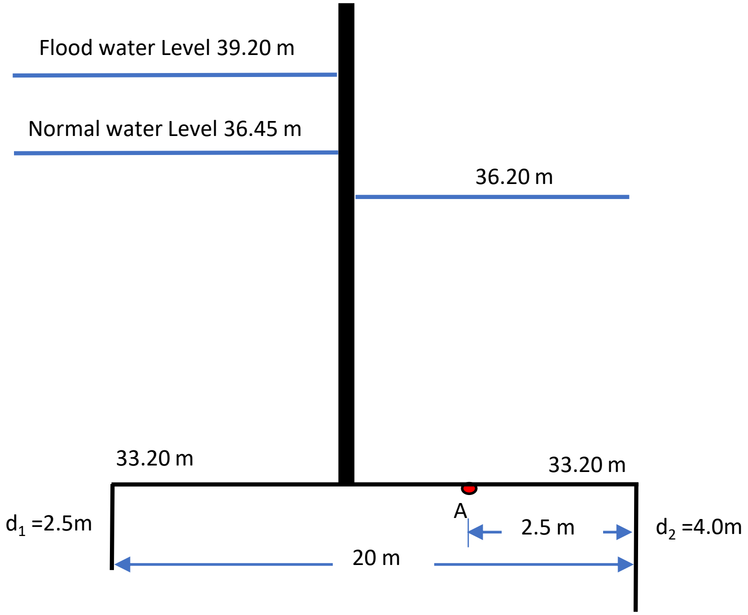
$$45.57 = \frac{0.61}{\left(1 + 0.61 * \frac{W}{6}\right)^{1/2}} * 6 * W * \sqrt{2 * 9.81 * 6}$$

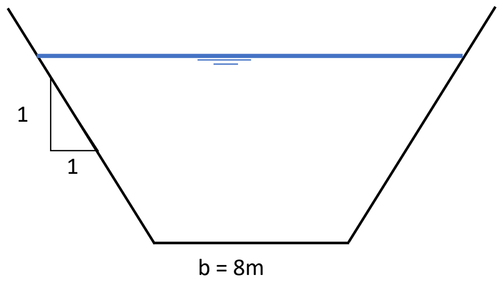
The area of flow (A) = $W * S_w$ = 6 * 1.215 = 7.29 m^2.

Thus, the velocity of the flow through the opening $V = \frac{Q}{A}$

$$V = \frac{45.57}{7.29}$$

$\boxed{V = 6.25\ m/sec.}$





$\boxed{Q = 45.57\ m^3/sec}$

$\boxed{y_1 = 6.0\ m.}$

$\boxed{W = 1.215\ m.}$

3. *Calculate the thickness of the floor at point A using Bligh's Theory.*

Assume (S_w= 6 m)

$$t_A = \frac{h_A}{G-1} * \frac{4}{3}$$

$$h_A = \mathrm{H}\,(1- \frac{\mathrm{L.W}_A}{\mathrm{L.W}})$$

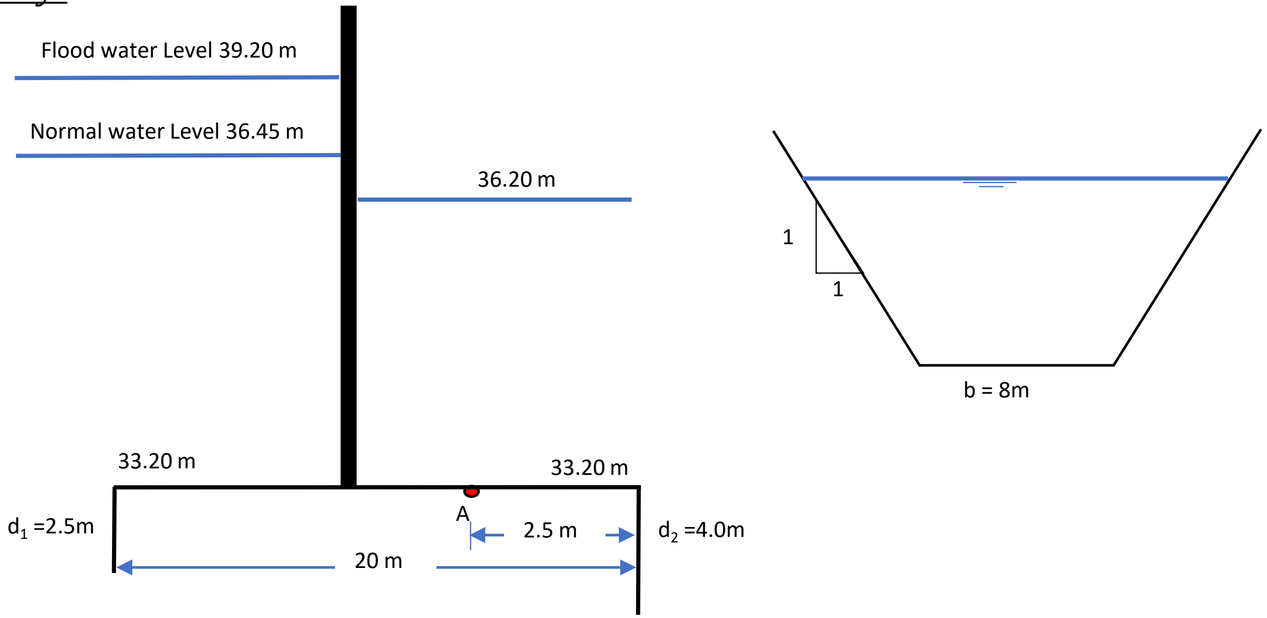
$$\mathrm{L.W} = 2d_1 + 2d_2 + b = 2(2.5+4)+20 = 33 \text{ m.}$$

$$\mathrm{L.W}_A = 2d_1 + L = 2*2.5+(20 - 2.5) = 22.5 \text{ m.}$$

$$H = 36.45 - 33.2 = 3.25 \text{ m.}$$

$$h_A = 3.25\,(1- \frac{22.5}{33})$$

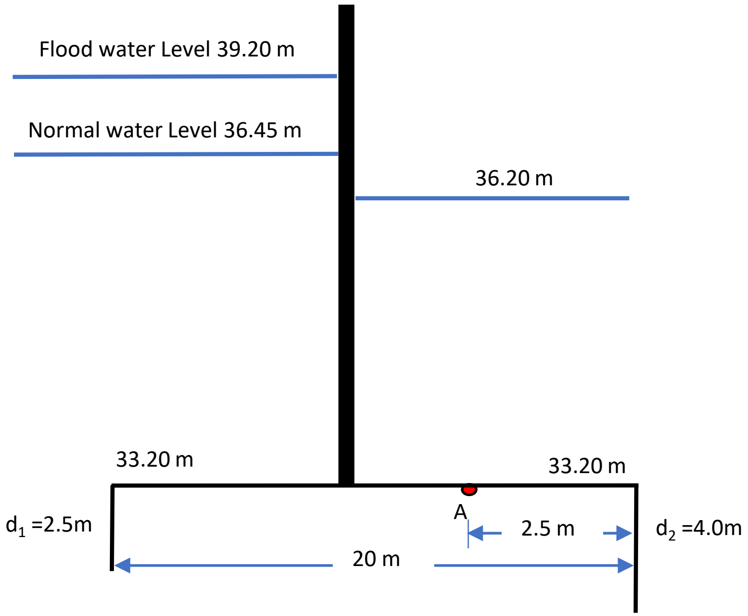
$$h_A = 1.034 \text{ m.}$$

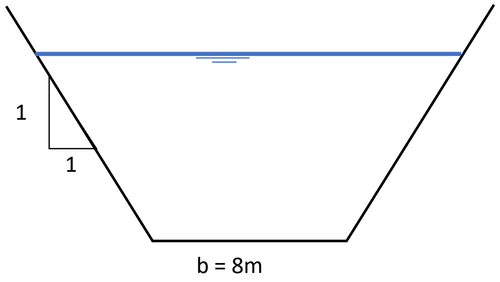


$$t_A = \frac{1.034}{2.4-1} * \frac{4}{3}$$

$$\boxed{t_A = 0.98\ m}$$

4. *Check if this structure is safe against piping*





The given safe limit of Hydraulic gradient of soil under this structure is (i = 1/12)

Hydraulic gradient $i = \frac{H}{L.W.}$

H = 36.45 - 33.20 = 3.25m.

Hydraulic gradient $i = \frac{3.25}{33} = \frac{1}{10.15} > \frac{1}{12}$

The structure ***is not safe*** against the piping failure.

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