Example 2.1

The figure below (Figure E-2.1) shows a section of a hydraulic structure on permeable foundation. Calculate the average hydraulic gradient according to

(a) Bligh's creep theory

(b) Lane's weighted creep theory

Also find the uplift pressures at points A and B and the floor thickness required at these points.

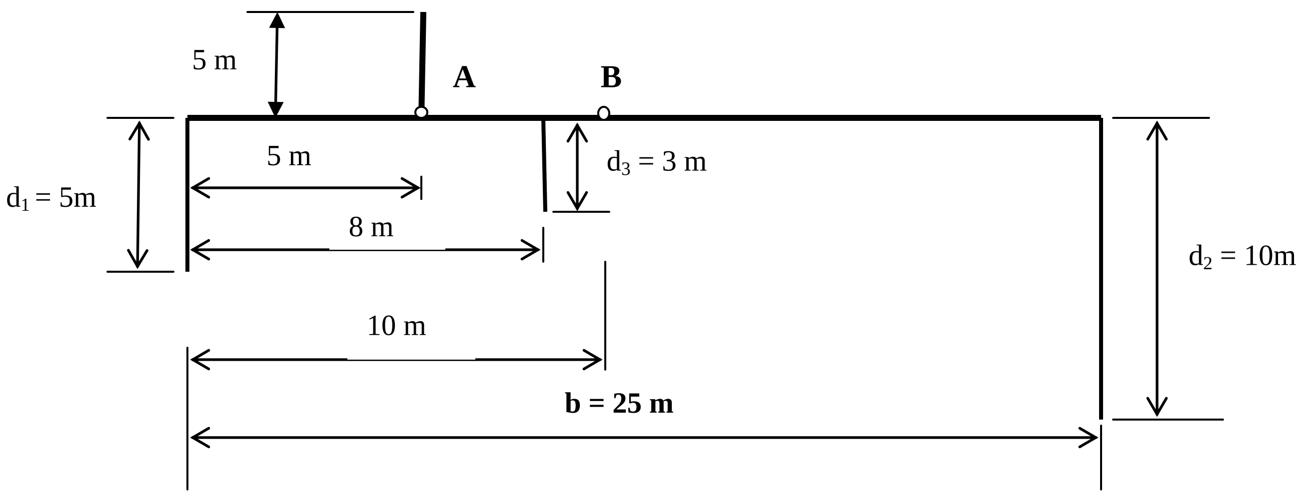


Figure E-2.1

Solution

(a) ***Bligh's creep theory***

- Total creep length, L = b + 2(d1 + d3 + d2) = 25 + 2 (5 + 3 + 10) = 61 m

Hydraulic gradient = H/L = 5/61 = 1/12.2

From Table 4.1, H/L < 1/C = 1/12 (Coarse grained sand)

Therefore, the structure would be safe on coarse grained sand.

- *Uplift pressure at point A*

Length of creep up to point A, $L_A = 2d_1 + 5 = 2 \times 5 + 5 = 15$ m

Residual seepage head at point A, $h_A = [H - (H/L)L_A] = H(1 - L_A/L)$

$= 5(1 - 15/61) = 3.77$ m

Uplift pressure at point A, $P_A = \gamma h_A = 9.81 \times 3.77 = 36.98$ kN/m^2

- Thickness of the floor at point A

$$t_A = \frac{4}{3}\frac{h_A}{S_m - 1} = \frac{4}{3} x \frac{3.77}{2.24 - 1} = 4.05 \text{ m}$$

- *Uplift pressure at point B*

  Length of creep up to point B, L_B = 10 + 2(5 + 3) = 26 m

  Residual seepage head at point B, $h_B = H[1 - L_B/L]$ = 5 (1 – 26/61) = 2.87 m

  Uplift pressure at point B, $P_B = \gamma h_B$ = 9.81 x 2.87 = 28.15 kN/m^2

- Required thickness of floor at B,

$$t_B = \frac{4}{3}\frac{h_B}{S_m - 1} = \frac{4}{3} x \frac{2.87}{2.24 - 1} = 3.09 \text{ m}$$

(b) ***Lane's weighted creep theory***

- Total weighted creep length, L_w = 2 (5 + 3 + 10) + 1/3 (25) = 44.33 m

Hydraulic gradient, H/L_w = 5/44.33 = 1/8.87 < $1/C_1$ = 1/8.5 (Table 4.2)

Therefore, the structure would be safe on very fine sand or silt.

- *Uplift pressure at point A*

Weighted creep length at A, L_{wA} = 2 x 5 + 1/3 (5) = 11.67 m

Residual head at A, h_A = 5(1 – 11.67/44.33) = 3.68 m

P_A = 9.81 x 3.68 = 36.1 kN/m^2

$$t_A = \frac{4}{3}\frac{h_A}{S_m - 1} = \frac{4}{3} x \frac{3.68}{2.24 - 1} = 3.96 \text{ m}$$

- *Uplift pressure at B,*

L_{wB} = 2(5 + 3) + 1/3 (10) = 19.33 m

h_B = 5 (1 – 19.33/44.33) = 2.82 m

P_B = 9.81 x 2.82 = 27.66 kN/m^2

$$t_B = \frac{4}{3}\frac{h_B}{S_m - 1} = \frac{4}{3} x \frac{2.82}{2.24 - 1} = 3.03 \text{ m}$$

Example 2.2

Determine the percentage pressures at various key points in figure E-2.2. Also determine the exit gradient and plot the hydraulic gradient line for pond level on upstream and no flow on downstream.

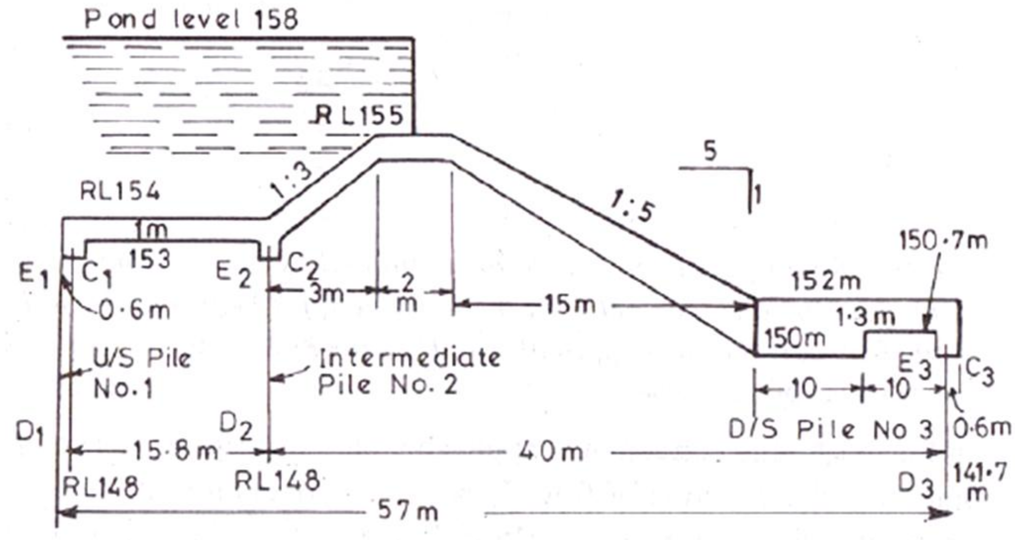


Figure E-2.2

***Solution*:**

(1) For upstream Pile Line No. 1

Total length of the floor, b = 57.0 m

Depth of u/s pile line, d = 154 – 148 = 6 m

$\alpha = b/d = 57/6 = 9.5$

$1/\alpha = 1/9.5 = 0.105$

From curve Figure 4.18 (b)

$\varphi_{C1} = 100 - 29 = 71$ %

$\varphi_{D1} = 100 - 20 = 80$ %

These values of φ_{C1} must be corrected for three corrections as below:

Corrections for φ_{C1}

(a) *Correction at C_1 for Mutual Interference of Piles:* (φ_{C1}) is affected by intermediate pile No.2

$$\text{Correction} = 19\sqrt{\frac{D}{b'}}\left(\frac{d+D}{b}\right)$$

$$= 19 \times \sqrt{\frac{5}{15.8}} \times \left(\frac{5+5}{57}\right)$$

$$= 1.88\ \%$$

Where, D = Depth of pile No.2 = 153 – 148 = 5 m

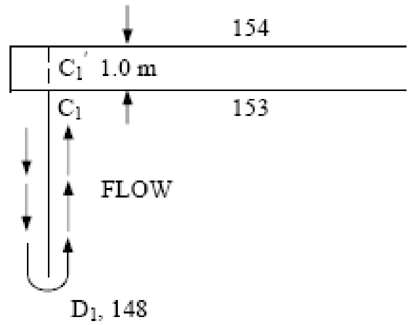
d = Depth of pile No. 1 = 153 – 148 = 5 m

b′ = Distance between two piles = 15.8 m

b = Total floor length = 57 m

Since point C_1 is in the rear in the direction of flow, the correction is positive.
Therefore, correction due to pile interference on C_1 = 1.88 % (+ ve)

(b) Correction at C_1 due to thickness of floor:
Pressure calculated from curve is at C_1', (Fig) but we want the pressure at C_1. Pressure at C_1 shall be more than at C_1' as the direction of flow is from C_1 to C_1' as shown; and hence, the correction will be + ve and



$$= \left[\frac{80\% - 71\%}{154 - 148}\right] \times (154 - 153)$$
$$= (9/6) \times 1$$
$$= 1.5\% \ (+\text{ ve})$$

(c) Correction due to slope at C_1 is nil, as this point is neither situated at the start nor at the end of a slope.

Therefore, corrected (φ_{C1}) = 71 % + 1.88 % + 1.5 %
= 74.38 % (answer)
And (φ_{D1}) = 80 %

(2) For intermediate Pile Line No. 2

d = 154 – 148 = 6 m

b = 57 m

α = b/d = 57/6 = 9.5

Using curves of Fig. 4.18 (a), we have b_1 in this case

b_1 = 0.6 + 15.8 = 16.4

b = 57 m

Therefore, b_1/b = 16.4/57 = 0.298 (for φ_{C2})

$(1 – b_1)/b$ = 1 – 0.298 = 0.702

φ_{E2} = 100 – 30 = 70 % (Where 30 % is φ_C for a base ratio of 0.702 and α = 9.5)

φ_{C2} = 56 % (For a base ratio 0.298 and α = 9.5)

φ_{D2} = 100 – 37 = 63 % (Where 37 % is φ_D for a base ratio of 0.702 and α = 9.5)

Corrections for φ_{E2}

(a) Correction at E_2 for sheet pile lines. Pile No. (1) will affect the pressure at E_2 and since E_2 is in the forward direction of flow, this correction shall be negative. The amount of this correction is given as:

$$\text{Correction} = 19\sqrt{\frac{D}{b'}}\left(\frac{d+D}{b}\right)$$

$$= 19\times\sqrt{\frac{5}{15.7}}\times\left(\frac{5+5}{57}\right)$$

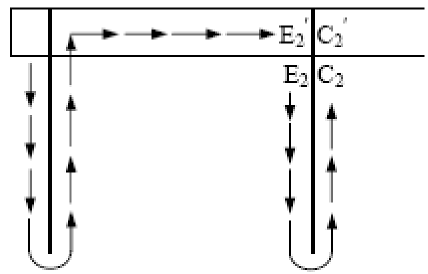
$$= 1.88\ \%\ (-\text{ve})$$

Where, D = Depth of pile No.1, the effect of which is considered = 153 – 148 = 5 m
d = Depth of pile No. 2, the effect on which is considered = 153 – 148 = 5 m
b′ = Distance between two piles = 15.8 m
b = Total floor length = 57 m

(b) Correction at E_2 due to floor thickness

$$= \frac{\text{Obs } \varphi_{E2} - \text{Obs } \varphi_{D2}}{\text{Distance between } E_2D_2} \times \text{Thickness of floor}$$

$$= \left[\frac{70\% - 63\%}{154 - 148}\right] \times 1.0 = (7/6)\times 1.0 = 1.17\ \%$$



Since the pressure observed is at E_2' and not at E_2, (Fig.) and by looking at the direction of flow, it can be stated easily that pressure at E_2 shall be less than that at E_2', hence, this correction is negative,

Therefore, correction at E_2 due to floor thickness = 1.17 % (- ve)

(c) Correction at E_2 due to slope is nil, as the point E_2 is neither situated at the start of a slope nor at the end of a slope.

Hence, corrected percentage pressure at E_2 = Corrected φ_{E2} = (70 – 1.88 – 1.17) % = 66.95 %

Corrections for φ_{C2}

(a) Correction at C_2 due to pile interference. Pressure at C_2 is affected by pile No.(3) and since the point C_2 is in the back water in the direction of flow, this correction is positive. The amount of this correction is given as:

$$\text{Correction} = 19\sqrt{\frac{D}{b'}}\left(\frac{d+D}{b}\right)$$

$$= 19\times\sqrt{\frac{11}{40}}\times\left(\frac{11+5}{57}\right)$$

$$= 2.89\ \%\ (+\text{ve})$$

Where, D = Depth of pile No.3, the effect of which is considered below the level at which interference is desired = 153 – 141.7 = 11.3 m
d = Depth of pile No. 2, the effect on which is considered = 153 – 148= 5 m
b′ = Distance between two piles (2 &3) = 40 m
b = Total floor length = 57 m

(b) Correction at C_2 due to floor thickness. It can be easily stated that the pressure at C_2 shall be more than at C_2', and since the observed pressure is at C_2', this correction shall be positive and its amount is the same as was calculated for the point E_2 = 1.17 %

Hence, correction at C_2 due to floor thickness = 1.17 % (+ ve)

(c) Correction at C_2 due to slope. Since the point C_2 is situated at the start of a slope of 3:1, *i.e.* an up slope in the direction of flow; the correction is negative.

Correction factor for 3:1 slope from Table 4.3 = 4.5

Horizontal length of the slope = 3 m

Distance between two pile lines between which the sloping floor is located = 40 m

Therefore, actual correction = 4.5 × (3/40) = 0.34 % (- ve)

Hence, corrected φ_{C2} = (56 + 2.89 + 1.17 – 0.34) % = 59.72 %

(3) Downstream Pile Line No. 3

d = 152 – 141.7 = 10.3 m

b = 57 m

1/α = 10.3/57 = 0.181

From curves of 4.18 (b), we get

φ_{D3} = 26 %

φ_{E3} = 38 %

Corrections for φ_{E3}

(a) Correction due to piles. The point E_3 is affected by pile No. 2, and since E_3 is in the forward direction of flow from pile No. 3, this correction is negative and its amount is given by

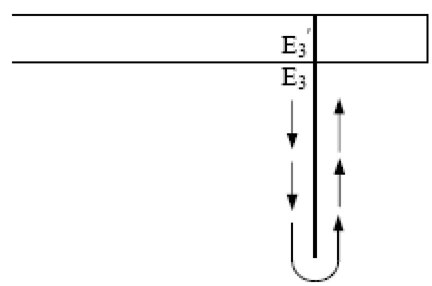
$$\text{Correction} = 19\sqrt{\frac{D}{b'}}\left(\frac{d+D}{b}\right)$$

$$= 19\times\sqrt{\frac{2.7}{40}}\times\left(\frac{9+2.7}{57}\right)$$

$$= 1.02\ \%\ (-\text{ve})$$

Where, D = Depth of pile No.2, the effect of which is considered = 150.7 – 148 = 2.7 m
d = Depth of pile No. 3, the effect on which is considered = 150 – 141.7 = 9 m
b′ = Distance between two piles = 40 m
b = Total floor length = 57 m

(b) Correction due to floor thickness



From the Figure, it can be stated easily that the pressure at E_3 shall be less than at E_3', and hence the pressure observed form curves is at E_3'; this correction shall be negative and its amount

$$= \left[\frac{38\%-32\%}{152-141.7}\right]\times 1.3 = (16/10.3)\times 1.3$$

$$= 0.76\ \%\ (-\text{ve})$$

(c) Correction due to slope at E_3 is nil, as the point E_3 is neither situated at the start nor at the end of any slope

Hence, corrected φ_{E3} = (38 – 1.02 – 0.76) % = 36.22 %

The corrected pressures at various key points are tabulated below in Table below

Upstream Pile No. 1	*Intermediate Pile No.2*	*Downstream Pile No. 3*
φ_{E1} = 100 %	φ_{E2} = 66.95 %	φ_{E3} = 36.22 %
φ_{D1} = 80 %	φ_{D2} = 63 %	φ_{D3} = 26 %
φ_{C1} = 74.38 %	φ_{C2} = 59.72 %	φ_{C3} = 0 %

Exit gradient

Let the water be headed up to pond level, *i.e.* on *RL* 158 m on the upstream side with no flow downstream

The maximum seepage head, H = 158 – 152 = 6 m

The depth of d/s cur-off, d = 152 – 141.7 = 10.3 m

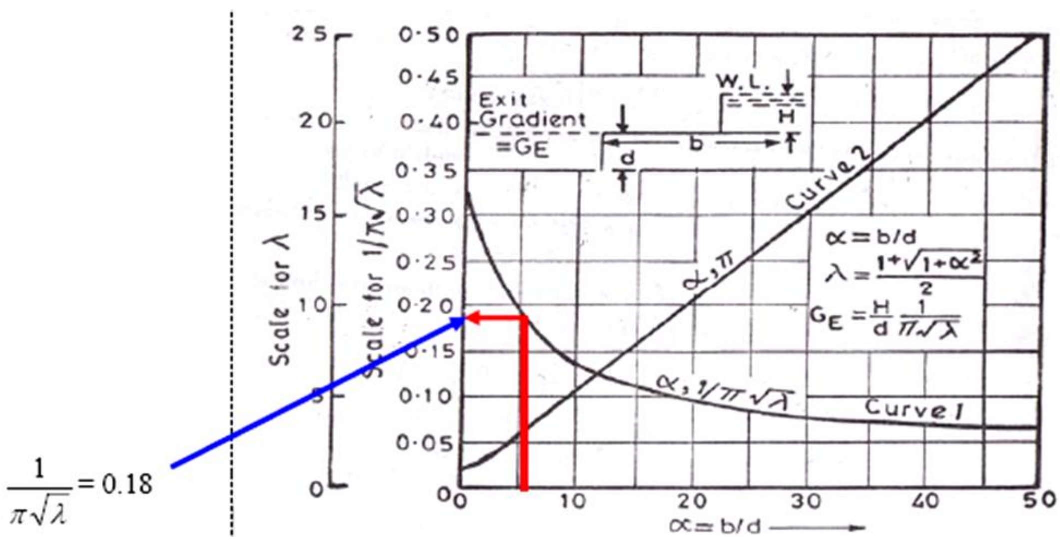
Total floor length, b = 57 m

$\alpha = b/d = 57/10.3 = 5.53$

For a value of α = 5.53, $\frac{1}{\pi\sqrt{\lambda}}$ from curves of Figure 4.18 is equal to 0.18.

Hence, $G_E = \frac{H}{d} \times \frac{1}{\pi\sqrt{\lambda}} = \frac{6}{10.3} \times 0.18 = 0.105$

Hence, the exit gradient shall be equal to 0.105, *i.e.* 1 in 9.53, which is very much safe.



Example 2.3

Design a vertical drop weir on the basis of Bligh's theory for the following site conditions:

(a) *Maximum flood discharge = 2585 m^3/s*
(b) *H.F.L. before construction = 255 m*
(c) *Minimum water level = d/s bed level = 248 m*
(d) *F.S.L. of canal = 254 m*
(e) *Allowable afflux = 1 m*
(f) *Coefficient of creep, C = 12*

Assume any other data not given.

If permissible exit gradient is 1/6, test the floor of the above weir by Khosla's theory and make changes if found necessary.

Solution

1) **Hydraulic Calculations**

i) $L = 4.75\,Q^{1/2} = 4.75 \times (2585)^{1/2} = 241.50$ m

$q = Q/L = 2585/241.50 = 10.70\ m^3/s/m$

ii) Regime scour depth, taking silt factor, f = 1

$$R = 1.35\left(\frac{q^2}{f}\right)^{1/3} = 1.35\left(\frac{10.70^2}{1}\right)^{1/3} = 6.56 \text{ m}$$

Regime velocity, V = q/R = 10.70/6.56 = 1.63 m/s

Velocity head = $V^2/2g = (1.63)^2/(2 \times 9.81) = 0.14$ m

iii) Level of d/s T.E.L. = H.F.L. before construction + velocity head

= 255 + 0.14 = 255.14 m

Afflux = 1 m

Level of u/s T.E.L. = Level of d/s T.E.L. + Afflux

= 255.14 + 1.0 = 256.14 m

Therefore, level of u/s H.F.L. = Level of u/s T.E.L. – $V^2/2g$

= 256.14 – 0.14 = 256.0 m

Actual d/s H.F.L. (allowing 0.5 m for retrogression) = 255.0 – 0.5 = 254.5 m

iv) $q = 1.70K^{3/2} \Rightarrow K = (q/1.70)^{2/3} = (10.70/1.70)^{2/3} = 3.41$ m

Crest level = u/s T.E.L. – K = 256.14 – 3.41 = 252.73 m

v) Pond level = Level of top of gates

= F.S.L. of canal + Head loss through regulator (*taken as 0.5m)*

= 254 + 0.5 = 254.5 m

Therefore, height of shutters, S = Level of top of gates – crest level

= 254.5 – 252.73 = 1.77 m

vi) Bottom level of u/s pile (cutoff) = u/s H.F.L. – 1.5 R

= 256.0 – 1.5 x 6.56

= 246.16 m

The u/s pile may be taken up to a level of 246.0 m.

Therefore, depth of u/s pile = 248.0 – 246.0 = 2.0 m

Bottom level of d/s pile = d/s H.F.L. after retrogression – 2R
= 254.5 – 2 x 6.56 = 241.38 m
Hence, the d/s pile may be taken up to a level of 241.0 m.
Depth of d/s pile = 248.0 – 241 = 7.0 m

vii) Head of water, H_s = Level of crest gates – bed level
= 254.5 – 248.0 = 6.5 m
Height of crest, H = Crest level – bed level
= 252.73 – 248.0 = 4.73 m
(Check: Hs = H + S = 4.73 + 1.77 = 6.5 m)

2) Design of Weir Wall

viii) Top width B_1

d = u/s H.F.L. – crest level = 256.0 – 252.73 = 3.27 m

- Top width, $B_1 = \frac{d}{\sqrt{S_m}} = \frac{3.27}{\sqrt{2.24}} = 2.18$ m
- $B_1 = \frac{3d}{2S_m} = \frac{3x3.27}{2x2.24} = 2.19$ m
- From practical consideration, B_1 = S + 1 = 1.77 + 1 = 2.77 m
  Hence, provide top width B_1 = 3.0 m.

ix) Calculation of bottom width, B

- Considering *State 1*, the overturning moment is given by

$$M_0 = \frac{\gamma(H+S)^3}{6} = \frac{\gamma H_s^3}{6}$$

$$M_0 = \frac{9.81 \text{ x } (6.5)^3}{6} = 449 \text{ kN} - \text{m}$$

Resisting moment is given by

$$M_r = \frac{\gamma}{12}\left[\{(S_m + 1.5)H + 2.5S\}B^2 + B_1(S_m H - H - S)B - \frac{1}{2}B_1^2(H + 3S)\right]$$

For H = 4.73 m, S = 1.77 m, B_1 = 3 m, and S_m = 2.24

$$M_r = \frac{9.81}{12}\left[\{(2.24+1.5)x4.73+2.5x1.77\}B^2 + 3\text{ x}(2.24x4.73-4.73-1.77)B - \frac{1}{2}x3^2(4.73+3x1.77)\right]$$

Therefore, equating M_0 and M_r,
$22.115B^2 + 12.286\,B - 594.42 = 0$, and solving the quadratic equation, we get the value of the bottom width, B = 4.914 m

- Considering *state 2*, the overturning moment is calculated as follows:

When the tailwater is just at the crest, d and h will be equal. For this condition, d (head over the crest) is given by

$$d = \left[\frac{q}{\frac{2}{3} C_d x \sqrt{2g}} \right]^{2/3}$$

Neglecting the velocity of approach, and taking C_d = 0.58,

$$d = \left[\frac{10.70}{\frac{2}{3} x\ 0.58\ x \sqrt{2x9.81}} \right]^{2/3} = 3.39 \text{ m}$$

Since d = h = 3.39 m

$$M_0 = \frac{\gamma h H^2}{2} = \frac{9.81x3.39x4.73^2}{2} = 372.02 \text{ kN} - \text{m}$$

The resisting moment is

$$M_r = \frac{\gamma H(S_m - 1)}{12}\left(B^2 + B_1 B\right) = \frac{9.81x4.73(2.24-1)}{12}\left(B^2 + 3B\right) = 4.795\ (B^2 + 3B)$$

Equating Mo and Mr,

372.02 = 4.795 (B^2 + 3B)

From which, B = 7.44 m

Adopting the greater of the two, we get B = 7.44 m. Provide **B = 7.50 m**

3) Design of Impervious and pervious aprons

x) *Total creep length*

L = CH_s = 12 x 6.5 = 78.0 m

xi) *Downstream impervious apron*

$$L_1 = 2.21C\sqrt{\frac{H_s}{13}} = 2.21x12\sqrt{\frac{6.5}{13}} = 18.75\text{m}$$, provide L_1 = 19 m

xii) *Upstream impervious apron, L_2*

$L_2 = L - L_1 - (B + 2d_1 + 2d_2)$ = 78 – 19 – (7.5 + 2 x 2 + 2 x7) = 33.5 m

xiii) *Total length of d/s apron*

$$L_3 = 18C\sqrt{\frac{H_s}{13} x \frac{q}{75}} = 18x12\sqrt{\frac{6.5}{13} x \frac{10.7}{75}} = 57.69\text{m}$$, provide L_3 = 57.7 m

xiv) *Length of inverted filter and launching apron on d/s side* = $L_3 - L_1$

= 57.7 – 19 = 38.70 m

$d_2 = 7.0$ m

Min. length of inverted filter = 1.5 d_2 = 1.5 x 7 = 10.5 m

Min. length of launching apron = 1.5 d_2 = 1.5 x 7 = 10.5 m

Total length of downstream pervious apron = 2 x 10.5 = 21 m

But the total length to be provided for both is 38.7 m.

Hence, provide inverted filter of length 17.7 m with 1 m thick stone or concrete blocks laid on 0.5 m thick graded filter; and launching apron of 21 m length and 1.5 m thickness.

xv) U/s block protection and launching apron

$d_1 = 2$ m,

Hence, provide block protection of length = d_1 = 2 m consisting of 1 m thick stone or concrete blocks laid on 0.5 m thick loosely packed stone.

Minimum length of u/s launching apron = 1.5 d_1 = 1.5 x 2 = 3 m

Provide 3 m long and 1.5 m thick launching apron.

xvi) Thickness of impervious floor

Provide a nominal thickness of 1 m for the portion u/s of the weir wall and 1.5 m for the portion below the weir wall.

At point A, just at the d/s toe of the weir wall, the residual seepage head

$$H_r = H_s - \frac{H_s}{L}\left(2d_1 + L_2 + B\right) \; = \; = 6.5 - \frac{6.5}{78}\left(2x2 + 33.5 + 7.5\right) \; = 2.75\text{m}$$

Therefore, required thickness of floor,

$$t = \frac{4}{3}\frac{H_r}{S_m - 1} = \frac{4}{3}\frac{2.75}{2.24 - 1} = 2.96\text{m},$$

Provide 3 m a thickness of 3 m from the d/s toe of the weir wall up to a point 6 m from it. For the rest of the d/s portion of the floor same procedure can be followed and thickness calculated (e.g. for portion d/s of the 6 m).

4) Check by Khosla's Theory

i) Check for exit gradient

Total length of impervious floor = 33.5 + 7.5 + 19 = 60 m

d_2 = 7 m (d/s pile)

$\alpha = b/d = 60/7 = 8.57 = 8.6$

From Khosla's curve for exit gradient, for $\alpha = 8.6,\ \frac{1}{\pi\sqrt{\lambda}} = 0.145$

Therefore, $G_E = \frac{H_s}{d}\frac{1}{\pi\sqrt{\lambda}} \quad = \frac{6.5}{7}x0.145 \quad = \frac{1}{7.4} < \frac{1}{6}$ *(permissible exit gradient)*

Hence, *SAFE*

ii) *Check for the floor thickness*

Pressures at key points C_1 and D_1 of the u/s pile

$$\frac{1}{\alpha} = \frac{d_1}{b} = \frac{2}{60} = 0.033$$

From Khosla's curves φ_{D1} = 89%; φ_{C1} = 82%

Correction for floor thickness for $\varphi_{C1} = \frac{\phi_{D1} - \phi_{C1}}{d}xt \quad = \frac{89-82}{2}x1.0 \quad = 3.5\% \quad (+ve)$

Correction for interference of d/s pile for φ_{C1}

$$C = 19\sqrt{\frac{D}{b'}}\left(\frac{d+D}{b}\right)$$

b = b' = 60 m; D = 7 m; d = 2 m

$$C = 19\sqrt{\frac{7}{60}}\left(\frac{2+7}{60}\right) \quad = 0.97\% \approx 1\% \quad (+ve)$$

Hence, corrected value φ_{C1} = 82 + 3.5 + 1 = 86.5%

Residual head at C_1 = H_s x φ_{C1} = 6.5 x 0.865 = 5.62 m

Pressure at key points E_2 and D_2 of the d/s pile

$$\frac{1}{\alpha} = \frac{d}{b} = \frac{7}{60} = 0.117$$

From Khosla's curves φ_{D2} = 21%; φ_{E2} = 30%

Correction for floor thickness for $\varphi_{E2} = \frac{\phi_{E2} - \phi_{D2}}{d}xt \quad = \frac{30-21}{7}x2.0 \quad = 2.6\% \quad (-ve)$

(Thickness of floor near pile = 2 m)

Correction for interference of u/s pile for φ_{E2}

$$C = 19\sqrt{\frac{D}{b'}}\left(\frac{d+D}{b}\right)$$

b = b' = 60 m; D = 2 m; d = 7 m

$$C = 19\sqrt{\frac{2}{60}}\left(\frac{7+2}{60}\right) \quad = 0.5\%(-\text{ve})$$

Hence, corrected value φ_{E2} = 30 – 2.6 – 0.5 = 26.9%

Residual head at E_2 = H_s x φ_{E2} = 6.5 x 0.269 = 1.75 m

Assuming linear variation of pressure for intermediate points, the pressures and floor thickness for points A, B and C are as follows:

Point A just at the d/s toe of the weir wall

$$P_A = 5.62 - \left(\frac{5.62-1.75}{60}\right)(33.5+7.5) \quad = 2.98\text{m}$$

$$t_A = \frac{2.98}{2.24-1} \quad = 2.40\text{m}$$

Actual thickness provided according to Bligh’s theory = 3 m

Hence, safe

Point B, 6 m from d/s toe of the weir wall

$$P_B = 5.62 - \left(\frac{5.62-1.75}{60}\right)(33.5+7.5+6) \quad = 2.59\text{m}$$

$$t_B = \frac{2.59}{2.24-1} \quad = 2.04\text{m}$$

Actual thickness provided according to Bligh’s theory = 2.5 m

Hence, safe

Point C, 12 m from d/s toe of the weir wall

$$P_C = 5.62 - \left(\frac{5.62-1.75}{60}\right)(33.5+7.5+12) \quad = 1.77\text{m}$$

$$t_C = \frac{2.2}{2.24-1} \quad = 1.77\text{m}$$

Actual thickness provided according to Bligh’s theory = 2 m

Hence, safe

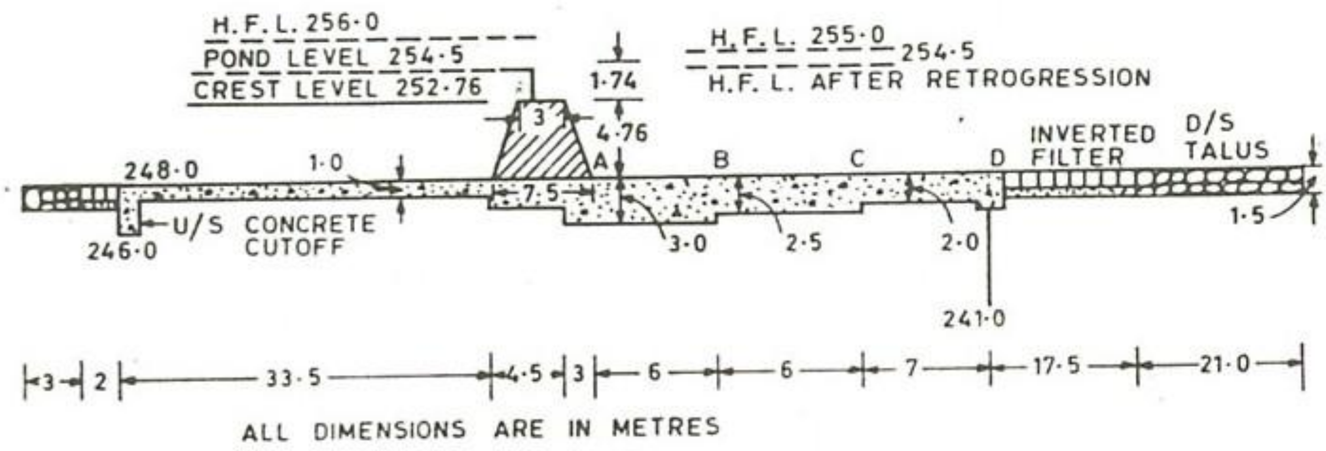


Figure E-2.3 Section of the example weir