Unit-V

Anchored Bulkheads :→

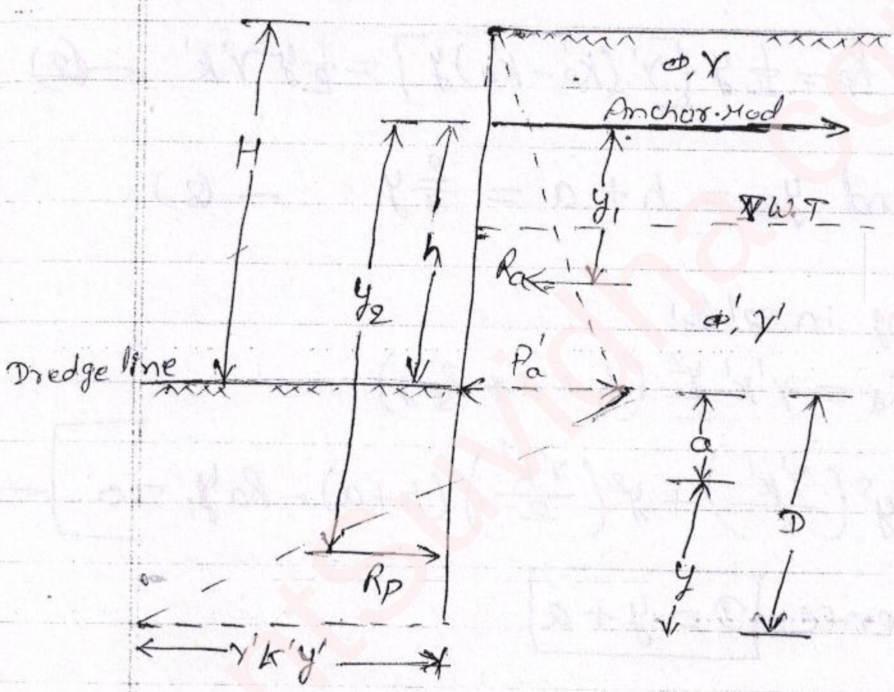
An anchored bulkhead is the one which is held above its driven depth by one or more tie rods or anchors at or near its top.
The design of anchored bulkhead consists of the determination of
(i) the length of embankment
(ii) the magnitude of the tensile force in the anchor or tie rod
(iii) design of the section of the sheet.

The various methods of analysis of anchored bulkhead can be broadly grouped under two categories :
(1) method of free-earth support
(2) method of fixed-earth support

☒ Design of anchored bulkhead by Free-Earth Support Method :-
(A) Granular Soil with variation of properties along the depth:
This method is based on following assumptions:
1) The sheet pile is perfectly rigid as compared to the surrounding soil.
2) The sheet pile is free to rotate at the anchor rod level with failure occuring by a

rotation about the anchor rod.

3) The active and passive soil pressure acting on the sheet pile may be computed by the Rankine theory and their distribution is hydrostatic.



<u>Simplified Pressure Distribution</u>

Let F_a = tensile force in the anchor rod

K_a' & K_p' = Co-efficients of active and passive pressures, based on ϕ'

$K' = K_p' - K_a'$

a = depth of point of zero pressure below the dredge line

If P_a' = active pressure intensity at the dredge line, we have

$$a\gamma'(K_p' - K_a') = P_a'$$

$$\boxed{a = \frac{P_a'}{\gamma'(K_p' - K_a')} = \frac{P_a'}{\gamma' K'}}$$

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Let R_a = Resultant active pressure, acting at y_1 below the anchor rod level.

R_p = Resultant passive earth pressure, acting at y_2 below the anchor rod level.

Applying $\Sigma M = 0$ at the tie rod level, we get

$$y_1 R_a = y_2 R_p$$

But $R_p = \frac{1}{2} y \left[\gamma'(K_p' - K_a')y\right] = \frac{1}{2} y^2 \gamma' K'$ — (2)

and $y_2 = h + a + \frac{2}{3} y$ — (3)

Putting in eq^n (2)

$$y_1 R_a = \gamma' K' \frac{y^2}{2}\left(h + a + \frac{2}{3} y\right)$$

$$\text{or, } y^3\left(\frac{\gamma' K'}{3}\right) + y^2\left(\frac{\gamma' K'}{2}\right)(h+a) - R_a y_1 = 0 \quad \text{— (4)}$$

Hence, $D = y + a$

This value of D may either be increased by 20 to 40% or K_p' may be divided by an appropriate factor of safety before substituting in Eq. (4).

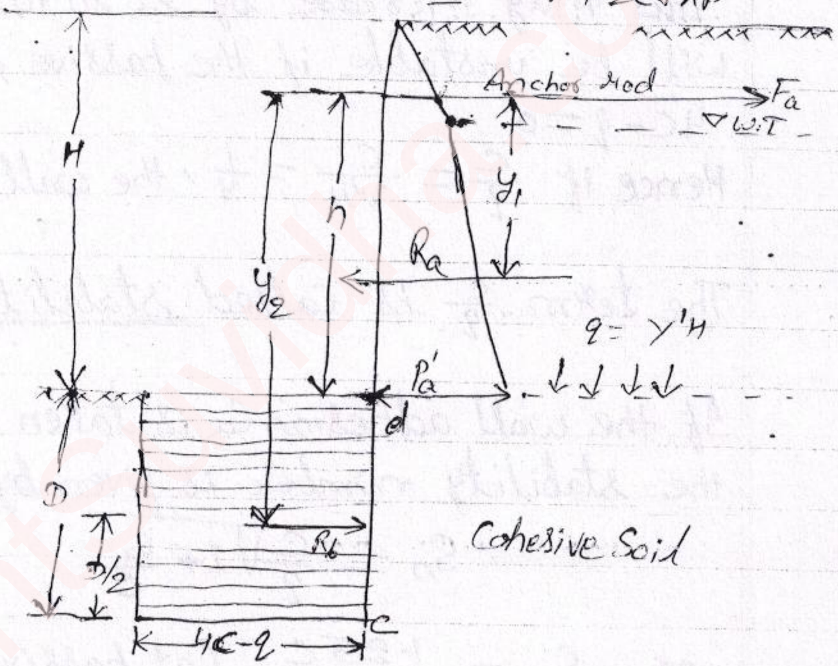
The force in the tie rod is obtained by equating $\Sigma H = 0$

$$\therefore F_a = R_a - R_p$$

(B) Cohesive Soil below dredge line:

If the soil is cohesive ($\phi = 0$) below the dredge line, but the backfill is granular, the passive pressure distribution will be rectangular with the pervious notation. To find the intensities of passive pressure, we use the equation, $P_p = \sigma \tan^2\alpha + 2C \tan\alpha$

$$= \sigma K_p + 2C\sqrt{K_p}$$



But for $\phi = 0$, $K_a = K_p = 1$, also $\sigma = \gamma' H = q$

$\therefore P_p = \sigma + 2C$ — (1)

Also $P_a = \sigma K_a - 2C\sqrt{K_a} = \sigma - 2C$ — (2)

At the dredge line, to the left of d, $\sigma = 0$

$(P_p)_d = 2C$ — (3)

At the dredge, to the right of d, $\sigma = q = \gamma' H$

$\therefore (P_a)_d = q - 2C = \gamma' H - 2C$ — (4)

$\therefore$ Net passive pressure at d is given by

$(P_p - P_a)_d = 2C - (q - 2C) = 4C - q$ — (5)

Let R_p = resultant pressure $= (4C - q)D$

Acting at $y_2 = h + \frac{D}{2}$ below the anchor rod

Putting $\Sigma M = 0$ at the anchor rod

$$R_a y_1 - D(4c-q)\left(h + \frac{D}{2}\right) = 0$$

or, $$D^2 + 2Dh - \frac{2y_1 R_a}{4c-q} = 0$$

This may increase by 20 to 40%. The wall will be unstable if the passive pressure $4c - q = 0$

Hence if $\frac{c}{q} = \frac{c}{\gamma H} = \frac{1}{4}$, the wall will be unstable

The term $\frac{c}{q}$ is called stability number S_n

If the wall adhesion C_a is taken into account the stability number is given by

$$S_n = \frac{c}{q}\sqrt{1 + \frac{c_a}{c}}$$

or, $$S_n = \frac{1.25c}{q} \text{ (at passive failure)}$$

For factor of safety $F = 1$ and $\frac{c}{q} = \frac{1}{4}$

$$S_n \simeq 0.3F$$

(c) Uniform Granular Soil:—

If the backfill has uniform properties (i.e. if γ and ϕ are the same throughout the depth), analysis becomes relatively simpler.

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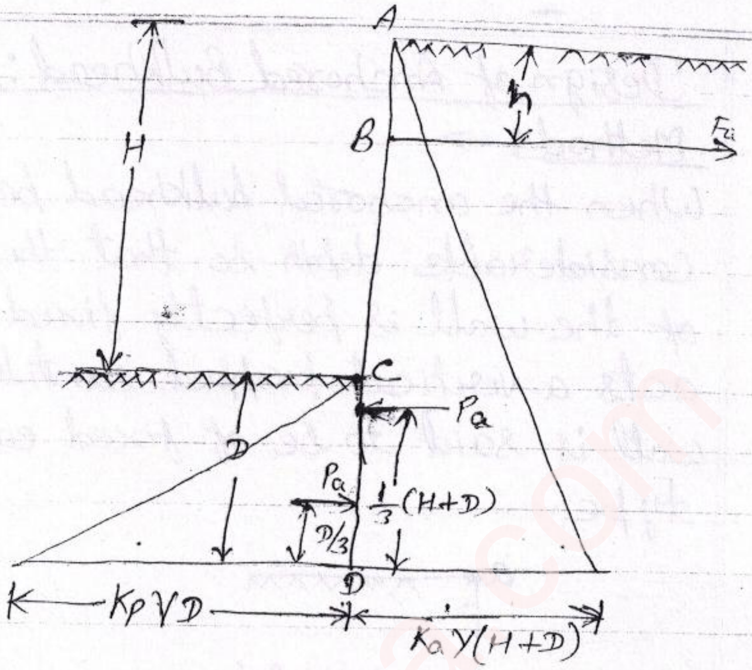


Maximum values of pressure intensities at point D, as $p_a = K_a\gamma(H+D)$ — (1)

and $p_p = K_p\gamma D$ — (2)

∴ ~~$P_p = K_p\gamma D$~~ $P_a = \frac{1}{2}K_a\gamma(H+D)^2$

and $P_p = \frac{1}{2}K_p\gamma D^2$

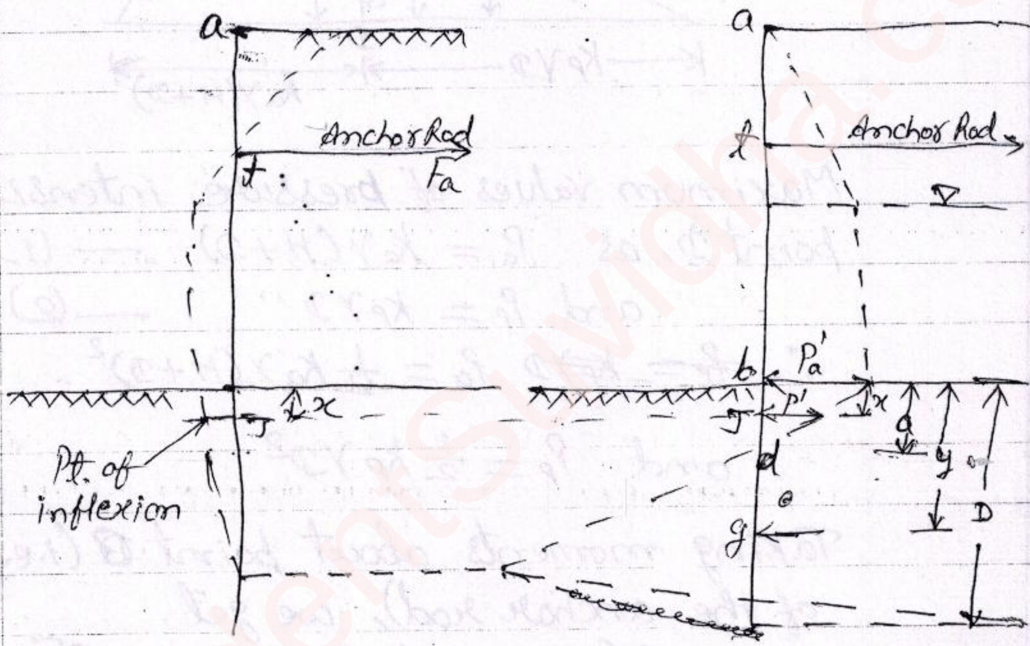
Taking moments about point B (i.e. level of the anchor rod), we get

$$\frac{1}{2}K_p\gamma D^2\left(H-h+\frac{2}{3}D\right) = \frac{1}{2}K_a\gamma(H+D)^2\left[\frac{2}{3}(H+D)-h\right]$$

or, $$K_p D^2\left(H-h+\frac{2}{3}D\right) = K_a(H+D)^2\left[\frac{2}{3}(H+D)-h\right]$$

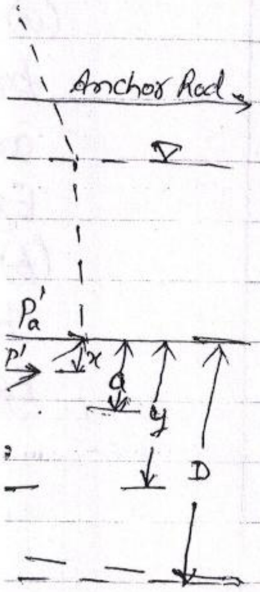
Design of Anchored Bulkhead: Fixed Earth Method: →

When the anchored bulkhead penetrates to a considerable depth so that the lower end of the wall is perfectly fixed and the wall acts a vertical propped cantilever, the wall is said to be of fixed earth support type.



(a) Elastic line (b) Pressure distribution

- The point g is the point of fixidity, below which the sheet pile remains vertically straight
- Point J is the point of contraflexure located at a distance x below the dredge line.
- The fixed-earth support problem can be solved by two methods:
  (1) Equivalent beam method
  (2) elastic line method.



In the Elastic Line Method, the distance y is first estimated, from which R_s is found by statics. Then the bending moment diagram is computed by any other method, and the tangential deviation of g is computed w.r.t the anchor rod level. The distance y is the revised till the computed tangential deviation is zero.

Equivalent Beam Method

The equivalent beam method was developed by H. Blum (1931). In this method, the pressure diagram is the same as in the elastic line method, but the point of contraflexure, located at x below the dredge line, is considered as a function ϕ, and may taken from the Chart of X plotted for $k_p = \frac{2}{k_a}$ (Verdegen & Rolsin).

This method consists in assuming a hinge at the point of contraflexure (point J), where the bending moment is zero.

The design computations are done in the following steps:

(1) Draw the pressure distribution diagram, and compute the value of P_a'. Calculate and K_a', K_p' and K.

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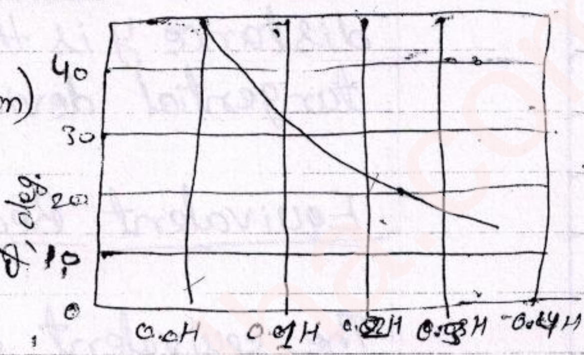
(2) Find a, the distance of point of zero pressure, below the dredge line by the relation:

$$a = \frac{p_a'}{\gamma'(K_p' - K_a')} = \frac{p_a'}{\gamma' K'} \quad \text{— (1)}$$

(3) Find x from chart, and compute pressure intensity p' at j (point of inflection)

$$p' = \frac{(a-x)\,p_a'}{a} \quad \text{— (2)}$$



Value of x →

(4) Find R_b' by equating ΣM, about tie rod to zero (Consider forces of the upper part only)

(5) Find the distance (y − x) by equating ΣM about point g to zero (Consider forces of the lower part only). Solve for y.

(6) Find D = 1.2 y

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