NATIONAL INSTITUTE OF TECHNOLOGY, HAMIRPUR

GEOTECHNICAL ENGINEERING- II (CED-313)
ASSIGNMENT NO. - 03

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Questions And Answers -

Q 1. (a) Discuss the forces to be considered in designing a bulkhead.

Sol. A number of forces are known to be acting over a bulkhead, some of which are constantly in play while others come in effect only occasionally and intermittently.

A sheet pile wall bulkhead may be subjected to some or all of the following lateral pressures,

- active and passive earth pressure.
- Lateral pressure due to rectangle load
- unbalanced water pressure and seepage pressure
- earthquake forces
- morning pull & ship impacted.

The classical earth pressure theories of Coulomb, which are based on the conditions of full initialization of the shear strength of soil due to yielding of the wall laterally by sticking or by rotating about its bottom, do not apply in the care of bulkhead where the deformation conditions are different. The earth pressure against sheet pile wall can be determined by theories which take into account the conditions of yielding of wall.

(b) An anchored bulkhead is to be designed to retain a granular backfill of 9 m height above dredge line. Anchor rod is provided at a depth of 1 m below top of fill. Assuming water table to be 2 m below top of fill and soil of fill as that below dredge line having same properties (c= 0, ϕ =33 □, γ=17 kN/m^3 and γ_{sat} =20 kN/m 3);compute the depth of embedment and tensile force in anchor rod of bulkhead. Use free earth support method and increase computed embedment depth by 40%. Also design the anchored bulkhead using fixed earth support method.

Solution :

1b.

Free earth support method:

γ=17KN/m3; γsat=20KN/m3 and γ'=10.19KN/m3

And $K_p = 3.39$

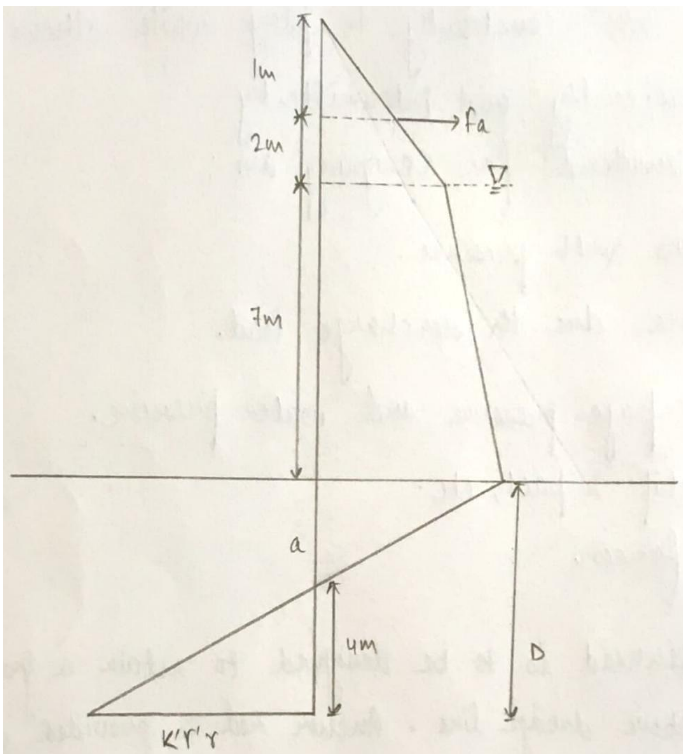
$P_a' = 0.295 \times 17 \times 2 + 0.295 \times 10.19 \times 7$

$P_a = 31.0724 KN/m^2$

$a = P'a/\gamma'K' = 31.0724/ 10.19 \times 3.095 = 0.985m$

$R_a = ½ \times 0.295 \times 17 \times 2 \times 2 + 0.295 \times 17 \times 2 \times 7 + ½ \times 31.0723 \times 0.985 + ½ \times 0.295 \times 10.19 \times 7^2$

Therefore, $R_a = 169.2KN$



Now Using,

$y^3(\gamma'K'/3) + y^2(\gamma'K'/2)(a+h) – R_a y_1 = 0$ ....(i)

$y_1 = (10.03 \times 1/3 + 70.21 \times 4.5 +73.648 \times 15.3031 \times 8.33)/169.1922$

$y_1 = 4.09156$

Using equation(i);

$y^3((10.19 \times 3.095)/3) + y^2 ((10.19 \times 3.095)/2)(0.985+8) – 169.19 \times 4.09 = 0$

$10.513y^3 + 141.68468y^2 – 692.25 = 0$

$y = 2.0587m$

$D = y + a = 3.0437$

Now, according to the equation providing 40% extra embedment,

$D = 3.0437 \times 1.4 = 4.26118m$

$R_p = ½\gamma’K’\gamma^2= ½ \times 10.15 \times 3.095 \times (2.0587)^2$

$R_p = 66.833KN$

$F = R_a – R_p = 169.1911 – 66.833$

$F = 102.3581KN$

Q 2. (a) Explain how will you design the cantilever sheet pile wall in -

(i) a granular soil and

Sol. The pile tends to point O deflecting away from the backfill. Above the point of rotation, the sheet pile wall deflects away from the backfill, thus generating active conditions on the back of the wall. At the same time, between the dredge line (point e) and the point of rotation (point O), as the wall tends to move towards the soil in front of the wall, passive conditions are generated in this side. However, below the point of rotation, the active and passive conditions generated on the two sides are reversed. The earth pressure diagrams are shown below.

The point of rotation located at distance a below the dredge line has zero earth pressure. The magnitude of earth pressure at locations e,O and b can be worked out, $p_{Ae} = K_a\, \boldsymbol{\gamma} \mathbf{H}$

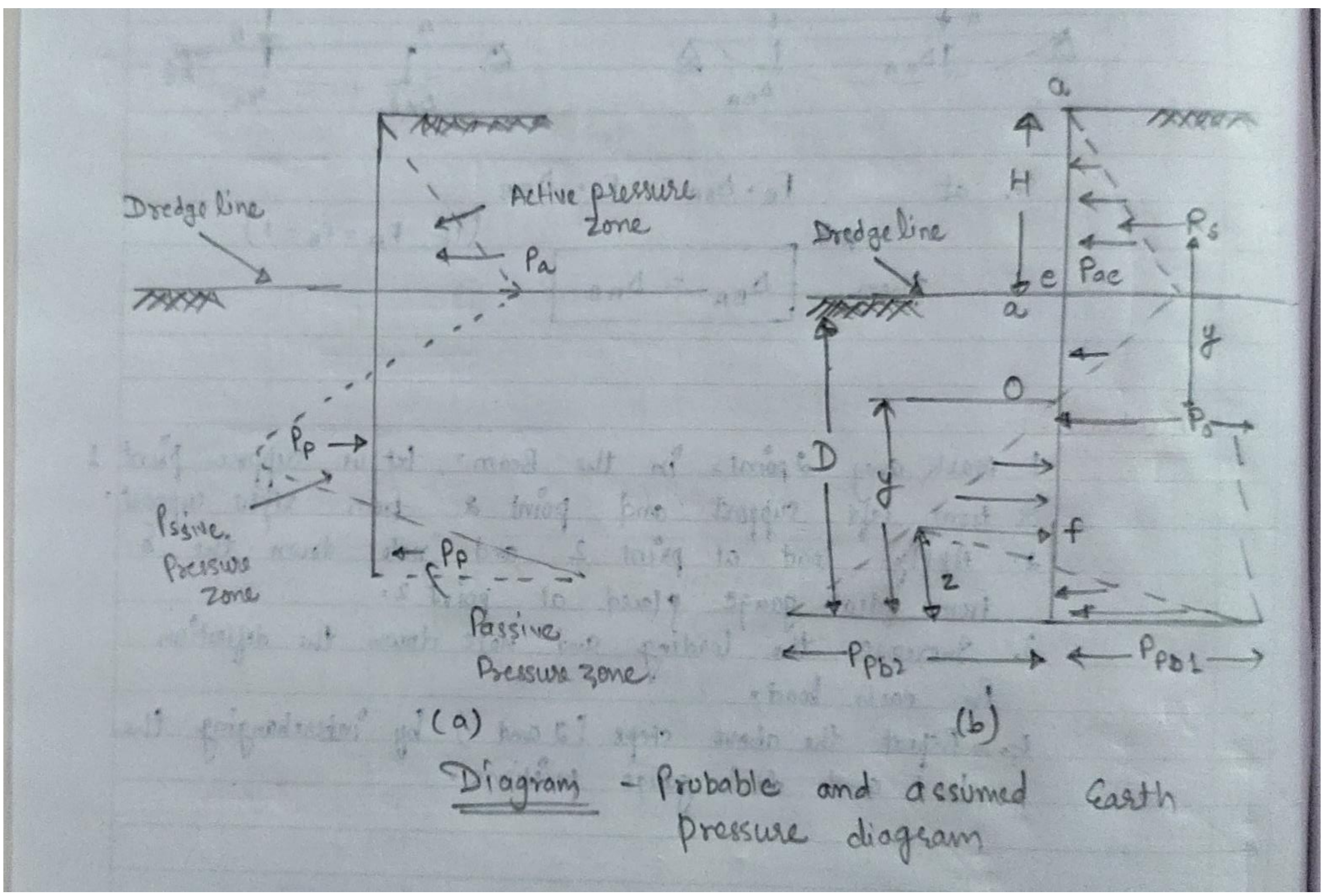
The magnitude of a is given by the equation, $p_{Ae} = (K_p\text{-}Ka)\, \boldsymbol{\gamma}\mathbf{a}$

$$a = \frac{p_{Ae}}{(K_p - K_a)\lambda}$$

$$\begin{aligned} p_{po} &= K_p\gamma(H + a) - K_A\gamma a \\ &= (K_p - K_A)\gamma a + K_p\gamma H \end{aligned}$$

$$\begin{aligned} p_{pb_1} &= p_{po} + (K_p - K_A)\gamma y \\ &= (K_p - K_A)\gamma D + K_p\gamma H \end{aligned}$$

$$p_{pb_2} = (K_p - K_A)\gamma y$$



Let R_a be the result of all forces above point O, acting at a distance ‘y' above O. the distance is worked out by satisfying horizontal equilibrium equation,

$$R_a + (p_{pb_1} + p_{pb_2})\frac{Z}{2} - p_{pb2}\frac{y}{2} = 0$$

$$Z = \frac{p_{pb_2}y - 2R_a}{p_{pb1} + p_{pb_2}}$$

Thus taking moments about base of the pile and satisfying the moment equilibrium.

$$R_a(y + \bar{y}) + \frac{Z}{3}(p_{pb_1} + p_{pb_2})\frac{Z}{2} - p_{pb_2}\frac{y}{2}\frac{y}{3} = 0$$

$$6R_a(y + \bar{y}) + Z^2(p_{pb_2} + p_{pb_1}) - p_{pb_2}y^2 = 0$$

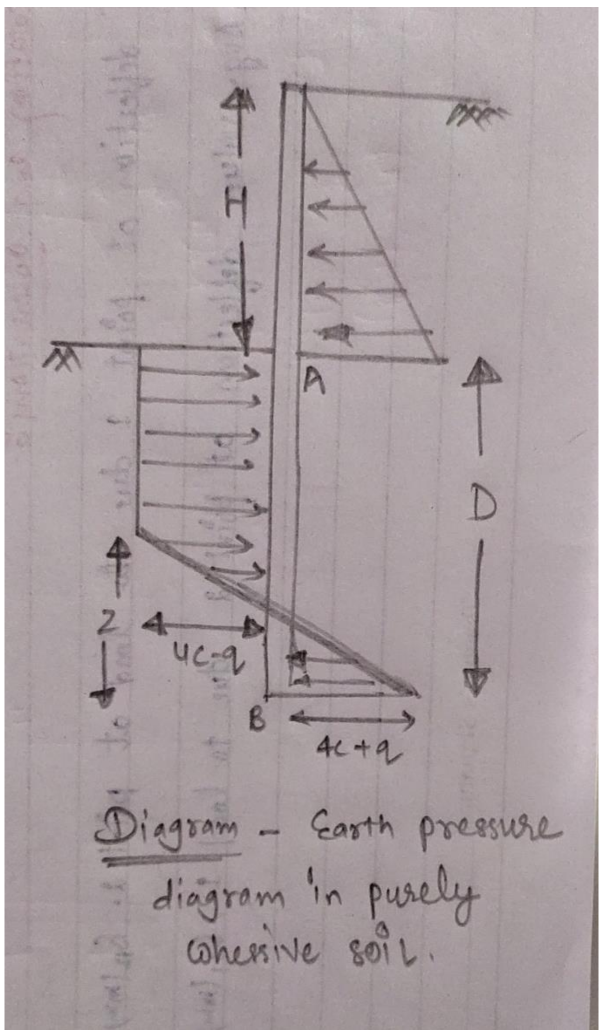
The value of ‘y' can be found and then the value of D=a+y. The computed D can be multiplied by factor 1.2 or 1

(ii) cohesive soil.

Sol. Cantilever sheet pile in cohesive soil: the analysis of cantilever sheet pile wall in cohesive soil is carried out in a manner almost similar to that in granular soils. However, certain phenomenon such as consolidated of clay in passive pressure zones, formation of tension cracks in the active zone may need additional consideration. Further, the clay may shrink and lose contact with the wall. To account for this, the benefit of wall adhesion is usually neglected in design.

The active earth pressure in purely cohesive soil is given by,

$p_A = qK_A - 2c\sqrt{K_A}$



where q is the effective vertical depth at any depth. For pure cohesive soil the frictional angle is zero then $K_A = k_P = 0$, then the above equation becomes,

$p_A = q - 2c$

Likewise, it can be shown that

$p_P = q + 2c$

The net pressure at A is, $(p_P - p_A)_e = (0+2c) - (q-2c) = 4c - q$ acting to the right. Similarly, at the base of the wall, i.e. point B, the net pressure is given by,

$$(p_p - p_A)_b = (q + \gamma D + 2c) - (\gamma\gamma - 2c)$$
$$= 4c + q$$

acting to the left.

condition of stability, $\sum F_H = 0$ Summing the pressure areas and satisfying the

$$R_a + \frac{Z}{2}(4c - q + 4c + q) - D(4c - q) = 0$$

$$Z = \frac{D(4c - q) - R_a}{4c} \quad \text{or} \quad R_a + \frac{Z}{2}(8c) - D(4c - q) = 0$$

or where is the resultant active earth pressure above the dredge line acting at ‘y' above the dredge line.

$$R_a(y + D) - \frac{D^2}{2}(4c - q) + \frac{Z}{3}\frac{Z}{2}(4c - q + 4c + q) = 0$$

substituting the value of Z from above equation and simplified the driving depth is determined.

$$D^2(4c - q) - 2DR_a - \frac{R_a(12cy + R_a)}{2c + q} = 0$$

Driving depth =1.2-1.4 D.

Further, some of the moments of forces about base are,

(b) An anchored bulkhead is to be designed to retain a granular backfill of 6 m height above dredge line. Anchor rod is provided at a depth of 1 m below top of fill. Assuming water table to be 3 m below top of fill and soil of fill as that below dredge line having same properties (cohesion $c = 0$, $\phi = \phi' = 30$, $\gamma = 18 kN/m^3$ and $\gamma_{sat} = 20 kN/m^3$); compute the depth of embedment and tensile force in anchor rod of bulkhead. Use free earth support method and increase computed embedment depth by one third.

Sol.2b

As we know

$p_{a1} = K_a \boldsymbol{\gamma} H_1$ = 1/3(54) = 18

p_{a2}=18+10.19*3/3 = 28.19

A= p_{a2}/ $\boldsymbol{\gamma}$'K' = 28.19/(2.67*10.19)= 1.035m

p_p = K' $\boldsymbol{\gamma}$' $\bar{y}^2$ = 0.5*2.67*10.19*y^2 = 13.6y2

R_a = 18*3/2 +18*3+1/2(10.19*3)+1/2(1.035*28.19)

R_a = 26.973+53.946+15.27+19.5738=110.7628

Hence $\bar{y}$ = = 2.9665m

D = $\bar{y}$ +a =4.0015m

Acc to question, D =4.0015*1.4 =5.6021 m

R_p =γ'K'γ^2/2 = = 119.7137kN

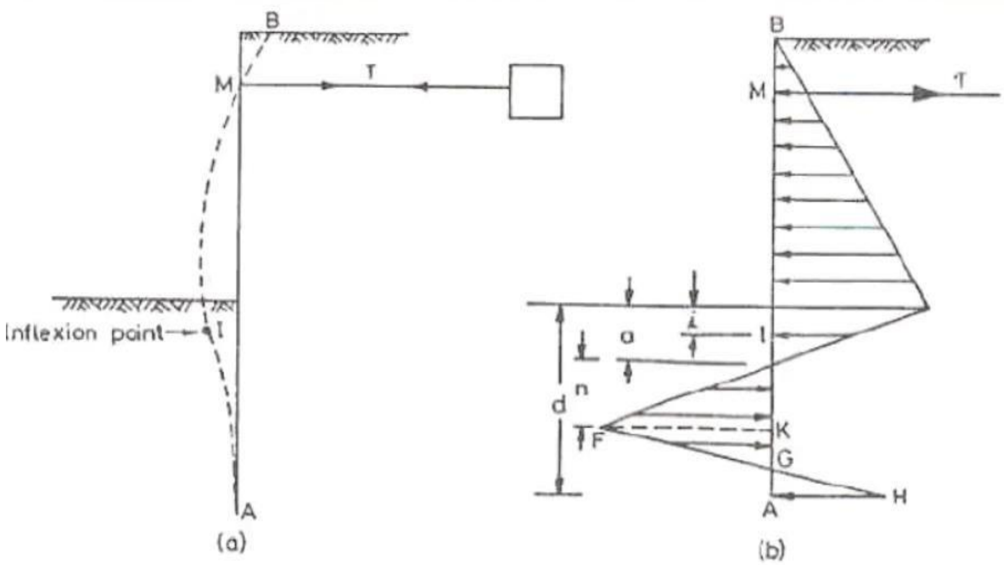
F = R_p-R_a = 119.7137-110.7628

=8.9509kN

Q 3. (a) Explain free earth support method & fixed earth support method for designing an anchored bulkhead.

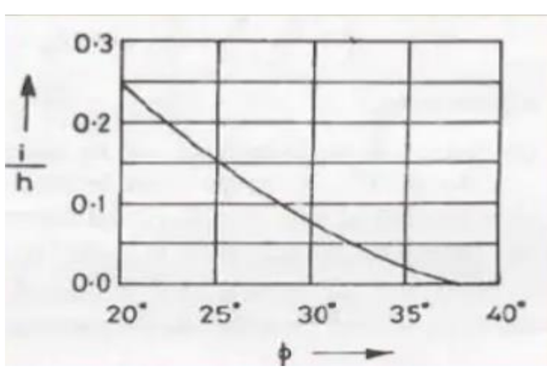
Sol. **<u>FIXED EARTH SUPPORT</u>**

The figure shows the deflected shape of an anchored sheet pile with fixed – earth support.



The elastic line changes its curvature at the inflexion point I. The soil into which the sheet is driven exerts a large line changes its curvature at the inflexion point I.

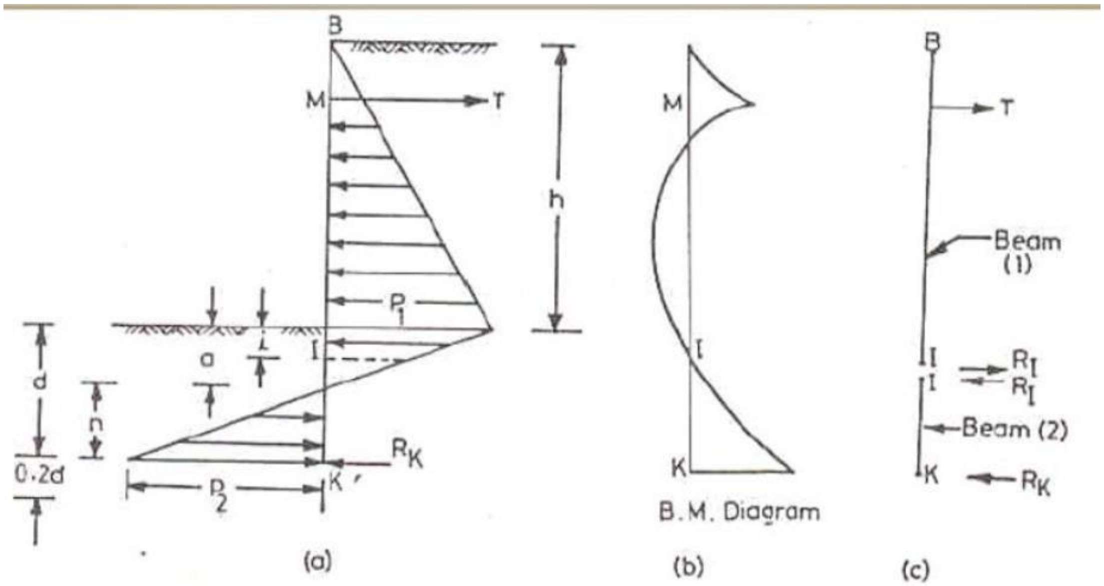
- The soil into which the sheet is driven exerts a large restraint on the lower part of the pile and causes a change in curvature.
- Blum gave a mathematical relationship between (i/h) and ∅, where I is the depth of the point of inflexion I below the dredge level and h is the height of



sheet pile above the dredge level. Thus inflection point I is located.

In figure, the lower portion of the pressure on the right side is replaced by a concentrated force Rk at point K.

1. The magnitude of Rk is initially unknown, but it is determined from the equation when the moments are taken about K.
2. Once the depth is found, Rk can be determined from the equilibrium equation in the horizontal direction.
3. An Equivalent- beam method is used . It is assumed that the sheet is a beam which is simply supported at the anchor point M and fixed at the lower end K.
4. The figure (b) shows the bending moment diagram.
5. The bending moment is Zero at the inflexion point I. Theoretically, the lower part IK of the pile can be removed and the shear force can be replaced by a reaction R1. The Simply supported beam BI is shown in figure.



The following procedure is used for the analysis of the sheet pile with fixed-earth support, using equivalent beam method.

(a) Upper Beam BI

- Determine the Pressure P1 at the dredge level.
- Estimate the angle of shearing resistance ∅ of the soil.
- Determine the distance I of the point of inflexion .
- Determine the distance a of the point of zero pressure from the equation.
- $a = P_1 / \gamma(K_p - K_a)$

Determine the pressure P0 at the point of inflexion from the relation,

$P_0 = P_1/a\ (a - I)$

- Determine the reaction R1 for the beam IB by taking moments about the point M of anchor of all the force acting on IB. (Shown in above figure)

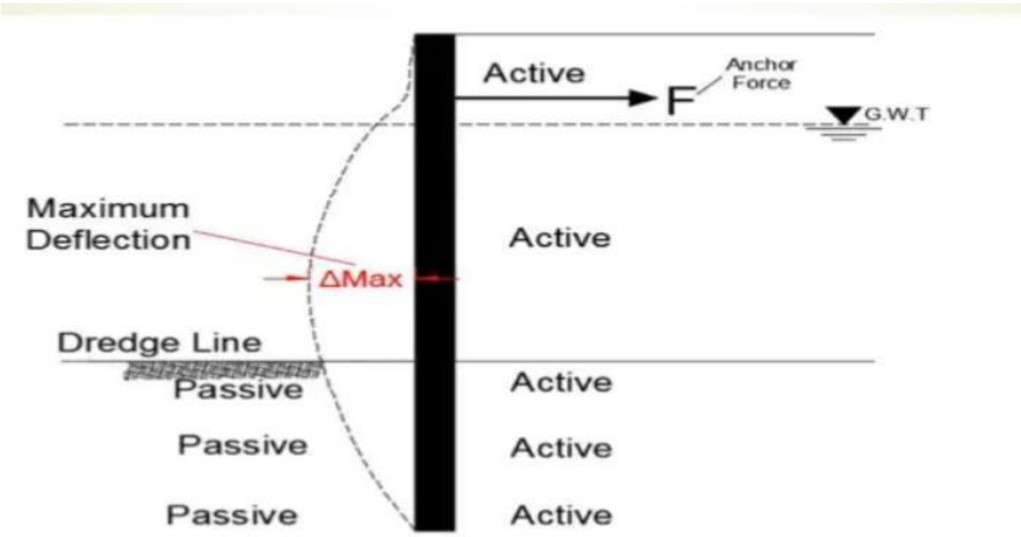
(b) Lower Beam IK

1. Determine the pressure P_2 from the relation $P_2 = (K_p - K_a)\ (d-a)$
2. Determine the distance (d-a) by taking moments of all the forces on the beam IK about K. The reaction R1 on the lower beam is equal and opposite to the upper beam.
3. Calculate d from pressure equation and hence find D = 1.2d.
4. Determine the tension T in anchor by considering the equilibrium of beam IB. Thus $T = P_1 - R_1$ Where P_1 = total force due to pressure on IB

FREE EARTH SUPPORT

In this method, the soil is assumed as a simply support (pin support) at the end of sheet pile, and also the wall is simply supported from its upper edge by anchor.

So the deflection of sheet pile will be similar to the deflection of simply supported beam as



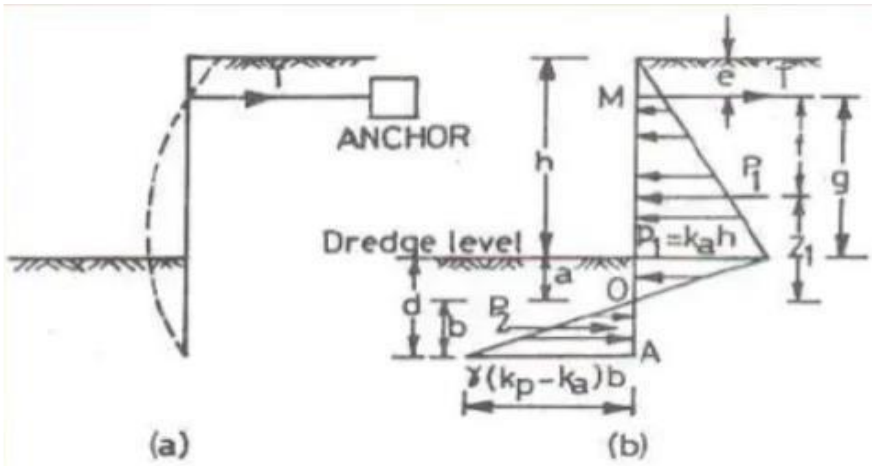
shown in the following figure:

The stability of the pile is mainly depend upon the anchor force in addition to that upon the passive earth pressure.

The embedment depth is small when it compared to the cantilever sheet pile.

So, in this method the length of the pile is reduced. Also , the additional cost of anchor is to be considered while judging the economy of the two type of construction.

The equation for the depth d are derived separately for the cohessionless and cohesive soil.



COHESIONLESS SOIL

The force acting on the pile, assuming that the material above and below the dredge line is cohessionless.

From Equilibrium, T + P2 – P3 = 0

Where T is the tension force in the anchor.

The depth a to the point of zero pressure can be determined as under.

$$\gamma\ K_a\ (h+a) - \gamma\ K_p a = 0$$

$$a\ \gamma\ (K_p\text{-}K_a) = \gamma\ (K_a h)$$

$$a= K_a h\ /(K_p - K_a)$$

Therefore, P2 = ½ P_2b = ½ γ (K_p-K_a) b^2

Where, P_2 = γ(Kp-Ka) b

Taking moments of all the forces about anchor point M,

P1 (a+ h-e-Z_1) - P2 (h-e+a+2b/3) = 0

Substituting the value of P2 in above equation

Finally the equation can be written as,

$$b3\ (K_p\text{-}K_a)\ \gamma/3 + b2\ (K_p\text{-}K_a)\ \gamma/2\ (g+a) - P_1 f = 0$$

b3 +1.5b2 (g+a) – 3P1f/ γ (Kp−Ka)

then f= a+ h-e-Z_1 ; g= h-e

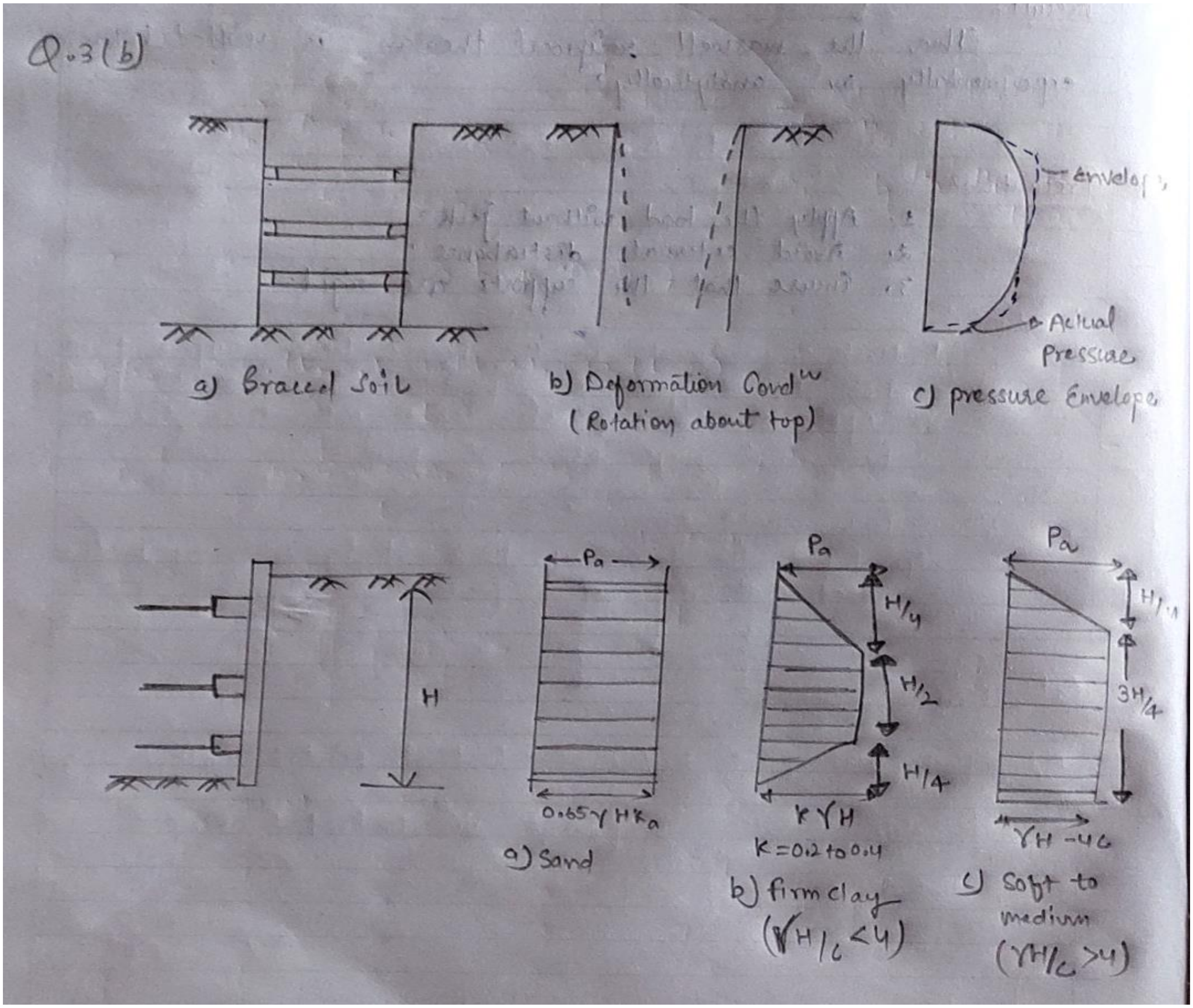
Then d is determined as d = b+a.

The actual depth D is taken equal to 1.2 to 1.4 times d.

The force in anchor rod can be obtained from the equation as T = P1 – P2

(b) Draw the soil pressure diagrams on strutted excavation in sand and clay.

Sol.



THANK YOU