Notes by-

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Earthen/Embankment Dam

Embankment Dam
- Earth fill
  - Rolled fill
    - Homogeneous
    - Zoned
    - Diaphragm type
  - Hydraulic fill
  - Semi-hydraulic fill
- Rock fill

Design of Earthen Dam

1) Crest width :- minimum 3 m
   Generally 6 - 12 m
2) Side Slopes :- 2:1 to 4:1
   week foundation flatter than 4:1
   strong foundation greater than 2:1
3) Free Board :- $1.5 h_w$ + safty factor (0.6 - 3)
4) Settlement allowance - 1% - 2% Height of dam.

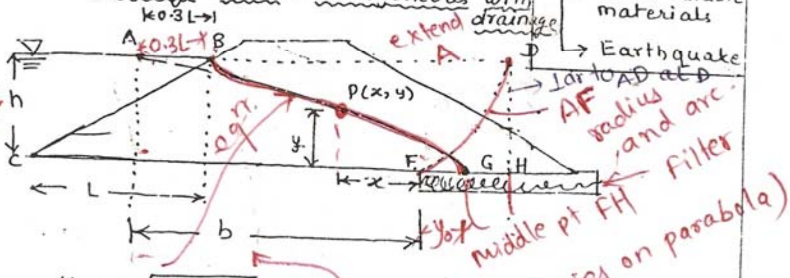
Criteria for Safe Design :-

1) Safety against overtopping during floods
2) Seepage line within the section
3) u/s & d/s section safe for critical condition
4) Foundation safe for shear stresses
5) No free passage from u/s to d/s
6) Dam & foundation safe for piping
7) u/s slope protected against erosion & wave action.
   d/s slope - erosion due to wind & rain

Causes of failure of earthen dam

- Hydraulic failure
  - Overtopping
  - Erosion of u/s slope by waves
  - Erosion of d/s slope by wind & rain
  - Erosion of d/s toe.
- Seepage failure
  - Piping through dam & its foundation
  - Conduit leakage
  - Sloughing
- Structural failures
  - Sliding of u/s & d/s slope
  - Slides due to spontaneous liquifaction
  - Burrowing animals
  - Water Soluble materials
  - Earthquake

Seepage Line : Homogeneous with drainage



(G, A lies on parabola)

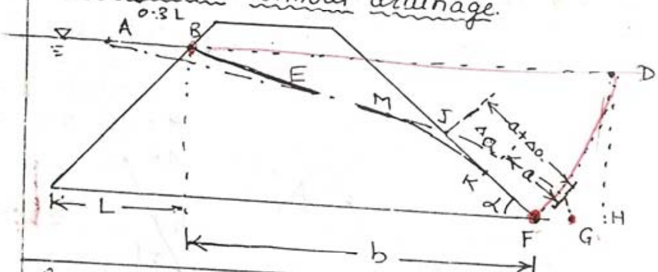
$$y_0 = \sqrt{b^2 + h^2} - b$$

$$y = \sqrt{y_0(2x + y_0)}$$

$q = k\, i\, A$ → area of c/s
k → coeff of permeability
i → hydraulic gradient h/L or dy/dx

Portion below seepage line is γ_{sat}.
Portion below seepage line is γ_{dry}.

Homogeneous without drainage.

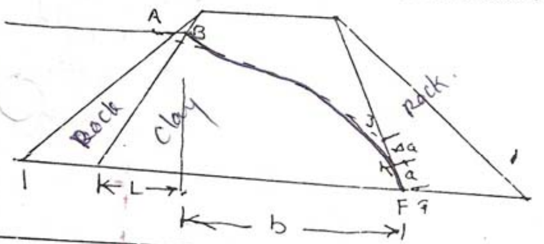


$$(a + \Delta a) = \frac{y_0}{(1 - \cos\alpha)} \rightarrow y_0 = \sqrt{b^2 + h^2} - b$$

α	Δa/(a+Δa)
30°	0.36
60°	0.32
90°	0.26
120°	0.18
135°	0.14
150°	0.10
180°	0.0

Δa can be found by above eqn & table.

Seepage line for zoned earthen dam.



Stability of Earthen Dam

1) Against headwater pressure $F_s = \frac{W \tan\phi}{H} > 2$
2) D/s and u/s portion against horizontal shear
3) Foundation of earthen dam against horizontal shear
4) Stability of side slopes.
   - (1) u/s slope for sudden drawdown
   - (2) (d/s) slope for steady seepage
   - (3) u/s & d/s slopes immidiately after construction

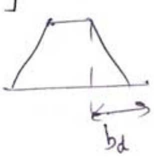
D/s and u/s portion for Horizontal shear

$$S_d = \left[\frac{\gamma H^2}{2 b_d}\tan^2\left(45° - \frac{\phi}{2}\right) + \frac{\gamma_w h_1^2}{2 b_d}\right] = \frac{H_d}{b_d} \text{ d/s}$$

$S_{md} = 2 S_d$ and $R_d = W_{ed}\tan\phi + c b_d$

$$H_d = \left[\frac{\gamma H^2}{2}\tan^2(45° - \phi/2) + \frac{\gamma_w h_1^2}{2}\right]$$ Imp.

$$F_d = \frac{R_d}{H_d} \geq 2$$



Similarly for u/s side.

$$F_u = \frac{R_u}{H_u} \geq 2 \text{ u/s}$$

$$H_u = \frac{\gamma_s H^2}{2}\tan^2\left(45 - \frac{\phi}{2}\right) + \frac{\gamma_w h_1^2}{2}$$

$S_u = \frac{H_u}{b_u}$, $S_{mu} = 2 S_u$

$R_u = W_{eu}\tan\phi + c b_u$

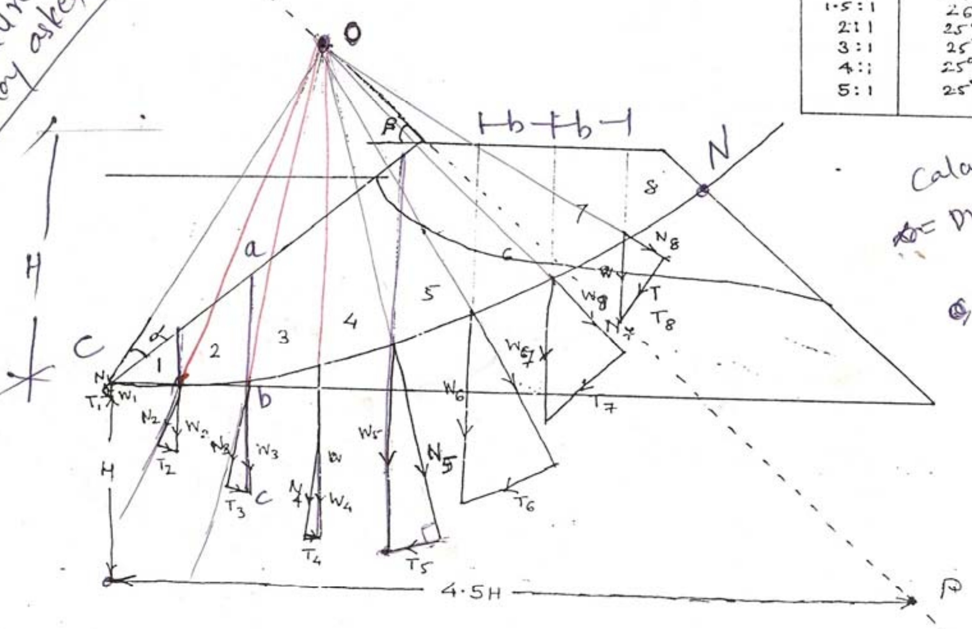
$$F_u = \frac{R_u}{H_u} > 2$$

$$F_{um} = \frac{\text{unit shear stth. at the pt of max. shear stress}}{S_{mu}}$$

⑤ Stability of side slopes:-

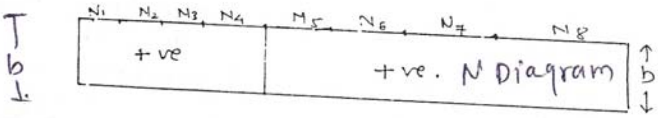
procedure may asked

Slope	Directional Angles α	β
0.58:1	29°	40°
1:1	27° 30'	37°
1.5:1	26°	35°
2:1	25°	35°
3:1	25°	35°
4:1	25°	36°
5:1	25°	37°



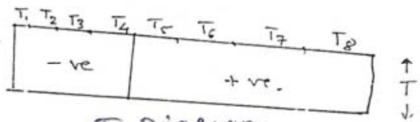
Calculate α & β.
- Draw α & β at shown both meet at O.
- From 'O' go H dist. below from H take 4.5H at 'P'. Join OP. OP is line on which centre of slip circle lies beyond 'O'.

O as centre & OC as radius draw arc. which is line on which slip of matl. occurs.



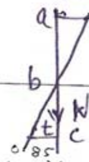
ΣN = Area of N dia × γ → γ may be γsub, γd

& Divide this arc in diff. slice of equal width. From O joint bottom pt as shown red & extend them.



T Diagram.

ΣT = Area of N dia × γ. & ab = bc Draw all. & join as

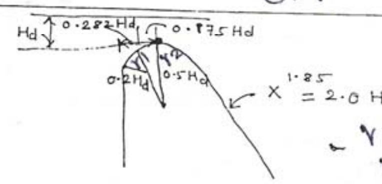


$$F_s = \frac{\Sigma(N-U)\tan\phi + cs}{\Sigma T} = 1.3 \text{ to } 1.5$$

PYQ Asked

ΣN - sum of normal components
ΣT - " " tangential "
ΣU " " Pore pressure.
C - cohesional resistance
S - length of the arc. = CN

Spillway
- → Base on Time of operation :- - Main, Auxillary, Emergency.
- → Based on control of flow → Gated, Ungated
- → Prominent Features → Free Overfall
  - → Ogee / Overflow
  - → Chute / Open channel / Trough.
  - → Side channel
  - → Morning Glory / Shaft
  - → Conduit / Tunnel.
  - → Siphon



$Y_1 = 0.5Hd$
$Y_2 = 0.2Hd$
$a = 0.175\ Hd$
$b = 0.282\ Hd$

1) $X^{1.85} = 2.0\ Hd^{0.85} \cdot Y$

$V = \sqrt{2g(Z + H_a - y)}$

Z - fall H_a - vel. of app. head.
y - Tail water depth

Energy Dissipators :-

$F_1 = 1.7$ to 2.5 - Horizontal apron
$F_1 = 2.5$ to 4.5 Type I stilling Basin
$F_1 > 4.5$ $V_1 < 15$ m/s Type II Stilling Basin
$V_2 > 15$ m/s Type III Stilling Basin
} USBR Stilling Basins.

2) $Q = C L H_e^{3/2}$ ungated

$Q = \frac{2}{3} C_d \sqrt{2g}\ L\left(H_1^{3/2} - H_2^{3/2}\right)$

Indian Standard Stilling Basins
1) JHC coincides TWC - Stilling Basin With Horizontal Apron.
② $F_1 < 4.5$ - Type I IS: Stilling Basin
$F_1 > 4.5$ - Type II " " "
2) TWC above JHC for all discharges - IS: Type III
. TWC above JHC Q large, TWC below JHC when Q small - IS: Type IV.

3) $L = L' - 2(N K_p - K_a) H_e$
L - effective length; L' - net length; N - no of piers; K_p, K_a - constants; H_e - Head.