3. DESIGN & CONSTRUCTION OF GRAVITY DAMS

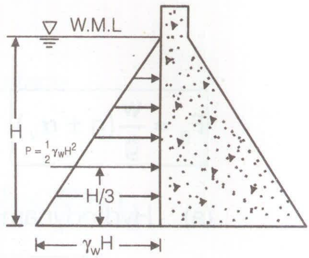
FORCES ACTING ON GRAVITY DAM

(i) Water Pressure

$$P = \frac{1}{2}\gamma_w H^2$$

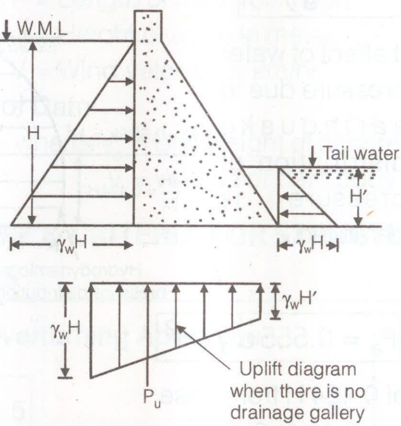
Acting at $\frac{H}{3}$ from base

where γ_w = Unit weight of water.

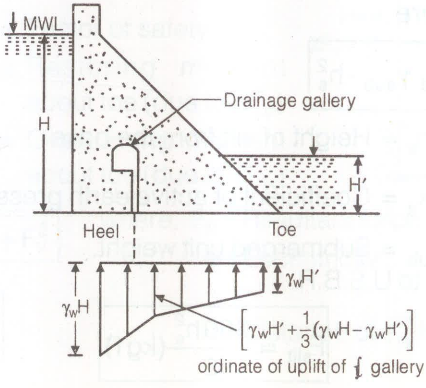


(ii) Uplift Pressure

(a) When Drainage Gallery is not Provided



(b) When Drainage Gallery is Provided



(iii) Earthquake Force

$$\boxed{\alpha_H = 0.1g \text{ to } 0.2g}$$ where, α_H = Horizontal acceleration

$$\boxed{\alpha_V = 0.75\alpha_H}$$ α_v = Vertical acceleration

$$\boxed{\alpha = \beta I \alpha_0}$$ α = Seismic coefficient

β = Soil foundation system factor

I = Importance factor

α_0 = Basic seismic coefficient which depends upon seismic zone of country.

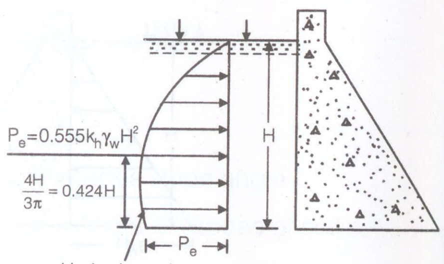
$$\boxed{F_g = \frac{w}{g}(g \pm \alpha_v)}$$ where, F_g = Body force

g = Acceleration due to gravity, +ve for upward & –ve for downward.

(a) Hydrodynamic force

(i) $$\boxed{F_H = \left(\frac{w}{g}\right)\alpha_H}$$ F_H = Horizontal Inertia force.

(ii) It effect of water pressure due to earthquake distribution of pressure is parabolic.



Hydrodynamic pressure distribution

$$\boxed{P_e = 0.555\,\alpha\,\gamma_w H^2}$$

at 0.424 H from base.

α = 0.1g to 0.2g

(iv) Silt Pressure

$$\boxed{F_{silt} = \frac{1}{2}k_a\,\gamma_{sub}\cdot h_s^2}$$

where, h_s = Height of silt from the base.

k_a = Coefficient of active earth pressure = $\frac{1-\sin\phi}{1+\sin\phi}$

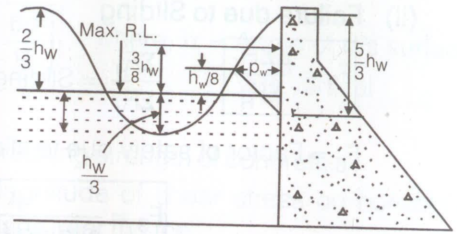
γ_{sub} = Submerged unit weight.

According to U.S.B.R

$$\boxed{F_{silt} = \frac{360h_s^2}{2}(\text{kg f})}$$

(v) Wave Pressure

$$\boxed{P_w = 2\cdot 4\gamma_w h_w}$$



Acts at $\frac{hw}{8}$ from still water level.

where, P_w = Resultant wave pressure.

$$\boxed{F_w = 2\gamma_w h_w^2}$$ acts at $\frac{3h}{8}$ from still water surface.

where F_w = Total wave force.

$$\boxed{h_w = 0.032\sqrt{VF} + 0.763 - 0.271(F)^{3/4}}$$ if F < 32 km.

$$\boxed{h_w = 0.032\sqrt{VF}}$$ when F > 32 km.

where, F = Length of reservoir in km

h_w = Height of wave in meter

V = Wind velocity in km/hr.

(vi) Self Weight of Dam

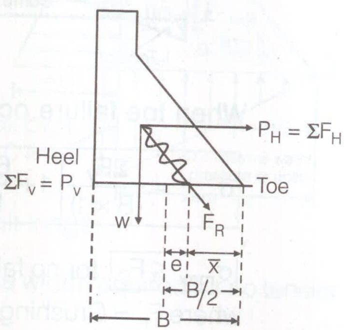
$$\boxed{W = \gamma_c V}$$ where, γ_c = Unit weight of concrete

V = Volume of dam body per unit length

MODES OF FAILURE & CRITERIA FOR STRUCTURAL STABILITY OF GRAVITY DAMS

(i) Failure by Overturning About Toe

$$\boxed{F_s = \frac{M_R}{M_o} > 1.5}$$



where, F_s = Factor of safety

M_R = Restoring moment about toe (due to ΣF_V)

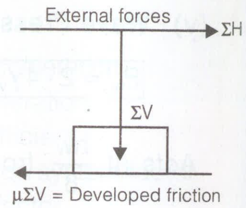
M_o = Overturning moment about toe (due to ΣF_H)

$$\boxed{F_R = \sqrt{F_H^2 + F_V^2}}$$ where, F_R = Resultant force

e = Eccentricity

$$\boxed{e = \frac{B}{2} - \bar{x}}$$ $\bar{x}$ = Distance of $\vec{F_R}$ from toe.

(ii) Failure due to Sliding



$$F_S = \frac{\mu \Sigma F_V}{\Sigma F_H}$$ $$\frac{\Sigma F_H}{\Sigma F_V} = \text{Sliding factor}$$

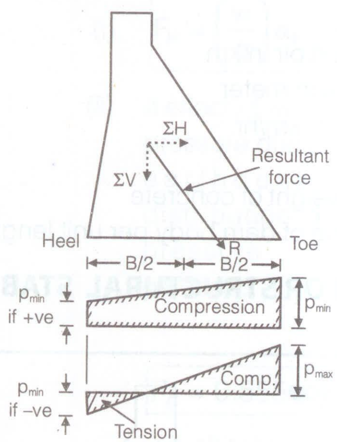
F_S = Factor of safety due to sliding.

$$F_S = \frac{\mu}{\text{sliding factor}} > 1$$

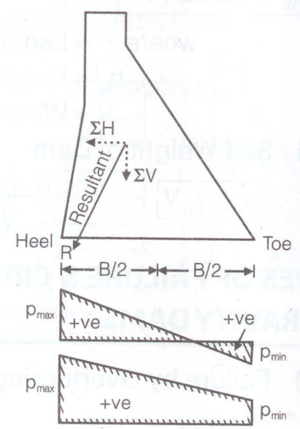
Case : If shear strength is also accounted then factor of safety is called shear frictional factor (S.F.F)

$$S\cdot F\cdot F = \frac{\mu \Sigma F_V + q(B \times 1)}{\Sigma F_H}$$ $$S\cdot F\cdot F > 3$$ where, B = Width in meter.

(iii) Failure due to Compression or Crushing



When toe failure occurs.



When heel failure occurs.

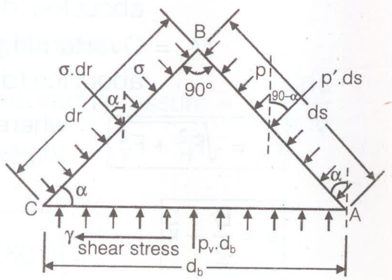
$$\sigma_{max} = \frac{\Sigma F_V}{(B \times 1)}\left[1 + \frac{6e}{B}\right]$$ $$\sigma_{min} = \frac{\Sigma F_V}{(B \times 1)}\left[1 - \frac{6e}{B}\right]$$

$\sigma_{max} \le F_C$ for no failure

where F_C = Crushing strength.

Case : (I) When shear stress also acts on horizontal plane.

$$\sigma_1 = \sigma_v \sec^2 \alpha - \sigma_2 \tan^2 \alpha$$



$$\sigma_v = \sigma_{max} = \frac{\Sigma F_V}{(B \times 1)}\left[1 + \frac{6e}{B}\right]$$ where, α = Angle of d/s surface with vertical

For no Failure,

$$\sigma_1 \le F_C$$ where, F_c = Crushing strength of concrete.

τ = Magnitude of shear stress on horizontal plane near the toe.

$$\tau = (\sigma_v - \sigma_2)\tan \alpha$$

Case (2): When earthquake force considered then

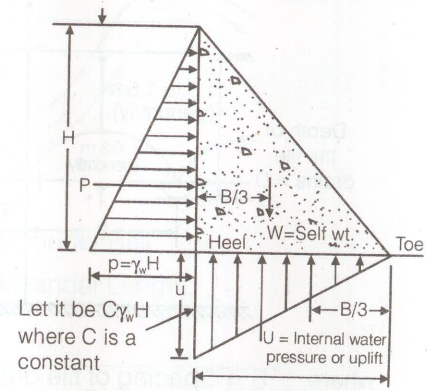
$$\sigma_1 = \sigma_v \sec^2 \alpha - (\sigma_2 - p_e)\tan^2 \alpha$$

$$\tau = [\sigma_v - (\sigma_2 - p_e)]\tan \alpha$$ where, P_e = Earthquake Pressure.

(iv) Failure due to Tension

$$\sigma_{min} \ge 0 \rightarrow e \le \frac{B}{\sigma}$$

ELEMENTARY PROFILE OF GRAVITY DAM



$$\Sigma F_H = P_H = \frac{1}{2}\gamma_w H^2$$

$$P_u = \frac{1}{2} C \gamma_w H \cdot B$$

where P_u = Uplift pressure i.e., Force of buoyancy.

C = Uplift pressure coefficient.

$$w = \frac{1}{2} G \gamma_w \cdot BH$$

where w = Weight of dam body for unit length

$$B = \frac{H}{\sqrt{G - C}}$$ where, B = Minimum base width required for no tension criteria.

$$B' = \frac{H}{\mu(G - C)}$$ B′ = Minimum base width for no sliding criteria.

G = Sp. gravity of concrete, i.e., that of the material of the dam

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