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Section : "B"

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Question no:01

A prototype gate valve which will control the flow in a pipe system conveying Parrafin is to studied in model. list the significant variables on which the pressure drop accross valve would depend. Perform dimensional analysis to obtain the relevant non-dimensional groups.

A 1/5 Scale model is built to determine the pressure drop accross the valve with water as the working fluid.

Part (a): - - - - - - - - - - - -

Part (b): - - - - - - - - - - - -

Part (c): - - - - - - - - - - - -

(The density and viscousity of paraffin are $800 kg \cdot m^{-3}$ and $0.002 kg m^{-1} s^{-1}$ respectively. Take the kinematic viscousity of water as $1.0 * 10^{-6} m^2 s^{-1}$).

Solution: The pressure drop Dp is expected to depend upon the gate opening h, the overall depth d, the velocity v, density ρ and viscousity μ.

⇒ list the relevant variables:

$\Delta p, h, d, V, \rho, \mu$

⇒ writing down dimensions:

$\Delta p \longrightarrow ML^{-1}T^{-2}$

$h \longrightarrow L$

$d \longrightarrow L$

$V \longrightarrow LT^{-1}$

$\rho \longrightarrow ML^{-3}$

$\mu \longrightarrow ML^{-1}T^{-1}$

Number of variables: $n=6$

Number of independent dimensions: $m=3$ (M, L and T)

Number of non-dimensional groups: $n-m=3$

Choose $m(=3)$ Scaling variables:

geometric (d); kinematic/time-dependant (V); dynamic mass dependent (ρ).

Form dimensionless groups by non-dimensionalising the remaining variables: $\Delta p, h$ and μ.

$\pi_1 = \Delta p d^a V^b \rho^c$

$M^0 L^0 T^0 = (ML^{-1}T^{-2})(L)^a (LT^{-1})^b (ML^{-3})^c$

$= M^{1+c} L^{-1+a+b-3c} T^{-2-b}$

$M = 0 = 1+c \Rightarrow c = -1$

$T = 0 = -2-b \Rightarrow b = -2$

$L = 0 = -1+a+b-3c \Rightarrow a = 1+3c-b = 0$

$\Rightarrow \Pi_1 = \Delta P V^{-2} \rho^{-1} = \dfrac{\Delta P}{\rho V^2}$

$\Pi_2 = \dfrac{h}{d}$ (by inspection, since h is a length)

$\Pi_3 = \mu d^a v^b \rho^c$ (Probably obvious by now, but here goes anyway)

$M^0 L^0 T^0 = (ML^{-1}T^{-1})(L)^a (LT^{-1})^b (ML^{-3})^c$

$= M^{1+c} L^{-1+a+b-3c} T^{-1-b}$

$M \Rightarrow 0 = 1+c \qquad \Rightarrow \boxed{c=-1}$

$T \Rightarrow 0 = -1-b+0 \qquad \Rightarrow \boxed{b=-1}$

$L \Rightarrow 0 = -1+a+b-3c \qquad \Rightarrow a = 1+3c-b \boxed{=-1}$

$\Rightarrow \Pi_3 = \mu d^{-1} V^{-1} \rho^{-1} = \dfrac{\mu}{\rho V d}$

Recognization of Reynolds number suggests that we replace Π_3 by

$$\Pi_3' = (\Pi_3)^{-1} = \frac{\rho V d}{\mu}$$

$\Rightarrow$ Hence dimensional analysis yields:

$$\Pi_1 = f(\Pi_2, \Pi'_3)$$

$$\text{i-e} \quad \frac{\Delta P}{\rho U^2} = f\left(\frac{h}{d}, \frac{\rho U d}{\mu}\right)$$

(a) Dynamic similarity requires that all non-dimensional group be the same in model and prototype; ie

$$\Pi_1 = \left(\frac{\Delta P}{\rho U^2}\right)_p = \left(\frac{\Delta P}{\rho U^2}\right)_m$$

$\Pi_2 = (h/d)_p = \left(\dfrac{h}{d}\right)_m \Rightarrow$ (automatic of similar shape)

$$\pi_3' = \left(\frac{\rho v d}{\mu}\right)_p = \left(\frac{\rho v d}{\mu}\right)_m$$

⇒ From the last, we have a velocity ratio

$$\frac{U_P}{U_m} = \frac{(\mu/\rho)_p}{(\mu/\rho)_m} \frac{d_m}{d_p} = \frac{0.002/800}{1.0 * 10^{-6}} * \frac{1}{5} = 0.5$$

Hence $\boxed{U_m = \frac{U_P}{0.5} = \frac{3.0}{0.5} = 6.0\,ms^{-1}}$

(b) The ratio of quantities of flow is

$$\frac{Q_P}{Q_m} = \frac{(\text{velocity} * \text{area})_p}{(\text{velocity} * \text{area})_m} = \frac{U_P}{U_m}\left(\frac{d_P}{d_m}\right)^2 = 0.5 * 5^2 = \boxed{12.5}$$

(c) Finally for the pressure drop,

$$\pi_1 = \left(\frac{\Delta P}{\rho U^2}\right)_p = \left(\frac{\Delta P}{\rho U^2}\right)_m \Rightarrow \frac{(\Delta P)_P}{(\Delta P)_m} = \frac{\rho_P}{\rho_m}\left(\frac{U_P}{U_m}\right)^2 = \frac{800}{1000} * 0.5^2$$

$\boxed{\text{Hence} \quad \Delta P_p = 0.2 * \Delta P_m = 0.2 * 60 = 12.0\,KPa}$

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Question no: 02

Design a practicle Profile of gravity dam with the following data:

1. Max. depth of water in reservoir is (78m = H)
2. Specific gravity of dam material is (G = 2.5)
3. Allowable compressive strength for the dam masonary is (786 T/m²)
4. Height of wave is Hw = 1.5m =
5. G and Hw is your own choice but differ from others.

Given Data:

* $H = 78m$
* $G = 2.5$
* $\delta_{all} = 786\ T/m^2$
* Height of wave = $H_w = 1.5m$
* $\mu =$
* No uplift Pressure = $C_u = 0$

Given Requirement:

Design of practicle profile of gravity dam.

Solution:

$$H\ \text{limiting} = \frac{\delta_{all}}{\gamma_w(G - C_u + 1)} = \frac{786 * 1000}{(1000)(2.5 - 0 + 1)}$$

$$\boxed{H\ \text{limiting} = 224.57m} > \boxed{H = 78m}$$

⇒ Hence the dam is low gravity dam.

② Top width (a):

$$\text{Free board} = 1.5 * H_w$$

$$\text{Free board} = 1.5 * 1.5$$

$$\boxed{\text{Free board} = 2.25m}$$

$$\text{Height of Dam} = H_D = H_w + F.B$$

$$H_D = 78 + 2.25$$

$$\boxed{H_D = 80.25m}$$

$$a = 14\% \text{ of } H_D$$

$$a = \frac{14}{100} * 80.25$$

$$\boxed{a = 11.235m}$$

③ Base width "b" (without offset)

① For no sliding criteria:

$$b' = \frac{H_w}{\mu \cdot G} = \frac{78}{0.7 * 2.5}$$

$$\boxed{b' = 44.571 \approx 45m}$$

(ii) For no tension Criteria:

$$b' = \frac{H}{\sqrt{G}} = \frac{78}{\sqrt{2.5}}$$

$$\boxed{b' = 49.33m}$$

Using $\boxed{b' = 49.33m}$

(4) Depth of Verticle portion on U/s side:

$$h' = 2a\sqrt{G - Cu}$$

$$h' = 2*(11.235)\sqrt{2.5 - 0}$$

$$\boxed{h' = 35.53 \approx 36m}$$

(5) Upstream offset $= \frac{a}{16}$

$$= \frac{11.235}{16}$$

$$\boxed{= 0.70m}$$

(6) Depth below the water level to the end of inclined Portion in U/s $= 3.14 * a\sqrt{G}$

$$= 3.14 * 11.235\sqrt{2.5}$$

$$\boxed{= 55.78m}$$

(7) Total width of the base of dam

$$b = b' + \frac{a}{16}$$

$$b = (49.33) + (0.70)$$

$$\boxed{b = 50.03m}$$

(8) $\tan \theta = \frac{b'}{H} = \frac{49.33}{78}$

$$\theta = \tan^{-1}\left(\frac{49.33}{78}\right)$$

$$\boxed{\theta = 32.31^\circ}$$

(a) Depth of verticle portion on D/s (from WL on U/s side)

$$\tan\theta = \frac{a}{d'} = \frac{11.235}{d'}$$

$$\frac{49.33}{78} = \frac{11.235}{d'} \Rightarrow (d')(0.6324) = 11.235$$

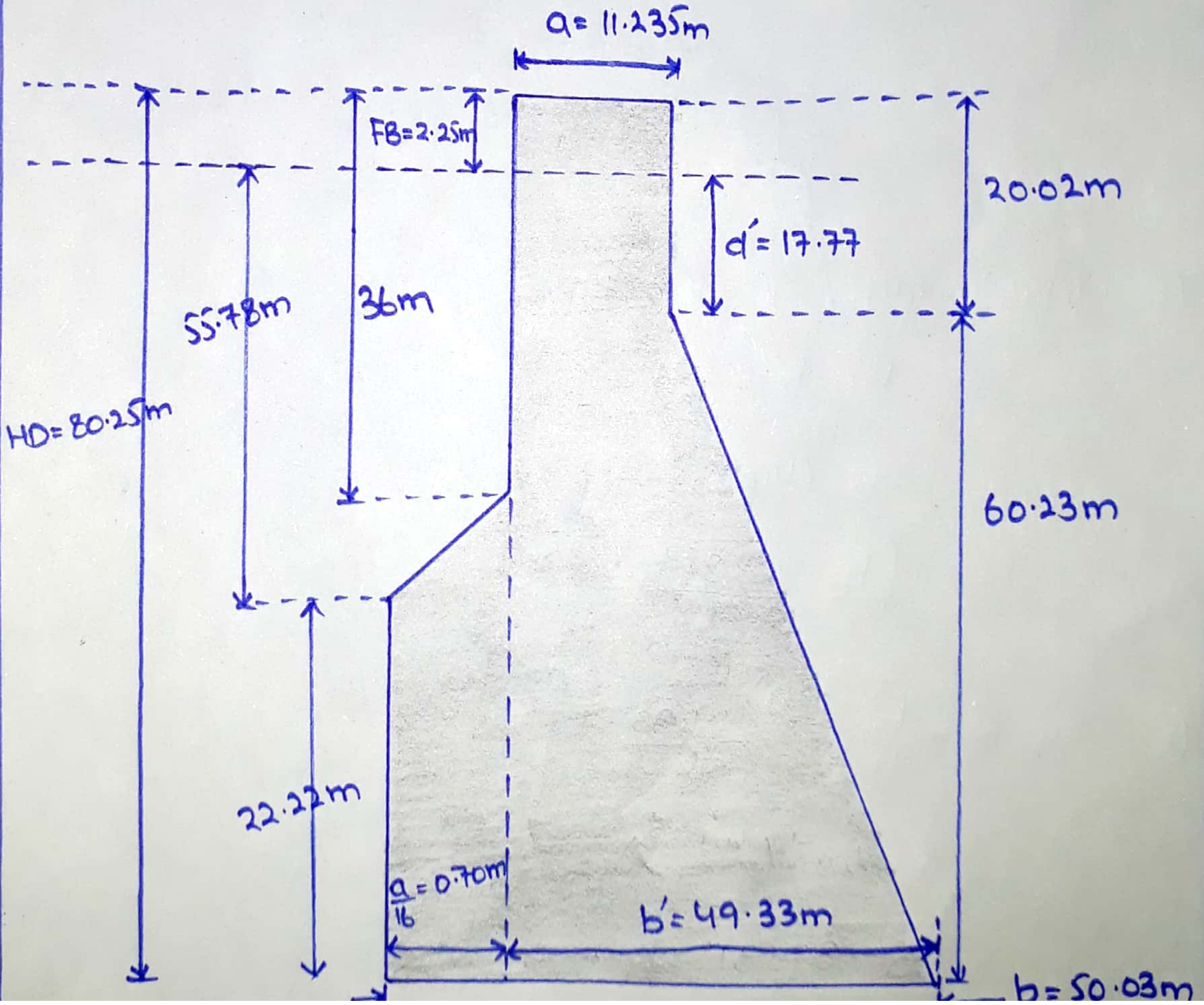
$$d' = \frac{0.6324}{11.235}$$

$$\boxed{d' = 17.77\,m}$$

Depth of verticle portion:

$$d = d' + F.B = 17.77 + 2.25$$

$$\boxed{d = 20.02\,m}$$



Question no: 03

⤇ Using any hydraulic model and explain the concept of Dimensional analysis and Similtitude. Each student Should have Saperate modal analysis.

Ans: **Dimensional Analysis:** It is a mathematical technique making use of study of dimensions. It deals with the dimensions of Physical quantities involved in the phenomenon.

⇒ In dimensional analysis, one first predicts the Physical parameter that will influence the flow and then by grouping these parameters in dimensionless combinations a better understanding of flow is made Possible.

Similtitude: It is Similarity between model and prototype in every respect which mean model and Proto-type have Similar properties or model and Prototype are completely Similar.

Model: Spillways

⇒ The discharge per unit crest length of rectangular weir could be expressed as:

$$q = g^{1/2} H^{3/2} \phi \left[\frac{\rho g^{1/2} H^{3/2}}{\mu}, \frac{\rho g H^2}{\sigma}, \frac{P}{H} \right]$$

⇒ The governing equation for spillways and weirs is identical. Flood discharges over spillways will result in very high Reynolds numbers, and since surface tension effects are also negligible the only factor effecting the discharge coefficient is P/H. In modelling dam spillways, therefore if the ratio of P/H in the model and prototype are identical and the crest geometry is correctly scaled.

$$\frac{q}{g^{1/2} H^{3/2}} = \text{Constant}$$

Therefore, spillways model are operated according to the Froude law and are made sufficiently large that viscous and surface tension effects are negligible.

$$\left(\frac{V}{\sqrt{gt}}\right)_m = \left(\frac{V}{\sqrt{gt}}\right)_P$$

$$Q = Vl^2$$

$$\Rightarrow \left(\frac{Q}{l^{5/2}}\right)_m = \left(\frac{Q}{l^{5/2}}\right)_P$$

where

$$Q_m = 1000\left(\frac{1}{25}\right)^{5/2} = 0.32 m^3/s$$

From Equation (ii)

$$U_p = V_m\sqrt{\frac{l_p}{l_m}} = V_m\sqrt{25}$$

$$\Rightarrow V_p = 1.5 * 5 \boxed{= 7.5 m/s}$$

Question no: 04

What will be the effect of Sediment Particle diameter, Particle density, Particle concentration, Particle Shape, viscousity of water, turbulence of water flowing in reservoir on fall velocity? Explain in detail.

Ans: The following will be the effect of Sediment on the fall velocity:

(i) Particle Diameter: The particle diameter or size of particle have a significant effect on the fall velocity.

⇒ The larger particles will settle more quickly as compared to the particles having small size. It is according to the principles of Stokes law.

⇒ Hence particle fall or sattling is directly proportional to fall velocity.

(ii) Particle Density: Those particles which have high density will settle down more faster then those particles of low density, with same sizes, will settle slower.

⇒ when pulp density is below 2% solids, free settling behavior occors and settling is much faster then when pulp density is high (Hindered sittling). These terms also apply the centrifugal classification in hydrocyclones and centrifuges.

(iii) Particle Shape: Particle Shape has a major effect on Settling - a sphere settles much faster than a Cube of the Same relative Size and S.G. Some particles are Shaped like flakes - these settles much slower then a Particle of Same relative Size and Specific Gravity (S.G).

* The greater the Settling of a particle, the greater will be the fall velocity.

(iv) Viscousity of water: The water having high viscousity will offer more resistance to the particles to settle down and hence there will be less particles settled in more viscous water and hence the fall velocity will be low due to high viscousity of water.

(v) Particle Concentration: when a Suspended concentration of Sediment increases, the settling velocity of each Particle decreases due to the modification of the flow induced by previous particles.

⇒ Hence Particle concentration have direct relation with fall velocity.

(vi) Turbulance of water: At high turbulence intensity the relative Settling velocities increases with the increasing relative tubulance intensity regardless of the Stroke number. At the ~~[illegible]~~ intermediate tubulance intensity, it seems that the Settling bifurcate.

The particles at the large Stokes number tend to be slowed, whereas the settling velocity of particles is increased at a small Stokes number.