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Q#1

→ Solution

The pressure drop Δp is expected to depend upon the gate opening h, velocity V, density ρ and viscosity μ.

→ Listing the relevant variables.

Δp, h, d, V, ρ, μ

→ Write down the dimensions

$\Delta p \quad ML^{-1}T^{-2}$
$h \quad L$
$d \quad L$
$V \quad LT^{-1}$
$\rho \quad ML^{-3}$
$\mu \quad ML^{-1}T^{-1}$

No. of variables $n = 6$
No. of independent dimension $m = 3$ (M, L, T)
No. of non-dimensional groups $n - m = 3$.

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Choose m (3) scaling variables:-

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

→ Form dimensionless groups by non-dimensionalising the remaining variables: Δp, 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 : $0 = 1+c$ → $c = -1$

T : $0 = -2-b$ → $b = -2$

L : $0 = -1+a+b-3c$ $a = 1+3c-b = 0$.

$\Rightarrow \Pi_1 = \Delta p V^{-2} \rho^{-1} = \Delta p / \rho V^2$

$\Pi_2 = h/d$ (by inspection, h is length)

$\Pi_3 = \mu d^a V^b \rho^c$

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

$M: \quad 0 = 1 + c \quad \rightarrow \quad c = -1$
$T: \quad 0 = -1 - b + 0 \quad \rightarrow \quad b = -1$
$L: \quad 0 = -1 + a + b - 3c \rightarrow a = 1 + 3c - b = -1$

$$\rightarrow \quad \Pi_3 = \mu d^{-1} V^{-1} \rho^{-1} = \frac{\mu}{\rho V d}$$

Recognition of the reynolds number suggests that we replace Π_3 by

$$\bar{\Pi}_3 = (\Pi_3)^{-1} = \frac{\rho V d}{\mu}$$

Hence, dimensional analysis yields

$$\bar{\Pi}_3 = f(\Pi_2, \bar{\Pi}_3)$$

i.e $\dfrac{\Delta p}{\rho V^2} = f\left(\dfrac{h}{d}, \dfrac{\rho V d}{\mu}\right)$

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Dynamic similarity requires that all non-dimensional groups be the same in model and prototype i.e

$$\Pi_1 = \left[\frac{\Delta p}{\rho V^2}\right]_p = \left[\frac{\Delta p}{\rho V^3}\right]_m$$

$$\Pi_2 = \left[\frac{h}{d}\right]_p = \left[\frac{h}{d}\right]_m$$

(automatic and similar shape i.e "geometric similarity").

$$\Pi'_3 = \left[\frac{\rho V d}{\mu}\right]_p = \left[\frac{\rho V d}{\mu}\right]$$

From the last we have a velocity ratio

$$\frac{V_p}{V_m} = \frac{(\mu/\rho)_p}{(\mu/\rho)_m} \frac{d_m}{d_p} = \frac{0.002/800}{1.0\times 10^{-5}} \times \frac{1}{5}$$

$$= 0.5$$

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Hence

$$V_m = \frac{V_p}{0.5} = \frac{3.0}{0.5} = 6.0\ ms^{-1}$$

The ratio of the quantities of flow is

$$\frac{Q_p}{Q_m} = \frac{(\text{Velocity} \times \text{area})_p}{(\text{Velocity} \times \text{area})_m} = \frac{V_p}{V_m}\left[\frac{d_p}{d_m}\right]^2 = 0.5 \times 5^2$$

$$= 12.5$$

Finally, for the pressure drop

$$\Pi_1 = \left[\frac{\Delta p}{\rho V^2}\right]_p = \left[\frac{\Delta p}{\rho V^2}\right]_m$$

$$\Rightarrow \frac{(\Delta p)_p}{(\Delta p)_m} = \frac{\rho_p}{\rho_m}\left[\frac{V_p}{V_m}\right]^2 = \frac{800}{1000} \times 0.5^2 = 0.2$$

Hence

$$\Delta p_p = 0.2 \times \Delta p_m = 0.2 \times 60$$

$$12.0\ kPa$$ - Answer.

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Q# 2

→ Given data:

Max depth = 78 m
Specific Gravity = 2.4
G_{av} = 785 T/m^2
Height of wave = 1.2 m

→ Solution

$$\cancel{H}\ \text{limiting} = \frac{G_{av}}{\gamma_w (G - \omega + 1)}$$

$$= \frac{782 \times 1000}{(1000 (2.4 + 1))}$$

H limiting = 230

→ Top width "a"

Free board = 1.5 × h wave
= 1.5 × 1.2
= 1.8

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⇒ Height of Dam = Hw + F.B

$= 78 + 1.8$

$H.D = 79.8$

$a = 14\%$ of HD

$= 0.14 \times 79.8$

→ Base width

$$b' = \frac{Hw}{\mu G} = \frac{78}{0.7 \times 2.4}$$

$= 46.42\,m$

$= 47\ m$

→ For no tension criteria

$$b' = \frac{Hw}{\sqrt{G}} = \frac{78}{\sqrt{2.4}}$$

$= 50.34$

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→ Depth of vertical portion on V/S

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

$= 2 \times 11.17 \sqrt{2.4-0}$

$= 34.60$

$= 35$ m

Upstream off $= \frac{a}{16} = \frac{11.17}{16}$

$= 0.6$

→ Depth below the water level to the end of inclined portion V/S

$= 3.14\, a \sqrt{G}$

$= 3.14 \times 11.17 \sqrt{2.4}$

$= 54.33$

Total width of the base of Dam

$b = b' + \frac{a}{16} = 50.34 + \frac{11.17}{16}$

$= 51.03$

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$$\tan\theta = \frac{b'}{H} = \frac{50.34}{78}$$

$$\theta = \tan^{-1}(0.64)$$
$$= 44.80^\circ$$

→ Depth of vertical portion on D/S (from WL on U/S side).

$$\tan\theta = \frac{a}{d'} = \frac{11.17}{d}$$

$$d' = 17.30 \text{ m}$$

$$\frac{(839)\times d'}{1300} = 11.17$$

→ Depth of vertical portion

$$d = d' + F.B$$
$$= 17.30 + 1.8$$
$$= 19.1 \text{ — Ans}$$

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Q#3

→ Given

A certain spillway for a dam is 20 m wide. A 1:15 model is constructed to study the flow chracteristics through the spillway.

→ Solution

The width w_m of the model spillway is obtained from the length scale, λ_l so that

$$\frac{w_m}{w} = \lambda_l = \frac{1}{15}.$$

and

$$w_m = \frac{20\,m}{15} = 1.33\ m$$

Of course all other geometric features (including surface roughness) of the spillway must be scaled in accordance with the same length scale

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With neglect of surface tension and viscosity.

$$\frac{V_m}{\sqrt{g_m l_m}} = \frac{V}{\sqrt{g l}} \quad (\text{Eq } 1)$$

Eq 1 indicates that dynamic similarity will be achieved if the froude numbers are equal between model and prototype.

Thus

$$\frac{V_m}{\sqrt{g_m l_m}} = \frac{V}{\sqrt{g l}}$$

and for $g_m = g$

$$\frac{V_m}{V} = \sqrt{\frac{l_m}{l}}$$

Flow rate $= Q = VA$

$$\frac{Q_m}{Q} = \frac{V_m A_m}{VA} \sqrt{\frac{l_m}{l}} \left(\frac{l_m}{l}\right)^2$$

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For $\lambda_l = 1/15$ and $Q = 125\ m^3/s$

$$Q_m = (1/15)^{5/2}\ (125\ m^3/s) = 0.143\ m^3/s$$

The time scale can be obtained from the velocity scale, since it is distance divided by time.

$$\frac{V}{V_m} = \frac{l}{t}\frac{t_m}{l_m}$$

or

$$\frac{t_m}{t} = \frac{V}{V_m}\frac{l_m}{l} = \sqrt{\frac{l_m}{l}} = \sqrt{\lambda_l}$$

This result indicates that time intervals will be smaller than the corresponding intervals in the prototype if $\lambda_l < 1$. For $\lambda_l = 1/15$ and a prototype time interval of 24 hr

$$t_m = \sqrt{1/15}\ (24\ hr) = 6.20\ hr$$

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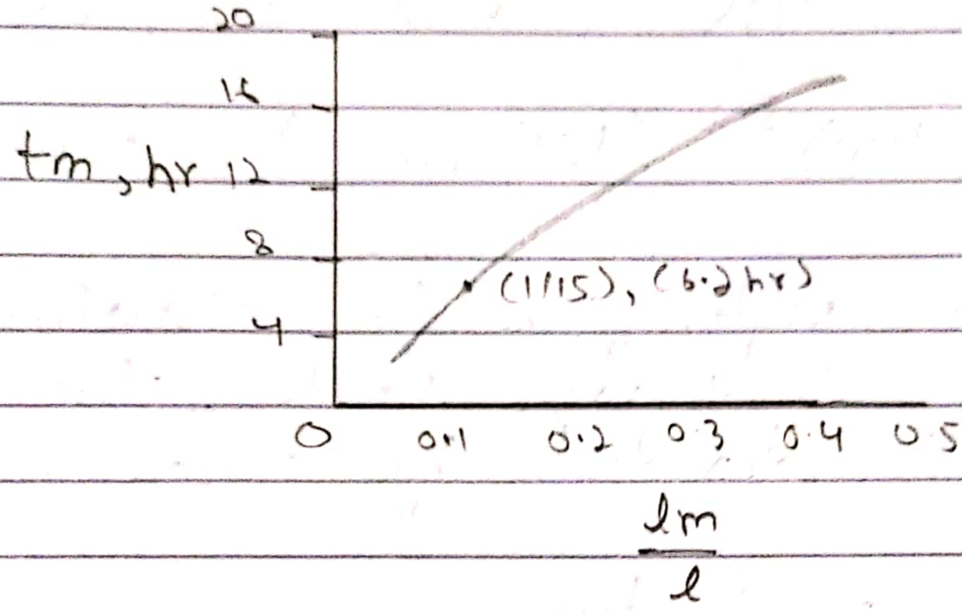

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Q # 4

→ Particle diameter :-

The diameter of the particle is directly propotional to the fall velocity because greater the size of the so it tends to move faster as compared to smaller particles thus there will be more gravitation force on particle of greater size so it will fall quickly due to its weight.

→ Particle density :-

~~Mix~~ Density of the particle is directly propotional to the rate of fall velocity since particle with high density tends to settle down early compared with particle of low density.

→ Particle shape :-

Particles having regular shapes tends to be effected more than irregular shapes since

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regular shape particles have even surfaces which offers very little or no friction while particles with irregular shape offers more friction. as the particles with smaller surface area are more likely to be effected due to thier less resistance.

→ Particle concentration :-

Concentration of particle size will considerably effect its fall velocity as the section having greater concentration will be settled down at the place thus causing more fall velocity comparing with section of low concentration.

→ Viscosity of water :-

From the experimental study we can see that parameter such as temprature and pressure changes the magnitude

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of viscosity so the section of water having more temprature and pressure will fall objectively more due to increase in the kinetic energy so fall velocity will be more.

→ Turbulence of water:-

It depends upon the different factors such as velocity. It will effect the fall velocity because of its zigzag motion thus the velocity varies at every point which is why it effect the fall velocity moreover increase in the k.e tends to effect the fall velocity compared with steady fluid.