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Question # 1

A prototype gate valve which will control the flow
.... non dimensional groups.
A 1/5 scale model is built to determine the pressure drop across the valve with water as the working fluid

a) For a particular opening when ...... for dynamic similarity?

(b) What is the ratio of the quantities .... and model?

(c) Find the pressure drop in the prototype if it is 60kPa in the model.

The desity and viscocity of paraffin are $800 kgm^{-3}$ and $0.002 kgm^{-1}s^{-1}$ respectively. Take kinem viscosity of water as $1.0 \times 10^{-6} m^2 s^{-1}$)

The presure drop ΔP is expected to depend upon the gate opening h, depth d, Velocity V, density ρ and viscosity μ.

Sol:-

The pressure drop ΔP is expected to depend upon the gate opening h, the overall depth d, the velocity V, density ρ and viscocity μ.

List the relevant variables:

$\Delta P, h, d, V, \rho, \mu$.

Write down dimensions:

ΔP	$ML^{-1}T^{-2}$
h	L
d	L
V	LT^{-1}
ρ	ML^{-3}
μ	$ML^{-1}T^{-1}$

Number of variable - $n = 6$

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); kinemetic / time-dependent (V) dynamic / mass-dependent (ρ).

From dimensionless groups by non-dimension lising 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: $0 = 1 + c \Rightarrow c = -1$
T: $0 = -2 - b \Rightarrow b = -2$
L: $0 = -1 + a + b - 3c \Rightarrow a = 1 + 3c - b = 0$

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

$\Pi_2 = \frac{h}{d}$ (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: $0 = 1 + c \Rightarrow c = -1$
T: $0 = -1 - b + 0 \Rightarrow b = -1$
L: $0 = -1 + a + b - 3c \Rightarrow a = 1 + 3c - b = -1$

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

Recognition of the Reynolds number suggests that we replace Π_3 by

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

Hence dimensional analysis yield.

$$\Pi_1 = f(\Pi_2, \Pi_3')$$

i.e

$$\frac{\Delta P}{\rho V^2} = f\left(\frac{h}{d}, \frac{\rho V d}{\mu}\right)$$

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

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

$$\Pi_2 = \left(\frac{h}{d}\right)_p = \left(\frac{h}{d}\right)_m$$

$$\Pi_3' = \left(\frac{\rho V d}{\mu}\right) = \left(\frac{\rho V d}{\mu}\right)_m$$

From the last we have velocity ratio

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

Hence

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

(b) The ratio of the quantities of flow is

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

$$= 0.5 \times 5^2 = 12.5$$

(c) 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,

$$\Delta P_p = 0.2 \times \Delta P_m = 0.2 \times 6$$

$= 12.0$ kPa. Ans

Question # 2

Design a practical profile of gravity dam with the following data.

Sol:-

Given data:-

- Maximum depth of water in the Reservior is 75 m.
- Specific Gravity of Dam = G = 2.42
- Allowable compressive stress for the dam masonary = 751 T/m^2
- Height of wave = 1.21 m

$\mu = 0.7$

No uplift pressure . $C_u = 0$

Sol:-

① $H_{limiting} = \dfrac{6all}{\gamma_w (G - C_u + 1)}$

$= \dfrac{751 \times 1000}{1000(2.42 - 0 + 1)} = 219.60\,m$

$H_{limiting} = 219.60\,m > H_w = 75\,m$

So it is low Gravity Dam.

② Top width "d"

Free board = 1.5 h_{curve}

Free board = 1.5 x 1.2

[F.B = 1.81m]

Height of Dam = H_0

$H_0 = H_w + F.B$

$H_0 = 75 + 1.81 = [76.81m]$

$d = 14\%$ of H_0

$d = 0.14 \times 76.81$

[$d = 10.753$ m]

③ Base width 'b' (without offset)

For no sliding Criteria

$b' = H_w / \mu G$

$= 75 / 0.7 \times 2.42$

$b' = 44.27$

[$b' \cong 45$m]

For No tension:-

$$b' = \frac{H_w}{\sqrt{G}} = \frac{75}{\sqrt{2.42}}$$

$[b' = 49m]$

[use $b' = 49m$]

(4) Depth of vertical porition on u/s side.

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

$$h' = 2(10.753)\sqrt{242 - 0}$$

$$h' = 33.45m \cong 34m$$

(5) Upstream offset.

$$a/16 = \frac{10.75}{16} = 0.67\ m$$

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

$$= 3.14 \times 10.75\sqrt{2.42}$$

$$= [52.51m]$$

⑦ Total width of the Base of Dam

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

$b = 49 + 0.67$

$b = 49.67 m$

⑧ $\tan\theta = b'/H$

$= 49/75$

$\theta = \tan^{-1}(49/75) = 33.15^\circ$

⑨ Depth of vertical portion on D/S

$\tan\theta = a/d' = \frac{10.75}{d'}$

$\frac{49}{75} d' = 10.75$

$d' = \frac{10.75 \times 75}{49} = [16.45 m]$

depth of vertical portion

$d = d' + F.B = 16.45 + 1.81$

$= 18.26 m$

Question #13

Using any hydraulic model. . . - - ?

Ans) Dimensional Analysis is a mathemathical technique making use of study of dimensions.

It deals with the dimensions of physical quantities.

In dimensional analysis one first predicts the physical parameters that will influence the flow and then by grouping these parameters in dimensionless combination a better understanding of the flow phenomenon is made possible.

This mathemathical technique is used. in research work for design and for conducting model tests

Types of Dimensions :-

1. Fundamental Dimensions.
2. Secondary Dimensions.

Fundamental Dimensions:-

These are basic quantities. For example

- Time, T
- Distance, L
- Mass, M

Time, T
Distance, L
Force, F

Force = Mass x Acceleration = MLT^{-2}

Secondary Dimensions:-

These are those quantities which posses more then the fundamental dimensions.

For example:-

- Velocity is denoted by distance per unit time L/T.
- Acceleration is denoted by distance L/T^2
- Density is denoted by mass per unit volume M/L^3

Since velocity, density and acceleration involve more than one fundamental quantities so these are called derive quantities.

Methodology of Dimensional Analysis :-

The basic principle is dimensional Homogeneity, which means the dimensions of each terms in an equation on both sides are equal.

So such an equation in which dimensions of each term in both sides of equation are same, is known as Dimensionally Homogenous Equation. Such equation are independent of system of units For example:

Let Consider the equation $V = (2gH)^{1/2}$

- Dimensions of $LHS = V = L/T = LT^{-1}$
- Dimensions of $RHS = (2gH)^{1/2} = (L/T^2 \times L)^{1/2}$
- Dimension of L.H.S = Dimension of R.H.S

So the equation $V = (2gH)^{1/2}$ is dimensionally Homogenous equation.

Characteristics		Units SI	Dimension (MLT)	Dimension (FLT)
Geometry	Length	m	L	
	Area	m^2	L^2	
	Volume	m^3	L^3	
Kinematic	Time	s	T	
	Velocity	m/s	L/T	
	Acceleration	m/s^2	L/T^2	
	Discharge	m^3/s	L^3/T	
Dynamic				
	Mass	kg	M	$FL^{-1}T^2$
	Force	N ($kg\text{-}m/s^{-2}$)	MLT^{-2}	F
	Pressure	Pa (N/m^2)	$ML^{-1}T^{-2}$	FL^{-2}
	Energy	J (N-m)	ML^2T^{-2}	FL
	Power	Watt (N-m/s)	ML^2T^{-3}	FLT^{-1}

Methods of Dimensional Analysis :-

If the number of variables involved in a physical phenomen are known then the relation among the variables can be determined by the following two methods.

1. Rayleigh's Method
2. Buckingham's π Theorm

Rayleigh's Method :-

It is used to determining expression for a variable which depend upon the maximum three to four variables.

If the no of independent Variable are more than 4 then it is very difficult to obtain expression for dependent variables

Let X is dependent variable which depend upon X_1, X_2, and X_3

$$X = f(X_1, X_2, X_3)$$

$$X = k\, X_1^a, X_2^b, X_3^c$$

Whr k is non dimensional Constant.

The diameter of a sphere particle has same specific gravity and the terminal uniform setling Velocity as the given particle in the same sedimentation.

Particle density:-

Particle density effect the settling fall vellocity As air density increases with decreasing altitude ab about 1% per 80 meter (260 ft) for every 160 meter of terminal speed decrease 1%.

Viscocity of water:-

Fluid Velocity through porous media is approximated as inversly proportional to the kinematic Viscosity. A decrease in viscosity therefore increases velocity of a Compound through porous media.

Turbulance of Water:-

Turbulance of water effect the fall velocity of water in reservior. because the non-linerity & zigzag path effect the flow of water & cause the variation in the flow.