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Subject Hydraulic Engg (2 credit hour)

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FINAL TERM PAPER

Q1) A prototype gate valve which will control - - - - - - - - - -

Solution:-

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 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 dependent (V); dynamic / mass-dependent (ρ)

Form dimensionless groups by non dimensionalising the remaining variables: Δp, h and μ

$$\Pi_1 = \Delta p\, d^a V^b \rho^c$$

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

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

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)

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

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

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

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

T : $0 = -1 - b + c \Rightarrow b = -1$

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

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

Hence, dimensional analysis yields

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

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

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

$$\Pi_3 = \left[\frac{\Delta p}{\rho V^2}\right]_p = \left[\frac{\Delta p}{\rho V^2}\right]_m$$

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

$$\Pi_3' = \left[\frac{\rho V d}{\mu}\right]_p = \left[\frac{\rho V d}{\mu}\right]_m$$

From the last, we have a velocity ratio

$$\frac{V_p}{V_m} = \frac{(\mu/\rho)_p}{(\mu/\rho)_m}\frac{d_m}{d_p} = \frac{0.002/800}{1.0\times10^{-6}}\times\frac{1}{5} = 0.5$$

Hence

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

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) 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

$$\Delta p_p = 0.2 \times \Delta p_m = 0.2 \times 60 = 12.0 \text{ kPa}$$

Q2 Design a practical profile of gravity dam with the following data:

1) Maximum Depth of water in reservoir $H = 74$ m
2) Specific gravity of Dam Material = $G = 2.9$
3) Allowable compressive stress of the dam masonary = $\sigma_{all} = 748\ T/m^2$
4) Height of wave = 1.5m

$\mu = 0.7$

No uplift pressure $C_u = 0$

Solution:-

1) $$H_{limiting} = \frac{\sigma_{all}}{\gamma_w (G - C_u + 1)} = \frac{748 \times 1000}{1000(2.9 - 0 + 1)}$$

$$H_{limiting} = 191.79 > H_w = 74m$$

so it is a low gravity dam

2) Top width "a"

Free board = $1.5\, h_{wave} = 1.5 \times 1.5$

$$F.B = 2.25m$$

height of Dam = $H_D = H_w + F.B = 74 + 2.25$

$$H_D = 76.25$$

$a = 14\%$ of H_D

$a = 0.14 \times 76.25$

$\boxed{a = 10.675}$

(3) Base width "b′" (without offset)

i) For No Sliding Criteria

$b' = \frac{H_w}{\mu G} = \frac{74}{0.7 \times 2.9}$

$\boxed{b' = 36.45}$

ii) For No Tension Criteria

$b' = \frac{H_w}{\sqrt{G}} = \frac{74}{\sqrt{2.9}}$

$\boxed{b' = 43.45}$

use $\boxed{b' \simeq 44}$

4) Depth of vertical portion on U/s side

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

2 $h' = 2 \times 10.67\sqrt{2.9 - 0}$

$\boxed{h' = 36.34m}$

5) Upstream off set $= \frac{a}{16}$

$$= \frac{10.67}{16}$$

$$= 0.66m$$

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

$$= 3.14 \times 10.67\sqrt{2.9}$$

$$= 57.05m$$

(7) Total width of the base of the dam

$$b = b' = \frac{a}{16} = 44 + 0.66$$

$$\boxed{b = 44.66}$$

8) $\tan Q = \frac{b'}{H} = \frac{44}{74}$

$$Q = \tan^{-1}\left(\frac{44}{74}\right)$$

$$Q = 30.73^\circ$$

9) Depth of vertical portion on D/s (from WL on U/s side)

$$\tan Q = \frac{a}{d'} = \frac{10.67}{d'}$$

$$\frac{44}{74} d' = 10.67$$

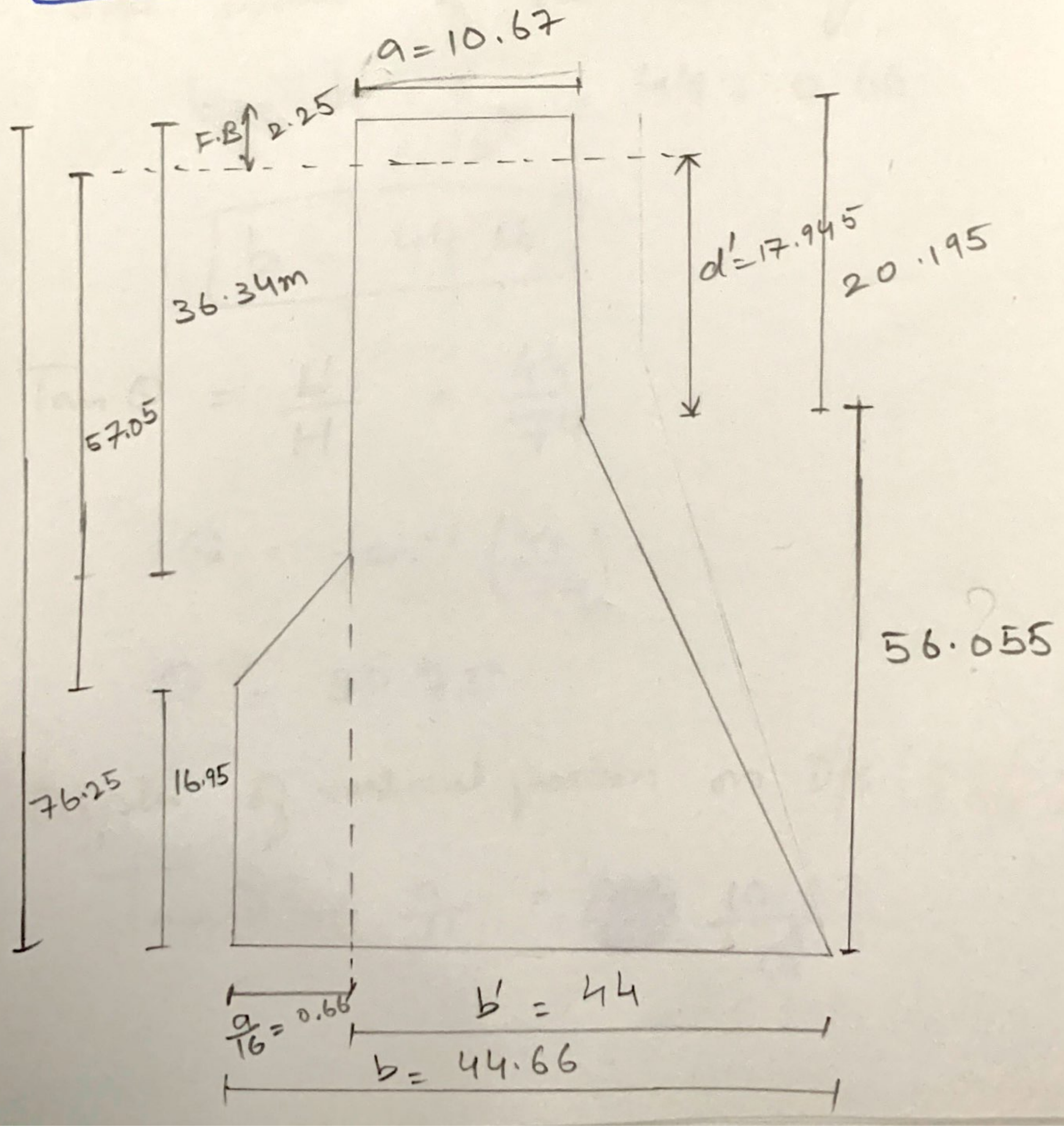
$$d' = \frac{10.67 \times 74}{44}$$

$$\boxed{d' = 17.945}$$

depth of vertical portion

$$d = d' + FB = 17.945 + 2.25$$

$$\boxed{d = 20.195}$$



Q3) Using any hydraulic model and explain the concept of Dimensional analysis and similitude. (9)

Ans Dimension analysis is a mathematical technique used to study the dimensions of a model.

Purpose:-

=> To obtain scaling laws so the performance of a prototype can be predicted from model Performance

=> To predict the relationship between parameter.

=> To generate non dimensional parameter that help in the design of experiment and in reporting of results.

Fundamental dimension:-

The basic quantities are

Example :- Distance, L, Mass, M

Secondary dimension:-

The quantities which posses more than one fundamental dimension

Velocity, L/T Acceleration, L/T

Density, M/L^3

Similitude:-

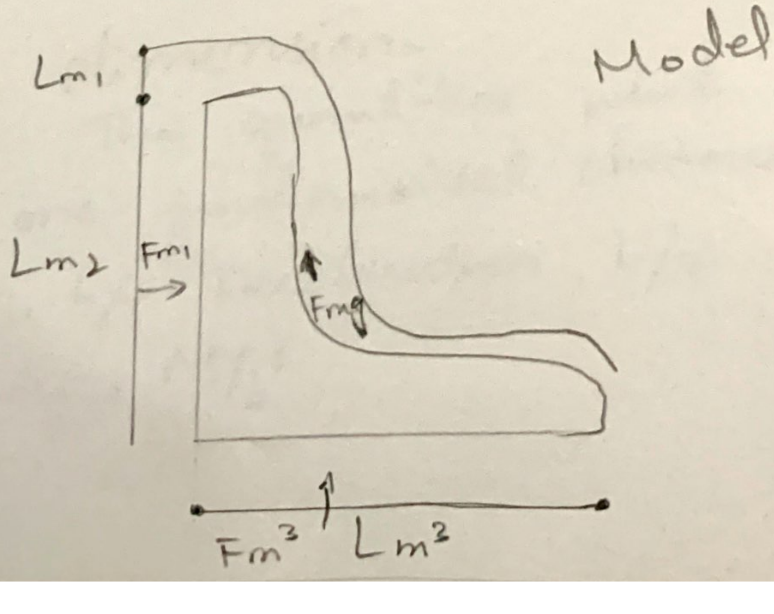
It is defined as the similarity b/w the model and the prototype in every aspect which means the model and the prototype have similar properties or they are completely similar.
It is used in testing engineering models.

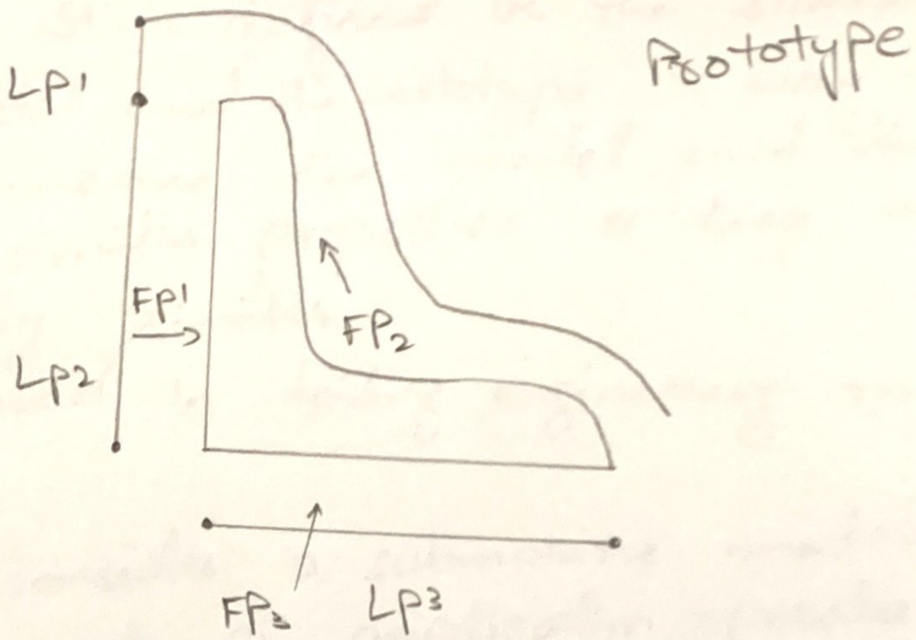
Example:-

Consider a submarine modeled at 1/40th scale, The application operates in sea water at 0.5°C at 5m/s. The model will be tested in fresh water at 20°C

Model Analysis:-

It is an experimental method of finding solution of complex flow problems. Tests performed on the models can be utilized for obtaining advanced and useful information about the performance of the prototype.




Lp1
Fp1
Fp2
Lp2
Fp3
Lp3
Prototype

Q4) what will be the effect of sediment

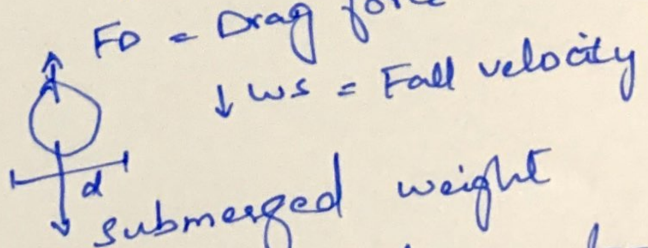
- - - - -

Ans) Fall Velocity:-

When a grain falls down in still water it obtains a constant velocity when the upward fluid drag force on the grain is equal to the downward submerged weight of the grain.
This constant velocity is defined as the fall velocity of the grain.
This is also called settling velocity

Fall velocity depends on:

1) Particle diameter
2) Particle density
3) Particle concentration
4) Particle shape
5) Viscosity of water (temperature)
6) Turbulance



The force balance b/w the drag force and the submerged weight gives

FD = submerged weight

$$\frac{1}{2} \rho C_D \frac{\pi d^2}{4} w_s^2 = (\rho_s - \rho) g \frac{\pi d^3}{6}$$

$A = \frac{\pi d^2}{4}$ = Projected Area

C_D = Drag coefficient

w_s = Fall velocity of sediment $= \sqrt{\frac{4gd}{3C_D}\left(\frac{\rho_s - \rho}{\rho}\right)}$

ρ = Density of water

ρ_s = Density of sediment particle.

Particle Diameter:-

The diameter of the particle is directly proportional to the fall velocity because greater the size of the particle the greater will be its velocity it will fall quickly due to the gravitational force is higher due to its weight.

Particle density:- Density of particle is directly proportional to the rate of fall velocity since particle with high density tends to settle down early compared to particles with less density.

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 compared to sections of low concentration.

Particle Shape:-

The fall velocity of smooth spherical grains can be predicted with high degree of accuracy. The difference in settling velocities between a spherical and non spherical particle with similar volume could could be directly attributed to the deviation from sphericity with grain roundness attributing a negligible role.

Viscosity of water:-

Fluid velocity through porous media is approximated as inversely proportional to the kinematic viscosity. A decrease in viscosity therefore increase the velocity of a compound through porous media.

Turbulance of water:-

Turbulance of water effect the fall velocity of water in reservoir because the non-linearity & zig zag path effect the flow of water and cause the variation in the flow.