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SUBMITTED TO — ENGR. FAWAD AHMED

SUBJECT — HYDRAULIC ENGINEERING

SECTION — B

MODULE — 6th

ID # — 7836

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1- A prototype gate valve which will control the flow in a pipe system in a model. List the significant variables on which the pressure drop across the value would depend. Perform dimensional analysis to obtain the relevant non-dimensional groups. A 1/5 scale model is built to determine the...

a) For a particular ..... ?

b) What is the ratio .... ?

c) Find the pressure drop... ?

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

→ List the relevant variables $(\Delta P, h, d, V, \rho, \mu)$

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.

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

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

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

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

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

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

→ $$\pi_1 = \Delta P V^{-2} \rho^{-1} = \frac{\Delta P}{\rho V^2}$$

Now $\pi_2 = \frac{h}{d}$ (by inspection, since h is a length).

$$\pi_3 = \mu d^a V^b \rho^c$$

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

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

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

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

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

→ $$\pi_3 = \mu d^{-1} V^{-1} \rho^{-1} = \frac{\mu}{\rho V d}$$

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 yields

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i.e $\pi_1 = f(\pi_2, \pi_3')$

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

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

$$\pi_1 = \left(\frac{\Delta P}{\rho V^2}\right)_p = \left(\frac{\Delta P}{\rho V^2}\right)_m$$

$$\pi_2 = (h/d)_n = (h/d)_m$$ (similar shape i.e geometric similarity).

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

From the last, we have a velocity ratio

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

Thus, $V_m = \frac{V_p}{0.5} = \frac{3.0}{0.5} = 6 \text{ m/s}$.

b) The ratio of the quantities of flow is

$$\frac{Q_p}{Q_m} = \frac{(\text{velocity} \times \text{area})_p}{(\text{velocity} \times \text{area})_m} = \frac{V_p}{V_m}\left(\frac{d_p}{d_m}\right)^2 = 0.5\times5^2 = 12.5$$

c) Finally, for the pressure drop,

$$\pi_1 = \left(\frac{\Delta P}{\rho V^2}\right)_p = \left(\frac{\Delta P}{\rho V^2}\right)_m \Rightarrow \frac{(\Delta P)_p}{(\Delta P)_m} = \frac{\rho_p}{\rho_m}\left(\frac{V_p}{V_m}\right)^2$$

$$= \frac{800}{1000} \times 0.5^2 = 0.2$$ Thus $\Delta P_p = 0.2 \times \Delta P_m = 0.2\times60$

$\Delta P_m = 12.0 \text{ KPa}$

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

1- Max depth of water in the reservoir is (your first two digits of R).

2- Specific gravity of dam material is G (can be your own choice).

3- Allowable compressive strength for the dam masonary is (your first T three digits of R T/m²).

4- Height of wave is Hw (your own choice).

5- G and Hw is of your own choice but should be differ from one another.

Sol:

$\because T = 783$, $\because G = 2.4$, $C = 0$

1- $H_{limiting} = \dfrac{\sigma_{all}}{\gamma_w (G - C + 1)} = \dfrac{120 \times 783 \times 1000}{1000 (2.4 - 0 + 1)} = 27635.29\,m$

let $H_w = 25000\,m$ Thus $27635.29 > H_w = 25000$

so it is low gravity dam.

2- Top width "a"

Free board $= 1.5\, h_{wave} = 1.5 \times 25000$

$F.B = 37500\,m$

Height of Dam $= H_D = H_w + F.B = 25000 + 37500$

$H_D = 62500\,m$

$a = 14\%$ of H_D

$= 0.14 \times 62500 \Rightarrow a = 8750\,m$

3- Base width "b" (with out offset).

(i) For No sliding criteria

$$b' = \frac{H_w}{\mu G} = \frac{25000}{0.7 \times 2.4} = 14880.95$$

$$\boxed{b' \approx 14881 m}$$

(ii) For no tension criteria

$$b' = \frac{H_w}{\sqrt{G}} = \frac{25000}{\sqrt{2.4}} = 16137.43 m$$

$$\boxed{b' \approx 16137 m}$$

4- Depth of vertical portion on u/s side:

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

$$h' = 2 \times 8750 \sqrt{2.4 - 0}$$

$$h' = 27110.88 m$$

$$\boxed{h' = 27111 m}$$

5- upstream off set $= \frac{a}{16} = \frac{8750}{16} = 546.875 m$

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

$$= 3.14(8750)\sqrt{2.14}$$

$$= 42564.1 m$$

7- Total width of the base of the dam

$$b = b' + \frac{a}{16} = 16137 + \frac{8750}{16}$$

$$\boxed{b = 16683.875m}$$

8- $$\tan\theta = \frac{b'}{H} = \frac{16137}{25000}$$

$$\theta = \tan^{-1}\left(\frac{16137}{25000}\right)$$

$$\boxed{\theta = 32.84^\circ}$$

9- Depth of vertical portion on D/S

$$\tan\theta = \frac{a}{d'} = \frac{8750}{d'}$$

$$\left(\frac{16137}{25000}\right) d' = 8750$$

$$d' = \frac{8750 \times 25000}{16137} = \boxed{13555.80m}$$

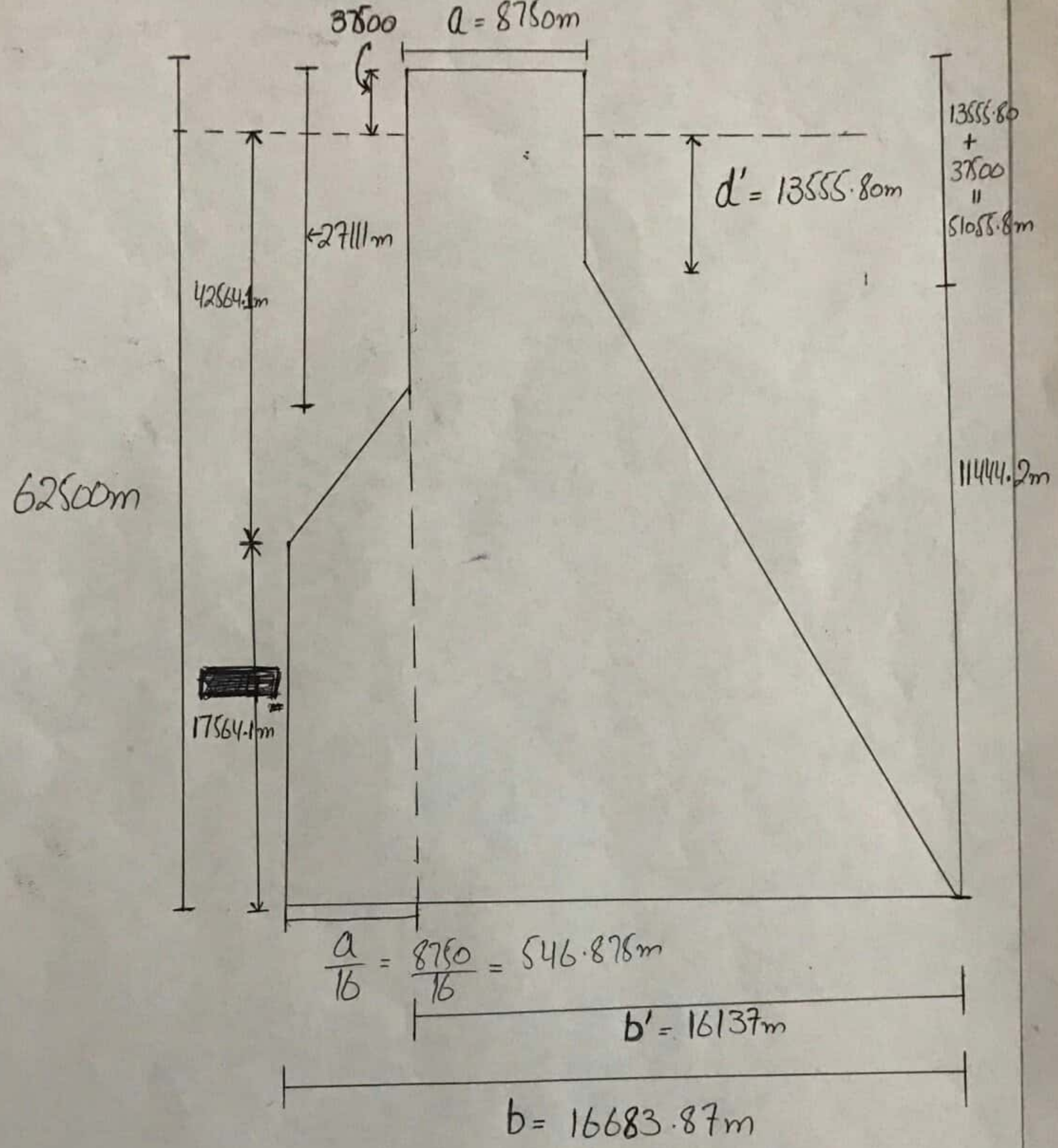
depth of vertical portion

$$d = d' + F.B = 13555.80 + 37500$$

$$\boxed{d = 51055.8\ m}$$

Diagram is drawn on next page!

P.T.O


37500
a = 8750m
13555.80
+
37500
=
51055.8m
d' = 13555.80m
←27111m
42564.1m
62500m
11444.2m
17564.1m
a/16 = 8750/16 = 546.875m
b' = 16137m
b = 16683.87m

P.T.O

Q3. Using any hydraulic model and explain the concept of dimensional analysis and similitude. Each student should have separate model analysis.

Ans: Dimensional analysis is a mathematical technique making use of study of dimensions.

→ Purpose of dimensional analysis:

- To generate nondimensional parameters that help inthe design of experiments (physical and/or numerical) and in reporting of results.
- To obtain scaling laws so that prototype performance can be predicted from model performance.
- To predict trends inthe relationships between parameters.

→ Fundamental dimensions:

These are the basic quantities, For example
Time, T ; Distance, L ; Mass, M

→ Secondary dimensions

Those quantities which posses more than one fundamental dimension.

Velocity, L/T
Acceleration, L/T^2
Density, M/L^3

SIMILITUDE :

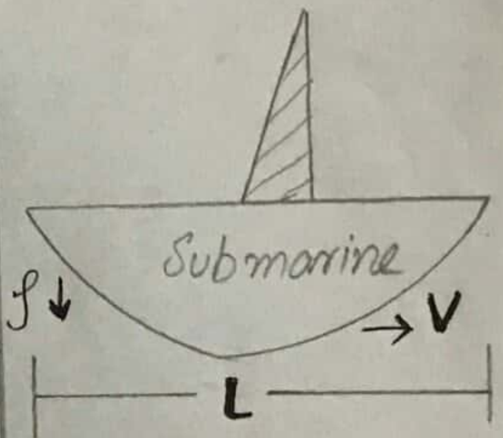
Similitude is defined as similarity between model and prototype in every respect which means model and prototype have similar properties or model and prototype are completely similar (conditions).

- It is used in testing of engineering models.

EXAMPLE :

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

- Free body diagram is constructed and relationships of force and velocity are formulated.



Variable	Application	Scaled model	Units
Length of sub-marine (L)	1	1/40	m
V (speed)	5	0.8	m/s
ρ (density)	1028	998	

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Q4. What will be the effect of sediment particle diameter, particle density, particle concentration, particle shape, viscosity of water, turbulence of water flowing in reservoir on fall velocity? Explain in detail.

Sol: PARTICLE DIAMETER:

The diameter of the particle is directly proportional to the fall velocity because greater the size of the particle so it will tend to move faster compared with particle of small size, thus there will be more gravitational force on particle of greater size so it will fall quickly due to it's weight.

PARTICLE DENSITY:

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

PARTICLE CONCENTRATION:

Concentration of the particle size will considerably affect it's fall velocity as the section having greater concentration will be settled down at the place thus causing more fall velocity comparing with section of lower concentration and vice versa.

P.T.O

PARTICLE SHAPE:

Particles having regular shapes tends to be effected more than irregular shapes since regular shaped 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 their less resistance.

VISCOSITY OF WATER:

From the experimental study we can see that parameters such as temperature and pressure changes the magnitude of viscosity; so the section of water having more temperature and pressure will fall objectively more due to increase inthe kinetic energy so fall velocity will be more & vice versa.

TURBULENCE OF WATER:

Turbulence of water depends upon the different factors such as velocity. It will effect the fall velocity because of it's zig-zag motion thus the velocity varies at every point which is why it effects the fall velocity, moreover increase inthe kinetic energy tends to effect the fall velocity compared with steady fluid.