Name:- Muhammad Hamza Rashid

ID # 7805 **Section:-** A

Semester:- 6th

Program:- B.Sc Civil Engineering

Subject:- Hydraulic Engineering

Submitted To:- Engr. Fawad Ahmad

Date:-

IQRA NATIONAL UNIVERSITY

DEPARTMENT OF CIVIL ENGINEERING

ID:- 7805

(Question - 01)

Q:- - - - - - - - - - - - -

Solution:-

Given that 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).

So the variables are

$$\Delta P = f(h, d, v, \rho, \mu)$$

$$\Rightarrow \quad f(\Delta P, h, v, \rho, \mu) = 0$$

So the total no. of variables (n) $= 6$

Number of fundamental dimensions (m) $= 3$

So the number of dimensionless π-terms will be,

$$\Rightarrow \quad n - m$$

$$\Rightarrow \quad 6 - 3 = 3$$

Thus $f(\pi_1, \pi_2, \pi_3) = 0$

Here,

Geometric Property $\longrightarrow$ d

Flow Property $\longrightarrow$ v

Fluid Property $\longrightarrow$ ρ

Hence the remaining variables are

$$\boxed{\Delta P, h, \mu}$$

Thus the π-terms are written as,

ID :- 7805

$$\pi_1 = \Delta P \, d^{a_1} v^{b_1} \rho^{c_1}$$

By dimensional Analysis

$$M^0 L^0 T^0 = (M L^{-1} T^{-2}) (L)^{a_1} (L T^{-1})^{b_1} (M L^{-3})^{c_1}$$

Equating Powers,

Power of $M \Rightarrow \quad 0 = 1 + c_1 \quad \Rightarrow \quad \boxed{c_1 = -1}$

Power of $T \Rightarrow \quad 0 = -2 - b_1 \quad \Rightarrow \quad \boxed{b_1 = -2}$

Power of $L \Rightarrow \quad 0 = -1 + a_1 + b_1 - 3c_1$

$$\boxed{a_1 = 1 + 3c_1 - b_1} \quad \text{—— (1)}$$

Putting the value of c_1 and b_1 in eq (1)

$$a_1 = 1 + 3(-1) - (-2)$$

$$\boxed{a_1 = 0}$$

$\Rightarrow$ Hence

$$\pi_1 = \Delta P \, v^{-2} \rho^{-1}$$

$$\boxed{\pi_1 = \frac{\Delta P}{\rho v^2}}$$

<u>Now</u> :- For π_2,

$$\pi_2 = h, d^{a_2}, v^{b_2}, \rho^{c_2}$$

$$M^0 L^0 T^0 = h \, \cancel{(M L^{-1} T^{-2})} (L)^{a_2} (L T^{-1})^{b_2} (M L^{-3})^{c_2}$$

Power of $M \Rightarrow \quad 0 = c_2 \quad \Rightarrow \quad \boxed{c_2 = 0}$

Power of $L \Rightarrow \quad 0 = a_2 + b_2 - 3c_2$

$$\Rightarrow a_2 = b_2 - 3c_2$$

$$\Rightarrow a_2 = b_2 - 3(0)$$

$$\Rightarrow \boxed{a_2 = b_2}$$

Power of $T \Rightarrow \quad 0 = -b_2 \quad \Rightarrow \quad \boxed{b_2 = 0}$

Hence

$\pi_2 = h d^{-1}$ $\Rightarrow$ $\boxed{\pi_2 = h/d}$

Now, for π_3 - terms :-

$\pi_3 = \mu d^{a_3} v^{b_3} \rho^{c_3}$

$M^0 L^0 T^0 = (ML^{-1} T^{-1}) (L)^{a_3} (LT^{-1})^{b_3} (ML^{-3})^{c_3}$

So,

Power of M $\Rightarrow$ $0 = 1 + c_3$ $\Rightarrow$ $\boxed{c_3 = -1}$

Power of L $\Rightarrow$ $0 = -1 + a_3 + b_3 - 3c_3$

$\boxed{a_3 = 1 + 3c_3 - b_3}$ —— (3)

Power of T $\Rightarrow$ $0 = -1 - b_3 + 0$ $\Rightarrow$ $\boxed{b_3 = -1}$

Putting the value of c_3 and B_3 in eq (3),

$a_3 = 1 + 3(-1) - (-1)$

$\boxed{a_3 = -1}$

Hence,

$\pi_3 = \mu d^{-1} v^{-1} \rho^{-1}$

$$\boxed{\pi_3 = \frac{\mu}{\rho v d}}$$

Hence, the relationship is,

$$f(\pi_1, \pi_2, \pi_3) = f\left(\frac{\Delta P}{\rho v^2}, \frac{h}{d}, \frac{\mu}{\rho v d}\right)$$

As we know that

Reynold Number (R) = $\dfrac{\mu}{\rho V D}$

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

$\pi_3' = (\pi_3)^{-1} = \dfrac{\rho V d}{\mu}$

$\Rightarrow \pi_3' = \left(\dfrac{\rho V d}{\mu}\right)_p = \left(\dfrac{\rho V d}{\mu}\right)_m$

From the above equation

$\Rightarrow V_p = \left(\dfrac{\mu}{\rho}\right)_p \times d_m$ —— (4)

$\Rightarrow V_m = \left(\dfrac{\mu}{\rho}\right)_m \times d_p$ —— (5)

a) VELOCITY OF WATER IN MODEL:-

Given velocity of Prototype (V_p) = 3.0 m/sec

From eq (4) and (5),

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

$$\boxed{\frac{V_p}{V_m} = 0.5}$$

$\because \left(\rho = 800 \text{ kg/m}^3, \; \dfrac{d_m}{d_p} = 1/5, \; \mu = 1.0 \times 10^{-6} \right.$

Hence from the equation,

$\dfrac{V_p}{V_m} = 0.5 \Rightarrow V_m = V_p/0.5$

$\Rightarrow V_m = \dfrac{3.0}{0.5}$

$\boxed{V_m = 6.0 \text{ m/sec}}$

ID :- 7805

b) :- Ratio of Quantities of Flow in Prototype and Model :-

By using Discharge Formula,

$$Q = AV$$

So the ratio will become,

$$\frac{Q_p}{Q_m} = \frac{(A \cdot V)_p}{(A \cdot V)_m} = \frac{V_p}{V_m}\left(\frac{d_p}{d_m}\right)^2$$

$$= 0.5 \times \left(5/_1 \right)^2$$

$$= 0.5 \times (5)^2$$

$$\boxed{\frac{Q_p}{Q_m} = 12.5}$$

C :- Value of Pressure Drop :-

By using the π_1 term, we can find Pressure drop

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

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

Hence $\frac{(\Delta P)_p}{(\Delta P)_m} = 0.2$ $\quad (\because (\Delta P)_p = 60 \text{ kpa})$

$$\Rightarrow (\Delta P)_p = 0.2 \times (\Delta P)_p$$

$$= 0.2 \times 60 = \boxed{12.0 \text{ kPa}}$$

(QUESTION - 02)

DESIGNING OF PRACTICAL PROFILE OF GRAVITY DAM:-

GIVEN DATA:-

=> Maximum Depth of water = (78 m)

=> Specific Gravity of Dam Material (G) = 2.5

=> Allowable Compressive strength for dam masonry

$S_{au} = 780\ T/m^2$

=> Height of Wave (H_w) = 1.55 m

=>

SOLUTION:-

STEP #1 :- (Checking OF High Gravity or Low Gravity Dam)

By formula,

$$H_{limiting} = \frac{S_{au}}{\gamma_w (G - C_u + 1)}$$

(∵ $\gamma_w = 1000\ kg/m^3$
C_u = uplift Pressure)

$$= \frac{780 \times 1000}{1000(2.5 - 0 + 1)}$$

$$= 222.86\ m$$

As, $222.86\ m > H_w = 78m$

So it is a Low Gravity Dam!

STEP #2 :- (Top Width of the Dam).-

Top width (a) = 14 % of H_D

first we will find H_D (Height of Dam)

$H_D = H_w + F.B$

=> Free Board (F.B) = $1.5 \times h_{wave}$

$= 1.5 \times 1.55$

$\boxed{F.B = 2.33m}$

=> Height of Dam $(H_D) = H_{water} + F.B$

$= 78 + 2.33$

$\boxed{H_D = 80.33\ m}$

=> Top width (a) = 14 % of H_D

$= \frac{14}{100} \times 80.33$

$\boxed{a = 11.25m}$

STEP #3 :- (BASE WIDTH) (Without Offset)

1) For No Sliding Criteria:-

By formula

$$b' = \frac{H_{water}}{\mu \cdot G} = \frac{78}{0.7 \times 2.5}$$

$b' = 44.57$

$\boxed{b' \simeq 45\ m}$

ii) For No Tension Criteria :-

By Formula,

$$b' = \frac{H_{water}}{\sqrt{G}} = \frac{78}{\sqrt{2.5}} = 49.3$$

$$\boxed{b' \simeq 50m}$$

For Factor of Safety, we will use

$$\boxed{b' = 50m}$$

STEP #4 :- (Depth of Vertical Portion on Upstream Side)

By formula

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

$$= 2(11.25)\sqrt{2.5 - 0}$$

$$h' = 35.57$$

$$\boxed{h' \simeq 36m}$$

STEP #5 :- (Upstream Offset)

By formula

Upstream offset $= a/16$

$= 11.25/16$

$= 0.71m$

STEP #6 :- (Depth below the water level to the end of Inclined Portion in upstream side)

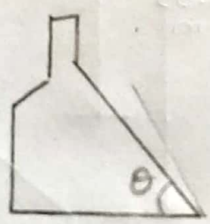
$$depth = 3.14 \times a \times \sqrt{G}$$
$$= 3.14 \times 11.25 \times \sqrt{2.5}$$
$$= 55.8 m$$

STEP #7 :- (TOTAL WIDTH OF BASE of the DAM)

$$b = b' + a/16$$
$$= 50 + \frac{11.25}{16}$$
$$\boxed{b = 50.71 m}$$

STEP #8 :- (Inclination Angle on D/s side)

By using tan θ



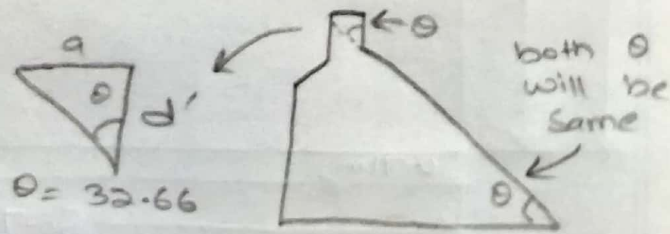
$$\tan\theta = \frac{b'}{H^*} = \frac{b'}{H}$$

$$\Rightarrow \theta = \tan^{-1}\left(\frac{b'}{H}\right)$$
$$= \tan^{-1}\left(\frac{50}{78}\right) \Rightarrow \boxed{\theta = 32.66^\circ}$$

STEP #9 (Depth of Vertical portion on D/s From water level on u/s)

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

$$\tan\theta = \frac{11.25}{d'}$$



$$\tan\theta = \frac{11.25}{d'}$$

$$\left(\frac{50}{78}\right) = \frac{11.25}{d'} \Rightarrow d' = \frac{11.25 \times 78}{50}$$

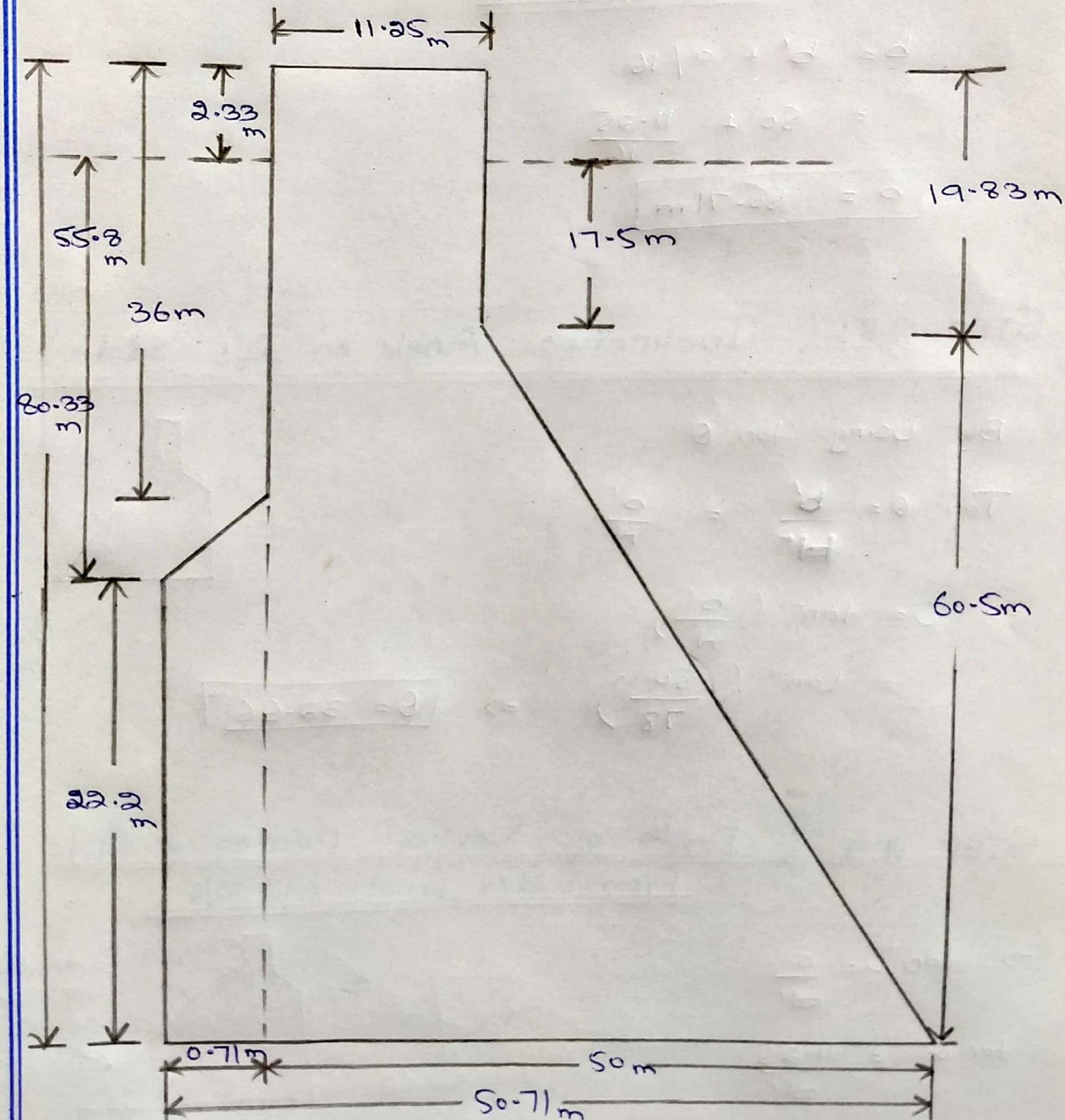
$$\boxed{d' = 17.5m}$$

So depth of vertical portion,

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

$$= 17.5 + 2.33$$

$$\boxed{d = 19.83m}$$

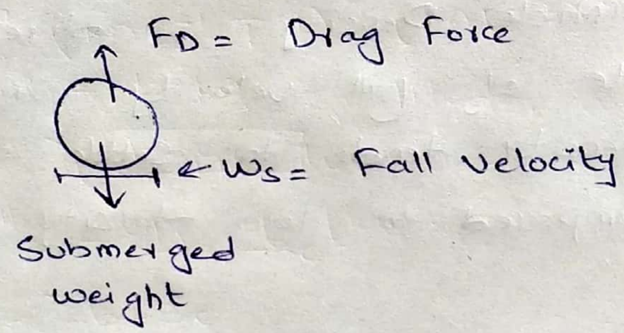


(QUESTION - 04)

Ans:-

FALL VELOCITY :-

When a Sediment particle falls down in still water, it obtains a constant velocity when the upward fluid force (drag force) on the particle is equal to the weight of the particle, present in water, this constant velocity is called fall velocity of the particle.



The fall velocity of the particle depends upon the following factors :

1- PARTICLE DIAMETER:-

The diameter of falling particle have a significant effect on the fall velocity.

According to Stokes Law,

$$F_D = 6 \pi \eta r v_T$$

Larger the diameter or radius of the falling Particle, higher will be the drag force acting on it and higher value of fall velocity will be obtained.

Particle Shape :-

Particle shape also have a significant effect on fall velocity. Particles with rough or smooth shape attains different velocities. Rough shape particle offers more resistance as compared to smooth surface and hence drag force increases. ~~Also, ... spheri~~.

Particle Density :-

Particle Density is directly propotional to the rate of fall velocity since particle with high density tends to settle down more quickly as compared to low density particle.

Viscosity OF Water :-

From stokes Law,

$$F_D = 6\pi \eta r v_T$$

Here η (viscosity) of the fluid is directly proportional to the drag force acting on the fluid which inturns increases the fall velocity.

Turbulance :-

Turbulance occured in water also effect the fall velocity of the particle. The zig-zag path in the flow decreases the drag force and fall velocity of the particle.

Particle Concentration:-

Particle concentration decreases with the increase in fall velocity of the particle because of the modification of the flow induced by Previous Particle.

(QUESTION - 03)

Ans:

For Dimensional Analysis and similitude, we take a small model of apparatus used in the labs for finding out the type of flow.

LAMINAR AND TURBULENT FLOW APPARATUS:-

=> It is an apparatus used in Fluid mechanics Labs for finding out the type of flow flowing in it.

=> It differentiates the type of flow on the basis of Reynold Number

Laminar flow $\longrightarrow$ $R < 2000$

Turbulent flow $\longrightarrow$ $R > 2000$

-> Also, Laminar flow occurs during slow motion of fluid and also if the fluid is more viscous.

=> Turbulent flow occurs during the fast motion of fluid.

=> The Densities of the fluid also effects on its motion.

Here the three basic parameters used are :-

Velocity of Fluid (v)
Viscosity of Fluid (μ)
Density of Fluid (ρ)

By using Dimensional Analysis Concent

Type of flow is dependent on all three parameters
So

Flow = $f(v, \mu, \rho)$

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

Powers of M = $0 = b + c$

$\Rightarrow \boxed{b = -c}$ or $\boxed{c = -b}$

Power of L = $0 = -a - b - 3c$

$\boxed{a = -b - 3c}$ —— ①

Put b in eq ①

$a = -c - 3c$

$\boxed{a = -4c}$

Power of T = $0 = -a - b$

$\Rightarrow$

$b = -a$

$b = 4c$

So

Flow = $f(v^{-4c}, \mu^{-c}, \rho^{-b})$

$= (v^{-4c}, \mu^{-c})\, \rho^{-b}$

Advantages of Dimensional Analysis:-

=> Less number of experiments are necessary, as opposed to the dimensional system.

=> Experiments become inexpensive

=> Data reduction becomes easier, single plot is sufficient to show the results.

Now,

=> The basic idea behind simitude shows the use of replica of actual model on small scale.

For example we have to construct a Turbine, so first we made its model and perform experiments on it whether it can work on actual site.

=> For example on site,
the power generation is 60 kW per hour, so here we will generate its half or more lesser value, and then for actual results, we will multiply it with desired number.

=> In this / discussed model of Laminar and Turbulent flow apparatus, similar is the case of checking the flow type first on apparatus and then on site for the construction of huge structures.