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SECTION # A

PAPER # HYDRAULIC ENGINEERING

Date = 25/06/2020

QUESTION NO = 01

SOLUTION:-

The pressure drop $\Delta p$ is expected to depend upon the gate opening $h$, the overall depth $(d)$, the velocity $(V)$, density $(\rho)$ and viscosity $(\mu)$.

List the Relevant variables.

$\Delta p, h, d, V, \rho, \mu$

Write down dimension

$\Delta p \quad ML^{-1}T^{-2}$

$h \quad L$

$d \quad L$

$V \quad LT^{-1}$

$\rho \quad ML^{-3}$

$\mu \quad ML^{-1}T^{-1}$

Number of variables $n = 6$

Number of independent dimension $m = 3$ (M, L and T)

Numbers of non-dimensional:

$n - m = 3$

Choose m ( ) scaling variables:

geometric (d); kinematic/time-dependent (v); dynamic/Mass-dependent (ρ).

Form dimensionless group by non-dimensionalising the remaining variables Δp, h and μ

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

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

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

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

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

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

$\Rightarrow \Pi_1 = \Delta p\, v^{-2} \rho^{-1} = \dfrac{\Delta p}{\rho v^2}$

$\Pi_2 = \frac{h}{d}$ (by inspection, since h is a lenght)

$\Pi_3 = \mu d^a v^b \rho^c$ (Probably obvious by Now, but here goes Anyway)

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

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

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

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

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

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

Recognition of Reynolds number suggests that we replace $\Pi_3$ by

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

Hence dimension 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 dimensions groups be the same in m photokype. i.e:

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

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

(Automatic if 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

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

$$= 0.5$$

Hence

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

b) The Ratio of the Quantities of flow is

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

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

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

$$\Delta P_m = 0.2 \times \Delta P_m = 0.2 \times 60 = 12.0\,KPa$$

## QUESTION # 2

### GIVEN DATA:-

Maximum depth of water in Reservoir = 78m
Specific Gravity of Dam Material = G = 2.6
Available compressive stress for the Dam masonary = 782 T/m²

Height of wave = H/W = 1.9

$\mu = 0.7$

$C\mu = 0$ (No uplift pressure)

### SOLUTION:-

1) $$H_{limiting} = \frac{\quad}{\gamma w (G - (u+1))}$$

putting values

$$H_{limiting} = \frac{782 \times 1000}{1000(2.6 - 0 + 1)}$$

$$H_{limiting} = \frac{782000}{3600}$$

$$H_{limiting} = 217.22$$

$H_{limiting} = 217.22m > H_W = 78m$

It is a low gravity dam.

2) **TOP width:-**

Free board = $1.5 \cdot h_{wave}$

$F.B = 1.5 \times 1.4$

$FB = 2.1m$

Height of Dam = $H_W + F.B$

$HD = 78 + 2.1 = 80.1m$

$HD = 80.1m$

Now $a = 14\%$ of $HD$

$a = \frac{14}{100} \times 80.1 = 11.214$

$a = 11.214m$

## 3) BASE WIDTH b' (Without offset):-

i) For no sliding criteria

$$b' = \frac{HW}{\mu G} = \frac{78}{(0.7)(2.6)} = \frac{78}{1.82}$$

$$\boxed{b' = 42.85}$$

ii) For Tension tension criteria:

$$b' = \frac{HW}{\sqrt{G}} = \frac{78}{\sqrt{2.6}} = \frac{78}{1.612}$$

$$\boxed{b' = 48.387m}$$

We will use b' = 48.387

4) Depth of verticle portion on u/s side

$h' = 2a\sqrt{G \cdot CY}$

$h' = 2\,(11.214)\,(\sqrt{(2.6)} - (1.0))$

$h' = 2(11.214)(1.612)$

$h' = 36.153$

5) upstream offset:-

$\Rightarrow \frac{a}{16} \Rightarrow \frac{11.214}{16}$

$= 0.70\,m$

6) DEPTH BELOW THE WATER LEVEL TO THE END OF INCLINED PORTION in U/S $= 3.14\,a\sqrt{G}$

$= 3.14 \times 11.214\sqrt{2.6}$

$= 56.77\,m$

7) TOTAL WIDTH OF THE BASIS OF DAM

$$b = b' + \frac{a}{16} = 48.387 + \frac{11.214}{16}$$

$$b = 48.387 + 0.70$$

$$\boxed{b = 49.087m}$$

8) $\tan\theta = b'/H$

$$\tan\theta = \frac{48.387}{78}$$

$$\tan\theta = 0.620$$

$$\theta = \tan^{-1}(0.620)$$

$$\theta = 31.798$$

$$\boxed{\theta = 31.7^\circ}$$

9) DEPTH OF VERTICLE PORTION ON D/S

$$\tan\theta = \frac{a}{d'} = \frac{11.214}{d'}$$

$$\tan\theta = \frac{11.214}{d'}$$

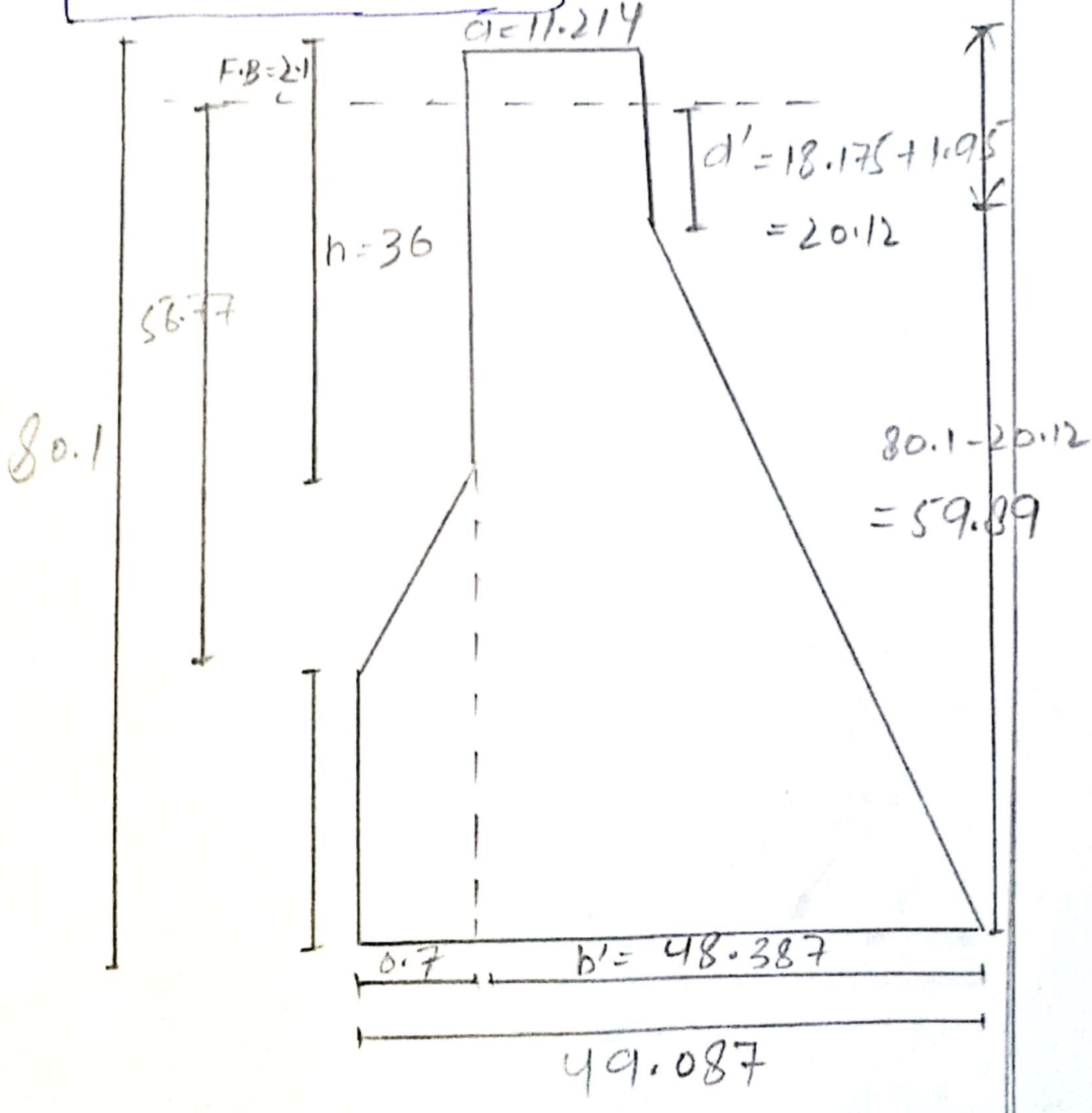
$$d' = \frac{11.214}{\tan\theta} = \frac{11.214}{\tan(31.7^\circ)}$$

$$\boxed{d' = 18.175m}$$

Depth of verticle portion

$$d = d' + FB = 18.175 + 2.1$$

$$\boxed{d = 20.272m}$$



# QUESTION = 03

## ANALYSIS OF TURMACHINES:-

- Pumps (centrifugul, axial, Flow)
- Turbines (impulse Reaction)

Dimension Analysis useful to make Generalization about similar turbo-Machines and distinguish b/w them

Revelant variable with Reference to power (P):

=) Impeller diameter (D)

=) Rotational speed

=) Flow

=) Energy added and subtracted.

$$H = Nm/Kg = m^2/s^2$$

## DIMENSION ANALYSIS FOR TURBOMACHINES:-

Assume the following Relationship among the variables.

$$f\{P, D, N, Q, H, \mu, \rho, E\} = 0$$

## BUCKINGHAM THEORM:-

3 Fundamental dimensions (M, L, T) and 8 variable imply that 8 - 3 = 5 $\Pi$ terms can be formed

Select ρ, D and N as variable containing the 3 fundamental dimensions to be combined with Remaining 5 variables.

(P, Q, H, μ and E)

P, D, N combined with μ - yields

$\Pi_1 = \mu^a \rho^b D^c N^d$

Solving the dimension Equation gives,

$$\Pi_1 = \frac{\rho N D^2}{\mu} = Re$$

Derive other π terms in the same manner

P, D, N Combined with F ->

$$\Pi_2 = \frac{\rho N^2 D^2}{F} = \frac{N^2 D^2}{a^2} = M^2$$

P, D, N combined with P ->

$$\Pi_3 = \frac{P}{\rho N^3 D^5} = CP$$

P, N, D combined with Q

$$\Pi_4 = \frac{Q}{ND^3} = CQ$$

P, D, N combined with H →

$$\Pi_5 = \frac{H}{N^2 D^2} = CH$$

## SUMMARIZING THE RESULTS:

$$\frac{P}{\rho N^3 D^5} = f'\{CQ, CH, Re, M\}$$

OR

$$\frac{Q}{ND^3} = f''\{CP, CH, Re, M\}$$

$$\frac{H}{N^2 D^2} = f'''\{CP, CQ, Re, M\}$$

## Specific Speed Turbines:

$$N_S = \frac{N\sqrt{P}}{\sqrt{\rho}\, H^{5/4}}$$

## QUESTION# 4

## FALL VELOCITY:-

When a grain falls down in still water it obtain in contant velocity when upward fluid drag force on the grain is Equal to the downward submerged weight of the grain. This constant velocity is define as the fall velocity of the grain.
This is also known as setting velocity.

## FACTOR DEPENDS:-

1) PARTICLE DIAMETER:-

As fall velocity of the sedimate is given by

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$$W_s = \sqrt{\frac{4gd}{3C_D}\left(\frac{\rho_s - \rho}{\rho}\right)} \rightarrow (1)$$

As $W_s \propto d$

From above equation, Fall velocity of the Sediment is ~~direction~~ directly Proportion to the diameter of the particle.

2) **PARTICLE DENSITY:-**

From Equation (1)

$W_s \propto \rho_s$

Where
$W_s$ = Fall velocity
$\rho_s$ = Density of Sediment

Fall velocity of the Sediment is directly Proportional to density of Sediment.

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3) PARTICLE CONCENTRATION:-

velocity of fall is directly proportional to particle concentration. So by increasing the concentration of particle, the fall velocity also increase.

4) SHAPE OF PARTICLES:-

Smooth (Round shape) particle will sit quickly, so the fall velocity for such particles will be more. And for Angular shape particles the fall velocity will be less because such particles will sit slowly.

5) VISCOSITY OF WATER:-

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

## TURBULENCE OF WATER:-

Turbulence of water effect the fall velocity of water in Reservoir because the non-linearity and zig zag path effect the flow of water and cause the variation in the flow.