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Section: A

Paper : Hydraulics Engineering

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Q.No(01)

Ans:- 01:

Solution:-

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

**List the relevant variables;**

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

**Write down dimensions:**

| | |
|---|---|
| $\rho$ | $ML^{-3}$ |
| $d$ | $L$ |
| $h$ | $L$ |
| $\Delta p$ | $ML^{-1}T^{-2}$ |
| $\mu$ | $ML^{-1}T^{-1}$ |
| $V$ | $LT^{-1}$ |

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

Number of non-dimensional groups: $n-m=3$

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Number of Variables: $n=6$

Choose $m(=3)$ scaling variables;
geometric ($d$): Kinematic/time-dependent ($V$);
dynamic/mass-dependent ($\rho$)
Form dimensionless group by non-dimensionalising the remaining variables: $\Delta p$, $h$ and $\mu$

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

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

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

$M$: $0=1+c$

$\Rightarrow c=-1$

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

$= a=1+3c-b$

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

$\Rightarrow b=-2$

$$\Rightarrow \pi_1 = \Delta p V^{-2}\rho^{-1} = \frac{\Delta p}{\rho V^2}$$

$\pi_2 = \dfrac{h}{d}$, (Since $h$ is a height)

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$\Pi_3 = \mu d^a V^b \rho^c$ (probably obvious by now, but here goes anyway)

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

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

$M: \; 0 = 1 + c$

$\Rightarrow c = -1$

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

$b = -1$

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

$\Rightarrow a = 1 + 3c - b$

$a = -1$

$\Rightarrow \Pi_1 = \mu d^{-1} V^{-1} \rho^{-1} = \frac{\mu}{\rho V d}$

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

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

Hence dimension analysis yields

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

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 quantity 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,

$$\pi_1 = \left[\frac{\Delta p}{\rho V^2}\right]_p = \left[\frac{\Delta p}{\rho V^2}\right]_m$$

$$\Rightarrow \frac{(\Delta p)_p}{(\Delta p)_m} = \frac{\rho_p}{\rho_m}\left[\frac{V_p}{V_m}\right]^2$$

$$\Rightarrow \frac{800}{1000} \times 0.5^2 = 0.2$$

Hence,

$$\Delta p_p = 0.2 \times \Delta p_m = 0.2 \times 60 = 12.0\,kPa.$$

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Q.No(02)

Ans:-

Given data:-

Maximum Depth of water in the Reservoir

$= H = 78$

Specific Gravity of Dam Material $= G = 1.2$

Allowable Compressive Stress for the Dam-Masonary

$$\sigma_{all} = 782 \frac{T}{m^2}$$

Height of wave $= 4.2m$

$\mu = 0.7$

No uplift pressure $C_u = 0$.

Solution:-

(1) $$H_{limiting} = \frac{\sigma_{all}}{\gamma_w(G - (\mu + 1))}$$

$$= \frac{782 \times 1000}{1000(1.2 - 0 + 1)}$$

$$H_{limiting} = 355.45m > 78m$$

So it is low Gravity Dam

2) Top width "a"

Free board = 1.5 hwave = 1.5 × 4.2

$\boxed{F.B = 6.3m}$

height of Dam = $H_D = H_w + F.B = 78 + 6.3$

$\boxed{H_D = 84.3m}$

$a = 14\%$ of $H_D$

$a = 0.14 \times 84.3$

$\boxed{a = 11.802m}$

(3) Base width "b" (with out off set)

(i) For No Sliding Criteria

$$b' = \frac{H_w}{\mu G} = \frac{78}{0.7 \times 1.2}$$

$b' = 92.85$

$\boxed{b' \simeq 93m}$

(ii) For No tension Criteria.

$$b' = \frac{H_w}{\sqrt{G}} = \frac{78}{\sqrt{1.2}}$$

$\boxed{b' = 27.38m}$

use $\boxed{b' = 27.38m}$

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(4) Depth of Vertical Portion on u/s side:

$h' = 2a\sqrt{G - C_4}$

$h' = 2 \times 11.802\sqrt{1.2 - 0}$

$h' = 25.85$

$\boxed{h' = 25.85m}$

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

$= \frac{11.802}{16}$

$= 0.737$

(6) Depth below the water level to the end of inclined portion in u/s.

$= 3.14a\sqrt{G}$

$= 3.14 \times 11.802\sqrt{1.2}$

$= 40.59$

(7) Total width of the base of the dam

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

$b = 27.38 + \frac{11.802}{16}$

$b = 27.38 + 0.737$

$\boxed{b = 28.117m}$

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(8) $\tan Q = \frac{b'}{H} = \left(\frac{28.117}{78}\right)$

$Q = \tan^{-1}(0.3604)$

$\boxed{Q = 20.003^\circ}$

(9) Depth of Vertical portion on D/S (from WL on U/S side)

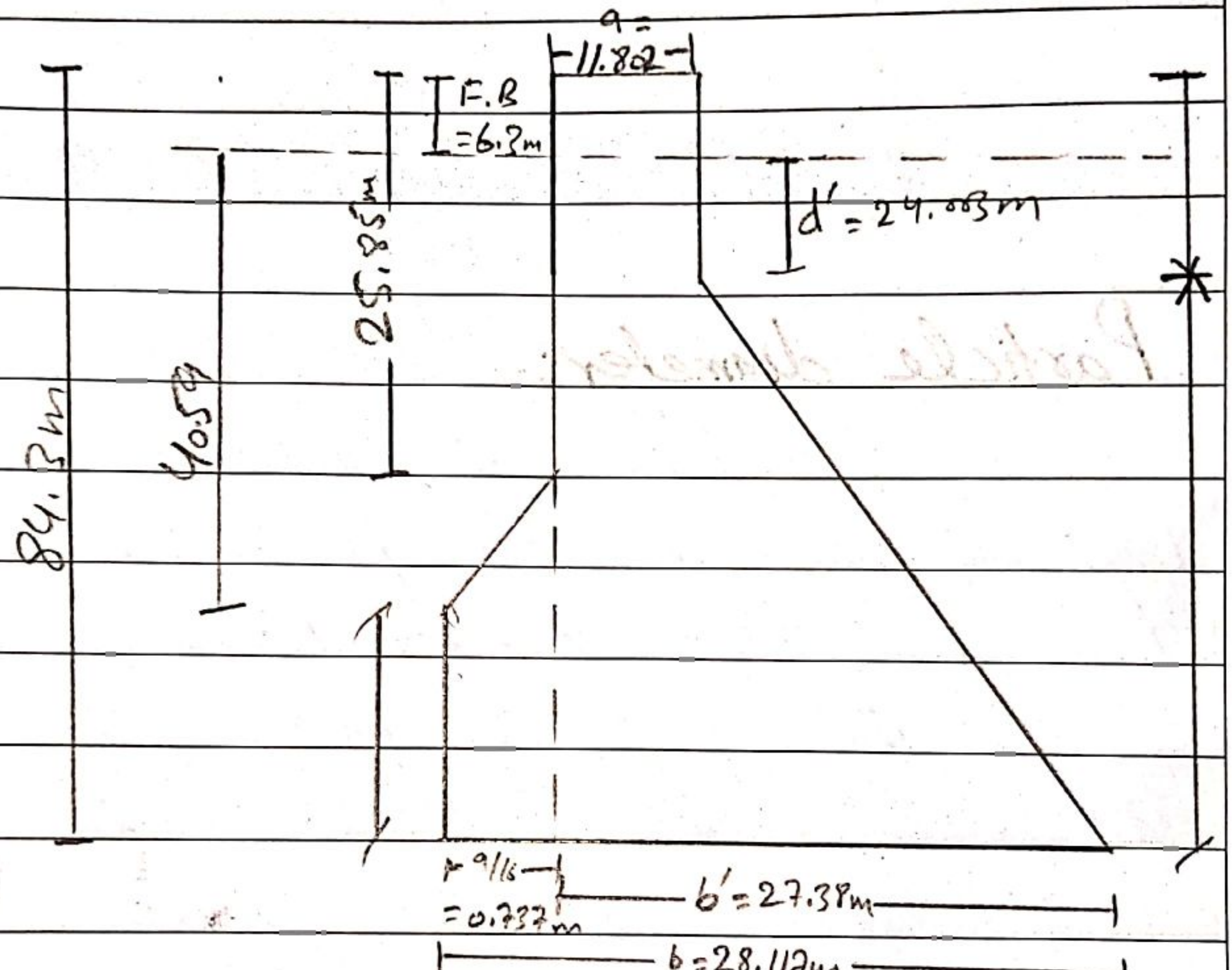
$\tan\theta = \frac{a}{d'} = \frac{11.802}{d'} \Rightarrow \tan\theta = \frac{4.5}{d'}$

$\frac{2}{3}d' = 11.802$

depth of vertical Portion

$d = d' + FB = 17.703 + 6.3$ $\quad d' = \frac{11.802 \times 3}{2}$

$\boxed{d = 24.003\,m}$ $\quad d' = 17.703$


a = 11.82
F.B = 6.3m
d' = 24.083m
25.85m
40.58
84.3m
a/16 = 0.737m
b' = 27.38m
b = 28.117m

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Q.No (03)

Ans-

Dimensional analysis:

If certain physical phenomenon is governed by

$\Rightarrow$ where some/all of the varibles($x$) are dimensional.

$f(x_1, x_2, \dots x_n) = 0$

Then the above phenomenon can be represented as

$\psi(\pi_1, \pi_2, \dots \pi_m) = 0$

where all the variables ($\pi$) are non-dimensional.

Buckingham Pi Theorem

$f(x_1, x_2, \dots x_n) = 0$

$\Rightarrow \psi(\pi_1, \pi_2, \dots \pi_m) = 0$

where $m < n$, $m = n - k$.

Minimum number of fundamental dimensions involved: $k$.

Example: $f(V, g, h) = 0$

$n = 3$, $k = 2$ $m = n - k = 1$

# Similitude: Basic idea behind model testing.

For the present case study $Fr = \left[\frac{V}{\sqrt{gh^3}}\right]$

Since the relation holds for similar model and prototype take if

$$\left[\frac{V}{\sqrt{gh^3}}\right]_{model} = \left[\frac{V}{\sqrt{gh^3}}\right]_{Prototype}$$

then $(Fr)_{model} = (Fr)_{prototype}$.

## Geometric Similarity: length-scale matching:

A model and prototype are geometrically similar if and only if all body dimension in all three coordinates have the same linear scale ratio.

All angles flow direction, orientation with the surroundings must be preserved.

Geometric Samilarity + Matching of Pi-terms.

- Geometric samilarity depends on proper design, manufacturing, material choice.
- Proper choice of variable to include necessary fluid dynamical effects.
- In reality, it is not always possible to attain complete similarity and forced to work with partial similarity. May happens for more than three dominan forces.

When fluid flows over an object the object experiences fluid resistance known as 'drag force'

For incompressible flow with 'smooth' objects the drag force is given by.

$$F = f(L, u, \rho, \mu)$$

Conduct dimensional analysis to identify the dimensionless numbers associated with the above phenomenon.

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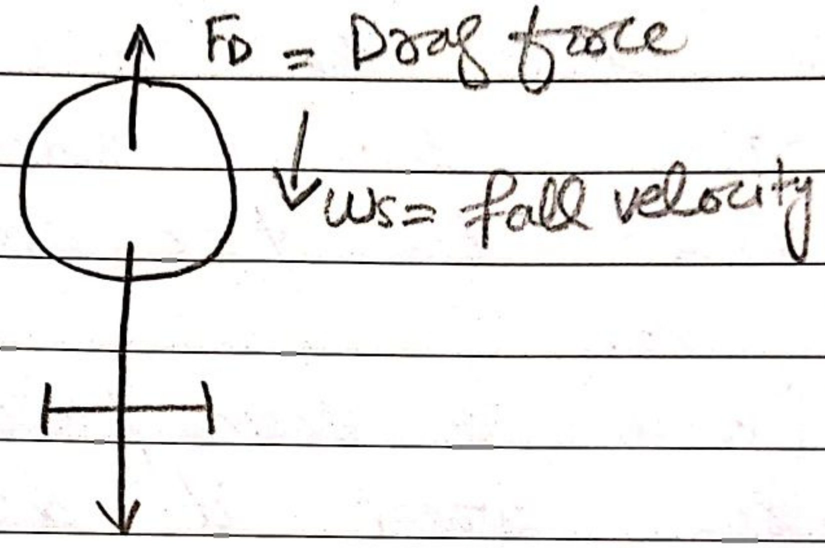
Dynamic Similarity (Force-Scale matching)

A model and prototype are dynamically similar if ratio of any two forces are same for model and prototype.

Q.no # 4
Ans:- **Fall Velocity:**
The downward velocity in a low dense fluid at equation in which the sum of the gravity force, buoyancy force and fluid drag force are equal to zero.
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 is also called setting velocity.

**Fall velocity effected due to:**
The following are the terms.
a) Particle diameter
b) Particle density

c) Particle Concentration.
d) Particle Shape.
e) Velocity of water [temperature]
f) Turbulance.




The force balance between the drag force and the submerged weight.

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

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

$C_D$ = Drag Coefficient
$W_s$ = fall velocity of sediment

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

$\rho$ = Density of water
$\rho_s$ = Density of sediment particle

**Particle diameter:**

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

**Particle Density:**

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

Particle Concentration:-

Concentration of particle size will considerably effect its fall velocity as the section flowing greater concentration will be settled down at the place thus causing the more fall velocity compacting with section of low concentration.

Particle Shape:-

Particle having regular shaps tends to be affected more than irregulare shape since regular shaps particles have even surfaces which offers very little or no friction while particles with irregular shape offers more friction as the particle with smaller surface area are more likely to be effected due to their less resistance.

Viscosity of water:-

Fluid velocity through porous media is approximated as inversely proportional to the kinematic viscosity.
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 & cause the variation in the flow.