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Section / A

Subject / Hydralic Engineering

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Exam / Final - term

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ID = 7877

QNO1 ⇒ A prototype gate valve which will control the flow in a pipe system conveying paraffine is to be studied in a model. List the significant variables on which the pressure drop across the valve would depend. Perform dimensional analysis to obtain the relevant non-dimensional groups.

A 1/5 scale model is built to determine the pressure drop across the valve with water as the working fluid.

a) For a particular opening, when the velocity of paraffin in the prototype is $3.0\ ms^{-1}$. What should be the velocity of water in the model for dynamic similarity?

b) What is the ratio of the quantities of flow in prototype and model?

c) Find the pressure drop in the prototype if it is 6 kPa in the model.

(The density and viscosity of paraffin are $800 \, kg \, m^{-3}$ and $0.002 \, kg \, m^{-1} s^{-1}$ respectively. Take the kinematic viscosity of water as $1.0 \times 10^{-6} m^2 s^{-1}$)

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.

Solution =>

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.

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

Write down dimensions:

Δp	$ML^{-1}T^{-2}$
h	L
d	L
V	LT^{-1}
ρ	ML^{-3}
μ	$ML^{-1}T^{-1}$

(3) ID = 7877

Number of Variables: $n = 6$

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

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

Chose $m (= 3)$ Scaling variable

geometric (d): kinematic/ time dependent (V); dynamic/mass-dependent (ρ):

From dimensionless groups by non-dimensionlisting the remaining variable: Δp, h and μ

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

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

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

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

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

$\Pi_2 = \frac{h}{d}$ (by Inspection since h is a length)

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

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

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

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

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

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

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:

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

i.e

$$\frac{\Delta P}{\rho V^3} = f\left(\frac{h}{d}, \frac{\rho V d}{\mu}\right)$$

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

$$\Pi_1 = \left[\frac{\Delta P}{\rho V^2}\right]_p = \left[\frac{\Delta P}{\rho V^2}\right]_m$$

$\Pi_2 = \left(\frac{h}{d}\right)_p = \left(\frac{h}{d}\right)_m$ (automatic similar shape ie geometric similarity)

(5) ID = 7877

$$\Pi_3 = \left(\frac{\rho v d}{\mu}\right)_p = \left(\frac{\rho v d}{\mu}\right)_m$$

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) ~~E~~ Finally, for the pressure drop:

$$\Pi_1 = \left(\frac{\Delta P}{\rho V^2}\right)_p = \left(\frac{\Delta P}{\rho V^2}\right)_m \Rightarrow \cancel{\left(\frac{(\Delta P)_p}{4(\Delta P)_m}\right)}$$

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

(6) ID = 7877

Hence

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

QNO2 ⇒ Design a partical profile of gravity dam with the following data:

1 ⇒ Maximum Depth of water in the reservior is 78 = R

2 ⇒ Specific gravity of dam material is $G = 2.8$

3 ⇒ Allowable Compressive Strength for the dam masonary 787 T/m^2

4 ⇒ Height of wave is $H_w = 1.2\,m$

5 ⇒ G and Hw is $= \mu = 0.7$

No uplift pressure : $C_u = 0$

Solution

1) $$H_{limiting} = \frac{\sigma_{all}}{\gamma_w (G - C_u + 1)} = \frac{787 \times 1000}{1000(2.8 - 0 + 1)} = 231.47$$

$H_{limiting} = 207.10\,m$ $\quad 207.10 > H_w = 78\,m$

So it is low gravity Dam.

2) Top width 'a'

Free board = 1.5 h_{wave} = 1.5×1.6

$$\boxed{FB = 2.4\,m}$$

(7) ID = 7877

height of dam = $H_D = H_w + F.B = 78 + 2.4$

$\cancel{H_D = 79.8}$ m

$\boxed{HD = 80.4m}$

Now

$a = 14\%$ of HD

$a = 0.14 \times 80.4$

$\boxed{a = 11.26m}$

3) Base width 'b' (will out off set)

(i) For No Sliding Criteria

$$b' = \frac{H_w}{\mu G} = \frac{78}{0.7 \times 2.8} = 39.8 = b'$$

$\boxed{b' \cong 40m}$

(II) For No tension Criteria :

$$b' = \frac{H_w}{\sqrt{G}} = \frac{78}{\sqrt{2.8}}$$

$b' = 46.61$

$\boxed{b' \cong 47m}$

(8) ID = 7877

(4) Depth of vertical portion on u/s side

$$h' = 2a\sqrt{q - c_4}$$

$$h' = 2 \times 11.26\sqrt{2.8 - 0}$$

$$h' = 37.58\,m$$

$$\boxed{h' = 38\,m}$$

5) Upstream off set :

$$\text{upstream off set} = \frac{a}{16} = \frac{11.26}{16} = \boxed{0.70\,m}$$

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

$$U/s = 3.14a\sqrt{q}$$

$$U/s = 3.14 \times 11.26\sqrt{2.8}$$

$$\boxed{U/s = 59.16\,m}$$

7) Total width of the base of the dam.

$$b = b' - \frac{a}{16} = 47 + \frac{11.26}{16}$$

$$b = 47 + 0.70$$

$$\boxed{b = 47.70m}$$

8) $$\tan Q = \frac{b'}{H} \quad \frac{47}{78}$$

$$Q = \tan^{-1}(0.602)$$

$$Q = 31.05^\circ$$

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

$$\tan Q = \frac{a}{d'} = \frac{11.26}{d'}$$

$$\tan\varphi \times d' = 11.26$$

$$\tan(31.05) \times d' = 11.26$$

$$d' = \frac{11.26}{0.602}$$

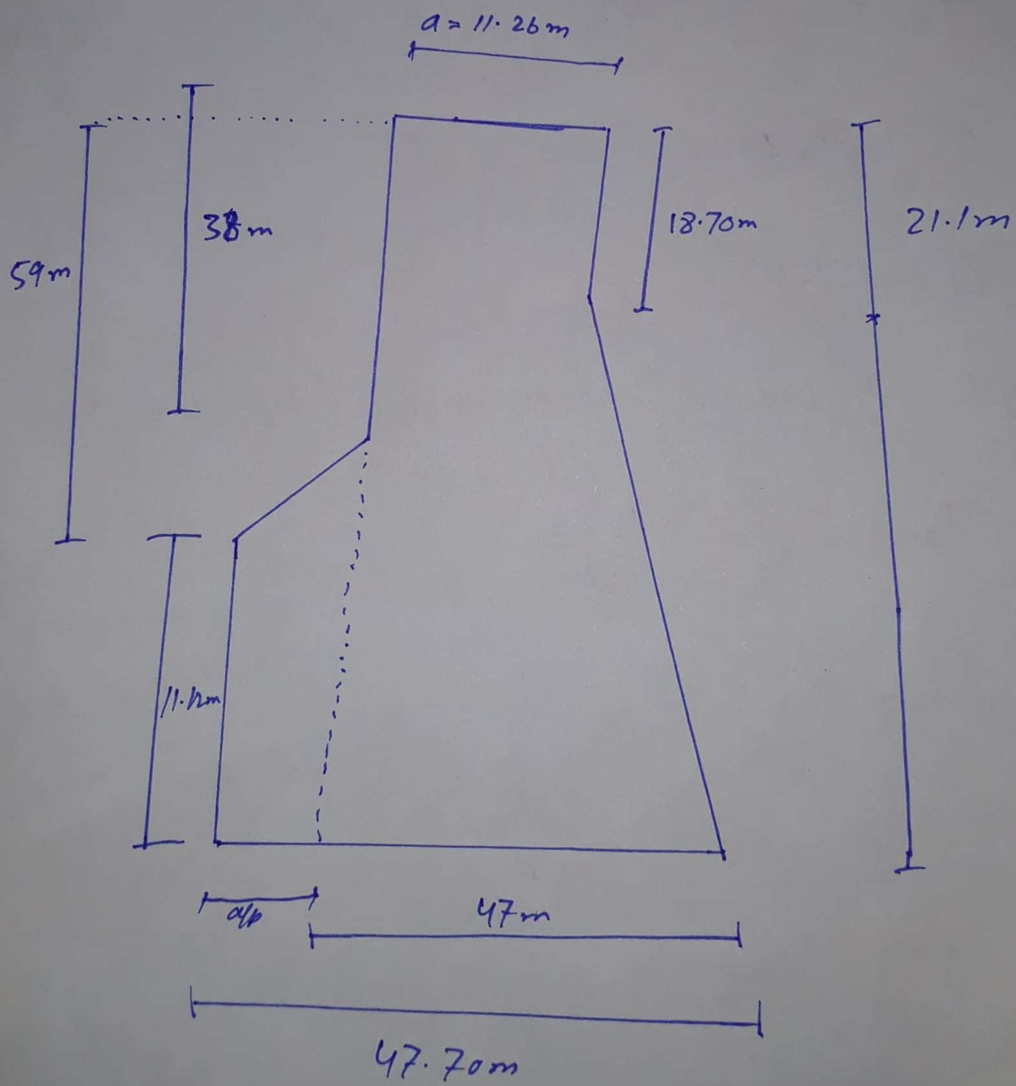
$$\boxed{d' = 18.70m}$$

(10) ID = 7877

depth of vertical portion:

$d = d' + F.B = 18.70 + 2.4$

$\boxed{d = 21.1m}$



QNo 3 ⇒ Using any hydraulic model and explain the concept of Dimensional. analysis and Similitude. E

Ans Dimensional Analysis and Simititude Analysis:

1 ▷ Background

* Althrough many particle engineering problem Involving Hydraulic enjineering Can be solved by Equation and Analytisal procedure, but yet a large number of problems relyon experimental data for their solution.

* In fact very few problems can be solved by only analytical procedure.

* In general, Solution is obtained through the use of a Combination of analysis and experimental data.

* An obvious goal of any experiment is to make the results widely applicable.

* To achieve this goal, the concept of Similitude is often used so that measurements made on one System (laboratory) can be used to describe the behavior of other system (out side of laboratory)

Dimensional Analysis

If certain physical phenomenon is governed by

$f(x_1, x_2 \ldots x_n) = 0$ where some/all of the variable (x) are dimensional

Then the above phenomena can be represented as

$\psi(\pi_1, \pi_2 \ldots \pi_m) = 0$ where all the variable (π) are non-dimencional

The nature of f and ψ may be obtained from experiment.

Buckingham Pi Theoram

$$f(x_1, x_2 \ldots x_n) = 0 \Rightarrow \psi(\pi_1, \pi_2 \ldots \pi_m) = 0$$

Where some/all x are dimensional

where all π are non-dimensional

Where $m < n$, $m = n - k$

Minimum number of fundamental dimensions Involved k

Example

$$f(v, g, h) = 0$$

$n = 3 \quad k = 2 \quad m = n - k = 3 - 2 = 1$

Pi Theoram: Repeating and non-repeating variables

$$(x_1, x_2 \ldots x_n) \Longrightarrow x_{r1}, x_{r2} \ldots x_{nr1}, x_{nr2} \ldots x_{nrm})$$

Construction of Pi-terms

Selection of repeating variable:

* They must be dimensionally Indepent.
* Togethe they must include all fundamental dimensions.

$$\pi_1 = x_{nr1} (x_{r1})^{a_{11}} (x_{r2})^{a_{12}} (x_{r3})^{a_{13}} \ldots\ldots (x_{rk})^{a_{1k}}$$

$$\pi_2 = x_{nr2} (x_{r1})^{a_{21}} (x_{r2})^{a_{22}} (x_{r3})^{a_{23}} \ldots\ldots (x_{rk})^{a_{2k}}$$

$$\pi_m = x_{nrm} (x_{r1})^{a_{m1}} (x_{r2})^{a_{m2}} (x_{r3})^{a_{m3}} \ldots\ldots (x_{rk})^{a_{mk}}$$

Advantages of dimensional analysis

$$f(v, g, h) = 0 \implies Fr = \omega(Fr/Re)$$

$$Fr = \frac{V}{\sqrt{gh}} \qquad \frac{Fr}{Re} = \frac{v}{\sqrt{gh^3}}$$

- Less number of experiments are necessary as opposed to the dimensional System.
- Experiments become Inexpensive
- Date reduction becomes easier, Single plot is sufficient to Show the resulte.

Conclution

One figures is enough, as opposed to many figures of dimensional system.

* Take size is irrelevent as long as our assumptions aren't violated.

The plot, developed from experiment in a smaller (model) tank may be used for similar bigger (prototype) tank.

Similitude

For the present case study

$$Fr = \omega\left(\frac{V}{\sqrt{gh^3}}\right)$$

Since the relation holds for similar model and prototype tanks

$$\text{if} \left(\frac{V}{\sqrt{gh^3}}\right)_{model} = \left(\frac{V}{\sqrt{gh^3}}\right)_{prototype}$$

$$\text{then } (Fr)_{model} = (Fr)_{prototype}$$

Model Studies (similitude)

Certain fluid mechinical phenomenon is governed by

$f(\pi_1, \pi_2 \dots \pi_n)$ where π_i are non-dimensional

When the model is similar to the prototype

$(\pi_i)_{mode} = (\pi_i)_{prototype}$, $i = 1, 2, \dots n)$

Complete similarity requires.

Geometric similarity + kinemetic similarity + Dynamic similarity.

16 17 ID = 7877

QNo4 ⇒ What will be the effect of sediment particle diameter, particle density, particle concentration particle shap, viscosity of water, turbulence of water flowing in reservoir on fall velocity? Explain:

Ans

Fall velocity

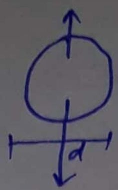
⇒ When a grain falls down in still water it obtains a constant velocity when the upward fluid drag force on the grain is equal to the grain. This constant velocity is define as the fall velocity, of the grain.

This is also called setting velocity

Fall velocity depende on

i) particle diameter
ii) particle density
iii) particle consentration
iv) particle shape
v) Viscosity of water (Temperature)
vi) Turbulence.

~~17~~ (18) ID: 7877



F_D = Drag Force

$\downarrow W_s$ = Fall velocity

Submerged weight

The Force balance between the drag Force and the Submerged weight gives

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

ρ = Density of water

ρ_s = Density of Sediment particle.

<u>Particle diameter</u>

$\Rightarrow$ The diameter of the particle is directly proportional to the fluid velocity, so it will ~~becom~~ ~~tendt~~ become greater the size of particle

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So, it will tends to the particle of small size thus there will be more gravitational force on particle of gravity size so it will fall quality due to it's weight.

Particle density

⇒ Particle density effect the settling fall velocity. As Air density increase with decreasing altitude at about 1% per 80 meter. (260ft) for every 180 meter of fall the ~~set~~ terminal speed decrease 1%.

Particle Concentration

⇒ When the suspended concentration of sediment increase, the setting velocity of each particle decrease due to the Indification of the flow Induced by previous particles.

Particle Shape =>

Particle having regulor shape tends to be effected more than Irrigular shap since regular shape particles have even surface which offers very littles or no friction while particles with smaller surface area are more likely to the effected due to their less resistance.

Viscosity of water =>

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