Universiti Malaysia PAHANG

HYDRAULICS

DIMENSIONAL ANALYSIS AND HYDRAULIC SIMILARITY

TOPIC 4.2

by

Nadiatul Adilah Ahmad Abdul Ghani
Faculty of Civil Engineering and Earth Resources
nadiatul@ump.edu.my

Universiti Malaysia PAHANG

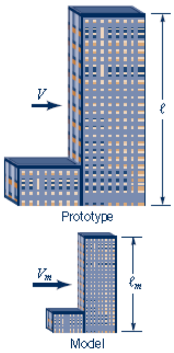
DIMENSIONAL ANALYSIS AND HYDRAULIC SIMILARITY

4.2

- Hydraulic Similarity

4.2 : HYDRAULIC SIMILARITY

4.2.1 : Hydraulic Scale Model



*A **model** is a representation of a physical system that may be used to predict the behavior of the system in some desired respect.*

The physical system for which the predictions are to be made is called the ***prototype.***

Universiti Malaysia PAHANG

a) Undistorted Model

Models which are geometrically similar to their prototypes.

❖ Linear dimensions (horizontal & vertical directions) are similar in ratios.

EXAMPLE 4.4 (Undistorted Method)

1. A model of spillway is constructed to a scale of 1:30 in a flume. The length of the spillway is 30m. If the discharge over the spillway at the head of 6m is 443.6m^3/s, calculate the corresponding head and discharge of the model required for this model study.

2. A dam 35m long is to discharge water at the rate of 114m^3/s under the head of 2.7m. Find the length of the model and head of water if the supply available in the laboratory is 30L/s.

b) Distorted Model

Models which are geometrically not similar to their prototypes.

- Linear dimensions (horizontal & vertical directions) are different in ratios.

EXAMPLE 4.5 (Distorted Method)

A diversion weir 240m long has discharging capacity of $250m^3/s$ under a head of 1.2m. A model of the weir is to be constructed in laboratory where the available channel is 3m wide and 500mm deep. Design the suitable model for the weir, if the water available in the laboratory is 25 L/s.

Communitising Technology

4.2.2 : Types of Similarity

a) Geometric Similarity

The ratio of the corresponding linear dimensions of a model and a prototype are equal:

$$L_r = L_m / L_p$$

Where:

L_r = length ratio

L_p = length prototype

L_m = length model

Communitising Technology

b) Kinematic Similarity

Similarity of motion in a model and prototype:

$$V_r = V_m / V_p$$

where :

V_r = velocity ratio
V_p = velocity prototype
V_m = velocity model

c) Dynamic Similarity

Similarity between forces in a model and prototype:

$$F_r = F_m / F_p$$

Where:

F_r = force ratio
F_p = force prototype
F_m = force model

EXAMPLE 4.6

A prototype of a volume of $1000m^3$ is investigated by a hydraulic model $1.0m^3$ in volume. If the length of the model is 2.25m, what is the length of the prototypes?

Solution:

$Vr = Lr^3 = Vm/ Vp = 1/1000$

Where Vr is the volume ratio of the model volume to the prototype volume. Therefore,

Lr = 1/10

Lr = Lm/ Lp = 2.25 /Lp

Lp = 2.25 x 10 = 22.5m

EXAMPLE 7.6 Reynolds Number Similarity

GIVEN Model tests are to be performed to study the flow through a large check valve having a 2-ft-diameter inlet and carrying water at a flowrate of 30 cfs as shown in Fig. E7.6a. The working fluid in the model is water at the same temperature as that in the prototype. Complete geometric similarity exists between model and prototype, and the model inlet diameter is 3 in.

FIND Determine the required flowrate in the model.

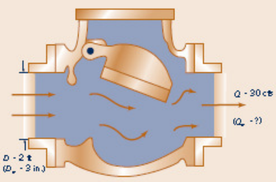


Figure E7.6a

SOLUTION

To ensure dynamic similarity, the model tests should be run so that

$$Re_m = Re$$

or

$$\frac{V_m D_m}{\nu_m} = \frac{VD}{\nu}$$

where V and D correspond to the inlet velocity and diameter, respectively. Since the same fluid is to be used in model and prototype, $\nu = \nu_m$ and therefore

$$\frac{V_m}{V} = \frac{D}{D_m}$$

The discharge, Q, is equal to VA, where A is the inlet area, so

$$\frac{Q_m}{Q} = \frac{V_m A_m}{VA} = \left(\frac{D}{D_m}\right)\frac{[(\pi/4)D_m^2]}{[(\pi/4)D^2]}$$
$$= \frac{D_m}{D}$$

and for the data given

$$Q_m = \frac{(3/12\text{ ft})}{(2\text{ ft})}(30\text{ ft}^3/\text{s})$$

$$Q_m = 3.75\text{ cfs} \qquad \textbf{(Ans)}$$

COMMENT As indicated by the foregoing analysis, to maintain Reynolds number similarity using the same fluid in model and prototype, the required velocity scale is inversely proportional to the length scale, that is, $V_m/V = (D_m/D)^{-1}$. This strong influence of the length scale on the velocity scale is shown in Fig. E7.6b. For this particular example, $D_m/D = 0.125$, and the corresponding velocity scale is 8 (see Fig. E7.6b). Thus, with the prototype velocity equal to $V = (30\text{ ft}^3/\text{s})/(\pi/4)(2\text{ ft})^2 = 9.50\text{ ft/s}$, the required model velocity is $V_m = 76.4\text{ ft/s}$. Although this is a relatively large velocity, it could be attained in a laboratory facility. It is to be noted that if we tried to use a smaller model, say one with $D = 1$ in., the required model velocity is 229 ft/s, a very high velocity that would be difficult to achieve. These results are indicative of one of the difficulties encountered in maintaining Reynolds number similarity—the required model velocities may be impractical to obtain.

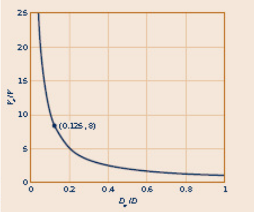


Figure E7.6b

Lecturer Information (Authors)

Pn. Nadiatul Adilah bt Ahmad Abdul Ghani
Dr Nor Azlina bt. Alias
Pn. Wafty bt. Abd Rahman
Dr. Jacqueline Isabella

Communitising Technology