FLOW MEASUREMENT AND ITS AUTOMATION OF HATHNIKUND BARRAGE USING PHYSICAL MODEL STUDIES

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ABSTRACT

A barrage constructed across a river comprises of the main diversion structure to control the river's water level and control its flow. Barrage Studies are conducted in a 2D, 1:50 geometrically similar scale model constructed in a 0.91 m wide flume wherein one full bay of spillway at center and part bays on both sides according to design available. The maximum and minimum discharge intensity for the spillway is 87.74 cum/s/m and 38.56 cum/s/m, their corresponding coefficient of discharge is 1.73 and 1.53 respectively. Similarly, the maximum and minimum discharge observed for the undersluice is intensity is 90.97 cum/s/m and 42.80 cum/s/m, their corresponding coefficient of discharge is 1.69 and 1.59 respectively same as we find out coefficient of discharge for various gate opening of design discharge intensity 3 cum/s/m to 22 cum/s/m is 0.61 to 0.68 respectively. These values of coefficient of discharge for different gates are incorporated in the SCADA System which facilitates control of barrage gates by PLC, telemetry, various flow measurement and water level measurement sensors. This project is a SCADA based Barrage gate control system which helps in keeping an eye on the operation and distribution of water resources from barrage for irrigation purposes and efficient operation of barrage gate according to the level of water. This proposed mechanism of barrage gate control reduces the water wastage and efficient usage of available water is ensured.

Keyword: - *Barrage, Undersluice, Spillway, Co-efficient of Discharge, SCADA and PLC*

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1. INTRODUCTION

A barrage constructed across a river comprises of the main diversion structure to raise the river's water level and control its flow. This project is a SCADA based Barrage gate control system which helps in keeping an eye on the operation and distribution of water resources from barrage for irrigation purposes and efficient operation of barrage gate (Vikas B. Rahangdale et. Al 2018). The hydraulic model is use to conduct studies on determination of coefficient of discharge and discharge capacity of sluice spillways bays with full and partial gate opening (Neena Isaac et.al 2012). The measurement of water flow can be calculated by using rectangular broad crested weir (Muhammad Bin Sahariz 2013). Now a days many problem that occurs in dam and barrage to avoid these problems some feasible measures required and need to apply a new technique of PLC and SCADA to operate gate efficiently(Makesh Iyer et. al). A monitored and controlled processes that are distributed among various remote sites by using SCADA system (Najm O. S. Alghazali et al.). The present study also has been done using hudraulic model, PLC and SCADA.

2. STUDY AREA

Hathnikund barrage constructed across a Yamuna river at Hathnikund in Yamuna district, Haryana state, India. The purpose of barrage are irrigation, water supply and flood control. The barrage covering a river reaches of 4.6 km upstream and 4.4 km downstream of Hathnikund hill.

Fig 1: Location Map of Hathnikund Barrage

3. AIM AND OBJECTIVES OF THE STUDY

To study the Flow Measurement and Stabilizing the value of coefficient of discharge of Hathnikund Barrage by using Physical Model and its automation of barrage gates.

1) To find out the discharge capacity of barrage gates.
2) To find out the discharge coefficient for entire range of discharges.
3) To determine coefficient of discharge for
a. Spillway Bays.
b. Under sluice Bays.
4) A gate regulation of barrage by using the SCADA.

4. THEORY AND METHDOLOGY

4.1 Barrage

A barrage is a type of low-head, diversion dam which consists of a number of large gates that can be opened or closed to control the amount of water passing through. This allows the structure to regulate and stabilize river water elevation upstream for use in irrigation and other systems.

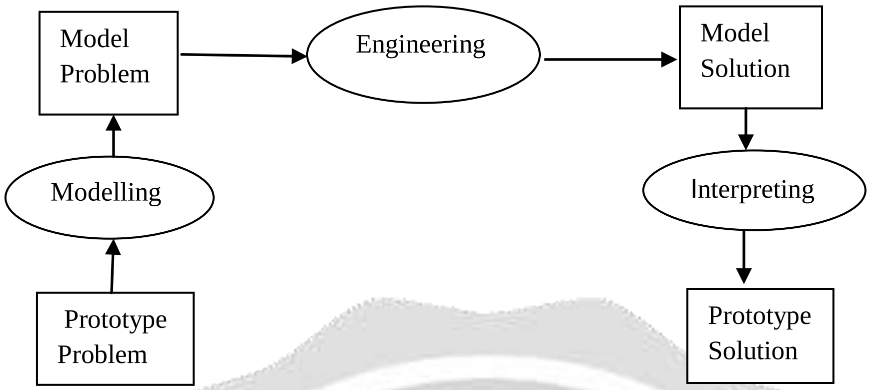
Table no.1 Froude Number and Reynolds Number

Froude Number (Fr):		**Reynolds Number (Re):**	
It is termed as a ratio square root of inertial and gravitational forces. $Fr = \frac{v}{\sqrt{gD}}$		It is termed as a ratio of inertial forces to viscous forces. $Re = \frac{\rho v L}{\mu} = \frac{vL}{\nu}$	
Froude number	**Flow type**	**Reynolds number**	**Flow type**
Fr = 1	Flow is critical if is equal to 1.0.	Re < 500	Flow is laminar flow.
Fr > 1	Greater than 1 means flow is supercritical.	Re = 500-2000	Flow is transition flow.
Fr < 1	If it is less than 1 means subcritical flow will occur.	Re > 2000	Flow is Turbulent Flow.

4.2. Development of Physical Models

The model studies for deciding the profile of the undersluice & barrage bays, length of downstream floors, shape of glacies, pier, energy dissipaters etc. are generally conducted on 2D geometrically similar scale models.

The general philosophy on the use of models is the same for scale models and numerical models.



These studies are conducted in a 2D model, 1:50 geometrically similar scale model constructed in a 0.91 m wide flume wherein one full span at center of flume with two adjacent part spans of the spillway and undersluice according to design available. In the model rigid portion of spillway and undersluice profile is produced in smooth cement plaster. Piers and gates is made from concrete and steel plates respectively. Upsteram and downstream concrete blocks and loose stone protection are not reproduced in the model according to prevalent practice followed for such studies. The study of the Hathnikund barrage will be conducted on 2D section model at scale of the 1:50. The model is based on Fraudian Criteria. The separate experiments would be conducted on models of

1. Spillway Bays. 2. Undersluice Bays.

4.3. Design Scale of Model

The design discharge of 20,000 cumec, subsequently was increased to 22,000 cumec, therefore the studies were performed for undersluice and spillway bays. The studies were conducted on a physical 3D river model constructed to horizontal scale of 1/150 and vertical scale of 1/50 and covering a reach of about 4.6 km upstream and 4.4 km downstream of the Hathnikund hill. The maximum discharge intensity for spillway and undersluice observed in the model was 87.74 cum/s/m and 90.97 cum/s/m respectively, which has been adopted for conducting the studies.
Maximum discharge intensity in prototype = 87.74 cum/s/m
General principle for hydraulic design,

Area, $\frac{A}{a} = \frac{B \times Y}{b \times y} = n \times n = n^2$

Velocity, $\frac{V}{v} = \frac{\sqrt{2gH}}{\sqrt{2gh}} = \sqrt{n} = n^{0.5}$

Discharge, $\frac{Q}{q} = \frac{A}{a} \times \frac{V}{v} = n^2 \times n^{0.5} = n^{2.5}$

Discharge intensity for model, $Q_{model} = \frac{Q_{proto}}{n^{0.5}}$

$$Q_{model} = \frac{87.74}{50^{0.5}} = 0.0049 \ \frac{cum}{s}/m$$

Manning's Formula

$V = \frac{1}{n} \times R^{2/3} \times S^{1/2}$………… a

$Q = A \times V$………………………… b

From eq. a and b, we get

$V = \frac{Q}{A} = \frac{1}{n} \times R^{2/3} \times S^{1/2}$……………… c

For wide rectangular channel R = y
Manning's coefficient n = 0.018 (for model)
Consider width of flume b = 0.91 m
Kinematic Viscosity, $\nu = 1 \times 10^{-6} m^2/s$
Slope s = 1/250
Area A = b × y
From eq. c, we get

$$\frac{0.0049}{y} = \frac{1}{n} \times R^{2/3} \times S^{1/2}$$

$$\frac{0.0049}{y} = \frac{1}{0.018} \times y^{2/3} \times (\frac{1}{250})^{1/2}$$

After solving above equation, we get
The value of y = 2.1 cm
Area A = 0.0182 m^2
Velocity V = 0.269 m/s

Froude number, Fr = $\frac{V}{\sqrt{gD}} = \frac{0.269}{\sqrt{9.81 \times 0.021}} = 0.61 < 1$

Hence flow is subcritical for Fr no. is less than 1
Gravitational flow is predominant.

Reynolds number, Re = $\frac{\rho v L}{\mu} = \frac{vL}{\nu} = \frac{0.269 \times 0.021}{10^{-6}}$

Re = 5649 > 2000

If Reynolds number greater than 2000, it is turbulent flow.

Hence all parameters are Safe. Therefore, assume scale 1:50 is Ok.

4.4 Observations

The C_d value for the fully gate opened as well as partial gate opening of spillways and undersluice found out for different discharge intensity.
For free flow condition = $C_d \times L \times H^{3/2}$ or q = $C_d \times H^{3/2}$

Where, Q = Discharge,
q = discharge intensity,
L = length of barrage,
H (Total Head) = h + h_a, h = head over crest,
h_a = velocity head ($V^2/2g$),
g = acceleration due to gravity.

1. Spillway

Table No. 1
Co-efficient of Discharge for Spillway Profile

Sr. No.	**Discharge Intensity in cum/s/m**	**Gate Opening in m**	**Water Level in m**		**Upstream head above crest including velocity head in m (H1)**	**Downstream head above crest including velocity head in m (H2)**	**Coefficient of Discharge**
			Up stream	**Down stream**			
1	87.74	Fully opened	340.92	336.37	13.68	7.749	1.73
2	38.56	………	337.57	333.67	8.602	4.052	1.52

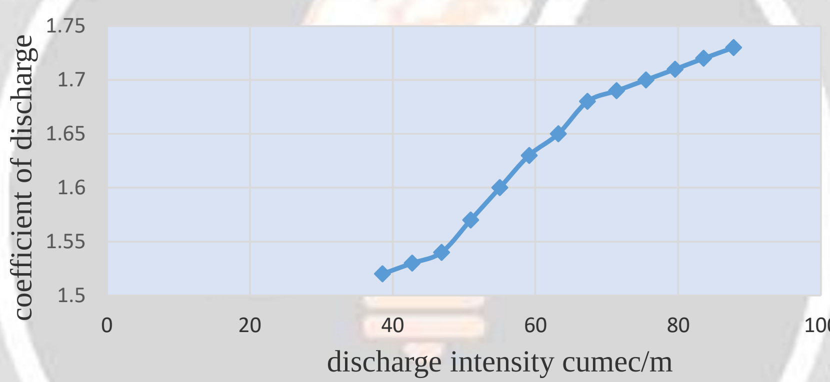


Chart no.1: Plot of Discharge Intensity Vs Coefficient of Discharge

Fig 1: Spillway Section of discharge intensity of 39 cum/s/m

Fig 2: Spillway Section of discharge intensity is 87.74 cum/s/m

2. Undersluice

Table no. 2
Coefficient of Discharge for Undersluice Profile

Sr. No.	Discharge Intensity in cum/s/m	Gate Opening in m	Water Level in m		Upstream head above crest including velocity head in m (H1)	Downstream head above crest including velocity head in m (H2)	Coefficient of Discharge
			Up stream	Down stream			
1	90.97	Fully opened	339.07	336.37	14.23	8.77	1.710
2	42.80	……	336.17	333.67	8.99	5.11	1.590

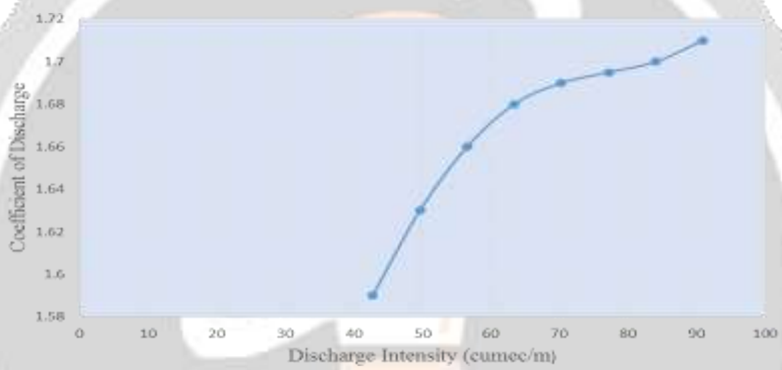


Chart no 2: Plot of Discharge Intensity Vs Coefficient of Discharge

Fig 3: Undersluice Section of discharge intensity is 43 cum/s/m

Fig 4: Undersluice Section of discharge intensity is 90.97 cum/s/m

Equation for calculation of coefficient discharge for barrage
For partial Gate Operation

$Q = C_d \times A \times \sqrt{2gH}$ or $q = C_d \times G_o \times \sqrt{2gH}$

Where, Q = Discharge,
q = discharge intensity,
L = length of barrage,

H (Total Head) = h + h_a,
h = head over crest,
h_a = velocity head ($V^2/2g$),
g = acceleration due to gravity,
C_d = Coefficient of discharge,
G_o = Gate opening,
A = Area of gate opening

Table no. 3
Gate openings observed in the model for various discharge intensities

Sr. No.	Q in cumec	q per unit cum/s/m	Upstream water level in m	Downstream water level in m	Gate opening in m	Total Head in m	Cd
1	167	3.00	334.32	329.00	0.5	5.10	0.610
2	2000	22.22	334.32	330.45	2.75	7.00	0.68

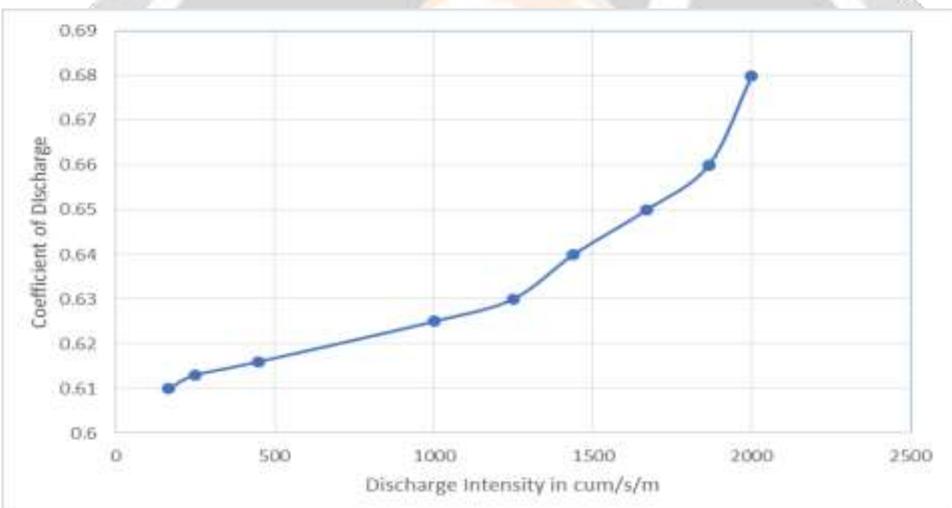


Chart no.3: Plot of Discharge Intensity Vs Coefficient of Discharge

Fig 3.11: Underslucie section of discharge intensity is 3 cum/s/m

Fig 3.12: Undersluice Section of discharge intensity is11 cum/s/m

4. AUTOMATION OF BARRAGE

A remote monitoring and control system interfacing with Supervisory Control and Data Acquisition (SCADA) system for the operation of 32 gates for Hathnikund Barrage, EYC and WYC head regulators. The control of Hathnikund barrage is organized through motorized vertical gates and gate opening/closure allows control of flows and barrage pond water level. SCADA shall provide an interactive HMI (Human Machine Interface), data communication for operation of 32 gates, hydraulic or otherwise of all operational details of Hathnikund Barrage in graphical and tabular forms. The PLCs (Programmable Logic Controllers) will control the regulating gates, collect and transmit sensor data to Barrage Control Room (BCR) and perform remote monitoring and automatic gate control functions. The coefficient of discharge for spillway and undersluice, upstream and downstream water level obtained in the 2D model are incorporated in SCADA System to operate barrage gates easily.

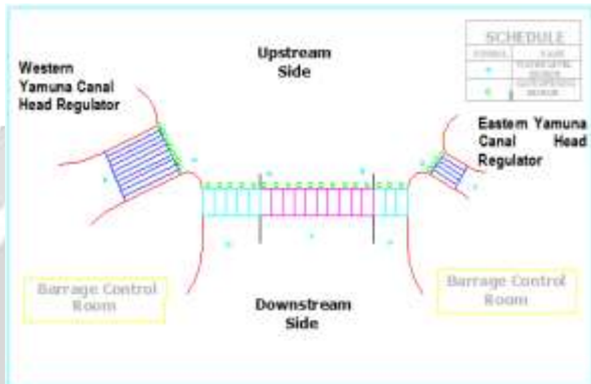


Fig 2: Schematic Representation of Barrage Gates

5. RESULTS AND DISCUSSION

1. The coefficient of discharge obtained in the model is 1.73 to 1.53 for design discharge intensities of 87.74 to 38.56 cum/s/m with the water level at upstream and downstream are 340.92 m and 336.37 m for spillway.
2. The coefficient of discharge obtained in the model is 1.69 to 1.59 for design discharge intensities of 90.97 to 42.80 cum/s/m with the water level at upstream and downstream are 339.07 m to 336.17 m for undersluice.
3. The coefficient of discharge obtained in the model for partial gate opening condition with maintaining pond level at 334.32 is 0.61 to 0.69.
4. It is observed that the discharge intensity increases same as the coefficient of discharge also increases.

6. CONCLUSIONS

1. Co-efficient of discharge adopted in the design for spillway and undersluice portion is in order.
2. The barrage gate regulation more gate opening in center of spillway and decreasing gate opening gradually towards the divide wall is suggested.
3. The model studies have indicated that there were no cross flows and vortex formation in vicinity of barrage.
4. A SCADA based Barrage gate control system which helps in keeping an eye on the operation and distribution of water resources from barrage for irrigation purposes and efficient operation of barrage gate according to the level of water.
5. It also helps in indicating about flood to people living in the surrounding.
6. This proposed mechanism of barrage gate control reduces the water wastage and efficient usage of available water is ensured.

6. REFERENCES

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