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Comparative Study of Ogee and Stepped Spillway for Enhancement of Energy Dissipation

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***Abstract*—The terminal structure of a spillway plays a major role in dissipating energy of excess flood to safeguard the downstream end of river channel .The ogee profile spillway is hydraulically more efficient to pass excess flood. Excess air entrainment causes positive pressure on spillway bed helpful to achieve maximum energy dissipation by replacing ogee profile with steps.The 2-D numerical model of ogee profile is validated with the results of physical model studies for various discharges using ANSYS software. This study shows that numerical tool like ANSYS are quite convenient to calculate velocities at the toe and at the ends sill. The 2-D numerical model of stepped profile is developed on ogee profile and model is simulated at design discharge and results are compared with the 2-D numerical model of ogee profile. For analysis purpose select weir with ogee profile to pass a design discharge up to 15700 m^3/s. In this project we have particularly used ANSYS fluent because we are concern with system's fluid dynamics. This paper represents that comparative study of ogee and stepped spillway for enhancement of energy dissipation**

Keywords*— *Ogee spillway, Stepped Spillway discharge, ANSYS, Energy Dissipation.

I. INTRODUCTION

The Spillway is a structure which is provided for the dam safely downstream side of the dam so as to discharge the excess flood to the downstream. Stepped spillway consists of series of steps which initiates at the crest of spillway and propagates downstream. The stepped spillways are being used commonly since ancient epoch because of considerable impact of steps on the energy dissipation caused by this spillway. But in the recent years, with the advent of new technologies like roller compact concrete and new manufacturing techniques for the concrete, innovations in the use of admixtures; the stepped spillways are more in use.

Generally, water is impounded on the upstream side of the dam which can be diverted for various purposes such as irrigation, hydropower generation. From practical and economic considerations it is necessary to pass down the excess water safely to the downstream of dam so as to avoid overtopping or damage to the dam. This is done with the help of spillways.

For spillways, roller buckets or trajectory buckets or hydraulic jump type stilling basins are used for dissipating the energy, but the stepped spillway provides an advantage over other spillways, as there is no additional energy dissipating devices are required.

The paper is organized as in methodology, Analysis and Design, numerical model results and its validation and Conclusion of paper.

II. METHODOLOGY

This section explains the methodology followed for experimentation. Important terms related to experimental synopsis and procedural flow charts are also the part of this section

A. Methodology

The 2-D numerical model of ogee profile is validated with the results of physical model studies for various discharges using ANSYS software. This study shows that numerical tool like ANSYS are quite convenient to calculate velocities at the toe of spillway and at the end sill.

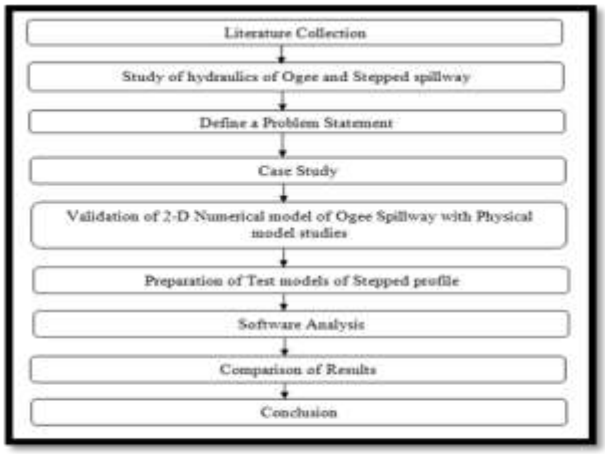

Fig. 1. Flow chart of study

The 2-D numerical model of stepped profile is developed on ogee profile and model is simulated at design discharge and results are compared with the 2-D numerical model of ogee profile. Fig.1 shows the flow chart of study.

B. Designing Steps

ANSYS is an advanced software which enables one to do all the engineering related simulations of problems related to fluid dynamics, chemical engineering, environmental engineering, hydrodynamics, metaphysics, electromagnetic, structural mechanics and so on.

Computational fluid dynamics (CFD) is a type of numerical modeling that is used to solve problems involving fluid flow. Since CFD can provide a faster and more economical solution than physical modeling, hydraulic engineers are interested in verifying the capability of CFD software. CFD gives an insight into flow patterns that are difficult, expensive or impossible to study using traditional physical modeling techniques. Literature shows successful comparisons between CFD and physical modeling. Although physical model studies may be more expensive and time consuming than computational modeling, they are still crucial for providing data for numerical model calibration and validation studies. The unique combination of computational expertise in physical flow modeling can be

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applied in concert to provide cost effective, practical solutions to flow problems.

The geometry for the stepped spillway has been created in the design modular of ANSYS workbench. In this research, a total of models has been created as there are 3 variants of discharge and 2 variants of step size. Slope of steps is 60 degree and angle of entry of water over the steps is kept 15 degrees with the horizontal. While creating the geometry, water and air both the fluids have been given their respective inlets. This is necessary in open channel flows as without defining the interface between the two different fluids computations cannot be carried out.

The basic procedure of the analysis is as follows:

1. The geometry and physical boundaries decided first with the help of Computer Aided Design (CAD). After that the data is suitably processed and fluid volume is extracted.

2. The volume occupied by the fluid is divided into discrete a cell that is mesh. The mesh may be uniform or non-uniform, structured or unstructured, consisting of a combination of hexahedral, tetrahedral, prismatic elements.

3. The physical modeling is defined by the equations of fluid motion.

4. The boundary conditions are defined which involves the fluid behaviour and properties at all boundary surfaces.

5. The simulation is started and then the equations are solved with the help of iterations as a steady state and transient.

6. Save the results..

C. Study Area

The present study is done on model of Weir with ogee profile to pass discharge of 15700 m^3/s, 8496m^3/s, 5640m^3/s, 2832m^3/s respectively.

III. ANALYSIS AND DESIGN

In this Section the detail discussion regarding design steps and its different variant is done. In this study, the analysis of Ogee and Stepped spillway with various discharge has been done using ANSYS fluent. The fluid simulation analysis is divided into 3 parts

- Pre-processing
- Meshing
- Post-Processing

Fig 1 shows weir profile for pre-processing.

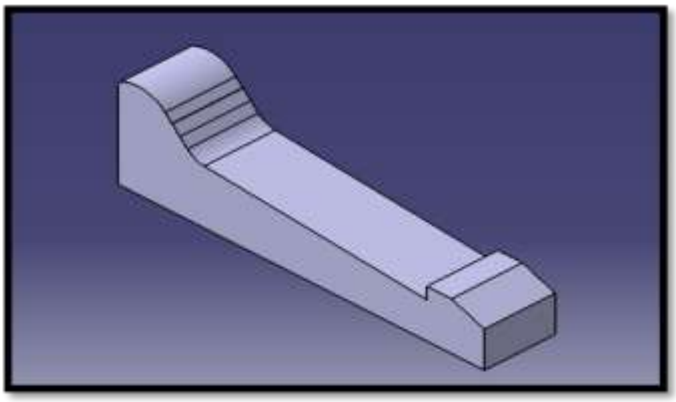

Fig. 1. Weir profile for Pre-processing

Fig 2 shows Meshing pattern of the model.

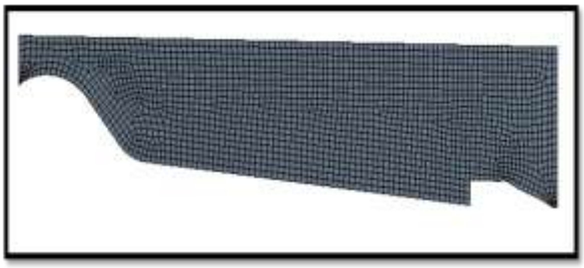

Fig. 2. Meshing pattern of the model

Fig 3 shows post- processing model of weir.

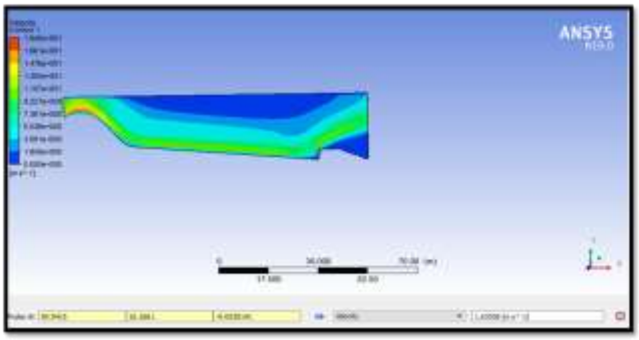

Fig. 3. Post-processing model of weir

Input velocity for different discharge are given in following table. table 1 shows input velocities for various discharges.

TABLE I. Input Velocities For Various Discharges

Discharge in m^3/s	**Input Velocity in m/s**
15700	10.6
8496	7.9
5640	7.3
2832	3.8

IV. NUMERICAL MODEL RESULT AND ITS VALIDATION

Numerical simulations were performed on 2-D model of ogee profile for various discharges. The 2D numerical model was validated with the results of physical model studies. Table II shows comparison of velocities in physical and numerical model at end sill. Table III shows comparison of velocities in physical and numerical model of ogee profile at toe.

TABLE II. Comparison of Velocities in Physical and Numerical Model at end sill.

Sr. No.	**Discharge m^3/s**	**Velocities at End Sill m/s**	
		Physical Model	**Numerical Model**

1	**15700**	1.51	1.6

TABLE III. Comparison of Velocities in Physical and Numerical Model of Ogee profile at toe

Sr. No.	Discharge in m^3/s	Velocities at Toe m/s	
		Physical Model	ANSYS Model
1	15700	15.6	15.8
2	8496	17.8	17.7
3	5640	17.5	17.4
4	2832	16.9	15.8

Overall the results obtained from numerical model were in good agreement with physical model

A. *Comparison of Velocities Numerical Models of Ogee And Stepped Spillway*

Numerical simulation were performed on 2-D model of stepped profile with different number of steps and results are compared with numerical ogee model. Velocities at the downstream of stepped profile model for 10 and 12 steps found to be considerably reduced as compare to 8 steps model. It is conclude that with increasing the number of steps, velocity get reduced.

Numerical simulations were performed on 2-D model of stepped spillway for a designed of 15700 m^3/s and results are compared with 2-D model of ogee profile. Table no IV shows Comparison of velocities of numerical models of ogee and stepped profile at end sill.

TABLE IV. Comparison of Velocities of Numerical Models of Ogee and Stepped Profile at End Sill

Sr. No.	Discharge value in m^3/s	Velocity at End Sill m/s	
		Ogee Spillway	Stepped Spillway
1	15700	1.6	0.4

TABLE V. Comparison of Velocities of Numerical Models of Ogee and Stepped Profile at Toe.

Sr. No.	Discharge value in m^3/s	Velocity at Toe m/s	
		Ogee Spillway	Stepped Spillway
1	**15700**	15.8	7.8

From the simulation velocity at the toe of stepped profile is found to be considerably getting reduced as compared to ogee profile .Hence it is concluded that stepped profile is dissipated 50% more energy than ogee profile.

V. Conclusion

For spillways, roller buckets or trajectory buckets or hydraulic jump type stilling basins are used for dissipating the energy, but the stepped spillway provides an advantage over other spillways, as there is no additional energy dissipating devices are required

Numerical simulation were carried out on ogee profile and compared with physical model studies. Then stepped spillway with various number of steps was again simulated and compared with ogee profile using ANSYS software.

For discharge of 15700 m^3/s, observed velocity at the end sill in physical model of ogee profile is 1.5 m/s and observed velocity in 2 D numerical model of ogee profile is 1.6 m/s which is nearly same as of physical model.

For discharge of 15700 m^3/s, observed velocity at the toe in a physical model of ogee profile is 15.6 m/s and velocities for discharges of 8496 m^3/s, 5640 m^3/s and 2832 m^3/s are 17.8 m/s, 17.5 m/s and 16.9 m/s respectively. Observed velocities in 2 D numerical models of ogee profile for same discharges are 15.8 m/s, 17.7 m/s, 17.4 m/s and 15.8 m/s respectively. Which is nearly same of physical model. Overall the results obtained from numerical model were in good agreement with physical models.

For discharge of 15700 m^3/s, observed velocity at the end sill in 2 D numerical model of ogee profile is 1.6 m/s and observed velocity in 2 D numerical model of stepped profile is 0.4 m/s.

for discharge of 15700 m^3/s, observed velocity at the at the toe in 2 D numerical model of ogee profile is 15.8 m/s and observed velocity in 2 D numerical model of stepped profile is 7.8 m/s which is less than observed velocity of ogee profile. Hence, Stepped profile dissipates 50% more energy than Ogee profile.

The above experimental results shows significant improvement in energy dissipation in stepped spillways, there is no need of additional energy dissipation devices. For higher discharges stepped spillway is performing but nappe flow not visible with given step size. For lower discharges stepped spillway is performing well.

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