Check for Effect of Number and Height of Steps with Different Flow Conditions on Energy Dissipation for Stepped Spillway

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Abstract - *The spillways provide controlled releases of surplus water in excess of the reservoir capacity. Stepped spillway is one such spillway where hydraulic energy in terms of head of water is dissipated by distributing this total head into number of heads in terms of steps. In this study the effect of number and height of steps on energy dissipation is studied. For this 2 different flow condition is used for experimentation. In this study an attempt has been made to prepare 3 models. Model A is with 7 steps having step height 2 cm, Model B is with 4 steps having 4 cm, Model C with 4 steps having 4 cm height and with end sill that have quarter circle shape at step edges. From observations of experimentations it is found that Model C (4 steps with end sills) shows improved energy dissipation in case of full flow. Model B (4 steps with regular shape) shows improved energy dissipation in case of partial flow. Model C with 4 steps of 4 cm height with end sill gives a better performance than model B with 4 steps of 4 cm with regular shape.*

Key Words: *step spillway, number of steps, Flow conditions.*

1. INTRODUCTION

To prevent damages to the structure in the downstream of dam the design of hydraulic structure must be check by doing hydraulic model studies. This hydraulic model studies includes the flow characteristics study and also behaviour of different parts of prototype by comparing it with model. This comparison is based on dimensional analysis.

Stepped spillway is a type of spillway with continuous steps of various sizes from crest to the toe of the spillway. The steps increase significantly the rate of energy dissipation along the chute and reduce the size of the energy dissipator downstream. The hydraulics of stepped spillway is complex than the conventional spillway due to two flow regimes i.e. nappe flow and skimming flow. Generally, the application of stepped spillway is limited to dam heights up to 40 m with discharge intensity up to $30m^3/s/m$.

Many researchers have studied geometry effects of steps on energy dissipation. According to Sorensen (1985), the discharge, slope of spillway, geometry of steps, the steps number are the parameters on which energy dissipation in spillway depends. Chinnarasri and Wongwises (2006) studied flow characteristics and energy dissipation factors by studying the impact of changes in the geometry for steps. High efficiency in terms of energy dissipation ratio was found in spillways containing steps with end sills. Hunt et al. (2009) concluded that as step height increases there is increase in energy dissipation. To prevent damages to the structure in the downstream of dam the design of hydraulic structure must be check by doing hydraulic model studies. This hydraulic model studies includes the flow characteristics study and also behaviour of different parts of prototype by comparing it with model. This comparison is based on dimensional analysis.

2. EXPERIMENTAL METHODOLOGY

2.1 Apparatus

In the present study experimentation work is carried out at fluid mechanics lab of civil engineering department of Pimpri Chinchwad College of engineering Pune. The flume used in this study is of length 500cm, 25cm in depth, 7.5cm width. The maximum flow rate range is 150(l/min), to control and regulate tail water and hydraulic jump at downstream there is sluice gates. Tank provided with capacity of 16 L capacity. The pump used in this experiment to pump the water with flow rate of (10 l/min to 150 l/min). The point gauges are used to measure the water depth. The location of models is at 100 cm from the inlet point.

2.2 Flow conditions

Two flow conditions used for given study work which are as follows:

1) Partial flow- In which the discharge controlling knob is rotated 6 times anticlockwise to reduce the flow while knob can be fully opened at 8 times anticlockwise rotations.

2) Full flow- In which discharge controlling knob is open fully with 8 anticlockwise rotations.

2.3 Specifications of models

3 models are used for the given study work. The description models are as follows:

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All 3 models have same width-7.5cm, height-15cm, and length- 36 cm. For all models downstream slope is 22.6º.

Model A-

Length – 36 cm

Width – 7.6 cm

Height – 15 cm

No of steps – 7

Step height – 2 cm

Shape of step -Regular

Type of material – Plywood

Model B

Length – 36 cm

Width – 7.6 cm

Height – 15 cm

No of steps – 4

Step height – 4 cm

Shape of step – Regular

Type of material – Plywood

Model C

Length – 36 cm

Width – 7.6 cm

Height – 15 cm

No of steps – 4

Step height – 4 cm

Shape of step – with end sills.

Type of material – Plywood

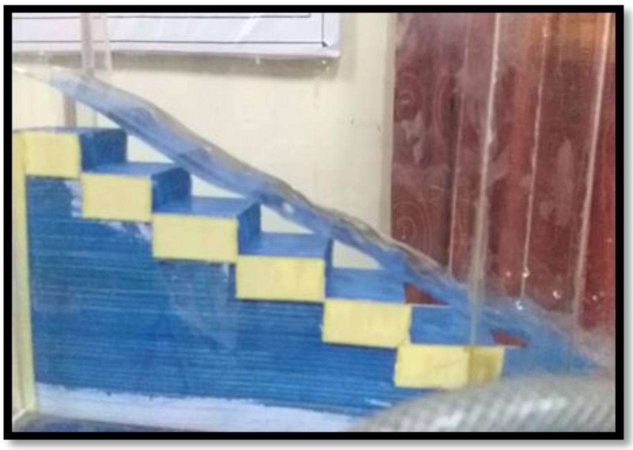


Figure 1 – Model A

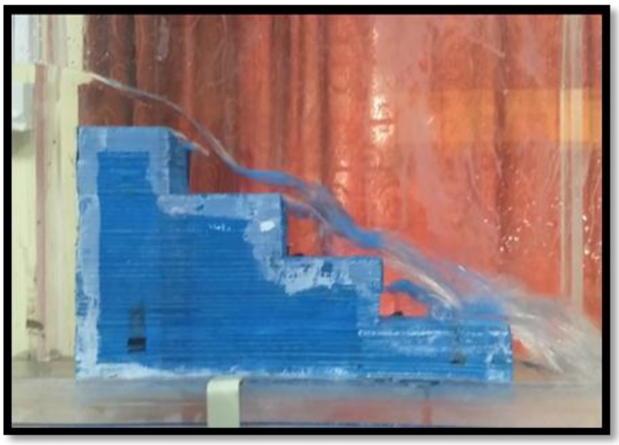


Figure 2 – Model B

Figure 3 – Model C

3. OBSERVATION TABLE

3.1 Nature of flow: Partial flow

Model	H (cm)	h_a (cm)	y_1 (cm)	Width (B) (cm)	Volume (Litre)	Time (sec)
A	15	2	1.4	7.6	16	18.02
B	15	3.6	1.7	7.6	16	17.12
C	15	3.1	1.7	7.6	16	17.07

Table 1: Partial Flow

3.2 Nature of flow: Full Flow

Model	H (cm)	h_a (cm)	y_1 (cm)	Width (B) (cm)	Volume (Liter)	Time (sec)
A	15	3.1	1.8	7.6	16	16.45
B	15	3.6	2	7.6	16	16.89
C	15	3.1	1.4	7.6	16	16.12

Table 2: Full Flow

4. QUANTITATIVE METHODOLOGY

The main aim of present study is to determine the effect of geometry of steps on energy dissipation process of steeped spillway. The E_a is the energy in upstream of models which is calculated by:

$$E_a = H + E_c = H + \sqrt[3]{\frac{q_a^2}{g}}$$

Energy at crest of spillway is denoted by E_c, H is the elevation up to crest of model, acceleration due to gravity is denoted by g which is equal to 9.81 m/s², h_a is the height of water over the crest and q_a is the intensity of discharge per unit width. E_b is the energy at downstream which is calculated by the following formula:

$$E_b = H_0 + \alpha \frac{V_b^2}{2g}$$

H_0 is the invert elevation of downstream which is in our case is zero, V_b is the velocity of flow of water at toe of spillway model, α=1.1 which is observed by boes and hager (2003).

Difference in energy between upstream and downstream is denoted by $\Delta E = E_d$. The energy dissipation efficiency is calculated by:

$$\% \frac{Ed}{Ea} = \frac{Ea - Eb}{Ea}$$

5. RESULTS AND ANALYSIS

5.1 Nature of flow: Partial Flow

Model	V1 (m/s)	V2 (m/s)	E1 (m)	E2 (m)	ΔE (m)	$\% \frac{Ed}{Ea}$
A	0.069	0.835	0.17	0.0495	0.12	70.51
B	0.066	0.724	0.19	0.043	0.14	76.88
C	0.069	0.726	0.18	0.0437	0.137	75.69

Table 3: Calculation for Partial Flow

5.2 Nature of flow: Full Flow

Model	V1 (m/s)	V2 (m/s)	E1 (m)	E2 (m)	Δ E (m)	$\% \frac{Ed}{Ea}$
A	0.071	0.71	0.18	0.044	0.14	75.80
B	0.070	0.94	0.19	0.058	0.13	68.82
C	0.069	0.62	0.18	0.040	0.14	78.01

Table 4: calculation for Full Flow

5.3 Results

The Table 5 gives values of percentage energy dissipation efficiency for all 3 models with 2 different flow conditions.

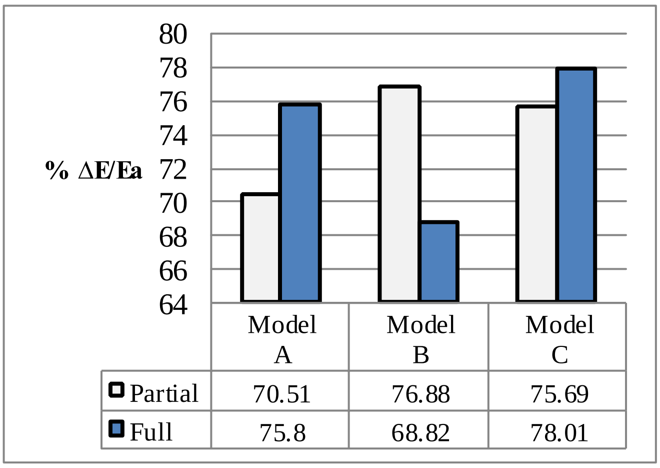
1) In model A which is of 7 steps with 2cm height of single step gives percentage of energy efficiency 75.80% for full flow and 70.51% for partial flow condition.

2) In model B which is of 4 steps with 4cm height of single step gives percentage of energy efficiency 68.82% for full flow and 76.88% for partial flow condition.

3) In model C which is of 4 steps with 4cm height of single step gives percentage of energy efficiency 78.01% for full flow and 75.69% for partial flow condition.

Model	Flow condition	ΔE (m)	$\% \frac{Ed}{Ea}$
A	Full discharge	0.1372	75.80
	Partial discharge	0.120	70.51
B	Full discharge	0.128	68.82
	Partial discharge	0.143	76.88
C	Full discharge	0.1412	78.01
	Partial discharge	0.137	75.69

Table 5: Energy Dissipation Efficiency



Graph 1: Comparison for Energy Dissipation Efficiency in model A, B, C

6. CONCLUSIONS

The conclusions obtained from results are:

1) Model C (4 steps with end sills) shows improved energy dissipation in case of full flow.

2) Model B (4 steps with regular shape) shows improved energy dissipation in case of partial flow.

3) Model C with 4 steps of 4 cm height with end sill gives a better performance than model B with 4 steps of 4 cm with regular shape.

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8. REFERENCES

1. Boes, R & Hager, W. Hydraulic design of stepped spillways, Journal of hydraulic Engineering, 129(9), 2003, pp. 671-679

2. Chanson, H. comparison of energy dissipation between nappe and skimming flow regimes on stepped chutes, journal of hydraulic research. 32 (2), 1994, pp. 213-218

3. Chinnarasri, C, & Wongwises, S. Flow patterns and energy dissipation over various stepped chutes, journal of irrigation and drainage engineering, 132(1), 2006, pp. 70 76

4. Hunt, S, & Kadavy, K. 'The effect of step height on energy dissipation in stepped spillways', In World Environmental and water resources congress 2009: Great Rivers (pp. 3061-3071), ASCE.

5. Udai A. Jahad, Riyadh Al-Ameri, Subrat Das. 'Energy Dissipation and geometry effects over stepped spillways', International Journal of Civil Engineering and Technology (IJCIET), Volume 7, Issue 4, July – August 2016, pp.188-198,