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Development of Working Model for Ogee Profile Spillway Using Steps and Roller Bucket for Enhancement of Energy Dissipation

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***Abstract*— The terminal structure of a spillway plays a major role in dissipating specific energy of excess flood to safeguard the river channel and downstream structure. The ogee profile spillway is hydraulically efficient, structurally stable and more adequate to dispose excess flood effectively on downstream end of river channel. This spillway will be helpful to control the erosion, scouring and pondage if suitable energy dissipater provided at terminal structure. Due to high discharge of excess flood there are chances of causing erosion on Spillway bed, which is a major problem to affect the spillway capacity. Excess air entrainment causes positive pressure on spillway bed and helpful to achieve maximum energy dissipation by replacing ogee profile by steps. Therefore the above problems are rectified by developing the working model on ogee spillway with consideration of combined effects of steps and roller bucket etc. In this present research the experiments are performed in a range of discharge 0.0052-0.0063 m3/s with different devices on developed model at 4 – 6.5 m head etc. It is observed that the ogee spillway with combination of plain roller bucket, steps and stilling basin device achieved 80.24 % energy dissipation and maintained 0.23 m tail water depth in stilling basin with Froude number 5.53.Therefore it is concluded that this device is found to be best suitable energy dissipating device to overcome the spillway problems by enhancing maximum energy dissipation.**

Keywords: - Ogee spillway, terminal structure, roller bucket, steps and energy dissipation etc.

I. INTRODUCTION

In ogee spillways the hydraulic jump type of stilling basin is generally preferred as an energy dissipater but it requires the longer span and creates the problems like scouring, erosion due to high amount of specific energy generated at toe portion of spillway.Roller bucket is another option of energy dissipation but it has the limitations. The movement of roller that mixes with incoming flow results in dissipation of energy and prevents the scouring. It requires also sufficient tail water depth for functioning effectively and need to maintain the tail water depth in a range of 1.1 to 1.4 time's sequent depth and preferred if Froude number is greater than 4.5. The stepped spillway is also more prominent and its steps act as roughness elements to reduce flow acceleration and terminal velocity. The reduced velocity and the cushioning effect of the entrained air thus reduce the cavitation's potential. There is now increasing interest and broad scope in finding ways to bridge gap by providing suitable energy dissipating devices at terminal structure to overcome the erosion and scouring problems in ogee spillway. In this present research the attempt has been made to identify effect of stepsand roller bucket utilized to overcome the scouring and erosion in ogee spillway.

Energy dissipation devices dissipate the kinetic energy of excess flood with the help of effective devices at the toe portion of spillway. It helps to obtain uniform flow at the downstream side of river also minimizes the erosion damage at the downstream end. To normalize the velocity distribution on spillway there is a need of suitable energy dissipation devices. Many failures of dams have been reported due to inadequate capacity or improper design of spillway. It improves the project with the ability to release excess or flood water in a controlled or uncontrolled manner to ensure the safety of the dam. To avoid the overturning of the dam. It is of paramount importance for the spillway facilities to be designed with sufficient capacity to avoid overtopping of the dam, especially when an earth fill or rock fill type of dam is selected for the project. Spillway is a

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hydraulic structure used to release water on a regular basis for water supply, hydroelectricity generation etc. Spillways are provided with energy dissipation devices (e.g. Stepped spillway, Stilling Basin, Chute blocks, Buckets, Friction Blocks, End Sill) for dissipation of energy arising out of change in energy level upstream and downstream of the structure. The present research is highly emphasis on utilization of combined effects of steps and roller bucket combinable at terminal structure of ogee spillway. Henceforth the model has been designed and developed with a scale of 1:33.33 for ogee spillway.

II. OBJECTIVES

• To study the problems with the existing ogee spillway and identified suitable energy dissipating device.
• To develop a working model of ogee spillway with combination of steps and roller bucket etc.
• To compare the results obtained from the experiments with different discharges and heads.
• To identify the best energy dissipating device for ogee spillway to rectify the existing problem by enhancing maximum energy dissipation.

III. METHODOLOGY

The following methods are usually adopted for energy dissipation in spillway:-

- By formation of hydraulic jump at the downstream portion of spillway
- The use of various types of roller buckets (Plain and Slotted)
- Jet Diffusion and free jet stilling basin
    a) Jet diffusion Basin
    b) Free jet stilling basin
    c) Impact stilling basin
    d) Hump stilling basin
- Intersecting jet and other special type of stilling basin

3.1 Development of Working Model

The design model is in scale 1:33.33 compared to actual design. Materials used for model are Foam sheet, Acrylic sheet of 6mm diameter, PVC sheet etc. Also the model joining material Lambi. The scale ratio of 1:1 of Auto-Cad sheet of Spillway profile of ratio 1:33.33 was provided for marking on foam sheet. Model cross-section cutting was done according to design sheet. Then the steps were made of foam sheet according design of rise and tread were 12 in numbers. Once the step profile got done we moved towards Ogee profile which was to be made from PVC sheet as per the design. The whole set up of profile is joined with the help of Lambi as sticking material. For no leakage criteria Acrylic sheet was joined to whole set up of spillway model which was cut with the help of cutter especially used for Acrylic sheets and foam sheet. A 0.3 m length barrier is provided front of energy dissipater at distance of 1 feet. Also 0.3m length Acrylic sheet is extended from crest height for non-ricocheting flow of water. At Equal distances of 4.5cm for ogee profile the pressure tubes brass holes of 6mm diameter were inserted. Total 20 pressure taps are marked on whole spillway. On middle part of tread of stepped spillway the pressure taps are created. Also for head measurement we pasted the measuring Ruler at short intervals. Dimensions of developed model are shown in following fig 3.2, table 3.1 and 3.2.

Fig.3.1Working Model of stepped spillway

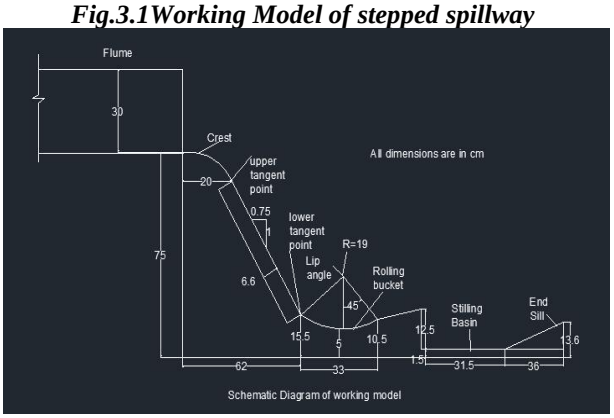

Fig.3.2 Dimensionsof working model

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Table 3.1 Dimensional Analysis

Sr.No	Description	Prototype (Khadakwasla Dam)	Model
Geometrical Similarities			
1	Crest Width (B)	10 m	0.3 m
2	Height (H)	23.75 m	0.7625 m
3	Length (L)	15.73 m	0.472 m
Kinematic Similarities			
1	Velocity (V)	0.586 m/s	0.1013 m/s
2	Discharge (Q)	2700 m^3/s	0.418 m^3/s
3	Head (H)	4.29 m	0.128 m(theoretical)

Table 3.2 Dimensional Analysis for Rolling Bucket

Description	Prototype	Model
R= P/4 Width & Spacing = 0.05R	= 5.93 = 0.05x5.93 = 0.296 ≈ 0.3	= 0.178 = $9x10^{-3m}$
Width at Bottom = 0.125R Width at Top= 0.05 R	= 0.125x5.93 = 0.74 = 0.3	= 0.022 m = $9x10^{-3}$m
Distance from depression = 0.5 R	= 2.96	= 0.088 m

3.2 Location of Hydraulic Jump

By performing experiment on working model with different heads the hydraulic jump has been located as shown in following tables

Table 3.3:-Location of Hydraulic Jump

Sr. No.	Description	Location Of Jump	
		Model (M)	Prototype (M)
For 6.5m Head			
1.	Step Set -01	0.85	28.30
2.	Step Set -02	0.83	27.66
For 4m Head			
1.	Step Set -01	0.79	26.33
2.	Step Set -02	0.77	25.66

Table 3.4:-Dimensions of Stepped Profile Spillway

Sr. No	Particulars	Dimensions	
		Set 01	Set 02
1	Length of Block	63cm	63cm
2	Width of Block	30cm	30cm
3	Thickness of Block	6.5cm	6.5cm
4	Rise of Steps	4cm	4.5cm
5	Tread of Steps	3.3cm	5cm
6	No. of Steps	12	9

IV. RESULTS AND DISCUSSION

The experiments are performed with a discharge in range of 0.0052 to 0.0064m3/s.The results of all devices are compared with specific energy and their energy dissipation values. The obtained results with ED and TEL are shown in table 4.1 and table 4.2.

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Table 4.1:- Comparison TEL for Ogee and Stepped Spillway for 4m head

Tapping distance cm	Ogee spillway (OS)	Stepped Spillway (SS)	
		Set 01	Set 02
	TEL m	TEL m	TEL m
23.5	0.695	0.6825	0.682
27.5	0.643	0.6139	0.613
38.5	0.499	0.49	0.495
65	0.195	0.1753	0.177
73	0.255	0.2497	0.250
99	0.245	0.236	0.238
118	0.19	0.2328	0.234
147.5	0.215	0.2392	0.239
156	0.237	0.2375	0.237

Table 4.2:- Comparison ED for Ogee and Stepped Spillway for 4m head

Tapping distance cm	Ogee spillway (OS)	Stepped Spillway (SS)	
		Set 01	Set 02
	ED %	ED %	ED %
23.5	12.68	14.25	14.32
27.5	19.22	22.87	22.99
38.5	37.31	38.44	38.44
65	75.50	77.97	**78.01**
73	67.96	68.63	68.71
99	69.22	70.35	70.35
118	76.13	70.75	70.85
147.5	72.99	69.95	69.97
156	69.45	70.16	70.22

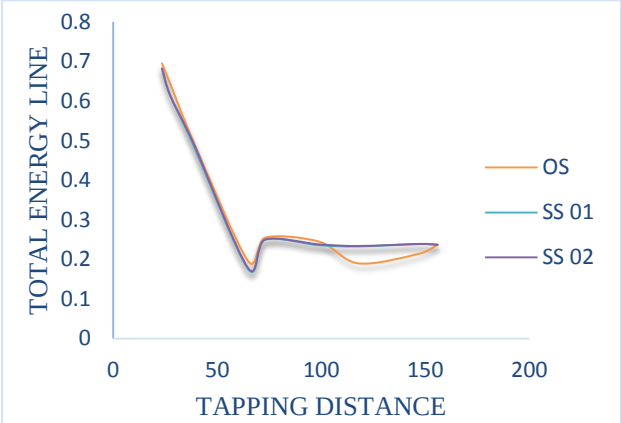

Fig. 4.1:- Comparison for TEL of Ogee and Stepped Profile Spillway for 4m head

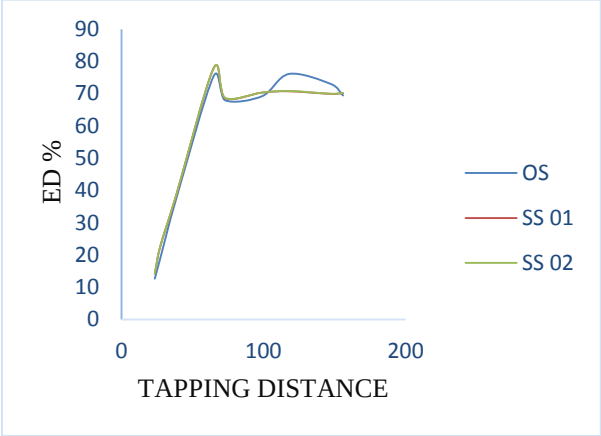

Fig 4.2:- Comparison for % Dissipation of Ogee and Stepped Profile Spillway for 4m head

Findings:

• T.E.L for spillway with ogee profile is 0.195 which is more over stepped profile spillway as 0.177 at tap distance 65 cm.

• % ED for spillway with steps is 78.01 which is more over ogee profile spillway as 75.5 at tap distance 65 cm.

• Spillway with steps shows better result over ogee profile spillway up to tap distance 65 cm.

Table 4.3:- Comparison TEL for Ogee and Stepped Spillway for 6.5m head

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Table 4.3:- Comparison TEL for Ogee and Stepped Spillway for 6.5m head

Tapping distance cm	Ogee spillway (OS)	Stepped Spillway (SS)	
		Set 01	Set 02
	ED %	ED %	ED %
23.5	6.73	12.36	12.36
27.5	10.67	22.32	21.32
38.5	34.05	31.16	37.16
65	68.61	**77.32**	**77.23**
73	67.59	63.72	63.72
99	67.21	64.94	64.94
118	68.23	65.65	65.65
147.5	67.59	65.00	65.00
156	66.05	63.53	63.53

Table 4.4:- Comparison ED for Ogee and Stepped Spillway for 6.5m head

Tapping distance cm	Ogee spillway (OS)	Stepped Spillway (SS)	
		Set 01	Set 02
	TEL (m)	TEL (m)	TEL (m)
23.5	0.734	0.688	0.688
27.5	0.703	0.619	0.619
38.5	0.519	0.495	0.495
65	0.247	0.179	0.179
73	0.255	0.286	0.286
99	0.258	0.276	0.276
118	0.25	0.271	0.27
147.5	0.255	0.275	0.275
156	0.267	0.287	0.287

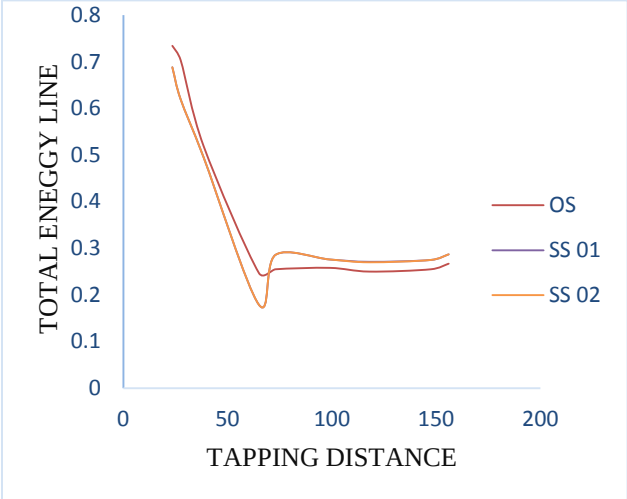

Fig 4.3:- Comparison for TEL of Ogee and Stepped Profile SpillwayFor 6.5m head

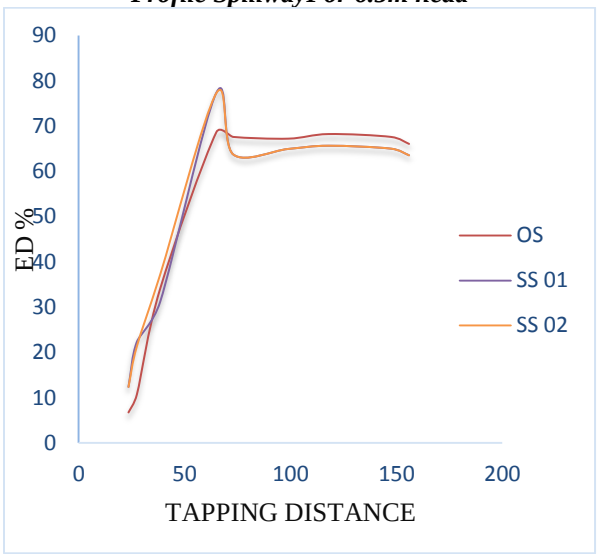

Fig 4.4 Comparison for % Dissipation of Ogee and Stepped Profile Spillway for 6.5m head

Findings -

• T.E.L for spillway with ogee profile is 0.247 which is more over stepped profile spillway as 0.179 at tap distance 65 cm.

• % ED for spillway with steps is 77.23 which is more over ogee profile spillway as 68.61 at tap distance 65 cm.

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• Spillway with steps shows better result over ogee profile spillway up to tap distance 65 cm

V. CONCLUSION

In this model the functions of roller bucket can be achieved effectively by raising the level of tail water in stilling basin by retaining flow backwith V Notch, which is helpful to achieve favorable condition for roller bucket. Due to provision of steps the intensity of velocity is reduced and the load of energy dissipation on roller bucket is automatically reduced.The energy dissipation is observed throughout its profile and finally achieved in stilling basin. It is observed that the energy dissipation is increases with decrease in step numbers and discharge value. The energy dissipation is increases with increase in length of steps and achieved the best results with the non-dimensional parameter (yc/h) upto 0.8.Therefore by consideration of above results with different models for different heads, it is found that stepped spillway with stilling basin for V notch up condition achieved the maximum energy dissipation. Therefore it is concluded that the ogee spillway with combination of plain roller bucket and stilling basin model (set 02) found to be the best suitable model for ogee profile stepped spillway.

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