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EXPERIMENTAL INVESTIGATION OF AN OGEE STEPPED SPILLWAY WITH PLAIN AND SLOTTED ROLLER BUCKET FOR ENERGY DISSIPATION

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ABSTRACT

Terminal structure of an ogee spillway plays a major role in dissipating specific energy of surplus water. Release of water from crest to toe of spillway creates high intensity of kinetic energy. This will cause scour and erosion on downstream face of spillway. In the past various types of energy dissipaters have been recommended for ogee spillway but they have limitations of energy dissipation, scouring and erosion problems. Therefore the need arises to provide a suitable energy dissipater to reduce intensity of kinetic energy and safely discharge surplus water at its downstream end. In this research, an attempt has been made to develop a physical model of an ogee profile stepped spillway for Khadakwasla dam with plain and slotted roller bucket as an energy dissipater. Laboratory experiments were performed for a design discharge with varying heads considering four combinations of ogee profile stepped spillway with plain and slotted roller bucket. It is found that the combination of stepped spillway with slotted roller bucket model (SSRB) at 6 m head dissipates specific energy (83.36 %), which is highest among all the combinations.

Key words: Ogee spillway, Stepped spillway, Roller bucket, Energy dissipation.

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1. INTRODUCTION

Terminal structure of an ogee spillway plays a major role to dissipate specific energy effectively and discharges flood safely on its downstream end. When water falls from higher head to lower head, it creates high amount of kinetic energy at the foot of spillway and hence need arises to dissipate energy effectively otherwise it will create scouring, erosion on its chute surface (*Ashiq and Sattar*, 2010). The hydraulic jump type II stilling basin is generally used as an energy dissipater for ogee spillway. The size of stilling basin is decided on the basis of Froude number, length of jump and height of jump. But it requires longer span (*Tung & Mayhannel*, 1982). *Sorensen et al.,* (1985, 2004), found that stepped spillway is a better option to minimize the intensity of kinetic energy on its profile itself. The steps of spillway act as roughness elements to reduce flow acceleration and terminal velocity. Moreover excessive turbulence can be induced by increasing the number of steps to enhance the development of a boundary layer and cause the entrainment of air to bulk the flow. Both the reduced velocity and the cushioning effect of the entrained air reduce the cavitations' potential. (*Sorensen*, 1985) *Chatiola & Jurdi,* (2004) conducted experiments on various step configurations for stepped spillway and achieved optimum amount of energy dissipation for design head less than 1.4 $H_{d.}$ *Chanson* (1994), *Chamani and Rajaratnam,* (1999) and *Chaft et al.,*(2010) studied the nappe flow for stepped spillway and observed that non dimensional parameter (dc/h) required less than 0.8.

It is seen that roller bucket is the best energy dissipater to alter flow regime condition in ogee spillway for attainment of maximum energy dissipation on its profile itself (IS 7365-2010). *Bhosekar, et al.,* (2012) investigated plain and slotted roller bucket model for Teesta low dam and Omkareshwar dam spillway. The study revealed that the performance of roller bucket was not satisfactory for the entire range of discharges, as the surface and ground rollers were not forming properly. Design charts given in IS 7365 - 2010 has many limitations and were not applicable for discharge intensity more than 50 m^3/s/m. As per the guidelines given by CDO, Nashik ; The roller bucket requires the sufficient tail water depth for functioning effectively in a range of 1.1 to 1.4 times sequent depth. Also the lip level of roller bucket should be kept higher than the bed level of stilling basin for preventing entry of bed material on its bucket surface (IS 7365-2010).

In this present research an attempt has been made to optimize the energy dissipation for the combined effects of step, plain roller bucket and slotted roller bucket for ogee spillway by developing physical model at a head of 4m & 6m etc.

2. MATERIAL AND METHODS

A physical model of ogee & stepped spillway was developed for Khadakwasla dam located in Pune, Maharashtra (India). Ogee spillway with plain and slotted roller bucket was designed with a scale of 1:33.33 on the basis of IS 6943 (1998), IS 7365-2010 and WES Profile. The invert level of roller bucket was kept above level of stilling basin for preventing entry of back material on bucket surface (*Ashiq and Sattar*, 2010). The model was fabricated by using foam sheet, acrylic sheet of 6 mm thick and PVC sheet. Acrylic sheet was extended by 0.3 m height from chute surface of model and provided on both sides for guiding flow towards downstream end of spillway. The piezometer taps were provided at an interval of 4.5 cm along its chute surface with brass holes of 6 mm diameter. Twenty piezometer's were installed on each pressure taps for measurement of static heads. Stepped spillway was designed on basis of non dimensional parameter $d_c/h = 2.5$, which shows that the entire surface is effective for energy dissipation (*Chatila & Jurdi*, 2004, *Hassan, et al.,* 2014).

2.1. Dimensional Analysis

The model study of ogee spillway was designed on the basis of Froude model law and with following assumptions.

- The head of water over the crest of ogee spillway is greater than 1.4 times design head (*Chatila & Jurdi*, 2004).

- Roller bucket is kept under submergence with tail water depth in the range of sequent depth.
- Roller bucket is designed for sound hard rock in the river bed.
- Froude number is greater than 4.5 for plain and slotted roller bucket.

The dimensions of model spillway are as follows; i) crest width 0.30 m, crest height (P) 0.76 m, crest length 0.47 m, downstream slope 0.75:1. ii) Kinematic similarities as velocity (V) 0.10 m/s, discharge (Q) 0.41 m^3/s, maximum design head (H) 0.13 m etc. The dimension of plain and slotted roller bucket is based on design of Grand Coulee and Angostura Dam in USA. Which includes radius of bucket (R) 0.18 m, bucket lip angle 45°, location of slots at a distance of 0.088 m from its tip end, width and spacing of slots 0.009 m. The dimensions of model are shown in Fig.1.

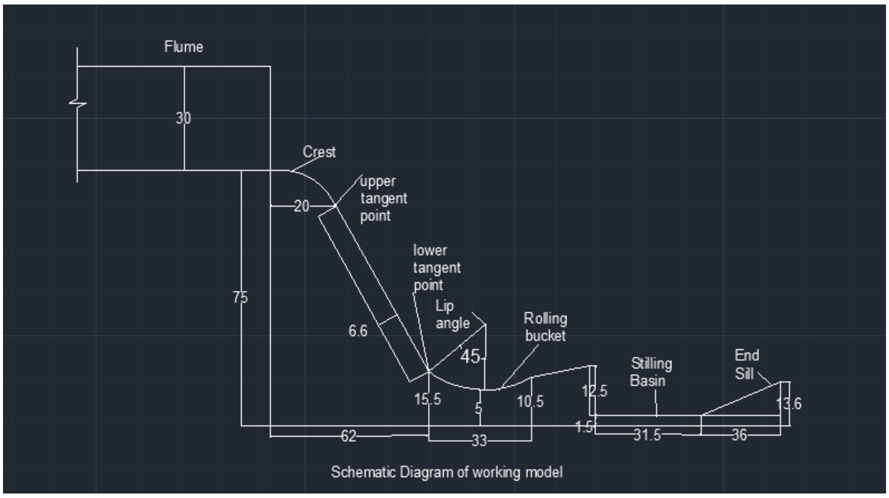

Figure 1 Typical cross section of an ogee profile spillway model

2.2. Experimentation

The experiments were conducted for different models in Fluid Mechanics laboratory of AISSMS's COE, Pune. The experiments were performed for four alternatives *namely;* i) ogee spillway with plain roller bucket (OPRB) model, ii) ogee spillway with slotted roller bucket (OSRB) model, iii) stepped spillway with plain roller bucket (SPRB) model and iv) stepped spillway with slotted roller bucket (SSRB) model. The experiments were performed in a 6 m long, 300 mm wide and 300 mm deep hydraulic flume for discharge range 0.0052 to 0.0063 m^3/s. The experiments were performed with 4m and 6m head resp. The discharge of water in flume was measured by using orifice meter and a kept horizontal for all observations. The head over the profile surface of model were measured by using pressure taps provided along the chute surface at an interval of 4.5 cm, as shown in Fig.2. The gross head of pumped water at 3 HP over the crest of model was measured by using pressure gauge attached to the flume. The plain bucket, slotted bucket and steps were interchangeable for 4 m and 6 m head.

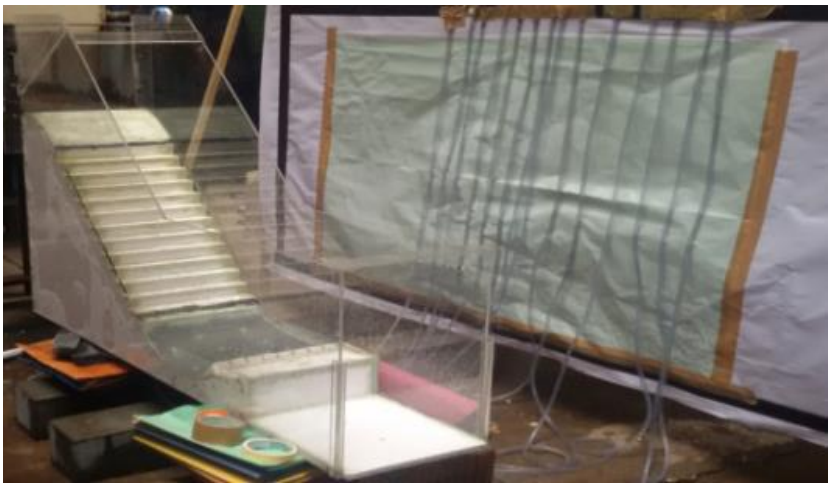

Figure 2 Experimental setup of ogee profile stepped spillway in laboratory

3. RESULTS AND DISCUSSIONS

The specific energy and energy dissipation are compared for OPRB, OSRB, SPRB and SSRB models at 4m & 6m head etc.

3.1. Specific Energy for Ogee and Stepped Spillway at 4 m Head

The specific energy for ogee and stepped spillway with all models at a head of 4 m are shown in Fig.3.

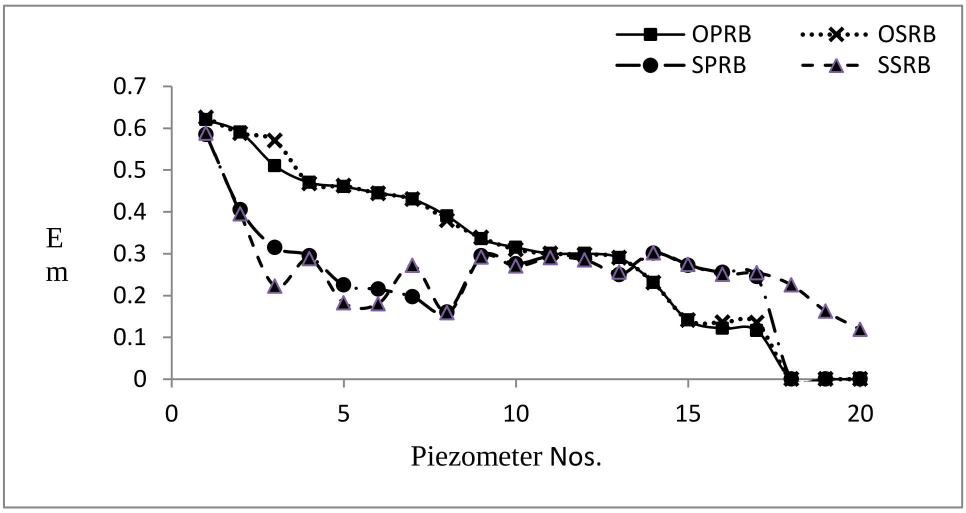

Figure 3 Graph of specific energy distribution at 4m head for all models

The Fig.3 shows that the specific energy obtained by ogee spillway for OPRB model and OSRB model is 0.62 m and reduces by 0.11m, 0.13m respectively at its downstream end of roller bucket. Whereas in stepped spillway the specific energy obtained for SPRB model and SSRB model is 0.58 m at its crest and reduces by 0.24 m towards toe of spillway. It is seen that in ogee spillway, there is 82 % reduction in specific energy obtained by OPRB model and 78 % by OSRB model. Whereas in stepped spillway 58 % reduction in specific energy obtained by SPRB model and 57 % by SSRB model. The specific energy in SPRB model and SSRB model is reduced due to formation of boundary layer below the lower tangent point on profile.

3.2. Specific Energy for Ogee and Stepped Spillway at 6 m Head

The specific energy for ogee spillway and stepped spillway with all models at a head of 6m are shown in Fig.4.

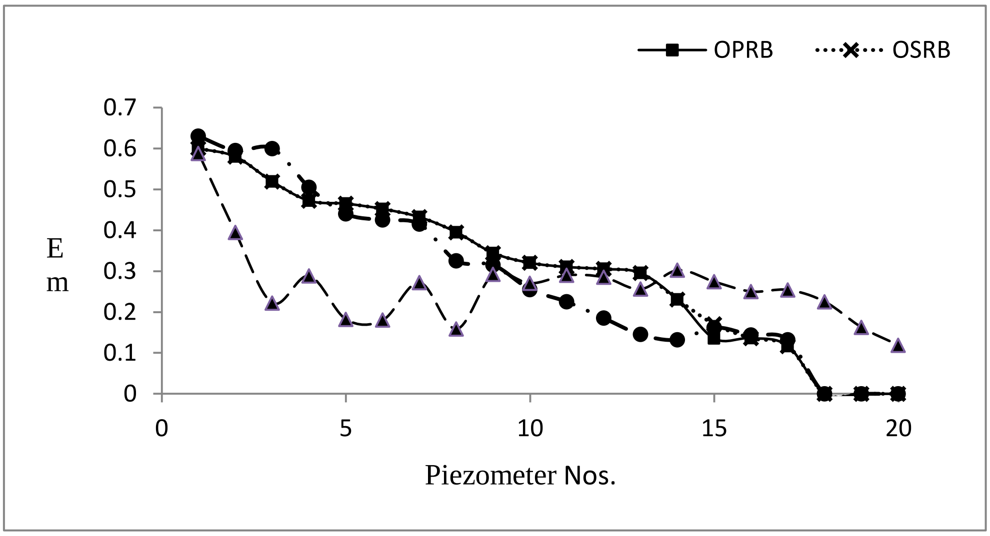

Figure 4 Graph of specific energy distribution at 6m head for all models

The Fig.4 shows that in ogee spillway specific energy obtained by OPRB model and OSRB model is 0.60 m at its crest and reduces by 0.11m for both models over the surface of roller bucket. Whereas in stepped spillway specific energy obtained by SPRB model is 0.63 m and by SSRB model is 0.58 m. The specific energy for SPRB & SSRB model reduces by 0.13m & 0.25 m resp. at lower tangent point of spillway. It is observed that in ogee spillway 79 % of specific energy is reduced by OPRB model and 82 % by OSRB model. However in stepped spillway 79 % of specific energy is reduced by SSPB model and 57 % by SSRB model.

3.3. Energy Dissipation for ogee and stepped spillway at 4 m head

The energy dissipation for ogee and stepped spillway with all models at a head of 4m are shown in Fig.5.

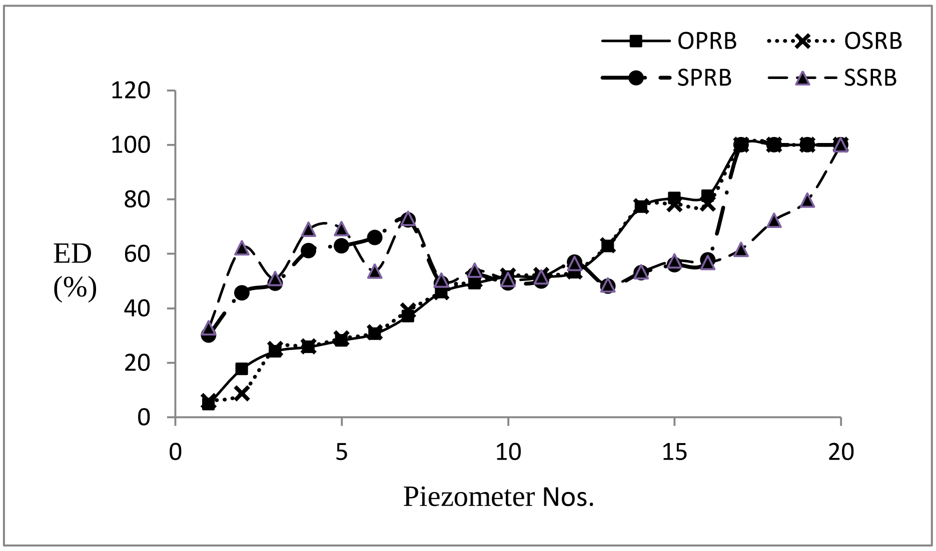

Figure 5 Graph of Energy Dissipation at 4 m head for all models

The Fig. 5 shows that energy dissipation (ED) observed by SPRB model and SSRB model of stepped spillway initiates with 32 % from its crest and 79 % over the surface of roller bucket itself. The energy dissipation is increased by SPRB model due to the provision of roller bucket. It is observed that OPRB model of ogee spillway dissipates maximum (81.26 %) specific energy at head of 4m.

3.4. Energy Dissipation for Ogee and Stepped Spillway with all Models at 6 m Head

Energy dissipation for ogee and stepped spillway with all models at head of 6m head are shown in Fig. 6.

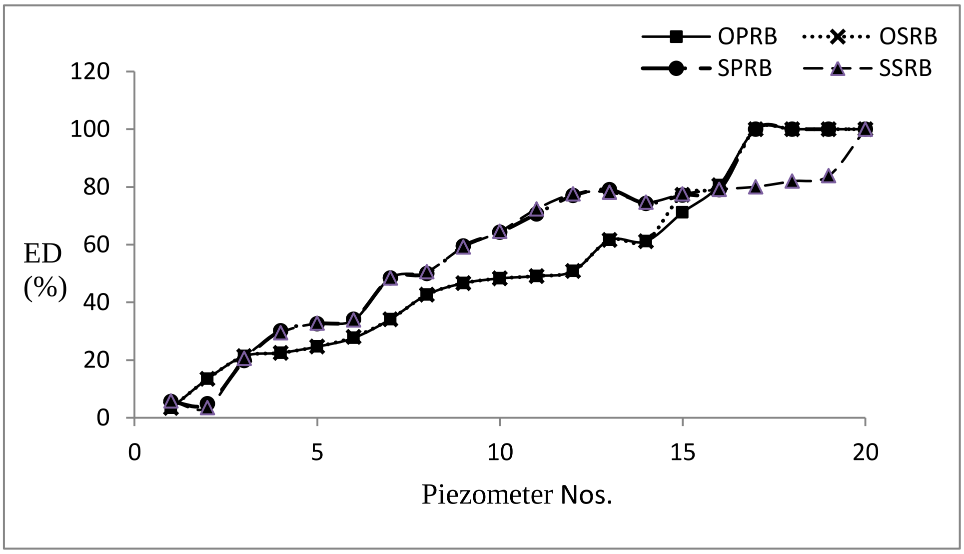

Figure 6 Graph of Energy Dissipation at 6 m head for all models

It is observed that SSRB model of stepped spillway shows better performance. The ED by SSRB model of stepped spillway is observed 65 to 80 % from its lower tangent point to lower face of roller bucket at a 6 m head. However in ogee spillway OPRB model and OSRB model dissipates 80 % of energy and observed at downstream side of roller bucket. The SSRB model of stepped spillway dissipates maximum (83.36 %) specific energy on its profile surfaces itself at 6 m head.

4. CONCLUSIONS

The present research reveals that the performance of all models for ogee and stepped spillway is compared with 4m and 6m head. It is observed that at lower head of 4m ogee spillway with plain roller bucket (OPRB) dissipates 80 % of specific energy for discharge 0.0052 m^3/s and for higher head of 6m stepped spillway with slotted roller bucket (SSRB) dissipates 83.36 % of specific energy for discharge 0.0062 m^3/s. Therefore it is concluded that stepped spillway with slotted roller bucket model (SSRB) can be considered a suitable energy dissipating model for Khadakwasla dam.

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