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HYDRAULIC JUMP TYPE ENERGY DISSIPATOR FOR SONURLE M.I. TANK

HINGE G. A.[1], JADHAV Y. S.[2], KULKARNI V. S.[2], SAUDAGAR N. N.[2], DEVARDE R. S.[2], DHURGUDE S.R.[2]

1. Head OF Civil Department, TSSM'S BHIVARABAI SAWANT COLLEGE OF ENGINEERING AND RESEARCH, NARHE, PUNE.
2. STUDENT, B. E. CIVIL, TSSM'S BHIVARABAI SAWANT COLLEGE OF ENGINEERING AND RESEARCH, NARHE, PUNE.

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Abstract: Design of stilling basins is a very vital issue in the field of hydraulic engineering and has wide applications in water resources sector. Present study leads to a new design of hydraulic jump type stilling basin for tail water deficiency. Due to inadequate tail water depth the jump has tendency to sweep out of the basin. The present project is undertaken to design stilling basin for Sonurle M.I. tank in Kolhapur district. It consists of an earthen dam with an ogee spillway on left flank. As per the provisions of codes, stilling basins are designed for design discharge of spillway, therefore at low discharges it produces either submerged or swept out jump. Further this tends to create damages to stilling basin, tail channel and other hydraulic structures. The design technique proposed here ensures formation of clear hydraulic jump within the stilling basin for all discharges, including discharges lower than designed discharge. The design is validated with the help of model study based on Froude's model law. For experimental verification of the weir performance, a sectional model (scale 1:50) of spillway and an innovative design of stilling basin are constructed. The model study has rendered satisfactory results as the jumps were located near toe of spillway for all discharges and percentage energy dissipation ranged between 60% to 70%. Thus it was concluded that the proposed design of stilling basin is hydraulically more efficient than the existing one. Also the proposed design recommends increase in elevation of stilling basin slab by 2.84 m and hence it is going to be economical.

Keywords: Energy Dissipation, Hydrolic Jump, Stilling Basin

Corresponding Author: MR. HINGE G.A.

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INTRODUCTION

For energy dissipation in stilling basins, forced hydraulic jumps are formed with the assistance of baffles and/or sill with or without sub critical tail water [1]. The maximum energy dissipation occurs when a free hydraulic jump forms near the toe of ogee spillway or front of jump coincides with the section where the supercritical pre jump depth is minimum [2], [3]. The required length of apron depends upon the length and location of the jump (for design discharge condition) which in turndepends on the pre jump depth (y1) and the relative

Authors would like to convey their gratitude to BSCOER for providing experimental facilities and the Superintending Engineer of Irrigation Department, Kolhapur, for supplying the data. Dr. G. A. Hinge is Professor and Head of Civil Engg. Dept., BSCOER, Pune, India (e-mail: gahinge@rediffmail.com) and project guide of final year undergraduate students who are other coauthors. Magnitudes of required post jump depth (y2) and available tail water depth (yt) [4], [5].In a rectangular stilling basin with horizontal slope, a front of hydraulic jump occurs at a location where the sequent depths satisfy Belanger momentum equation [6], [7]. In case of tail water deficiency condition, the tail water rating curve lies below the jump height curve for all discharges and the hydraulic jump may partially or fully sweep out of the basin. This may prove to be dangerous from the safety point of view of stilling basin, tail channel and other hydraulic structures [8], [9]. In present practice, rise in y2 is achieved either by depressing the apron or by constructing a rectangular broad crested weir at the end of the apron [10], [11]. The depth of depression or the height of weir is designed for design discharge of spillway.

Thus at flood discharges lower than design discharge, a drowned or submerged jump is formed. The deleterious effects of drowned jump are well known [12]. To address this problem, a rectangular broad crested stepped weir geometry that would assure formation of free jump near toe of spillway for the design discharge as well as for the lower discharges is developed.

PROBLEM STATEMENT AND PROPOSED SOLUTION

For appropriate location of hydraulic jump inside the apron for all operating conditions with reference to varying discharges and the corresponding tail water depths few researchers who have tried in past have not taken corresponding tail water submergences (Sr) into consideration [12], [13]. A proposed stepped weir design involves two aspects. As shown in Fig.3, for any cumulative discharge Qn, $y2 = y' + h$. The widths of individual steps should be such that the summation of particular discharges contributed by individual steps under consideration should be equal to cumulative discharge.

DESIGN METHODOLOGY AND EXPERIMENTS

Assumptions

1. Stilling basin is rectangular and prismatic with horizontal slope.
2. Flow is steady and head on upstream of spillway (H) is constant.
3. Spillway is either ungated or the gate opening is uniform.
4. Discharge conditions are varying. (Variation up to 20% of design discharge).
5. Coefficient of discharge Cd remains constant.

Project Site Details

The data is obtained from Irrigation Department. At Sonurle M.I. Tank (refer Fig.1.), there is an acute tail water deficiency on account of steep slope in the tail channel portion. Therefore the stepped weir is designed as per the guidelines given by Hinge et al [14].

Experimentation

The physical model study is carried out by using Froude's model law with a scale of 1:50. Considering the discharge facility available in the laboratory, the 1/3rd width of spillway is reproduced. The experimental setup is fabricated in perspex and the existing water recirculation facility in fluid mechanics laboratory is connected to it. Fig.2. shows various details of the setup.

Table I shows various parameters pertaining to prototype and model. Table II gives the geometry of weir in terms of rise and tread of various steps. The stepped weir performance is judged from the ability of weir to form free hydraulic jumps near toe of spillway from Qmin to Qmax.

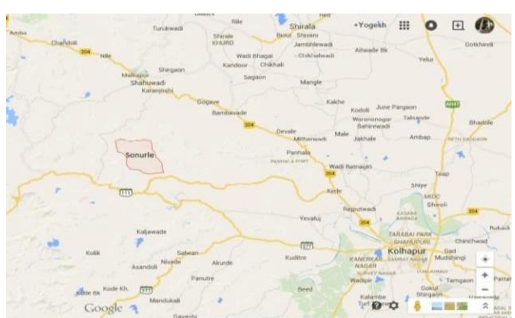

Fig.1. Location map of Sonurle M.I. Tank, Kolhapur

The observed-y1and y2 are measured with the help of a point gauge attached with a vernier of 0.1 mm accuracy. y1 is measured just downstream of toe of spillway. The observed-y2 and ideal-y2 values for 5-trials are given in Table III.

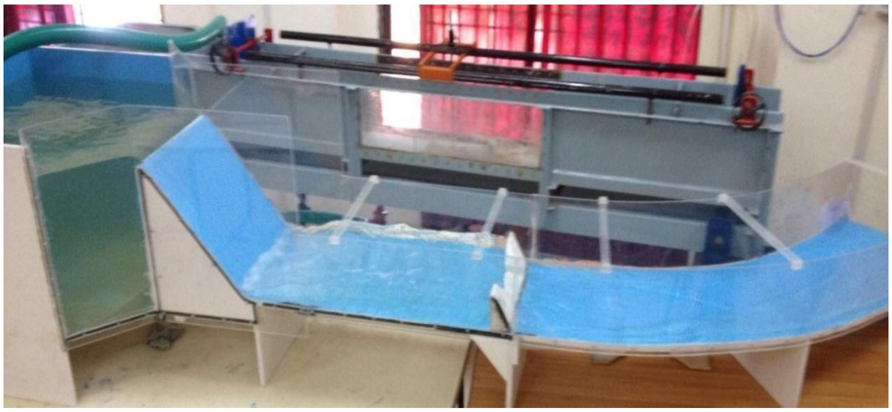

Fig. 2. Experimental setup of Sonurle M.I. Tank spillway and energy dissipator.

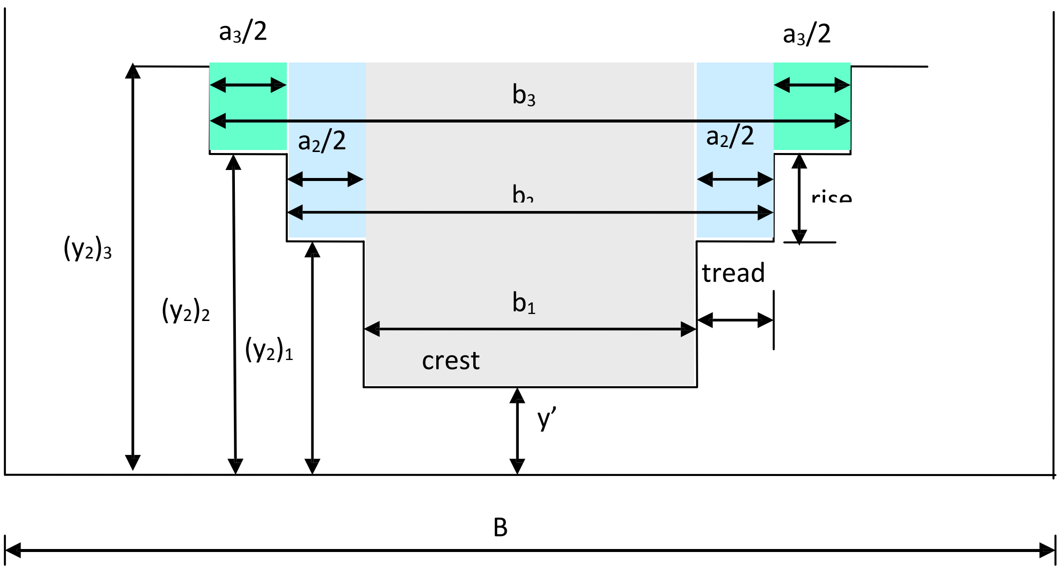

Fig.3. Design of stepped weir (first 3-steps shown)

TABLE I. DETAILS OF SECTIONAL MODEL (SCALE 1:50)

Parameter	Prototype	Model
Height of Spillway (H)	19.66 m	**0.3932 m**
Width of Stilling Basin (B)	59 m	**0.394 m**
Length of Stilling Basin (L)	37.45 m	**0.749 m**
Design Discharge (Qmax)	318 m3/s	**0.006 m3/s**
20% of Design Discharge (Qmin)	63.6 m3/s	**0.0012 m3/s**
Range of Froude Number (Fr)	**11 To 17**	**11 To 17**

TABLE II. GEOMETRY OF BROAD CRESTED STEPPED WEIR

Step number	Rise (m)	Tread (m)	Step number	Rise (m)	Tread (m)	Step number	Rise (m)	Tread (m)
1	0.0310	0.071	5	0.005	0.005	9	0.004	**0.004**
2	0.007	0.013	6	0.004	0.005	10	0.004	**0.003**
3	0.005	0.008	7	0.004	0.004	11	0.004	**0.003**
4	**0.006**	**0.006**	**8**	**0.004**	**0.004**			

TABLE III. EXPERIMENTAL RESULTS FOR THE BROAD CRESTED STEPPED WEIR

Q m3/s	y -obs. m 1	F obs. R	y -ideal m 2	y - obs. m
0.00527	0.0063	11.22	0.0847	**0.084**
0.00424	0.0051	12.39	0.076	**0.078**
0.00328	0.0040	13.80	0.0672	**0.069**
0.00248	0.0031	15.29	0.0586	**0.060**
0.00178	**0.0023**	**17.17**	**0.0498**	**0.050**

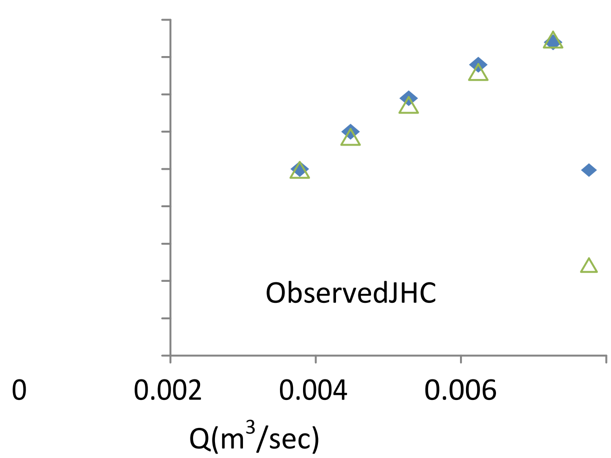

Fig.4. Plot of Ideal JHC and Observed JHC

RESULTS AND DISCUSSION

Although the location of front of hydraulic jump, is found to be slightly fluctuating near the toe of spillway, the mean location of front of jump is found to be constant (near the toe of spillway) over a complete range of Q. On either side of stepped weir, in the corners, little part of flow is observed to be separated. The ideal y2 depths and observed y2 depths are plotted against Q in Fig.4. It shows that, over a range of Q an observed jump height curve (JHC) is overlapped on ideal jump height curve. It shows a satisfactory agreement between these two curves. This ensures that over a complete range of Q, front of hydraulic jump is located near the toe of spillway.

PRACTICAL APPLICATIONS OF PROPOSED STILLING BASIN

Following are the unique advantages of a proposed new design of a stilling basin which makes it different from the conventional designs.

1. As tail water level lies below the water level on apron, the chances of horizontal eddies bringing the sediments / riprap material back into the basin get nullified. [15].
2. The proposed stepped weir assures appropriate location of jump for all operating conditions and thus the corresponding Fr1 and energy dissipation is maximum. It is particularly suitable in the case where tail water level requires certain time to develop to its full magnitude. This further reduces the chances of jump sweep out in such situation.
3. As air entrainment is directly proportional to Fr1 [15], in the present case a maximum air entrainment would occur. This would be helpful to mitigate the cavitation damage to the basin floor and appurtenances against fluctuating pressures depressions.
4. The proposed basin requires no appurtenances like chute blocks or baffle blocks. Thus there is saving in their cost of construction.

CONCLUSIONS

Geometry of rectangular broad crested stepped weir is designed to control the location of hydraulic jump. With the help of sectional model (scale 1:50) of spillway and a new design of stilling basin, the performance of stepped weir is experimentally verified as the location of front of hydraulic jump is restricted near the toe of spillway for different discharges (ranging from Qmin to Qmax).

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NOTATIONS

B	=Width of stilling basin
b	=Width of step of rectangular broad crested stepped weir
Cd	=Coefficient of discharge
Fr1	=Supercritical Froude number
H	=Head on upstream of spillway
h	=Head over stepped weir crest
Q	=Discharge
Sr	=submergence ratio for the stepped weir crest
v1	=Supercritical velocity
y´	=Height of weir crest from the channel bed
y1	=Pre jump depth
y2	=Post jump depth
yt	=Tail water depth