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Effect of End Sill in the Performance of Stilling Basin Models

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Abstract An experimental investigation on effect of end sill on the performance of stilling basin models for a non circular pipe outlet has been presented in this research paper. New physical models for non circular pipe outlet stilling basin have been developed in the laboratory. These newly models were tested in the laboratory for three Froude numbers namely Fr = 1.85, 2.85 and 3.85. The new models are developed by changing the geometry of end sill of same height while keeping the other configuration of stilling basin geometry same. Total twenty one test runs of one hour duration each were performed. The performance of the models was compared by performance number (PN) to evaluate the performance. The study indicated that, for the given Froude number range, the triangular end sill of height 1d with width 1d (slope 1V:1H), is performing better in comparison to other shapes of the end sill for the given flow conditions. The study also confirmed that there is a significant effect of the shape of the end sill geometry on the performance of the stilling basin models.

Keywords: *end sill, froude number, physical model, performance number, stilling- basin*

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1. Introduction

In order to reduce the excessive kinetic energy of flowing water downstream of the structures like overflow spillways, sluices, pipe outlets, etc., stilling basins with appurtenances are used [1]. Various types of recommended stilling basin used for pipe outlets are USBR VI stilling basin [2], Manifold stilling basin [3] Contra Costa energy dissipator [4], USU energy dissipator [5], counter current energy dissipator [6], Garde energy dissipator [7], Verma energy dissipator [8] and Mahakaal stilling basin [9], etc. For any stilling basin, appurtenances play an important role in the reduction of energy of flowing water. Stilling basin for a pipe outlet uses appurtenances like splitter block, impact wall, intermediate sill and an end sill, etc. The end sill is a terminal element in the stilling basin, which has a great contribution to enhance the reduction of energy of flowing water and assists to improve the flow pattern downstream of the channel, thereby helping in reducing the length of stilling basin also. The sill height, configuration and position have great impact on the dissipation of energy of the flowing water. Several shapes of end sill have been used by many investigators such as vertical, stepped, dentated/ solid wall, etc. [10]. In the USBR stilling basin type VI model, a sloping end sill is used [2], while some past investigators have recommended a semi circular shaped end sill [7,8]. In present study four different end sills, namely; rectangular, square sloping and trapezoidal as shown in Figure 1 & Figure 2, have been experimentally investigated in the newly developed stilling basin model for non circular pipe outlet and performance of model is compared with performance number (PN).

2. Materials and Methods

2.1. Stilling Basin Model Design

To reach the purpose of this study, experiments were carried out in a recirculating flume of dimensions 0.95 m wide, 1 m deep and 25 m long in the hydraulics laboratory of Civil Engineering Department of MANIT Bhopal. The rectangular pipe of 10.8 cm x 6.3 cm has been used as a non circular pipe outlet. The exit of outlet pipe was kept above stilling basin by one equivalent diameter (d = 9.3 cm) as per the design. For fixing the appurtenances inside the basin a wooden floor of size 58.8cm wide and 78.6 cm long was provided, downstream of the exit of the pipe outlet. Three inflow Froude numbers namely Fr = 1.85, 2.85 and 3.85 were taken as per discharge consideration in the flume. After the basin, the sand passing through IS sieve size 3.18 mm and retained on IS sieve size 1.18 mm was used to form a movable sand bed. The sand was filled up to the height of end sill and properly leveled then normal depth was maintained over the sand base by allowing the flow for a particular Froude number. After one hour test run, the value of maximum depth of scour (dm) and its location from the end sill (ds) were noted to know the performance of the stilling basin model. All the models were tested for constant run time of one hour and with the same sand base for all Froude numbers. Initially, a stilling basin model was designed for the inflow Froude number (Fr = 3.85) and fabricated in the flume. It includes an impact wall of size 1d x 2.2d having bottom gap of 1d, located at 3d from the exit of pipe outlet and having basin length as 8.4d. Later on, in order to study the end sill geometry; new stilling basin models were fabricated by changing the shapes of end sills. Four end sills having rectangular, square, triangular and trapezoidal cross section were used. Model having triangular end sill which performed better amongst other tested end sill was also evaluated through contour of sand bed after test run. The scheme of experimentation of stilling basin models tested in the present work has been mentioned in Table 1, and also diagram of some models are shown in Figure 1 & Figure 2.

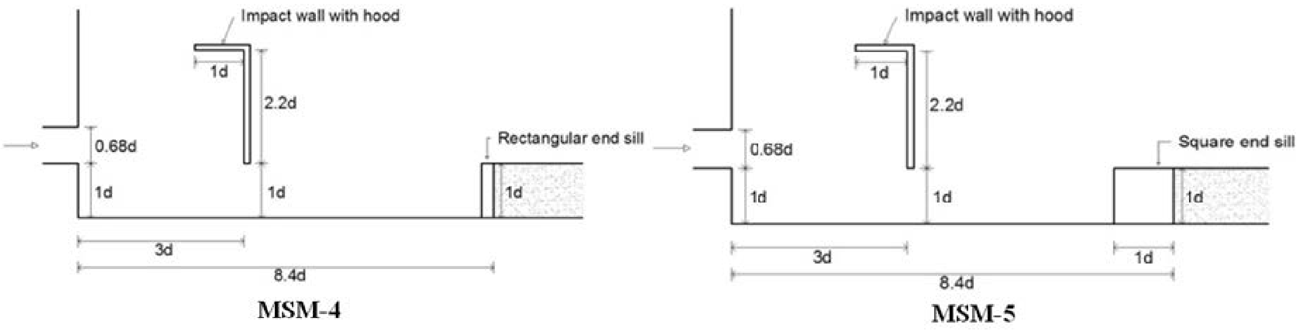

Figure 1. Stilling basin Models with Rectangular and Square End -Sill

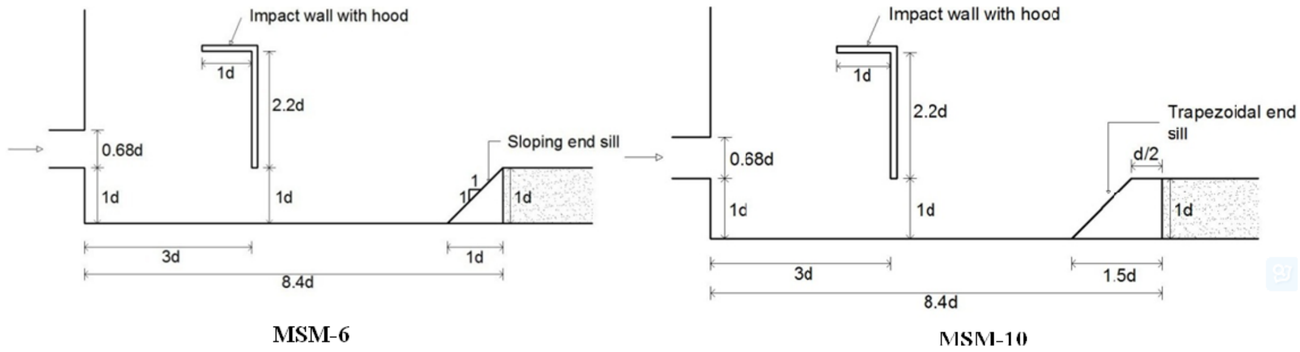

Figure 2. Stilling Models with Sloping and Trapezoidal End- Sill

Table 1. Scheme of experimentation

Model number	Stilling basin length	Impact wall			End sill of height 1d
		Size	Location	Gap	
MSM-1	8.4d	-	-	-	Rectangular
MSM-2	8.4d	-	-	-	Square
MSM-3	8.4d	-	-	-	Triangular (1V:1H)
MSM-4	8.4d	1dx2.2d	3d	1d	Rectangular
MSM-5	8.4d	1dx2.2d	3d	1d	Square
MSM-6	8.4d	1dx2.2d	3d	1d	Triangular (1V:1H)
MSM-10	8.4d	1dx2.2d	3d	1d	Trapezoidal

d = equivalent diameter of the pipe outlet

Table 2. Values of Performance Number (PN) at different Froude Numbers

Model No.	Fr =1.85	Fr = 2.85	Fr = 3.85
MSM-1	0.204	0.221	0.215
MSM-2	0.229	0.220	0.233
MSM-3	0.325	0.308	0.374
MSM-4	0.332	0.348	0.350
MSM-5	0.448	0.425	0.429
MSM-6	0.523	0.440	0.559
MSM-10	0.314	0.236	0.232

2.2. Evaluation of Performance for Stilling Basin Models

The performance of a stilling basin model was tested for different outlet Froude number (Fr) which is a function of channel velocity (v), the maximum depth of scour (dm) and its location from end sill (ds). A stilling basin model that produces smaller depth of scour at a longer distance is considered to have a better performance as compared to another stilling basin which results in a larger depth of scour at a shorter distance when tested under similar flow conditions [11]. Based on this concept dimensionless number was used to evaluate the performance of the basin model and called as performance number (PN), which is given as below [9].

$$PN = \frac{1}{2} * V * d_s / (g * d_m{}^3)^{0.5} \quad (1)$$

Where, V - the mean velocity of channel, ds - distance of maximum depth of scour from end sill, dm- depth of maximum scour, g – gravitation acceleration. A higher value of performance number suggests a better performance of a stilling basin model for a given flow conditions of the pipe outlet channel downstream. Values of performance number for various runs on each model for different Froude are given in Table 2.

3. Results and Discussions

Experimental investigations were carried out with the stilling basin models (MSM-1, MSM-2 and MSM-3) as shown in Figure1 for Fr = 1.85, 2.85 and 3.85, and the values of Performance number (PN) obtained are mentioned in the Table 2. The model with triangular end sill (1V:1H) is performing better as compared to model MSM-1 and MSM-2 since the values of PN (0.325, 0.308 and 0.374) for model MSM-3 are higher side for all Froude numbers and has been also shown with the bar chart in Figure 3. During the experimentation it was observed that for end sill having proper slope, the flow over the bed materials was approaching to tranquilized stage. The model having rectangular or square shaped end sill generates more undulated flow over the sand base by which performance number is lower side as compared to sloping end sill. Further rectangular square, triangular and trapezoidal end sills were tested in models MSM-4, MSM-5, MSM-6 and MSM-10 respectively along with impact wall of height 2.2d with a bottom gap of 1d placed at 3d from the exit of the pipe for Fr = 1.85, 2.85, 3.85 and the values of performance number obtained are mentioned in Table 2. On close observation of Table 2, it is found that the values of performance number for MSM-6 are higher side.

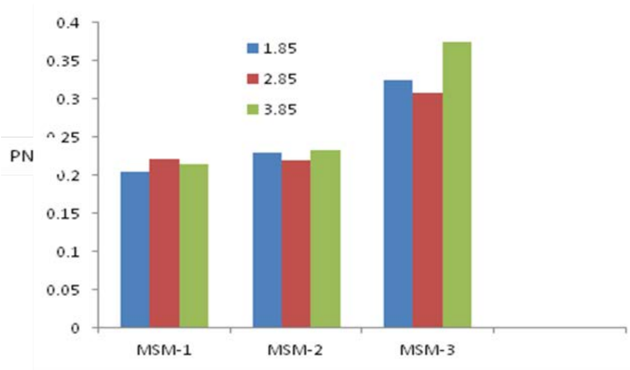

Figure 3. Variation of performance numbers for models MSM-1(rectangular end sill), MSM-2(square end sill), MSM-3 (triangular end sill) without impact wall

The comparison of performance numbers indicate that there is a improvement in the performance of each of the models MSM-4, MSM-5 and MSM-6 as compared to the corresponding models MSM-1, MSM-2 and MSM-3. Improvement in performance is due to the provision of impact wall, which equalizes the distribution of flow of water over the channel width. However, the model MSM-6 is performing best in series MSM-1 to MSM-6 and MSM-10 as shown in the bar chart of Figure 4. Values of performance numbers in Table 2 clearly indicate that stilling basin model (MSM-6) having sloping end sill produces smaller depth of scour hole for all Froude number tested as compared to other stilling basin models tested, which is also shown with the colored contour in Figure 5. In this investigation it is also observed that the performance of the trapezoidal end sill (MSM-10) is worst amongst all tested end sills (MSM-4, MSM-5 and MSM-6). It is due to fact that dissipation of energy in a basin having sloping end sill is more as compared to other shape of end sill tested, because slope of the end sill reduces the momentum of water thereby reduction in energy is promoted. Similar observation was also reported by some past investigators [9,12,13,14,15].

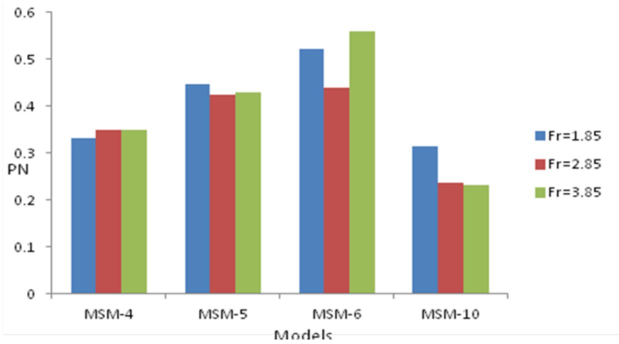

Figure 4. Variation of Performance numbers for Models MSM-4, MSM-5, MSM-6 and MSM-10 Impact wall

4. Conclusions

An experimental investigation was carried out in the laboratory by fabricating the physical models to study the effect of end sill in the design of stilling basin for non circular pipe outlet by using different size and shape of end sill, namely; rectangular, square, triangular and trapezoidal end sill. Based on the analysis of experimental investigations, it is concluded that the shape of end sill in a stilling basin model affects the performance of basin significantly due to change in the flow conditions at the downstream of end sill, thereby scour pattern of base material changed. Higher values of performance number for model MSM-6 (PN = 0.523, 0.440 and 0.559) indicate that the triangular vertical end sill having height and width as 1d enhanced the energy dissipation of flowing water and found to perform better for all flow conditions as compared to other end sills tested for non circular pipe outlet basin. Thus end sill plays a vital role in the performance of stilling basin models.

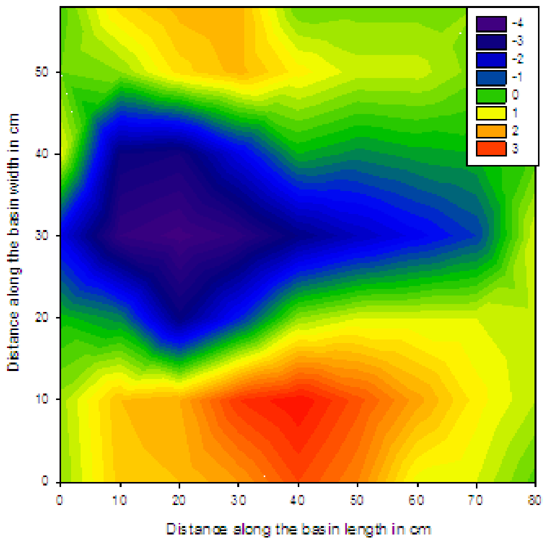

Figure 5(a). Scour Pattern of Sand Bed for Model MSM-6 at Fr = 3.85 (Left to right) after one hour Test Run at Normal Depth

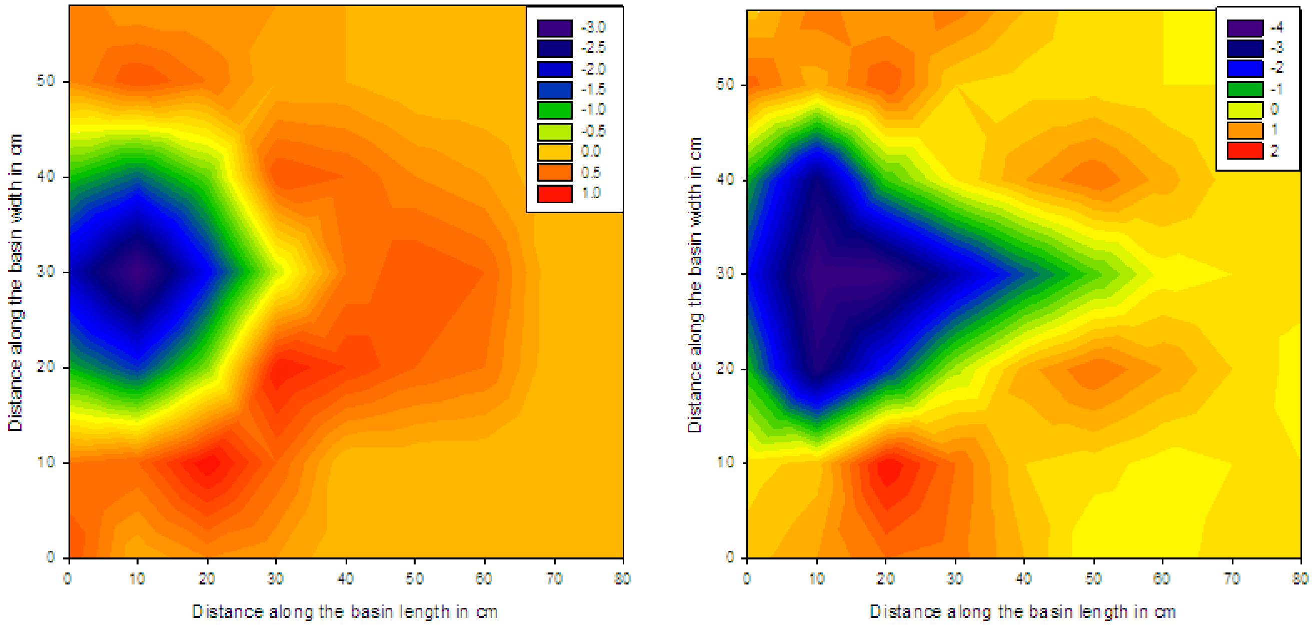

Figure 5(b). Scour Pattern of Sand Bed for Model MSM-6 at Fr = 1.85 and 2.85 (Left to right) after one hour Test Run at Normal Depth

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