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Effect of Intermediate Sill on the Performance of Stilling Basin Model

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Abstract : This research paper investigates about the performance of stilling basin models with different geometry of intermediate sill having height equivalent to the diameter of pipe outlet. The experimental study was carried out for three Froude numbers namely 3.85, 2.85 and 1.85 for non-circular pipe outlet. Performance index (PI) has been used to evaluate the performance of stilling basin models tested using same sand base material and test run time. The scour pattern was measured for each test run and flow pattern was also observed. After 15 tests runs, it was found that scour process were reduced for a specific geometry of intermediate sill having saquare shape of the height 1d at a particular location on stilling basin floor combined with end sill of particular size and shape. Performance of this model was found to be better than USBR VI impact basin for similar flow condition.

Keywords: **Intermediate sill, pipe outlet, stilling basin, Scour pattern.**

Introduction : Stilling basins are normally used in reducing the excess energy downstream of hydraulic structure like over flow spillway, sluices, pipe outlets, etc. The effect of sill on the flow and or scour characteristics depends upon the configuration of the sill, its geometry and the flow regime [1]. Various types of recommended stilling basin designs for pipe outlets are by Bradely and Peterka [2], Fiala and Maurice [3], Keim [4], Vollmer and Khader [5], Verma and Goel [6 &7], Goel [8], Tiwari et al. [9,10, &11], Tiwari and Gahlot [12] and Tiwari [13 &14]. Appurtenances play an important role in the reduction of kinetic energy of flowing water in the stilling basin. A stilling basin for a pipe outlet consists of appurtenances like splitter block, impact wall, intermediate sill and an end sill etc. The vertical end sill is a terminal element in the stilling basin, which has a great contribution in reduction of energy of flowing sheet of water and assists in to improve the flow pattern downstream of the channel thereby helps in reducing the length of stilling basin also.

The sill height, configuration and position have great impact on the formation and control of hydraulic jump and ultimately leading to the dissipation of energy of flowing water. The present research paper concentrates on the improvement of the performance of stilling basin model by using different intermediate sill of height equivalent of diameter of pipe outlet along with end sill and impact wall. Performance of stilling basin models is compared with performance index (PI). Higher value of PI indicates better performance of the model.

Experimental Arrangement and Procedure

The experiments were conducted in a recirculating laboratory flume of 0.95 m wide 1 m deep and 25 m long. The width of flume was reduced to 58.8 cm by constructing a brick wall along the length for keeping ratio of width of basin to equivalent diameter of rectangular outlet equal to 6.3 as per design of Gardes et al. [15]. A rectangular pipe of 10.8 cm. x 6.3 cm. was used to represent the outlet flow. The exit of pipe was kept above stilling basin by one equivalent diameter (1d =9.3cm). To observe the scour after the end sill of stilling basin a erodible bed was made of coarse sand passing through IS sieve opening 2.36 mm. and retained on IS sieve opening 1.18mm. The maximum depth of scour (dm) and its distance from end sill (ds) was measured for each test after one hour run time. The depth of flow over the erodible bed was maintained equal to the normal depth of flow. The model stilling basin USBR type VI, proposed by Bradley and Peterka [2] was fabricated with impact wall of size 20.46cm.x58.8 cm with hood of size 9.3cmx58.8cm and sloping end sill of height 9.3cm and base width 9.3cm was fabricated. The discharge was measured by a calibrated venturimeter installed in the feeding pipe. With the operation of tail gate the desired steady flow condition with normal depth was maintained. After one hour the test run, motor was switched off. The value of maximum depth of scour (d_m) and its location from the end sill (d_s) were noted. USBR VI model was tested with impact wall and end sill and then again models were tested with four different intermediate sills. All tested models with appurtenances are shown in Figures 1to 3. All the testing were performed for constant running time of one hour and with the same erodible material for three Froude numbers ie,3.85, 2.85 and 1.85. Further scouring pattern was observed by using intermediate sill of same height with different geometry, kept at the distance of 4d from the exit of the pipe, thus total 15 test runs were performed to evaluate the performance of stilling basin as shown in Table 1.

Criteria for performance of evaluation for a stilling basin

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 condition Verma & Goel [7]. The performance of a stilling basin models were tested for different Froude number (Fr) which is a function of channel velocity (v), the maximum depth of scour (d_m) and its location from end sill (d_s). A new non dimensional number, called as performance index (PI) developed by Tiwari et al [9] has been used for comparison of performance of stilling basin models. This is given as below:

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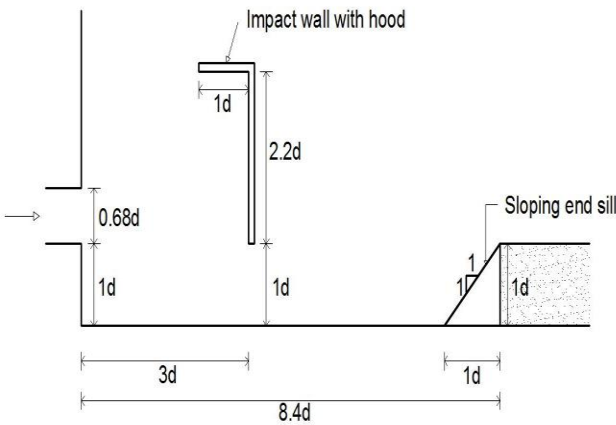
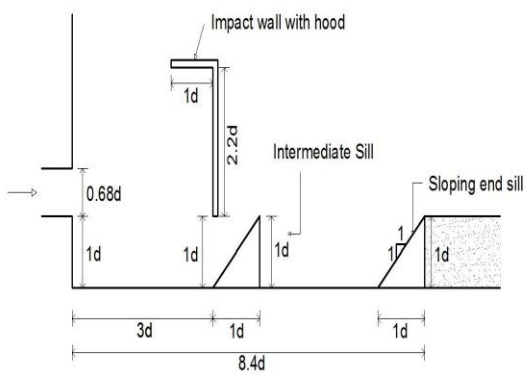
$$PI = \frac{V x d_s}{2 d_m \sqrt{g \frac{\rho_s - \rho_w}{\rho_w} d_{50}}}$$

Where, V - the mean velocity of channel, d_s - distance of maximum depth of scour from end sill, d_m- depth of maximum scour, g – gravitation acceleration, $\boldsymbol{\rho_s}$- density of sand, $\boldsymbol{\rho_w}$ density of water, d_{50}- the particle size such that 50% of the sand particle is finer than this size, A higher value of performance index indicates a better performance of the stilling basin model. The value of Performance index for various runs on each model for different Froude numbers are given in Table 2.

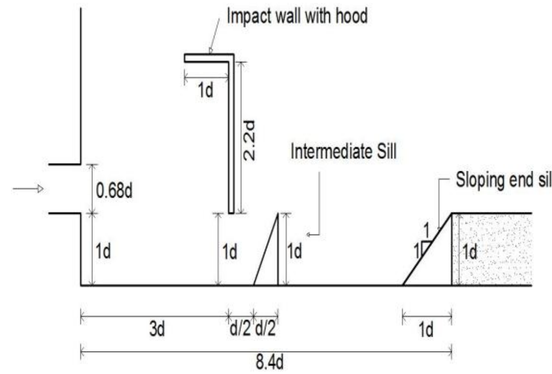


MSM-6

Figure 1 USBR VI Impact Wall and End Sill (Models MSM-6)

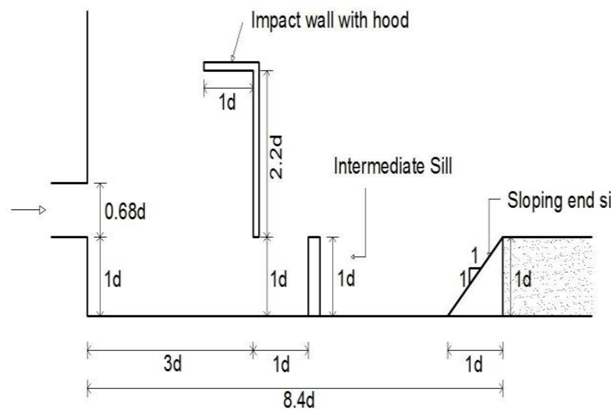


MSM-21

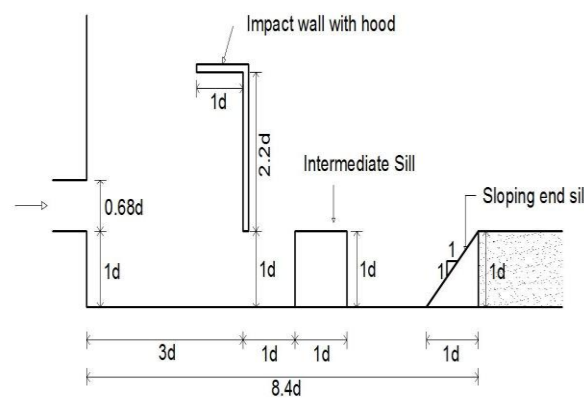


MSM-23

Figure 2 Models (MSM-21 & MSM-23) with sloping Intermediate Sill of varying width but same height of 1d with Vertical Face Downstream



MSM-25



MSM-27

Figure 3 Models (MSM-24 & MSM-27) with rectangular and square Intermediate Sill of height1d

Results and Analysis : To study the effect of geometry of intermediate sill on the performance of stilling basin models for pipe outlet, five models, were tested for three Froude numbers, namely 1.85, 2.85 and 3.85. The data pertaining to depth of scour and its location from end sill were collected for each model and reported in table2 to evaluate their performance by using performance index. First of all USBR VI model (MSM-6) was tested and values of PI was computed as 2.67, 2.63 and 3.42 for Fr=1.85, 2.85 and 3.85 respectively.

In continuation of the investigation of the geometry of intermediate sill, the performance of the basin models were tested with intermediate sill of sloping, rectangular and square with same height along with impact wall located at 3d and sloping end sill fixed at 8.4d. In models MSM-21 &MSM-23 vertical face of the sloping end sill was downstream, with varying width 1d and 0.5d with same height as 1d. It was reported that by reducing the base width of intermediate sill performance of model (MSM-23) reduces as compared to the performance of model (MSM-21) for Froude number 3.85 and 2.85because PI values reduces to 3.31 and 3.87 as compared to 4.56 and 4.39as shown in Table 2. But for Froude number 1.85, performance of model improved as PI value is more (5.15 as compared to 4.59). Further models MSM-25 and MSM-27 were tested with rectangular and square intermediate sill with same height of 1d. It was found that model with square intermediate sill produces higher values of PI (8.41, 5.26 &5.46) as compared to other tested models as shown in Table 2.

After analysis, it was found that by changing the geometry of intermediate sill there is improvement in the performance of the basin. It is so because of impact action, a reduction of energy is more, thereby improvement of the basin performance. Intermediate sill of suitable geometry promotes the dissipation of energy in the basin by lifting high velocity filaments from the bed. No doubt performance of the stilling basin models improves with the inclusion of intermediate sill, which also confirms the findings of Negm [1].Similar finding was also reported by Tiwari & Tiwari [16].

CONCLUSIONS

An experimental investigation was conducted to study the effect of geometry of inter mediate sills along with impact wall and end sill. Four intermediate sills of different geometry were tested. The scouring is significantly reduced there by increasing the performance index for square intermediate sill of height d and base width d, placed at the distance of 4d from the exit of pipe outlet. It is found that intermediate sill of square cross section used in model MSM-27, produces higher performance indices and thus performs better as compared to all other tested models for all Froude numbers tested. Based on the results of experimental studies on stilling basin models, it can be concluded that the geometry of intermediate sill greatly affect the performance of a stilling basin. Efficient stilling basin model (MSM-27) have been evolved by experimentation as compared to USBR VI stilling basin model.

Acronym-USBR = United State Bureau of Reclamation, MSM = Mahaakaal Stilling Basin Model, Fr = Froude Number, ES = End sill, IS = Intermefiate sill, IW = Impact wall

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Table 1 Scheme of Experimentation

Testing of Models to Study the Intermediate Sill Geometry with Triangular End Sill (1V:1H) of height 1d for Basin Length 8.4d								
S.N.	Model Name	USBR VI Impact Wall with hood			Intermediate sill			
		Size	Bottom gap with basin floor	Location from outlet exit	Shape	Height	Width	Location from outlet exit
1	MSM-6	1d×2.2d	1d	3d	-	-	-	-
2	MSM-21	1d×2.2d	1d	3d	Triangular with vertical face D/S	1d	1d	4d
3	MSM-23	1d×2.2d	1d	3d	Triangular with vertical face D/S	1d	d/2	4d
4	MSM-25	1d×2.2d	1d	3d	Rectangular	1d	0.2d	4d
5	MSM-27	1d×2.2d	1d	3d	Square	1d	1d	4d

Table 2 Performance index for different models tested with ES, IW and IS

S. No.	Model name	Fr = 1.85			Fr = 2.85			Fr= 3.85		
		d_m	d_s	PI	d_m	d_s	PI	d_m	d_s	PI
1	MSM-6	3.2	10.5	2.67	4.4	12.5	2.63	4.6	15.5	3.42
2	MSM-21	1.4	7.9	4.59	2.4	11.8	4.56	3.1	13.4	4.39
3	MSM-23	0.9	5.7	5.15	3.3	11.8	3.31	4.3	16.4	3.87
4	MSM-25	0.8	5.1	5.19	1.5	8.2	5.07	2.2	11.1	5.13
5	MSM-27	0.3	3.1	8.41	0.6	3.4	5.26	0.8	4.3	5.46