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Development of Stilling Basin Models with Appurtenances

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ABSTRACT

This research paper describes about the experimental work leading to the sustainable hydraulic structures by developing new stilling basin model as compared to USBR VI stilling basin model for pipe outlet using with sills. 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 21 tests runs, it was found that the performance of stilling basin model improved even by reducing the length of basin from 8.4 d to 6 d by introducing intermediate sill of square cross section along with USBR VI impact wall and end sill. Performance of this model was found to be better than USBR VI impact basin for similar flow condition at reduced length of 6 d from 8.4d where d is the equivalent diameter of pipe outlet.

Keywords-- Sill, Pipe Outlet, Stilling Basin, Scour Pattern

I. 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, Negm (2004). Various types of recommended stilling basin designs for pipe outlets are by Bradley and Peterka (1957), Fiala and Maurice(1961), Keim (1962), Flammer et al. (1970), Vollmer and Khader (1971), Verma and Goel (2000 & 2003), Goel (2008), Tiwari et al. (2011, 2012,2013,2014 & 2015), Tiwari and Gahlot (2012), Tiwari (2013 & 2013) and Tiwari & Goel (2014 &2016). Appurtenances play an important role in the reduction of kinetic energy of flowing water in the stilling basin model design. 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 placing of sill over stilling basin floor has great impact on the formation and control of hydraulic jump and ultimately leading to the reduction of kinetic energy of flowing water. The present research paper concentrates on the improvement of the performance of USBR VI stilling basin model by using square sill placed after impact wall 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 stilling model for pipe outlet (Tiwari et al.2014).

II. 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 Garde et al. (1986). 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 (1957) 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. First of all stilling basin model without impact wall was tested and named as M-1 then USBRVI impact wall was placed and model(renamed as M-2) was again tested in similar flow condition as M-1. Further length od basin was reduced to 7d and models were tested without impact wall and with impact wall and they were named as M3 and M4. Further to improve the performance of the model square sill was introduced and again model was tested and it was renamed as M-5. After testing the model at 7d length was reduced to 6d and models were tested without impact wall and renamed as M-6. To make the model more efficient impact wall and sill was also introduced and model was tested in similar flow condition and performance was evaluated and model was re-designated as M-7. Some tested models with appurtenances are shown in Figures 1to3. 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 also, thus total 21 test runs were performed to evaluate the performance of stilling basin models by using sill along with USBR VI impact wall and end sill. Scheme of experimentation is shown in Table 1.

III. CRITERIA FOR PERFORMANCE OF EVALUATION FOR A STILLING BASIN

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 (2011) has been used for comparison of performance of stilling basin models. This is given as below:

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

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.

Table 1: Scheme of Experimentation

Testing of Models with Triangular End Sill (1V:1H) of height 1d								
S.N.	Model Name	Impact Wall with hood			Intermediate sill of square cross section			Basin length
		Size	Bottom gap with basin floor	Location from outlet exit	Cross section	Width along basin width	Location from outlet exit	
1	M-1	-	-	-	-	-	--	8.4d
2	M-2	1d×2.2d	1d	3d	-	-	--	8.4d
3	M-3	-	-	-	-	-	-	7d
4	M-4	1d×2.2d	1d	4d	-	-		7d
5	M-5	1d×2.2d	1d	3d	0.5d x 0.5d	6.3d	4d	7d
6	M-6	-	-	-	-	-	-	6d
7	M-7	1d×2.2d	1d	3d	0.5d x 0.5d	6.3d	4d	6d

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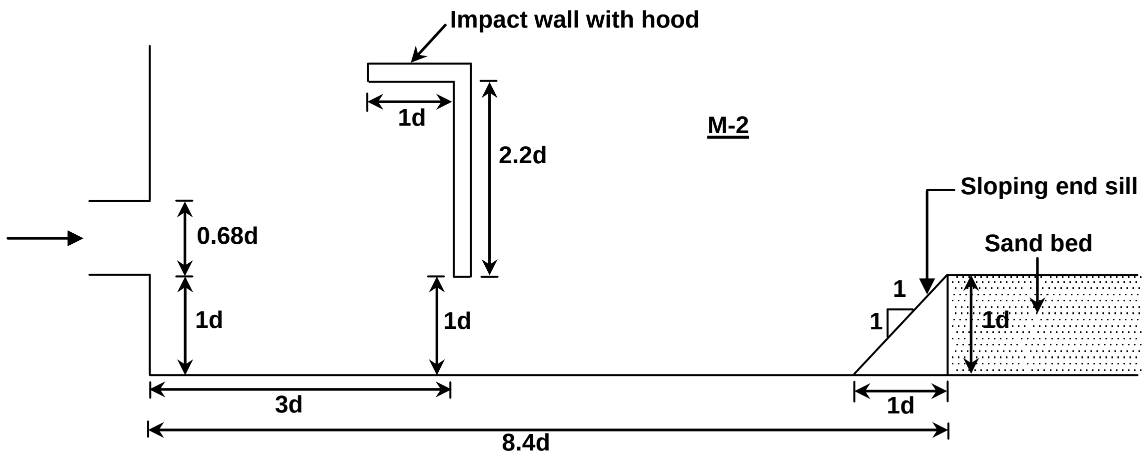

Figure 2: USBR VI stilling basin model at basin length 8.4d

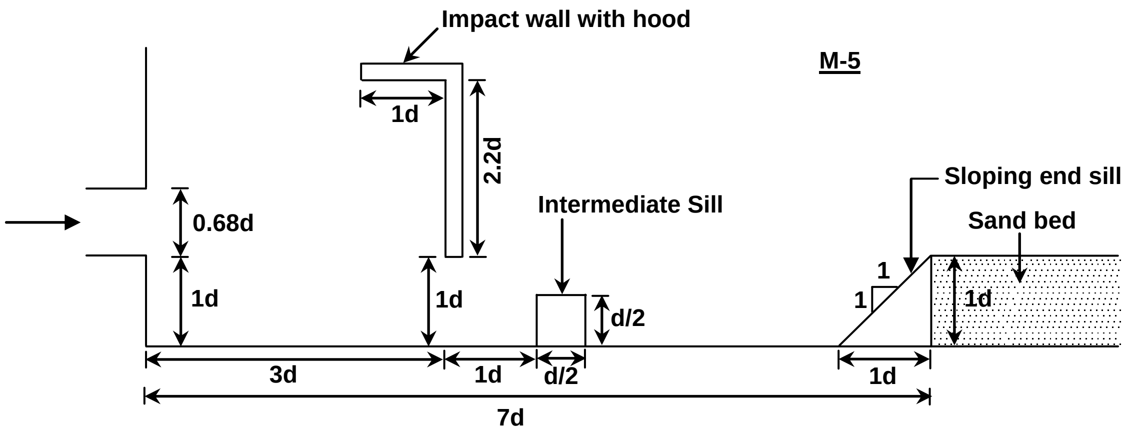

Figure 3: New stilling basin model at basin length 7d with square sill

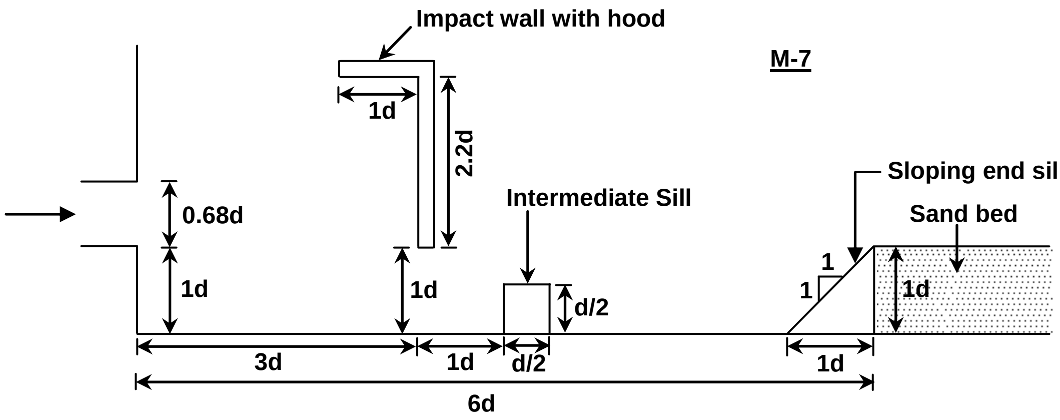

Figure 4: New stilling basin model at basin length 6d with square sill

IV. RESULTS AND ANALYSIS

An experimental work was carried out to design efficient new stilling basin model as compared to existing USBR VI design. First of all model (M-1) was tested with sloping end sill without impact wall and value of PI were found to be 2.03,2.01 and 2.7o for Froude number 1.85, 2.85 and 3.85 respectively, USBR VI impact wall was placed and again testing of USBR VI model(M-2) was carried out in similar flow condition as for M-1 and PI values were obtained as 2.67, 2.63 and 3.42 for Froude number (Fr) =1.85, 2.85 and 3.85 respectively, which are higher than M-1 stilling basin model. Thus performance of M-2 model is better as compared to model M1, which includes only end sill. After that stilling basin model length was reduced to 7d from 8.4d and in similar flow condition model M-1 and M-2 were retested and re-designated as M-3 and M-4 respectively. Values of PI were computed and mentioned in Table2. From Table 2, it obvious that PI values of model M-3 and M-4 are reduced as compared to M-1 and M-2 respectively as basin length is reduced to 7d from 8.4d. Further to improve the performance of stilling basin model a square sill was introduced after impact wall at 4d length from exit of the pipe length as shown in Figure 3 and model (M-5) was tested in similar flow conditions and computed values PI are come out as 2.40, 2.96 and 4.2 for Fr=1.85, 2.85 and 3.85 respectively, which are higher than the values obtained for USBR VI model (M-2),whose values are 2.67, 2.63 and 3.42 for Fr=1.85, 2.85 and 3.85 respectively, thus performance of model with square sill at basin length 7d is better as compared to USBR VI model of basin length 8.4d. Further to economize the model basin length was reduced to 6d and it was again tested and model was re-designates as M-7 and f PI values appeared as 3.01, 2.69 and 3.87 for Fr = 1.85, 2.85 and 3.85 respectively, which are still more than values obtained for USBR VI model (M-2) at basin length 8.4d.Thus performance of new developed model with square sill at basin length 6d is better as compared to USBR VI model of basin length 8.4dwhich is also shown in Table 2 . During the test run of this model, it was also observed that flow was very smooth for all Froude numbers and amount of eroded material of sand bed was also lesser as compared to other models.

After analysis, it was found that by introducing the 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 height 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 square cross section, which also confirms the findings of Negm (2007).Similar finding was also reported by Tiwari & Tiwari (2013) and Tiwari et al. (2014).

V. COMPARISON OF USBR VI WITH NEW DEVELOPED MODEL

On analyzing the USBR VI stilling basin model (M-2) proposed by Bradley & Peterka (1957) and new developed stilling basin model (M-7) for noncircular pipe outlet, it is found that the value of performance index are M-7 (PI = 3.01, 2.69 and 3.87 for Fr = 1.85, 2.85 and 3.85 respectively,) is higher side as compared to the value of performance index for USBR-VI model (PI= 2.67, 2.63 and 3.42 for Fr = 1.85,2.85 and 3.85 respectively) even at reduced length from 8.4d to 6d. Thus there is improvement of performance for tested Froude number and also the length of the basin for new design model is reduced from 8.4d to 6d. Reduction of the basin length from 8.4d to 6d (29%) makes the new stilling basin model (M-7) more economical as compared to USBR-VI model (M-2). Comparative analysis is also shown in Table 3.

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	M-1	4.8	12.0	2.03	5.7	12.9	2.10	6.4	17.0	2.70
2	M-2	3.2	10.5	2.67	4.4	12.5	2.63	4.6	15.5	3.42
3	M-3	8.8	17.8	1.64	9.8	19.6	1.85	11.2	25.8	2.34
4	M-4	3.4	9.5	2.27	6.4	14.8	2.14	6.8	20.4	3.051
5	M-5	1.1	4.6	3.40	2.6	8.3	2.96	2.9	12.6	4.42
6	M-6	11.9	20.2	1.38	13.5	21.5	1.47	16.9	27.8	1.67
7	M-7	4.3	15.9	3.01	6.5	19.2	2.69	8.9	24.3	3.87

Table 3: Comparison of new developed model

Name of model	PI for Fr = 1.85	PI for Fr = 2.85	PI for Fr = 3.85	Remark
M-2	2.67	2.63	3.42	USBR VI model Basin length = 8.4d
M-7	3.01	2.69	3.87	New developed model, basin length = 6d
Improvement of performance for all Froude Numbers with 29% reduction in length as compared to USBR VI model				

VI. CONCLUSION

An experimental study was conducted in the laboratory by fabricating physical models for the development of new model for non circular pipe outlets by using square sill along with end sill and impact wall as per USBR VI design. Investigation was carried out at varying basin lengths (8.4d, 7d and 6d) for rectangular shaped pipe outlet with 21 test runs for Froude numbers 3.85, 2.85 and 1.85. The scouring is reduced there by increasing the performance index for square intermediate sill placed at the distance of 4d from the exit of pipe outlet. It is found that square intermediate sill of height of0.5 d and base width as 0.5d, used in model M-7, produces higher performance indices (3.01, 2.69 and 3.87 for Fr = 1.85, 2.85 and 3.85 respectively) which are still more than values obtained for USBR VI model (M-2) at reduced length of 6d from 8.4d and thus performs of new developed model(M-7) is better as compared to USBR VI model (M-2)for all Froude numbers tested. Based on the results of experimental studies on stilling basin models, it can be concluded that there is an improvement of performance for tested Froude number and also the length of the basin for new design model is reduced from 8.4d to 6d. Reduction of the basin length from 8.4d to 6d (29%) makes the new stilling basin model (M-7) more economical as compared to USBR-VI model (M-2).

REFERENCES

[1] Bradley, J.N. & Peterka, A. J. (1957). Hydraulic design of stilling basins. Journal of A.S.C.E., Hydraulic Engg,, 83(5), 1401-1406.

[2] Fiala, J. R. & Maurice, L. A. (1961). Manifold stilling basins. *Journal of A.S.C.E., Hydraulic Div*., *87*(4), 55-81.

[3] Garde, R .J., Saraf, P.D. & Dahigaonkar, D.J. (1986). Evolution of design of energy dissipator for pipe outlets. *J. of Irrigation & Power*, *41*(3), 145-154.

[4] Goel, A. (2008). Design of stilling basin for circular pipe outlet. *Canadian Journal of Civil Engineering, 35*(12), 1365-1374.

[5] Keim, S. R. (1962). Contra costa energy dissipator. *Journal of A.S.C.E., Hydraulic Division, 3077*, 109-122.

[6] Negm, A.M. (2004). Effect of sill arrangement on maximum scour depth DS of abruptly enlarged stilling basins. *Proc. of Int. Conf. Hydraulics of Dams and River Hydraulics*, *Tehran, Iran*.

[7] Tiwari, H.L., Goel, A. & Gahlot, V.K. (2011). Experimental study of sill controlled stilling basins for pipe outlet. *International Journal of Civil Engg. Research*, *2*(2), 107-117.

[8] Tiwari, H.L., Goel, A. & Gahlot, V.K. (2011). Experimental study of effect of end sill on stilling basin performance. *International Journal of Engg. Sci. and Technology*, *3*(4), 3134-3140.

[9] Tiwari, H.L, Gahlot, V.K. & Tiwari Seema. (2013). Reduction of scour depth downstream of stilling basin. *International Research Journal of Engineering Sciences*, *2*(7), 20-25.

[10] Tiwari, H.L. & Gahlot, V. K. (2012). Experiments on new Stilling basin for Pipe outlets. *STM*, *AISECT University*, *2*(2), 17-20.

[11] Tiwari, H.L. (2013). Design of stilling basin with impact wall and end sill. *International Research Journal of Resent Sciences*, *2*(3), 59-63.

[12] Tiwari, H.L. (2013). Analysis of baffle wall gap in the design of stilling basin models. *International Journal of Civil Engineering and Technology, 4*(4),66-71.

[13] Tiwari, H.L. & Tiwari Seema. (2013). Design of stilling basin models with intermesiate sill. *Journal of Science, Technology and Management*, *2*(4), 66-71.

[14] Tiwari, H.L, Gahlot, V.K. & Sharma, A. (2014). Effect of of intermediate sill on the performance of of stilling basin models. *International Journal of Sc. Engineering & Technology*, *3*(4), 414-417.

[15] Tiwari, H.L. & Goel, A. (2014). Effect of end sill in the performance of stilling basin. *American Journal of Civil Engg. and Architecture*, *2*(2), 60-63.

[16] Tiwari, H.L., Goel A. & Tiwari Seema. (2015). Effect of inverted T shape Splitter block in the performance of stilling basin models. *Science Direct, Aquatic Procedia, 4*, 1561-1568.

[17] Tiwari, H.L. & Goel A. (2016). Effect of impact wall on energy dissipation in stilling basin. *KSCE Journal of Civil Engg.*, *20*(1), 463-467.

[18] Vollmer, E., Khader, M.H.A. (1971). Counter current energy dissipator for conduit outlets. *International J. of Water Power*, *23*(7), 260-263.

[19] Verma, D.V.S & Goel, A. (2000). Stilling basins for outlets using wedge shaped splitter blocks. *ASCE Journal of Irrigation and Drainage Engineering*, *126*(3), 179-184.

[20] Verma, D.V.S. & Goel, A. (2003). Development of efficient stilling basins for pipe outlets. *ASCE Journal of Irrigation and Drainage Eng.*, *129*(3), 194-200.