Investigation the Effect of Upstream Slope in Stepped Spillway on Discharge Coefficient

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Abstract: Upgrading and organizing rivers that crossing drawn from urban and rural areas requires consideration of the characteristics and specific issues for type of river. Spillways are some of hydraulic structures that applicated to adjust the water level, flow measurement and stabilization of bed rivers. The kinetic energy of water can cause erosion of the river bed, scour the foundation and occurrence of cavitation. In this study, the effect of geometric and hydraulic parameters and stepped on the discharge coefficient were studied experimentally. Experiments were Performed in the channel length of 12 meters, width 0.5 meters, height of 0.8 meters in Engineering lab water, Sari University of Agricultural Sciences and Natural Resources. In this study is made of Plexiglas and stepped spillways in four of Different step height (h) the length of the stairs (L)=0.5 and 0.67 and 1 and 2 was designed and built. The results showed that discharge coefficient stepped spillway depends on tan (β) and dimensionless parameters B/H_d, h/H_d, L/H_d and P/H_d. With the increase in the dimensionless parameters, discharge coefficient decreases. when P/H_d is fixed, with Increasing upstream side slopes, the discharge coefficient increases. with constant flow rate, the lowest upstream water level related to upstream slope (60 degree) and the most upstream water level related to upstream with no slope that shows the model of the upstream slope of 60 degrees in time flooding caused less flooding farmland upstream rivers. In all four upstream slope Stepped spillway, in constant P/H_d the most flow rate as in Model 2, Model 1, Model 3 and Model 4. So in model 2 flooding is less in arable land upstream. finally discharge coefficient equation relations Be extracted in the form of stepped that Show high accuracy is calculated statistical parameters relations.

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Keywords: water level upstream, the river, stepped spillway, upstream slope, discharge coefficient, physical model.

1. Introduction

Development and organization of rivers that cross drawn from urban and rural areas requires consideration of the characteristics and specific issues of this type revers. In this regard, one of the significant issues, the problem of erosion floor, especially in periods with slope floor swift. This leads significant damage to buildings and technical and protective facilities. In general, many procedures were suggested to stabilize riverbeds and seasonal streams for various basins is proposed to strengthen them against erosion. These methods include the use of Stairway structures with nappe flow and or skimming flow, using a variety of energy dissipation structures, using resistant materials against erosion combinations of structures such as stepped spillway, stilling basin and more. Use stepped spillway In addition, the reduced speed and energy loss through turbulent flow during its structures, thereby influencing the self-purification of the river through proper aeration steps in the overflow area as well and this kind of spillways during low-charge has beauty make up (Zand Parsa and Shafaee Begestan, 2004). Stepped spillways was being used of ancient times (about 2500 years ago) But so far, some aspects of Hydraulic parameters of them is unknown (Chen et al., 2002). Mrdshty et al. (2007) how to assess and measure the energy dissipation stepped spillway usual, given the importance of the contribution and the roughness of the bed river of energy dissipation by the natural pattern-stable form stairs - Hvzchhay in mountain rivers with steep show the new design stepped spillway combined with the context of stairs - the pool. Rostami et al. (2007) simolated flow on stepped spillway on the river of Khalkayy numerically, and the results were compared with experimental results. The results show that a flow of non-falling on stepped spillway Khalkayy is formed. Farhoodi et al. (2007) by investigation the effect of the upstream slopes in Rectangular broad-crested for discharge coefficient and flow characteristics showed that changing the way upstream, discharge coefficient and coefficient of flow rate and as the result spillway discharge capacity, according to latest upstream steep increases. Farhoodi and Shah alamy (2005) investigated the effect of side slopes upstream of the spillway discharge coefficient with the upstream sloping rectangular's wide-brimmed. Their results showed that the upstream slope factor affected on spillway discharge, so that the slope of the upstream discharge efficiency increases. Sarjison and Percy (2009) reviews Hydraulic Laboratory broad-crested weirs with different side slopes, showed that the discharge capacity of the upstream inclined to overflow Increasing. Shokri et al. (2008) investigated the impact Upstream and downstream inclined a rectangular broad-crested weir flow coefficient and flow characteristics showed that discharge coefficient overflow downstream slope with almost constant while changing the upstream side slopes, discharge coefficient and thus Overflow discharge capacity increases. Oskoee et al. (2014) studied labyrinth weir models place the cutting edge with steep faces and the results showed that by increasing the overflow water level, discharge coefficient is reduced. With the upstream side and both sides sloping Upstream and downstream simultaneously, commensurate with the increased slope, charge coefficient increases. Ranga Raju et al. (1979) conducted Tests, De Marchi correctly equation (1934) In estimating the amount of discharge from overflows the edges sharp and broad-brimmed confirmed and relationships to calculate this overflow discharge coefficient presented.

Overflow edge in certain assumptions used to estimate the relationship between upstream and Dubai has been registered head, widely using overflow edge by using Physical models were studied and relationships to determine the discharge coefficient (Bagheri and Heidarpour, 2010 and Sisman, 2009 and El-Alfy, 2005 and Boss, 1989). In none of the studies, the effect on the upstream side slopes of stepped spillway discharge coefficient has not been studied. So In this study, using studies laboratory implications of these changes on the characteristics of flow on stepped spillway discharge coefficient is discussed, including using dimensional analysis, correlation coefficient charge is also presented.

2. Materials and methods

Introducing the flume and the closed system

Laboratory flume used in this section, a rectangular cross section with a metal skeleton. The length, width and height of the flume, respectively are 12, 0.5 and 0.8 meters. The walls are made of transparent glass to observe the flow of the two sides and it is shown in Figure 1 Schematic view. At the entrance to the flume tank that turbulent flow of water that enters the centrifugal pumps and inters laminar flow into the flume's Laboratory. Flow charge flume of three pumps with a total flow rate of 60 liters per second providing a triangular overflow Output was measured. Pages EPS to reduce surface waves of 6 meters is placed upstream version. At the end of the flume also, the pages on a triangular lattice to reduce the kinetic energy of water located upstream, as a free-falling waterfall it dose. Then, water cube into a reservoir and pumping from the bottom of the tank and is then sent into the pipes and flow water circulates again.

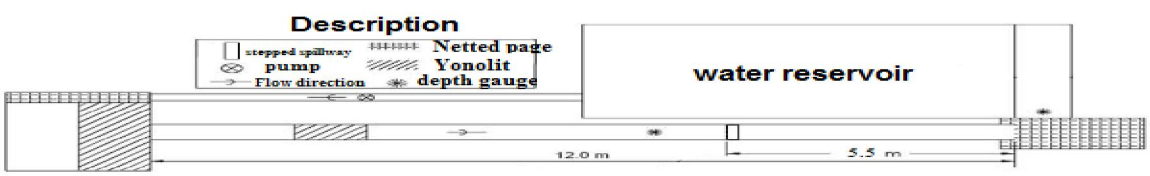


Figure 1. Water circulation system in the experimental flume

The model used

In this study, four models stepped spillway, each with total height of 20 cm and the ratio (h/L) were Plexiglas different was used. View stepped spillway models shown in Table 1. Due to the difference of (h/L) So different is the number of stairs.

Table 1. Specification of built physical models

$\frac{h}{L}$	Horizontal length of steps (cm)	Steps height (cm)	Spillway height (cm)	Width of the spillway crest, cm))	Number of steps	
2.00	2	4.0	20	30	5	Model 1
0.50	5	2.5	20	30	8	Model 2
0.67	6	4.0	20	30	5	Model 3
1.00	5	5.0	20	30	4	Model 4

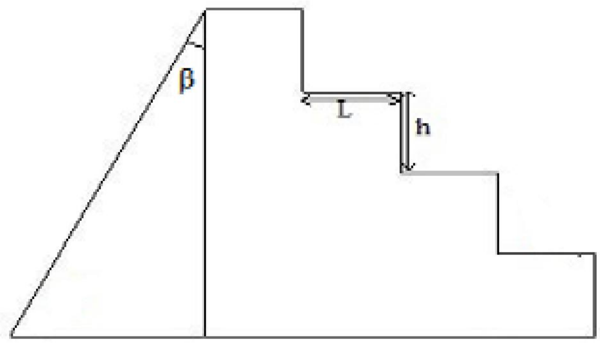


Figure 2. Schematic view a stepped spillway with slope upstream

Figure 3. Position of model 1 in flume

Figure 4. Position of model 2 in flume

The location of these structures due to lower input current volatility and fluctuations in water level upstream of the structure and also precise measurement of water level, at 5.5 meters remaining to the end is downstream. To measure water depth upstream stepped spillway (H) is at a distance of 1 meter depth gauge with accuracy of 0.1 mm high structures were used. After drying glue, pump and valves input by the setting and then ensure constant flow, water depth upstream triangular and stepped spillway reading and the process for different rate charges. Figure 2 shows the schematic of a stepped spillway at the upstream side slopes. Figures 3 and 4 and 5 placement of several models used in the flume show.

Figure 5. Position of model 3 in flume

Dimensional analysis

Dimensional analysis is to reduce the number of variables in a physical phenomenon into a smaller number of dimensionless groups of the same variables. Using dimensional analysis can be paid to the selection of parameters studied. For finding the relationship between factors affecting the discharge coefficient stepped dimensional analysis is conducted on effective parameters. Discharge coefficient can be dependent on variable geometry, kinematics and dynamics wrote below:

$C_d = f_1 (B, g, P, \rho, \beta, H_d, V, \sigma, \mu, h, L)$ (1)

B: width of the spillway crest [L], g: acceleration of gravity [LT^{-2}], P: height of the structure [L], ρ: density [ML^{-3}], β: upstream side slopes [without dimension], H_d: Water on the spillway crest elevation [L], V: velocity of water in the channel [LT^{-1}], μ: dynamic viscosity[$ML^{-1}T^{-1}$], h: height of the step [L], L: length of the stairs [L] and σ: surface tension[MT^{-2}] is. After dimensional analysis matrix method, Equation 2 that the relationship between Q and scale is achieved comes:

$$Q = f_5 \left(\frac{1}{We}, \frac{1}{Re}, \frac{B}{H_d}, \frac{P}{H_d}, \frac{h}{H_d}, \frac{L}{H_d}, \beta\right) * \sqrt{g} * L_C * h^{\frac{3}{2}} \quad (2)$$

$$C_d = \frac{Q}{h^{3/2} * L_C * \sqrt{g}} = f_5 \left(\frac{1}{We}, \frac{1}{Re}, \frac{B}{H_d}, , \frac{P}{H_d}, \frac{h}{H_d}, \frac{L}{H_d}, \beta\right) \quad (3)$$

Public relation stepped spillway discharge coefficient according to Equation 3 is calculated and is shown as a function of the discharge coefficient 7 dimensionless parameter Re, h/H_d, P/H_d B/H_d, L/H_d, β and We is (Henderson, 1964 and Sisman, 2009).

The evaluation criteria used in this study, parameters NRMSE and SEE and their relationship is as follows (Ashofte and Shakor Bafande, 2012):

$$NRMSE = \frac{\sum(C_{calc} - C_{obsr})^2}{\sum C_{obsr}^2} \quad (4)$$

$$SEE=\sqrt{\frac{1}{N\,(N-1)}\sum_{i=1}^{N}(C_{\mathrm{obsr}}-\mathrm{Ccalc}_{average})^2} \quad (5)$$

that NRMSE: normal root mean square error, N: number of data, C_{obsr} and C_{calc}: Respectively the observed and calculated discharge coefficient and SEE: Is the standard error of the estimate. In this study, the average estimation error for each model of stepped spillway equal to the absolute value of the difference between laboratory C_d and C_d of relationship 6 is. Overflow triangular volumetric method was calibrated and then use the Dubai curve - triangular overflow discharge, discharge was calculated in each stage.

3. Results and discussion

According to Cubas in 1980, to less than 3 cm of the surface tension of the water depth increases (Novak et al., 2013). In other words, for models with a number Weber greater than 1 can be avoided effect of surface tension (Novak et al., 2007 and Akbari and Karbasi, 2007). According to the dimensions analysis conducted, the dimensionless number Weber for reading the water level greater than 3 cm in the upstream structures and dimensionless parameters Reynolds Due to exposure in a range of 8000-89000 and flow is turbulent, regardless of the weber and Reynolds. Finally, the effect of dimensionless parameters L/H_d, h/H_d, P/H_d, B/H_d and tan (β) on the discharge coefficient is investigated.

The results of model 1

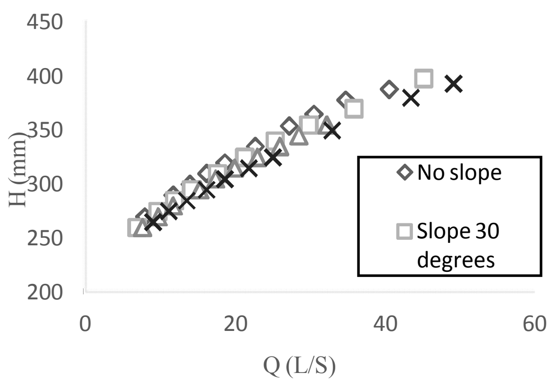


Figure 6. Comparison relationship between discharge and upstream head at 4 upstream slopes in model 1

Experiment with different slope than the one that took the spillway crest spillway slope angles funds respectively, stepped spillway has been no slope, 30, 45 and 60 degrees. Of Figure 6 is shown in a fixed H by increasing the slope upstream of the non-slope to slope 60 degrees, the discharge capacity increased 8.7%. And at a constant flow rate, the water level of the structure is reduced by 15%. Lowest water level upstream of the upstream slope is 60 degrees, indicating that this model upstream side slopes of 60 degrees in less time flooding caused flooding farmland upstream rivers.

Figure 7 The relationship between the dimensionless parameters P/H_d and discharge coefficient for stepped spillway with upstream slopes without slope, 30, 45 and 60 ° show. when P/H_d is fixed, with Increasing upstream side slopes, the discharge coefficient increases. According to the chart by increasing the slope upstream of the non-slope to slope 60 degrees, discharge coefficient increased on average by 11.9%. Which range discharge coefficient is 0.47 to 0.65 and the range of P / H_d is between 1.01 to 3.33.

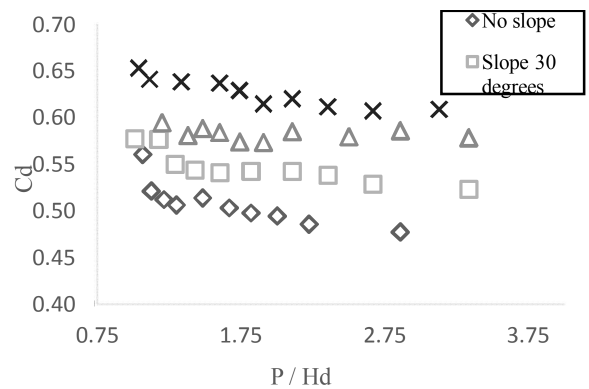


Figure 7. Comparison the relationship between Cd and $\frac{P}{H_d}$ at 4 upstream slopes in model 1

Based on dimensional analysis, process flow coefficient versus dimensionless ratios B/H_d, h/H_d, L/H_d were investigated. According to figures 8, 9 and 10 with an increase in all three dimensionless parameters, discharge coefficient decreases. As shown in Fig. 8 in a fixed B/H_d, least discharge coefficient is owned stepped spillway no slope.

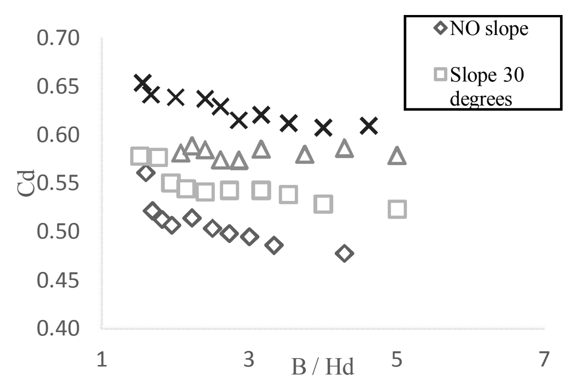


Figure 8. Comparison the relationship between Cd and $\frac{B}{H_d}$ at 4 upstream slopes in model 1

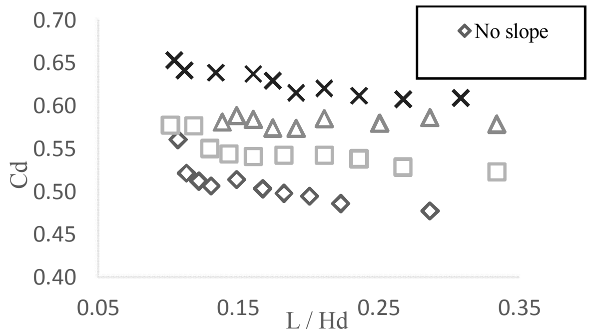


Figure 9. Comparison the relationship between Cd and $\frac{L}{H_d}$ at 4 upstream slopes in model 1

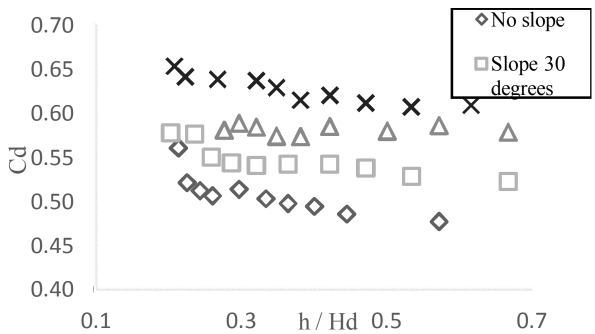


Figure 10. Comparison the relationship between Cd and $\frac{h}{H_d}$ at 4 upstream slopes in model 1

The results of model 2

Experiment with different slope than the one that took the spillway crest spillway slope angles funds respectively, stepped spillway has been no slope, 30, 45 and 60 degrees. Of Figure 11 is shown in a fixed H by increasing the slope upstream of the non-slope to slope 60 degrees, the discharge capacity increased 4.3%. And at a constant flow rate, the water level of the structure is reduced by 15%. Lowest water level upstream of the upstream slope is 60 degrees, indicating that this model upstream side slopes of 60 degrees in less time flooding caused flooding farmland upstream rivers.

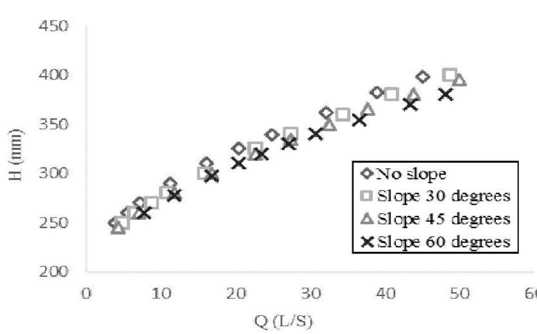


Figure 11. Comparison relationship between discharge and upstream head at 4 upstream slopes in model 2

Figure 12 The relationship between the dimensionless parameters P/H_d and discharge coefficient for stepped spillway with upstream slopes without slope, 30, 45 and 60 ° show. when P/H_d is fixed, with Increasing upstream side slopes, the discharge coefficient increases. Which range discharge coefficient is 0.4 to 0.71 and the range of P / H_d is between 1 to 4.4.

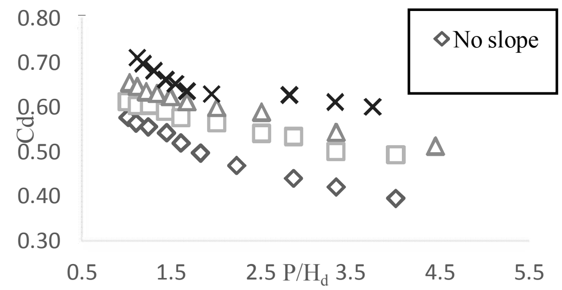


Figure 12. Comparison the relationship between Cd and $\frac{P}{H_d}$ at 4 upstream slopes in model 2

Based on dimensional analysis, process flow coefficient versus dimensionless ratios B/H_d, h/H_d, L/H_d were investigated. According to figures 13, 14 and 15 with an increase in all three dimensionless parameters, discharge coefficient decreases. As shown in Fig. 8 in a fixed B/H_d, least discharge coefficient is owned stepped spillway no slope.

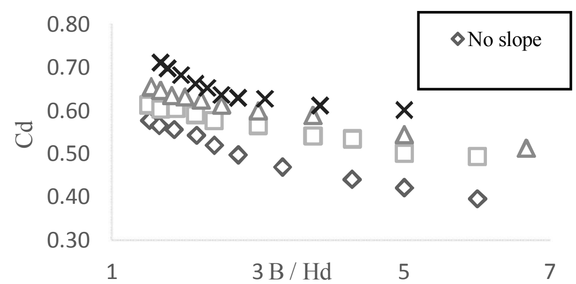


Figure 13. Comparison the relationship between Cd and $\frac{B}{H_d}$ at 4 upstream slopes in model 2

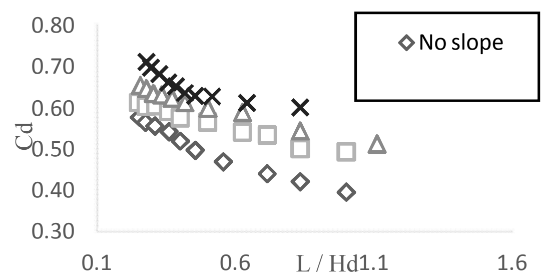


Figure 14. Comparison the relationship between Cd and $\frac{L}{H_d}$ at 4 upstream slopes in model 2

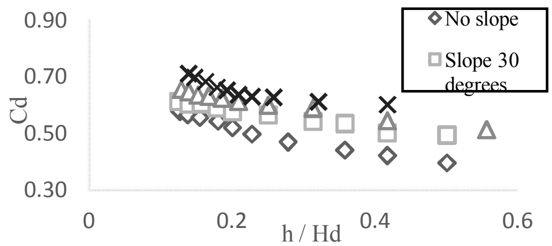


Figure 15. Comparison the relationship between Cd and $\frac{h}{H_d}$ at 4 upstream slopes in model 2

The results of model3

Discharge-eshel curve in Figure 16 for stepped spillway without slope, 30, 45 and 60 is shown. According to the chart, flow rate increases with increasing H, At a constant flow rate, the lowest water level upstream of the upstream slope is 60 degrees.

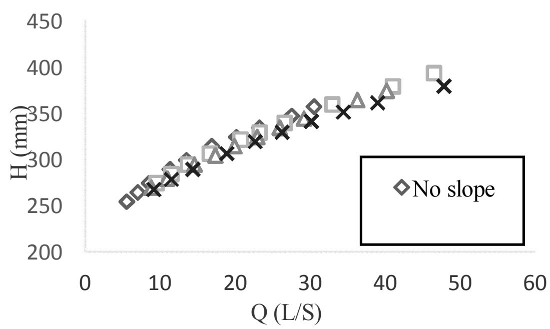


Figure 16. Comparison relationship between discharge and upstream head at 4 upstream slopes in model 3

Figure 17 The relationship between the dimensionless parameters P/H_d and discharge coefficient for stepped spillway with upstream slopes without slope, 30, 45 and 60 ° show. when P/Hd is fixed, with Increasing upstream side slopes, the discharge coefficient increases. Which range discharge coefficient is 0.46 to 0.71 and the range of P / H_d is between 1.03 to 3.63.

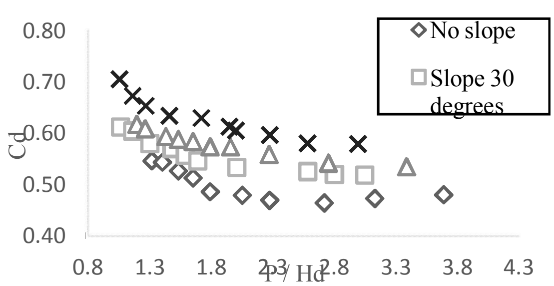


Figure 17. Comparison the relationship between Cd and $\frac{P}{H_d}$ at 4 upstream slopes in model 3

Based on dimensional analysis, process flow coefficient versus dimensionless ratios B/H_d, h/H_d, L/H_d were investigated. According to figures 18, 19 and 20 with an increase in all three dimensionless parameters, discharge coefficient decreases. As shown in Fig. 8 in a fixed B/H_d, least discharge coefficient is owned stepped spillway no slope.

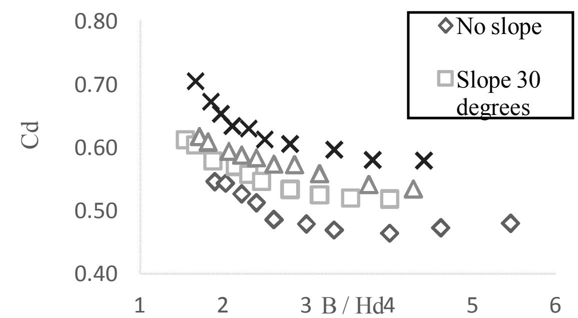


Figure 18. Comparison the relationship between Cd and $\frac{B}{H_d}$ at 4 upstream slopes in model 3

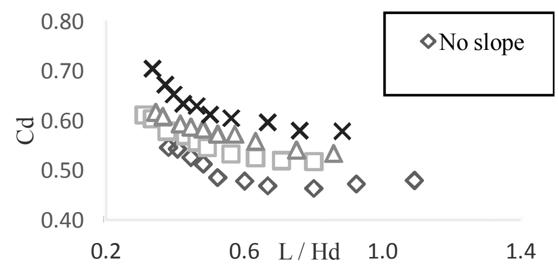


Figure 19. Comparison the relationship between Cd and $\frac{L}{H_d}$ at 4 upstream slopes in model 3

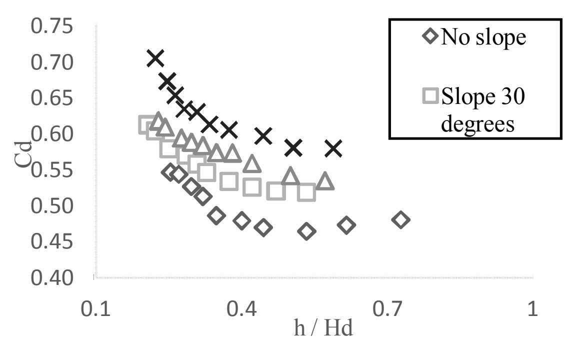


Figure 20. Comparison the relationship between Cd and $\frac{h}{H_d}$ at 4 upstream slopes in model 3

Results of the model 4

Experiment with different slope than the one that took the spillway crest spillway slope angles funds respectively, stepped spillway has been no slope, 30, 45 and 60 degrees. Of Figure 6 is shown in a fixed H by increasing the slope upstream of the non-slope to slope 60 degrees, the discharge capacity increased 8.4%. And at a constant flow rate, the water level of the structure is reduced by 27%. Lowest water level upstream of the upstream slope is 60 degrees, indicating that this model upstream side slopes of 60 degrees in less time flooding caused flooding farmland upstream rivers.

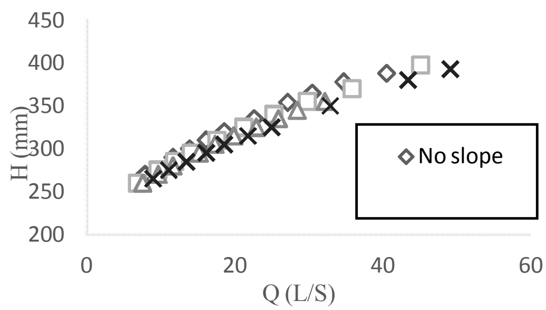


Figure 21. Comparison relationship between discharge and upstream head at 4 upstream slopes in model 4

Figure 22 The relationship between the dimensionless parameters P/H_d and discharge coefficient for stepped spillway with upstream slopes without slope, 30, 45 and 60 ° show. when P/H_d is fixed, with Increasing upstream side slopes, the discharge coefficient increases. Which range discharge coefficient is 0.31 to 0.64 and the range of P / H_d is between 1.14 to 3.33.

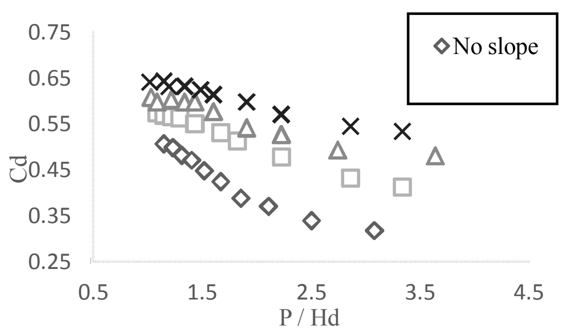


Figure 22. Comparison the relationship between Cd and $\frac{\mathbf{P}}{\mathbf{H_d}}$ at 4 upstream slopes in model 4

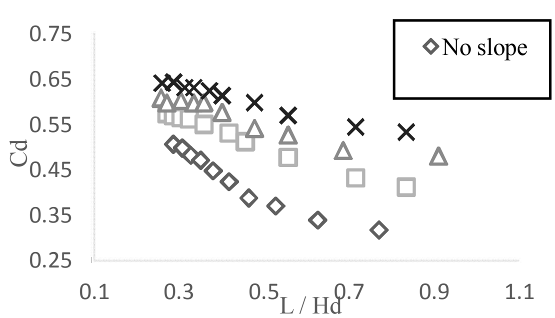


Figure 23. Comparison the relationship between Cd and $\frac{\mathbf{L}}{\mathbf{H_d}}$ at 4 upstream slopes in model 4

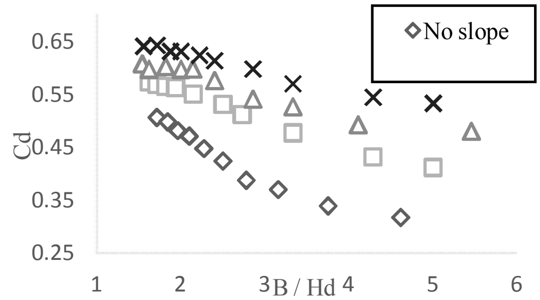
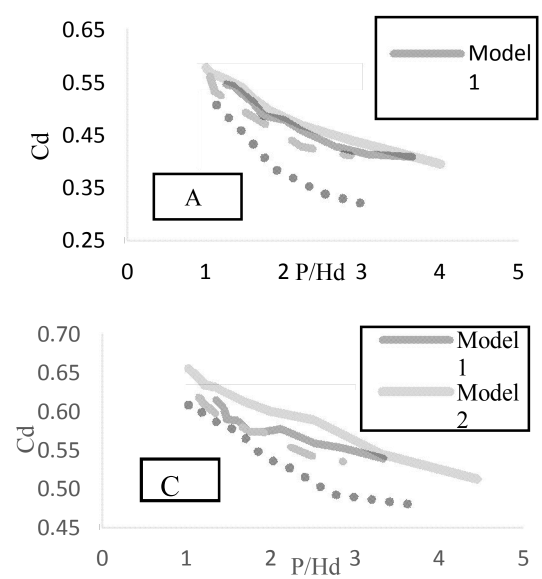


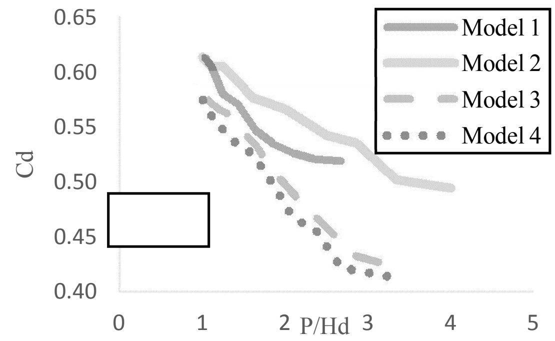
Figure 24. Comparison the relationship between Cd and $\frac{\mathbf{B}}{\mathbf{H_d}}$ at 4 upstream slopes in model 4

Based on dimensional analysis, process flow coefficient versus dimensionless ratios B/H_d, h/H_d, L/H_d were investigated. According to figures 23 and 24 with an increase in all three dimensionless parameters, discharge coefficient decreases. As shown in Fig. 8 in a fixed B/H_d, least discharge coefficient is owned stepped spillway no slope.

The results of the upstream slopes

Figure 25 The relationship between the discharge coefficient versus dimensionless parameter for 4 models stepped spillway in each of the four states show the upstream slope. According to Figure 25 in all four upstream side slopes at a constant P/H_d in order of highest discharge coefficient in Model 2, Model 1, Model 3 model 4. In stepped spillway without gradient, flow rate ranges is between 0.31 to 0.56. In the upstream slope of 30 degrees, ranges discharge coefficient is between 0.41 to 0.61. In the upstream slope of 45 degrees, ranges discharge coefficient is between 0.48 to 0.65 and In the upstream slope of 60 degrees, ranges discharge coefficient is between 0.53 to 0.71.





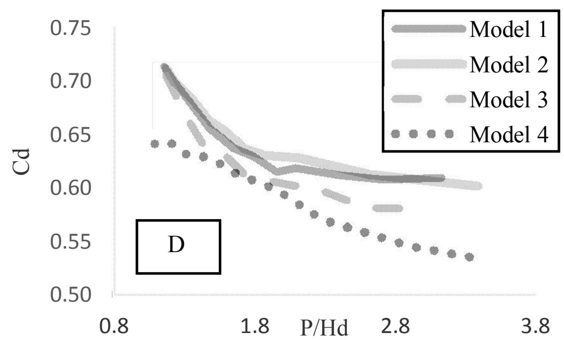


Figure 25. Comparison the relationship between Cd and $\frac{P}{H_d}$ at 4 stepped spillway models in upstream slopes- A. No slope, B. Slope (30 degree), C. Slope (45 degree), D. Slope (60 degree)

Determination of the discharge coefficient steppingstone for 4 models

SPSS software was used to derive the equation discharge coefficient and power equations (6) between the discharge coefficient and dimensionless parameters $\frac{B}{H_d}$, $\frac{P}{H_d}$, $\frac{h}{H_d}$, $\frac{L}{H_d}$ and tan (β) was extracted. In this equation, the values of C_1, C_2, C_3, C_4, C_5 and C_6 are constants Coefficients.

$$C_d = C_1\left(\frac{B}{H_d}^{C_2} + \frac{L}{H_d}^{C_3} + \frac{h}{H_d}^{C_4} + \frac{P}{H_d}^{C_5} + tan^{C_6}\beta\right) \quad (6)$$

In Table 2, the constant coefficient for stepped spillways is shown. As is known, the coefficient of determination for the whole relations presented in the table with a good approximation close to one. also uses statistical indicators NRMSE and SEE relations Were compared to low values of parameters, represents an accurate prediction coefficient is used to calculate the discharge coefficient.

Table 2. Constant coefficients for equation discharge coefficient with evaluated parameters in the Stepped spillway models

Average estimation error (%)	SEE	NRMSE	R^2	C_6	C_5	C_4	C_3	C_2	C_1	Upstream slope	Model
0.32	0.016	0.00038	0.914	1.00	-0.740	-0.419	2.628	0.223	0.261	0	1
0.49	0.012	0.00031	0.921	1.84	-0.891	-0.169	1.332	0.421	0.701	30	
0.35	0.008	0.00017	0.897	1.32	-1.971	-0.311	0.893	1.873	1.056	45	
0.87	0.007	10^{-5}*3.46	0.996	1.946	-1.375	-1.691	2.647	0.250	0.318	60	
0.21	0.016	$^{5-}$10*2.73	0.992	1.00	-0.273	1.346	-0.273	-0.273	0.175	0	2
0.19	0.015	0.00024	0.987	1.92	0.542	0.116	-2.321	0.524	0.432	30	
0.71	0.013	$^{5-}$10*2.24	0.983	1.12	1.432	0.211	-1.431	0.082	0.721	45	
0.42	0.011	0.00021	0.995	0.993	0.997	0.913	0.699	-0.996	1.000	60	
0.77	0.012	0.00011	0.972	1.00	-0.819	2.086	-0.842	0.437	0.124	0	3
0.37	0.009	0.00017	0.991	1.14	-0.816	0.514	-0.228	0.412	0.321	30	
0.36	0.011	0.00014	0.972	1.65	-0.672	0.516	2.167	0.398	0.635	45	
0.87	0.017	0.00018	0.993	1.713	-1.531	2.191	-0.201	-0.171	0.132	60	
0.67	0.023	0.00016	0.990	1.00	-0.680	-0.719	0.079	-0.667	0.104	0	4
0.84	0.020	$^{5-}$10*3.25	0.974	1.66	-0.294	2.162	2.257	-0.296	0.319	30	
0.32	0.017	0.00014	0.991	1.00	-0.332	2.451	2.104	0.325	0.215	45	
0.55	0.011	$^{5-}$10*3.22	0.967	0.999	-0.856	-0.881	0.997	0.051	1.000	60	

Finally for stepped spillways were extracted a general relationship that has a high coefficient of determination and NRMSE and SEE is low. Due to the general equation for stepped spillway discharge coefficient can be concluded that the discharge coefficient with B/H_d parameter and tan (β) has a direct relationship and with the dimensionless parameters $\frac{h}{H_d}$ □ $\frac{L}{H_d}$ and $\frac{P}{H_d}$ inverse relationship.

Table 3. Constant coefficients for total equation for discharge coefficient in the Stepped spillway

Average estimation error (%)	SEE	NRMSE	R^2	C_6	C_5	C_4	C_3	C_2	C_1	Model
8.762	0.008	0.017	0.742	1.456	-10.453	-0.158	-0.356	11.163	0.006	Stepped spillway

In Figure 26, the discharge coefficient in both laboratory and computational seen, discharge coefficient obtained in table 3 in comparison with results are described is shown. The results of this relationship is acceptable for measured data. Value correlation coefficient is R^2=0.742.

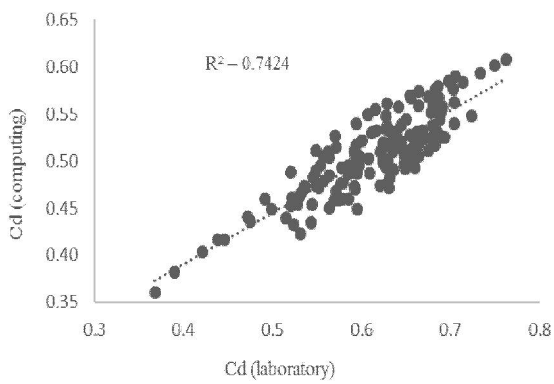


Figure 26. Comparison results of computing and laboratory of discharge coefficient in the Stepped spillway for measured data

Total resulting

1. In a P/H_d, L/H_d, h/H_d and B/H_d fixed, minimum and maximum discharge coefficient of stepped spillway Respectively Belongs is to without slope and stepped spillway with upstream slope 60 degrees. Indicating that the upstream slope of 60 degrees in less time flooding caused flooding areas Grain is upstream.

2. P/H_d is fixed, with Increasing upstream side slopes, the discharge coefficient increases. at a constant P/H_d in order of highest discharge coefficient in upstream slope 60, 45, 30 degrees and no slope.

3. In a constant discharge, head water over without slope in the spillway stepped is the highest and at a constant height, the discharge capacity of the lowest values.

4. Parameters p/H_d L/H_d, h/H_d and B/H_d and tan (β) are effective on discharge coefficient. So by increasing these parameters, discharge coefficient varies from 0.3 to 0.75.

5. There is an inverse relationship between the parameter Cd and P/H_d, by raising the water level on the spillway crest, discharge coefficient increases.

6. In a B/H_d fixed, according to fixed B, by reducing the amount H_d, discharge coefficient increases.

7. By comparing the models stepped spillways at one slope upstream was found on a slope in a fixed P/H_d highest discharge coefficient, respectively in Model 2, Model 1, Model 3 and Model 4.

8. Finally, the relationship of power to discharge coefficient for stepped spillways using SPSS software that the results of statistical indicators show high accuracy equivalent.

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