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EFFECT OF UPSTREAM SIDE SLOPE OF CRUMP WEIR ON DISCHARGE COEFFICIENT

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ABSTRACT

The current study examines the flow characteristics under free flow conditions over a crump weir. The impact of the side slopes of the weir on the coefficient of discharge (Cd) is taken into account. Four physical models with crest heights of 0.15 m under free flow circumstances and four upstream side slope (1:3, 1:2.5, 1:2 and 1:1.5) were used to investigate the impact of various variables on discharge coefficient (Cd). Using the dimensional analysis technique, the elements influencing the crump weir's discharge coefficient were determined based on laboratory tests. For the same flow rate, Cd value decrease by decreasing upstream side slope. It notices that a decrease in upstream slope (from 1:3 to 1:2.5) reducing Cd value about (2.61 %), decrease upstream slope from (1:3 to 1:2) reducing Cd value about (4.16 %) and when decrease upstream slope from (1:3 to 1:1.5) reducing Cd value about (5.81 %).

KEYWORDS

Crump weir, Upstream side slope, Discharge Coefficient, Free flow conditions, Laboratory test.

1. INTRODUCTION

Weirs are hydraulic structures with different applications, such as measurement of flow, diverting of flow, and control of flow. Ensuring accurate and simple water flow rate prediction over weirs is crucial. A weir can have a design with a standard shape with vertical upstream and downstream faces or it can be customized by angling one or both faces to improve its hydraulic properties (Alomari, N.K., et al. 2023, Majedi-Asl, M., et al. 2024, Alomari, N.K., et al. 2024). Measuring the discharge coefficient in hydraulic structures is one of the important and main topics in water system management (Parsaie, A. and Haghiabi, A.H., 2016).

In this research, the researcher was interested in studying the effect of the height and roughness of the surface (resulting from different construction materials) of crump weir on the drainage coefficient under different conditions of flow (Demetriou, J., Retsinis, E., 2013). the researcher studied the effect of the crump weir geometry on the drainage coefficient (cd) under the influence of changing the flow conditions (Al-Shukur, A., et al. 2017). Study modified the crest of a crump weir to be V-shaped, using four wooden models with varying middle crest heights. The modified models were tested under different flow rates and depths. A nonlinear multiple regression formula was created, showing a clear effect on water level at low flow rates (Al-Khateeb, H.M.M., et al. 2019). The study compares traditional crump weirs and a new one with opening holes, revealing that increasing opening holes increases energy dissipation and discharge coefficient, aiding fish egg transport, and exhibiting better flow behavior (Al-Naely, H., et al. 2019). This research aims to determine a suitable crest depth position for estimating flowrate above a curved crump weir at ten different slopes and compare it with measured and CFD-simulated flowrates (Muhsun, S.S., et al. 2020). The study uses artificial intelligence to predict the discharge coefficient of crump weirs using 18 models with varying apex angles, the curve fitting neural network (CFNN) model achieved the highest precision and accuracy, the most efficient crump model was model 17 for having the least Cd of 1.14914 and least percentage error of 12.97412, which has been optimized using GA with Cd value of 1.14815 (Khalifa, S.Y., et al. 2022). Current studies explore the crump weir, incorporating artificial intelligence technology to alter its geometric shape, height, and angle of inclination, resulting in increased discharge coefficient and flow energy dissipation (Obaida, A.A.M. and Mohammed, A.Y., 2023).

In this research, effect of upstream side slope of crump weir on discharge coefficient will be studied, and laboratory work will be conducted on four weir models with side slope (1:3, 1:2.5, 1:2 and 1:1.5)

2. DIMENSIONAL ANALYSIS

The discharge coefficient (Cd) in general is depending on three types of variables 1)characteristics of the fluid (water), 2) fluid properties and 3) geometric dimensions of the model. (Arora, 2005). The symbols used in the dimensional analysis are shown in Table 1.

Table 1. outlines these variables and their units.

Symbol	Definition	Dimensions
FLOW CHARACTERISTICS		
Q	Discharge at free flow condition	L^3T^{-1}
g	Gravitational acceleration	LT^{-2}
H	Total upstream head	L
FLUID PROPERTIES		
$\boldsymbol{\rho}$	Mass density of water	ML^{-3}
$\boldsymbol{\mu}$	Dynamic viscosity of water	$ML^{-1}T^{-1}$
$\boldsymbol{\sigma}$	Water surface tension	MT^{-2}
GEOMETRICAL CHARACTERISTICS		
P	Crump weir height	L
Z	Upstream Slope of crump weir	
B	Channel width	L

$$C_d = f(H, P, Z, B, \mu, \rho, \sigma, g) \tag{1}$$

According to Buckingham's theoremthe following relationship was obtained.

$$C_d = f\left(\frac{P}{H}, Z\right) \tag{2}$$

Therefore, laboratory experiments will be carried out depending on the variables that have been obtained from the dimensional analysis technique for each shape of crump weirs

3. EXPERIMENTAL WORK

Laboratory works were done in a free outward chute in hydraulic laboratory in the Faculty of Engineering of Al-Kufa University. The laboratory flume used in the present research is quadrangular chute of 15 m length, 0.3 m width, and 0.45m height as shown in Fig. 1. Sidewalls of the flume are made of fiberglass in order to make visual observation possible, but flume bed is stainlessness steel. To operate the pump and tilting system, an electric controller is sited at the upstream side of the flume.

Crump weir models are made of wood. Four different model of crump weir were used, four upstream side slope (Z) (1:3, 1:2.5, 1:2 and 1:1.5) While the side slope of the downstream is fixed at (1:3) with crest height (P) for each 15 cm. as shown in Fig. 2.

Fig. 1. The flume

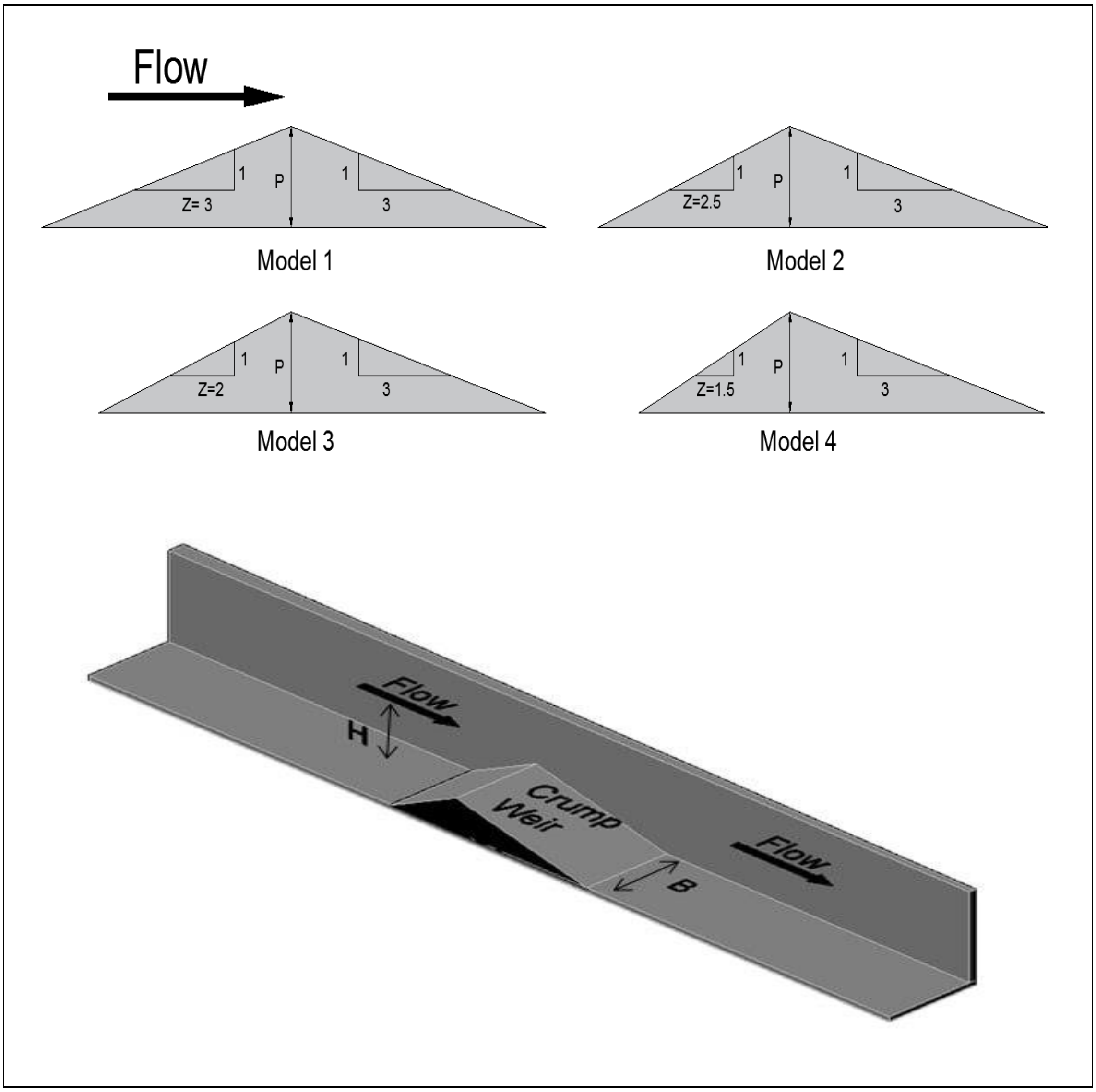

Fig. 2. model of crump weir (height 0.15 m with different upstream side slope)

The crump weir is singular kind of broad crested weir with triangular profile as shown in Fig.3. In the present research the coefficient of discharge (C_d) of crump weir measured using the equation (3) (ACHOUR, B., and AMARA, L., 2022).

$$Q = C_d \; L \; H^{\frac{3}{2}} \sqrt{g} \qquad (3)$$

Q : Discharge at free flow condition

C_d : Coefficient of discharge

L : Weir width = Channel width = 0.3 m.

H : Total upstream head

g: Gravitational acceleration

Fig. 3. Crump weir model

4. RESULTS AND DISCUSSION

The following results of the parameters are taken from results of the experimental work and using equation (3) as demonstrated in Tables below for each crump weir conditions:

Table 2. Mode 1 (upstream Side Slope 1:3)

Q_{act} (L/s)	Q_{act} (m^3/s)	H (m)	P/H	C_d
22.63	0.02263	0.3309	0.4532	0.1265
19.87	0.01987	0.3199	0.4690	0.1169
17.56	0.01756	0.3130	0.4792	0.1067
15.37	0.01537	0.3080	0.4870	0.0957
12.88	0.01288	0.2991	0.5015	0.0838
10.56	0.01056	0.2923	0.5131	0.0711
8.19	0.00819	0.2823	0.5313	0.0581

Table 3. Mode 2 (upstream Side Slope 1:2.5)

Q act (L/s)	Q act (m3/s)	H (m)	P/H	Cd
22.63	0.02263	0.3345	0.4485	0.1245
19.87	0.01987	0.3245	0.4623	0.1144
17.56	0.01756	0.3186	0.4707	0.1039
15.37	0.01537	0.3137	0.4782	0.0931
12.88	0.01288	0.3047	0.4923	0.0815
10.56	0.01056	0.2985	0.5025	0.0689
8.19	0.00819	0.2918	0.5141	0.0553

Table 4. Mode 3 (upstream Side Slope 1:2)

Q_{act} (L/s)	Q_{act} (m^3/s)	H (m)	P/H	C_d
22.63	0.02263	0.3376	0.4444	0.1228
19.87	0.01987	0.3276	0.4579	0.1128
17.56	0.01756	0.3220	0.4659	0.1023
15.37	0.01537	0.3178	0.4720	0.0913
12.88	0.01288	0.3085	0.4862	0.0800
10.56	0.01056	0.3018	0.4971	0.0678
8.19	0.00819	0.2950	0.5085	0.0544

Table 5. Mode 4 (upstream Side Slope 1:1.5)

Q_{act} (L/s)	Q_{act} (m^3/s)	H (m)	P/H	C_d
22.63	0.02263	0.3407	0.4403	0.1211
19.87	0.01987	0.3309	0.4533	0.1111
17.56	0.01756	0.3251	0.4613	0.1008
15.37	0.01537	0.3209	0.4675	0.0900
12.88	0.01288	0.3124	0.4801	0.0785
10.56	0.01056	0.3069	0.4888	0.0661
8.19	0.00819	0.3005	0.4991	0.0529

5. ANALYSIS OF DATA

The discharge coefficient of crump weir is influenced by numerous factors, each of which will be examined in turn below.

5.1. Effect of the discharge Q

The coefficient of discharge (Cd) increasing with the increasing of Q for the same upstream slope as shown in Fig. 4.

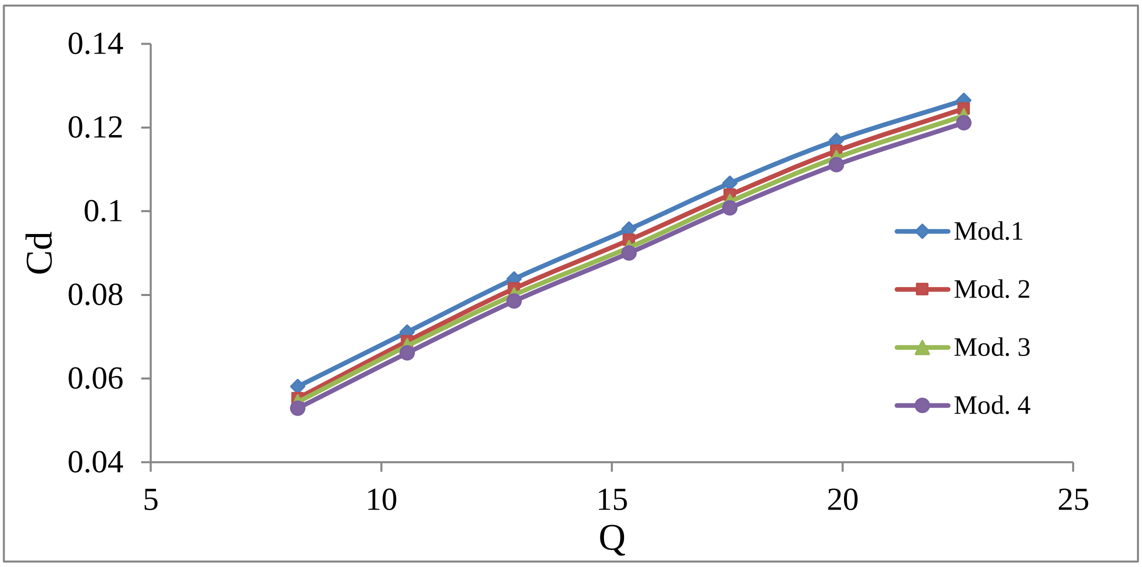

Fig. 4. Variation of Cd versus Q

5.2. Effect of the hydraulic parameter P/H

The coefficient of discharge (Cd) decreases with the increasing of P/H for the same upstream slope as shown in Fig. 5.

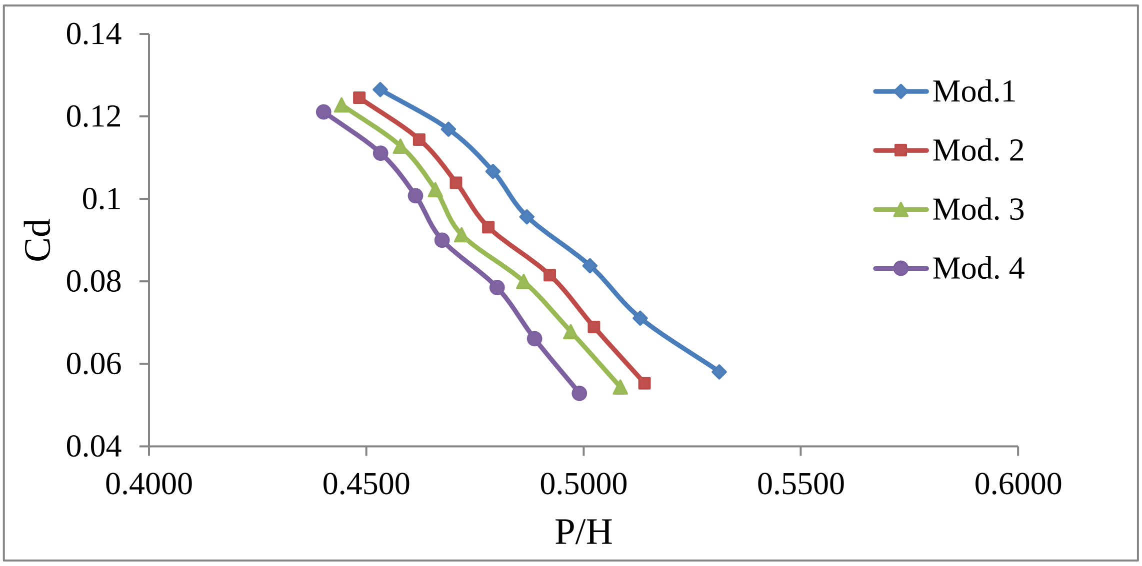

Fig. 5. Variation of Cd versus P/H

5.2.1. Upstream Side slope

The coefficient of discharge (Cd) is directly proportional with the upstream Slope (Z) as shown in Fig.6. The rate of decreases in Cd was calculated based on dividing the change of average value of Cd by original of average value of Cd. When reducing the slope (Z) by 0.5, Cd decreases about (2.61 %) and decreases about (4.16 %) when reducing Z by 1. While Cd decreases about (5.81 %) when decreases Z by 1.5

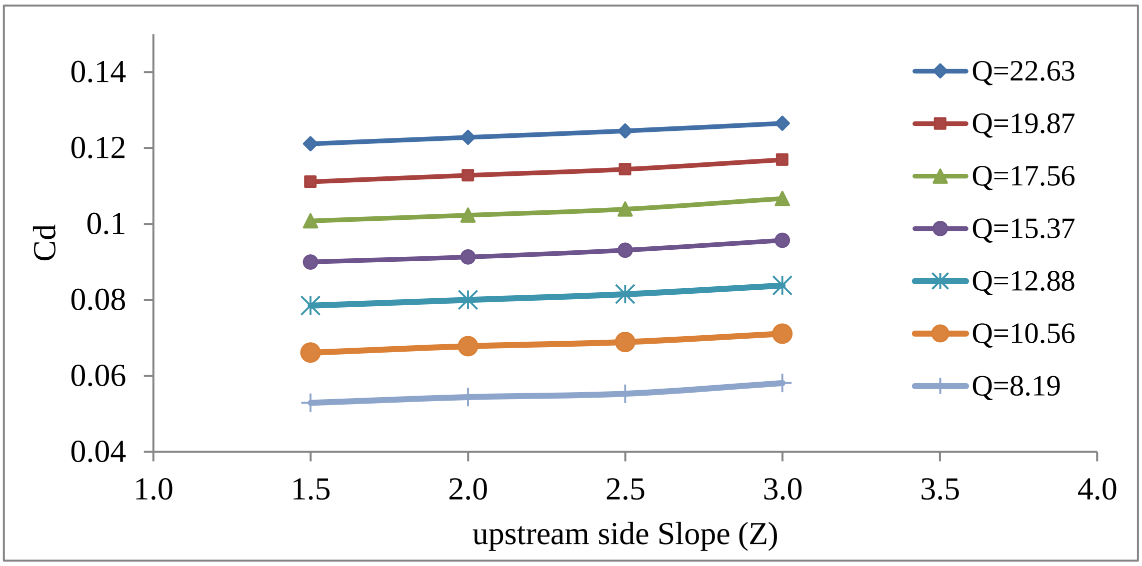

Fig. 6. variation of (Cd) with upstream side slope (Z) for different discharge

6. CONCLUSIONS

In the present research the following points have been concluded.

1- The discharge coefficient (Cd) increasing with increasing discharge (Q)

2- For the same discharge, Cd value decrease by decreasing upstream angle value. It notices that a decrease in upstream slope (from 1:3 to 1:2.5) reducing Cd value about (2.61 %), decrease upstream slope from (1:3 to 1:2) reducing Cd value about (4.16 %) and when decrease upstream slope from (1:3 to 1:1.5) reducing Cd value about (5.81%).

3- The best and highest discharge coefficient occurs at upstream slope (1:3).

4- The coefficient of discharge decreases with the increasing of P/H for the same us stream slope.

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