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Determination of Discharge Coefficient in Ogee Spillways and Investigation the Effects of Submergence, Upstream Slope and Apron Elevation on Its Variations

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ABSTRACT: Discharge over the ogee spillway is related to the length of crest, upstream total head, and discharge coefficient. Also, the discharge coefficient is influenced by several factors. In this study, some parameters that are affecting the discharge coefficient in ogee weir are investigated. These are ogee spillway upstream slope, apron elevation, and downstream submergence. In this regard, some ogee spillway physical models were fabricated. These models include (1) ogee spillway with vertical upstream face, (2) ogee spillway with inclined upstream face (18, 33, and 45 degrees), (3) ogee spillways with downstream apron elevations (3, 5, 7, and 10 cm thickness) in free flow, and (4) ogee spillway with the vertical upstream slope in submerged flow condition. Results showed that in all the ogee weirs, the discharge coefficient (C) increases with increasing (P/He) and then remain constant. The value of the discharge coefficient decreased from 2.25 (in free flow) to 2.15 (in submerged flow). For a constant value of head over ogee spillways (He), the discharge coefficient decreased with increasing downstream apron elevation and submergence. The relative discharge coefficient had a constant trend at the beginning with parameter (hd/He), then it had a decreasing trend. The threshold value for submergence (hd/He), was 0.75 in the ogee spillway in this study. With increasing relative submergence (hd/He) from 0.75 to 1, the relative discharge coefficient (Cs/C0) decreased from 0.88 to 0.24.

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1. INTRODUCTION

In dams, spillways are hydraulic structures that are built to convey the excess flow from floods that are extra from dam capacity. Spillways should be strong, reliable, and high-performance structures to prevent severe damages. Therefore, the design and construction of dam spillways are very important. If a dam spillway is correctly designed and constructed, flood risks can be prevented by proper management when a flood occurs [1]. Spillways are made in different types, and this can be attributed to geological, hydraulic, project site topography, and most importantly economic costs. The most common spillway that is capable of passing large amounts of water on its own is the ogee spillway. These spillways are often used in diversion dams due to their high hydraulic efficiency [2]. Tullis and Neilson investigated the performance of the submerged ogee spillway and its stage-discharge relationship [3]. Tullis evaluated the changes of the ogee spillway discharge coefficient [4]. Shamsi *et al.* investigated the discharge coefficient (C_d) of cylindrical weirs and its capability of inflow energy dissipation. The results showed that in the H/D range between 0.15 and 2, the discharge coefficient varies from 1 to 1.4 [5]. Sheikh Kazemi and Saneie studied the effect of the approaching channel velocity on the weir discharge coefficient with axial arch and convergent walls [6]. Eshrati *et al.*, studied the physical model of an arc plan weir as well as normal (perpendicular to flow) weir with similar geometrical and hydraulic conditions to investigate the discharge coefficient variations [7]. Salmasi (2018) studied the effect of downstream apron elevation and downstream submergence in the discharge coefficient of ogee weir [8]. In that study, Salmasi (2018) used classic regression equations as well as artificial intelligence methods.

A review of previous studies showed that the effects of ogee spillway upstream slope, downstream apron elevation, and weir submergence on discharge coefficient, have been less carried out in ogee spillway. Therefore, in the present study, the effects of these three factors on the discharge coefficient of ogee spillway were investigated by constructing physical models of ogee spillway in laboratory dimensions. For this purpose, dimensional analysis of the effective parameters on the discharge coefficient was identified and the results of the experiments were analyzed using dimensionless forms.

2. MATERIAL AND METHODS

The experiments were conducted in the hydraulic laboratory of the water engineering department, University of Tabriz, Iran. A Laboratory flume was a rectangular shape 10 meters long, 25 cm wide, and 50 cm high that is made of metal with glass walls. This flume is located on a chassis 110 cm above the ground and has a constant slope of 0.002. The flume also has been equipped with a series of parallel plates

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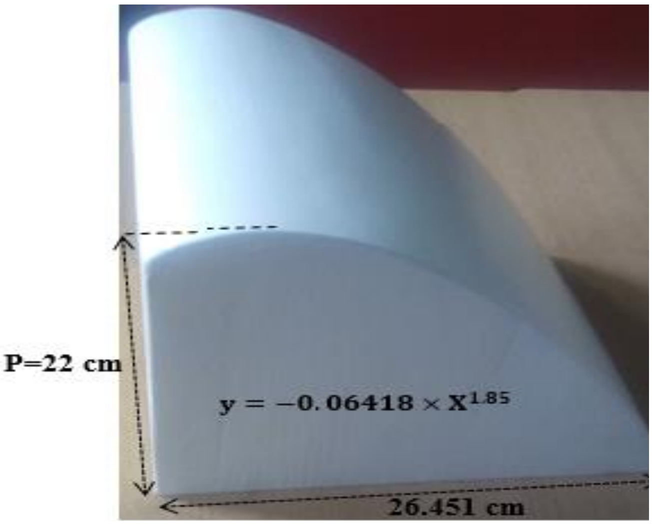

Fig. 1. A view of an ogee spillway used in the experiments

upstream. Therefore, it decreases the turbulence of the inlet flow to the flume and increases the accuracy of water depth measurement. Excess water, overflow when necessary, and return to the main tank through pipes. The maximum flow rate in the flume was 40 l/s and the flow discharge in this range was accurately adjustable by the valve at the beginning of the flume.

The ogee spillway profile was designed and developed by the US Bureau Reclamation (USBR) and with the discharge of 11 l/s. The spillway body was built with wood (Fig. 1), the downstream apron was made with polyethylene, and the three pieces of MDF wood with a thickness of 8 mm. The model was inserted into the flume and then a special adhesive was used to seal it. In each experiment, after determining the desired conditions, upstream water level, downstream water depth, and discharge were determined. Then, using the upstream total water head, the total discharge, and the spillway width, the discharge coefficient was determined.

3. RESULTS AND DISCUSSION

Figs. 2 and 3 show that for all ogee spillways in different states, the discharge increases with increasing in upstream water head (H_e).

The results showed that the maximum discharge coefficient for vertical upstream face is about 2.25 whereas, its maximum value for sloping faced spillway is about 1.9 (Fig. 4). In the word, the slope of the spillway face reduces the discharge coefficient by an average of 12%.

According to Fig. 5, it can be concluded that by increasing the apron elevation downstream of the spillway, the discharge coefficient reduces.

According to the results, as the ratio (p/H_e) increases, the value of the relative discharge coefficient (C_i/C_0) initially has a constant trend until it reaches (p/H_e)=1.4. Then it has a downward trend and then it reaches (p/H_e)=1.9, and it has a constant trend. In this range, the value of C_i/C_0 reached an approximate value of 0.985.

The results showed that in the range of p/H_e=1.2 to p/H_e=1.7, the value of C_d for 18 degrees spillway is lower than that of the other slopes (Fig. 6).

4. CONCLUSION

The results showed that variations in discharge coefficient (C_d) with parameter P/H_e in all spillways initially increased, and then reached an almost constant value. However, this increase was lower for the vertical upstream face. This indicates that upstream face slope or downstream submergence decreases the discharge coefficient. Spillway with 3 cm apron elevation had the lowest decrease in C_d and spillway with

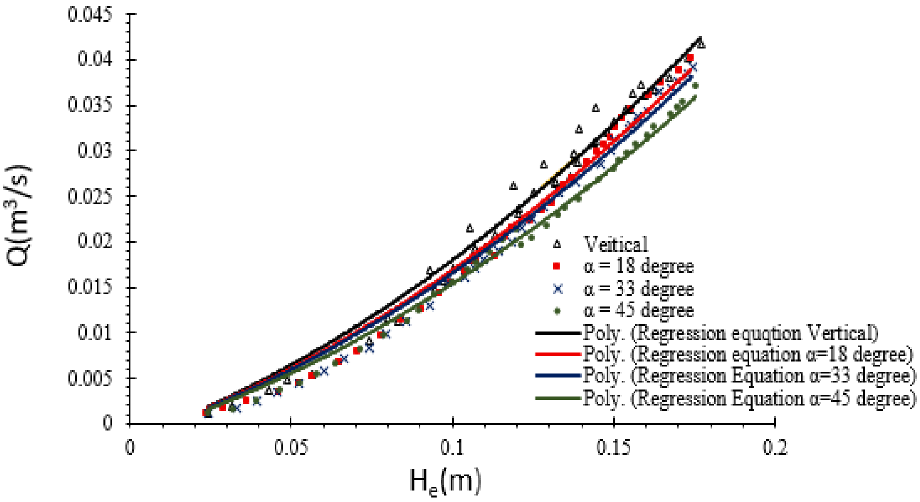

Fig. 2. Variation of H_e against Q in the ogee spillways with vertical upstream face and inclined upstream face

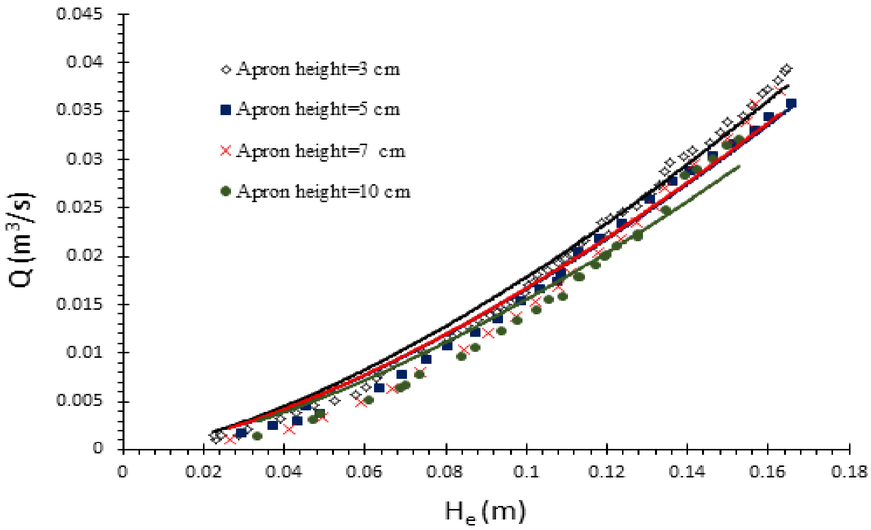

Fig. 3. Variation of H_e against Q in the ogee spillways with different downstream apron heights

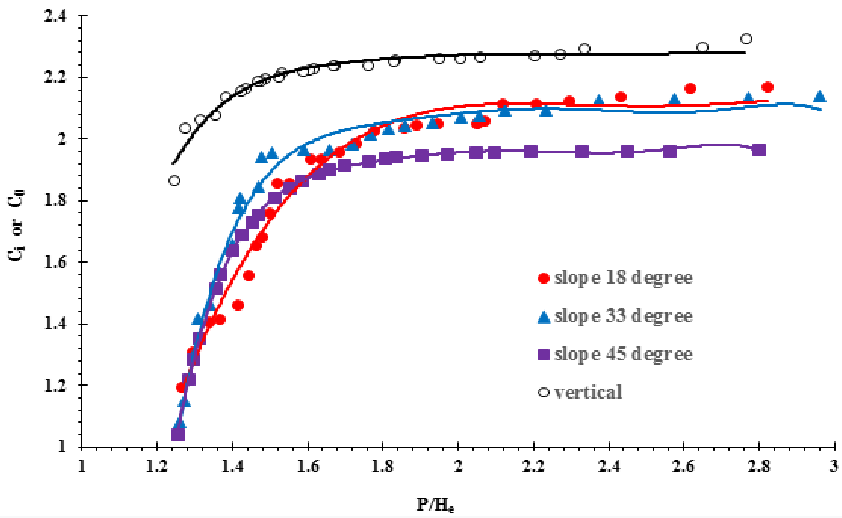

Fig. 4. Variation of discharge coefficient (C_i) against dimensionless parameter p/H_e

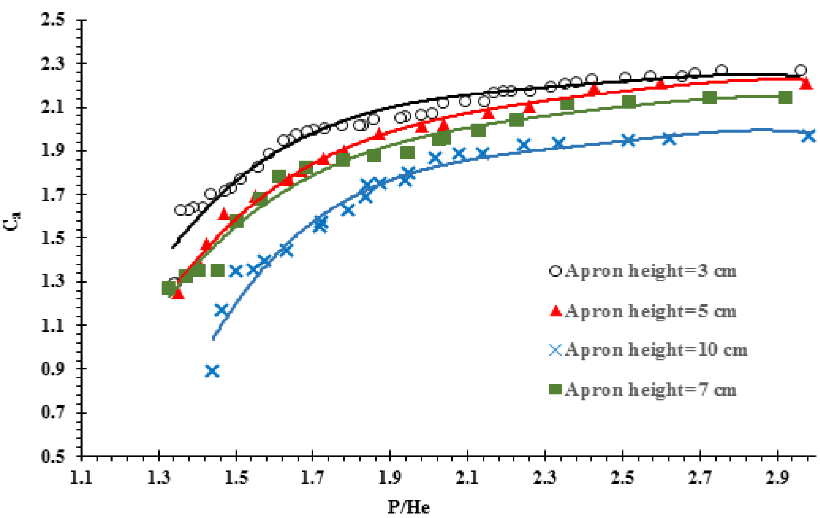

Fig. 5. Variation of discharge coefficient (C_a) against dimensionless parameter p/H_e

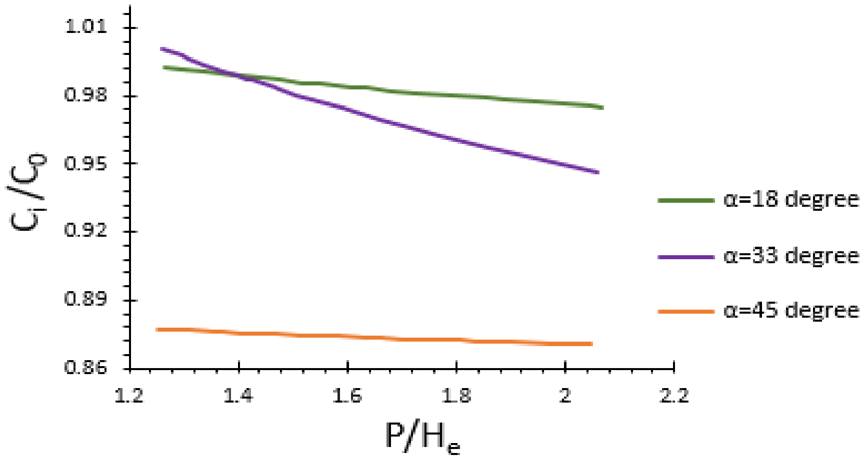

Fig. 6. Comparison of changes in the relative discharge coefficient ($\frac{C_i}{C_0}$) against dimensionless Parameter p/H_e

10 cm apron thickness had the highest decrease in C_d. The discharge coefficient decreased with increasing submergence rates. The threshold value for submergence (h_d/H_e), was 0.75 in the ogee spillway in this study. With increasing relative submergence (h_d/H_e) from 0.75 to 1, the relative discharge coefficient (C_s/C_0) decreased from 0.88 to 0.24.

REFERENCES

[1] W. Boiten, Environmental Research Instruments. Venturi gate, Adjustable gate for discharge measurement and fish migration, Elsevier, 13(6) (2002) 203-207.

[2] M. Mahmoudian Shooshtari, Principles of flow in open channels. Shahid Chamran University of Ahvaz Publications. First Edition. (2009). Volume II 508 pages.

[3] B.P. Tullis, and J. Neilson, Performance of Submerged Ogee-Crest Weir Head-Discharge Relationships, Journal of Hydraulic Engineering, ASCE, 134(4) (2008) 486-491.

[4] B.P. Tullis, Behavior of Submerged Ogee Crest Weir Discharge Coefficients, Journal of irrigation and Drainage Engineering, ASCE, 137(10) (2011) 677-681.

[5] Z. Shamsi, A. Parsaie and A.H. Haghiabi, Optimum hydraulic design of cylindrical weirs. ISH Journal of Hydraulic Engineering: 1-5. doi: 10.1080/09715010.2019.1683474 (2019).

[6] J. Sheikh Kazemi, and M. Saneie, The Effect of Approach Channels on the Discharge of Ogee Spillway in the Axial Arc Condition with Convergent Sidewalls, Journal of Middle East Applied Science and Technology (JMEAST), 22(2) (2014) 119-123.

[7] T. Eshrati, R. Fazloula, M. Sanei, A. Emadi, Laboratory Study of Hydraulic Performance of Ogee Spillway and Downstream Canal with Axial Arc, Journal of Water and Soil, 9(4) Sept.-Oct (2015) 874-885.

[8] F. Salmasi, Effect of downstream apron elevation and downstream submergence in discharge coefficient of Ogee weir, ISH Journal of Hydraulic Engineering, 2018, DOI: 10.1080/09715010.2018.1556125.

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