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Experimental Investigation of Flow Behavior Over a Piano Key Weir with Varying Inlet to Outlet Crest Height

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ABSTRACT

A piano key weir is a more modern type of hydraulic infrastructure designed to increase a dam's discharge in spillway hydraulics to release more flow and enhance performance. Piano key weirs are very important to increase the current system's discharge capacity, even though they can also be very effective in reducing reservoir flood stress. There are more benefits to piano key weirs than to labyrinth weirs. Due to its complex of shape, there is no standard design for a safe and economical design. In free flow conditions within an open channel, this study examines the energy dissipation and coefficient of discharge of trapezoidal piano key weirs under various geometric configurations. Using Piano key weir model to the flow direction and varying crest heights (Pi/Po = 1.00 cm, 1.17 cm, and 1.25 cm) a total of seven different discharges were utilized in an open channel flow. Here, Pi is the inlet crest height while Po is outlet crest height. This work aims to experimentally assess the impact of geometry on a piano key weir's energy dissipation (ΔE) and coefficient of discharge (Cd). To determine the Cd in each of the experiment and flow depths have been recorded at up and downstream of the weir. The collected data showed that changing the geometric parameter, or crest height, have a significant impact on Cd. The results 32.5cm, 32cm and 30cm were found on higher heads (h/P >20) and 23cm, 22cm, 21.5 were found on lower heads (h/P<20). The 32.5 cm had the highest value of Cd, while the 21.5 cm had the lowest value of Cd. When considering energy dissipation, the rate of energy dissipation was found as 56% at lower heads and 44% at higher heads. However, Pi/Po = 1.17, and 1.25, the energy dissipation rate were found to be 2%, 4%, respectively lesser than Pi/Po=1.00. When the crest height was 22cm, the value of energy dissipation ΔE was at its highest, and when it was 32.5cm, it was at its lowest.

Keywords: Coefficient of discharge, Energy dissipation, Trapezoidal Piano Key Weir

1 INTRODUCTION

A piano key weir, also known as a PK weir, is a type of overflow control structure that is frequently utilized in flow regulation applications and as the crest of spillways. This hydraulic structure can be categorized as a particular kind of labyrinth weir, which HydroCoop originally presented has a layout that is rectangular in shape. The most typical feature of piano key weirs is their sloped floor with parts of the crest reaching beyond the weir base, causing overhangs in the upstream and/or downstream directions. PK weirs also incorporate inlet and outlet keys (or units) 2001 [1].

At Bundesanstalt für Wasserbau (BAW), the energy dissipation and flow characteristics downstream of rectangular labyrinth weirs were examined within a restricted range. They observed that the energy dissipation offered by trapezoidal and rectangular labyrinth weirs is comparable in various ways 2018 [2]. A spillway and a small stilling basin might work well together with PK weirs. Piano key weirs over stepped spillways dissipate effective energy more quickly than ogee weirs under the same circumstances. They suggested conducting additional testing with a shorter stepped spillway. By evaluating four stepped spillway lengths, Silvestri et al. [03] expanded on the significant work of and found that downstream of PK weirs, shorter stepped spillway lengths achieve uniform flow conditions and flow energy 2011 [04]. The short base length of the piano key weir gives it an edge over the labyrinth weir in terms of hydraulic performance and construction cost, making it a more cost-effective solution (Schleiss 2011). Based on their upstream and downstream projection, piano key weirs are divided into four types: type A has projection toward both upstream and downstream on both sides; types B and C only have projection downstream and upstream, respectively; type D has no projection toward either upstream or downstream. Fig. 1 depicts the usual PKW plan and 3D perspective with geometric parameters. Table 1 provides an explanation of the PKW's geometric parameters. A major consideration in the design of free overfall hydraulic structures is energy dissipation. The process of lowering the kinetic energy of flowing water is known as energy dissipation, and it is frequently used to stop erosion, safeguard structures downstream, or regulate water velocity.

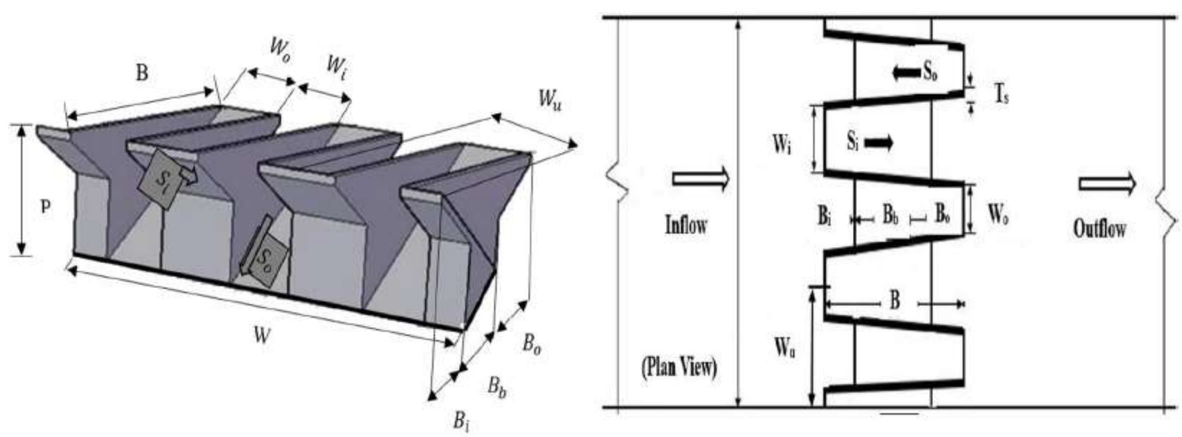

Figure 1: 3D view and a plan view of PKW (Type-A)

Table 1: hydraulic and geometric parameters of PKW.

Parameter Symbol	Definition
Pi	Height of weir at the inlet key
Po	Height of weir at the outlet key
B	Total width of PK weir
Bb	The width between the inlet and output key
Bi	Inlet key width (m)

Bo	Outlet key width (m)
Cd	PK weir's discharge coefficient
H	On the upstream side, head over the crest (m)
L	Total length of weir crest (m)
P	Height of weir (m)
q	Unit discharge (m3/s/m) via a PK weir
Q	Discharge (m3/s) over a linear weir
V	Fluid's velocity (m/s) on upstream weir side

2. EXPERIMENTAL PROCEDURE

All of the experimental work was carried out in the hydraulics laboratory of the University of Engineering and Technology Taxila The experimental investigation was conducted using the computer-controlled channel. It was a rectangular-sectioned tube with glass walls. The canal measured 10 meters in length, 0.31 meters in width, and 0.5 meters in depth. Figure 2 depicts the flow channel.

Figure 2: The Research project's computerized flow channel

Wood was used to prepare the weir models. For all of the experimental work, the flow was subcritical (Fro < 1).
Point gauge were used to measure the level of a water in the center of the channel at intervals of 0.5 meters on the upstream and downstream of the weir. The weir models were positioned in the water flume bed approximately 5 meters from the upstream inlet.

3. MODEL DESCRIPTION

In this study, Piano key weir have been used with varying crest heights. Pi/Po = 1 cm, 1.17 cm, and 1.25 cm respectively. Wooden materials were used to create the weir models. To make the models waterproof, silicone gel was utilized to seal the joints. The piano key weir model was positioned five meters away from the channel's inlet for every experiment. The depth of the water was measured using a level gauge with an accuracy of ± 0.1 mm. For each run, at a known discharge (Q) value, the velocity and specific energy at the u/s and d/s of the TPKW model were determined using the corresponding average value of the upstream and downstream depths.
Figure 3 (a) displays the piano key weir wooden model.

Figure 3: PK Weir wooden model

4. RESEARCH METHODOLOGY

In this study, Piano key weir model with the flow direction have been used with varying crest height was 1.00cm, 1.17cm, and 1.25cm. Seven different discharges (Q) were employed for every scenario.
At both the upstream and downstream ends of weir, flow depth measurements was taken at one-meter interval. These depths were measured with point gauges. Following the setup of the experimental model, seven different trials with seven different discharge levels were conducted.

Table 2: Explains the geometric and hydraulic conditions.

Cases	Inlet crest height (Pi)	Outlet crest height (Po)	Ratios (Pi/Po)
1	20cm	20cm	01cm
2	20cm	17cm	1.17cm
3	20cm	16cm	1.25cm

5. RESULTS

In Figure 4 (a). The variation of Cd for various PK weir heights is depicted. The values of Cd drop as the crest heights changes from minimum to maximum. Therefore, it is concluded that the relationship between Cd is inversely proportional to H/P

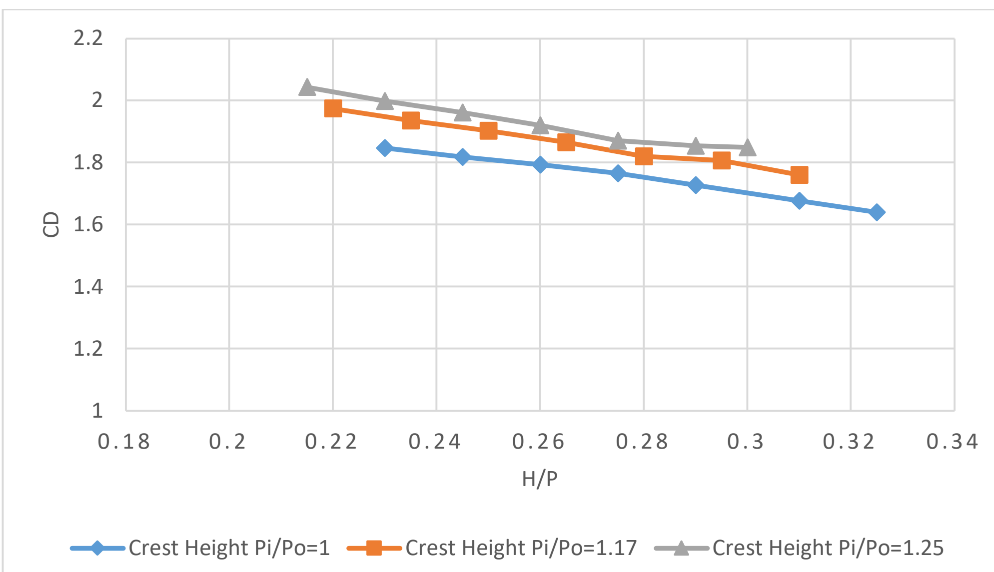

Figure 4(a): Cd vs H/P for different crest heights

Fig. 4 (b) shows that the results are justified by the fact that the overflow head increases as the discharge values rise.

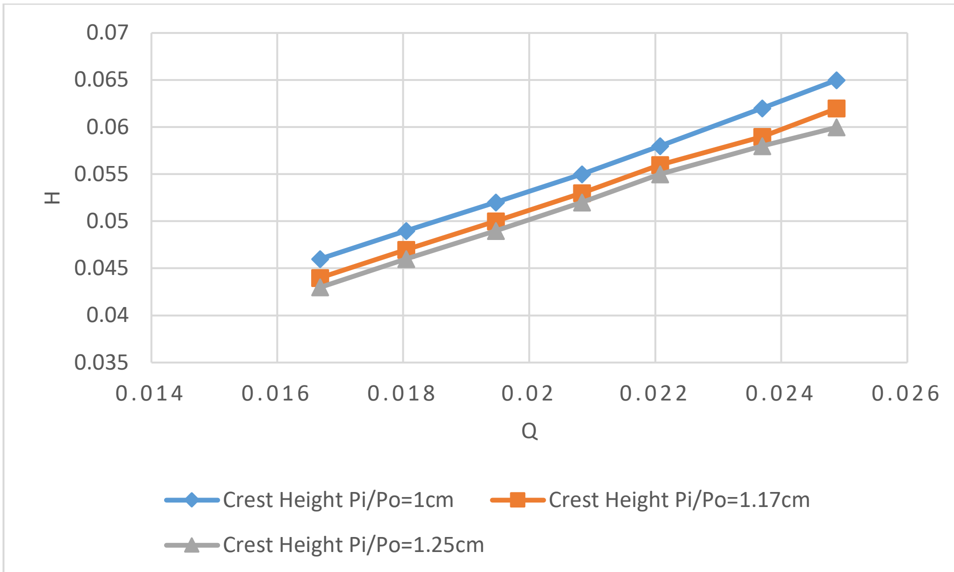

Figure 4(b): Discharge relationship for different crest heights

Fig. 4 (c) shows when the crest height was 22cm, the value of energy dissipation ΔE was at its highest, and when it was 32.5cm, it was at its lowest.

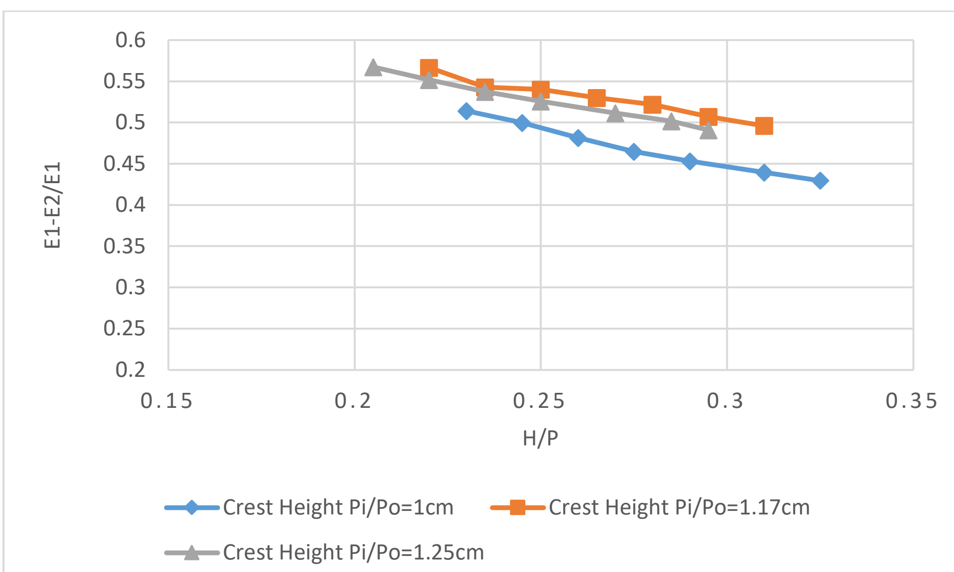

Figure 4(c): The effect of different heights on ΔE/E1

6. CONCLUSION

Following conclusion are findings from this research project:
1. The maximum and minimum Cd values were found for crest heights of 21.5cm and 32.5cm, respectively.
2. It was observed as well that the overflow head (H) rises as the discharge does under free flow conditions.
3. As the (H/P) ratio rises, the discharge coefficient values often drop, especially as crest height increases.
4. The energy dissipation maximum was noted for a height of 56cm, and it decreases with increasing H/P.

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8. REFERENCES

1. BLANC, P.; LEMPÉRIÈRE, F. LABYRINTH SPILLWAYS HAVE A PROMISING FUTURE. HYDROPOWER DAMS 2001, 8, 129–131

2. JÜSTRICH, S.; PFISTER, M.; SCHLEISS, A.J. MOBIL RIVERBED SCOUR DOWNSTREAM OF A PIANO KEY WEIR. J. HYDRAUL. ENG. 2016, 142.

3. MERKEL, J.; BELZNER, F.; GEBHARDT, M.; THORENZ, C. ENERGY DISSIPATION DOWNSTREAM OF LABYRINTH WEIRS. IN PROCEEDINGS OF THE 7TH IAHR INTERNATIONAL SYMPOSIUM ON HYDRAULIC STRUCTURES, AACHEN, GERMANY, 15–18 MAY 2018.

4. ERPICUM, S.; MACHIELS, O.; ARCHAMBEAU, P.; DEWALS, B.; PIROTTON, M.; DAUX, C. ENERGY DISSIPATION ON A STEPPED SPILLWAY DOWNSTREAM OF A PIANO KEY WEIR—EXPERIMENTAL STUDY. IN LABYRINTH AND PIANO KEY WEIRS—PKW 2011; CRC PRESS: LONDON, UK, 2011; PP. 105–112.

5. MERKEL, J.; BELZNER, F.; GEBHARDT, M.; THORENZ, C. ENERGY DISSIPATION DOWNSTREAM OF LABYRINTH WEIRS. IN PROCEEDINGS OF THE 7TH IAHR INTERNATIONAL SYMPOSIUM ON HYDRAULIC STRUCTURES, AACHEN, GERMANY, 15–18 MAY 2018.

6. REFERENCE CROOKSTON, B.M.; ERPICUM, S.; TULLIS, B.P.; LAUGIER, F. HYDRAULICS OF LABYRINTH AND PIANO KEY WEIRS: 100 YEARS OF

PROTOTYPE STRUCTURES, ADVANCEMENTS, AND FUTURE RESEARCH NEEDS. J. HYDRAUL. ENG. 2019,

7. ERPICUM, S.; SILVESTRI, A.; DEWALS, B.; ARCHAMBEAU, P.; PIROTTON, M.; COLOMBIÉ, M.; FARAMOND, L. ESCOULOUBRE PIANO KEY WEIR: PROTOTYPE VERSUS SCALE MODELS. IN LABYRINTH AND PIANO KEY WEIRS II—PKW 2013; CRC PRESS: LEIDEN, THE NETHERLANDS, 2013; PP. 65–72.