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Enhancing Discharge Capacity of Piano Key Weir by Varying Number of Cycles

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ABSTRACT

Innovative structures called piano key weirs are used in hydraulic engineering to regulate flow. This study intends to investigate the effects of changes in the geometry of the piano key weir, namely the number of cycles, on discharge performance. The study looked at how a piano key weir's discharge capacity would change as the number of cycles changed. In this work, a series of controlled laboratory tests were carried out in which several piano key weir models were examined at various heads in the range of 0.042m to 0.078m. The findings showed that some modifications to the geometric parameters can have a substantial effect on the PKW's discharge efficiency. The piano key weir's discharge rates increased as the number of cycles was reduced, showing that fewer cycles enable better flow control and water management capabilities. Furthermore, the value of discharge capacity of PK weir with number of cycles 3 was found to be 3.36% and 5.95% greater than PK weir with number of cycles 4 and 5 respectively. The research's conclusions offer useful information for engineers and professionals working on water resource projects, assisting them in making wise choices when putting piano key weirs to use in practical situations.

KEYWORDS: Piano Key Weir, discharge capacity, hydraulic systems, water management, flood control.

1 INTRODUCTION

One of the most often used hydraulic structures in water management and civil engineering is a weir, which is used, for example, to measure flow in a river, raise the water level, and control flow. [1]. The process of selecting the best kind of weir for a given site entails optimization with the goal of achieving maximum discharge capacity while lowering construction costs. Weir's discharge capacity is mostly determined by its form and crest length [1]. Because of their high discharge passage capacity, labyrinth and piano key weirs with nonlinear planes like rectangular, triangular, trapezoidal, and parabolic are gradually replacing linear weirs. Weir's of this kind often have one or more critical cycles. With a shorter base length than the labyrinth weir, the piano key weir is more cost-effective in terms of both hydraulic performance and construction costs [2]. The ratio L/W is used to describe the PK-Weir's non-linear shape-induced elongation of the crest. This ratio illustrates the proportion between the weir's width and the whole length of the crest. Increment in L/W enhances the discharge capacity of PK weir of both types [3]. Because of its shorter base length than the labyrinth weir, the piano key weir is more cost-effective to construct and has better hydraulic performance [4] [5]. Numerous investigations have been conducted to examine the impact of the geometric and hydraulic parameters of weirs on their downstream characteristics [6].

The head-toweir height ratio (h/P), inlet-to-outlet key width ratios (Wi /Wo), inlet-to-outlet key slope ratios (Si /So), and number of cycles (Nu) are among the hydraulic and geometric characteristics that affect the PKWs' discharge capacity [7].Noui and Ouamane investigated the effects of adding a ski-jump at the base of PKW outlet keys. According to their findings, this design prevents the water jet from hitting the dam body directly. Nevertheless, they noticed that the PKW's hydraulic efficiency dropped as the energy dissipation across the weir rose [8]. PKWs have been built in many different locations throughout the world because of their excellent hydraulic performance and site flexibility [9]. Over 34 PKW projects have been built in Europe, North America, Australia, and Asia. They have been built as run-of-river structures (Dakmi 2 and Van Phong Barrage, Vietnam), at gravity dams (Malarce Dam, France), and on embankment dams (Lake Peachtree Dam, GA, USA) [10] [11].

To the authors' knowledge, however, only few research have been conducted to investigate the effect of number of cycles (Nu) on TPKW's discharge capacity; as a result, there is currently insufficient data about the effect of this component on TPKW's discharge capacity. In order to deliver a larger release of water and enhance the overall efficiency, the current study set out to determine how the cycle count affected the weir's ability to release water. Due to the increasing number of deteriorating dams, the frequency and intensity of critical weather events, and the possibility of high magnitude failures and cascading accidents on vital infrastructure networks, this innovation is extremely important.

2 MODEL PREPARATION AND EXPERIMENTATION

2.1 Channel Configuration: Every experiment was conducted at the University of Engineering and Technology Taxila's hydraulic laboratory in the Civil Engineering department. The trials were conducted using a rectangular flume with dimensions of 10 m in length, 0.31 m in width, and 0.45 m in height. Water was delivered to the channel headbox by a pump from a storage tank. The

channel provided a regulated and reliable setting for analyzing the discharge capacity characteristics of the piano key weirs. For all flows, the channel's horizontal slope remained unchanged. Glass was used for the side walls and stainless steel for the channel bed. An electrical source, such a main switch, might be connected to the channel to determine the flow rate and other factors.

2.2 Model Placement: A lot of effort was put on accurately placing the piano key weir model within the channel in the free flow condition. To keep the models waterproof, silicone gel was utilized to affix the joints. The PKW model was positioned five meters away from the channel's intake for every experiment.

2.3 Flow Initiation: The researchers decided on a specific frequency of 22Hz as the beginning point to start the flow in the free flow scenario. The researchers were able to measure critical variables necessary for comprehending discharge capacity events at these precise sites. The researchers were able to examine changes in variables including discharge, head and discharge capacity by taking measurements both upstream and downstream, which gave them important insights into the piano key weir models' discharge capacity characteristics.

2.4 Parameter Measurement: A scale was utilized in the experiment to get accurate measurements. At a point 5 meters upstream from the scale model of the piano key weir, the scale tip made contact with the water's surface. This made guaranteed that readings of important parameters were correct.

From Q value of 0.0117 m^3/s to 0.02208 m^3/s, the measurement procedure was carried out methodically for each frequency. They were able to thoroughly examine the piano key weir's performance under various flow conditions using this wide frequency range, giving them important information about the weir's discharge capacity characteristics.

2.5 Calculation of coefficient of discharge (Cd):

For flow through an open channel, we calculated the coefficient of discharge (Cd) using the following formula:

$$Cd = \frac{Q}{\sqrt{2g}bh^{3/2}}$$

Where: Cd = Coefficient of discharge Q = Actual flow rate through the orifice (m^3/s)

The researchers put different values of heads we measure in above equation and respective discharge at different frequencies to get the value of coefficient of discharge (Cd). Then software

Microsoft excel was used for plotting graphs between different parameters under observation such as Cd and /P, H an Q, Cd and Fr.

3 RESULTS AND DISCUSSION

1) Coefficient of discharge vs ratio between head above the crest and height of weir, graph of PKWM 1 with three Nu at discharge ranging from 0.0117 m^3/s to 0.02208 m^3/s. The graph showing a decrease in discharge capacity of the weir as head increases in Fig 1.

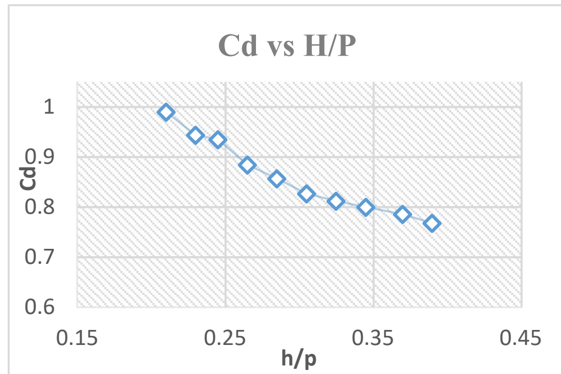

Figure 1: Coefficient of discharge vs H/P

2) Coefficient of discharge vs ratio between head above the crest and height of weir, graph of PKWM 2 with four Nu at discharge ranging from 0.0117 m^3/s to 0.02208 m^3/s. The graph showing a decrease in discharge capacity of the weir as head increases in Fig 2.

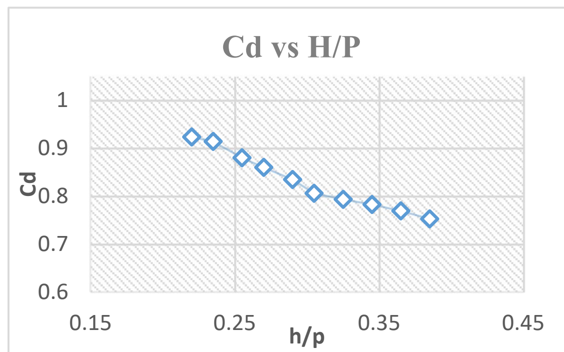

Figure 2: Coefficient of discharge vs H/P

3) Coefficient of discharge vs ratio between head above the crest and height of weir, graph of PKWM 3 with five Nu at discharge ranging from 0.0117 m^3/s to 0.02208 m^3/s. The graph showing a decrease in discharge capacity of the weir as head increases in Fig 3.

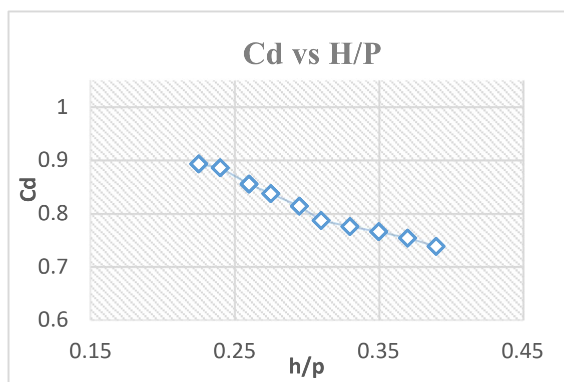

Figure 3: Coefficient of discharge vs H/P

Table 1 Comparison of Cd of all PKW's model at diff values of discharge

Q (m^3/s)	PKWM 3Nu	PKWM 4Nu	PKWM 5Nu
0.0117	0.989922	0.9232	0.892598
0.01279	0.94411	0.91414	0.885722
0.01392	0.934618	0.880183	0.854916
0.01482	0.884552	0.860095	0.836745
0.01601	0.856777	0.834715	0.813584
0.01668	0.826529	0.806288	0.78686
0.01805	0.811888	0.793225	0.775265
0.01947	0.799635	0.782314	0.76561
0.02084	0.785576	0.769489	0.753944
0.02208	0.767481	0.752579	0.738153

The number of cycles was identified as a critical parameter affecting the discharge capacity. Decreasing the number of cycles of piano key weir led to higher discharge rates, suggesting that a less number of cycles allows for greater flow control and enhanced water management capabilities. We analyzed three different models of PKW keeping number of cycles as three, four and five. Results revealed that discharge capacity was maximum at three number of cycles and discharge capacity decreased from 0.860 to 0.831 (3.36 %) as we move number of cycles from three to four and further reduced from 0.831 to 0.810 (2.59 %) as we move to PKW with five number of cycles. So, an overall 5.95 % increment in discharge capacity was noticed by using PKW with three number of cycles as compared to PKW with five number of cycles. Comparison between coefficient of discharge capacity of all the PKW models at different discharge (Q) values is also shown in table1.

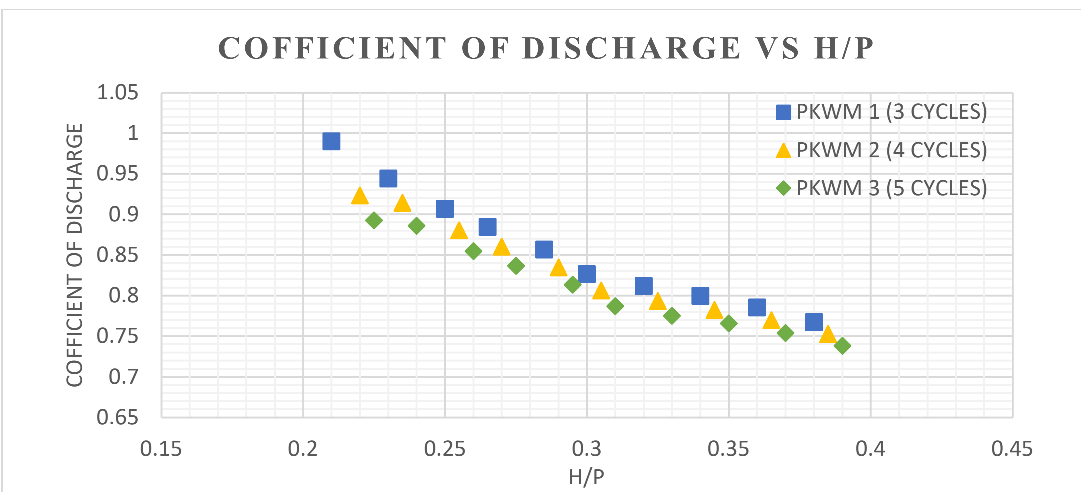

Figure 4: Coefficient of discharge vs H/P of all PKWM's

4 CONCLUSIONS

From the result of this study, following conclusion have been withdrawn:

- A crucial factor impacting discharge capacity was found to be the number of cycles. The piano key weir's discharge rates increased by overall 5.95% as the number of cycles was increased from five to three, showing that fewer cycles enable better flow control and water management capabilities. We examine three PKW models while maintaining cycles of three, four, and five. The outcomes showed that discharge capacity peaked at three cycles.
- The number of cycles influenced the flow pattern over the weir's crest. With more cycles, the flow may became more uniform and less turbulent.
- An inverse relation was found out between fraude number and discharge capacity of piano key weir.

5 RECOMMENDATIONS

The result of this study shows an enhancement in discharge capacity of piano key weir using less number of cycles, it is recommended in a literature review that less number of cycles should be employed to improve discharge capacity of piano key weir.

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