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EXPERIMENTAL STUDY OF DIFFERENT SILL GEOMETRIES IN PIANO KEY WEIRS

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ABSTRACT

Piano Key (PK) Weirs are non gated type of weirs with increased discharge capacity because of their increased plan length. PK weirs are better than other conventional types of weirs for applications where the channel width is restricted. These are cost effective hydraulic structures and can work efficiently at low heads also. In this paper, two physical PK weir models with different sill geometries were tested; one with sloping sill and the other with triangular sill. Based on the experimental results, it has been found that the discharge coefficient (C_d) for sloping sill and triangular sill are 0.243 and 0.264 respectively. The said modifications don't exhibit remarkable improvement in coefficient of discharge as compared to the regular PK weir, but can have greater efficiency for higher discharges. Finally, suggestions regarding different shapes of sill walls of PK weir such as sloping and triangular sills compared with existing plain crest without any sill are presented in the end.

Key Words: Piano Key Weirs, Piano Key, Head Discharge Relationships, Coefficient of discharge.

1. INTRODUCTION

The piano key weirs (PKW) are an enhancement to the labyrinth type weirs. The structural changes in the piano key weirs that would improve the discharge capacity at lower heads keeping the other advantages alike is the area of prime focus in this paper.

It has been found that increase in the plan length of the weir crest can possibly lead to improvement in the discharge capacity as well as lowers the head of water at the upstream side as equation (1).The discharge of the weir is calculated by equation (1).

$$Q = C_d.\frac{2}{3}.L.H_t^{\frac{3}{2}}\sqrt{2g} \qquad (1)$$

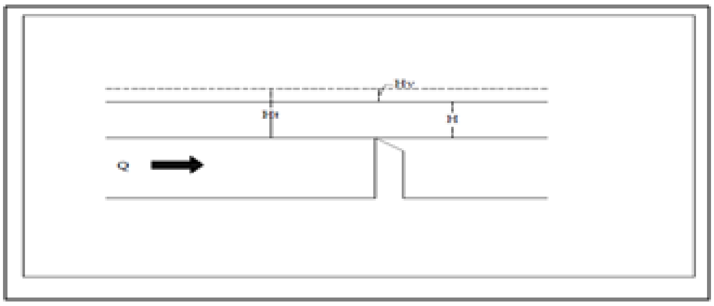

Fig. 1 Side elevation of a weir under flow

Where,
Q =discharge,
C_d = discharge coefficient,
g =gravitational constant,
L=crest length, and
Ht=total upstream head [piezometric head (H) measured relative to the weir crest plus velocity head ($V^2/2g$)].

Thus the study of the crest geometry in relation to this area of weir capacity improvement becomes significant. In an effort to aid clearer understanding of the differences in head-discharge relationships or discharge capacities of modified PK weirs over the regular PK weirs and to comprehend the influences of the various PK weir geometric parameters on discharge efficiency, the following study was undertaken.

For a PK weir installed on a deformable soil foundation, there are likely stability and seepage concerns that would need to be addressed. The short upstream to downstream footprint of the foundation results in high seepage gradients across the base of the structure. In addition, the PK weir is unstable if full uplift is allowed to develop beneath the base. The addition of a concrete slab extending from the upstream edge of the base to the upstream end of the weir would add some stability to the structure. The addition of this slab would increase the concrete quantity, reducing the cost savings of the PK weir over the labyrinth weir by 5 to 10%. In addition, an upstream cut off may be required for the PK weir to further reduce uplift pressures [1].

Fig. 2 Goulours dam, France with a Piano Key Weir

2. PIANO KEY WEIRS

A piano key (PK) weir is a recently developed alternative to traditional labyrinth weir designs that was developed specifically for smaller control structure footprint applications. The two main differences of PK weir designs, relative to traditional trapezoidal labyrinth weir designs are:

- The PK weir has a simple rectangular crest layout (in top view), essentially creating a labyrinth weir with no side wall angle (rectangular labyrinth weir), and
- The PK weir geometry has sloped or ramped inlet and outlet cycle or key floors. Where the available footprint for the control structure is limited, the sloped floors cantilever the cycles beyond the spillway footprint providing the PK weir with a longer crest length relative to traditional labyrinth weir designs with the same footprint.[2]

3. RESEARCH OBJECTIVES

The research objectives included:

1. To improvise certain changes in the sill-structure on the piano key weir crest.
2. To study the change in the discharge capacity of the weir due to the improvisations made.
3. To establish the head- discharge relation for the different models.
4. To establish and analyze the discharge and coefficient of discharge relation for the different models.

4. EXPERIMENTAL SETUP

The rectangular flume of testing comprised of two tanks made in mild steel connected laterally. The tank 1 was 2 m long, 0.6 m wide and 0.8 m deep whereas the tank 2 was 1 m long, 0.6 m wide and 1.1 m deep. These two tanks were connected with a water tight weld and this junction of two tanks was utilized for installing the fabricated models. A 1.5HP electric motor pump was connected to the flume through a Venturimeter. The pump discharge varies from 1 liter per second to 8 liters per second. Water was allowed to enter from top of tank 1 with special pipe arrangement. The flow was regulated with the help of butterfly valve. The inlet and outlet of Venturimeter were connected to a U tube manometer. The U tube manometer was filled with mercury as the manometric fluid with specific gravity 13.6.

The flume is also equipped with a micrometer screw point gauge which was used to measure the depth of water surface and crest elevations at various Pre-decided length (distances) from the starting of the inlet points of models on the upstream side. The point gauge has a Vernier scale with a least count of 0.01cm i.e. 0.1mm.

One side of the flume was fitted with transparent acrylic sheet to facilitate visual observations. Due to low discharge capacity of the pump, no significant turbulence was created and hence, baffle walls were not provided in the flume.

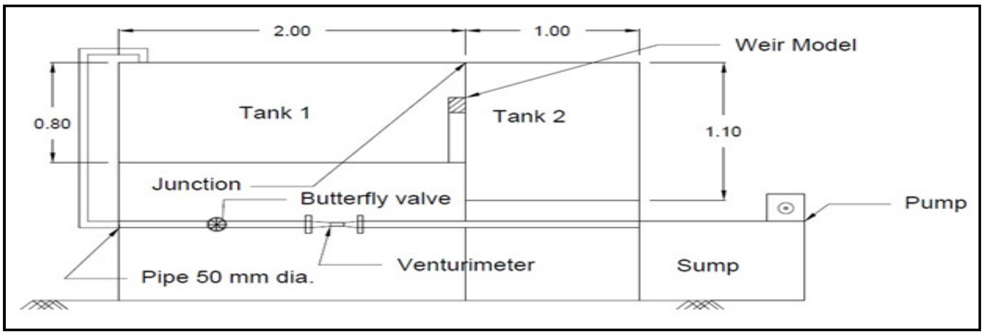

Fig. 3 Experimental Setup

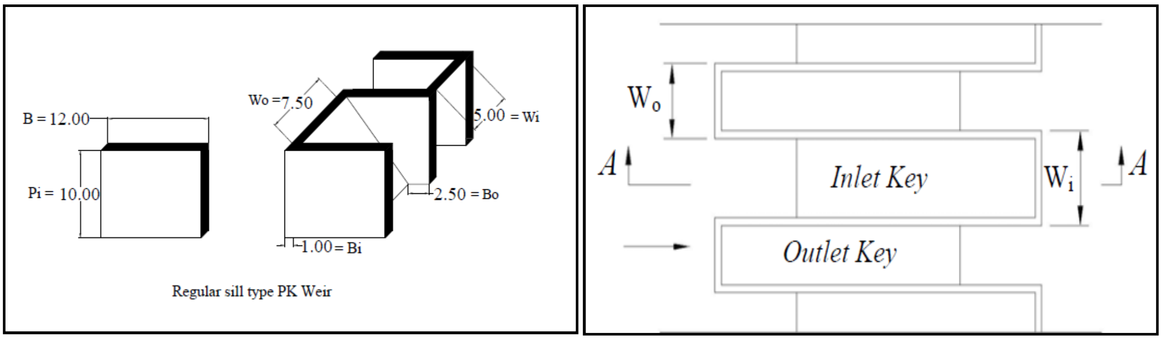

Fig. 4 Regular Sill Type PK Weir

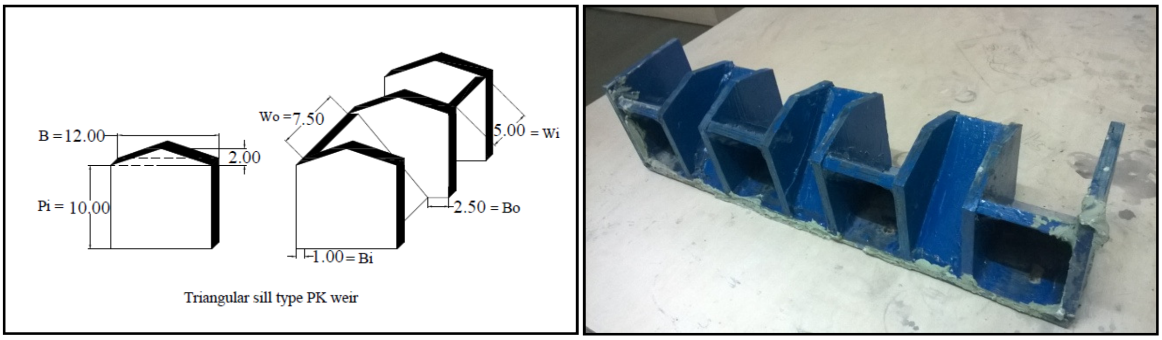

Fig. 5 Triangular Sill Type PK Weir

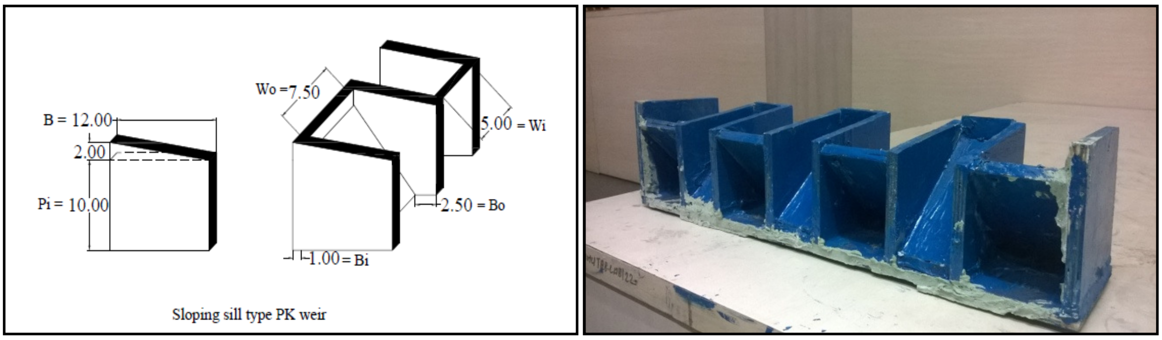

Fig. 6 Sloping Sill Type PK Weir

5. RESEARCH METHODOLOGY

5. 1 Design of models and flume

The models of the modified piano key weirs were designed based on the guidelines given by *Tullis et. al.* and the models were constructed and checked whether they complied to the design drawings. The design details of the models have been presented in table 1. The entire structure of flume was designed to be constructed in MS box section, angle section and plates. The flume was constructed by cutting and welding of steel components and was fabricated such that the models would fit in.

Table 1: Design values of modified piano key weir models

Sr. No.	Parameter.	Range. Min.	Range. Max.	Design value
1.	L/W	2.50	8.50	2.57
2.	Wi/Wo	0.00	2.45	1.50
3.	Pi/Wi	0.59	4.71	1.60
4.	Pi/Ts	5.00	300	1.20
5.	Si	0.25	2.00	1.10
6.	So	0.25	2.00	0.90
7.	N	1.50	-	3.50

Wi = inlet cycle width; Wo = outlet cycle width; Bo = upstream or outlet cycle cantilever length; Bi = downstream or inlet cycle cantilever length; L = weir length; N = weir cycles; Si = slope of inlet cycle or key floor; So = slope of outlet cycle or key floor; W = width of weir.

5.2 Fabrication of models

The modified piano key weir models were constructed in water proof wooden material of 12 mm average thickness. The modified piano key weir models were installed in the flume and were sealed with leak proof wooden sealant. The modified piano key weir models were coated with damp proof paint so that they could withstand water. Tests were conducted on the models to check whether any water leakages were present in the models.

5.3 Testing of modified PK weir models

Water was passed from the sump into the flume with the help of a 1.5 HP Centrifugal pump with a 50 mm diameter pipe connected to the inlet of the flume. The pipe was installed with a Venturimeter and its coefficient of discharge was calibrated to be 0.884 using the equation (2):

$$Q = \frac{C_d . a_1 . a_2 . \sqrt{2gh}}{\sqrt{(a_1^2 - a_2^2)}} \quad (2)$$

Where,
C_d = Coefficient of discharge,
a_1 = Area of inlet,
a_2 = Area of throat,
h = Manometric head difference,
The depth of water level at the upstream side of the weir models was recorded at six regular intervals of distances for different discharge values. The viscosity and surface tension of water being fluid properties, scale effects occur for small overflow depth on weir crests.

However, these parameters cannot be scaled and hence were not included in the analysis. The water levels were taken laterally in the channel in stagnant water, away from the width reduction where the effect of the velocity head was absent and H identical to the total head [3].

Based on the recordings of the varying heads that developed during the testing of the three models of different sill geometries and the difference in the manometric heads in the differential manometer, the discharges and the subsequent discharge coefficients for each model were calculated. Graphs expressing the relationships between the head and discharge as well as the coefficient of discharge and the discharge were plotted based on the calculated values. A comparative study of the models with respect to the discharge carrying capacity, head discharge relationships, etc. was done.

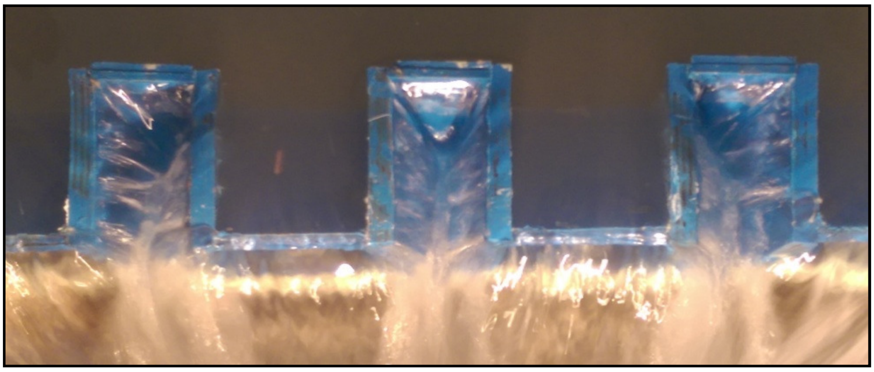

Fig. 7 Testing of Models

6. RESULTS

On successful testing of 3 models with different sill geometries, it was found that,

1. The variation of head (H) with discharge (Q) for regular PK weir model as well as the modified PK weir models is as shown in figure 3.

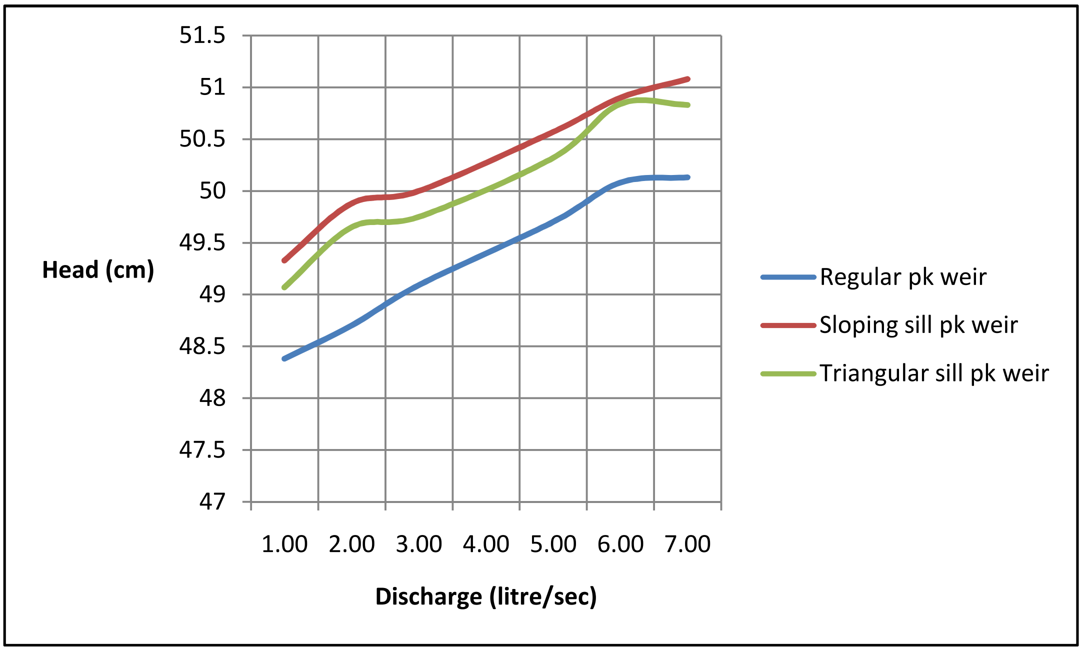

Fig. 8 Head Discharge Relationships

2. Also the variation of coefficient of discharges (C_d) for regular as well as modified PK weir is shown in figure 4.

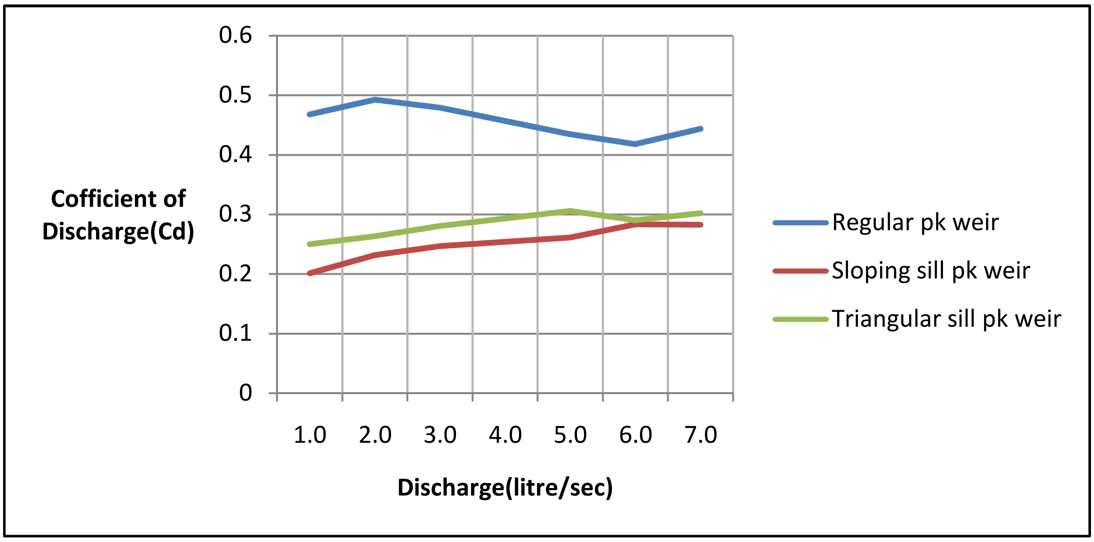

Fig. 9 Variation of C_d with Discharge

3. The average coefficient of discharge (Cd) for modified PK weir model with sloping sill is found to be 0.243 and that for modified PK weir model with triangular sill is found to be 0.264, which are lesser than the average coefficient of discharge for regular PK weir model i.e. 0.46.
4. However, at full discharge of the pump, the two improvised models went under submergence and showed remarkable efficiency of discharge coefficient.
5. The development of head at the upstream of the models in case of submergence i.e. at full discharge of the pump was not very high; which was an expected result.

7. CONCLUSION AND DISCUSSION

1. The behavior of two structurally changed models at lower discharges was not much remarkable.
2. However, at full discharge of the pump, the 2 improvised models went under submergence and showed remarkable efficiency of discharge.
3. The development of head at the upstream of the models in case of submergence i.e. at full discharge of the pump was not very high; which was an expected result.

From the remarkable behavior of the improved models of Piano Key Weirs at higher (or highest) discharges in the channel, it may be inferred that a further study of such sill design geometries has good scope. In order to tackle the problem of sudden flooding of water in the channels of rivers, these types of weirs can prove to be beneficial. It is concluded that further model study of this geometry in Piano Key Weirs should be done.

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