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Experimental study of piano key side weir with oblique keys

Mahmoud karimi[1], Mohammadreza Jalili Ghazizadeh[2,*] , Mojtaba Saneie[3] , Jalal Attari[4]

[1] Ph.D. Student, Dept. of Civil, Water, and Environmental Engineering, Shahid Beheshti Univ., Evin, Tehran
[2] Associate Professor, Dept. of Civil, Water, and Environmental Engineering, Shahid Beheshti Univ., Tehran
[3] Associate Professor, Agricultural Research Education and Extension Organization, Soil Conservation and Watershed Management Research Institute, Tehran, Iran.
[4] Associate Professor, Dept. of Civil, Water, and Environmental Engineering, Shahid Beheshti Univ., Tehran

ABSTRACT: Side weirs have many applications in water distribution and regulation in irrigation and flood control. For a constant opening length, weir crest can be design as labyrinth or piano key shape to increase the developed length and discharge coefficient. Another way to increase the side weir efficiency is the oblique design, which make the weir crest aligned with the diverted flow. Combining the two noted approachs leads to design a side weir with longer developed crest length and aligned with flow which has high performance. In this study, piano key side weirs with different key angles were studied. Flow characteristic including deflection angle and streamlines and also discharge coefficient were studied. Results show that angled keys aligned with the flow direction, increases performance of the piano key side weir up to 12 percent in high Froude numbers. Oblique keys can reduce the disturbances usually occurs in symmetric piano key side weir and results in higher discharge coefficient. The obtained results can be used to design a side weir which applied in conditions with high Froude numbers such as flood control.

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1. INTRODUCTION

Side weir is placed at the channel bank to divert a part of the flow[1]. The flow in the main channel diverts with a deflection angle. The deflection angle increases toward the downstream of the side weir and its value depends on the Froude number[2]. Considering this deflection angle, the performance of the side weir can be improved by an oblique weir which its crest has better orthogonality with the diverted flow[3, 4]. Oblique shape can also be used in a labyrinth side weir which increase the efficiency[5].

Piano key weir (PKW) is a kind of labyrinth weir with small footprint and up and downstream overhangs[6]. A PKW can also be used as a side weir which have high efficiency[7]. A piano key side weir (PKSW) can also be design in asymmetric shape. The objective of this study is: (i) to investigate the flow characteristic over a PKSW with angled keys and (ii) to find the best angle for the oblique keys.

2. THEORETICAL BACKGROUND

The discharge over a weir can be calculated by classic weir equation[1]:

$$Q = \frac{2}{3} C_d \sqrt{2g} W h^{1.5} \quad (1)$$

where Q is the discharge over the weir, C_d is the discharge coefficient, g is the gravitational acceleration, W is the weir width, h is the piezometric head (y - P) and P is weir height. In case of side weir which water surface changes along the side weir, the average depth of upstream and downstream ($(y_1+y_2)/2$) can be used in Eq. 1 as known as Schmidt approach[8].

3. METHODOLOGY

The experimental study was carried out on a 10 m long channel with 0.6 height and 0.6 width. A circulating system with a pump and a reservoir supply the water. An opening at the channel bank with a side channel were constructed to divert the flow. Discharge in the main channel and the side channel was measured with a V-notch and a rectangular weir, respectively. In this study 16 PKSW with different key angle were tested. Fig. 1 shows the geometrical characteristic of the weirs and Table 1 shows the geometrical and hydraulic ranges of the tests.

4. RESULTS

The observation of the flow shows that the PKSW with zero or negative angle have more disturbance especially at the connection of the weir crest and there are also some vortexes in the first inlet key. As Fig. 2 shows, PKSW with positive

*Corresponding author's email: m_jalili@sbu.ac.ir

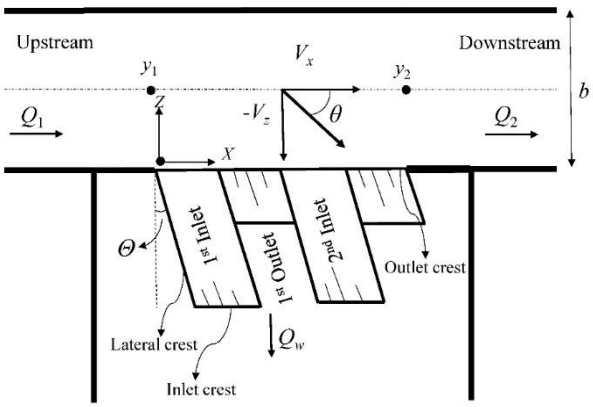

Fig. 1. Schematic view of geometrical characteristic of the main channel and the side weir

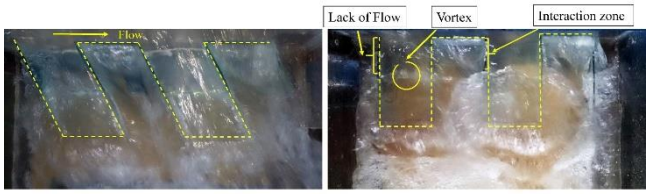

Fig. 2. Flow behavior F_1 = 0.4 for (a) $PKSW_{+30°}$ and (b) $PKSW_{0°}$

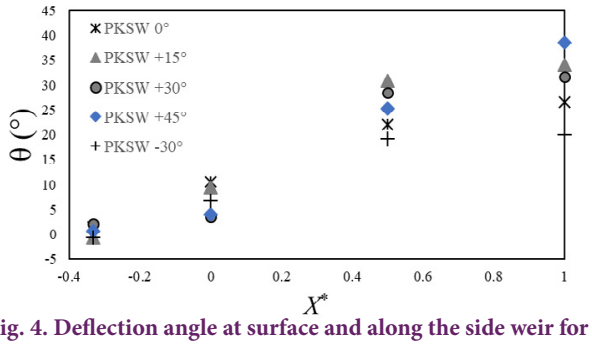

Fig. 4. Deflection angle at surface and along the side weir for PKSW with different Θ in F_1 = 0.33

overhangs have more uniform flow with low disturbance which show the weir keys are more aligned with the diverted flow.

Figs. 3 and 4 show the deflection angle (θ) at surface and along the side weir for PKSWs with different Θ in F_1 = 0.33 and F_1 = 0.33, respectively. The study of the deflection angle (θ) in this study shows that for high Froude numbers (F_1 > 0.3), the PKSWs with positive key angel show higher deflection angle. Higher deflection angle can indicate better performance of the side weir[2].

Fig. 5 shows the values of discharge coefficient versus keys angle for different ranges of Froude number. The PKSW with negative key angle have low C_d compared to even zero angle PKSW. The PKSW with zero angle have the highest C_d in low Froude numbers. However, by increasing the F_1

Table 1. Geometrical and hydraulic characters of Piano key side weirs

Weir name	Θ	P (cm)	b (m)	h_1/P	F_1
$PKSW_{0°}$	0	5, 10, 15	0.4-0.6	0.2 - 2	0.1 – 0.7
$PKSW_{15°}$	15	5, 10, 15	0.4-0.6	0.2 - 2	0.1 – 0.7
$PKSW_{30°}$	30	5, 10, 15	0.4-0.6	0.2 - 2	0.1 – 0.7
$PKSW_{45°}$	45	5, 10, 15	0.4-0.6	0.2 - 2	0.1 – 0.7
$PKSW_{-15°}$	-15	10, 15	0.6	0.2 - 2	0.1 – 0.35
$PKSW_{-30°}$	-30	10, 15	0.6	0.2 - 2	0.1 – 0.35

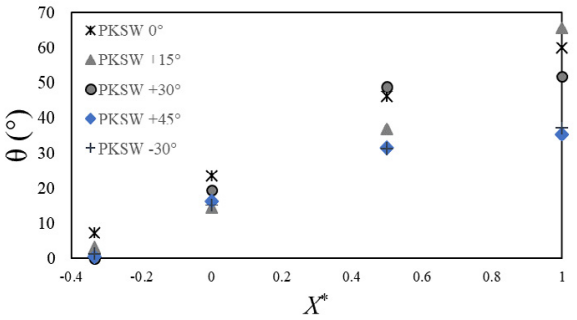

Fig. 3. Deflection angle at surface and along the side weir for PKSW with different Θ in F_1 = 0.17

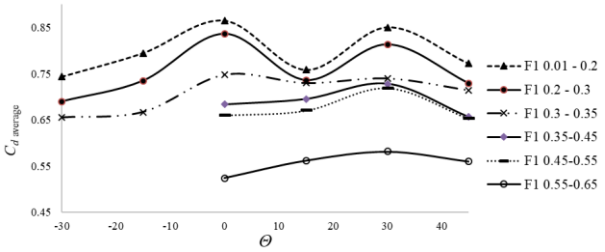

Fig. 5. Discharge coefficient versus Θ for PKSW for different F_1 ranges

the performance of the $PKSW_{0°}$ decreases due to the more disturbance which happen in higher F_1. $PKSW_{30°}$ has the highest C_d among all weirs which shows that 30° has the best orthogonality with the diverted flow in high F_1.

5. CONCLUSION

In his study, 16 piano key side weirs with different key angle have been studied. The results show that PKSW with positive overhang have less disturbance in high Froude numbers and the flow is more uniform. The study of the deflection angle in this study shows that by increasing Froude number, the PKSWs with positive keys angel show higher deflection angle which indicate better performance. $PKSW_{30°}$ has the highest C_d among all weirs which shows that 30° has the best orthogonality with the diverted flow in high Froude numbers. The finding of this study is useful to design a side weir in high Froude number conditions (e.g., flood control).

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