Experimental Study of Triangular Sharp-Crest Weir in Open Channels

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Abstract

Triangular sharp-crest weirs are commonly seen in practice. To test their hydraulic performances, a specially designed rectangular flume is designed and constructed with the size of 2.0m×1.2m×26.0m (width × height ×length). The tested results show that the nappe over the weir is of the inward curved type. The discharge formula perform differently and the most accurate formula indicates that the relationship between the discharge and the flow depth should be of the form of $Q \propto H^{2.47}$. The upstream water heads above the triangular weir measured at different locations play little roles in discharge evaluation. For convenience, the flow depth measuring points should be placed where the flow surface is stable, and they should be not too far from the weir. In addition, the influence of the sediment accumulation upstream of the weir is accessed, and the results show that it doesn't largely influence the discharge evaluation either.

1. Introduction

Weirs are kind of flow controlling structures. And they perform hydraulically differently depending on the weir types [1,2]. Of all triangular sharp-crest weirs are of commonly used type. They always have stable relationship between the discharge and the weir head, thus frequently used in the discharge measurement for the open channel flows. Besides, lots of researches have been done and some practical formula have been proposed [3,4]. However, there are still some problems we haven't fully understood, and sometimes it could confuse us. For example, of all the commonly used formula by which the discharges in the flume are calculated, which formulae can be recognized to be the most accurate. Another confusing problem is how the sedimentation deposit upstream of the weir influence the discharge indication.

In this paper, we have made a special triangular sharp-crest weir. The height of the triangular breach is 0.50m and the corresponding angle is 90°. To test its hydraulic performances, we have also built a specially used rectangular flume. The flow patterns, the nappes, the discharge ~ weir head relationship and the influences of the deposit should all be tested.

2. Testing system

2.1 Rectangular flume

To test the hydraulic performance of the triangular sharp-crest weir, a specially designed testing flume has been built in Daxing Experimental Base of China Institute of Water Resources and Hydropower Research (IWHR). It is 26m long and the weir is planned to be located 5m upstream of the downstream end of the flume. The cross section of the flume is 2.0m×1.2m (width ×depth). Its inflows come from a high-level water tank which is fed by the ground reservoir and can provide a stable outflow. Two iron pipes of DN500 are employed to hydraulically link the water tank. In addition, the flume bottom is elevated by 0.4m for convenience of construction and the bottom slope is set to be 0. The overall layout of the testing flume is shown as Figure 1.

2.2 Triangular sharp-crest weir

The basic structure of the triangular sharp-crest weir is shown in Figure 2. The cross section is of the triangular type. The height of the breach is 0.50m. The typical vertex is on the right downside. The triangle angle θ is in the range of 20°~100°. In this test, 90° is chosen as an example. In addition, to ensure stable flow surface, long enough guiding flume is needed. Thus, the triangular sharp-crest weir is located 5m from the downstream end of the flume and the guiding flume can be ensured to be larger than 21m.

The determine the discharge, some formulae are proposed. Equation (1) is given by "Verification Regulation of Open Channel Weirs and Flumes for Flow Measurement" (JJG 004-2015) and "Standards for municipal wastewater discharge measurement – Triangular notch (V notch) thin-plate weir" (CJ/T 3008.1-1993).

$$Q = C\frac{8}{15}\tan\frac{\theta}{2}\sqrt{2g}h_e^{5/2}. \quad (1)$$

in which,

$$h_e = h + K_h. \quad (2)$$

where, Q represents the discharge, C is discharge parameter, θ is the triangular angle, he is effective water head, h is measured water head, Kh is adjusting factor for water head, and takes the value of 0.00085 when θ =90°.

In addition, some other simple-form formula are also used in practice, such as

$$Q = 1.4h_e^{5/2}. \quad (3)$$

$$Q = 1.343h_e^{2.47}. \quad (4)$$

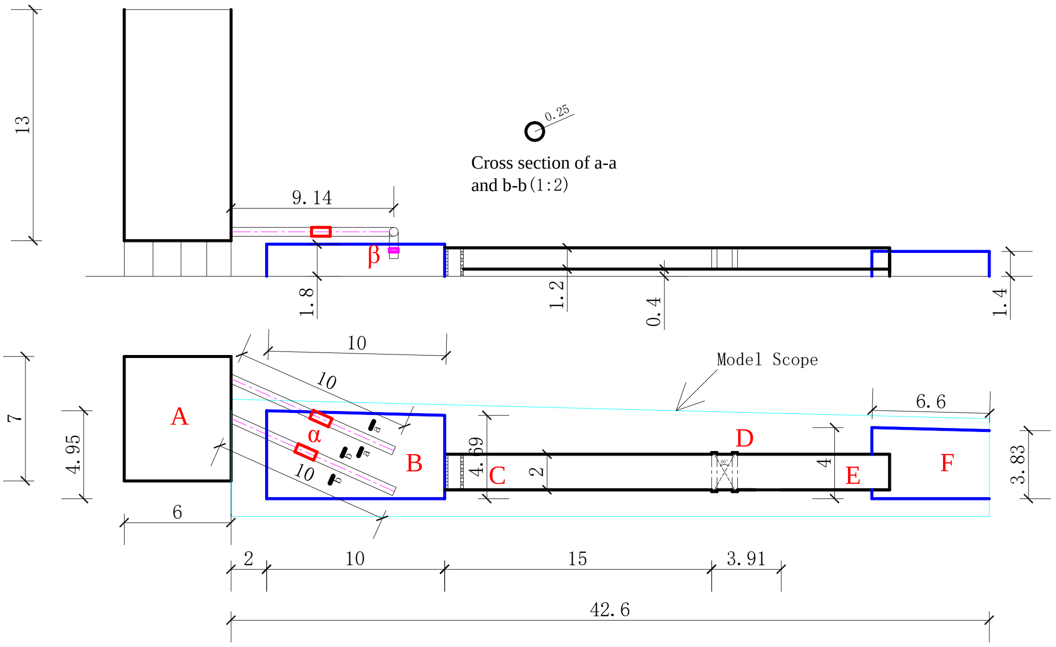

Figure 1: Layout of the testing flume (length unit: m).

Figure 2: Triangular sharp-crest weir.

2.3 Measuring devices

In this paper, two master flow meters are used to indicate discharges in the flume. They are installed in the inflow pipes and are pre-calibrated before installed. The velocity is measured using Micro ADV made by SonTek and the measuring points are 0.2m, 0.3m and 1.5m upstream of the weir, respectively. The flow depth is given by point gauges. And the flow depth measuring points are all at the middle of the flume, and they are 2m, 4m, 6m, 8m and 10m upstream of the weir.

3. Results and discussion

3.1 Flow patterns

In all typical cases, the flow surface is stable in the flume, with only slight wave formed. However, when approaching the triangular sharp-crest weir, the flow surface begins to deform. The middle part of the flow surface is gradually declining, and a nappe of inward-curved shape is formed. Clearly fully aerated cavity exists under the nappe. In addition, downstream water level can hardly influence the discharge capacity as a free water drop is formed at the triangular sharp-crest weir. The typical flow pattern is shown in Figure 3 when the weir head is 40.08cm.

Figure 3: Typical flow patterns (weir head is 40.08cm).

3.2 Velocity profile

According to the tested results, it is showed that the velocity profiles are similar in all the typical cases. Herein the case with the flow rate of 768m^3/h is taken as an example to make analysis. The velocity profile is shown as Figure 4. Clearly the velocities are distributed evenly along the flow depth at the location 1.5m upstream of the weir. When the flow approaching to the weir, the velocity profile begins to change and the velocities in the upper layer become larger while those in the lower layer are getting smaller. From Figure 4, the largest velocity is 13.7cm/s upstream of the weir. After the flow approaching the weir, the largest velocity increases to 59.59cm/s when the measuring points are 0.2m upstream of the weir. When the flow arrives at the weir, the largest velocity increases to 190.50cm/s. In addition, the velocity distribution performs differently depending to the location. The velocities are getting larger with the increasing elevation when the measuring points are located upstream of the weir. However, when the flow gets at the weir, the velocities are getting smaller with the increasing elevation. In addition, from Figure 4 we can see that the velocities at the upstream bottom of the weir is approaching 0.

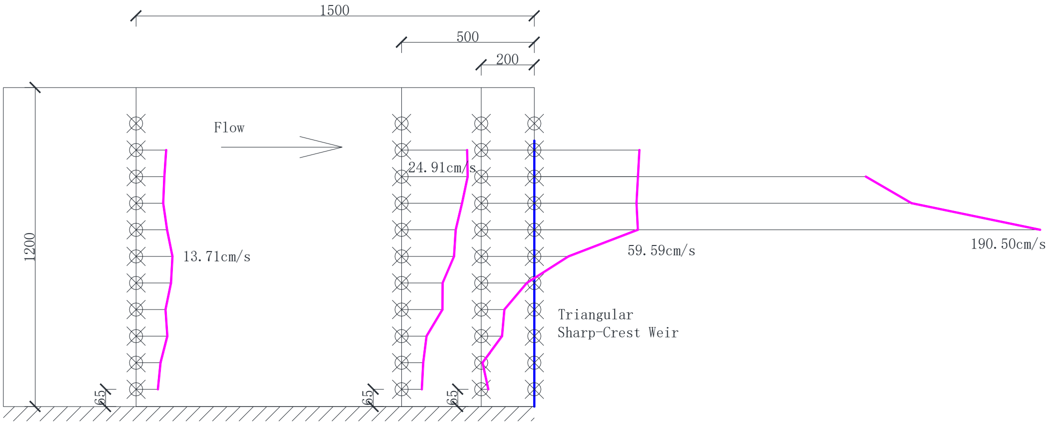

Figure 4: Velocity profile at the middle upstream of the weir when Q = 768m^3/h (length unit: mm).

3.3 Discharge capacity

In this paper, all the 3 cases, namely Equation (1) ~ (3), are all used to calculate the discharge in the flume, and the results are shown in Figure 5 and Figure 6. Clearly, all the 3 commonly used formula can well reflect the discharges in the flume and the largest error is smaller than 3.0%. Comparing the hydraulic performances of all the 3 formula can conclude that $Q \propto H^{2.47}$ can better reflect the relationship of discharge and weir head for the triangular sharp-crest weir than $Q \propto H^{2.50}$. It is the uneven velocity distribution at the weir that influence the relationship between the discharge and the weir head.

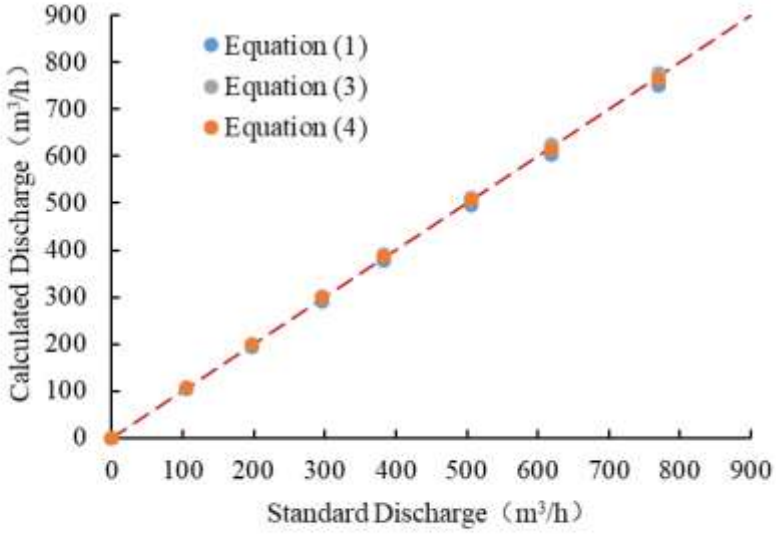

Figure 5: Calculated discharge V.S. standard discharge.

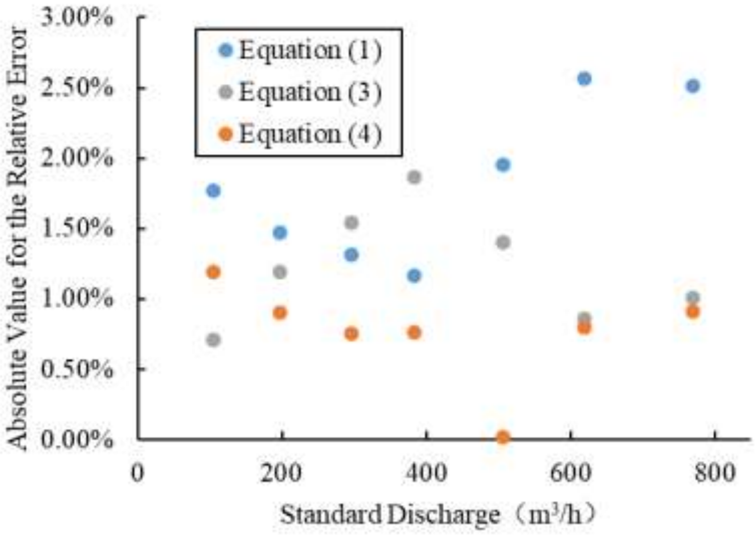

Figure 6: Absolute value for the relative error.

Besides, we have also tested the influences of the flow depth location and the typical results are shown in Table 1. Clearly the errors between different flow depth measuring location is within 2mm. Thus, the flow depth measuring points could be located where the flow surface is stable and not too far away from the weir.

Table 1: Weir heads at different measuring locations.

Q (m^3/h)	Weir head (cm)				
	2 m	4 m	6 m	8 m	10 m
105.9	21.28	21.24	21.20	21.25	21.35
198.0	27.56	27.52	27.50	27.44	27.53
296.0	32.23	--	--	--	32.37
383.1	35.94	35.85	35.89	35.86	35.95
517.0	40.03	--	--	--	40.08
615.0	43.18	--	--	--	43.37
768.0	47.32	47.20	47.22	47.22	47.35

3.4 Sediment deposit

To illustrate the influences of the sediment deposit upstream of the weir, we have generalized the deposit of rectangular type with the size of 73cm×43cm×33cm, and placed it at two typical places which are shown as Figure 7. For either typical place, 2 cases are tested. And the typical discharges are 676m3/h and 202m3/h, respectively. In the case where the sediment deposit is placed the relationship between discharges and weir heads is tested, and the corresponding points are plotted in Figure 8. It can be seen that whether to place a deposit didn't influence the trend of Q ~ H, thus in practice low sediment deposit can be ignored when measuring the discharge using triangular sharp-crest weirs.

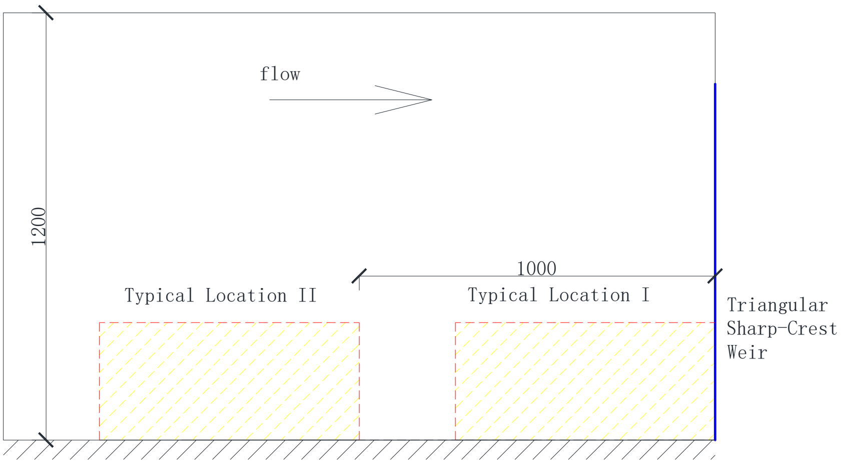

Figure 7: Absolute value for the relative error.

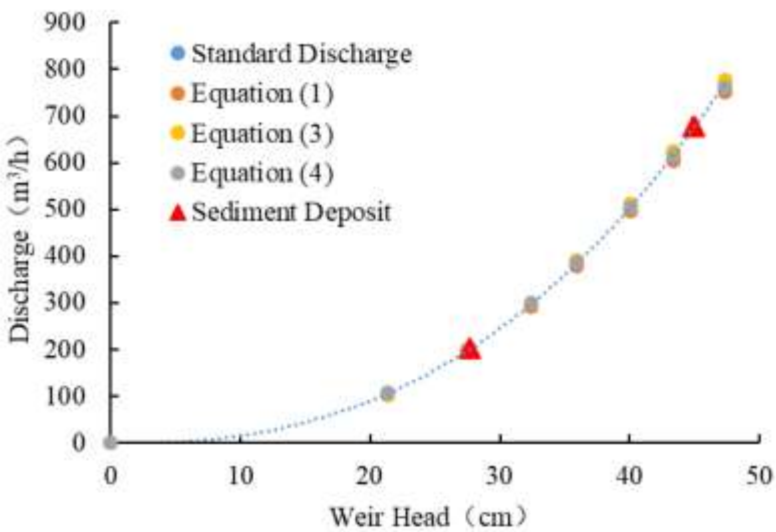

Figure 8: Absolute value for the relative error.

4. Conclusions

Triangular sharp-crest weirs are a kind of commonly used weirs. In this paper, the hydraulic performances of these weirs are tested using physical models. And the main results are list as follows:

(1) The flow surface upstream of the weir is relatively stable. Only slight wave is formed at the surface. When the flow approaches the weir, the flow surface is deformed. And the nappe is of inward curved type.

(2) The flow velocity is distributed evenly far upstream of the weir. After the flow gets close to the weir, the velocity profile begins to be adjusted. And the velocity of upper flow layer begins to get larger. The velocity at the upstream side of the weir is small to zero.

(3) Three commonly used formula are tested about their performances on discharge indication. And the results show that the relationship of discharges and weir heads obeys $Q \propto H^{2.47}$.

(4) Sediment deposit is commonly formed upstream of the triangular sharp-crest weir. Physical model tests verify that low deposit won't introduce large errors when indicating discharges based on weir heads.

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