Laboratory study of the hydraulics of flow in gabion stepped weirs

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ABSTRACT

In this study, different components that effect in energy dissipation on flow over gabion stepped spillways were investigated using physical models and comparisons were made with the other studies. Flow over gabion spillway was conducted in both through flow and overflow simultaneously. The discharge is in the range of 5 to 65 liters per second. Uniform particles with three medium diameters of 10, 25 and 40 mm were used. The height and width of the physical models were 60 and 40 cm respectively, with 3 steps and downstream slope of weirs were 1:1, 1:2, and 1:3 (V: H). Tow end sills including rectangular and inclined shapes were used. The results showed that the effect of end sills in gabion stepped weirs with lower slope is more than that of weirs comprising higher slope. The effect of the end sills on the energy dissipation in the weir for d_{50}=40 mm and S=1: 2 is about 10% more than the weir with d_{50}=10 mm and S=1:1. In weir including d_{50}=10 mm and S=1:2 is about 30 to 35 percent more than the weir with d_{50}=10 mm and S=1:1. Therefore, the existence of end sills in the weirs with the body of materials of d_{50}=10 and 40 mm have the highest and the least effects on the energy dissipation. On the other hand, the effect of the rectangular end sill on the energy loss is about 3-4% more than that the effect of the triangular end sill.

KEYWORDS

Energy loss; Gabion; Inclined end sill; Rectangular end sill; Stepped weir

1. Introduction

Stepped weirs consists a set of steps that are started from the weir overflow crest and continue to the downstream weir toe. High energy dissipation by stepped weirs reduces the depth of excavation, length and height of the stilling basin and thus reduces the cost of construction of the stilling basin [1]. Most of the studies previously have been conducted on impermeable solid weirs, and less researches have been done on stepped gabions (permeable) which have many advantages. The advantages of stepped gabion weirs are the ease of operation, use of accessible naturally materials, sustainability, flexibility, high permeability, cost-effectiveness and, most importantly, environmental compatibility [2]. In general, solid concrete weirs were used, but nowadays alternative structures made of loose stones such as gabion weirs are preferred since the latter can better meet natural and ecological requirements. From the viewpoint of water quality, physical and chemical substances such as sediments and suspended organic matter can pass downstream through the permeable body. This eventually minimizes sedimentation and eutrophication in an impoundment. Between the stones, bacteria inhabiting the granular surface may decompose organic matter. This biochemical reaction contributes to the purification of river or canal water as it flows through the stones, just like in water purification and sewage water plants. It is also expected that turbulence generated in the granular media will promote aeration through the air-water interface helping in the aerobic decomposition of organic matter. In these respects, the gabion weir might be a structure with minimal negative impact on the water environment and is considered to be more environmentally friendly than most of the recently constructed impermeable weirs [3].

2. Methodology

The experiments were performed in the hydraulic laboratory at University of Tabriz, Department of Water Engineering. According to Fig. 1, the experiments were performed on a horizontal glass-steel flume 10 m long, 0.4 m wide, the first 2 m long with a height of 1 m and the rest with a height of 0.5 m, with a fixed floor slope. The flow in the experiments was measured using an ultrasonic device installed at the beginning of the water flow inlet pipe. The flow depth at the downstream of the gabion was measured at a distance of three to four times the length of the weirs and at a maximum distance of one

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meter from the last step at weir toe, where the mixing of water and air is minimized. The height and width of the physical models were fixed of 60 and 40 cm, respectively, with 3 steps and the downward slope of the weirs 1:1, 1:2 and 1:3 (V: H). The end sills used in this study are rectangular and sloping (in the form of gabion), the details of which are shown in Fig. 2.

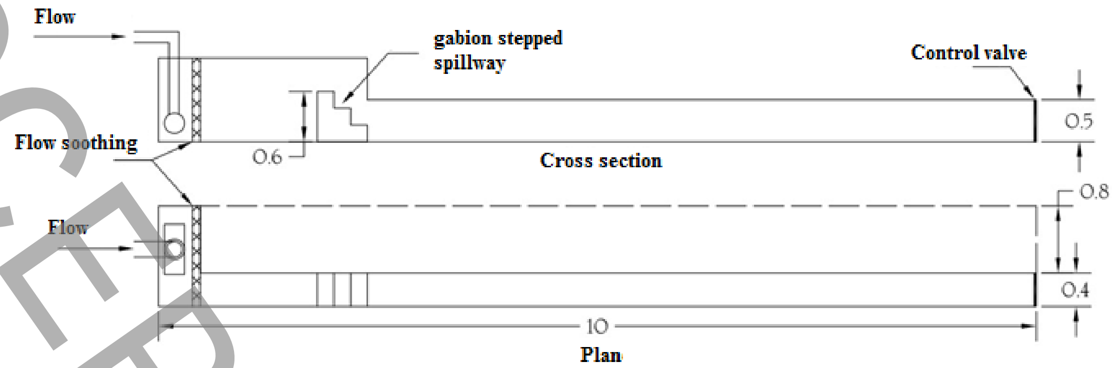

Figure 1: View of the laboratory flow and location of the stepped gabion spillway (dimensions in meters)

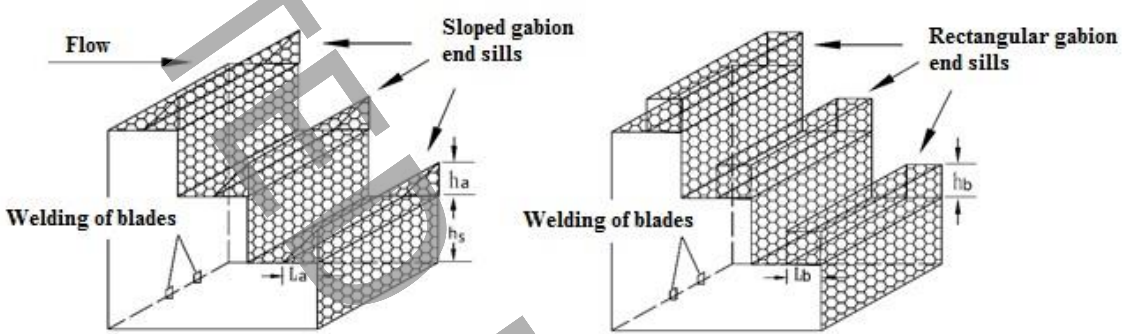

Figure 2: 3D view of gabion stepped spillway details including rectangular and inclined end sills

3. Results and Discussion

Figure 3 shows the relative changes in energy loss vs. the relative discharge (q^2/gH_w^3) comprising with the rectangular and sloping end sills. According to Fig. (3A), when the average diameter of the material particles in the body of the gabion stepped weir is 40 mm, the end sill (rectangular and sloping) did not significantly effect on relative energy loss. However, according to Fig. (3B), when the average diameter of the material particles in the gabion stepped weir is 10 mm, the effect of the gabion end sill on energy dissipation is more obvious. The main reason is that in d_{50}= 40 mm, by passing the water flow through the coarse-grained particles, it consumes more energy. However, this current energy is less depleted due to less water permeability from fine particles (10 mm), so it can be said that the use of end sill (rectangular or sloping) in step treads with medium diameter of larger particles has little effect on depreciation and the effect of using the end sill is almost negligible with the lower slope (Fig. 3C). According to the Fig. 3, with the increase of rectangular and sloping end sills (increasing the ratios of h_b/h_s and h_a/h_s), the relative energy loss also increases. In Fig. 3D, the experiments were performed on a 3-step weir with an average diameter of 10 mm particles in the body and a low slope of 1:1 and 1:2, within a range of discharge the effect of a rectangular end sill with specifications h_b=0.5h_s, d_{50}=10 mm is greater than the effect of a rectangular end sill with specifications h_b=0.5hs, d_{50}=40 mm. But with the rise of discharge, this trend was reversed. It should be noted that this trend also applies to slope end sills (Fig. 3B and 3D).

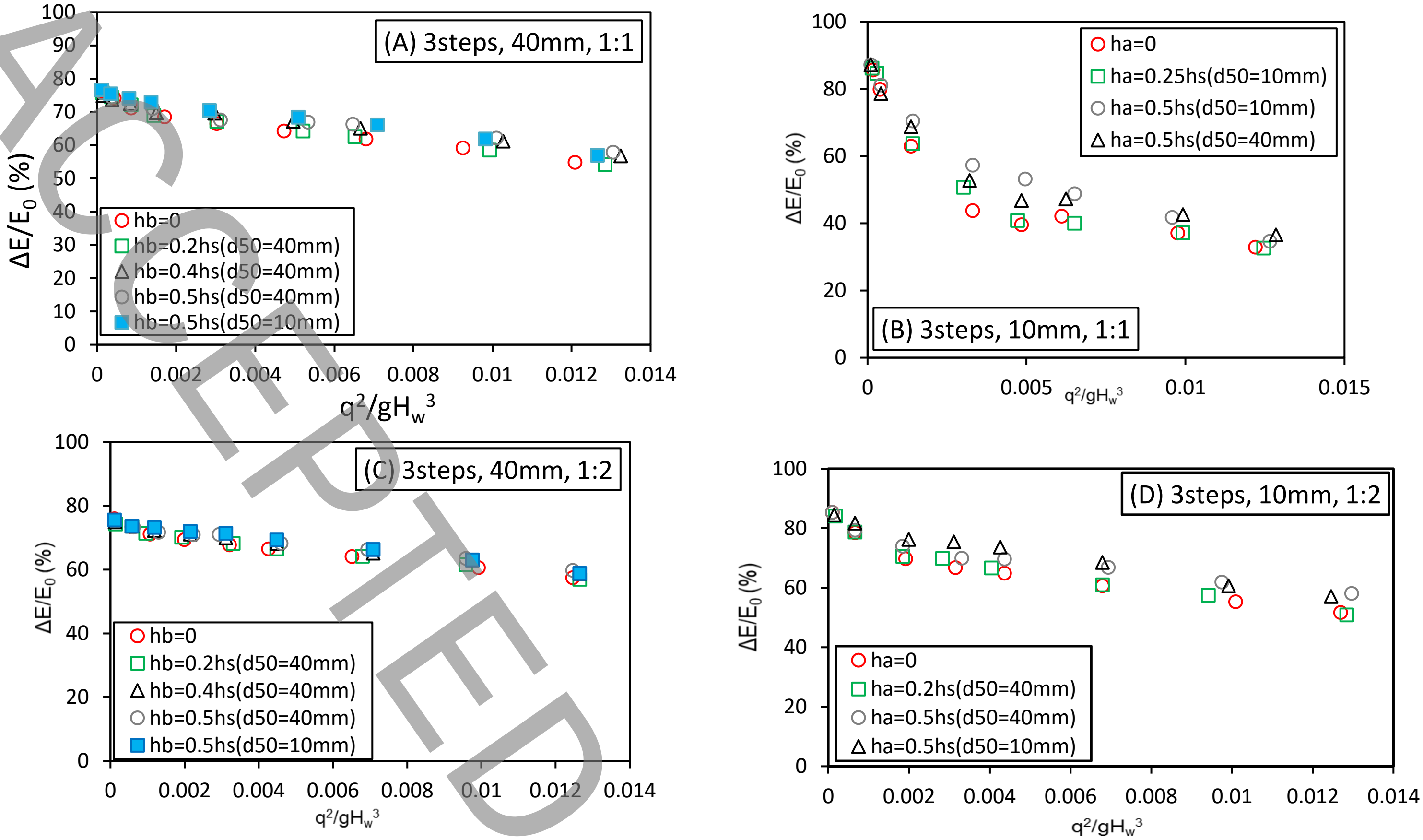

Figure 3: Relative energy loss changes against to q^2/gH_w^3 for gabion rectangular and slopped end sills

4. Conclusions

As the flow discharge increases, the energy loss decreases. The roughness conditions play the most important role in estimating the energy loss. A three-step weir with a large scale roughness (d_{50}=40 mm) consumes about 23% more energy than that the small scale roughness (d_{50}=10 mm). In stepped gabion weirs with d_{50}=40 mm stones, due to high permeability, the end sill (rectangular or sloping) does not have much effect on the relative energy loss. But in gabion stepped weir with 10 mm materials, due to low permeability, part of the residual overflow on the end sills was dissipated. In overflows with materials of 10 mm in a range of discharge (45 liters per second) the effect of the rectangular end sill with specifications h_b = 0.5h_s and d_{50} = 10 mm is greater than that the rectangular end sill with specifications h_b=0.5h_s and d_{50}=40 mm. But with the rise of discharge, the trend is reversed. The effect of the end sills on the head loss with d_{50}=40 mm materials and 1:2 downstream slope is about 10% more than that the same weir with 1:1 downstream slope and in the weir with 10 mm materials and downstream slope 1:2 is about 30-35% more than that the same weir with 1:1 slope.

References

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