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Energy Dissipation of Converged Ski-jump Buckets by using Dividing Wall

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ABSTRACT: Ski-jump bucket spillway is one of the energy dissipation structures applied at downstream of spillways or bottom outlets. In this study, the effect of the convergence angle of the ski-jump bucket on the flow energy dissipation was experimentally investigated and the results were compared with the conventional bucket model. For this purpose, four convergence angles of 10, 20, 30 and 40 degrees were created using deflectors in the bucket. The effect of adding a dividing wall, in two modes of bucket splitter wall (BSW) and full separator wall (FSW), on the conventional and convergent buckets were investigated. The results showed that the flip buckets dissipated about 60 to 65 percent of their energy. At a 20-degree convergence angle, the energy dissipation of the flow increased by about 5 percent, however, at a 30-degree convergence angle, the energy dissipation decreased by about 15 percent. In general, the energy dissipation decreases by increasing the flow discharge. Adding a dividing wall to the bucket does not have a significant effect on energy dissipation, although adding a separator wall to a converged bucket eliminates the effect of reduction in the energy dissipation due to convergence of the bucket. By mounting the dividing wall on the bucket, a local disturbance is created in the flow pattern, however, the resulting loss is not significant compared to the energy dissipation caused by the jet colliding with the bottom of the stilling basin. Whereas full separator wall (FSW) divides the bucket into two parts and it doesn't cause major disruption to the flow pattern.

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1- Introduction

Ski-jump buckets are of the most widely used energy dissipation structures in large dam projects, whose poor design and implementation may reduce their performance and may cause extensive damage to dam body and downstream structures.

Juon and Hager [1] examined the hydraulic characteristics of flow in the flip bucket and the energy dissipation rate at the presence of the deflector. They compared their results with the conventional flip buckets. All studies include examining the effect of model scale, the pressure distribution in the flip bucket and the flow blade. Their results showed that the flow pattern around the deflector follows a second-order curve. The deflector suddenly deflects the flow direction, causing a shock wave. The deflector makes the issuing jet through the bucket to be more diffuse than the conventional type of bucket. They stated that the deflector with an installation angle of 20 generated a significant deviation in the flow pattern and created the highest shock wave height. Zhang et al. [2] designed a new type of energy dissipating structure known as Allodapic hybrid-type flip bucket, having the advantages of sprayed bucket with narrow base bucket. This type of energy dissipaters sprays the flow better than others. Deng et al. [3] proposed a new type of buckets. The bottom of this model has a given slope and the side walls have an angle along with the bucket. Their results showed that the bed slope of 30 to 45 degrees has the best hydraulic performance, leading to the best way to spray the issuing jet.

2- Methodology

This study examines the effect of the convergence angle of the bucket on the flow pattern and the energy dissipation of the flow passing through the spillway with the bucket. For this purpose, four convergence angles of 10, 20, 30 and 40 degrees were considered in the bucket, and the results were compared with the conventional bucket model (Fig 1). Then, the separator walls were added to the control and converged models, respectively, as installed in full separator wall (FSW). The buckets were installed at the end of the Ogee spillway's chute. The height of the spillway was 0.4 m, the radius of the bucket was 0.16 m and the angle of the bucket edge was 30 degrees. The experiments were performed on the models at 10 flow discharges in the range of 16 to 25 lit/s.

3- Discussion and Results

The main idea of the design of converged buckets is taken from the hydraulic of collision of the jets, and the main idea

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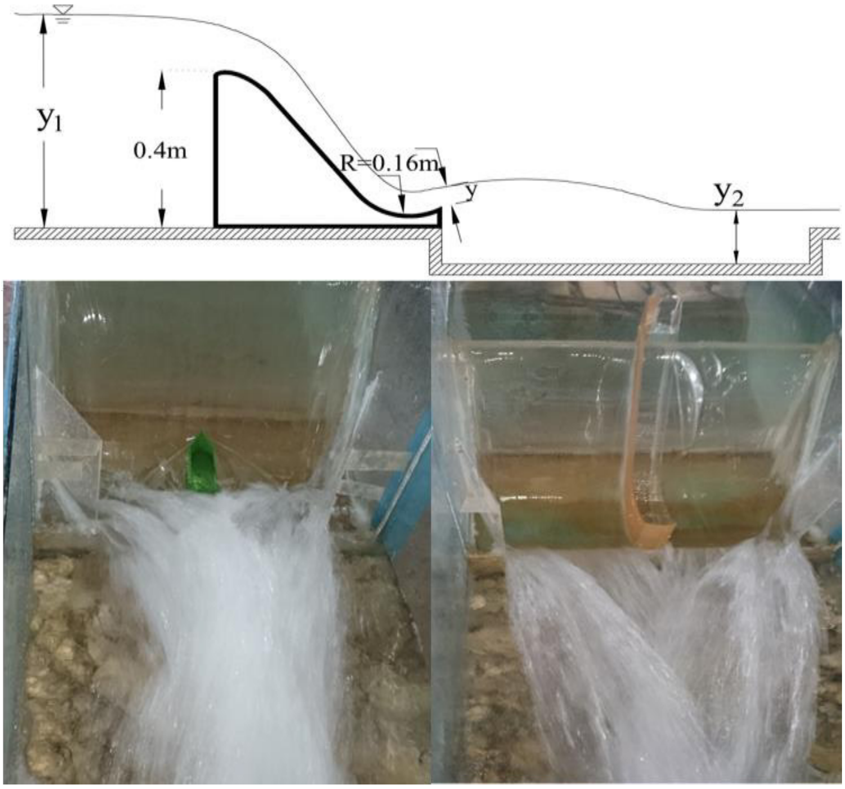

Fig. 1. Converged bucket with separator wall in bucket splitter wall (BSW) and full separator wall (FSW).

of the use of the separator walls was taken from the separation of the issuing jet from the bucket. Energy dissipation is a function of the relative critical depth (y_c/R) that indicates the effect of inflow rate to the bucket, the Froude number of the outflow from the bucket (Fr), the angle of the bucket edge (θ), ψ convergence angle the bucket, the effect of the separator wall the bucket (ξ) and the full separating wall (λ). The amount of dissipated energy in all models was calculated using the Bernoulli equation. As shown in Fig 1, first, the flow depth and velocity were measured at the upstream (section 1) and downstream (section 2); then, using Eqs. 1 to 3, the energy dissipation of the flow through the bucket was calculated. The results of each scenario considered in this study, including the effect of the separator wall, the effect of the convergence angle, and the simultaneous effect of the separating wall and the convergence angle on energy dissipation will be separately presented. The effect of the bucket splitter wall (BSW) and full separator wall (FSW) on the energy dissipation of the flow is shown in Figure 2. As can be seen, the effect of separator wall on the energy dissipation rate is also compared with the control model. Examination of the baseline model shows that this structure can dissipate approximately 60 to 65 percent of the energy. As shown in this figure, with increasing the flow discharge, the performance of the structure in energy dissipation decreases; however, this rate is about 5%. From hydraulic point of view, it should be noted that some of the outflow energy from the bucket is dissipated by spraying the jet from the bucket to the air. Figure 2 shows the performance of the bucket at the presence of the bucket splitter wall (BSW) and full separator wall (FSW) against the relative critical depth and the Froude number of outflow from the bucket. As shown in this figure, adding the separator wall either in bucket splitter wall (BSW) or full separator wall (FSW) does not have a significant effect on increasing or decreasing the performance of the bucket in energy dissipation. From hydraulic point of view, this phenomenon should be re-considered in Figure 1. As can be observed in this figure, the disturbance caused by the separator wall of the bucket occurs at a small section (local disturbance and loss) and its effect appears as a shock wave. It should be noted when the flow enters the air as a spraying jet, it also destroys some of the disturbances and neutralizes its effect. On the other hand, as mentioned before, a large amount of flow energy is dissipated by the collision of the jet with the bottom of the downstream stilling basin; therefore, it can be concluded that the local loss in this case in comparison with the energy dissipation due to the collision of the jet with the bottom of the stilling basin is not noticeable. For full separator wall (FSW) and according to Figure 1, it should be noted that due to the full extension along the spillway and bucket, this structure does not cause almost significant disruption in the flow pattern.

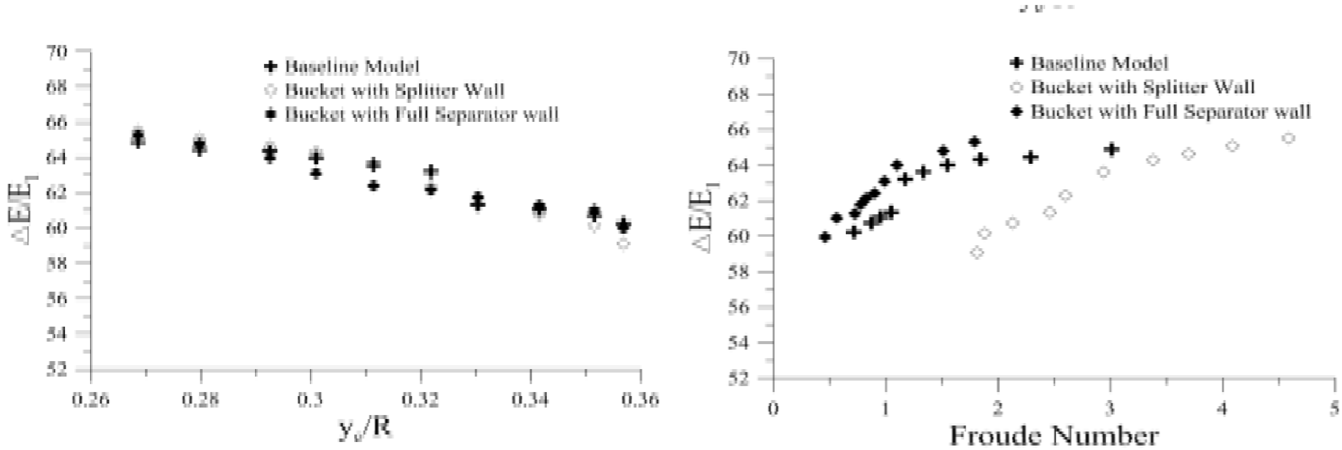

Fig. 2. Variations of the Froude number vs. relative critical depth and relative energy dissipation

4- Conclusions

The summary of the results of this study is as follows:

- The ski jump bucket can dissipate about 65 to 60 percent of the flow energy.
- Adding a BSW or FSW does not have a significant effect on increasing the energy dissipation of the flow. The reason for this is that the disturbance caused by the BSW occurs in a small range (local disturbance) and then the flow enters the air in the form of jet spraying; in this stage, it also significantly destroys the effect of the local disorder. On the other hand, the local head loss caused by separator walls is negligible compared to the energy dissipation caused by the collision of the falling jet with the stilling basin. As for the FSW, it should be said that this structure has almost no local disturbance in the flow pattern and almost divides the bucket into two parts with separate performance.
- Regarding the effect of deflector angles, it should be said that the convergence angle of 20 degrees increases the energy dissipation by about 5% and the convergence angle of 30 degrees of convergent cup model performance decreases by about 15%. It should be noted that adding a BSW to the converging bucket at a 30-degree angle does not affect its performance, but adding an FSW will eliminate its performance reduction.

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