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A flume experiment study of energy lose at downstream of a sluice gate

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Abstract. A sluice gate is a controllable barrier that controlling the elevation of the water at the channel. Generally, energy change occurs at the upstream and downstream of watergate, caused by the impact of the water flow at watergate upstream. This study aims to analyze the energy change at Watergate and to compare the value of energy change that occurs at the channel with or without sediment. This research was carried out by the Civil Engineering Hydraulics Laboratory of the Faculty of Engineering, Hasanuddin University, which runs from December 2018 to March 2019. In this research, we use some variables that are channel bed condition, flume slope, debit, and watergate openings. The result of this research shows that debit and watergate openings really affect the value of the energy change, while the flume slope is not really affected it. The energy change that occurs at the flume without sediment is bigger than the energy change that occurs at the flume with sediment in it.

1. Introduction

A sluice gate is a barrier that can be set open to regulate or control the water level in a channel. In general, a hydraulic jump occurs at the downstream of the sliding door. The height of a hydraulic jump depends on the speed, water flow, the bed slope of the channel, and the roughness of the channel. At the downstream of the sluice gate dam, a stilling basin was built to reduce the energy contained in the flow.

In general, energy changes at the upstream and downstream of the sluice gate, due to flow friction at the sluice gate. Energy changes of the flow can be observed visually and measurement of the flow depth on both upstream and downstream of the sluice gate.

Laboratory flume experiments on the sluice gate have been made in the previous works [1-3]. For example, Kim discussed energy dissipation on the sluice gate, while Habibzadeh discussed the energy loss due to the sluice gate, however, more studies are needed in order to obtain a deeper understanding of energy changes due to sluice gate.

In this study, we will discuss energy changes in the upstream and downstream sluice gate on various variations, sure the basic conditions of the channel, the slope of the channel, the discharge, sediment bed, and the opening of the sluice gate.

The purpose of this study is to calculate the total energy on both upstream and downstream of the sluice gate, then we calculate the head loss. Besides that, we analyze the correlation of the energy loss with the slope of the channel, water discharge, the opening of the sluice gate.



2. Flume experiments

2.1. Experimental apparatus

2.1.1. Laboratory flume

In the experiments, the rectangular flume was used, as shown in figure 1. It is 9 m long and 30.5 cm wide, with the changeable bed slope.

A sluice gate was installed at the station 3.7 m upstream from the downstream end. The length of the sluice gate was 30.5 cm.

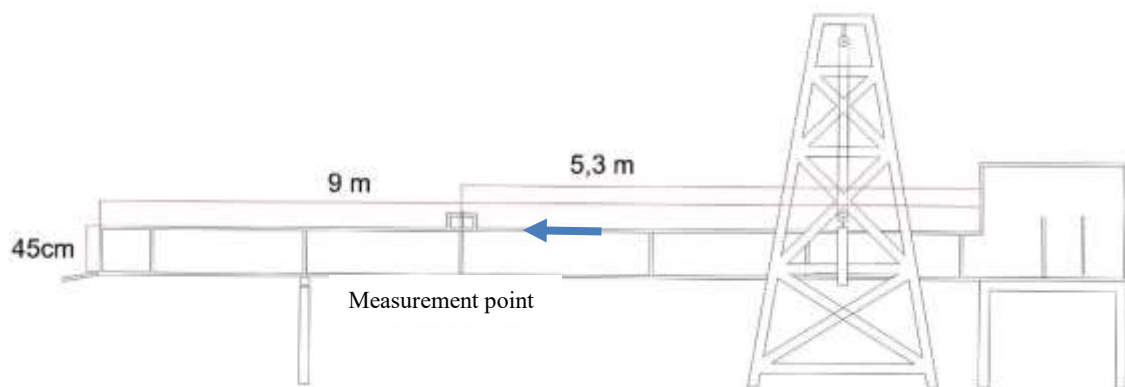


Figure 1. Laboratory flume.

2.1.2. Sluice gate.

The sluice gate as in figure 2 is used to adjust the water level on the flume channel. The mechanism of the sluice gate is to rotate the lever on the top of the gate, to open or close the gate.



Figure 2. Sluice gate.

2.1.3. Sediment

In this study, clay was used as a variation of the bed on the flume channel. The clays were taken in the location nearby Civil Engineering Department building. The location is shown in figure 3.



Figure 3. Sediment location.

2.2. Experimental procedure

2.2.1. Flume preparation

Before the experiments, there are several preparations were done on the flume channel which is described as follows:

- First, install the sluice gate at the distance 3.7 meters from the downstream end of the flume channel.
- Adjust the slope of the flume with a change of 10 cm from its base state.
- Turn on the water pump, then adjust the pump lever to adjust the discharge. For discharge variations $Q_1 = \pm 0.0010$ (opening tubs 17 cm).
- The water depth on the model bridge was measured after the confirmation of the steady flow.
- For variations of flume with sediment base, put soil into flume with a thickness of about 10 cm, then compact the soil. After that stage, repeat the procedure 2 to 4.

2.2.2. Velocity measurement procedure

To find out the flow velocity on the flume channel, we must know the cross-sectional area and discharge data. Following are the steps to find the discharge value and cross-sectional area:

- Set sluice gate to reach the opening of 0.5 cm
- Catch the water by using buckets 3 times, with duration 2 to 3 seconds each
- Measure the volume of water in each bucket using a measuring tube
- Measure the water level at the upstream and downstream of sluice gate using a level gauge
- Repeat steps 1 to 4 with changes in slope into 15 cm and 18 cm
- Repeat steps 1 to 4 with 18 cm and 19 cm tubs
- Repeat steps 1 to 4 with sluice gate openings of 1 cm and 1.5 cm.

From both of the procedures above, the volume and height of the water level in the flume channel are obtained. With this data, we can calculate the discharge value and flow velocity on the flume channel.

3. Results and discussion

3.1. Energy loss on sluice gate without sediment

Energy loss equation introduced in the following equation [4]. Then, the energy loss equation for the sluice gate case due to the friction on the sluice gate is expressed as equation 1.

$$\Delta E^n \equiv \left\{ \frac{(v_1^n)^2}{2g} + h_1^n \right\} - \left\{ \frac{(v_2^n)^2}{2g} + h_2^n \right\} \tag{1}$$

ΔE^n = energy loss between the upstream and downstream station of the sluice gate without sediment

v_1^n = velocity of the upstream station of the sluice gate without sediment

h_1^n = water depth of upstream station of the sluice gate without sediment

v_2^n = velocity of the downstream station of the sluice gate without sediment

h_2^n = water depth of upstream station of the sluice gate without sediment

From the calculation, the result for each different slope is plotted as shown in figure 4, figure 5, and figure 6. The graphs show less difference between them, which means that the slope change does not affect the energy loss so much. On the other hand, the sluice gate opening affects the energy loss. If the sluice gate is opened above the normal depth of the flow, there will be only a little energy loss around the sluice gate.

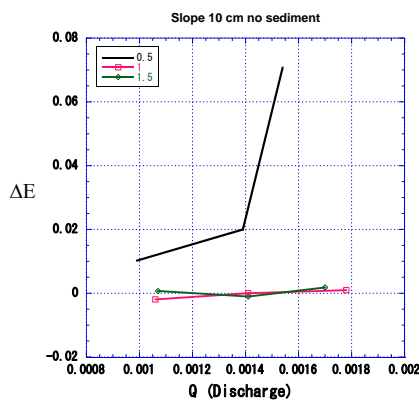


Figure 4. Relationship between discharge and energy loss for the 10 cm slope without sediment.

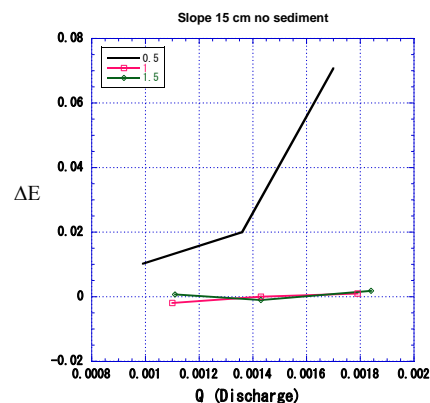


Figure 5. Relationship between discharge and energy loss for the 15 cm slope without sediment.

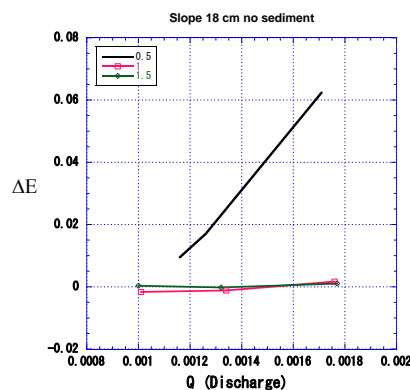


Figure 6. Relationship between discharge and energy loss for the 18 cm slope without sediment.

3.2. Energy loss on sluice gate without sediment

Similar to the formula above, energy loss due to the friction on the sluice gate with sediment on its bed is expressed as equation 2.

$$\Delta E^s \equiv \left\{ \frac{(v_1^s)^2}{2g} + h_1^s \right\} - \left\{ \frac{(v_2^s)^2}{2g} + h_2^s \right\} \tag{2}$$

ΔE^s = energy loss between the upstream and downstream station of the sluice gate with sediment

v_1^s = velocity of the upstream station of the sluice gate with sediment

h_1^s = water depth of upstream station of the sluice gate with sediment

v_2^s = velocity of the downstream station of the sluice gate with sediment

h_2^s = water depth of upstream station of the sluice gate with sediment

From the calculation, the result for each different slope is plotted as shown in figure 7, figure 8, and figure 9. The graphs show less difference between them, which means that the slope change does not affect the energy loss so much. Similar to the non-sediment case, the sluice gate opening affects the energy loss. If the sluice gate is opened above the normal depth of the flow, there will be only a little energy loss around the sluice gate.

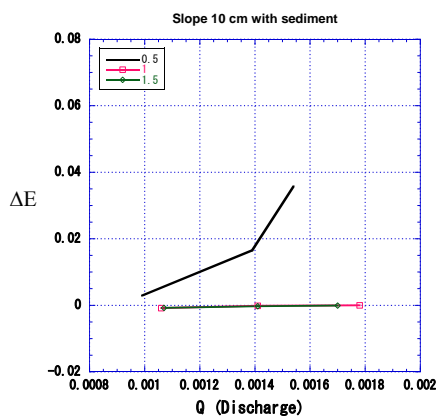


Figure 7. Relationship between discharge and energy loss for the 10 cm slope with sediment.

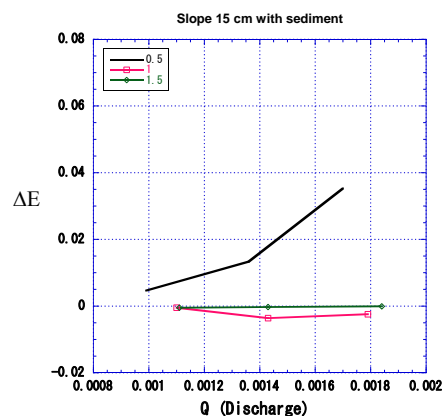


Figure 8. Relationship between discharge and energy loss for the 15 cm slope with sediment.

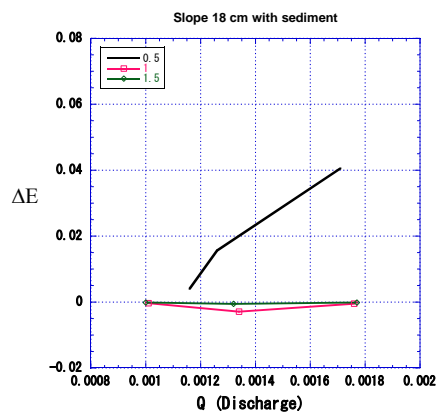


Figure 9. Relationship between discharge and energy loss for the 18 cm slope with sediment.

3.3. Comparison between energy loss on sluice gate with sediment and without sediment

By combining the line of each case into a plot, the combined figure of each case can be shown in figure 10 and figure 11. There are three variations for each case with sediment and without sediment; variation of discharges, a variation of opening, and variation of the slope. The figures show that the opening of the sluice gate at 0.5 cm above the bed has a significant change in its energy loss for different discharge. However, the opening of the sluice gate at 1.0 and 1.5 cm have less energy loss, due to the water depth did not reach the sluice gate. Moreover, the comparison graph analysis of energy changes in channel variations shows the energy loss that occurs in the variation of flume without sediment is greater than the variation of flume with sediment.

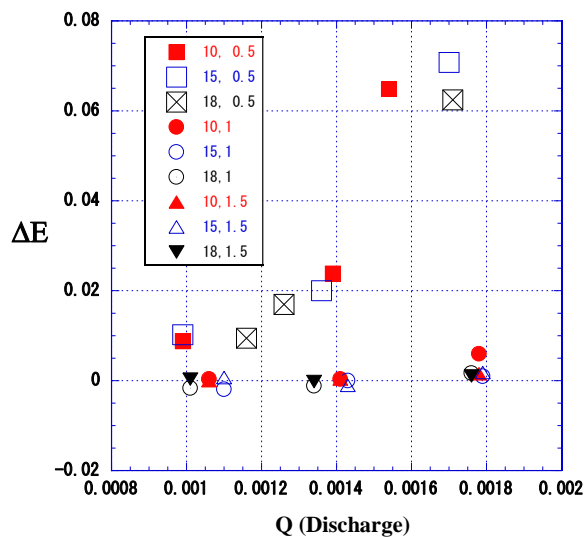


Figure 10. Relationship between discharge and energy loss for each slope without sediment.

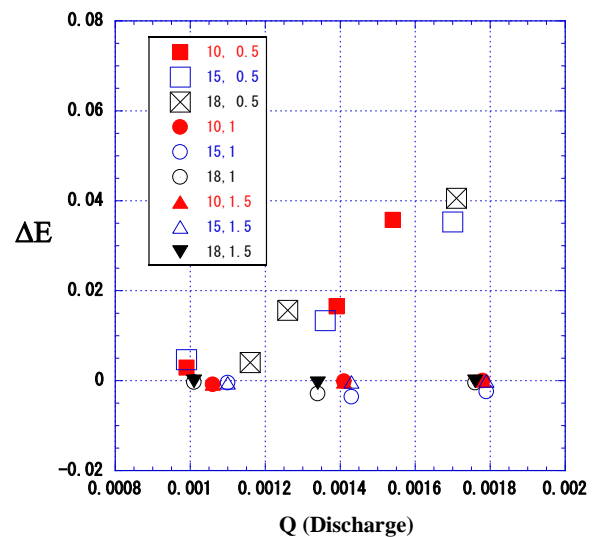


Figure 11. Relationship between discharge and energy loss for each slope with sediment.

4. Conclusions

- Based on the graph analysis of energy loss in several slope variations, the energy loss between the upstream and downstream determined by discharge.
- The variation of the slope does not greatly affect the energy loss
- From the comparison graph analysis of energy loss in channel variations, the energy loss that occurs in the variation of flume without sediment is greater than the variation of flume with sediment.
- Therefore, the condition of the flume bed affects the amount of energy loss.

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