International Journal of Modern Research in Engineering and Technology (IJMRET)
www.ijmret.org Volume 4 Issue 1 ǁ January 2019.

Analysis of the Energy Dissipation Effect According to the Height and Arrangement of Hydraulic Energy Dissipaters

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ABSTRACT *: The purpose of this study is to analyze the energy dissipation effect of hydraulic energy dissipaters installed to address the problem of scouring in a movable weir downstream, and to analyze the influence of the height and arrangement of baffles on the flow dissipation effect. The experiment was divided into 39 cases and the dissipation effect was analyzed by comparing the flow velocity for the height and arrangement type of each case. The test results showed that the flow velocity dissipation effect gradually increased as the height of the baffle increased. The flow velocity dissipation efficiency increased by about 10%-60% when the baffle was installed, and the flow velocity dissipation was higher when the baffle height was higher or when the baffles were arranged in multiple rows. In addition, the largest dissipation effect occurred when the height was 20% of the floodgate, and no significant changes in the flow velocity dissipation efficiency were evident at higher heights. Therefore, when arranging the baffles in a single row, adjusting the height to within 20% of the height of the weir or floodgate is considered to be most effective.*

KEYWORDS *: Movable Weir, Baffle, Hydraulic Energy Dissipater*

I. INTRODUCTION

Although the weir is a structure across the horizontal width of a river for water utilization and flood control purposes, there are technical limitations to the design of medium-sized weir structures (fixed weir, movable weir, etc.) since the river design standards only present design criteria for general weirs. In particular, the river design standards define the weir as a small structure constructed with a maximum height of 2 m-3 m, so there are not sufficient design criteria and methods for downstream baffle structures. In addition, although weirs should be constructed after considering the flow dissipation for stabilizing the downstream river bed like dam structures, flood control stability issues continue to arise because technologies for downstream dissipation are not applied due to a lack of design standards.

Domestic and international case studies on scouring(erosion) have mainly involved numerical simulations of local scouring caused by hydraulic structures and simulations of scour depth predictions for the flow velocity[1-5]. In addition, research on the influence of the weir downstream hydraulic jump has been performed, but proposed only to improve the river bed material calculation formula according to the hydraulic jump downstream turbulence intensity[6]. Kim et al. performed a hydraulic model experiment on the scour phenomenon in the downstream apron of the structure and the amount of settlement that occurs after installing the riprap protection, and proposed a non-dimensional settlement calculation formula for riprap protection, but only presented the criteria due to a lack of validation[7]. Park et al. proposed the flow characteristics of the overflow-type and downstream discharge-type weirs, analyzed the hydraulic jump length according to changes in the downstream water depth, and proposed the specific energy loss per unit distance depending on the type of weir[8].

McLaughlin Water Engineers proposed appropriate structures for each region by investigating the pros and cons of various types of river-crossing structures[9], and Agricultural research service and Little performed a study on the change of scour depth through hydraulic experiments for each case[10-11].

However, most studies have mainly been focused on numerical analysis and the main purpose of analyzing the scour depth. Therefore, the purpose of this study is to analyze the energy dissipation effect through hydraulic experiments according to the height and arrangement of baffles, which are hydraulic energy dissipaters in the movable weir downstream for the safety of river-crossing structures.

II. STUDY METHOD

2.1Experimental configuration

The experimental equipment used for the hydraulic experiment were divided into the channel and discharge supply unit. The discharge supply unit consists of an underground water storage and a pump and the experimental equipment consists of a baffle pool, a model channel, and a downstream collector wall. The pump used in the experiment was installed to allow a maximum flow rate of 0.3 m3/s. The hydraulic tests were performed as a fixed bed experiment on a straight channel with a rectangular cross-section, in which the dimensions of the channel were 1.5 m wide, 30.0 m long, and 1.2 m high (Fig. 1).

The movable weir of the test structure was made of a 0.3 m wide lift-type gate and the fixed weir was constructed in a basic shape with a width of 0.6 m (left) and 0.6 m (right) (Fig. 2). To measure the flow change caused by installing the baffle, we set the experimental measurement section to 2 m downstream of the movable weir. The measurement interval was 0.2 m in the longitudinal direction and 0.15 m in the transverse direction, and the total number of measurement points was 15. The baffle model was produced in a cylindrical shape with a diameter of 0.05 m (Fig. 3).

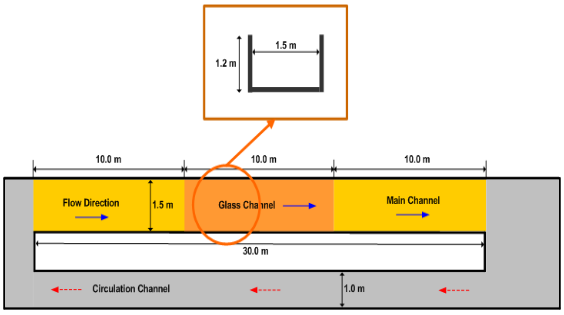


Figure 1. Experimental Channel

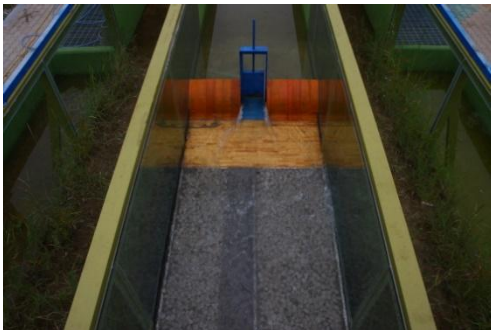


Figure 2. Experimental weir

Figure 3. Experiment picture

2.2 Experimental method

The water that flows downstream through the movable weir generates strong flows that are very different from the upstream flows. For this hydraulic behavior, a bogie was installed to enable the flow velocity to be measured according to the baffle height and arrangement, and a hydrometer was attached to move to the measurement points. This study used a VO1000 hydrometer, which is a one-dimensional propeller-type hydrometer manufactured by KENEK (Japan). The VO1000 can measure one-way flow velocity, with a measurement range of ±3 to±200 cm/s and a measurement error of ±3 cm/s depending on the range of flow velocity. The measurement interval can be measured at an average flow velocity of 5, 10, 20, 40, and 60-second intervals. In this experiment, the average flow velocity was measured by setting a time interval of 20 seconds. The flow velocity was measured using a one-point method that measures the point 60% of the water surface.

Fig. 4 shows the measurement points, in which the flow velocity measurement points are marked on the sideline and bogie at the upper side of both channel walls so that the measurements can be made at the correct points.

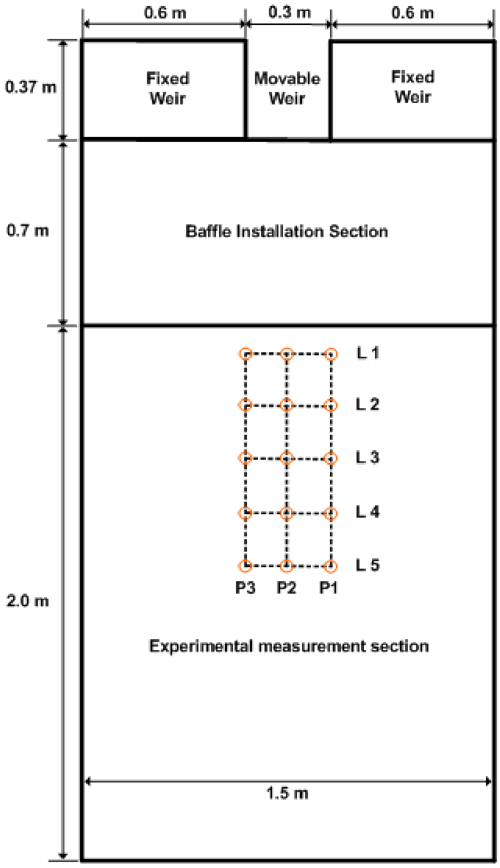


Figure 4. Baffle installation section

2.3Experimental conditions

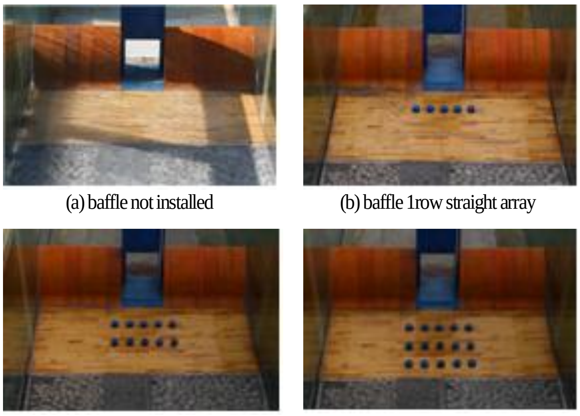
Three discharge conditions were set as shown in Table 1 to analyze the flow dissipation effect according to the baffle height and arrangement in the movable weir downstream. To compare the differences according to the baffle height and arrangement, this study performed experiments for a total of 39 cases by combining 3 flow conditions, 4 baffle height conditions, and 3 baffle arrangement conditions (Table 1-2). Fig. 5 shows the types of baffle arrangement for the hydraulic experiments, in which experiments were conducted for a total of 3 cases. Case 0 refers to the case before installing the baffle.

Table 1. Boundary conditions

Sort (Gate opening height)	Upstream discharge condition (Q)	Downstream water level condition (H)
A (0.10 m open)	0.062 m^3/s	0.04 m
B (0.15 m open)	0.072 m^3/s	0.05 m
C (0.30 m open)	0.099 m^3/s	0.07 m

Table 2. Experimental conditions

Case	Baffle height	Baffle arrangement
Case 0	-	baffle not installed
Case 10-1	0.03 m (10% of weir height)	baffle 1row straight array
Case 10-2	0.03 m (10% of weir height)	baffle 2row straight array
Case 10-3	0.03 m (10% of weir height)	baffle 3row straight array
Case 20-1	0.06 m (20% of weir height)	baffle 1row straight array
Case 20-2	0.06 m (20% of weir height)	baffle 2row straight array
Case 20-3	0.06 m (20% of weir height)	baffle 3row straight array
Case 30-1	0.09 m (30% of weir height)	baffle 1row straight array
Case 30-2	0.09 m (30% of weir height)	baffle 2row straight array
Case 30-3	0.09 m (30% of weir height)	baffle 3row straight array
Case 40-1	0.12 m (40% of weir height)	baffle 1row straight array
Case 40-2	0.12 m (40% of weir height)	baffle 2row straight array
Case 40-3	0.12 m (40% of weir height)	baffle 3row straight array



(a) baffle not installed (b) baffle 1row straight array
(c) baffle 2row straight array (d) baffle 3row straight array

Figure 5. Arrangement conditions

III. STUDY RESULTS AND ANALYSIS

3.1 Flow velocity measurement results by discharge condition

Through measuring the flow velocity according to the discharge conditions (A-C), it was found that when the flow velocity data was compared according to baffle installation, baffle height, and arrangement as shown in Figs. 6-8, the flow velocity tended to decrease as the baffle height and arrangement increased. In particular, when a strong flow velocity occurred according to the increase of discharge from A discharge condition to C discharge condition, the flow velocity tended to decrease even further.

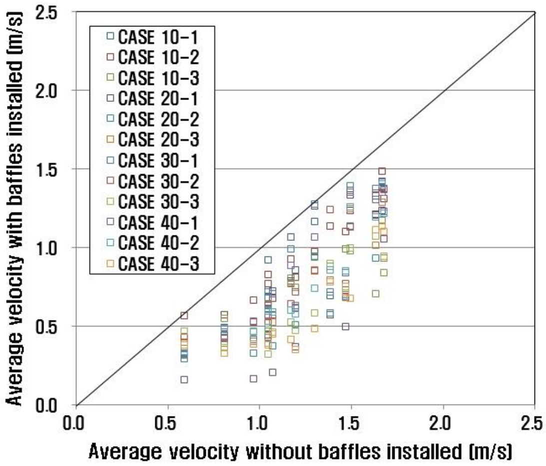


Figure 6. Comparison of flow velocity measurement data according to baffle installation(A discharge condition)

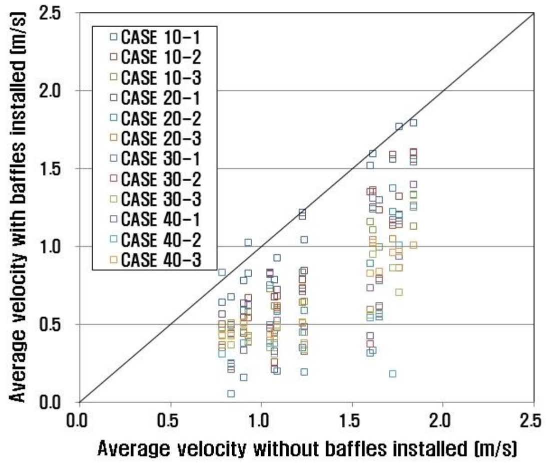


Figure 7. Comparison of flow velocity measurement data according to baffle installation(B discharge condition)

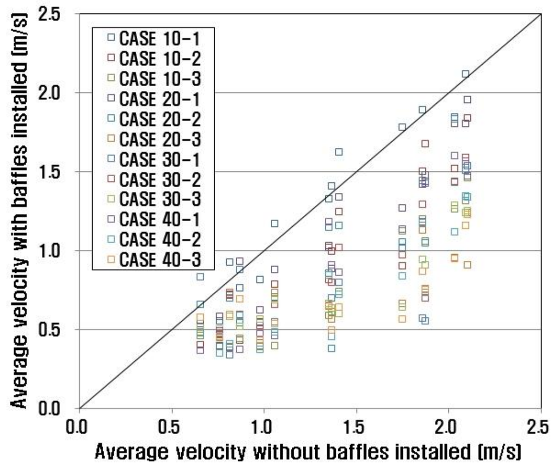


Figure 8. Comparison of flow velocity measurement data according to baffle installation(C discharge condition)

3.2Analysis of scouring dissipation effect according to the hydraulic energy dissipater height and arrangement

Table 3-Table 5 show the experimental results of the average flow velocity, maximum flow velocity and hydraulic jump distance for each experiment from A discharge condition to C discharge condition, and Fig. 9 shows the conversion of the X and Y axis values into dimensionless coefficients such as the average flow velocity according to baffle installation, hydraulic jump distance, weir height, and baffle height. The results of the experiments show that the flow velocity dissipation effect gradually increases as the baffle height increases. In terms of comparing the baffle installation status, the flow velocity dissipation efficiency increased by about 10%-60% when the baffle was installed, and the flow velocity dissipation was higher when the baffle height was higher or when baffles were arranged in multiple rows. However, the largest dissipation effect occurred when the height was 20% of the floodgate, and did not show any significant changes in the flow velocity dissipation efficiency at higher heights. Therefore, when the baffles are arranged in a single array, adjusting the height to within 20% of the height of the weir or floodgate is considered to be most effective.

Table 3. Experimental results (A discharge condition)

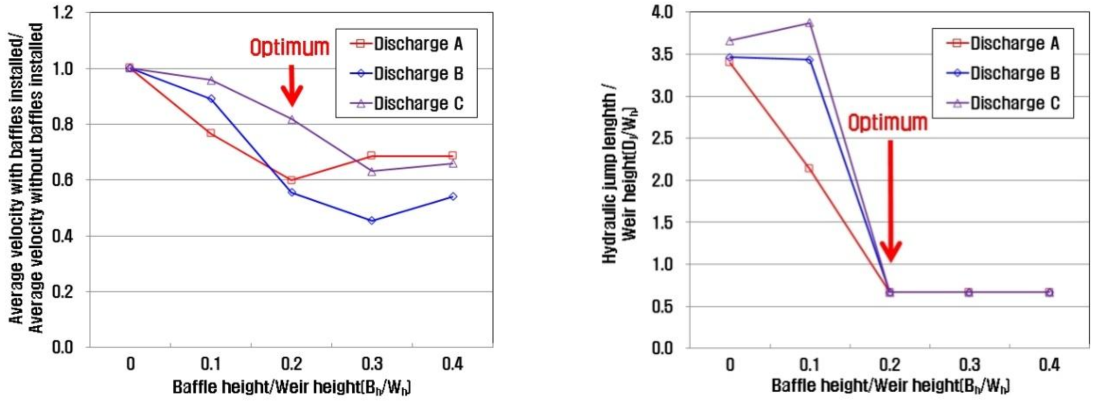
Case	Gate opening height (m)	Baffle height	Baffle arrangement	Average flow velocity (m/s)	MAX flow Velocity (m/s)	Hydraulic ju mp distance (m)
Case 0	0.10	-	Not installed	1.235	1.679	1.02
Case 10-1	0.10	0.03 m (10% of weir height)	1row straight array	0.946	1.414	0.64
Case 10-2	0.10	0.03 m (10% of weir height)	2row straight array	0.950	1.483	0.48
Case 10-3	0.10	0.03 m (10% of weir height)	3row straight array	0.740	1.168	0.40
Case 20-1	0.10	0.06 m (20% of weir height)	1row straight array	0.699	1.330	0.20
Case 20-2	0.10	0.06 m (20% of weir height)	2row straight array	0.716	1.383	0.20
Case 20-3	0.10	0.06 m (20% of weir height)	3row straight array	0.735	1.286	0.20
Case 30-1	0.10	0.09 m (30% of weir height)	1row straight array	0.846	1.390	0.20
Case 30-2	0.10	0.09 m (30% of weir height)	2row straight array	0.836	1.377	0.20
Case 30-3	0.10	0.09 m (30% of weir height)	3row straight array	0.662	1.138	0.20
Case 40-1	0.10	0.12 m (40% of weir height)	1row straight array	0.846	1.419	0.20
Case 40-2	0.10	0.12 m (40% of weir height)	2row straight array	0.777	1.403	0.20
Case 40-3	0.10	0.12 m (40% of weir height)	3row straight array	0.605	1.138	0.20

Table 4. Experimental results (B discharge condition)

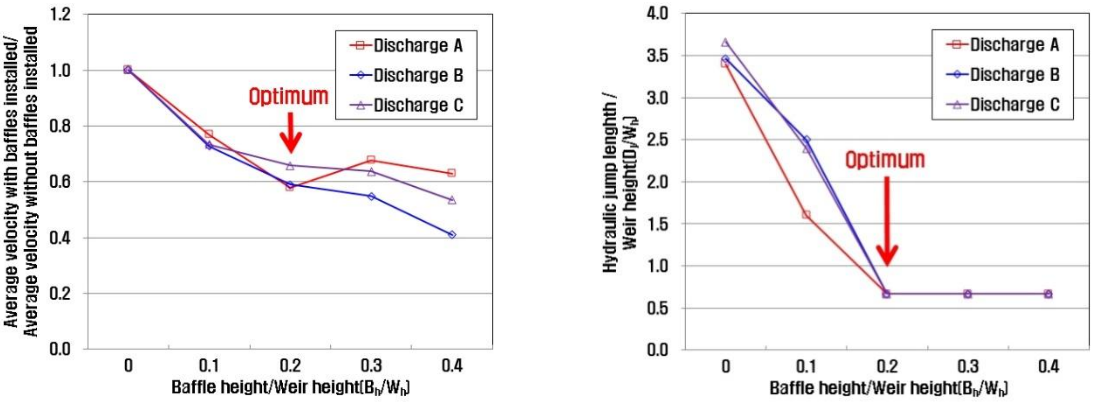
Case	Gate opening height (m)	Baffle height	Baffle arrangement	Average flow velocity (m/s)	MAX flow Velocity (m/s)	Hydraulic ju mp distance (m)
Case 0	0.15	-	Not installed	1.288	1.838	1.04
Case 10-1	0.15	0.03 m (10% of weir height)	1row straight array	1.148	1.787	1.03
Case 10-2	0.15	0.03 m (10% of weir height)	2row straight array	0.936	1.584	0.75
Case 10-3	0.15	0.03 m (10% of weir height)	3row straight array	0.788	1.154	0.60
Case 20-1	0.15	0.06 m (20% of weir height)	1row straight array	0.716	1.605	0.20
Case 20-2	0.15	0.06 m (20% of weir height)	2row straight array	0.759	1.330	0.20
Case 20-3	0.15	0.06 m (20% of weir height)	3row straight array	0.641	1.263	0.20
Case 30-1	0.15	0.09 m (30% of weir height)	1row straight array	0.584	1.542	0.20
Case 30-2	0.15	0.09 m (30% of weir height)	2row straight array	0.705	1.598	0.20
Case 30-3	0.15	0.09 m (30% of weir height)	3row straight array	0.579	1.322	0.20
Case 40-1	0.15	0.12 m (40% of weir height)	1row straight array	0.697	1.392	0.20
Case 40-2	0.15	0.12 m (40% of weir height)	2row straight array	0.528	1.249	0.20
Case 40-3	0.15	0.12 m (40% of weir height)	3row straight array	0.637	1.021	0.20

Table 5. Experimental results (C discharge condition)

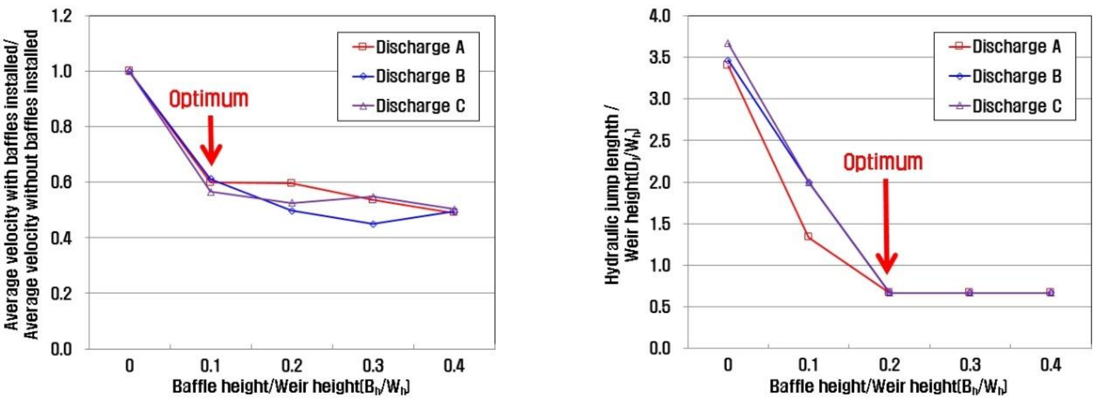
Case	Gate opening height (m)	Baffle height	Baffle arrangement	Average flow velocity (m/s)	MAX flow Velocity (m/s)	Hydraulic ju mp distance (m)
Case 0	0.30	-	Not installed	1.399	2.104	1.10
Case 10-1	0.30	0.03 m (10% of weir height)	1row straight array	1.342	2.112	1.16
Case 10-2	0.30	0.03 m (10% of weir height)	2row straight array	1.027	1.833	0.72
Case 10-3	0.30	0.03 m (10% of weir height)	3row straight array	0.791	1.460	0.6
Case 20-1	0.30	0.06 m (20% of weir height)	1row straight array	1.144	1.953	0.20
Case 20-2	0.30	0.06 m (20% of weir height)	2row straight array	0.921	1.545	0.20
Case 20-3	0.30	0.06 m (20% of weir height)	3row straight array	0.735	1.155	0.20
Case 30-1	0.30	0.09 m (30% of weir height)	1row straight array	0.883	1.830	0.20
Case 30-2	0.30	0.09 m (30% of weir height)	2row straight array	0.891	1.583	0.20
Case 30-3	0.30	0.09 m (30% of weir height)	3row straight array	0.766	1.283	0.20
Case 40-1	0.30	0.12 m (40% of weir height)	1row straight array	0.923	1.597	0.20
Case 40-2	0.30	0.12 m (40% of weir height)	2row straight array	0.748	1.339	0.20
Case 40-3	0.30	0.12 m (40% of weir height)	3row straight array	0.704	1.223	0.20



(a) Baffles 1 row straight array



(b) Baffles 2 rows straight array



(c) baffle 3 rows straight array

Figure 9. Experimental result analysis graph

IV. CONCLUSION

This study analyzed the influence of the height and arrangement of baffles, which are hydraulic energy dissipaters in the movable weir downstream, on their energy dissipation effect, in order to address the issue of scour in the movable weir downstream. Through the experiments, it was found that when the flow velocity data were compared according to baffle installation, baffle height, and arrangement, the flow velocity tended to decrease as the baffle height and arrangement increased. In particular, when a strong flow velocity occurred according to an increase of discharge condition, the flow velocity tended to decrease even further. The results of this analysis showed that the flow velocity dissipation effect gradually increased as the height of the baffle increased. In terms of comparing the baffle installation status, the flow velocity dissipation efficiency increased by about 10%-60% when the baffle was installed, and the flow velocity dissipation was higher when the baffle height was higher or when baffles were arranged in multiple rows. However, the largest dissipation effect occurred when the height was 20% of the floodgate, and did not show any significant changes in the flow velocity dissipation efficiency at higher heights, and showed similar values. Therefore, when the baffles are arranged in a single array, adjusting the height to within 20% of the height of the weir or floodgate is considered to be most effective.

V. Acknowledgements

This research was supported by a grant(18TBIP-C112927-03) from Technology Business Innovation Program(TBIP) funded by Ministry of Land, Infrastructure and Transport of Korean government.

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