Journal of Ferdowsi Civil Engineering, Vol.33, No.3, 2020.

The Role of Chute Blocks Geometry in Current Erosion Power Loss

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1. Introduction

The high energy stored in the outflow stream from the overflows is controlled by designing energy-consuming structures in the chute or downstream stilling basin. However, the occurrence of local scouring downstream is one of the biggest threats to the stability of overflows.

Hence, Dargahi in 2003, with increasing roughness of the stilling basin, showed that although no special change is formed in the normal flow pattern, but it causes a sharp decrease in sediment transfer downstream and the scour hole is 17 to 57% smaller without the roughness. In 1964, Peterka and Karon introduced a chute structure with baffle blocks as a type of current energy shock dissipator. They believed that the baffle blocks in the chute do not reduce the flow velocity, but reduce the kinetic energy in the downstream by reducing the flow acceleration. So the most favorable conditions will be when the blocks are placed perpendicular to the inlet stream.

Laboratory studies of Kaya and Emiroglu in 2010 on the effect of T-shaped, trapezoidal and stepped block foundations on two different slopes of the shooting bed on the energy loss of the current passing through this structure, showed that the T-shaped block in terms of increasing energy loss and the amount of oxygen entering the stream outperformed other geometries. Karimi et al. in 2019 examined the effect of chute wall divergence with three different geometries (rectangular, triangular and semicircular baffle blocks) by constructing a physical model in the laboratory on the depth and dimensions of the scour hole below shoot. For this purpose, 9 models of baffled chute with divergence ratios (1, 1.45, 1.75 and 2.45) were made. Comparing the results related to the effect of block geometry in different divergence ratios, it was found that using the blocks proposed in this study instead of the standard USBR blocks, on average, reduces the scour hole depth by up to 50%. For a given block geometry, the mean and maximum depth and length of the scour hole are reduced by 75, 58 and 50%, respectively.

Looking into the research background and the importance of scouring at the foot of overflows, the present study investigates the effect of installing the base of rectangular, triangular and circular blocks on the chute in order to control the erosive power of the flow in the overflow claw (reducing scour depth and length). It can be a cheaper replacement for blocks on USBR ropes or complex and expensive stilling basins. Experiments on the variation of the input landing number examined the effect of the installation pattern and the geometric shape of the blocks on the energy drop along the path from the overflow to the foot of the chute.

2. Materials and Methods

The experimental model was fabricated in a glass channel with length, width and height of 6, 0.5 and 0.5 meters, respectively, in the laboratory of hydraulic models of Ferdowsi University of Mashhad. Overflow and shot geometry specifications by the USBR instruction and Tuna's recommendation in 2012 with width and height, respectively; 0.5 and 0.3 m and was designed on a slope with an optimal angle of 30 degrees (Figure 1).

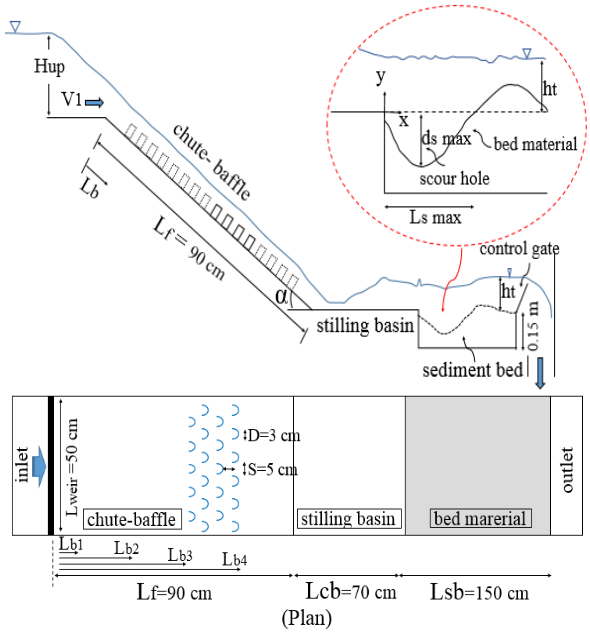

Figure 1. Schematic of the channel and plan of the laboratory model

The number of installation blocks in each row of the model was selected according to Blaisdell's recommendation in 1948 in the range of 40-50% of the width of the chute floor. Therefore, in each row, 6 blocks with a fixed opening width (D) equal to 3 cm with a distance of 5 cm were installed. Moreover, according to the USBR instruction, the depth of flow on a chute without a block base in the design flow conditions is the experimental criterion for selecting a height of 1.5 cm baffle. The longitudinal position of the installation for the arrangement of four rows of bases was selected as a ratio of the total length of the slope of the chute (Lb/Lf =0.2, 0.4, 0.6 and 0.8) (Figures 1 and 2).

In order to investigate the effect of the geometric shape of the block foundations with the proposed geometric characteristics, three modes were considered according to Figure 2.

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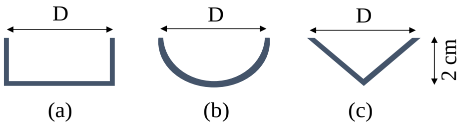

Figure 2. Geometric shapes of baffle blocks. (a) Rectangular block (REB) (b) Semicircular block (SCB) (c) Triangular block (TRB)

According to the theory of Raudkivi and Ettema in 1983, the average particle diameter should be more than 0.7 mm to prevent the formation of ripples during the experiment. Moreover, when the geometric standard deviation of the particles is less than 1.3, the non-uniform effect of the particles on the scour depth can be ignored. For this purpose, non-stick sediments with an average diameter of 0.72 mm, specific gravity of 2.65 g/cm3, and a standard deviation of 1.12 were used.

3. Results and Discussion

Examination of the geometric characteristics of the scour hole showed that the use of the shape and pattern of installation of the block base on the slope of the chute in all tested models has affected the scaled dimensions and has always reduced the dimensions of the scour hole. In summary:

1. The final depth and length of the scour increases with increasing number of landings upstream of the overflow;
2. In the series of concavity tests against the flow of blocks, the scour dimensional parameters have always had lower values than the convexity against the flow;
3. By reducing the installation distance of the blocks in relation to the overflow claw, the scour reduction in depth and length increases, so that in the installation position of the blocks (Lb / Lf = 0.8) the highest energy consumption occurred compared to other installation positions. The installation of blocks between 15 to 61.2% has been effective in reducing the depth of the scour hole.
4. In position (Lb/Lf=0.6), rectangular and semicircular blocks with convexity against current and also, in position (Lb/Lf=0.8) triangular block with concavity against current, with function on average, 38.1 to 73.4% have the highest decrease during scouring compared to other conditions.
5. By increasing the landing number of the stream upstream of the overflow crown, the relative dissipated energy of the stream at the point of the chute decreases.