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EXTENDED ABSTRACT

Examination of the Effect of Cubic Artificial Roughness Density inInclined Channel on Downstream Scour Depth

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Introduction

Water passage from steep slopes in river engineering issues and the design of water transfer structures is inevitable. Because of the steep slope of the surface, the surface velocity and surface erosion rates are high. Energy control in high-speed flows is one of the challenges of designing hydraulic structures. These flows, for example, occur in places such as dam overhead structures, drainage systems of urban areas and Mountain Rivers with a steep slope. One of the ways to reduce dimensions or eliminate energy depreciating structures is to use methods to reduce the kinetic energy of flow over the weir, including using of stairs or blocks on the overflow. The use of large-sized stairs or blocks will cause the passing jets of flow to be separated and as a result turbulent, which can effectively deplete the kinetic energy of the current. The problem with using a staircase or block is a huge cost of built and a high risk of cavitation. Another method of energy depreciation is to apply roughness at the overflow bed, which may be an efficient way to reduce energy. Roughness can dramatically reduce the flow turbulence, and thus reduces the risk of cavitation. Also, roughness can reduce the flow power over the overflow and reduce the depth of the lower erosion pit by removing or reducing the dimensions of the relaxation basin. Most studies in this field have investigated the effect of these roughs on the amount of energy depletion, which in addition to energy depletion is also important for lowering the erosion of the structure. However, for the economic design of hydraulic structures, designers need to have full knowledge of the particle mechanics and the dimensions of the scour hole, so that they can consider the requirements for the stability of the structure, which has so far been investigated insufficiently. Therefore, the present study aimed to investigate the effect of roughness density on sloped bed surface on its downstream scour depth.

Methodology

In this research, the effect of artificial roughness density on the scour depth of the sandy bottom was investigated. Lower scouring of the slope is dependent on a large number of variables related to hydraulic flow over the slope along the presence of roughness, as well as the characteristics of hydraulic jump and sediments. Then, a general non-dimensional relationship was developed as follows (equation 1).

$$\frac{d_s}{y_2} = f\left(\frac{q^2}{gH_{dam}{}^3}\text{،} d\%\right) \quad (1)$$

A laboratory model including an overflow weir with a height of 60 cm and a length of 180 cm was built. The surface of the overflow covered with cubic artificial roughness, in three concentrations of 5%, 10%, and 15% and scouring inside the basin in four different cascades ranging from 0.800 to 0.003 was investigated. To put roughs on a sloping bed, they were first drawn using AutoCAD software with dimensions of 1.5 * 3 * 3. Then they were cut from Plexiglas by laser cutting. The steps of the experiment are such that the sediments were first manually flattened and the surface of the bed was measured by a laser meter with 0.1 mm accuracy. In order to prevent the unwanted washing of the materials, the water level was slowly increased at first, and after the balanced condition, the Flume inlet valve was opened, the flume was opened and the amount of discharge was adjusted. After the fixation of the jump site, the experiments continued for 150 minutes.

Results and discussion

At this stage, four experiments were carried out with 150 minutes' period in four different cascades of 0.0008, 0.001, 0.002, and 0.003 under free jump (type A) on a flat surface. As the number of cascades increased from 0.002 to 0.003, the scour depth increased by 30%. In order to investigate the effect of compression, various scour length profiles with different density percentages presented, and It was observed that by increasing of the scour depth density and the total scour length the total scour depth decreased by 43% and 23% respectively, then the flat bed at a density of 15%. As well as changes in the depth of the dimensionless scour depth versus the cascade number for flat bed and density of 5%, 10% , and 15% were drawn. With increasing the cascade number, the dimensionless depth of the scour at the density of 15% and 38% increases. The variation of scour in terms of density change showed that increasing density by 15% caused the greatest reduction in scouring inside the basin. Roughness can reduce the scour depth, including depth and scour length, by generating vortices and flowing collisions perpendicular to the surface of the roughness and increasing the current resistance. The dimensionless depth of scouring in different percentage densities shows that there is an inverse relationship between increase in percentage of density and dimensionless depth of scouring. In this way, with increasing density percentage, the dimensionless depth of scouring decreases. In order to evaluate the quantitative results, we can estimate the variation of the scour depth reduction ((% R) from equation (2):

$$R = \frac{d_{smax5,10,15-d0s}}{d0s} \times 100 \quad (2)$$

In the above equation, $d_{smax5,10,15}$ shows the scour depth at the channel's surface slopes of 5%, 10%, and 15% , respectively. d_{0s} Shows flatbed scour. In table (2), the percentage of scour depth reduction compared to the flat surface for different densities in the range of the cascade number from 0.2008 to 0.003 is presented. According to table (2), for a specific cascade number, by increasing percentage of density, the percentage of scour depth reduction has increased. By increasing the density of 15%, the average reduction in scour depth, cavity length, total scour length were changed approximately by 43%, 27%, 33%, respectively.

Conclusion

The results indicated that under a fixed cascade number, by increasing the roughness density, the flow strength through the inclined channel because of the shear resistance is weakened. Hence, with the effect of roughness on reducing the flow strength of vortices generated in the course of a low hydraulic jump in the inclined channel, the scour depth decreases. In the case of increasing the density by 15%, the scour depth in the cascade number is reduced by a maximum of 30%, this amount of decrease in the density by 5% reaches to a maximum of 10%. The results also showed that reducing the scour depth in two condensations of 10% and 15% in each of the four cascades will decrease by about the same percentage. Ultimately, a general equation was proposed to predict the amount of scour depth reduction in this type of channel, and it was found that the equations obtained have an acceptable agreement with the laboratory data.