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Experimental Investigation Effect of the Porosity and Angle of Permeable Obstacles on Density Current Sedimentation

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ABSTRACT: Flood flow in rivers is often of density current type. Hence, recognizing and exploring these currents can solve some problems of sedimentation. In this study, the effect of porosity and the angle of permeable obstacles on the control and trapping of density current have been investigated in the laboratory. For this purpose, an expanded polystyrene (EPS) polymer was used with 1.135 g/L density and average diameter of 1.15 mm. The experiments were carried out with two concentrations (10 and 20%) and 5 porosity and 4 angles. The obstacles were made of palsy glass plates and two types of groove and cavity with 8.2 mm width of the groove and the diameter of the cavity. The results showed that, with an increase in porosity ratio, the amount of trapping to optimum porosity decreases and then increases. The optimal porosity of the cavity and groove is 22 % and 19%, respectively. In experiments, the cavity trapping was observed more than the groove, in the concentrations of 10.20% it was 0.13 and 0.14%, respectively. Also, with the increase of the angle, the amount of trapping has reduced and its value was observed in the groove more than the cavity. The correlation coefficient in the grooves and cavities was 0.996 and 0.937, respectively. The major effect of obstacles, reducing velocity and slowing flow were identified as the average velocity in the cavity was 3.62% higher than the groove. Accordingly, in the same conditions, the cavity obstacles have better performance than the groove obstacles.

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1. INTRODUCTION

The flood of the rivers are often density currents. Hence, the investigation of these flows can resolve a part of the sedimentation issues. Despite a lot of research that has been conducted to understand better the behavior of the density currents [1 - 5], evaluation of these currents' behavior that have suspended sediment loads and encounter permeable obstacles in their path requires further studies. For this purpose, the process of changes in the sedimentation with different angles of permeable obstacles is investigated in this research. Speed and depth of the density currents affected by permeable obstacles and the process of encounter and passing of them through the permeable obstacles are also evaluated.

2. MATERIALS AND METHODS

A flume with a length of 10 m, a width of 30 cm, and a height of 45 cm has been examined in this study, as shown in Fig. 1. Two obstacles with grooves and pits porosity at different percentages of 10, 15, 20, 25 and 30 and in the with an equal slit width and diameter of 3 mm, were mounted respectively.

3. RESULTS AND DISCUSSION

Flow velocity measurement was conducted by lateral imaging of the flume. The vertical profiles of flow velocity and concentration at a distance of 2 meters upstream of the obstacle are shown in Fig. 2.

As shown in Fig. 2, as the density current gets closer to the obstacle, the mean velocity reduces and the depth velocity becomes more dispersed. Also, due to the sedimentation in the path toward the obstacle, the concentration of materials diminishes, and the concentration in the deep parts of the flow increases. Changes of depth in the upstream vicinity of the obstacles are shown in Fig. 3.

As shown in Fig. 3, the more the porosity of obstacle is, the less the rate of depth reduction gets. Studies have shown that the flows containing the obstacles with pits have a less upstream depth (4.14%) and a more velocity (3.62%), due to easier passing of the flow. In addition, the mean velocity of the head and back of the current density mass was estimated to be 10.7 and 4.6 cm/s, being 37% more and 30.2% less than the mean velocity of flow, respectively. The analysis of time of the test from the beginning of the injection of density current to the base flow to the last particle of suspended load passing through the obstacle shows that the distribution and changes in the test duration are more at the concentration of 10% compared to that of 20%. Moreover, the process of changes in the test duration at the concentration of 20% is more balanced compared to that at the concentration of 10%. Fig. 4 shows how the flow passes through the obstacle and the sedimentary materials accumulate upstream it.

The amount of materials passing through the obstacles

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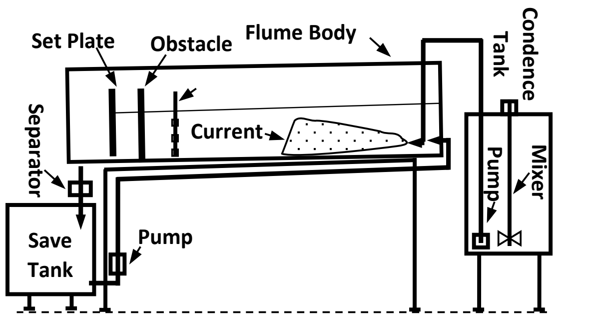

Fig. 1. The overall view of flume and laboratory equipment used

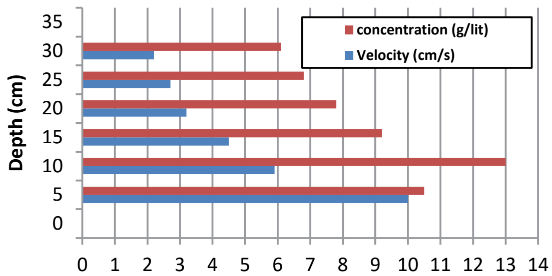

Fig. 2. The flow velocity and concentration at a distance of 2 meters upstream the obstacle

is shown in Fig. 5 for two different concentrations and five various porosities.

The results showed that in all cases, the trapping performance of the obstacles with pits is better than those with grooves. The mean trapping of the obstacles with pits was reported to be more than those with grooves by 0.14 and 0.13% at the concentrations of 10 and 20%, respectively. At low concentrations, the performance of the two types of obstacles is relatively similar. At high concentrations, however, the obstacles with pits have been effective with a better rate of trapping. Accordingly, at the porosities of 20 and 25% the lowest trappings were observed for the concentrations of 10 and 20%, respectively. Optimum porosity, which has the highest amount of passing materials, was estimated at 22 and 19% for the obstacles with grooves and pits, respectively.

To examine the effect of the angle of installation, the obstacles were rotated by 90, 105, 120 and 135 degrees relative to the horizontal direction of the floor in the flow direction. The trend of changes in the passing materials through the obstacles for different angles is presented in Fig. 6.

Studies have shown that by increasing the angle of installation, the trapping by both types of obstacles decreases. The amount of trapping reduction in the obstacles with pits was observed to be more than those with grooves. The correlation coefficients in the obstacles with grooves and pits

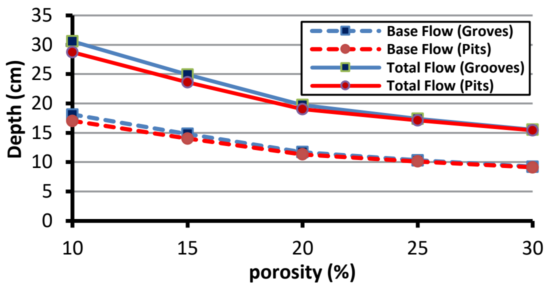

Fig. 3. The status of changes of depth in the vicinity of obstacles for the base and total flow

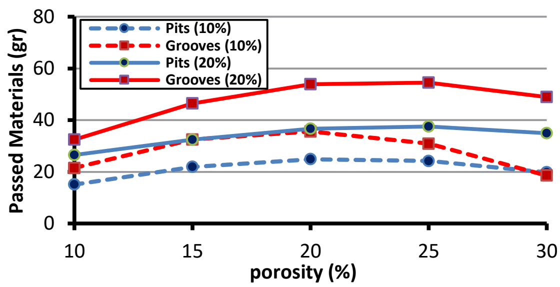

Fig. 5. The materials passing through the obstacles with different porosities and concentrations

Fig. 4. The accumulation of sedimentary materials upstream the obstacle

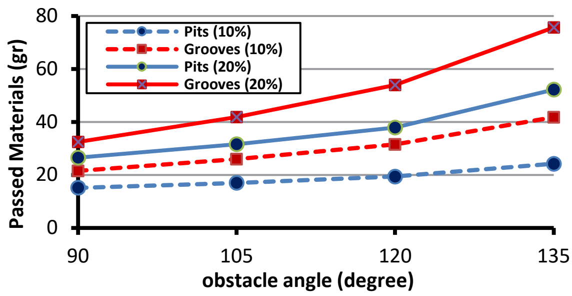

Fig. 6. Changes in the passed materials with the angle at different concentrations

were obtained 0.961 and 0.937, respectively. This can result from easier passing of the flow and evacuation of the materials caused by the pressure on the obstacles with pits.

The results approved the obstacle's efficiency in controlling the density current. It was found that permeable obstacles, due to their capacity to transmit a part of the flow and higher pressure reduction compared to impermeable ones, require smaller dimensions and have higher stabilities.

4. CONCLUSIONS

A review of experimental results showed that the optimum porosity for obstacles with pits and grooves are 22 and 19%, respectively. By increasing the porosity, the trapping reduces up to the optimal porosity and then increases. Evaluation of various angles of the obstacles relative to the direction perpendicular to the floor of the flow showed that by increasing the angle, the amount of trapping decreases. The amount of reduction in trapping for the obstacles with grooves was more compared to those with pits. The mean velocity of flow by using the obstacles with pits was 3.62% more compared to those with grooves. Totally, at the same conditions, the obstacles with pits have always shown a better performance than those with grooves.

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