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Experimental Iinvestigation of the Effect of the Ttriangular Vanes on the Channel Bed Ttopography

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ABSTRACT

The main purpose of this paper was to evaluate the performance of the triangular vanes located on the bed and their effect on the bed topography considering different flow conditions. For this purpose, tests were carried out on a straight flume for different flow conditions (five Froude numbers of 0.18, 0.20, 0.22, 0.24 and 0.26) by installing a series of triangular vanes at a space of 4Le (Le is the effective length of the structure) and considering a 30 degrees angle to the upstream bank. At the end of each test, the bed topography was measured by the laser distance measurer. The results showed that the geometric dimension of the scour hole for the rectangular spur dikes was larger than the triangular vanes. On average, the length and depth of the scour hole for the rectangular spur dikes were 1.3 and 1.5 times in comparison to the triangular vanes, respectively. In addition, the maximum scour depth considering the triangular vanes was about 40% farther from the bank in comparison to the case with the rectangular spur dikes, that was an advantage for the triangular vanes.

Keywords

Spur dike, Triangular vanes, Scour, River banks.

1. Introduction

Rivers have always been transformed in their evolutionary path by the erosion of the beaches and river bends as well as sedimentation in other parts that is an unnecessary change for the inhabitants of the rivers. One of the methods of river bank protection is construction of the structures that affects the flow lines and deviates them from the erodible banks to the middle parts of the river, or reduces the flow impact velocity to the walls by decreasing the speed and increasing the ability to precipitate the flow. Spur dikes, submerged vanes, bendway weirs and triangular vanes are among these structures (Anonymous 2008). Spur dikes are among the most widely used structures that are transversely constructed from the riverbank to its axis with different angles to the river bank. Construction of a spur dike on the banks of a river will cause eddy currents around it, as well as increasing the bed shear stress, especially at the structure's nose. Combination of these factors will lead to removal of the river bed sediments from the nose of the structure which will cause large scour holes at the tip of the structure in a long time, which in turn will lead to destruction of the structure. Scouring of the nose is one of the disadvantages of these structures. For this reason, many studies have been carried out in the country and abroad regarding the prediction and reduction of the scour depth

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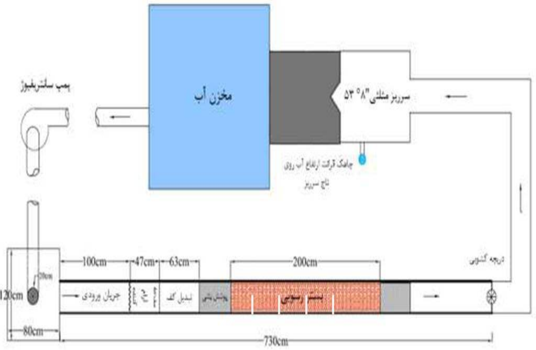
around the spur dike. In this regard, remarkable are studies by Yasi (1999), Sanei (2007), Abbaspoor et al. (2010), Mousavi et al. (2010), Vaghefi et al. (2012), Hoseinzadeh Tabrizi et al. (2014), Divsalar and Mousavi Jahromi (2014), Alizadeh Armaki et al. (2015) in Iran and Gill (1972), Melville (1992), Cohnell et al. (1999), Zhicong et al. (2008), Zhang et al. (2012) Yan et al. (2012) and Ibrahim (2014) in other countries. Despite the extensive studies on the spur dikes to reduce the depth of its nose scouring, this is still a major problem for the spur dikes. Destruction of the Zanjanrood River drains confirms this. Attempts have been made to modify the spur dikes in order to reduce the scour depth. Recent research carried out by Bahrami Yarahmadi and Shafai Bejestan (2016-a) showed that the maximum scour depth and eroded sediment volume around the triangular vanes were 49% and 44% less than the rectangular spur dikes, respectively.

new spurs are structures in the form of triangles that are constructed with small angles (20-30 degrees) and repulsive on the river bank. Effects of the angles, effective length (the distance between the tip of the structure on the bed from the outer bank) and the distance between the triangular vane on the pattern of scouring and sedimentation around them in the river bend have been studied before (Shields 1983; Hey 1992, 1994, 1996; Rosgen 2006). Bahrami Yarahmadi and Shafai Bejestan (2014, 2015-a, 2015-b, 2016-b) results showed that by increasing the angle of the vane relative to the upstream bank, the depth and volume of the scouring in the axis of the structure increased so that 23 and 30-degree angles had the lowest and 60-degree angle had the highest result. By decreasing the effective length of the structure, the maximum scour depth and scour volume in the claw decreased and the maximum scour depth in the structure with the effective length was one fifth the minimum flume width. Meanwhile, the results showed that by increasing the distance between the vanes, maximum scour depth in the tiller of the structure and its expansion extended to the outer shore. Investigations showed that the distance of 8 times the effective length of the structure was not a suitable distance for the triangular vane. Bahrami Yarahmadi et al. (2015) studied the effect of combining the triangular and horizontal vanes on the bed topographic changes in a gentle 90-degree bend. The results indicated that the use of a horizontal blade between the vanes reduced the maximum scour depth in the vane toe and prevented its extension to the outer bank. On average, the use of a horizontal blade reduced 70% of the maximum scour depth in the tabs of the vane. Bhuiyan et al. (2010) used triangular vanes in a laboratory research to control river erosion. The results showed that when one or a group of vanes is installed on the bank, erosion is filled in the outer bank bed and the thalweg is transferred to the center of the river. The vanes create a spiral flow cell that neutralizes the spiral flow in the bend. Vanes whose heights are as large as the overflow level have shown a better performance than the vanes whose height is equal to half the flow level. Recent studies have shown that triangular vanes have less scour depths in nests and more sedimentation on the bank than spur dike droplets. On the other hand, due to the fact that no studies have been done on the performance of this structure on straight channels, this research was carried out.

2.Experimental setup

Experiments were carried out at the Hydraulic Lab of the Faculty of Engineering Sciences of Shahid Chamran University, Ahvaz on a direct flume of 7.3 meters length and 0.56 m width and a height of 0.6 m. As can be seen from Fig. 1, required flow in the flume was supplied using a centrifuge pump from an underground water reservoir and entered the stilling basin located at the entrance of the flume. At the end of the flume, a gate was installed to adjust the flow depth. The flow was measured through a triangular 53-degree overflow located at downstream of the flume. In the experiments, 20, 22, 25, 27 and 30 liters per second flows with a constant depth of 16 cm were used (Froude numbers of 0.18, 0.2, 0.22, 0.24 and 0.26, respectively) in clear water conditions. The angle of the triangular vane was 30 degree and the effective length (the vertical distance between the tip of the structure on the bed and the bank) was 20% of the width of the flume. The distance between the vanes was 4 times the effective length of the structure (4Le). Natural sand with a uniform gradation (σ<1.3) and d_{50}= 0.7 mm was used as bed material. The first structure was placed at a distance of 3 meters from the beginning of the flume to allow the flow to be fully developed to the first structure. The experiments were performed with the rectangular spur dike as a control and to compare the scour depth around the triangular vane with the rectangular spur dike. The angles and effective lengths of the rectangular spur dike were the same for the triangular vane. In the control experiments, 20, 22 and 25 liters per second discharges were used with a constant depth of 16 cm (Froude numbers of 0.18, 0.2 and 0.22, respectively). The experiments were carried out in this way that after the installation of the structure, the bed was completely flattened and leveled, and using a laser meter with a precision of one-millimeter, topography of the bed was taken after which the sedimentation and erosion could be precisely measured. Before starting the pump, the end valve was closed and then, water was slowly guided into the channel. After raising the water level in the flume and ensuring that there was no erosion of the sediments, the pump was started up at a low velocity and slowly adjusted to the required level by the main gate valve. By adjusting the gate, the flow depth (16 cm) and the desired flow discharge was adjusted accurately. These conditions were kept constant for 180 minutes. Long term initial tests showed that the scour in 180 minutes was 87% of the scour in 9000 minutes and since the purpose of this study was to compare different alternatives, it was decided to take 180 m as the time duration for all the experiments. Then, the pump was turned off and the water in the flume was slowly drained while the gate was closed, in order not to influence the bed topography. When water inside the flume completely drained, the bed topography formed in the range of the structures was taken by the laser meter.



A. Laboratory direct flume plan

B. Triangular vanes

Fig. 1. The flume and triangular vanes used in the study

3. Results and discussion

3.1. Bed topography around the structures

In order to study the bed topographic changes around the structures, bed profile was taken by the laser meter and the pattern was depicted using Surfer software. Figure 2 (A) shows the topographic pattern around the triangular vanes for different flow conditions. As can be seen, the scoure hole was created in the triangular vane nose in all the experiments. As the flow discharge increased, dimensions of the scour hole increased due to increasing the flow velocity and the power of the vortex vortices. The deepest scour hole developed in the upstream and downstream of the structure tip. In all the experiments, the scour depth at the tip of the first structure was more than other structures. Figure 2a shows the bed topography in the test considering the lowest flow discharge. It is carefully observed in the figure that the dimensions of the scour hole in the claw of the triangular vane are small, so a lower amount of sediment is deposited on the bed behind the vanes. In Fig. 2, the flow as well as the scour depth increased, especially in the first structure. The scour depth was lower at the tip of the second and fourth triangular vanes, because the flow rapidly transmits to the middle of the flume by the upstream vanes.

As the flow discharge decreased, the scoure hole became larger (Fig. 2-c, d, e). Figure 2, which refers to a Fr=0.26, indicates that the scoure hole at the tip of the first triangular vane had the largest dimensions so that it extended to the bank, while scoure hole at the tip of other structures did not. Visual observations with colored ink showed that the triangular vane deviated the flow from the bank to the middle of the duct, which caused erosion of the bed. In all the experiments, sediments from the erosion of the tip of the vanes were found to interfere with the structures and cling to the bank. For high Froude numbers, sediments shifted from the bank to the center of the development of the transverse and reached the nose of the next structure and filled its scour hole. This sort of sedimentation is an advantage to the triangular vanes because it creates a new bank and also fills the scoure hole of the lower structures. The above results are consistent with the results of Bahrami Yarahmadi and Shafai Bejestan (2014, 2015-a, 2015-b, 2016-b), as well as Bhuiyan et al. (2010), which were performed in the river bends.

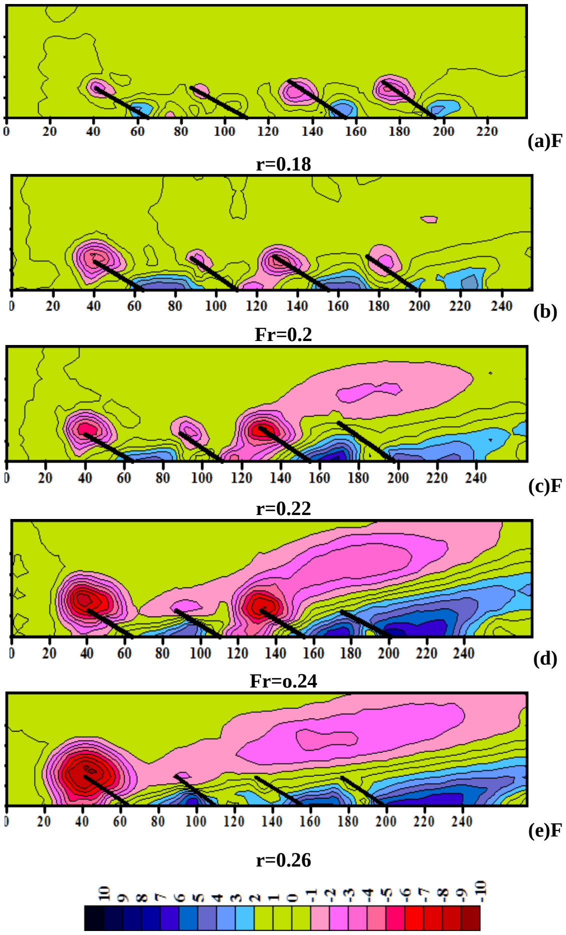
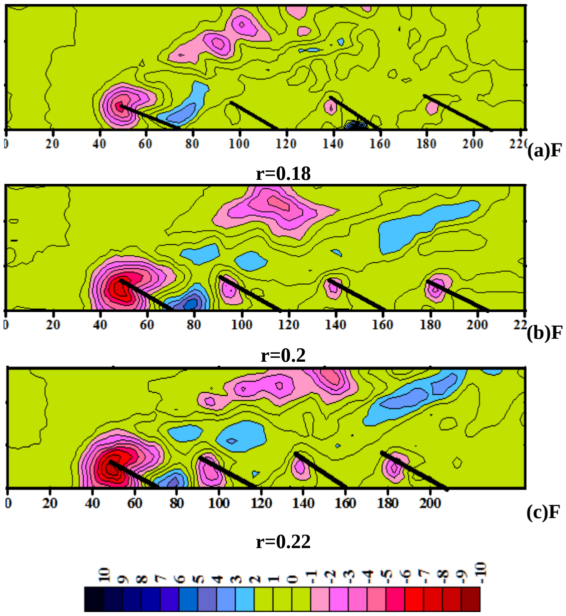


Fig. 2. Bed topographic changes around the triangular vanes for different Froude numbers

In Fig. 3 (a) to (c), bed topographic changes are shown around the rectangular spur dike for different Froude numbers. As can be seen, the largest scour hole was formed around the first spur dike in all the experiments. The maximum scour depth in the first spur dike was more than the subsequent spur dikes and lowered around the nest spur dikes due to collision of the flow into the first spur dike and its deviation to the middle of the conduit. It should be noted that the attack of the stream was less noticeable to the nose of the next spur dike.

Visual observations with colored matter showed that in the rectangular spur dike, the entire stream approaching the structure diverged from the front of the dipper to the center of the flume. In the triangular vane, part of the flow from the front of the tip and another part from the crown of the structure towards the mid-flume was diverted, which caused larger and deeper scour pits than the triangular vane. By comparing Figs. 2 and 3, it is seen that the amount of the deposited sediments on the bank by using the rectangular spur dikes was less than the triangular vanes, which is indicative of a higher ability of the triangular vanes than the rectangular spur dikes in creating a new bank line.



(a)Fr=0.18

(b)Fr=0.2

(c)Fr=0.22

Figu. 3. Bed topographic changes around the rectangular spur dike for different Froude numbers

3.2. Scour hole dimensions

Flow collision to the upper body of the structure and formation of the destructive vortices on one side and the increase of shear stress around the structures due to a reduced flow cross section on the other hand, caused a local erosion and formation of the scour holes in the nose of the structures. One of the important indicators in determining the characteristics of scour hole and its prediction and expansion is the maximum scour depth. Investigations showed that for the triangular vanes and spur dikes, scouring was more pronounced on the nose of the first structure, and in most of the experiments, the maximum scour depth occurred at the nose of the first structure, which is why the scoure hole around this structure was investigated. In Fig. 4, the scoure hole and its geometric characteristics are shown schematically in length and width of the hole. In Figs. 5, 6 and 7, the effect of Froude number on development of the scoure hole of the first structure in length (L/Y), (W/Y) and depth (ds/Y) for Froude numbers of 0.18, 0.2 and 0.22 is shown. It was observed that by increasing the Froude number, due to an increased flow velocity and as a result of the shear stress of the bed as well as increasing the power of the vortex vortices around the structures, dimensions of the scour hole increased. In the triangular vanes, by increasing the flow discharge from 0.18 to 0.26, the width and depth of the scour hole increased 3, 1.8 and 2.7 times, respectively. In the rectangular spur dikes, by increasing the flow discharge from 0.18 to 0.22, the length, width and depth of the erosion crater increased 1.7, 1.3 and 1.6 times, respectively. In addition, Figs. 5 to 7 show that the geometric dimensions of the scour holes in the rectangular spur dikes were larger than the triangular vanes so that the average length and depth of the scour hole in the rectangular spur dikes were 1.3 And 1.5 times the triangular vanes and the width of the scoure hole in both structures was approximately the same.

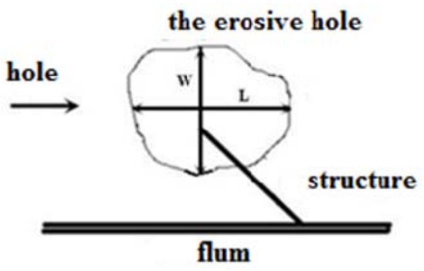


Fig. 4. Geometric dimensions of the erosive hole

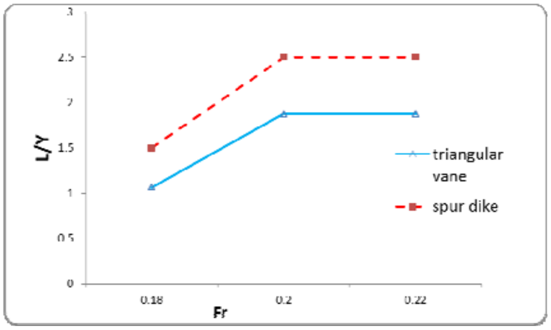


Fig. 5. Length of the scour hole versus the flow discharge for the triangular vane and the rectangular spills

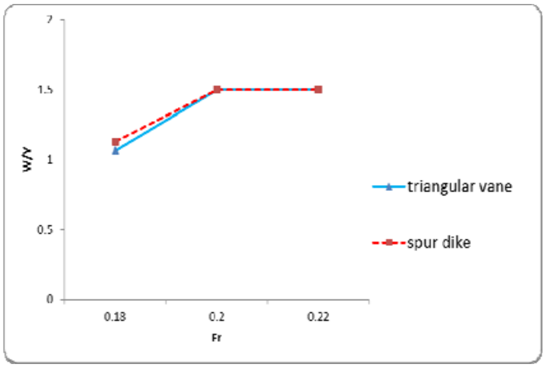


Fig. 6. Width of the scour hole versus flow discharge for the triangular vane and the rectangular spur dike

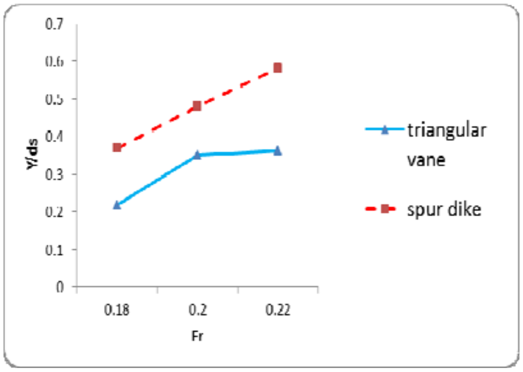


Fig. 7. Maximum variation of scour depth in the nose of the first structure for the triangular vanes and the rectangular spills for different Froude number.

In Fig. 8, variations in the distance of the maximum scour depth from the bank are depicted versus the Froude number. In this figure, the horizontal axis represents the Froude number and the vertical axis indicates the distance of the maximum scour depth relative to the effective length of the bank (S/Le). In the triangular vanes, for the Froude numbers of 18/0 to 22/0, the distance of the maximum scour depth was from the bank of the quarter and equal to 1.2 times the effective length of the structure (1.2Le).

In the rectangular spur dikes, the maximum scour depth at the bank was 0.95 times the effective structural length (0.85Le). Therefore, the maximum scour depth in the triangular vanes is about 40% more than that of a rectangular spur dike from the bank, which is an advantage for the triangular vanes.

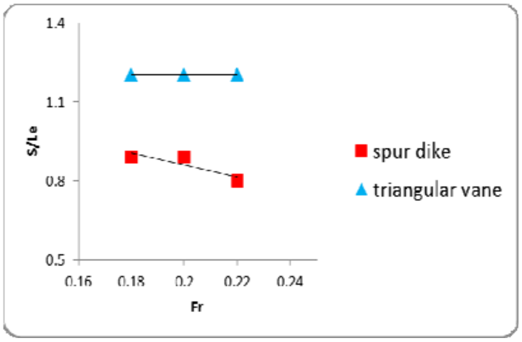


Fig. 8. Distance of the maximum scour depth from the bank for different Froude numbers

4. Coclusions

In summary, the results of this study were as follows:

In a series of the triangular vanes, the scouring deposits were transferred to the bottom and deposited between the plates and clinging to the shore. As the flow discharge decreased, the scouring flow increased as well as the amount of scaling. Sediments transferred from the first structure to the scoure holes of the lower plates, which reduced the maximum scour depth around the lower structures relative to the first structure.

In a series of the rectangular spur dikes, scum deposits from the nose of the upstream spillway were not damaged by the spurts.

In the triangular vanes and the rectangular spur dikes, the maximum depth of the scour around the first structure increased by 0.18, 0.2 and 0.22, respectively.

The maximum scour depth around the first structure in the triangular vanes reduced by 41, 27 and 38 percent, respectively compared to the rectangular spur dikes.

The maximum distance of scour depth from the bank in triangular vanes was calculated for Froude numbers from 0.18 to 0.22, 1.2 times the effective length of the structure (1.2Le), while in rectangular spur dikes 0.85 times the effective length of the structure (0.85Le).

Variation in the width of the scour hole in the first spur dike is the same for both spur dikes and is 1.5 times the flow depth. While the cavity length in the rectangular spur dike is approximately 2.5 times the flow depth, and the same dimension in the triangular spur dike is 1.7 times the flow depth.

The average scour hole length in rectangular spur dikes was 3.1 times the triangular vanes and the width of the scour hole in both structures was approximately equal to 1.5 times the flow depth.

By increasing the Froude number from 0.18 to 0.22, the maximum erosion depth in the case of the triangular vanes and the rectangular spur dikes increased by 1.5 and 1.6 times, respectively.

In the triangular vanes, the maximum scour depth around the first structure for the Froude numbers of 0.18, 0.2, 0.22, 0.24 and 0.26 was 22%, 35%, 36%, 55% and 59% of the depth of the flow, respectively, and for the rectangular spur dikes for the Froude numbers of 0.18, 0.2 and 0.22, was 37%, 48% and 58% of the flow depth, respectively.

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