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Original article

Evaluation the effect of attack angle of submerged vanes on reducing scour caused by contraction strand (Case study: contraction to 30 cm)

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ABSTRACT

When a hydraulic structure is placed on the river bed or on either side of a stream, river section is dropped and a contraction is occurred in river section that caused scouring process is exacerbated. In this condition, scouring process is taken place which is called contraction scour. Different methods have been proposed for the reduction and control of scouring, but still have not been to using of the submerged vanes in the reduction of contraction scour. Submerged Vanes are small structures that are installed in the river bed with a small angle relation to flow direction to modify the flow patterns in the river. The present study aimed to investigate the effect of attack angle of submerged vanes on reducing of contraction scour. Various experiments were carried out in a flume with 20 m length, 0.6 m width and 0.6 m height. Galvanized iron sheets with 10 mm thickness were used in other to creating contraction section. The width of contraction in this study is 30 cm. Submerged vanes were placed under three angles such as 10, 20, and 30 degrees relation to the cannel center and attached to the wall of cannel with 50 cm spacing from each other. All experiments were repeated with 3 discharges such as: 20, 30, and 40 lit/s. The result of this study shows that using of these submerged vanes is effective in reducing of contraction scour in each 3 angels. The most reduction in bed elevation is 61.56 percent occurred for 20 degrees angle of attack in

20 lit/s discharge.

1. Introduction

Scouring is a phenomenon that occurred by the erosion action of stream flow on the bed and transport of bed materials by force that the flow opposes to them. When a hydraulic structure is based in a river bed, a contraction is occurred in the river section that caused changing the hydraulic conditions in river, particularly in times of flood. Limiting the river bed will lead to increasing the velocity of river flow, shear stress, eroding energy, solids carrying capacity of the river, and sediment transport coefficients of fluid. In this condition, scouring process is taken place which is called contraction scour and also Local scour is localized around obstacles and structures in the flow path (Department of Energy, 2009). Contraction scour is created with reducing the cross section of the river bed due to the approaching flow between two Abutments or between two existing bridge piers on the river bed (Briud and et all, 2004).

The structures can create contraction scour in cross rivers include: bridge piers, abutments, bridge approach embankments (to lower the bridge), protection structures such as the open channels for protected of walls against corrosion, breakwater, and levees.

Research shows that most destruction of water structures caused by water scour is due to the scouring in abutments. For example, Macky (1990) in report of the Scientific and Industrial Research Organization of New Zealand says that from about 50 percent of considered total costs intended to protect and repair water structures such as damaged bridges, more than 70 percent is spent for scouring caused by abutment.

So evaluating the scouring behind water structures and the use of techniques and equipment to reduce scour around structures is very important. Few studies have been conducted on contraction scour at river, especially in the field of prevention and control of scour at contraction. Olive and Hager (2002) have developed relationships for estimating the equilibrium depth of scouring in abutments. Strab and Over (2010) also did a lot of tests in order to estimate the depth of contraction scour caused by the river bridge in cohesive soils and also they have suggested relationships.

Submerged vanes or plates are small structures that usually made of wood, metal, concrete, or such as it. Using technique of submerged vanes that is developed plan of the old method of Bottom Panels Was designed by Odgaard and Kennedy (1983) for first time to prevent erosion of outer arc coast of river. These vanes are installed in the river bed with a slight angle relative to the direction of flow of the river in order to modify the flow pattern. Performance of these vanes is according of creating the second rotation in the opposite direction of the existed secondary flow in main flow of river. This rotation changes the direction of the bottom shear stresses and also caused changes in velocity distribution, depth, and sediment transport in the area of affected vanes (Odgaard and Kennedy, 1983). Omidi and her colleagues (2012) have used from submerged vanes in the inlet of intake and observed that the presence of submerged vanes has increased the water discharge in intake and decreased the maximum of scour depth on inlet of the intake.

An overview of the sources shows that few studies have been done in relation to the using of submerged vanes in contraction place of river section. In the present study we try to examine the effects of these vanes in reducing scour in contraction place of river section and also present the right angle positioning of vanes.

2. Materials and method

Several experiments were performed in a flume with 20 m length, 60 cm width and height in the Hydraulic Laboratory of Shahre kord University in Iran in order to evaluation the effectiveness of submerged vanes on the contraction scour reduction. Flume has metal floor and glass walls are made of fiberglass. In this channel, water is pumping from a large tank located outside the laboratory into the lab with the help of a centrifugal pump and entering to the small stilling basin in the beginning of the flume through inlet pipe of cannel (figure 1). After a relative calm, input stream flows into the channel and after passing length of 20 meters of cannel and crossing over the drawbridge in end and falling into precipitation basin, flow enters to the tank via gravity (figure 2).

Fig. 1. Cannel with 20m length.

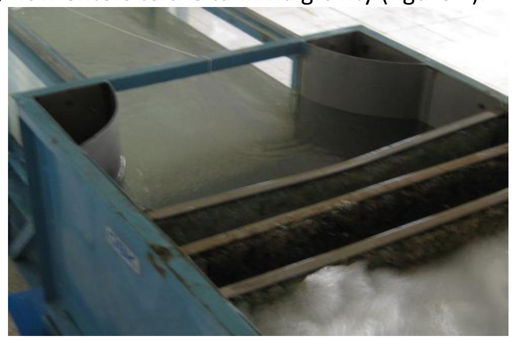


Fig. 2. Stilling basin in upstream of the flume.

According to provided criteria by Raudkivi and Ettma (1983), average particle diameter should be greater than 0.7 mm in order to prevent ripple formation by non cohesive deposits that reduce the maximum scour depth. So, for doing this study were used from cleaned and with average diameter of 0.78 mm. According to searches of Ghorbani and Kells (2008), bed material thickness of the flume was considered 160 mm. Range of 3 meters of laboratory flume was filled with non cohesive sediment. In order to control and protect of sediment against power of the flow, two wooden slope plates with significant amounts of coarse sand were used in upstream and downstream (figure 3 and 4).

Fig. 3. upstream protection of bed.

Fig. 4. downstream protection of bed.

In this research, three double compressed plastic vanes with 10 mm thickness and 90 mm length were used. The height of vanes was considered equal height of sandy bed in the flume. Because according to the research result of Ghorbani and Kells (2008), the maximum reduction in scour rate occurred at zero elevation of vanes relative to the substrate surface. Six vanes were used for experiments. According to the researches of Parsmehr and her partners (2011), position of vanes was considered to be attached to the wall. Figure submerged vanes were installed at the contraction under angle of α (Figure 5). The angle α is contains three angles: 10, 20 and 30 degrees. The side walls that create contraction should be built gradually to prevent of the passage of the waves on the walls (ride up). So, the best angle for the contraction or expansion is calculated according to the equation (1 and 2). In other words, this angle is the smallest angle that should be considered.

$$\tan\alpha = \frac{1}{3F} \qquad (1)$$

$$F = \frac{V}{\sqrt{gd}} \qquad (2)$$

In this equation, F is the froude number and V is the average velocity and d is the flow depth at the beginning and end of the changed section (U.S Bureau of reclamination, 1977).

Therefore, after the calculation of the discharge, the bend angle of 55 degrees was considered to create contraction with 30 centimeters wide in flume that is shown with B2 in Figure (5). And 1 mm thick galvanized iron was used.

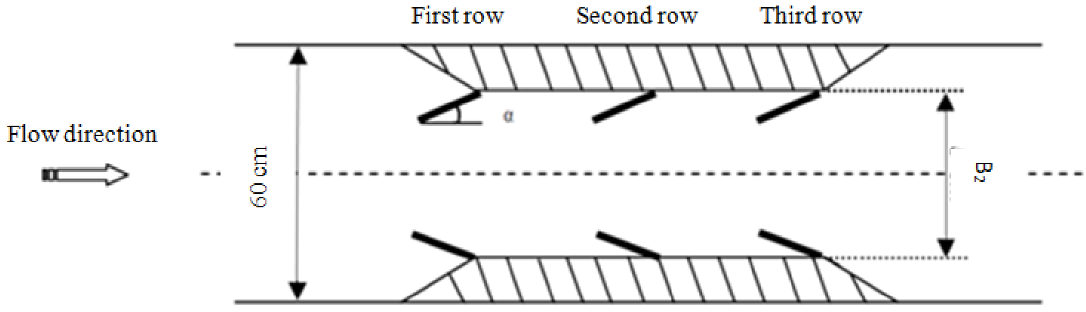


Fig. 5. Plan of position of vanes.

For each experiment, the control valve in end of flume is closed and then the pump is turned on with low flow. The water level will rise so much that live-bed conditions are not created. In all experiments, the flow depth is considered constant and equal to 30 cm. Flow rate is increased from low to the extent that is considered with control of the inlet valve. These conditions were maintained for 7 hours to stabilize the scour. After it the pump is turned off and the maximum scour depth was determined by the depth gauge with an accuracy of a millimeter.

3. Results and discussion

In order to evaluate the effectiveness of attack angle of submerged vanes on reducing contraction scour, doing some experiments in the presence and absence of submerged vanes at contraction is necessary.

3.1. Tests without the presence of submerged vanes (Control tests)

In order to determine the scour depth in presence of a series of submerged vanes, doing a series of experiments without the presence of submerged vanes in contraction is necessary. For this purpose, three control experiments were performed in a fixed period of seven hours with three different flow rates of 20, 30 and 40 liters per second. During this period, the depth of scour was read and in the end the maximum scour depth was recorded, then scour changes were plotted against time for the three experiments in Figure (6). As seen in this figure, the scour depth increases with time and much of occurred scour in this seven hours process is in the first five hours of testing. With doing the control tests were observed that scouring in contraction place has the maximum depth at the beginning of the contraction place and the scour depth is reduced symmetrically and sediments are separated from the first part accumulate at a distance away from it. Cavities and the accumulation of material at the beginning of the contraction are shown after ending of the test in (Figure 7) and (Figure 8).

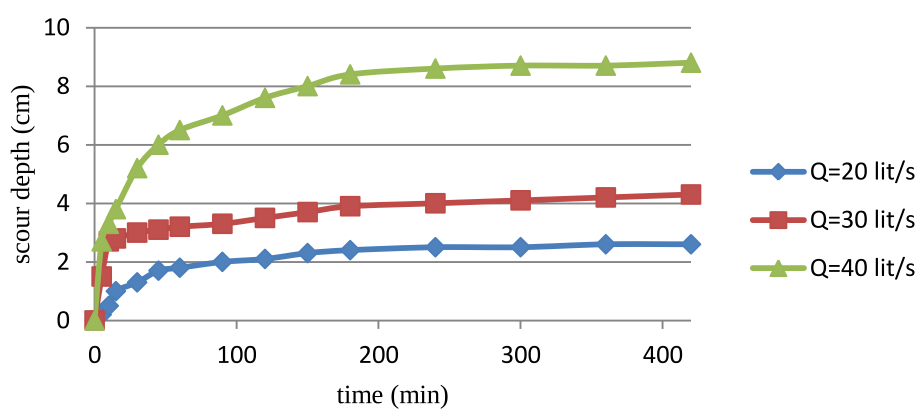


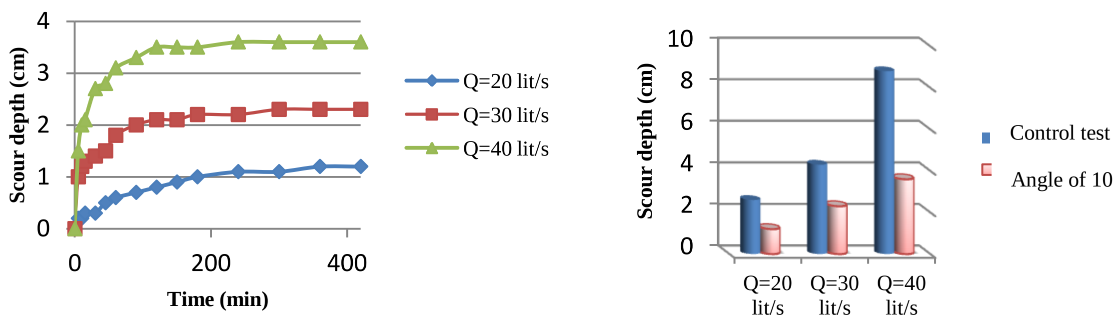
Fig. 6. Chart of time variation of scour in control test.

(a) (b)

Fig. 7. Scour in start of contraction: a) Q=20lit/. b) Q=30 lit/s.

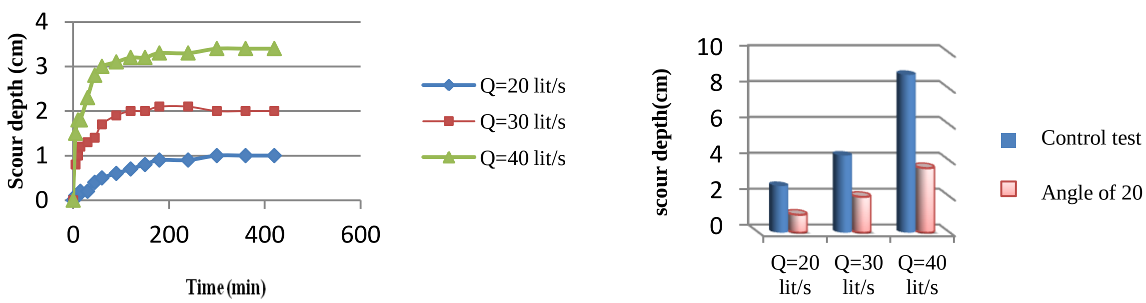
3.2. Tests in the presence of submerged vanes

At this stage, the 9 experiments were tested. The submerged vanes were placed in two rows with 50 cm space from each other and from the beginning of the contraction and attached to the wall. The vanes were installed under the angle α, which included angles of 10, 20 and 30 degrees relative to the direction of flow. And experiments were repeated with three rates of 20, 30 and 40 liters per second. Figures (8), (9) and (10) show the time variation of scour at three angles of attack (10, 20 and 30 degrees) relative to the direction of flow and also maximum depth of scour with discharge, respectively 20, 30 and 40 liters per second.



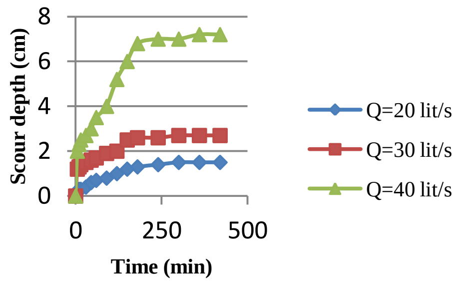
(A) (B)

Fig. 8. A) Chart of time variation of scour. B) Maximum depth of scour under the angle of 10 degrees.

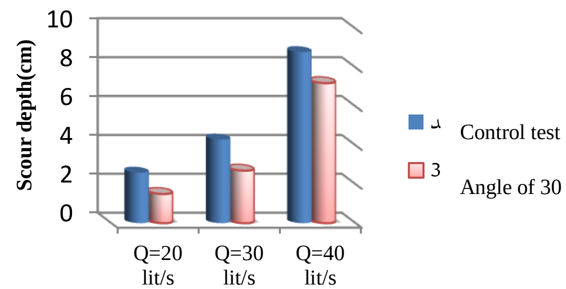


(A) (B)

Fig. 9. A) Chart of time variation of scour. B) Maximum depth of scour under the angle of 20 degrees.



(A)



(B)

Fig. 10. A) Chart of time variation of scour. B) Maximum depth of scour under the angle of 30 degrees

As seen in the above figures, all figures have increased with over time which represents an increase of scour depth. Much of scour has occurred in the first five hours of test.

3.3. Evaluation the effect of different angles of attack in the amount of scour

At this stage, has been paid to evaluate the obtained results of placement of submerged vanes in three situations discussed above. In general, it can be concluded that existence the submerged vanes are positive in reducing scour. Figures (11), (12) and (13) show the without dimension chart of the time variation of scour for 9 experiments were carried out under three angle of attack (10, 20 and 30 degrees) for different discharges (20, 30 and 40 liters per second).

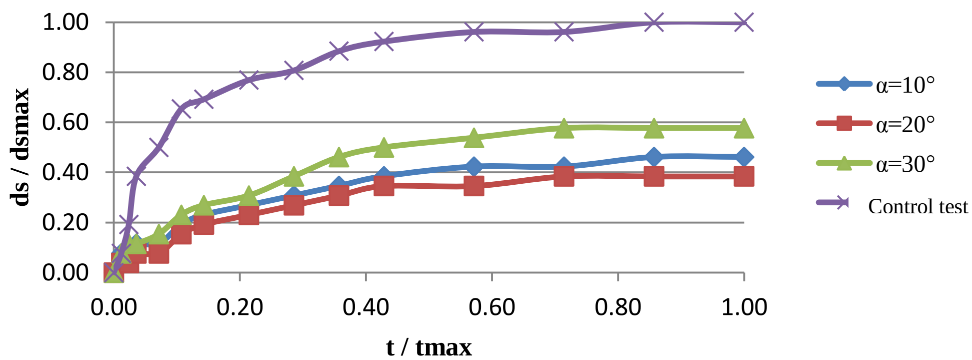


Fig. 11. Dimensionless chart of the time variation of scour in Q = 20 lit/s.

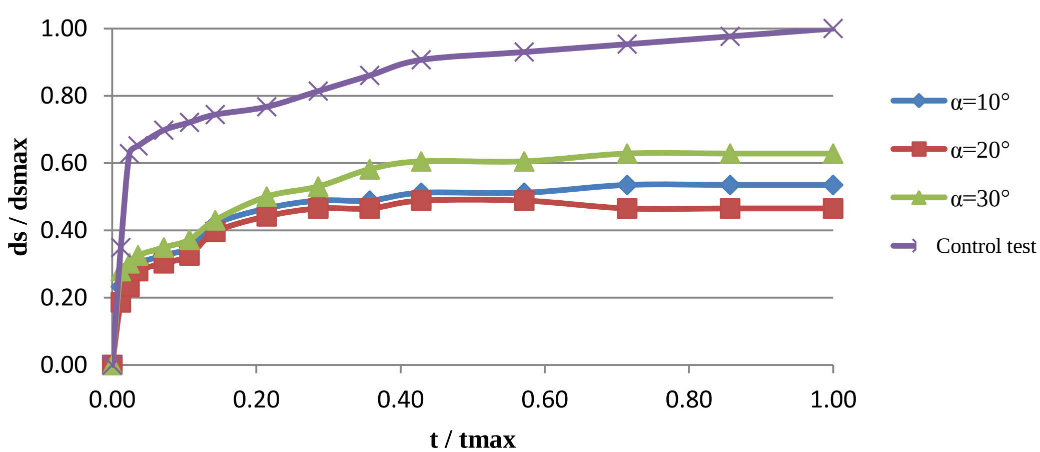


Fig. 12. Dimensionless chart of the time variation of scour in Q = 30 lit/s.

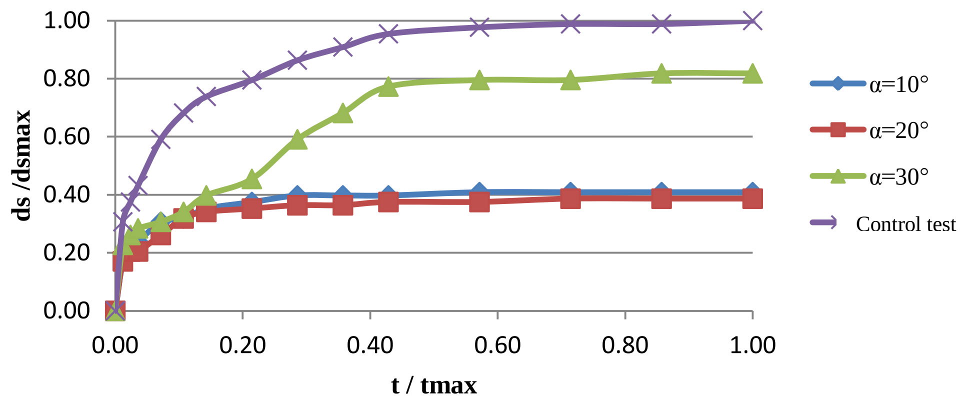


Fig. 13. Dimensionless chart of the time variation of scour in Q = 40 lit/s.

According to the above dimensionless charts, as seen that in all diagrams the scour depth increases with time and increasing discharge and the obtained scour charts from experiments in the presence of submerged vanes have been under the curve of experiments without vanes (control test) that shows presence of submerged vanes has caused the scour depth decreases. It is noteworthy that the lowest scour chart is relative to the control chart is related to the position of vanes under the angle of 20 degrees that presents this angle has the best performance compared to other angles in reducing of scour. But the impact of this trend in reducing scour is less in the angle of 30 degrees. The cause of these changes can be known in the collisions of flow to walls that created contraction. This collision is created the hydrodynamic force in the front of wall. After the collision of the force to vanes, probably secondary vortex is created around the vanes that caused changes in amount and direction of shear stress and pattern of velocity distribution and also in the sediment transport.

4. Conclusion

According to the results of Table 1 that shows the percent of scour reduction of submerged vanes with using the maximum depth of scour in 3 different positions for three discharge, can be seen that if submerged vanes are placed under angle of 20 degrees, the most reduction will be occurred about 62% in Q=20 lit/s, 61.36% in Q=30 lit/s, and 57.14% in Q=40 lit/s. Figure 14 shows the maximum and minimum depth of scour for different positions.

Table 1
The maximum depth of scour and percent of scour reduction.

Width of contraction (cm)	Discharge (lit/s)	Control test	Scour(cm) In presence of vanes(degree)					
			10		20		30	
			Depth (cm)	Reduction (%)	Depth (cm)	Reduction (%)	Depth (cm)	Reduction (%)
	20	2.6	1.2	53.85	1	61.54	1.5	41.32
30	30	4.3	2.3	46.51	2	53.49	2.7	37.21
	40	8.8	3.6	59.09	3.4	61.36	7.2	18.18

It is noted about the above diagram that the maximum depth of scour is occurred in position of 30 degrees in discharge of 40 lit/s, and the minimum depth of scour is occurred in position of 20 degrees in discharge of 20 lit/s.

The experiments were carried to investigate the effect of the angle of attack of submerged vanes in reducing scour is indicated following results:

The place of scour is in beginning of the contraction and occurs in the vicinity of the channel walls symmetrically and increases with time.

Scour has a direct relationship with the flow rate, thus with increasing the flow rate, scour is increasing.

Created scour within contraction in present of submerged vanes suggest the reduction of scour in range of contraction in all situations with three different angles of attack.

Best performance of vanes is when submerged vanes are placed under the angle of 20 degrees to the direction of flow.

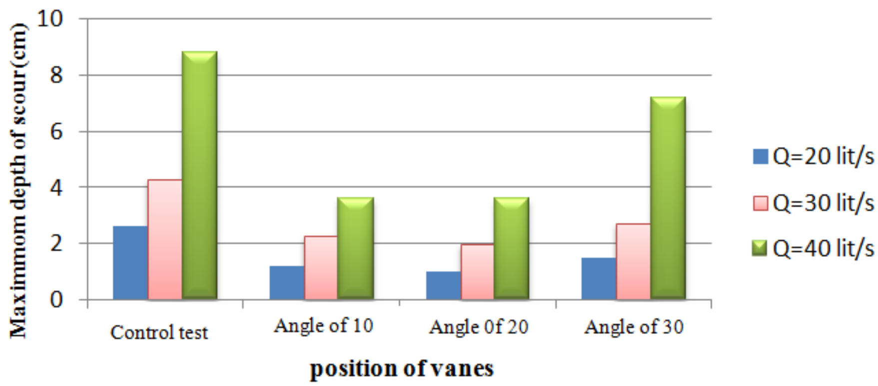


Fig. 14. The maximum depth of scour chart at three angles of attack and three discharges.

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