Journal of Applied Sciences

ISSN 1812-5654

ANSInet
an open access publisher
http://ansinet.com

Journal of Applied Sciences 12 (4): 362-368, 2012
ISSN 1812-5654 / DOI: 10.3923/jas.2012.362.368

Scour Depth at the Edge of Different Submerged Vanes Shapes

Reza Azizi, Mahmood Shafai Bejestan and Mehdi Ghomeshi
Faculty of Water Science Engineering, Shahid Chamran University, Ahvaz, Iran

Abstract: The technique of submerged vanes is a new and efficient sediment management method in rivers. This method has positive environmental effects. The performance and efficiency of a submerged vane is related to its shape. In the present study, physical hydraulic model testing is performed to investigate four shapes of vanes: a simple rectangular vane and three vanes that are beveled at leading edge in 30, 45 and 60 degrees with respect to the base, respectively. The experiments show that cutting the leading edge of the vanes reduces the local scour around the vanes. Maximum scour depth reduction occurred due to the maximum chamfer at leading edge of the vanes. Based on the results, cutting the leading edge of the vanes is a performance improving and also cost saving modification, too.

Key words: Submerged vanes, sediment control, alluvial channels, local scour

INTRODUCTION

In river meanders especially at the base of outer bank sever erosion can occur (Javaheri *et al*., 2008; Samadi *et al*., 2011). This type of erosion is called bed scouring which can occur in other parts of rivers such as river confluence (Ghobadian and Bejestan, 2007; Bejestan and Hemmati, 2008). Many measures have been developed to control such erosion in the past. Among these are Spur dike (Masjedi *et al*., 2010; Nasrollahi *et al*., 2008). Vegetation also can increase the bed roughness and can be benefit for reduction of bank scouring (Fathi-Moghadam, 2007; Sabegh *et al*., 2011). One of the new technique which have been used recently is the submerged vane. Submerged vanes (Iowa vanes) are designed in order to modify the near-bed flow pattern and bed-sediment motion in transverse direction in the rivers. The vanes are installed vertically on the channel bed, at an angle of attack α with the approaching flow (Odgaard and Wang, 1991a). The vanes height, length, distance from banks and distance from each other as well as the vane angle are very important parameters for design. The vane should not be too closed to each other to act as a bed roughness. Since investigators have shown that bed roughness can dissipate more kinetic energy of flow (Bejestan and Neisi, 2009; Ezizah *et al*., 2012). All investigations indicate that the local scour depth, d_s, increases with an increase in α. At larger α, the vane will be subjected to a relatively larger drag force, with increased flow resistance. The major problem in the use of larger α is occurrence of great scour around the vane that may dislodge the vane. Because of these reasons, vanes with α>20° are not practical in field applications (Gupta *et al*., 2010). Therefore, presenting the practical methods to surmount the scour problem is very important. Regarding to this fact that the most of vanes are pre-constructed structures, modifying the vane shape can be considered as a practical approach for this purpose.

River bank protection is one of the applications of the vanes (Odgaard and Kennedy, 1983; Odgaard and Mosconi 1987; Wang and Odgaard 1993; Johnson *et al*., 2001; Marelius, 2001). The submerged vanes technique is used to deepening the rivers in order to navigation purposes and reduction of the shoaling problems, too (Odgaard and Spoljaric 1986; Odgaard and Wang 1991a). In addition, the vane system can be used to limit the influx of bed-load sediment into riverside intake structures (Nakato *et al*., 1990; Wang *et al*., 1996; Nakato and Ogden, 1998; Barkdoll *et al*., 1999; Michell *et al*., 2006; Emamgholizadeh and Torabi, 2008; Lila and AliReza, 2006).

In general, the cost of the submerged-vane technique compares favorably (Odgaard and Wang, 1991b) with that of the structural and conventional methods such as dike, gabion, riprap and etc. Thereby cutting the leading edge of the vanes after design of the baseline rectangular vane reduces the required construction material of the vanes. Ouyang (2009) investigated the effect of the shape and dimensions of a submerged vane, with constant area in all alternatives, for sediment management in alluvial channels by using a numerical model; however, the vane-induced local scour is not introduced in the model. In the present study, the local scour around the vanes is the major of the investigation and also the area of the vanes is not constant. The present study is focused on the four shapes of the vanes, including a simple rectangular plate

---

Corresponding Author: Mahmood Shafai Bejesta, Faculty of Water Science Engineering, Shahid Chamran University, Ahvaz, Iran

and three flat-plate types of vanes with reduced area due to 30, 45 and 60 degrees (θ) chamfer at leading edge of the vanes, respectively. For the rectangular vane, $\theta = 0°$. Cutting the leading edge of the vanes leads to reduction of the effective area of the vanes. Most of the existing studies have been restricted in to a range of $0<Fr = 0.25$ (Gupta *et al.*, 2010). This study's experiments carried out at 0.14, 0.16 and 0.20 Froude numbers (corresponding to 30, 35 and 45 L sec^{-1} flow rates).

LABORATORY SETUP

In the present study, a laboratory recirculating flume has been used, 7.3 m in length, 0.56 m width, 0.6 m height and constant slope of 0.0028, with side walls of transparent Plexiglas. The vanes were made of Plexiglas sheets with thickness of 10 mm. A 3.67 m-long reach of the flume bottom was covered with sand of relative density 2.65 having median grain size d_{50} of 0.5 mm. The depth of the sediment bed layer of the test reach was fixed at 10 cm (Fig. 1).

A subsurface reservoir supplies the required water flow (Q). A centrifugal pump discharges the water into the stilling tank at the entrance of the flume. In order to uniform the inflow water, a screen is established at 1 m distance from the flume entrance and then a transition with $\Delta z = 10$ cm, connects the main flume bottom to the surface of the sediment bed layer. A tail gate is used to adjust the depth (d_0) of water in the flume to a constant value of 25 cm, without causing backwater effects in the flume. The discharge is measured and adjusted by using a standard 53° triangular weir which was installed at the outlet system of flume. In this study 12 experiments carried out with three Froude numbers of Fr = 0.14, 0.16 and 0.20 and four vane shapes.

In each experiment, the vane was installed at the centerline of the flume at an angle of attack of 20° with the approaching flow. After placement of the vane, the sediment bed of the flume was leveled using a spirit level. Water flow was introduced to the flume very slowly by closing the tail gate so that no scouring occurred around the submerged vane during the startup. After the experiment was over, the scour and sedimentation pattern was measured in 2×2 mesh grids with the help of a laser distance meter that could be moved along rails fitted at the top of the flume. The time taken for the scour to attain equilibrium was 3 h.

The dimensions of the vanes are determined using the Odgaard and Wang (1991a) design criteria: whit a vane-height-to-water-depth ratio of $H_0/d_0 = 0.3$ and aspect ratio of $H_0/L = 0.3$, the mean flow depth of $d_0 = 25$ cm yields $H_0 = 7.5$, $L = 25$ cm and vane relative submergence of $T/d_0 = 1-H_0/d_0 = 0.7$. The perspectives of the designed vanes are presented in Fig. 2a-d.

EXPERIMENTAL OBSERVATIONS

In present study both clear water and live bed conditions have been considered. In Fr = 0.14 and Fr = 0.16 clear water scour is occurred, thereby the sediment movement from upstream of the vane is negligible and flow velocity is less than critical velocity. The critical velocity was calculated by empirical formulae. In Fr = 0.20 the sediment transport form upstream of the vanes is considerable. Placement of the vane with 30° chamfer is shown in Fig. 3a-d.

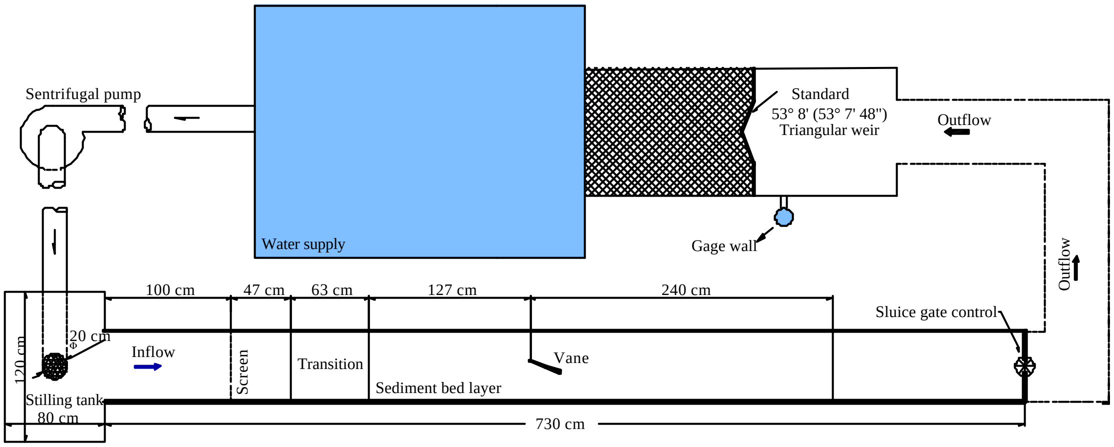

Fig. 1: Sketch showing experimental set-up

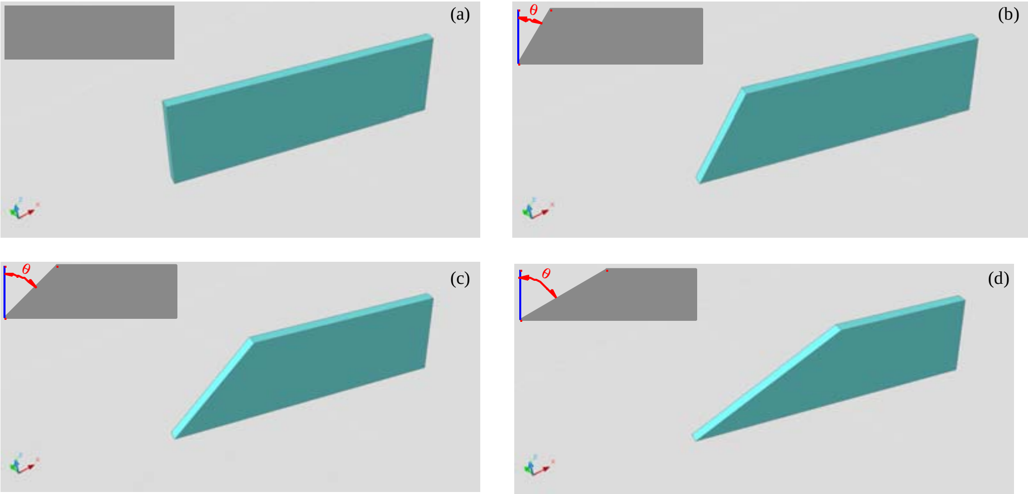

Fig. 2(a-d): Schematic showing four types of vanes that are used in this study: (a) Simple rectangular vane (θ = 0°), (b) θ = 30°, (c) θ = 45° and (d) θ = 60°

Fig. 3(a-b): Sediment bed (a) Initial level bed and (b) final topography

Figure 3a shows the initial level bed before introducing flow to the flume. Figure 3b shows the final topography of the sediment bed. According to Fig. 3, the vane function to remove sediments form left portion of the flume and deposit sediments on the right-hand side of the flume. Scour hole develops at the high-pressure side of the vane that vertical velocity components are generated. After primary changes in the sediment bed of the flume, the dune bed form is visible at downstream of the vane. Another observation is that the induced changes in the bed topography decay slowly in the downstream direction.

ANALYSIS

Investigation on the effect of vanes shape for local scour around the vanes and sedimentation pattern at downstream of the vanes is performed by using the topography data of the sediment bed in the test reach. The sediment bed topography was measured in a 0.7 and 0.8 m reach at clear water and live bed conditions, respectively. In addition, the transverse sediment bed profile measured at distance of s = $8H_0$ downstream from the center of the vanes. H_0 is the vanes initial height.

Figure 4a-c show the graphs of transverse bed profile at leading edge of the vane for chamfer angles of θ = 0°,

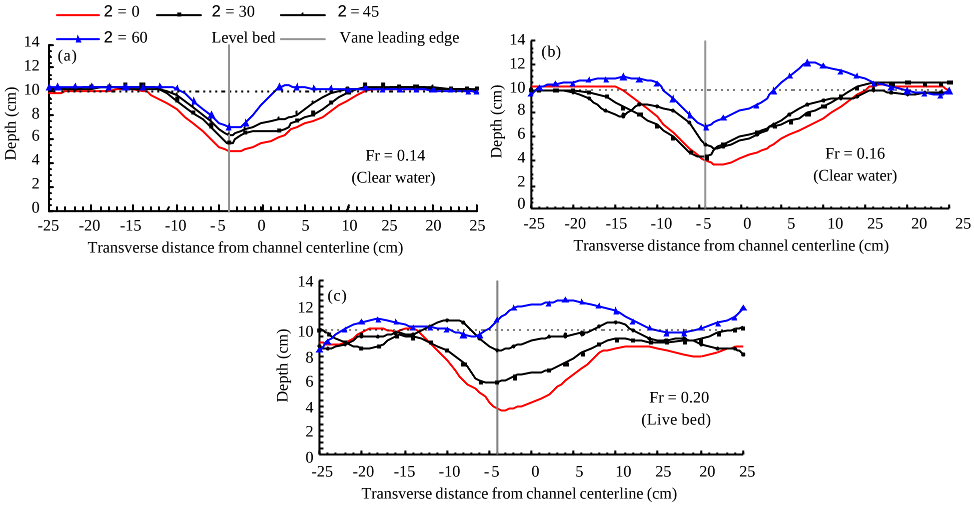

Fig. 4(a-c): Transverse bed profile at leading edge of the vane: (a) Fr = 0.14, (b) Fr = 0.16 and (c) Fr = 0.20. The symbols and dashed line represent the different chamfer angles and primary level bed, respectively. The vertical solid line represents the position of leading edge of the vanes in cross section at planed coordinate system

Table 1: Summary of scour depth measurements at leading edge of the vanes

	Fr (-)											
	0.14				0.16				0.20			
	0	30	45	60	0	30	45	60	0	30	45	60
Factor	θ°				θ°				θ°			
d_s (cm)	5.1	4.4	3.7	3.0	6.0	5.6	4.6	3.1	6.3	4.1	1.6	-0.9
Reduction (%)	0.0	13.7	27.5	41.2	0.0	6.7	23.3	48.3	0.0	34.9	74.6	No scour

30, 45 and 60° and Froude numbers of Fr = 0.14, 0.16 and 0.20. Graphs in Fig. 4 indicate that by increasing θ, the scour depth decreases. Figure 4a and b show the local scour at clear-water condition and Fig. 4c is related to live bed condition. As shown in Fig. 4c, at θ = 60° in Fr = 0.20, there is not scour and also some deposition has been occurred. Experiment condition at Fr = 0.20 is similar to field conditions due to the fact that in natural rivers there is often sediment transport from upstream watershed or river sections to downstream sections. Therefore, cutting the leading edge of the submerged vanes has effective role in reduction of local scour around the vanes and also it is practical and easy for field applications. According to Fig. 4, the scour depth at leading edge of the vanes (d_s) at three Froude numbers is summarized in Table 1.

Last row in the Table 1 represents the sour reduction percent respect to the d_s values for baseline rectangular vane at different Froude numbers. There is no scour at leading edge of the vane for θ = 60° at Fr = 0.20 and also some deposition has been occurred. Figure 5a-d present 3D plots of the bed topography around the vane in a 0.7 m reach including scour hole for four shapes of vanes (i.e., θ = 0, 30, 45 and 60°) and Froude number of Fr = 0.14. As is illustrated in Fig. 5 the scour hole becomes smaller for larger values of θ. The depth of initial level bed adjusted to a value of 10 cm, so according to Fig. 5a, for θ = 0° the maximum scour depth of d_{sm} = 5.7 cm. d_s is reduced to the values of 5.1, 4.5 and 3.8 cm (i.e., 10.5, 21.1 and 33.3% to the baseline rectangular vane) for θ = 30, 45 and 60°, respectively (Fig. 5b-d).

Contour maps of scour hole in a 0.8 m long reach at Fr = 0.20 and for different θ values are shown in Fig. 6. The vanes orientation is illustrated in this Figure. For rectangular flat-plat (Fig. 6a) the maximum score depth has been occurred at the leading edge of the vane. As indicated in Fig. 6b and c by increasing θ to the values 30 and 45° the scour hole is moved toward the trailing edge, along high-pressure side of the vane. From Fig. 6d the scour hole is moved to downstream of the vane and there is some deposition at leading edge of the vane.

In order to investigate the sedimentation pattern at downstream of the vanes, the transverse bed profiles have been compared at the distance of s = $8H_0$. i.e., 296 cm downstream from the center of the vanes. H_0 is initial

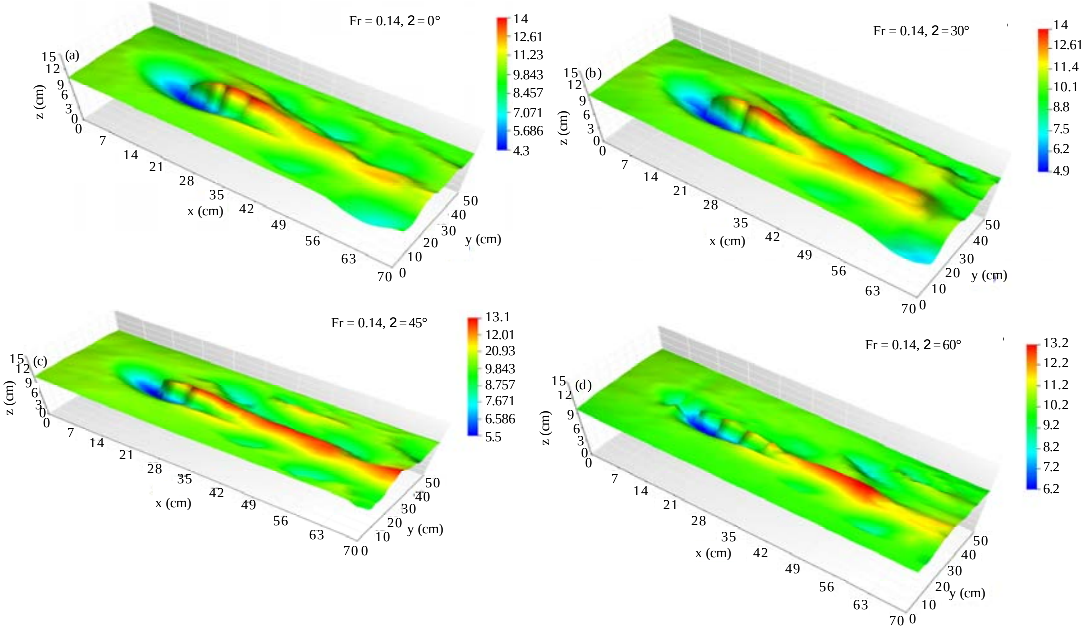

Fig. 5(a-d): Bed topography in 0.7 m long reach including scour hole, for Fr = 0.14 at: (a) θ = 0°, (b) θ = 30°, (c) θ = 45° and (d) θ = 60°

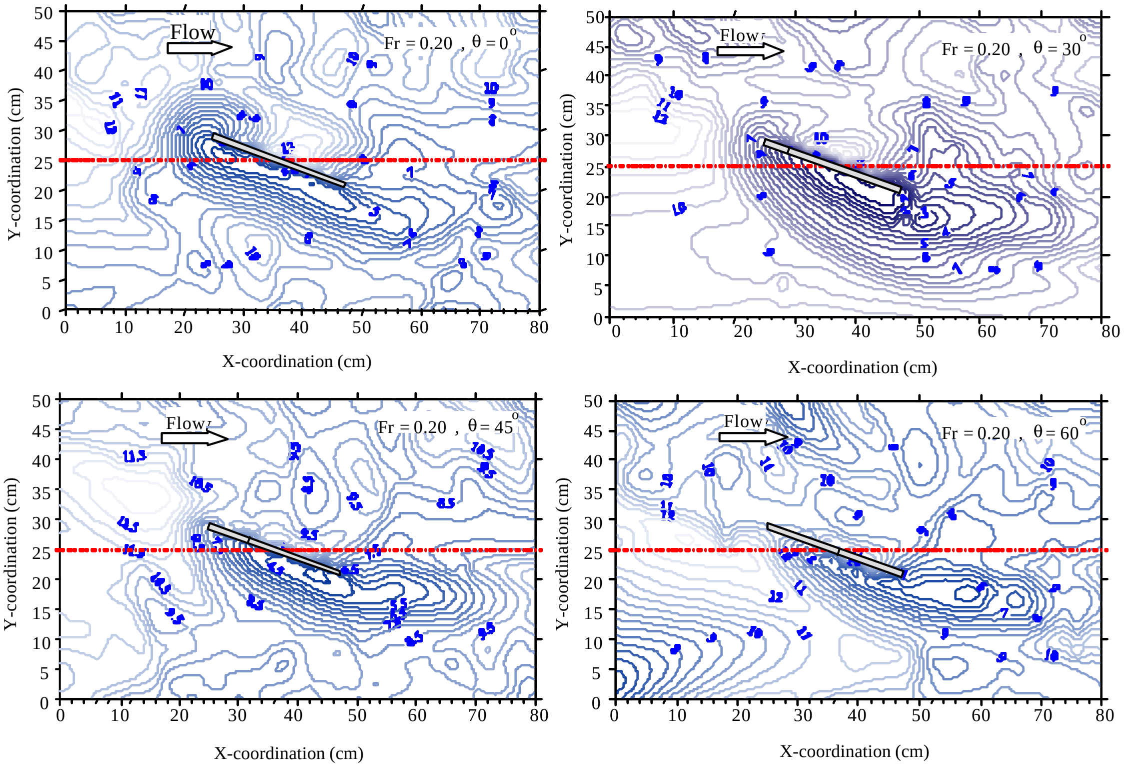

Fig. 6(a-d): Contour maps in 0.8 m long reach including scour hole, for Fr = 0.20 at: (a) θ = 0°, (b) θ = 30°, (c) θ = 45° and (d) θ = 60°. The dashed-dotted line and narrow rectangular represent the center line of the flume and top view of the vanes, respectively

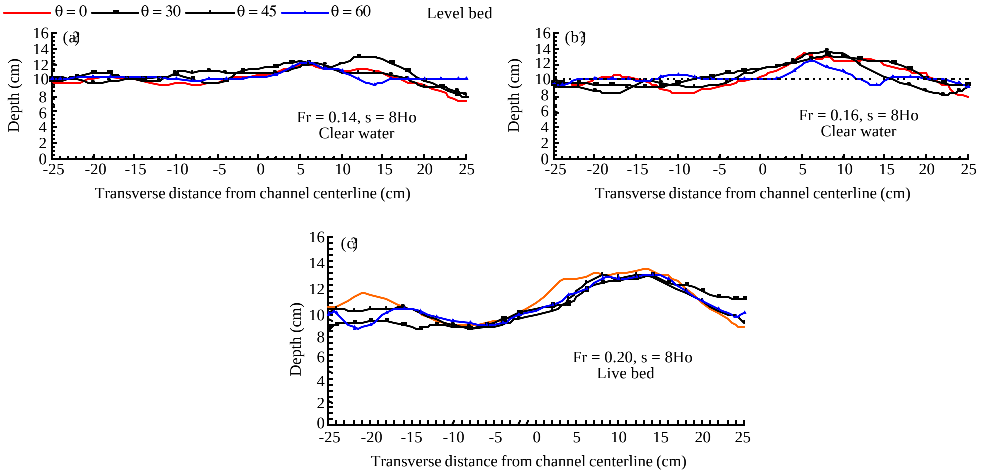

Fig. 7(a-c): Transverse bed profile at the distance of s = 8H_0 from the center of the vanes: (a) Fr = 0.14, (b) Fr = 0.16 and (c) Fr = 0.20. The symbols and dotted line represent the different chamfer angles and primary level bed, respectively

height of the vanes (Fig. 7). Transverse bed profiles at downstream of the vanes for different values of Froude number, indicating that Sedimentation pattern at downstream of the vanes are not significantly affected by cutting the leading edge of the vanes. There is some differences in transverse bed profile at clear water condition (Fig. 7a, b) but due to sediment movement from upstream of the vanes in live bed conditions, the similarity of the bed profile is more visible (Fig. 7c). Similar behavior is founded for bed profiles at other cross sections (not shown). Deposition in the right half bank and scour at other portion of the sediment bed is illustrated in Fig. 7c.

CONCLUSIONS

In this study a physical hydraulic model is utilized to investigate the effects of the shapes of four types of flat-plate submerged vanes on local scour around the vanes and sedimentation pattern at downstream of the vanes. The experiments are carried out at three flow rates of Q = 30, 35 and 45 L sec^{-1}. (corresponding to Fr = 0.14, 0.16 and 0.20). The results show that cutting the leading edge of the vanes leads to decrease the local scour around the vanes. Maximum scour depth reduction occurred due to the maximum chamfer at leading edge of the vanes. The scour depth reduced by 41.2, 48.3 and nearly 100% at Froude numbers of Fr = 0.14, 0.16, 0.20, respectively. Investigation on transverse bed profiles and sedimentation patterns at downstream of the vanes shows that performance of the vanes does not affected significantly by reduction of vanes area resulted from cutting the leading edge of the vanes. In practical applications more number of vanes is required for sediment control in rivers. Thus cutting the leading edge of the vanes leads to decreases the construction materials of the vanes. In other words mentioned modification has economical benefits and could be used as well as other local scour retarder approaches, such as slot and collar.

ACKNOWLEDGMENT

The financial support for this study is received from research grant of the second author. The author would like to thank vice chancellor for research of Shahid Chamran University-Ahwaz for providing the research grants.

REFERENCES

Barkdoll, B.D., R. Ettema and A.J. Odgaard, 1999. Sediment control at lateral diversions: Limits and enhancements to vane use. J. Hydraulic Eng., 125: 862-870.

Bejestan, M.S. and K. Neisi, 2009. A new roughened bed hydraulic jump stilling basin. Asian J. Applied Sci., 2: 436-445.

Bejestan, M.S. and M. Hemmati, 2008. Scour Depth at river confluence of unequal bed level. J. Applied Sci., 8: 1766-1770.

Emamgholizadeh, S. and H. Torabi, 2008. Experimental investigation of the effects of submerged vanes for sediment diversion in the veis (ahwaz) pump station. J. Applied Sci., 8: 2396-2403.

Ezizah, G., N. Yousif and S. Mostafa, 2012. Hydraulic jumps on new roughened beds. Asian J. Applied Sci., 5: 96-106.

Fathi-Moghadam, M., 2007. Physical properties of tall vegetation for resistance to flow. J. Agron., 6: 194-198.

Ghobadian, R. and M.S. Bejestan, 2007. Investigation of sediment patterns at river confluence. J. Applied Sci., 7: 1372-1380.

Gupta, U.P., C.S.P. Ojha and N. Sharma, 2010. Enhancing utility of submerged vanes with collar. J. Hydraul. Eng., 136: 651-655.

Javaheri, N., M. Ghomeshi and S.M. Kashefipour, 2008. Use of the fuzzy method for determination of sediment balance and its role on the morphological changes in meandering rivers. Asian J. Scientific Res., 1: 32-40.

Johnson, P.A., R.D. Hey, M. Tessier and D.L. Rosgen, 2001. Use of vanes for control of scour at vertical wall abutments. J. Hydraulic Eng., 127: 772-778.

Lila, H. and K. AliReza, 2006. Bed scouring and fish habitats at dam-less river water intake. J. Fish. Aquatic Sci., 1: 32-53.

Marelius, F., 2001. Experimental investigation of vanes as a means of beach protection. Coastal Eng., 42: 1-16.

Masjedi, A., M.S. Bejestan and P. Rahnavard, 2010. Experimental study on the time development of local scour on around single T-shape spur dike in a 180 degree flume bend. Res. J. Environ. Sci., 4: 530-539.

Michell, F., R. Ettema and M. Muste, 2006. Case study: Sediment control at water intake for large thermal-power station on a small river. J. Hydraul. Eng., 132: 440-449.

Nakato, T., J.F. Kennedy and D. Bauerly, 1990. Pump-station intake-shoalling control with submerged vanes. J. Hydraulic Eng., 116: 119-128.

Nakato, T. and F.L. Ogden, 1998. Sediment control at water intakes along sand-bed rivers. J. Hydraul. Eng., 124: 589-596.

Nasrollahi, A., M. Ghodsian and S.A.A.S. Neyshabouri, 2008. Local scour at permeable spur dikes. J. Applied Sci., 8: 3398-3406.

Odgaard, A.J. and J.F. Kennedy, 1983. River-bend bank protection by submerged vanes. J. Hydraul. Eng., 109: 1161-1173.

Odgaard, A.J. and A. Spoljaric, 1986. Sediment control by submerged vanes. J. Hydraul. Eng., 112: 1164-1181.

Odgaard, A.J. and C.E. Mosconi, 1987. Streambank protection by submerged vanes. J. Hydraul. Eng., 113: 520-536.

Odgaard, A.J. and Y. Wang, 1991a. Sediment management with submerged vanes. I: Theory. J. Hydraulic Eng., 117: 267-283.

Odgaard, A.J. and Y. Wang, 1991b. Sediment management with submerged vanes. II: Applications. J. Hydraulic Eng., 117: 284-302.

Ouyang, H.T., 2009. Investigation on the dimensions and shape of a submerged vane for sediment management in alluvial channels. J. Hydraul. Eng., 135: 209-217.

Sabegh, M.S., M.S.M. Amin and M. Habibi, 2011. Study on using riparian buffer in urbanizing rural floodplain. Res. J. Environ. Sci., 5: 714-721.

Samadi, A., M.H. Davoudi and E. Amiri-Tokaldany, 2011. Experimental study of cantilever failure in the upper part of cohesive riverbanks. Res. J. Environ. Sci., 5: 444-460.

Wang, Y. and A.J. Odgaard, 1993. Flow control with vorticity. J. Hydraulic Res., 31: 549-562.

Wang, Y., A.J. Odgaard, B.W. Melville and S.C. Jain, 1996. Sediment control at water intakes. J. Hydraulic Eng., 122: 353-356.