World Applied Sciences Journal 13 (9): 2047-2051, 2011
ISSN 1818-4952

Study of Effect Angle of Submerged Vanes on Scour Hole at Flume Bend

[1]Alireza Masjedi, [2]Behnam Morattab and [2]Ali Savari

[1]Department of Agriculture, Ahvaz Branch, Islamic Azad University, Ahvaz, Iran
[2]Islamic Azad University Branch Ahvaz, Ahvaz, Iran

Abstract: Investigation on scour and determination of hole of scoring are among the most important issues in submerged vane designation with model submerged vanes were measured in a laboratory flume with 180 degree bend under clear-water. Experiments were conducted for four angle of attack 15, 20, 25 and 30 degree with the flow with various Froude number. In this study, the volume of the scour hole around the submerged-vane plates was studied. The results of the model study indicated that the maximum volume of scour is highly dependent on the experimental duration. It was observed that, suitable control at scour hole associated with angle 15 degree submerged vane. With increasing Froude number the maximum scour hole increases.

Key words: Angle of submerged vanes · Scour hole · 180 degree flume bend · Froude number

INTRODUCTION

The scour occurring at a submerged vane is divided into three categories, general scour, constriction scour and local scour. Local scour results directly from the impact of the submerged vane on the local flow pattern.

The flow past the submerged vane may be divided into three zones: a main flow zone from the head of the submerged vane to the opposite side of the channel, a wake zone behind the spur dike and a mixing zone in-between them (Fig. 1).

The flow in local scour generally shows obvious 3D characteristics. This 3D flow may be divided into several components. In front of the submerged vane, there exists a bow wave near the water surface and a down flow towards the channel bed due to the stagnation of approaching flow. As the result of the flow separation, a horseshoe vortex develops in the local scour hole and a wake vortex system forms behind the submerged vane (Fig. 2).

Estimation of the volume of scour in the vicinity of submerged vanes has been the main concern of engineers for years. Therefore, knowledge of the anticipated maximum scour hole for a given discharge is a significant criterion for the proper design of a submerged vanes foundation.

Odgaard and Wang [4] recent research results with the submerged vane technique for sediment control in rivers are described. Submerged vanes are small flow-training structures (foils), designed to modify the near-bed flow pattern and redistribute flow and sediment transport within the channel cross section. The structures are installed at an angle of attack of 15–25° with the flow and their initial height is 0.2–0.4 times local water depth at

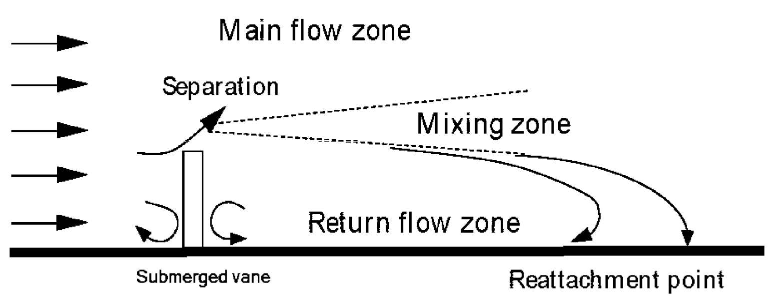

Fig. 1: Flow around submerged vane

Corresponding Author: Alireza Masjedi, Assist. Prof., Islamic Azad University Ahwaz Branch, Ahwaz, Iran.

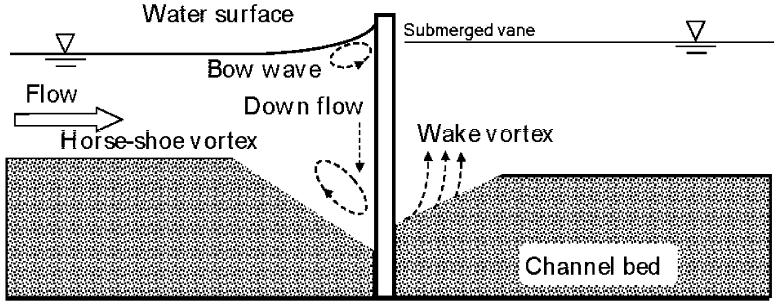

Fig. 2: Flow in a scour hole

design stage. The vanes function by generating secondary circulation in the flow. The circulation alters magnitude and direction of the bed shear stresses and causes a change in the distributions of velocity, depth and sediment transport in the area affected by the vanes. As a result, the river bed aggrades in one portion of the channel cross section and degrades in another. The vanes can be laid out to develop and maintain any desired bed topography. Vanes have been used successfully for protection of stream banks against erosion and for amelioration of shoaling problems at water intakes and bridge crossings.

Nakato and Ogden [3] results from five physical hydraulic model studies of riverside water intakes situated along the Missouri River reach between Sioux City, Iowa and St. Louis, Missouri, are presented. Movable-bed, undistorted Froude-scale models are used to determine the effectiveness of structural modifications in the vicinity of the intake to limit the influx of bed-load sediments. Solutions developed in each case include a series of submerged flow-turning vanes located on the riverward side of the intake. A sediment-barrier wall between the vanes and intake increases the stream wise velocity component, enhancing the effectiveness of flow-turning vanes in maintaining a deep scour trench. Effective solutions determined using physical hydraulic models are verified at the prototype scale, as demonstrated by years of trouble-free operation at locations where the recommended sediment-control measures have been installed. Results presented in this paper provide design guidelines for bed-load sediment control at riverside water-intake structures on sand-bed rivers.

Sinha and Marelius [5] details of recently undertaken numerical study to analyze the physics of the flow past a submerged vane is presented. The numerical model solves the fully three-dimensional Reynolds-averaged Navier-Stokes equations in conjunction with the standard two-equation k-e turbulence closure. The governing equations are formulated in generalized boundary-fitted coordinates to accurately resolve the bed topography and the shape of the vane. The bed roughness effects are introduced by means of a two-point wall functions approach. The predictions from the numerical model are compared against measurements from an experimental study performed in a deformable-bed straight rectangular channel. Detailed experimental measurements of all three components of velocity, both in the neighborhood as well as in the far field of the vane are compared to judge the performance of the numerical model.

Tan *et al*. [6] the use of submerged vanes to divert sediment movements on seabed and open channel flows are common in many engineering projects. In the present study, experiments were conducted to investigate the characteristics of flow and sediment motion around a submerged vane in a large flume, 30m long, 6m wide and 0.6m high, paved with lightweight cylindrical plastic material with specific gravity of 1.05. The size of the uniform plastic material is 2.8mm in diameter and 3.1mm in height. The vane was made of 10mm thick steel plate. The height of the vane above the mean bed ranged from one-eighth to one-third of the flow depth and its length is between 1 to 4m. The alignment of the vane to the approach flow varied from 15° to 90°. The effectiveness of the submerged vane in sediment diversion depends on the vane alignment to the approach flow and the height and length of the vane. The optimum skew angle to the approach flow for the purpose of sediment diversion is about 30°. The optimum vane height of two to three times the height of the bed form would be able to resist the bed load “escaping” over the bed form crest.

Masjedi *et al*. [2] studied on the time development of local scour at a spur dike in a 180 degree flume bend. Tests were conducted using one spur dike with 110 mm length in position of 60 degree under four flow conditions. In this study, the time development of the local scour around the spur dike plates was studied. The effects of various flow intensities (u*/u*c) on the temporal development of scour depth at the spur dike were also studied. The time development of the scour hole around the model spur dike installed was compared with similar studies on spur dikes. The results of the model study indicated that the maximum depth of scour is highly dependent on the experimental duration. It was observed that, as flow intensities (u*/u*c) increases, the scour increases. Measuring time and depth of scouring based on experimental observation, an empirical relation is developed with high regression coefficient 97%.

Characteristic of flow in bend is different than in straight channel. Since in bend the general helical current induced by the balance of centrifugal force and the gravity force will force the water surface layers move toward the outer bank and the lower layers moved toward inner bank. Such flow pattern can redistribute the flow velocity and shear stress at the bed. The maximum flow velocity and shear stress occur at the outer bend. Therefore it is the principal objective of this study is to carry out experimental tests on the effect of scour hole around a submerged vane in a 180 degree bend.

MATERIALS AND METHODS

Experiments were carried out at the Hydraulic Laboratory of Islamic Azad University, Ahwaz. The main channel consisted of a 9 m long upstream and a 6 m long downstream straight reaches (Fig. 3). A 180 degree channel bend was located between the two straight reaches with a relative radius of Rc/B=4.7 (Rc= Central radius and B=Flume width).

In this study to maintain the clear water condition without formation of ripple, uniform sediment with median size of $d50$ = 1.3 mm and geometric standard deviation of $\sigma g \sim 1.4$ were used [1]. A thickness of 15 cm and covered the total length of channel.

The experiments was carried out using four angle for submerged vane 15, 20, 25, 30 was used [4]. For all of the tests, submerged vanes installed at d/H=25 (i.e. d=distance of submerged vane and H=height of submerged vane) H/Y=0.3 (Y=flow depth), L/H=3 (L=length 0f submerged vane) [4]. In this study the experiments were performed under clear-water conditions at four Froude numbers of 0.236, 0.252, 0.269 and 0.286 were applied in order to investigate the effect of flow conditions on the scouring. At end of test time, for find volume of scour (v), scour length (l), scour width (w) and scour depth (ds) were recorded using the point gauge having an accuracy of ±0.01mm. Figure 4 shows a schematic illustration of a submerged vane and scour hole in flume.

Experiments were run under clear water scour regime for a period of more than 24 hrs when movement of sediment from scour hole was almost negligible and equilibrium state of scour reached. As it can be seen approximately 96% of scouring occurs during the first 3 hours. Therefore in all remaining of our experimental tests, duration of 3 hours was selected for each test. Therefore in all our experiments, the scour length (l), scour width (w) and scour depth (ds) 3 hours after the start of each test was recorded and considered here as maximum scour depth.

RESULTS AND DISCUSSION

Effect of Froude Number on the Scour Hole: Figure 5 shows effect of Froude number on the scour hole for relative scour volume (v/Y^3) at four angle 15, 20, 25 and 30 degree. Four different Froude numbers 0.236, 0.252, 0.269 and 0.286 were applied in order to investigate the effect of flow conditions on the scouring. Increasing Froude number is associated by increase in the flow velocity, as a result the scour volume increases. The main reason of such finding is that with increases in Froude number, occurs increases in vortex. This finding also is in agreement with the results of and Masjedi *et al*. [2] and Odgaard and Wang [4] which they found that, as Froude number increases, the vortex and scour increases.

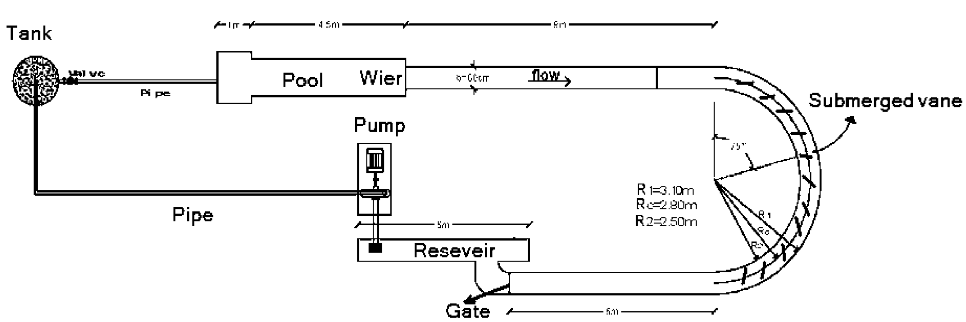

Fig. 3: The experimental setup (Plan)

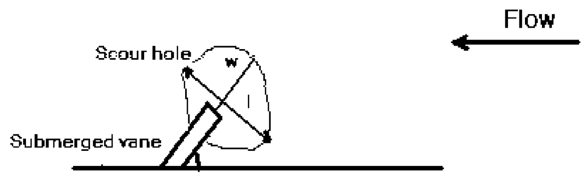

Fig. 4: A submerged vane and scour hole (Plan)

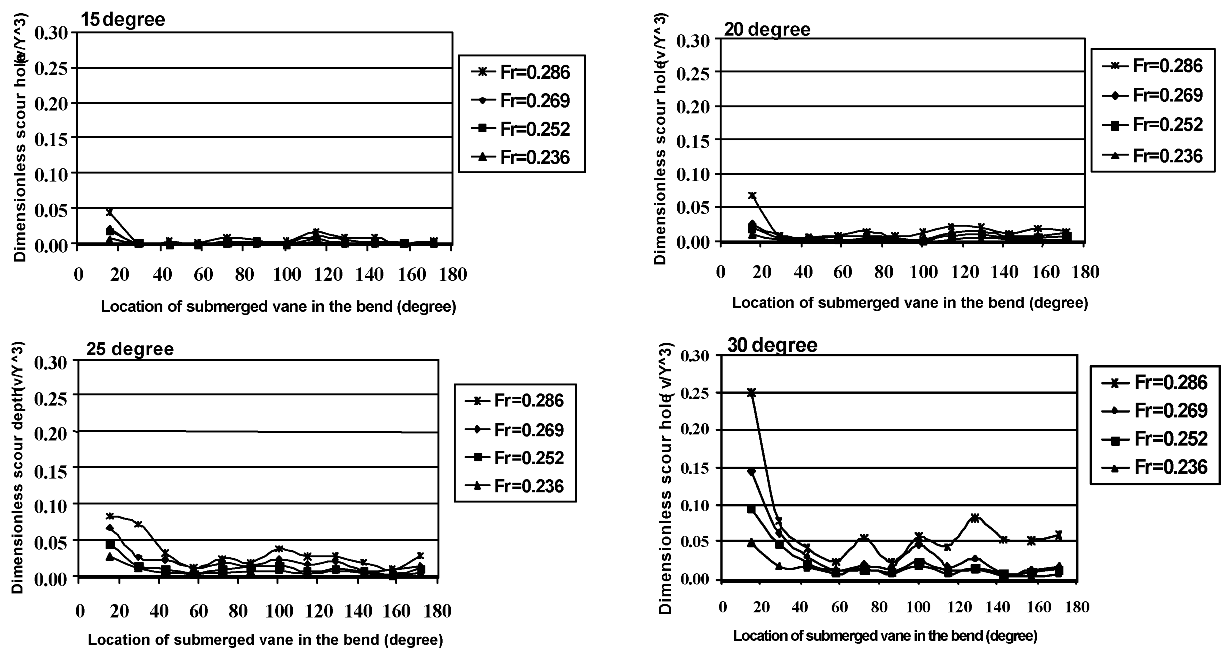

Fig. 5: Scour hole for different Froude number

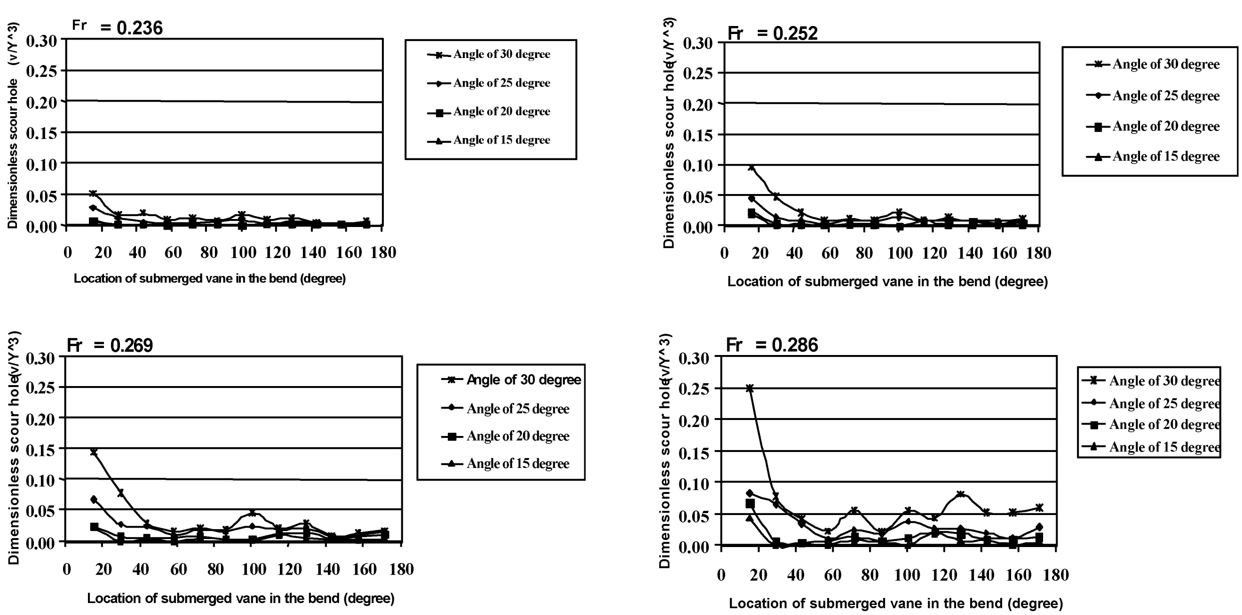

Fig. 6: Scour hole for different angle

Effect of Angle of Submerged Vanes on the Scour Hole: Figure 6 show typical dimensionless graphs for the relative scour hole (v/Y^3). This figure corresponds to Fr =0.236, 0.252, 0.269 and 0.286 and for four angle of attack 15, 20, 25 and 30 degree with the flow. Results shown, for angle of 15 degree, the scour hole decreases and angle of 30 degree is increase. It is clear that the angle of the submerged vanes decrease with the flow, the maximum scour hole decrease. The main reason of such finding is that at angle of 15 degree with the flow a maximum decreases in vortex. This finding also is in agreement with the results of and Odgaard and Wang [4] and Tan *et al.* [6].

CONCLUSIONS

The effects of Froude number and angle of submerged vane on the scour hole around submerged vanes in a 180 degree bend were investigated in this study. It was found that:

- By increasing Froude number the maximum scour hole increases.
- Decreases scour hole occurs at angle of 15 degree with the flow.

ACKNOWLEDGEMENT

Author thankfully acknowledges the financial support provided by Islamic Azad University Ahwaz Branch and Khuzestan Science and Research Branch.

REFERENCES

1. Dey, S., S.K. Bose and G.L.N. Sastry 1995. Clear water scour at circular piers: a model. J. Hydraulic Engineering, 121(12): 869-876.
2. Masjedi, A., M. Shafai Bejestan and A. Moradi, 2010. Experimental study on the time development of local scour at a spur dike in a 180 degree flume bend. J. Food, Agriculture & Environ., 8(2): 904-907.
3. Nakato, T. and F. L. Ogden, 1998. Sediment Control at Water Intakes along Sand-Bed Rivers. J. Hydraulic Engineering, 124(6): 589-596.
4. Odgaard, J. and Y. Wang, 1990. Sediment Management with Submerged Vanes. I: Theory. J. Hydraulic Engineering, 117(3): 267-283.
5. Sinha, S.K. and F. Marelius, 2000. Numerical analysis of flow past submerged vanes. J. Hydraulic Engineering, 38(1): 65-71.
6. Tan, S.K., G. Yu, S.Y. Lim and M.C. Ong, 2005. Flow Structure and Sediment Motion around Submerged Vanes in Open Channel. J. Waterway, Port, Coastal and Ocean Engineering, 131(3): 132-136.