Effect of Submerged Vanes on Intake Ratio and Water Surface profile at 55° Diversion

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ABSTRACT
Submerged vanes are commonly used as hydraulic structures for sediment control at intake entrance. In the present research, which was undertaken at the Hydraulic Laboratory in Water Engineering Department of Shiraz University, the hydraulic performance of these structures in sub-critical flows was studied experimentally, and the effects of submerged vanes, angle variations of submerged vanes and discharge rates on intake ratio and water surface profiles in the main channel near the lateral intake with rounded entrance and angle of 55 degree which is named as the best intake angle were investigated. In this study the submerged vanes had four installation angles of 10, 20, 30, 40 degrees along with the two setups of 2 and 3 parallel vanes across the entrance, considering for levels of discharge value. The results showed that the application of submerged vanes, regardless of their angles, caused in increase of water surface elevation near the upstream of the vanes as compared to the no vanes condition. Submerged vanes causes an increase in intake ratio. Finally the results show that the submerged vanes with angle of 30 and three parallel vane setup across the entrance had the best intake efficiency.

KEYWORD
Intake ratio, Lateral intake, Submerged Vanes, Water Surface Profile

INTRODUCTION
Water intakes are used to divert flow from a main canal into irrigation networks and from a river into irrigation channels, at installation of water treatment, and entrances for hydropower. Setting of submerged vanes is an effective and cheap method for preventing sediment deposition at entrances of intakes. Submerged vanes are used in one to quadruple rows and in parallel and zigzag arrangements. The application of submerged flow-turning vanes at water intakes was first reported by Nakato (1984) [5] and Nakato et al. (1990) [6] for shoaling control at MidAmerican Energy Company's Council Bluffs power station. The primary purpose of the vane installation for the above station was to produce a scour trench in front of the water intake. The submerged vanes and flow-turning vanes for river training are also discussed by Odgaard et al. (1990) [10], Odgaard and Wang (1991a, b) [8], Wang (1991) [11], Fukuoka and Watanabe (1993) [2], and Wang et al. (1996) [12]. In the above studies, to modify bed geometry in curved channels, the bed shear-stress distribution was modified using vane-induced stresses. Odgaard and Kennedy (1983) and Odgaard and Wang (1991a, b) [8,9] proposed the technology of submerged vanes with an angle of 15–30° versus direction of flow and with a height of 0.2–0.5 of flow depth. In the above studies the distance between vanes and sidewall was selected to be less than four times the vanes' height. Also the length of the vanes was selected to be two to three times the vanes' height. Keshavarzi and Shamsaddini-Nejad (2002) [3] used a group of submerged vanes at a 90° water intake with parallel and zigzag arrangements. They found that the zigzag submerged vane at a 20° angle is the optimum arrangement for sediment reduction at a 90° water intake in which the sediment entering was reduced by 72.9% when compared with when there was no submerged vane. Keshavarzi and Habibi (2005) found the 55° water intake as the optimum angle for impoundment with minimum separation in flow. Therefore, in this study, water level control at a rounded edge angle 55° water intake is selected for this study. The determination of optimum angle and vane arrangement was also selected to be the main objective of this study.
The experiments were performed at flow rate of 10, 20, 30 and 40 L/s. The velocity of flow was measured in three sections as locations 0.5 m in upstream and 1 m after intake in downstream of the main channel. Section A is located 0.5 m upstream of the intake, B is located at 1 m in the downstream from the intake entrance (Figure 3). The depth of flow in the above-mentioned sections was measured at 3, 6 and 12 cm from the bed in which they are 0.2, 0.6 and 0.8 times the flow depth from the water surface.

The secondary current at the water intake is defined here as flow circulation in a horizontal plane and the velocity difference between two ends of the horizontal plane is expressed as the strength of secondary current. The secondary currents are one of the important parameters for entrance water and water level at the entrance of a delivery channel. The strength of secondary current depends on the angle of delivery channel to the main channel, ratio of mean velocity in main channel to the mean velocity in the delivery channel and ratio of width of delivery channel to width of main channel. By measurement of flow velocity and also depth of water in horizontal plane at section B inside the delivery channel, the strength of the secondary current in calculated. Then the angle and arrangement of submerged vanes with minimum quantity of strength of secondary current, is selected as the optimum angle. The strength of secondary current is calculated by

\[ \delta = U_{max} - U_{min} \]  

where \( \delta \), \( U_{max} \) and \( U_{min} \) are strength of secondary current, maximum and minimum velocity in section B, respectively. To determine water level deposition at the entrance of the lateral channel, the bed was covered with 2.6 cm thickness. The bed topography was determined for the conditions with and without submerged vanes. The amount of water level entering into the intake was measured for different vane arrangements and the results compared with the amount of water level entering with no vane installation. In the following, the \( W_d \), 10, 20, 30, 40 stand for no vane installation, water depth, angle of attack of 10, 20, 30 and 40° to the flow, respectively.

### MATERIAL AND METHOD

The experimental tests were carried out in a nonrecirculating long flume with a lateral. The experimental model was built in the hydraulic laboratory of Shiraz University, Shiraz, Iran. To study the effect of submerged vanes in controlling water level at water intake, a rounded edge intake at 55° was built at one side of the main channel. The rounded edge was set edge with a 20 cm radius. Two series of vanes with parallel triplet and binary in width arrangements were installed at 10, 20, 30 and 40°. The pattern of installation and the location of the submerged vanes are shown in Figure 1. The vanes’ height was set at 3 cm according to the suggestions of Odgaard and Kennedy (1983) [4] and Odgaard and Wang (1991a, b) [8, 9]. They suggested that the best height of the vanes must be 0.2 times maximum water depth. The maximum depth of the water in this study was selected to be 15 cm. An optimised water intake with the presence of submerged vanes in irrigation canals.

<table>
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<th>( \delta_d )</th>
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RESULTS AND DISCUSSION

The flow structure and concept behind submerged vanes is that they generate vortex. As discussed by Barkdoll et al. (1999) [1] and Odgaard and Wang (1991a, b) [8], the purpose of using a group of submerged vanes at the bed of a river and at the intake is that they produced a tip vortex, which circulates downstream. Therefore, the vanes-induced circulation and streamwise velocity produce a helical motion or vortex downstream from the vanes. The helical flow then causes transverse shear stresses at the bed of the river, and transport water level in the transverse direction. The transverse shear stresses causes water level to be picked up on the vane's suction side and deposited on the pressure side (Odgaard and Wang 1991a, b) [8,9]. The above phenomena make vanes useful as a means for minimizing water level ingestion in the lateral diversions. The optimum installation of vanes at a river intake is very important to minimize sediment ingestion in the lateral. To find the optimum vane angle, Keshavarzi and Shamsaddini-Nejad (2002) [3] used a group of submerged vanes at the front of a 90° water intake and they found that the zigzag arrangement with 20° angle is the optimum arrangement to minimize sediment at the water intake. Furthermore, to find the optimum angle of the water intake, Keshavarzi and Habibi (2005) [4] carried out a comprehensive experimental test with water intakes of different angles and they found that the 55° water intake produced a minimum separation zone at the entrance. Therefore it was selected as the optimum angle for the water intake. The above finding must be examined for a 55° water intake to find the optimum arrangement of vanes at the entrance.

3.1 Fixed bed experiments

The experimental tests were done with four flow rates of 10, 20, 30 and 40 L/s for the conditions of no installation of submerged vanes and installation of submerged vanes with parallel and parallel triplet and binary in width arrangements.

3.2 No installation of submerged vanes

The depth of flow at sections A, B and was measured at depth of 0.2d, 0.6d and 0.8d from the water surface. The variation of depth in section B and at a distance of 0.6d for different flow rates is shown in Figure 4. It was found that by increasing flow discharge, the flow depth at location of 1 of section B, increases. This is due to the increasing width of the separation zone at the above location.

Figure 4. installation of submerged vanes and real view of structures in near to intake

Figure 5. No installation of submerged vanes and curve The depth of flow at sections longitude profile of water level and discharge is 20 L/s

Figure 6. installation of submerged vanes triplet in width and curve The depth of flow at sections longitude profile of water level and discharge is 20 L/s

Figure 7. installation of submerged vanes binary in width and curve The depth of flow at sections longitude profile of water level and discharge is 20 L/s
attack of 30° to the flow for the parallel entering the intake were considered. Ultimately, an attack of 10, 20, 30 and 40° to the flow, then the strength of the secondary current and the pattern of water level at the entrance of the water intake and the amount of water level entering the intake were considered. Ultimately, an angle of attack of 30° to the flow for the parallel arrangement triplet and binary in width depth of water 16-39% increasing respect without submerged vanes and also for the triplet arrangement 5-9 % stronger then binary arrangement was selected as the optimum angle for decreasing water levelentering the intake; also the effectiveness of the parallel triplet arrangement is more than the binary arrangement in the 55° water intake with rounded edge.

REFERENCES


