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Ananth Wuppukondur
Indian Institute of Technology Madras
India

K. B. Ranjith
Indian Institute of Technology Madras
India

Venu Chandra
Assistant Professor
Indian Institute of Technology Madras
India

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Athens Institute for Education and Research
8 Valaoritou Street, Kolonaki, 10671 Athens, Greece
Tel: + 30 210 3634210 Fax: + 30 210 3634209 Email: info@atiner.gr URL: www.atiner.gr
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An Experimental Study to Reduce Sediment Entry into an Intake Canal

Ananth Wuppukondur

K. B. Ranjith

Venu Chandra

Abstract

Purpose of an intake canal is supplying water to irrigation, industrial, thermal power plants etc. Quantity of water decreases in the canal because of sedimentation caused due to sediment entry from main water source. Experiments are conducted to identify a method to reduce sediment entry into the canal. A physical model which consists of main rectangular channel of bed width 55cm filled with a sediment of size d_{50}=0.28mm and also a rigid bed trapezoidal channel of a bed width of 12cm with side slopes of 1:1, is used for this purpose. The rectangular and trapezoidal channels in the model represent the river and intake canal, respectively. Both channel bed levels are meeting at the same elevation. The diversion angle of intake canal is 45^0. All experiments are conducted at a constant discharge of $0.025m^3/s$ with a flow depth of H=8cm. The sediment entry into the intake channel (Q_s) is estimated first without vane arrangement. Then, seven rectangular vanes of equal height 0.375H, width of 0.18H and 1 mm thick, are installed at the canal entrance making an angle of 15^0, 30^0 and 45^0 with respect to the flow direction in a rectangular channel, to reduce Q_s. Two vane arrangements with 8cm and 12cm vane spacing (S_v) are used to conduct the experiments. When S_v is 8cm, Q_s decreases by 52%, 51% and 44% for 15^0, 30^0 and 45^0 vane angle, respectively. Further, with an increase of S_v to 12cm, Q_s reduces by 59%, 55% and 52% for 15^0, 30^0 and 45^0 vane angle, respectively. However, Q_s decreases to 60%, 57% and 49% by introducing a second parallel row of vanes at 8cm spacing for 15^0, 30^0 and 45^0, respectively. Hence, Q_s reduces with an increase of vane spacing and increases with an increase of vane angle. Also, Q_s decreases with an addition of vane row except 45^0 vane angle.

Keywords: Intake canal, Sedimentation, Submerged vanes, Vane angle, Vane spacing.

Introduction

An Intake canal is used to withdraw water safely from a water source for various purposes such as drinking, irrigation, cooling in thermal power plants and other industrial purposes. The flow pattern of the main river varies at the entrance of the intake canal (Bosman et al., 2002). The interaction between the velocity gradient and the curvature of the primary flow generates a secondary flow in transverse direction which picks up sediments from river bed (Odgaard and Kennedy, 1983). The change in flow pattern results in sediment entry from the main river into intake canal, as a result of which quantity and quality of water in the intake canal reduces. Screens or sedimentation tanks are conventionally used to reduce sedimentation in the intake canals but are prone to various problems and a high maintenance cost. Installation of vanes at the entrance of the intake canal to change the river bed profile is considered a possible solution for minimizing the sedimentation in the canal (Odgaard and Wang, 1991a; Odgaard and Spoljaric, 1986). The vanes create a horizontal helical flow in a longitudinal direction which leads to the deepening of river bed near the intake canal mouth (Barkdoll et al., 1999). As a result, the sediments are carried to the downstream of the river rather than entering into the intake canal.

According to Yonesi et al. (2009) the spacing between the vanes is important in controlling the sediment entry. The vane installation can be varied with the number of vanes. Number of vanes at the entrance of the intake canal depends on the width of intake canal. Studies with multiple rows and various arrangements such as different spacing between vanes, vane angle were carried out by Odgaard and Wang, 1991a; Wang et al., 1996; Barkdoll et al., 1999 etc. Optimum spacing between the vanes in longitudinal and lateral directions is reported in some studies by Yonesi et al., 2008; Odgaard and Wang, 1991a; Wang et al., 1996. Apart from lateral and longitudinal spacing, the spacing between vanes and the riverbank is also important. The stretch of the river up to which vanes are to be provided is another important parameter. Vanes in the upstream side up to 3 times the longitudinal spacing between the vanes is reported as minimum number by Odgaard and Wang, (1991b).

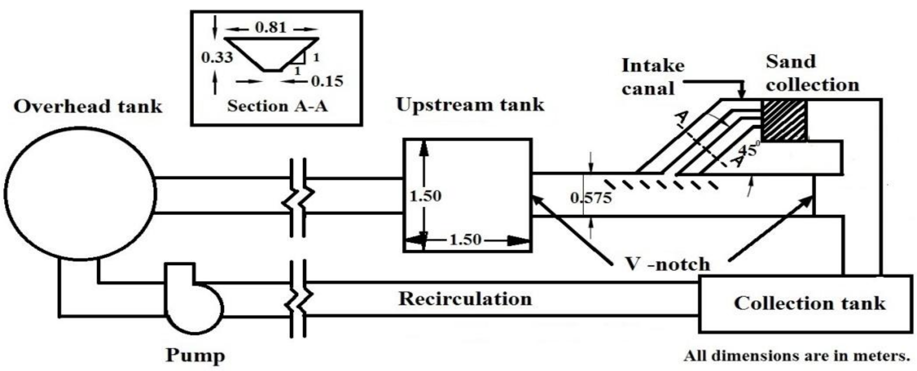
The vane installation can be made with a single row or multiple rows. In the case of multiple rows of vanes, it is important to understand the interaction of the flow with vanes. Studies are conducted to understand the interaction between multiple vanes by Ouyang et al., 2008. However, the maximum number of vanes in a single row, considered in this study is three. Number of vanes to be installed at the entrance of intake canal depends on the width of the intake canal and the sediment carrying the capacity of the flow in the river. Multiple rows of vanes and various arrangements are studied by Odgaard and Wang, 1991; Wang et al., 1996; Barkdoll et al., 1999. Most of the studies are carried out without considering the scaling of the sediment size, since the particles were readily movable on the bed with the flow (Nakato and Kennedy, 1990). Also, the earlier studies are carried out at very low vane angles in order to account lesser local scour. All the studies were conducted with vanes of equal submergence height and the vertical turbulence that may arise because of different vane heights is neglected.

The present study is carried out in a physical model to understand the effect of different vane arrangements such as spacing between the vanes, vane angle, vane heights and multiple rows of vanes on sediment entry into the intake canal. Submerged vanes are arranged in a single row and experiments are conducted for different spacing between the vanes, different angle of attack and vane height. The bed profile changes in the main channel with the installation of vanes that are observed. The sediment entry into the intake canal in experiments with and without vanes is also quantified and reported. In addition, the local scour around the vanes is also obtained.

Experimental Setup

The experimental setup used in this study consists of a main channel with a movable bed filled with a sediment of size d_{50}=0.28mm and geometric standard deviation, σ_g=1.64. The main channel representing the river is 57.5 cm wide and 21 cm deep. A rigid-bed trapezoidal intake channel with a bottom width of 15 cm, a height of 33 cm and side slopes of 1:1, off-takes at an angle of 45^0 from the main channel (Figure 1). The experimental set up is designed by considering laws of similitude and Shields criterion (Cao et. al., 2006; Abderrezzak et. al., 2014). The flow in the model is allowed through network pipes. In the experiments, a constant discharge of 0.030 m^3/s is allowed with a constant flow depth (*H*) of 8cm in the main channel. The discharge is measured with electromagnetic flow meters and also using calibrated triangular notches on the upstream and downstream of the entrance of the intake channel. The flow in the main channel is hydrographically allowed. A digital point gauge is used in measuring the bed levels of the test section at the intake canal which consisted of 1.12m in the main channel. The experiments are conducted until the equilibrium scour is attained in the main channel and each experiment lasted typically for 3 to 4 hours. A sediment feed of 0.002 m^3 is allowed every 15 minutes during the experiments.

Figure 1. *Plan View of Experimental Setup*



Methodology

Initial experiments are conducted without vanes to quantify the sediment entry in the intake canal. Using a digital point gauge, the bed levels at the test section were obtained before and after the experiment. From the bed levels, the contour map of scour depth at the test section is prepared. The volume of the sediment that eroded from the test section is then calculated based on the difference of the initial and final bed levels. In addition, the sediment collected at the downstream of the intake canal is weighed in order to determine the quantity of the sediment entering from the main channel into the intake. Later, vanes of equal height (0.375H), width of 0.18*H* and thickness 1 mm are used to conduct experiments to reduce a sediment entry into the intake channel. The vanes are placed in a row at a constant spacing of *H* or 1.5*H*. The angle of attack of vanes (θ) is maintained as 15^0, 30^0 and 45^0 in different experiments. The vanes are installed in the main channel up to a distance of 2*H* and *H* in the upstream and downstream of the intake entrance, respectively. In addition to bed levels at the test section, the local scour depth around the vanes is obtained using a digital point gauge during the experiment at a regular interval of 30 minutes from the beginning of the experiments. The scour depth is represented as a non – dimensional parameter called the Scour depth ratio (R_s) which is a ratio of scour depth (S_d) to the mean flow depth of main flow in the upstream (*H*). Each experiment is referred as P-X where P represents the spacing between the vanes i.e., *s* (8cm or 12cm), and X represents the vane angle i.e., 15^0 or 30^0 or 45^0. The arrangement of vanes at the entrance of the intake canal is shown in Figure 2.

Figure 2. *Arrangement of Vanes at the Entrance of Intake Canal*

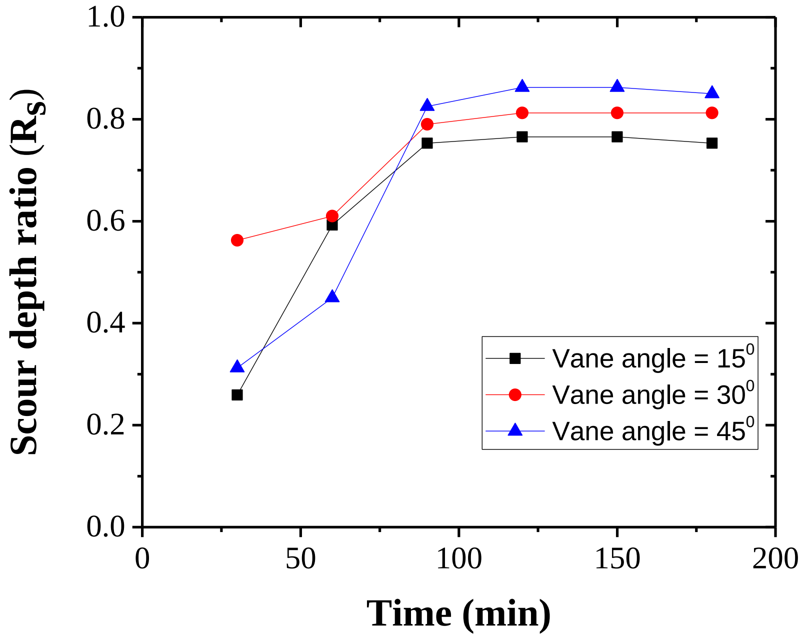
Results and Discussion

The effect of spacing between the vanes and the angle of attack of the vane on the scour depth and sediment entry into the intake canal is studied in detail. The results of the experiments conducted with various vane arrangements are discussed in this section.

Effect of Vane Angle

In the case experiments conducted with *s*=8cm, *n*=1 and for the arrangement of A, R_s=0.77, 0.81 and 0.86 for θ=15^0, 30^0, and 45^0, respectively. It is observed that the local scour ratio increases with the increase of vane angle (Barkdoll et al., 2010). Hence, it can be observed that the local scour ratio increases with the increase of the vane angle. When the spacing between the vanes is increased to 12cm, R_s is observed as 0.56, 0.72 and 0.80 for θ=15^0, 30^0, and 45^0, respectively. Therefore, it can be observed that the local scour ratio increases with the increase of the vane angle similar to that of the former vane arrangement. However, lesser scour depths are observed for experiments with s=12cm, irrespective of vane angle. The variation of local scour around vanes with the vane angle, when the vanes are placed at a spacing of 8cm is shown in Figure 3.

Figure 3. *Variation of Local Scour around Vanes with Vane Angle*



Local Scour Analysis for Vane Arrangement 'A' at Vane Angle of 15^0

In this particular arrangement, all the vanes are installed at an equal height. The wavy nature of sediment deposition and erosion is observed i.e., once the sediment gets deposited, and later it gets eroded. Initially, the rate of erosion is more and the rate of deposition is less. This elevates the curve to higher values of the local scour ratio. It is observed that the arrangement 8-15^0 has the maximum local scour value compared to experiments with 12-15^0. The variation of the local scour around vanes with spacing between the vanes, when the vanes are placed at an angle of 15^0 with respect to flow in main channel is shown in Figure 4. The maximum local scour depth for different vane arrangements is presented in Table 1.

Figure 4. *Variation of Local Scour around Vanes with Spacing between the Vanes*

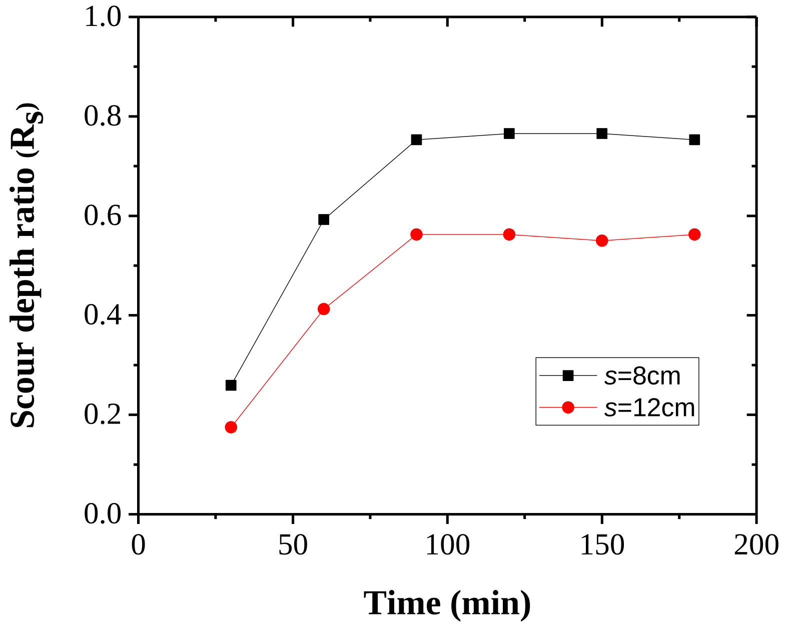


Table 1. *Maximum Scour Depth at the Test Section with Various Vane Arrangements*

Spacing between vanes (cm)	Maximum scour depth ratio (R_s)		
	Vane angle		
	15^0	30^0	45^0
8	0.77	0.81	0.86
12	0.56	0.72	0.80

Local Scour Analysis of Experiments with Vane Angle of 30^0

As the angle of attack increased from 15^0 to 30^0 there is an increase in the local scour ratio, since the obstruction to the flow is higher. The local scour ratio is the minimum for the arrangement of 8-30^0 and a maximum for the arrangement 12-30^0. The initial scour is observed to be very high when the vane angle is 30^0 and also, a deeper scour around the vanes is observed.

Local Scour Analysis of Experiments with Vane Angle of 45^0

In this case, the vanes are exactly perpendicular to the flow in the intake since the intake is diverted at an angle of 45^0. It has been observed that the local scour ratios have further increased because of the increased turbulence and flow obstruction. It is also observed that the maximum local scour ratios for arrangement 8-45^0. For vane angles of 15^0 and 30^0, the scour is the highest due suction variation in the vertical direction. Whereas, minimum R_s. was observed for experiment 12-45^0.

Sedimentation in Intake Canal

All the experiments are conducted to find out the optimal arrangement with the minimum sediment entry into the intake canal. The methods available in the literature for controlling the sedimentation concentrate on the river bed modification only. These studies did not discuss and present the results in terms of the quantity of the sediment entering into the intake canal. However, in the present study the eroded sediment is collected and the volume is measured.

Change in Sedimentation in Intake Canal with Vane Angle

Sedimentation is the volume of the sediment entering into the intake canal eroded from entire test section (river bed). As mentioned in the previous sections, the initial experiment is conducted without vanes to quantify the volume of sediment entering into the intake canal. It is observed that 49.35% of the total sediment eroded from the test section that entered into the intake canal. The volume of sediment eroded from the test section is 0.064 m^3. In case of experiments with vanes, the percentage of sedimentation increases with increase in the vane angle which is similar to the local scour increase with vane angle. From the experiments, it is observed that the sedimentation in the intake canal decreased with an increase of spacing between the vanes, irrespective of vane angle. The least sedimentation in the intake canal is observed for experiment 12-15^0 with 20.05% of eroded sediment from the main channel entering into the intake canal. The maximum sedimentation in the intake is observed for experiment 8-45^0 with 27.86% of sedimentation in intake. Overall, the experiments with vane spacing of 12 cm lead to the lowest sedimentation in the intake. The sedimentation is higher for the experiments with a single row of vanes kept at a distance of 8 cm. The sedimentation in the intake canal with various vane arrangements is shown in Table 2.

Table 2. *Sedimentation in the Intake Canal for Various Vane Arrangements*

Spacing between the vanes (cm)	**Sedimentation in the intake canal (%)**		
	Vane angle		
	15^0	**30^0**	**45^0**
8	23.6	23.82	27.86
12	20.05	22.09	23.42
Experiment without vanes	49.35		

Bed Profile Modification

From the experiments, it is observed that with the installation of the vanes, the river bed profile is modified significantly. This can be identified and explained with contour maps of scour depth at the test section. Both the contour maps shown in Figures 5 and 6 represent the river bed profile after

3 hours of the experiment duration. In the initial experiments, the scour depth is high in the upstream and it is almost half the flow depth in the first contour map i.e. in the experiments without vanes. The formation of a deepened channel can be observed in the second contour map (Figure 6). This deepened portion will permit the sediment from the upstream to directly go to the downstream side, without entering into the intake canal. The depth near the intake is lesser in the second case. This also prevents the entry of the sediment into the intake canal. Lower scour depth at the entrance of the intake canal will not lead to the collapse of the intake canal foundation. Similar bed profile modifications are observed in other vane arrangements also.

Figure 5. *Scour Depth Contour Map for Experiment without Vanes*

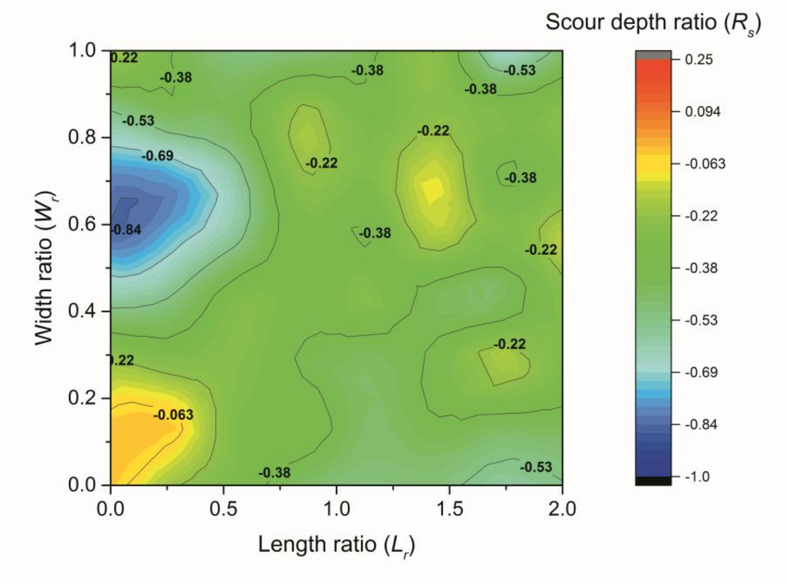
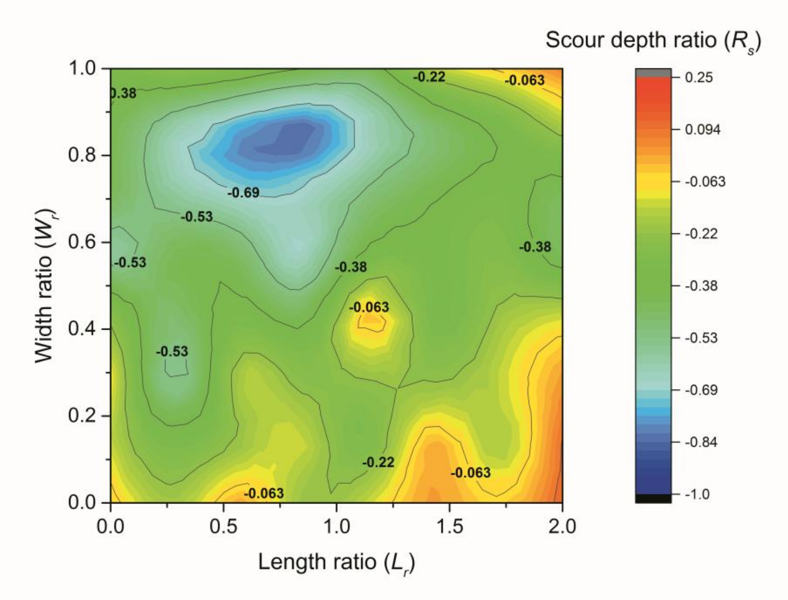


Figure 6. *Scour Depth Contour Map for Experiment with Vanes at a Spacing of 12cm and Vane Angle of 15^0*



Conclusions

Intake canals withdraw water safely from water sources for various purposes such as irrigation, water supply and thermal power plant cooling system. Sedimentation in the intake canal is a major problem which reduces discharge and water quality in the intake canal. The sedimentation can be controlled by installing submerged steel vanes in the river bed. In the present study the vanes are installed at various angles (15^0, 30^0 and 45^0) in a single row with different spacing between the vanes. The spacing between the vanes is kept constant in an experiment as 8cm or 12cm. Experiments are conducted with vanes of equal submergence height. The experimental results are compared between sedimentation in the intake canal without vanes and with vanes for different arrangements. The following conclusions are made with the help of the results obtained from the present experimental study.

- The sedimentation in the intake canal is observed as 49.35% of the total sediment eroded from the main channel in case of without vanes.
- The sedimentation in the intake canal reduces with the installation of vanes and the sedimentation in the intake canal increases with an increase in the vane angle.
- Less sediment entry into the intake canal is observed when the spacing between vanes is maintained as 12cm.
- The vane arrangement in which a single row of vanes is kept at a spacing of 8 cm, the maximum sedimentation is observed for the arrangement 8-45^0 (~28%). The minimum sedimentation is observed as ~20% for the arrangement 12-15^0.

References

Abderrezzak, K. E. K., Moran, A.D., Mosselman, E., Bouchard, J. P., Habersack H., and Aelbrecht D. (2014). "A physical movable-bed model for non-uniform sediment transport, fluvial erosion and bank failure in rivers." *Journal of Hydro-Environmental Research,* 8, 95-114.

Barkdoll, B. D., Ettema, R., and Odgaard, A. J. (1999). "Sediment control at lateral diversions: Limits and enhancements to vane use." *Journal of Hydraulic Engineering,* 125(8), 862- 870.

Bosman, D. E., Prestedge, G. K., Rooseboom, A., and Slatter P. T. (2002). "An investigation into the removal of sediments from water intakes on rivers by means of jet type dredge pumps." *Water Research Commission Report,* 1187/1/02.

Cao Z., Pender, G., and Meng, J. (2006). "Explicit formulation of the Shields diagram for incipient motion of sediments." *Journal of Hydraulic Engineering,* 132:10, 1097-1099.

Nakato, T., and Kennedy, J. F. (1990). "Pump-station intake-shoaling control with submerged vanes." *Journal of Hydraulic Engineering,* 116(1), 119-128.

Odgaard, A. J., and Kennedy, J. F. (1983). "River-bend bank protection by submerged vanes." *Journal of Hydraulic Engineering,* 109(8), 1161- 1173.

Odgaard, A. J., and Spoljaric, A. (1986). "Sediment control by submerged vanes." *Journal of Hydraulic Engineering*, 112(12), 1164- 1180.

Odgaard, A. J., and Wang, Y. (1991a). "Sediment management with submerged vanes. I: Theory." *Journal of Hydraulic Engineering*, 117(3), 267- 283.

Odgaard, A. J., and Wang, Y. (1991b). "Sediment management with submerged vanes. II: Theory." *Journal of Hydraulic Engineering*, 117(3), 284- 302.

Wang, Y., Odgaard, A. J., Melville, B. W., and Jain, S. C. (1996). "Sediment control at water intakes." *Journal of Hydraulic Engineering*, 122(6), 353-356.

Yonesi, H.L., Omid, M.H., and Haghiabi, A.H. (2008). "A study of the effects of the longitudinal arrangement of submerged vanes on sediment behavior near intake structures." *Journal of Hydraulic Research*, 46(6), 814-8190.