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Minimizing the Diverted Sediment at Lateral Intakes Using Submerged Vanes

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ABSTRACT

The present paper shows an experimental study that was executed in order to investigate the efficiency of submerged vanes to minimize the sediment that entered the intake channel. Forty four experiments were carried out considering various vane heights, angles, and positions under different flow conditions. A case of flat floor without vanes is included to estimate the influence of using the submerged vanes technique. Obtained results were analyzed and graphically presented in order to determine the optimum vane characteristics.

هذا البحث يقدم دراسة معملية لتقييم كفاءة ا وجهات الصناعية ا غمورة لتقليل إنتقال ا واد الرسوبية إ قناة ا أخذ. الدراسة احتوت على أربعة وأربعون ربة معملية آخذت الاعتبار مكان ا وجهات بالنسبة لعرض ا أخذ وإرتفاع ا وجه بالنسبة لعمق ا اء وزاوية ا وجه بالنسبة لأ ـ اه السريان بالقناه الرئيسية والتصرف الرئيسى وتصرف ا أخذ وعمق ا ياه ا لفى بالقناة الرئيسية. وبتحليل النتائج تعي الصفات ا ميـزة لتلـك ا وجهات.

Keywords: Submerged vane, Intake, Physical model, Sedimentation.

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1. INTRODUCTION

The application of the submerged vanes at water intakes was first reported in 1983 by Odgaard, and Kennedy, **Odgaard, J. A., and Wang, Y. (1991 a).** The main applications of submerged vanes are erosion control, channel cross section maintenance, adjusting the stream direction and creating new bed morphology.

The most important application of the submerged vanes is in water intakes that adjust the flow and sediment patterns at the intake channels. The primary purpose of the vane application was to produce a scour trench in front of the intake. This scouring action makes vanes useful as a means to minimize the bed-sediment ingestion into diversions from alluvial channels.

The concept behind vanes is that, the vanes generated a secondary circulation in the main flow, when the approach flow attacks the vane, a high-pressure zone forms at the upstream face, and a low-pressure zone forms at the downstream face. The pressure difference across the vane induces a current over the top of the vane, which is carried downstream as a helicoidal vortex. The helicoidal vortex is responsible for the changes in the near-bed velocity, shear stress, and the bed topography in the vicinity of the vane. The helical flow created by the vortex causes transverse shear stresses on the riverbed, resulting in sediment transport in a direction transverse to the flow direction. The transverse shear stresses caused sediment to be picked up on the vane's suction side and deposited on the pressure side. **Odgaard, J. A., and Wang, Y. 1991 b.**

The present study is thus concerned with investigating the efficiency of installing of double or triple rows of vanes in front of the intake to minimize the sediment that enters the intake channel.

2. EXPERIMENTAL WORK

Figure (1), shows the apparatus used in the present study. The flume is 60 cm wide, 60 cm deep, and 20.0 m long, and is fitted with a 90° lateral-intake channel (20 cm wide, 60 cm deep, and 3.0 m long). The flume is constructed of bricks sealed with smooth cement mortar. The flume consists of head and tail tanks and main, lateral and by-pass channels. Two centrifugal pumps are used; the first is to supply water to the head tank from the ground sump, and the other is submerged in the intake channel to deliver water to the bypass-channel. Water is controlled using a control valve installed on the pipe connected to the feeding pump. The head tank has a weir, and a gravel box, the first is calibrated to measure the flow that feed the flume, the gravel box is used to provide an even flow distribution across the flume. The flow enter the flume through an inlet screen to absorb any water eddies.

The model is made of smooth cement-sand mortar, overlaid on a layer of sand of 0.5 m thickness. To represent the movable bed, 5 m of the flume in front of the intake is filled with a 0.15 m deep layer of a uniform PVC material with D_{50} = 2.5 mm, and a specific gravity of 1080 kg/m^3. Precise point gauge is installed to measure the bed level, and the depth of water. The gauge is mounted on an x-y carriage. The carriage travels on two sets of rails. Downstream water depth is controlled using a hinged gate. The intake channel is located 8.0 m downstream the flume-channel inlet. The fixed-floor elevation of the intake was leveled with the movable bed in the flume. The intake channel has a sediment-collection trap followed by a screen to collect the bed material.

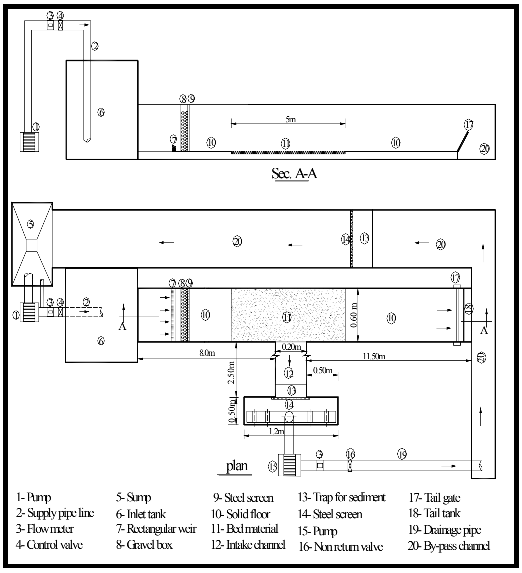
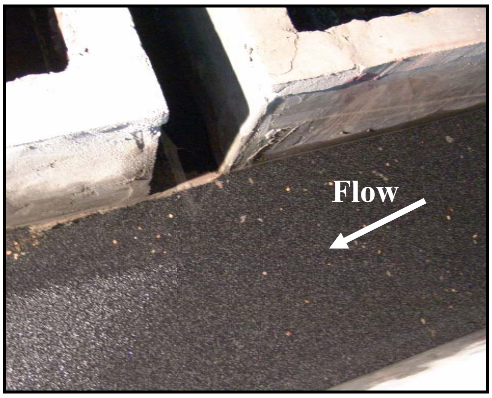
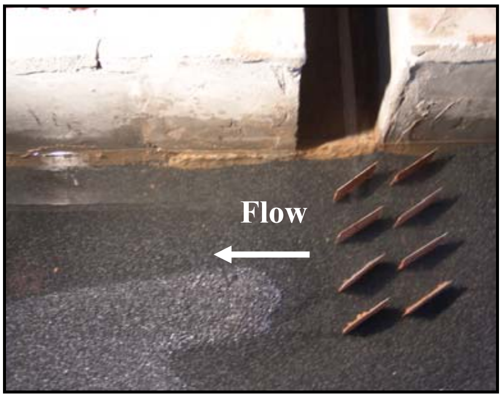


Figure (1) Experimental set-up

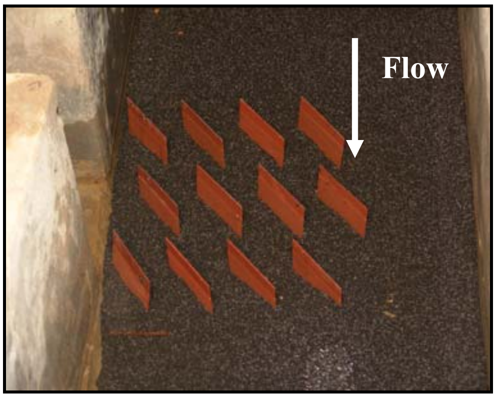
To study the influence of the submerged vanes, flume flow was kept constant at 25 Lit/sec, and four discharge ratios are considered (Q_r = 0.10, 0.15, 0.20, and 0.30). The tail water depth is fixed were equal to 0.12 m. Four vanes are installed in each row. The vanes are made of a steel plate of 2 mm thickness and are 12 cm long. The vanes array is fixed on a 2 mm thick steel plate. The distance between two vanes in the direction of flow is 10 cm, the distance of inner vanes from the intake wall is 7 cm, and the distance between the other two vanes in each row is 10 cm. Photo (1), shows the different tested cases.



a- Flat floor without vanes



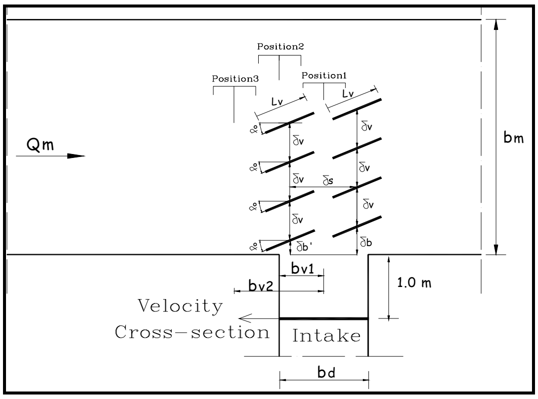
b- Double vane rows



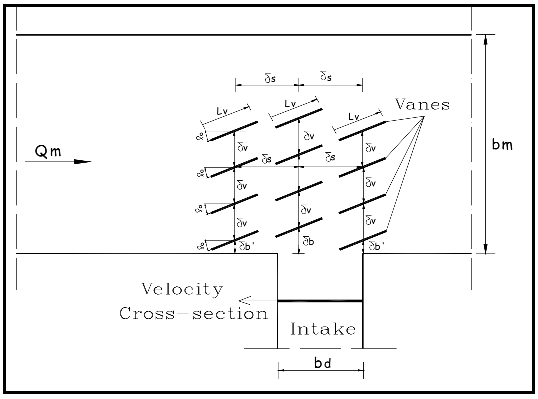
c- Triple vane rows

Photo (1) Tested Cases

Figure (2), shows the proposed alignment of the tested cases. In case of triple rows of vanes, three oriented angles is considered α = 20º, 30º, and 40º, to estimate the best angle. At the optimum orientation, the height of submerged vanes is changed three times, H_v/Y_t = 0.2, 0.3, and 0.4, to define the best height, that lead to the minimum diverted sediment. The optimum angle and the best height of the case of triple rows are used to estimate the best position of double rows of vanes where four positions b_v/b_d = 0.0, 0.5, 1.0, and 1.5, were tested.



a- Layout of double vane rows



b- Layout of triple vane rows

Figure (2) Layouts of the Vanes

Forty four runs were conducted including four runs without vanes to act as a reference case. For each run backwater feeding is started first until the depth reaches more than the required downstream depth, Y_t, then upstream feeding is started to adjust the depth of tail water, the tail gate is screwed gradually until the required depth is reached.

Two hours after many trials was chosen as a constant time for all runs. Flow velocity was measured using an electromagnetic current-meter. The velocity cross-section is chosen at a distance from the intake entrance equal to 5 times the intake width.

After the running time, the flume was emptied. The volume of sediment that entered the intake channel was measured. A squared beaker of (16.8 cm x 16.8 cm x 150 cm) was used to measure the volume of the sediment,

The working part was recorded with the precision point gauge to monitor the bed topography on a grid 20 cm x 10 cm, sometimes 5 cm x 10 cm depending on the shape of the bed topography to estimate the maximum scour.

3. RESULTS AND ANALYSIS

In order to illustrate the influence of using the submerged vanes, and to define the optimum parameters in case of triple, and double rows of vanes, the following dimensionless parameters were considered:

S_V/S_{Vw}, d_s/d_{sw}, b_v/b_d, α, H_v/Y_t, v_r/v_l, Q_r, and λ

Results showed that, increasing the values of Q_r, led to an increase in the values of S_V/S_{Vw}, and a decrease the values of d_s/d_{sw}. For all tested runs, the values of d_s/d_{sw} were more than one, while the values of S_V/S_{Vw} were less than one.

- **Case of triple rows of vanes**

Relationships between the values of b_v/b_d, S_V/S_{Vw}, and d_s/d_{sw} are illustrated as shown in Figures (3), and (4), considering the values of Q_r. From these figures it is clear that, the value of $\alpha \approx 30°$, gave the minimum S_V/S_{Vw} values. The value of d_s/d_{sw} increased as the value of α increased. The value of $\alpha \approx 30°$, gave the maximum ds/d_{sw} values.

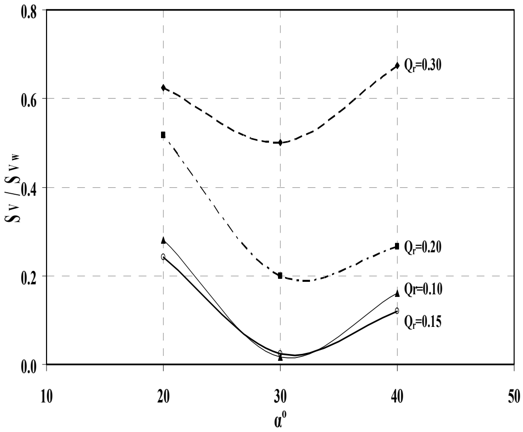


Figure (3) Relationship between α, and S_V/S_{Vw}, for different Q_r

Figures (5), and (6), show the relation between S_V/S_{Vw}, d_s/d_{sw}, and H_v/Y_t. From these figures, one can observe that, the value of $H_v/Y_t \approx 0.3$, gave the minimum S_V/S_{Vw} values. The value of d_s/d_{sw} increases as the value of H_v/Y_t increases.

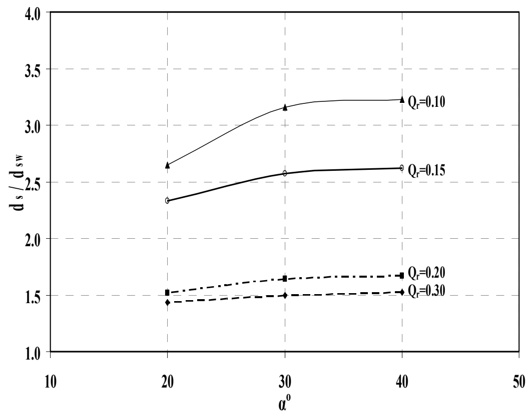


Figure (4) Relationship between α, and d_s/d_{sw}, for different Q_r

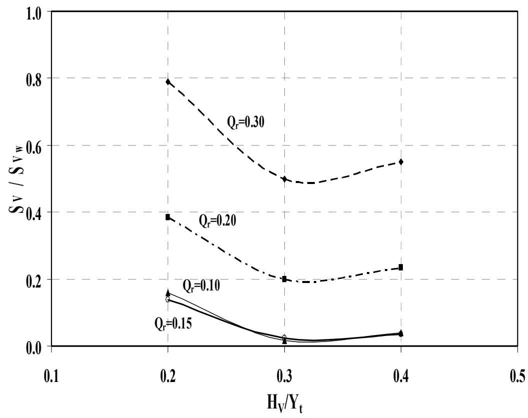


Figure (5) Relationship between H_v/Y_t, and S_V/S_{Vw}, for different Q_r

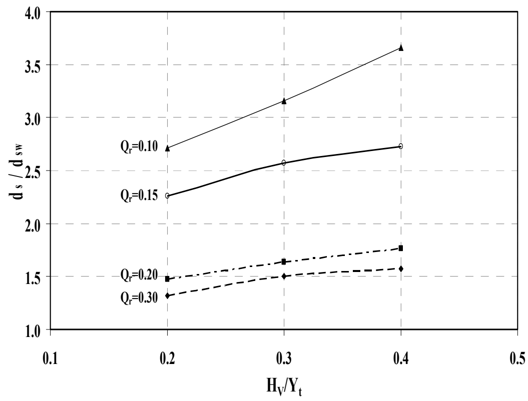


Figure (6) Relationship between H_v/Y_t,, and d_s/d_{sw}, for different Q_r

- **Case of Double rows of vanes**

The obtained results of triple vane rows are used to estimate the best position of the double rows of vanes

Figures (7), and (8), Show that, the value of b_v/b_d = 1.0, gave the minimum S_V/S_{Vw} value, The value of b_v/b_d = 1.0, gave the maximum d_s/d_{sw} value, while at the value of b_v/b_d =1.5, gave the minimum d_s/d_{sw} value was obtained.

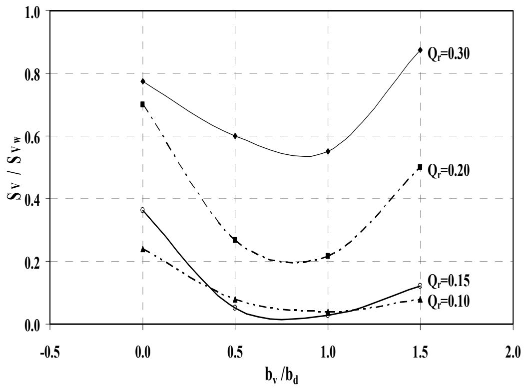


Figure (7) Relationship between b_v/b_d, and S_V/S_{Vw}, for different Q_r

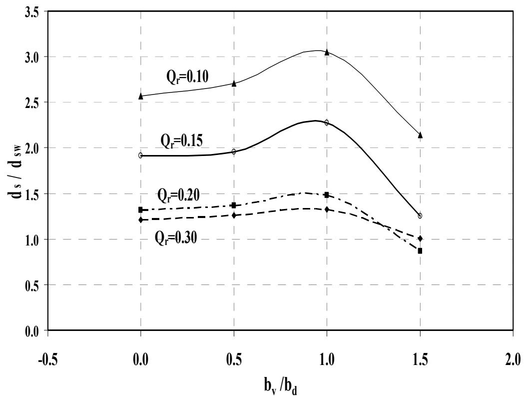


Figure (8) Relationship between b_v/b_d, and d_s/d_{sw}, for different Q_r

Figure (9) shows that, using vanes decreases the values of v_r/v_L. This means that using vanes led to a non-uniform distribution of the velocity in the intake channel.

The values of v_r/v_L, had the maximum values for the case of flat floor (without vanes), while values for the case of double vane rows were minimum.

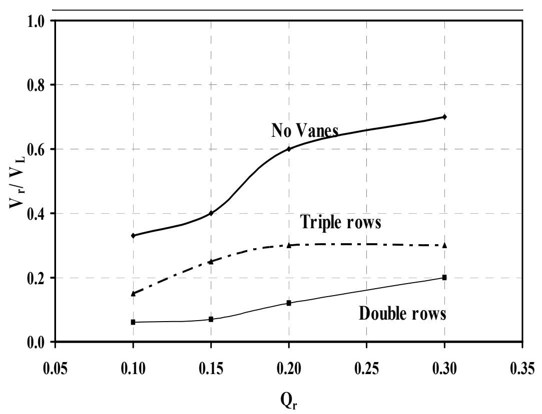


Figure (9) Relationship between Q_r, and v_r/v_L for different vane cases

The previously published papers addressed that the submerged vanes be the limit of $Q_r > 0.2$. Although the present proposed alignment of the vanes minimized the sediment from entering the intake channel for $Q_r > 0.2$. On the other-side the scour increases with increasing the Q_r.

4. CONCLUSIONS

From the above, the following conclusions are drawn:

- In case of the vanes oriented with the main flow direction at angle about 30º, the volume of the sediment that entered the intake channel was the least quantity among the tested cases.
- The optimum height of vanes is about 0.3 of the tail water depth.
- The best position of the double rows of vanes should be at $b_v/b_d = 1.0$.
- The triple vane rows of that were tested under the considered conditions are reduced the sediment by 50% to 90 %, while for case of double rows of vanes reduced the sediment by 50% to 85 %.
- The maximum scour occurs at the pressure side of the vane near the leading edge for the lower angles, but shifts towards the trailing edge with increasing angle of attack. The maximum scour depth increases with increasing vane height and increasing angle of attack. This result finds to be close to **M.M. Hossain, et al. (2004)**.
- The case of triple rows of vanes gave the maximum scour depth values in front of intake channel.
- The use of vanes increased the separation zone length in the intake channel, and led to a non-uniform distribution of flow in the intake channel.

5. NOTATION

b_m : Main channel width
b_d : Intake channel width
b_v : Distance from the centerline of the intake to the centerline of vane's row
d_s : Maximum scour depth at the front of the intake
d_{sw} : Maximum scour depth at the front of the intake in case of no vanes
D_{50} : Median grain size of sediment
F_r : Tail Froude number
g : Gravitational acceleration
H_v : Vanes height above the bed
Q_d : Discharge passing through the intake channel
Q_m : Discharge passing through the main channel
Q_r : Relative discharge $=Q_d/Q_m$
S_V : Volume of sediment entering the intake channel
S_{Vw} : Volume of sediment entering the intake channel in case of no vanes
v : Mean flow velocity of the main channel
v_r : Flow velocity beside the right wall of the intake channel
v_L : Flow velocity beside the left wall of the intake channel
Y_t : Tail water depth of the main channel
λ : Kinetic-flow factor $= F_r^2$
α : Angle of vanes with the direction of main flow

6. ACKNOWLEDGMENTS

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