The Effect of Current Deflecting Wall on Reduction of Sediment Transport Entering into Lateral Intake in the River Bend

Seyed Vahab Belyadiyan and Alireza Masjedi

ABSTRACT

Erosion at the intake mouth of the rivers for irrigation and drainage networks, power plants and water treatment plants, has caused sedimentation in these areas and is of great importance. In order to control the sediments entering the water supply reservoirs of above installations at first traditional methods were used such as concrete, vegetation, cobblestone, stone mesh, cement, and construction of breakwater wall. However, due to high costs and adverse side effects they have been abolished. Given the importance of the matter, researchers have been looking for new solutions and after conducting numerous experiments they have come to conclusions that have led to the creation of new ideas such as the use of current deflecting wall-sill to control the sediments entering the lateral intakes. In this research, by taking inspiration from the pattern of flow in the basin inlet which is specifically complicated and creates flow dividing plates and separation zone within the basin, the performance of current deflecting wall-sill as a new method on the control of sediment entering the intake by maintaining the discharge efficiency in the river bend was investigated. The results showed that in the width of the primary channel of current deflecting wall by 12.5 cm and the width of the secondary channel by 8.5 cm in different flows, the lowest rate of sediment has entered the lateral intake and the current deflecting wall-sill had the best performance.

KEY WORDS: discharge ratio, lateral intake, sediment control, current deflecting wall-sill, river bend

INTRODUCTION

Gravity intake which was one of the best ways to take water from the rivers in the past has now changed into an entirely engineering structure based on designing principles the simplest kind of which is a 90-degree divergence of direct span of the river. Flow in the basin inlet has complicated characteristics and creates separation zone within the main channel and the branch. These areas include a separation zone in the inner wall of the split that is immediately after the intake entrance, a separation zone (zone A), a separation zone in the main channel after the intersection (zone B), and a stagnation point near the bottom of the split (Figure 1).

Fig. 1: Flow pattern at entrance to lateral intake.
Neary and Odgaard (1993) carried out their laboratory studies on the hydraulic flow in 90-degree intakes in direct line and investigated the flow pattern, the flow dividing line, the static and separation zone. Formation of secondary flows and rotating zones will lead to sweeping the near-bed sediments into the intake and their entrance to the rotation zones and will disrupt the operation of discharge system.

Control of Erosion and sedimentation at the intake mouth of the rivers for irrigation and drainage networks, power plants and water treatment plants, has long been emphasized and methods such as concrete, vegetation, cobblestone, stone mesh, cement, and construction of breakwater wall were used that were followed by high costs and adverse side effects. Due to high cost of traditional methods thought to make new structures and the newest method is the use of current deflecting wall-sill.

Application of current deflecting wall-sill in different combinations and various channel widths of primary and secondary deflecting walls in the discharge ratio of 0.2 has a significant effect on the rate of sediment entering the lateral intake, so that up to the height of wall-sill as 0.3 of the depth of the current, installing the wall-sill will have a good performance and higher than that it will be a negative parameter. These structures are designed for secure and maximal water uptake, reduction of entering sediments and if possible complete elimination of them along with the reduction of negative effects on morphological conditions of the river and decrease of the costs of construction, operation, and maintenance. In general, with regard to the pattern of intake flow the mechanism of reducing the entrance of sediments into the intake and maintaining the efficiency of intake should be based on reducing or neutralizing the secondary flow, limiting the spread of flow divider level in bed, decreasing the size of separation zone and increasing the longitudinal acceleration rate around the stagnation point in the lower tip of the intake. Given the intake inflow pattern, the size of flow divider screen determines the rate of flow discharge by the diversion channel and on the other hand it is possible that the entered sediments accumulate near the inner wall of the diversion channel. Current deflecting walls are designed based on modeling and shape of flow divider screen, flow separation zone within the intake in the left side and the stagnation point in the bottom corner. By weakening the power of whirlpool area in form of the intake, the secondary flows within the intake draw away the sediments from the intake mouth.

For the first time researchers in Hamburg in 1980 used a structure named current deflecting wall-sill (CDW) to prevent sediments from entering the harbours. Due to pressure difference between the upper and lower layers of the water column behind the primary current deflecting wall-sill a divergent vortex with horizontal axis is formed in front of the harbour and draws away the sediments from there.

Open-channel dividing flow is characterized by the inflow and outflow discharges, the upstream and downstream water depths, and the recirculation flow in the branch channel. Ramamurthy and Satish, (1988), Ingle and Mahankal (1990), Ramamurthy et al. (1990), and Hager, (1992) recognized that the downstream-to-upstream discharge-ratio of the main channel is the most relevant parameter in the analysis of open-channel 90 degree dividing flow.

Masjedi et al. (2011) studied laboratory research into effect intake angle on discharge ratio in lateral intakes in 180 degree bend. Investigation on lateral intake and determination of intake angle is among the most important issues in lateral intake on discharge ratio with model intake angle were measured in a laboratory flume under clear-water. Experiments were conducted for various intake angles and different locations with one Froude number. The results of the model study indicated that in all locations at 180 degree flume bend, increases discharge ratio occurs at angle of lateral intake of 45 degree.

![Fig. 2: The experimental setup (Plan).](image)

**MATERIALS AND METHODS**
All of the experiments were conducted in a flume located at hydraulic laboratory of Islamic Azad University of Ahvaz. The experiment reported herein was conducted in a recirculation flume, with central angle of 180 degree, central radius of \( R_c = 2.8 \text{ m} \) and width of \( B = 60 \text{ cm} \). Relative curvature of bend was \( R_c/B = 4.7 \) which defines it as a mild bend. Straight entrance flume with the length of 9.1 m was connected to the 180 degree bend flume. This bended flume is connected to another straight flume with the length of 5.5 m. The test area of the flume is made up of an aluminum bottom and Plexiglas sidewalls along one side for most of its length to facilitate visual observations. At the end of this flume a controlling gate was designed to adjust the water surface height at the desired levels. Lateral channel was wide \( b = 0.25 \text{ m} \) and ended with a weir to ensure that the considered downstream sections were sub critical and nearly uniform. The division corner to the branch channel was sharp-edged rectangular and open-channel junction consisting of a main channel (Fig. 2).

The water flow was initially directed from the main channel downstream into the channel to prevent damage to the flat bed at the beginning of the experiment and to do proper drainage of the bed so that its point could reach a uniform density.

After water covered the surface of sediments completely and the depth of water on the bed was appropriate, the main flow of water slowly entered the main channel and the water level and uniform depth were created and controlled in the main channel (\( Y_m \)) by means of downstream valve and the altimeter that was along the main channel.

The discharge ratio in the width unit equal to 80-20 was examined. In this case, the first digit on the left represents the output percentage of the end of main channel and the second digit represents the discharge of lateral channel and the ratio of 80-20 was equal to the discharge ratio of 0.2. The experiments depth boundary was selected in such a way that there was only the bed load movement. The bed load was provided by the movement of bed materials at the intake upstream.

After reaching steady flow conditions, the input valve of intake was adjusted as the discharge ratio of 0.2 by means of 90 degree triangular weir downstream of the intake and by controlling the output discharge. After the test time about 2 hours and reaching the relative balance state, the water flow was gently interrupted. At the end of each experiment and after the full discharge of water in the flume the bed load sediments entering the intake canal were collected.

The diverted sediment was collected in special containers and was sent to the laboratory to get dry. The variables of the experimental model and its installation position in front of intake are displayed in figure (3).

![Diagram](image)

1- Flow direction in intake channel 2- Secondary CDW angle 3- Secondary CDW width 4- Secondary CDW 5- Current deflecting wall-sill 6- Primary CDW width 7- Downstream track width 8- Sill 9- Sediment bed 10- Flow direction in main channel

**Fig. 3:** The variables of experiment model and its installation position in front of intake.

Since there was no specific recommendation about the length and radius of primary and secondary diversion walls results are displayed in Table (1), it was tried to select some values for the radius of primary and secondary diversion walls so that the curvature of the walls would be in accordance with the intake flow pattern and the created turbulence would be minimized. The radius of the curvature of primary diversion wall is 0.33m (\( r_{p/bm} = 0.55 \)) and the length of the wall ranges from 0.322 to 0.412. In the present research, the length of 0.367 m was used. The length of secondary diversion wall is 0.11 m and its radius is 0.18 m. (\( r_{s/bd} = 0.75 \)). The flow depth (\( Y_m \)) ranges from 6.85 to 11.7 cm and in this research the flow depth is 10cm. The flow discharge changes (\( Q_m \)) in the main channel ranges from 10.67 to 25.89 l/s and the discharges of 17, 18, 20 l/s have been selected. The width of primary channel (\( W_p \)) ranges from 11 to 15.5 cm and the widths of 14, 11, 12.5 cm were selected. The width of secondary channel (\( W_s \)) ranges from 5.5 to 10 cm and the widths of 6.5, 7.5, and 8.5 cm were
selected. Among the values of $43^\circ$ and $63^\circ$ for the $\alpha$ angle, the angle of $63^\circ$ which had produced the best results in the research conducted by Mahtabi et al. (2011) was used. The sill height ($h_{\text{sill}}$) ranges from 1.2 to 3.2 cm and the height of 3 cm was selected. The end position of diversion wall (the width of downstream trick) ($z$) ranges from 0.42 to 0.52 ($Z/b_d = 0.42-0.52$) and due to better performance of primary and secondary diversion wall-sill at $Z/b_d = 0.42$ in all experiments $z$ is considered to be $0.42*25$ which is equal to 10.5 cm; $b_d$ is the width of intake channel which is equal to 25 cm.

**RESULTS AND DISCUSSIONS**

In this study, in order to investigate the effect of current deflecting wall-sill on the reduction of sediment transport entering the lateral intake in the river bend an at three Froude numbers 0.33, 0.3, and 0.28, structural and non-structural experiments (Figure 4) were carried out in order to obtain the best primary and secondary channel widths to minimize the relative discharge of diversion sediment over the arched flume. The percentage of relative diversion discharge is obtained by the discharge ratio of diversion channel to the main channel multiplied by 100. Moreover, the percentage of relative diversion sediment discharge is obtained by the discharge ratio of diversion sediment to the sum of diversion and passing sediment discharge multiplied by 100.

![Fig. 4: Diversion wall installed in front of intake inlet.](image)

*The effect of channel widths of primary diversion wall ($W_p/b_m$) on the reduction of sediment entering the intake at different $W_\text{s}$.*

In Figures (7-a, 7-b, 7-c) the effect of channel width of primary diversion wall on the reduction of input sediment is shown for three channel widths of secondary diversion wall and different discharges. As it is observed in the figures, the entrance of sediment into the intake reduces as the channel width of primary diversion wall increases.

In Figure (7-a) at the discharge of 17 l/s and secondary channel depth of 6.5 cm and primary channel depth of 12.5 cm the best performance was achieved, i.e. the sediment reduction was equal to 86.98%. In general, at the primary channel depth of 12.5 cm in all discharges of 17, 18, 20 l/s at the state of $w = 6.5$ cm, the highest percentage of reduction of sediment entering the intake was obtained. In Figure (7-b) at the discharge of 17 l/s and the secondary channel depth of 7.5 cm as the primary channel width increases, the rate of sediment entering the intake channel has increased, i.e. the percentage of reduction of sediment entering the intake has decreased and the highest rate belongs to the primary channel depth of 11 cm. At discharges of 18 and 20 l/s and the primary channel depth of 7.5 cm the highest percentage of the reduction of sediment entering the intake at the primary channel depth of 12.5 cm is obtained. It seems like that as the channel width of primary deflecting wall increases and the ending tip of the primary diversion wall is placed in the inlet suction position, the power of vertical whirlwind current at the downstream corner and the horizontal whirlwind current inside the intake has decreased. This makes less sediment enter the intake.

In Figure (7-c) at various discharges (17, 18, 20 l/s), and secondary channel depth of 8.5 cm and primary channel depth of 12.5 cm, the percentage of reduction of sediment entering the intake is maximized. The review of three figures (7-a, 7-b, 7-c) indicates that the highest percentage of reduction of sediment entering the lateral intake occurred at the discharge of 17 l/s, primary channel depth of 12.5 cm and secondary channel depth of 8.5 cm. In this research, the percentage of reduction of sediment entering the lateral intake was equal to 90%. Therefore, in such conditions, the lowest rate of sediment enters the lateral intake. In order to demonstrate how the experiment is carried out, some images have been taken from its different stages (Figure 8).
Fig. 7: The effect of channel widths of primary diversion wall ($W_p/b_m$) on reduction of sediment entering the intake at various $W_s$. 
Fig. 8: The effect of channel width of primary diversion wall \((W_p/b_m)\) on the reduction of sediment entering the intake at various \(W_s\).

**Results comparison:**

In order to compare the effect of channel width of primary deflecting wall \((W_p)\) on the reduction of sediment entering the intake at various widths of secondary channel \((W_s)\), in this research and the other ones, the results of the studied conducted by Mahtabi, Gh., Hassanzadeh Dalir, A. (2011) are used that show the percentage changes of the reduction of sediment entering the intake with the flow discharge ratio at different channel depths of secondary diversion wall \((W_s)\). As it can be seen in the figures, the entrance of sediments into the intake has decreased as the channel width of the primary diversion wall has increased. The best performance of the wall belongs to the primary widths of 14 and 15 cm, secondary width of 8.5 cm, and the discharge ratio of 0.2 which have almost minimized the amount of sediment entering the intake (Figure 8).

**Conclusion:**

In this research, the effect of current deflecting wall and the combination of different patterns of its components on the discharge ratio and control of sediment was investigated. The results showed that in the primary pattern of current deflecting wall with the installation angle of 63° for the secondary diversion wall less sediment entered the intake. As the discharge increased in the main channel the rate of sediment entering the intake increased, too and at higher discharges the rate of sediment entering the intake has intensified more. Installing the sill carried away the bed load current in front of the intake and directed it towards the central part of the main channel. In the early moments of the experiment, a scour begins to be formed along the vertical axis or the line of primary diversion wall, beneath the wall and due to rotational flows downstream of the primary diversion wall a fake wall consistent with the primary diversion wall is formed. The fake wall along with the sill controls the bed load sediment entering the intake quite well and the entrance of sediments into the intake from the upstream is almost stopped. Due to high speed of the flow entering the secondary channel, the sediments that entered through the third slot had no chance to settle at the intake inlet and nearly no sediment was settled in front of the intake inlet especially in the turbulent region. As the channel width of the primary diversion wall increased, the sediments entering the intake decreased and in this research the highest percentage of reduction of sediment entering the intake by 89.6% was observed at the primary channel width of 12.5 cm and secondary channel width of 8.5 cm. In other words, by installing the model at the intake the rate of sediment entering the intake reduced about 90%. It seems like that as the channel width of primary diversion wall increased, the
replacement of the ending tip of the primary diversion wall in the inlet suction segment, the power of vertical whirlwind current at the downstream corner and the horizontal whirlwind current inside the intake decreased. Moreover, the results showed that the current deflecting wall was sensitive to the channel width of secondary diversion wall, so that as the channel width of secondary diversion wall increased and the rate of flow passing through the channel decreased, the interactive effect of this parameter and the channel width of primary diversion wall affected the structure performance. The increase of sill height is considered as a negative parameter because it reduced the speed in near-bed layers in front of the bed and consequently decreased the performance of current deflecting wall. In this research the height was considered to be fixed.

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REFERENCES