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Feasibility study of sedimentation reduction in river intake

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A B S T R A C T

Sedimentation in river intakes causes many problems such as reduction of system delivery efficiency and increasing of maintenance costs. Several methods have been introduced for sediment control in river intakes and an effective method for preventing sediment entering into river intake is submerged vanes. The overall effective strategy for reducing bed sediment transport into the intake should be based on reducing the strength of the secondary flow and limiting the extent of the dividing stream surface at the bed. The objective of this study is to explore the possibility of applying an effective structure to control bed load sediment at the river intake. Current Deflecting Wall-Sill (CDW-Sill) was employed as a new method of controlling bed load sediment at river intake. The experiments were carried out under the live bed condition at the flow intensities (V/VC) of 1 and 1.1 for five hours. The relative discharges of the flow into the diversion which is defined as a ratio of diversion unit discharge to main channel unit discharge (qr) were equal to 0.2, 0.4 and 0.6. The results showed that the performance of the CDW-Sill, up to the available specific discharge ratio of 0.6, was better than the submerged vanes. However up to specific discharge ratio of 0.4, the width of primary CDW channel equal to 14 cm had the best performance which eliminated the sediment uptake.

1. Introduction

River intakes are structures which divert water directly from a river for irrigation networks, water supply, power stations, and other water uses. Design of intake in rivers must consider issues related to erosion and sedimentation. The structure should be designed in a condition that minimizes the amount of bed load sediment that enters into the intake. Flow pattern in river intake is turbulent and wholly three-dimensional (3D). Figure 1 shows the 3D flow patterns generated due to river intake [1 and 2]. As shown in Figure 1, because a larger portion of the near-bed flow is diverted; the intake channel will receive a relatively large amount of bed sediment. Accumulation of sediment at the entrance of river intake (zone A, Figure 1) causes decreasing of the flow passing width and reduction of channel conveyance efficiency [1 and 2].Several methods have been introduced to sediment control in the river intake and suitable means are required to overcome sedimentation difficulties. An effective and cheap way based on altering of the bed shear stress distribution is the use of submerged vanes [3 and 4]. Submerged vanes change the near bed flow pattern and produce a scour trench in front of the river intake. This makes submerged vanes useful to be the means of minimizing bed sediment transport into diversion [5]. Efficiency of submerged vanes is depending on an especial hydraulic condition. In the values of qr<0.2 (ratio of unit discharge in the river intake to unit discharge in the main channel), submerged vanes eliminate the sediment entering into

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the intake. The effectiveness of the vanes diminishes in qr>0.2. The performance of the vanes can be improved in several ways. One way is the use of a skimming wall in along with the vanes [5].Neary et al. [2] stated that effective strategies for minimizing sediment entering into the intake should be regarded as: reducing the strength of the secondary circulations, limiting the extent of the dividing stream surface at the bed and promoting the longitudinal velocities in main channel around the stagnation point. Siltation is an important problem in river harbors. A relatively new method to minimize harbor sedimentation is the use of Current Deflecting Wall-Sill (CDW-Sill).

This structure consists of three parts (Figure 2): a vertical screen, curved in the horizontal plane, a channel between the wall and the riverbank and a sill at the sea-side of the harbor entrance [6, 7 and 8]. During 1991, the CDW was used at the entrance of the Kohlfleet harbor in Hamburg and studies showed that sedimentation could be reduced by about 40%. The function of the CDW-Sill is that it captures the water required at the harbor from the upper section of the water column that contains little sediment [7, 9 and 10]. Winterwerp [8] stated that the efficiency of CDW-Sill strongly depends on its detailed shape and structural details such as the length and curvature of the CDW, the distance between the CDW and the streambank (defined as the CDW channel) and the shape.

The objective of this study is to explore the possibility of applying an effective structure to control bed load sediment at the lateral intake. Current Deflecting Wall-Sill (CDW-Sill) was employed as a new method of controlling bed load sediment at lateral intake and the performance of Current Deflecting Wall-Sill was evaluated.

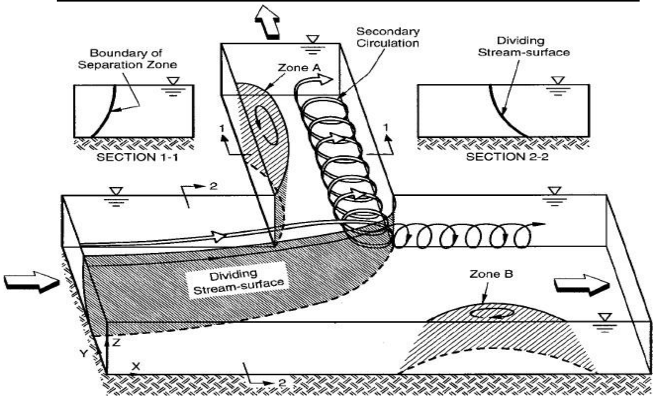

Fig.1. 3D flow pattern in river intake [2]

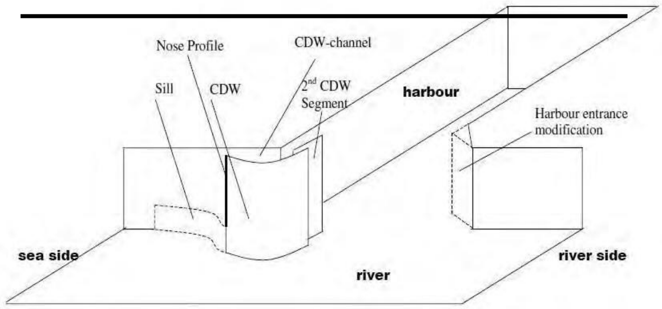

Fig.2. Design of the CDW-Sill system for Parkhafen harbor and its components [10]

2.Materials and Methods

2.1.Experimental set up and procedure

The experiments were conducted in a sediment channel with a lateral channel perpendicular to the main channel. The main channel was 6 m long and 0.6 m wide. It was filled with a 15 cm deep layer of uniform sediment and the grain diameter was 1.145 mm. The lateral intake was located 3.2 m downstream from the channel entrance. Lateral channel was 4 m long and 0.24 m wide. The diversion floor level was the same as the bed level in the channel. The relative discharges of the flow into the diversion which is defined as a ratio of diversion unit discharge to main channel unit discharge (qr) were equal to 0.2, 0.4 and 0.6. The experiments were carried out under the live bed condition at the flow intensities (V/VC) of 1 and 1.1 for five hours [11]. At the end of each experiment, amount of sediment entering into lateral diversion was collected, dried and weighed. The performance of sediment control of Current Deflecting Wall-Sill was investigated and compared with performance of submerged vanes. Length and radius of CDW was fixed and effect of width of primary and secondary CDW channel was investigated (WP and WS, respectively). The 2D and 3D schematic layout of Current Deflecting Wall-Sill in front of diversion and its variables tested are shown in Figure 3 and 4, respectively. Dimensions and layout of submerged vanes were chosen based on researchers' suggestions [3, 4 and 5]. In table 1, CDW-Sill parameters which were tested in experiments are shown.

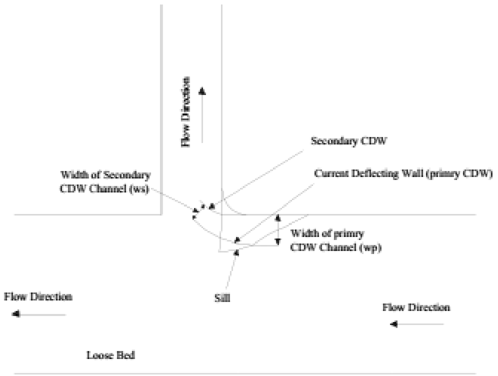

Fig.3. Current Deflecting Wall-Sill in front of intake and its variables

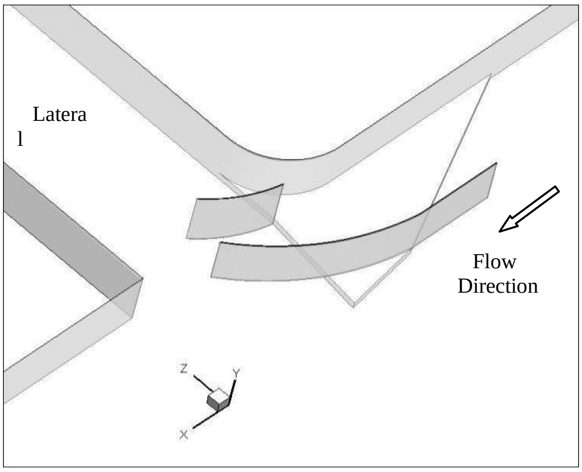

Fig.4. 3D schematic of Current Deflecting Wall-Sill in front of intake

Table 1- Tested parameters of CDW-Sill in experiments

Width of secondary CDW channel (W_S, cm)	Width of primary CDW channel (W_P, cm)
6.5-8.5	11-14

3. Results and Discussions

As shown in Figure 5, by increasing lateral intake discharge (qr), rate of sediment entering into the intake (Qb) increases. In the experiments, it was also observed that the performance of the CDW-Sill, up to the available specific discharge ratio of 0.6, was better than the submerged vanes and sediment entering into intake reduced 51.2 percent. Since the primary CDW was installed in direction of main channel so, water was evenly supplied by primary CDW channel from entire of flow depth. The results showed that application of sill kept the bed load away from the diversion entrance efficiently and due to flow circulation in downstream of primary CDW and creating an artificial wall in downstream of primary CDW, no sediment entered into the lateral channel from upstream of main channel. The artificial wall stretched from the end of Sill and continued to the downstream edge of diversion entrance.

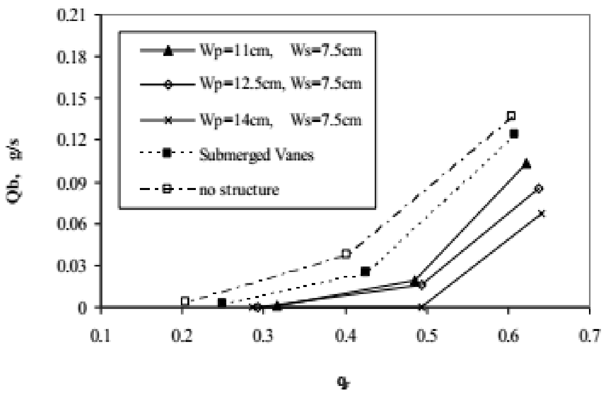

Fig.5. Variation of bed load sediment transport into the intake (Q_b) versus q_r

Figures 6 shows the performance of CDW-Sill in reduction of entering sediment versus various widths of primary CDW channel respectively (W_P) in various q_r at W_S=7.5 cm. As shown in Figure 6, by increasing width of primary CDW channel, entrance of sediments into the lateral intake decreases at various q_r. However up to specific discharge ratio of 0.4, the width of primary CDW channel equal to 14 cm had the best performance which eliminated the sediment uptake. The function of primary CDW channel is to supply water needed for diversion, therefore by increasing its width, strength of incoming flow into lateral intake reduces at the downstream edge of entrance. In lower specific discharge ratio (q_r=0.2), there was flow returning from entrance of lateral channel to main channel. This returning flow pattern was observed in side of downstream lateral channel wall. Sediment entering into intake settled far away from diversion entrance (approximately three times width of lateral channel) with low height and no sediment settled in intake entrance and in the separation zone (Figure 7).

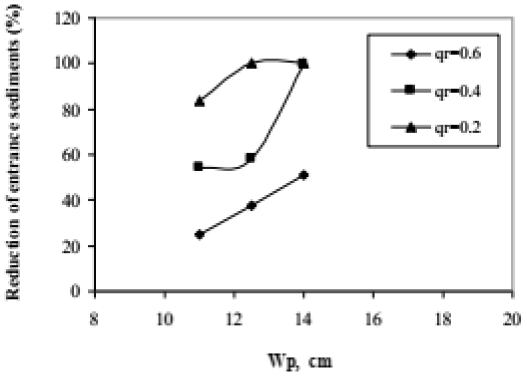

Fig.6. Variation of reduction of sediment transport into the intake versus q_r at W_S=7.5 cm

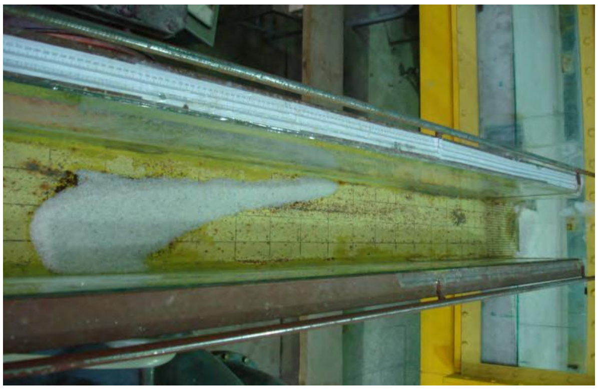

Fig.7. Pattern of bed sediment topography in intake channel at the experiment with CDW-Sill (q_r=0.6)

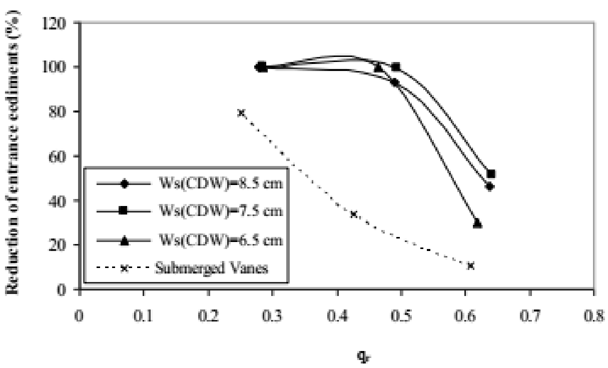

Fig.8. Variation of reduction of sediment transport into the intake versus q_r at W_P=14 cm

The performance of various widths of secondary CDW channel in reduction of sediment entering into the intake versus q_r is shown in Figure 8. As shown in this Figure, CDW-Sill has approximately the same performance in various width of secondary CDW channel. On the other hand, the performance of CDW-Sill almost doesn't rely on W_S. Also, no sediment has entered into intake up to relative diversion unit dischargeof 0.5. It shows that with the CDW-Sill it is possible to reduce the sediment entering into the intake by 28– 100 % in various relative diversion unit discharges.

4. Conclusion

Sedimentation is a serious problem at many river intakes. In recent decades, many studies have been conducted on the subject, aiming to reduce the sedimentation at river intake. Several methods have been introduced for sediment control in river intakes and the suitable means are required to overcome sedimentation difficulties. In this research, the Current Deflecting Wall-Sill is used as a new way to reduce sedimentation in river intake. According to these experiments, under live bed conditions, it was concluded that CDW-Sill can prevent the sediment entering into river intake efficiently. In the most successful case (the model with WP=14cm), no sediment entered into diversion up to specific discharge ratio of 0.4. Also, the CDW-Sill increases the rate of diversion discharge by 14-38 percent up to the specific discharge ratio of 0.4. Further researches are required to establish the effect of different parameters of the CDW-Sill in sediment control at river intake

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