Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 54(11) (2023) 821-824
DOI: 10.22060/ceej.2022.19130.7080

Study of the effect of various scenarios of the sediment control on banks in the vicinity of lateral intake entrance

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ABSTRACT: One of the main goals in diverting water flowing in rivers is to provide the required water (for different purposes) with a minimum of sediments, which is usually met through the installation of sediment control structures with different arrangements to significantly decrease the sediment that enters the intake. In addition to sediment control, serious attention should also be paid to the impact of these structures and sediment control scenarios on the riverbank and other relevant facilities located in the vicinity of the intake entrance. Using a laboratory scale canal, equipped with recirculating sediment and included a 90° lateral intake and a bed moving because of dunes movement, the effects of these structures including sill, spur dike, and submerged vanes on the banks in the vicinity of intake entrance experimentally investigated at four different sediment control scenarios and different discharge ratio. In order to accurately evaluate the scour near the banks, after dynamic equilibrium was achieved at the bed due to continuous changes of its elevation in these conditions, scour time series analysis was performed at upstream and downstream points near the intake, along the banks on either side of the main canal. The results show that different behaviors are observed near the intake due to various factors influencing the flow. While in the range of discharge ratios studied, the spur dike increases the depth and length of scour zone at the intake downstream by an average of about 72% and 34%, respectively, the submerged vanes reduce the length of scour zone by 37% and at the discharge ratio of 0.12, an increase of about 66% in the depth of scour zone is observed, while at the discharge ratio of 0.18, a decrease of about 24% in the depth of scour zone occurs.

Review History:

Received: Oct. 14, 2020
Revised: Mar. 22, 2021
Accepted: May, 21, 2022
Available Online: Aug. 16, 2022

Keywords:

Scour
Intake
Sill
Spur dike
Submerged vanes

1- Introduction

In the field of river engineering, the supply of water required for industrial, urban or agricultural uses with minimal sediment is one of the top concerns in diverting water from rivers. There are many researches done to identify the flow pattern around the intake and to investigate the associated influencing parameters [1-8]. In addition, as an integral part of the river system, sediment can enter the lateral intake along the river flow, which can eventually lead to the disruption of water withdrawal targets. In this regard, various conditions and scenarios have been considered by researchers including the use of hydraulic structures such as sill, spur dike or dike, and submerged vanes to control the sediment entering the reservoir. Although these structures alone or in combination with other structures, under some conditions show very high efficiency in controlling sediment entering the reservoir through applying a series of changes in the flow pattern, they may cause significant negative impacts on the areas around the reservoir of the river, including scour and sedimentation areas around the reservoir, especially on the coast side, that can adversely impact the stability of the coast or the operation of ancillary facilities. Therefore, evaluating the possibility of sedimentation and scour on the shores around the reservoir can be highly beneficial in the design of reservoirs and positioning-related structures. In this study, the behavior of the bed is investigated under different conditions, by measuring the elevations of the bed with time around the intake entrance at the left and right shores.

2- Methodology

In this study, the experiments were performed in a canal with a length and width of 18 and 1 m, respectively, with a wall made of Plexiglas, 1 cm thick. The floor has a siliceous sediment bed with an average diameter of 1 mm and a slope of 0.001. At a point located 11.2 m downstream of the beginning of the main canal on the left bank, a diversion channel 2 m and 0.4 m long and wide, respectively, with an angle of 90 degrees to the main canal has been installed. Both the main canal and the intake are equipped with a recirculating sediment system and the sediment leaving the canals is directed to the beginning of the main canal by a sludge pump. At a flow rate of 56 lit/s and three ratios of discharge of 0.12, 0.15, and 0.18,

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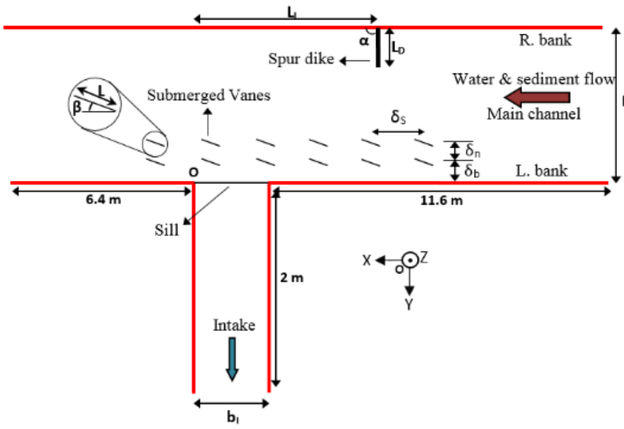

Fig. 1. The array of sediment control structures in the fourth scenario

Table 1. Design characteristics of the fourth scenario (dimensions (m), angles (degree)

Design characteristics	H_s	L_I	L_D	α	β
	0.035	1	0.25	90	20
Design characteristics	L	B_m	B_I	δ_s	δ_b
	0.108	1	0.4	0.18	0.108
Design characteristics	δ_n	H_v	h_m		
	0.108	0.036	0.118		

the experiments were carried out at four scenarios of sediment control as follows; first scenario: No Structure or "NS", second scenario: use of Sill or "S" scenario, third scenario: simultaneous use of Sill and Spur Dike or "SD" scenario and the fourth scenario: simultaneous use of sills, Spur Dike and submerged vanes or "SDV" scenario (Figure 1 and Table 1). In each of the experiments, the changes of the bed elevation were recorded with time until the end of the experiment (i.e., after the bed reached a dynamic equilibrium).

3- Results and Discussion

Figure 2 shows the longitudinal profile of the bed near the left bank at different sediment control scenarios and an identical Qr. Comparison of the first and second scenarios' results indicates that the presence of the sill causes the accumulation of sediment in front of the intake. Part of these sediments directed downstream with the flow, reduces the length and depth of the scour zone along the flume wall downstream of the diversion near the left bank, particularly at the discharge ratios of 0.15 and 0.18. By installing a spur dike on the right bank, due to the increase of flow velocity near the left bank, scour occurs from the upstream to the downstream of the intake adjacent to the left bank of the main canal, which leads to an increase in the size of scour holes at the upstream and downstream and a reduction in the bed elevations in front of the intake. By adding submerged vanes in front of the intake, severe scour occurs near the left bank due to the vane-induced secondary circulation flow of the vanes.

Also, at the upstream of the main canal, the scour depth increases as it approaches the intake opening and reaches its maximum near the upstream edge of the intake, which is due to the increase in vane-induced secondary circulation flow as a result of participation of more vanes in the secondary flow production.

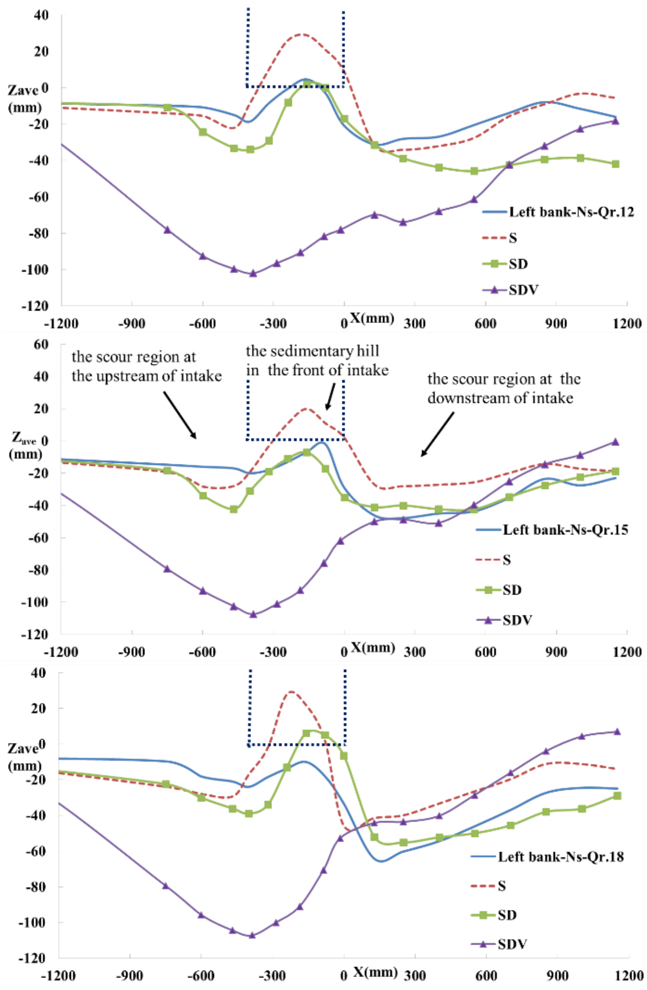

Fig. 2. The average of bed longitudinal profile at the left bank under various scenarios of sediment control

By moving towards the downstream and away from the upper edge of the intake the scour depth decreases. The scour depth reduction can be explained by the reduction of flow rate and flow velocity as a result of the diversion of part of the flow into the intake and also the reduction of vanes efficiency due to distance from the optimal angle of the vanes. Moreover, after the last row of vanes downstream of the intake, the power of vane-induced secondary circulation flow is reduced due to the lack of vanes leading to the accumulation of swept sediments from the upstream, which causes the scour depth gradually approaches zero at the downstream.

4- Conclusions

- The diversion of water from the main canal to the intake creates two scour zones upstream and downstream of the intake adjacent to the shores in the main canal.
- The downstream scour zone, which covers about a quarter of the front of the intake, has a greater length, width and depth than the upstream scour zone, which extends to the middle of the intake.
- Due to the influence of various factors such as suction conditions in the intake, momentum changes with depth of flow in the main canal, fully three-dimensional flow conditions and the effects of each of the aforementioned structures on water flow, under different conditions the effects of structures on the length, depth and width of the scour zones upstream and downstream of the intake vary.

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HOW TO CITE THIS ARTICLE

A. Attarzadeh, A. Babakhani, Study of the effect of various scenarios of the sediment control on banks in the vicinity of lateral intake entrance , Amirkabir J. Civil Eng., 54(11) (2023) 821-824.

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