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ORIGINAL ARTICLE

Enhancing sediment distribution at the vicinity of power plant intakes using double rows of vanes and groins (Case study: New tebbin power plant)

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Abstract In terms of the importance of power plants, the adverse effect on the morphology of its neighboring area was investigated. As a case study, the New Tebbin Power Plant was investigated. A movable bed model, with a scale of 1:50 and relative density of 2650 kg/m^3, was constructed at Hydraulics Research Institute (HRI), the National Water Research Center (NWRC). The used particles have a mean diameter D_{50} of 0.17 mm. A comprehensive model test program was designed to cover the different river flow conditions and operation modes of the power plant. Sixteen (16) experiments were run at different flow conditions. Double rows of submerged vanes were mounted vertically at an angle of 60° to the main flow direction. These rows were set to generate a secondary circulation in the main flow in order to modify the near bed flow pattern thus re-distributing the flow and the sediment transport within the channel cross-section. For comparison purposes, a case was tested in the absence of vanes. Also, groins were added at the left bank (i.e., downstream of the intake structure along the flow direction) in order to minimize the sediment deposition downstream of the intake structure.

The study results showed that, in case of vanes absence, sediments with rates 1–2 m^3/week were stuck within the sediment trap under the winter conditions. Also, the results indicated that the submerged vanes play an important role in preventing the sediment intrusion. Also, it was clear that using groins might lead to enhancing the sediment distribution at the intake vicinity.

1. Introduction

Sediment deposition at the entrance of river intake structures is a vital problem especially at power plants that use river water for cooling. Sediment deposition reduces the withdrawn capacity, causes damages to the pumping system, and causes partial or full blockage of the intake. Sediment blockage might cause the plant to stop.

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The main functions of submerged vanes are erosion control, channel cross- section maintenance, adjusting the stream direction, and creating new bed morphology. The primary purpose of the vane application is to produce a scour trench in front of the intake. This scouring action allows the vanes to minimize the bed sediment intrusion into the diversions of the alluvial channels.

As a case study, New Tebbin Power Plant (NTPP) was investigated. This study was conducted in the Hydraulics Research Institute (HRI) experimental hall, the National Water Research Center (NWRC). The main objective of this study is to investigate the morphological conditions at the vicinity of power plants under different operation modes in order to mitigate the sedimentation problems at the intake structure vicinity.

The research phases of this study are presented in this paper as follows.

2. Reviewing the literature

Many studies were carried out to mitigate the enterance of sediment into intakes. Among these are:

Abdel-Fattah (2004) studied the river morphological changes using 2-D numerical model to investigate sediment distribution at El-Kurimat thermal power plant intake using both dredging and adding groins upstream the intake using different scenarios. He stated that using groins and dreading upstream intake increase the flow ratio in front of intake and divert sediment away off it. By surveying the field site after implementing these solutions, it was found that the intake still faces sedimentation problems [1].

AbdelHaleem (2008) executed an experimental study to minimize the sediment that enters the intake channel using a single row of submerged vanes. Throughout the research, he defined the optimum heights, angles, and positions of the submerged vanes in front of the intake channel [2].

AbdelHaleem (2009) executed an investigation using double and triple rows of vanes perpendicular to the flow direction. The main objective of this research was to determine the optimum vane characteristics. He recommended that the optimum vane characteristics should be as follows: attack angle 30° and vane height 0.3 water depth. He mentioned that these characteristics reduced the diverted sediment by 50–90% in case of triple rows and by 50–85% in case of double rows [3].

Hassanpour and Ayoubzadeh (2008) investigated experimentally the hydraulic performance of the submerged vanes within high Froude numbers. They indicated that in supercritical flow, a sudden increase in flow depth occurred downstream close to intake compared to the condition with no vanes. Their results showed that the application of 25° angle submerged vanes causes an increase in intake ratio. However, a reduction in intake ratio was observed in the case of 15° angle vanes and no change occurred to the intake ratio when the angle 20° was used [4].

Hossain et al. (2004) studied experimentally the scour around and downstream the bottom vanes. They developed empirical formulae for predicating the maximum scour depth to serve the determination of a safe depth for bottom vanes. The developed formulas related the flow depth and the projected area of the vane. They did not consider other parameters due to the fact that the equilibrium live-bed scour do not vary by increasing the velocity or the grain size [5].

Odgaard (2005) described the Iowa vanes, as structures placed in an eroding streambed that cause the flow to be redirected, which results in the deposition of sediment on the eroding bank. He visualized that vanes stabilize the stream without affecting the sediment load and velocity of other parts of the stream [6].

Sadjedi Sabegh (2004) made an experimental investigation on sediment control in intakes using submerged vanes in the intake of Bishe-zard River in Iran. He concluded that, in the three vanes orientation, the best result was obtained when the distance of inner vanes from the channel wall is 3 h (*h* is the vane height) and the distance between the other two vanes, in each row, is 2 h. For vanes with zigzag form, when the inner distance was 1 h and the across distance between vanes was 3 h, the best solution was obtained. Also he mentioned that, in case of using three vanes in each row, the sedimentation in the intake and delivery channel was decreased by 55%. However; in case of applying vanes in zigzag orientation, the depth and shape of groove became more suitable and the sediment deposition decreased by 75% [7].

Tan Soon-Keat et al. (2005) investigated the flow around the submerged vane which is 3-D in nature. They mentioned that the flow may be divided into four different zones according to the different locations around the vane. They described the flow structures in these flow zones (i.e., the left and right head zones in the direction of the flow, the immediate frontal zone, and the lee zone) [8].

In a recent investigation, the bed changes in a section of the river were computed using a 3-D model. The results were in accordance with the regular bed level surveys before and after the flow discharge at maximum, minimum, and dominant flow conditions.

Utilizing the reviewed literature, the present study was initiated. It focuses on investigating the efficiency of installing double rows of vanes in front of the intake in the flow direction with the addition of groins to the left side of the flow to redistribute the sediment downstream of the intake channel.

3. Executing experimental work

An experimental work was executed. It was conducted in the Hydraulics Research Institute (HRI) experimental hall, the National Water Research Center (NWRC). During this phase, the following was achieved.

3.1. Outlining the model similarity

For correct reproduction of a hydraulic model, a number of requirements must be fulfilled when determining the model scales. For example, the geometrical, the kinematic, and dynamic similarity. In the present case, the condition that Froude Number in both nature and model is equal (i.e., the velocity, discharge, and time scale ratios) was taken into consideration. They were determined, after the following relations.

$$\text{Velocity scale ratio} = n_v = (n_h)^{0.5} \tag{1}$$

$$\text{Discharge scale ratio} = n_\mathrm{q} = n_l n_h n_v = n_l (n_h)^{1.5} \tag{2}$$

$$\text{Time scale ratio} = n_\mathrm{t} = n_l / n_v = n_l (n_h)^{0.5} \tag{3}$$

where n_t is the time scale ratio, n_v is the velocity scale ratio, and n_l is the length scale ratio.