Numerical Investigation of formation of bed topography in a U Shaped Channel Bends with Lateral Intake with SSIIM2

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1-Introduction

Rivers are a major source of water for meeting various demands. A lateral intake in a straight reach of the river is the simplest method of flow withdrawal. In spite of its simple layout, using this system leads to complex flow patterns and sedimentation problems. Due to the suction pressure at the end of the branch, the flow in the main channel is divided into two portions. A portion enters the intake channel and the remainder continues downstream in the main channel. Along the main channel, before the junction region, there is a curved shear-layer surface known as the dividing stream surface that separates these two portions. Since the entering flow has considerable momentum in the direction of the main channel flow, a separation region forms along the branch channel. A natural curved stream can be said to represent one of the most complex fluid-flow situations encountered in the environment. Hence in river bends, centrifugal effects lead to secondary flow where the water in the upper part of the river is driven outward.

Secondary flow advects the main flow, leading to a high velocity at the outer side of the bend. Flow near the bottom is directed towards the inside bank. The interaction of the main flow with this secondary flow forms the so-called three-dimensional helical flows. Knowledge of the hydrodynamic process in such curved flows is of significant practical importance since such knowledge facilitates the prevention of silting, the positioning of navigable routes, the dynamic stabilization of river topography and the choice of location for intake structure.

Hydraulic engineers attempt to reduce the sediment amount entering the intake and increase the discharge capacity of the diversion system. One strategy for sediment control is to mechanically separate the sediment from the water and eject it from the intake. Such an approach is expensive and may adversely influence the river environment by disturbing the local sediment regime. Other cost effective strategies are based on approach-flow modification that alters the bed-shear stress distribution, using e.g. arrangement of guide walls and submerged vanes to allow the most bed load sediment to bypass the intake. The design of such devices requires complete understanding of the underlying flow physics and the interaction between flow and sediment transport.

Due to the role of helical motion in driving the upper part of the river bend flow outward and directing the bottom currents toward the inside bank, the outer bank is a suitable choice of location for lateral intake structure. The helical motion causes the bed sediment particles to move towards the inside bank and consequently reduces the entering sediment to lateral intake. In contrast, the intake structure withdraws water from the upper layers of the main channel that contain minimum amount of sediment. The helical motion along the curved reach of the river together with the lateral intake suction form a complex flow along the main channel and through the lateral diversion because of the complexity of the flow and the large degree of variability in geometrical configurations e.g. location and inclination angle of the diversion channel and flow conditions. Laboratory experiments alone cannot provide a deep insight of the complex 3D flow pattern and the associated phenomenon as bed and bank shear stress distributions.

3D numerical modeling, on the other hand, provides a powerful tool, which employed in conjunction with laboratory experiments which can enhance greatly the understanding of the mechanism of flow and sediment transport in channel bend.

2-Experimental model

The studied field is a channel with a 180° bend with intake used in Montaseri's lab studies (2008) that carries out at the hydraulic laboratory of Tarbiat Modares University in Tehran.

The main channel consisted of 7.2 m long upstream and 5.2 m long downstream straight reaches.

A 180° bend channel was located between the two straight reaches. The channel was of rectangular cross-section 0.6 m width and 0.7 m height with 2.6 m radius of bend to centerline. The ratio of radius of bend to channel width was equal to 4.34. Fig. 2 shows a schematic view of the channel and experimental set up. The bed and the side walls of the channel were made of Plexiglas supported by a metal frame. The lateral intake was 2.5 m long with 0.25 m width. Lateral intake is located at position θ=115° of the channel

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bend. The diversion angle (□) was 45 degree.

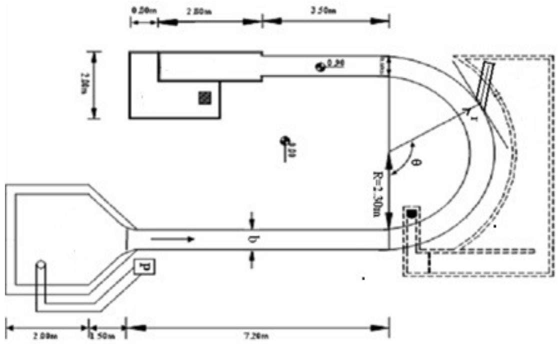


Fig 1. Geometrical specifications of 180° curved channel and lateral intake (Montaseri et. al., 2008)

3-Numerical model

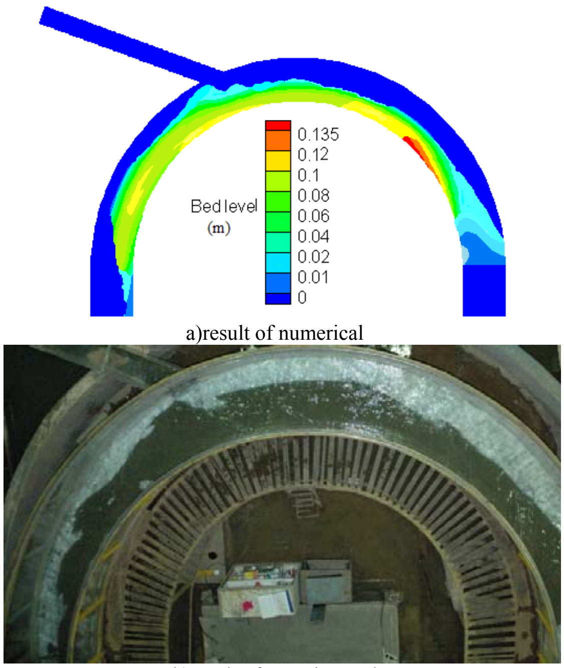
SSIIM is abbreviation for Sediment Simulation In Intakes with Multiblock option. This numerical model was developed by Nils Reidar Olsen. The SSIIM numerical model solves the Navier_Stokes equations with the *k*-*ε* model on a three-dimensional space. A control volume method is used for the discretization, together with the power-law scheme or the second order upwind scheme. The SIMPLE method is used for pressure coupling [14].

The main strength of SSIIM compared to the other CFD program is the capability of modeling sediment transport with movable bed in a complex geometry. This includes multiple sediment sizes, sorting, bed load and suspended load, bed forms and effects of sloping beds. The latest modules for wetting and drying in the unstructured grid further enable complex geomorphological modeling. Some limitations of the program consist of the following: the program neglects non-orthogonal diffusive terms; the grid lines in the vertical direction have to be exactly vertical; kinematic viscosity of the fluid is equivalent to water at 20° C and the program is not made for marine environments. So all effects of density gradient due to salinity differences are not taken into account [19].

4- Result

The mechanisms of sediment transport and bed topography are simulated with SSIIM software in the U shaped channel with lateral intake using injection of sediment on rigid bed. Lateral intake is located at position θ=115° of the channel bend, the diversion angle is 45 degrees and the discharge ratio is 30% of total discharge. The numerical model is implemented to see how bed forms in the U shaped channel with lateral intake developed. The numerical results show that the prediction of development of bed forms, mechanism of sediment entry into the intake, location of intermittent dunes and location of sediment deposition are in fairly good agreement with experimental data.

It is clear from Figure 2. that after about 60 minutes the sediment diversion rate is almost constant. Therefore, the time of experiments and numerical model was considered to be equal to 60 minutes. It was found that after the equilibrium time, there is a continuous sediment entry from the downstream edge of the intake and a periodic sediment entry from the upstream edge of the intake (for Q_r=30%).



a)result of numerical

b)result of experimental

Fig 2. Mechanism of sediment entry to water intake Numerical and experimental model