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Numerical and Empirical Studies on the Hydraulic Conditions of 90 degree converged Bend with Intake

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Abstract: A river's outer bank is the best place to install intake to mitigate the harmful effects of sedimentation. Flow pattern in the intake zone depends on bend geometry, intake location, and intake angle. All previous investigations on a ninety-degree channel bend are limited to studying the flow pattern in non-converged channel bends in the absence of wooden debris. Non-converged channel bends, in natural streams, convert to converged bends due to sedimentation effects. The minimum sedimentation in intake, in forest streams, can be seen in the best intake angle in converged channel bends. The experimental model has been employed to determine the best intake angle and the numerical model is used to investigate on flow regime in intake zone by Fluent. Comparing numerical results with empirical results shows that Fluent has a good capability to model flow in converged bend with intake.

Keywords: intake angle; wooden debris; converged bend; Fluent; Flow pattern

1. INTRODUCTION

One of the oldest and cheapest way to divert flow in streams for various purposes is to build gravity river intakes. Sediment and floating trees entrance into the intakes are the main problems in water transfer systems. The flow velocity within intakes are less than the main streams. Hence, the intakes are the best places for sedimentation and floating trees entrance.
Agaccioglu and Yuksel investigated on the sharped-crested weir discharge coefficient in different locations of a 180-degree bend [1]. Blanchet conducted a research to find the best stream diversion place in the rivers [2]. Dehghani and Salehi studied on the intake angle effect on the intake entering discharge. Georgiadou and Smith considered stream in converging 90-degree bend by experimental and numerical methods [3]. Nazari and Shafaie investigated intake angle in non-converged 90-degree bend. Novak et al., examined various intake degrees in the straight channels [4]. Raudkivi conducted the experimental research in straight channels to figure out the optimized intake angle to minimize the deviated sediment into the intake [5]. Toru investigated on the discharge and sediment within eleven intakes in the rivers [6]. Schmocker and Hager carried out the debris accumulated tests at a debris rack to determine the effects of various model parameters on the resulting backwater rise. The results of tests demonstrated that the accumulation process depending on the various factors and certain randomness should be considered.

The best intake angle should carry more water flowrate and less sediment flowrate simultaneously. To obtain this intake angles, sets of experiments have been carried out. To figure out flow pattern in intake zone, the numerical model has been employed by Fluent software.

2. EXPERIMENTAL SETUP

Experiments have been carried out in a 60 centimeters width and 40 centimeters height rectangular Flume. Arc center radius of curvature is 170 centimeters. The flume image is shown on Figure1. The flume has been made by glass wall. It consists 450 centimeters straight part follows by 90-degree convergent curve part with 5.0 convergence ratio and another straight section at the end. The Flume is located in Hydraulic laboratory, Azad University of Eghlid, Iran. Trapezoidal and triangle weirs are used to measure input discharge and input discharge to the intake (Figure 2). Experiments have conducted with different discharges (from 6.41 to 27.78 L/s) and five intake angles (30, 45, 60, 75 and 90 degrees).

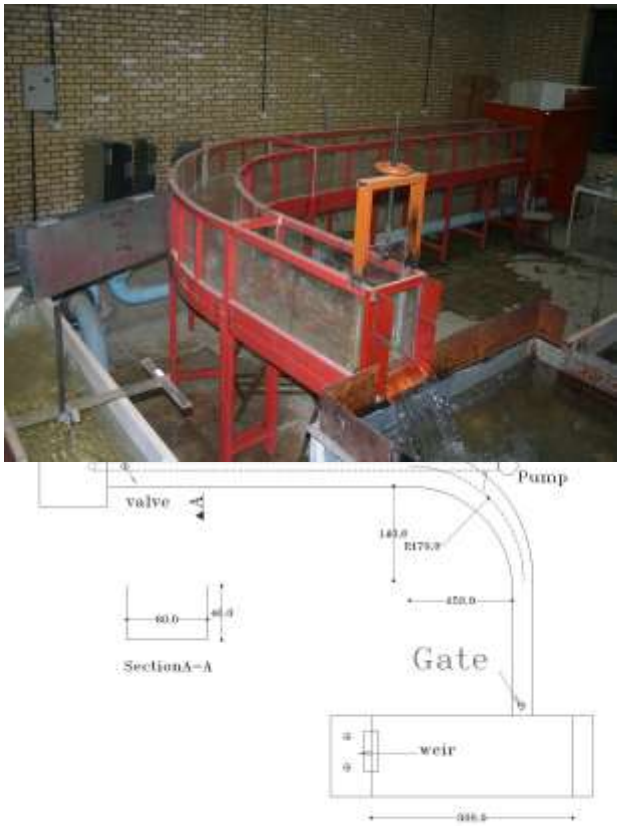
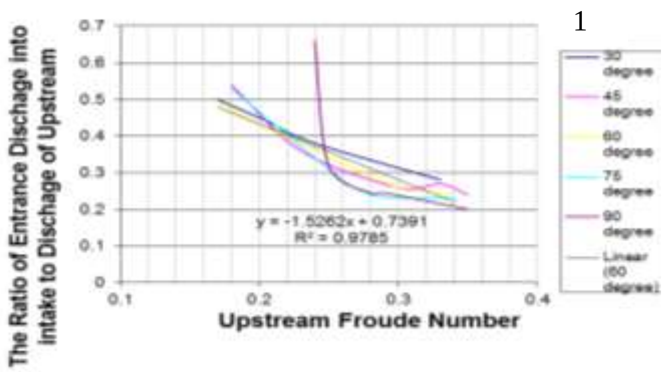


Figure 1. Plan and details of the flume

Figure 2. Trapezoidal and triangle weir

3. EXPERIMENTAL RESULTS AND DISCUSSIONS

Test results have been shown on the five distinct graphs. First graph shows the ratio of discharge within intake to discharge at upstream of converged bend versus the upstream Froude number. The second graph shows the ratio of number of debris entering into intake to total debris (ratio of NIT) versus the upstream Froude number. Third graphs demonstrates average of ratio of NITs for different intake angles. Fourth graph shows the average ratio of discharge conveying into intake (DIT) to discharge at upstream of bend for different intake angles. Ratio of DITs versus Ratios of NITs are shown on fifth graph.



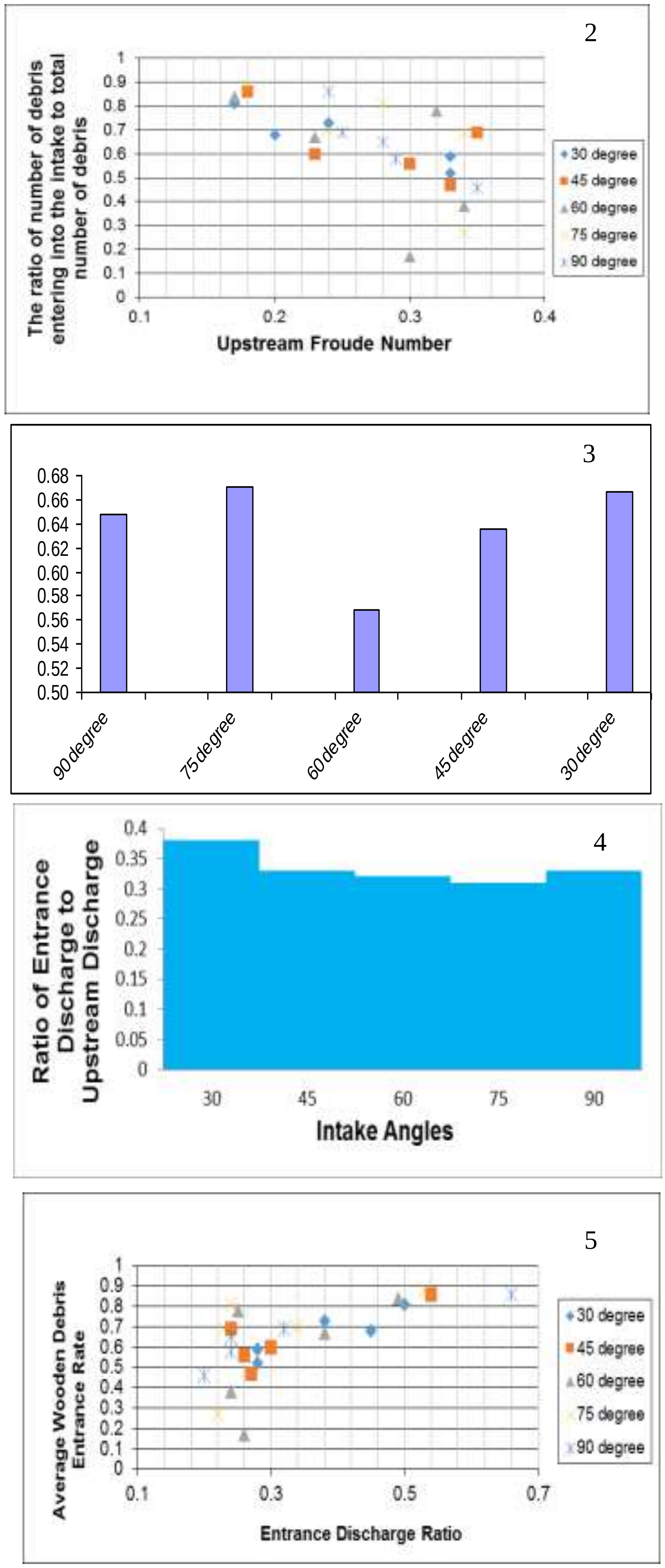


Figure 3. Experimental result graphs

It can be concluded from graphs on Figure 3 that the entrance discharges into the intake is inversely related to the Froude number. Also, 60 degree of intake angle is the best angle to catch less debris and 30 degree of intake is the best angle to intercept more discharge.

4. NUMERICAL RESULTS AND DISCUSSIONS

Numerical methods and artificial intelligence are widely used for simulation and prediction in engineering [7] [8]. Fluent is employed to solve Naiver-Stokes' equations. Many researchers used turbulent model (K- ε) to solve Naiver-Stokes' equations [9] [10] and compared their results with experimental works [11]. Since, this turbulent model is used to compute continuity and momentum equations in this study. The geometry of model is defined similar to experimental flume and meshed in Gambit.

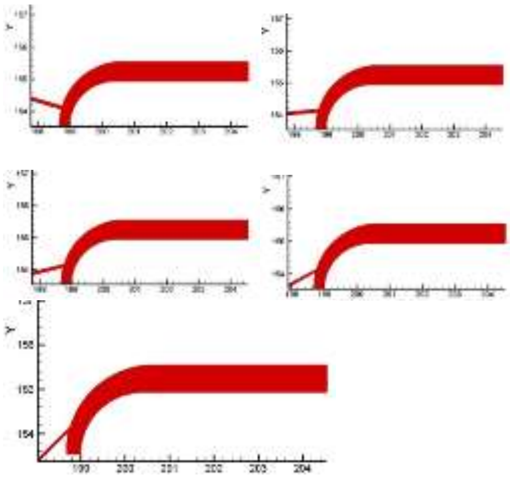
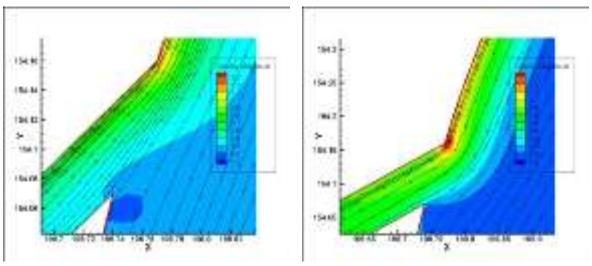


Figure 4. Details of mesh in geometry with different intake angles

To verify the numerical model, the experimental results is compared with numerical results in the following aspects: flow pattern and size of vortex zone.

4.1 Investigation on flow pattern

The secondary flow plays important role in flow pattern. When flow enters the bend, the water surface at outer bank will stay at higher elevation than water surface at inner bank. It causes pressure gradient toward inner bank. Figure 5 shows the streamline in intake zone for different intake angles. It can be seen on Figure 5 that vortex arises at 90 degree intake. It expresses that 90 degree intake is not an appropriate angle. This result is consistent with other researchers' results.



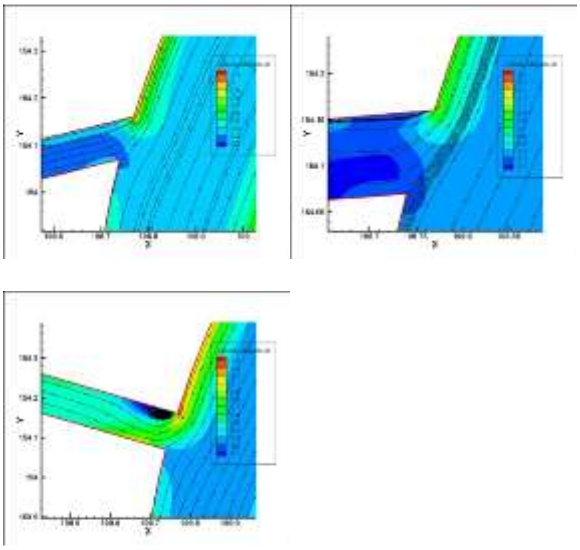
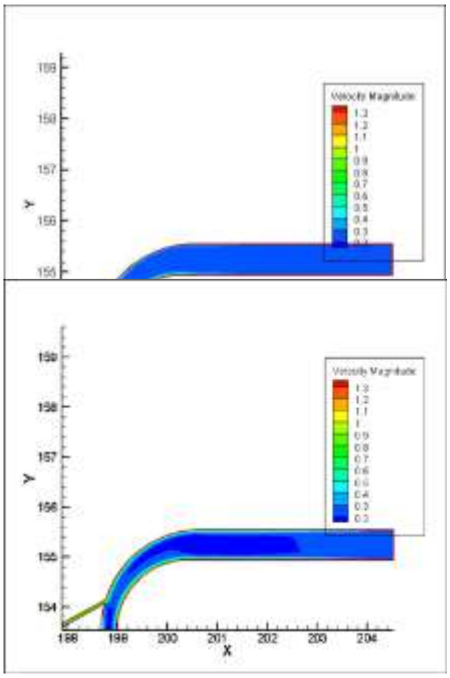


Figure 5. Streamlines shown in intake zone for different intake angles

4.2 Investigation on velocity magnitude

The velocity magnitude counters are shown on Figure 6. It can be seen on Figure 6 that the velocity distribution is symmetric before the flow enters the bend. When the flow enters the bend, the velocity distribution will be changed by secondary flow and the velocity at inner banks will increase.



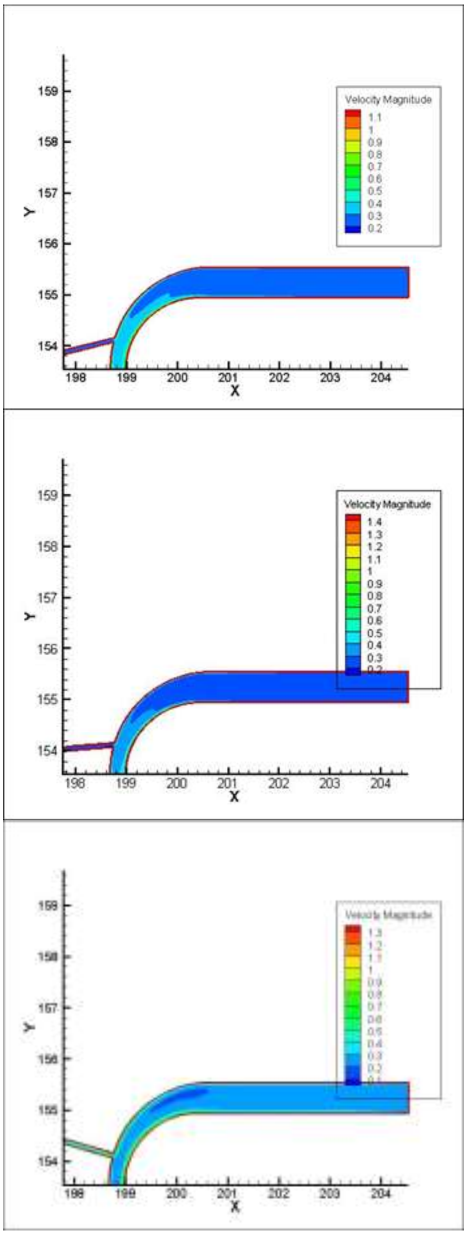


Figure 6. Counter of velocity magnitude for different intake angles

5. CONCLUSION

Intakes are lateral structures that are constructed on rivers for intercepting water discharge. Also, wooden debris and sediment are transferred into intakes by water discharge as well. They cause severe problems such as blockage and reduction of intake efficiency. Therefore, the sediment control method should be studied to mitigate these problems. In bend of rivers, the sediments transfer from outer bank to inner bank due to secondary flow. Hence, the outer bank is the best place to install intake. In other hand, the entrance of sediments and wooden debris into intake relates to shape of bend intake position and angles. These parameters were studied in this paper. In order to obtain this goal, the experimental and numerical models are employed. In order to determine the best angle of intake, 25 experiments were carried out with five different intake angles (30º, 45º, 60o, 70º and 90º) under five different hydraulic circumstances. The following results are obtained from experimental and numerical models.

60 degree intake angle is the best angle by consideration of sediment intercepting and discharge catchment.

The numerical model confirms the above result and also shows that 90 degree intake angle is the worst angle for discharge intercepting.

6. REFERENCES

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