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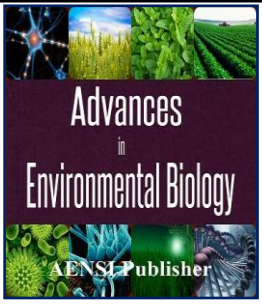

The Effect of Slot on Scouring Around Spur Dike at 180 Degree Bend

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ABSTRACT

In this study the performance of slots as a way to reduce the scouring around the installed flat spur dike in a 180 degree bend has been evaluated and development of scouring in slotted spur dike was compared with spur dike with no slot. To evaluate the effect of slot position to spur dike tip on the development of scouring around it, a flat spur dike made of Plax glass was installed in a position of 70 degree at 180 degree bend in the flume. After determining the maximum of scouring depth at tip, to reduce the scouring caused by secondary and eddy flows around the spur dike, a slot with a fixed height was placed in four different positions in spur dike. Experiments with four different discharges and constant flow depth in clear water conditions were conducted. The results of the experiments showed that creating slot reduces the scouring depth toward the spur dike with no slot and the effects of slot in reducing the scouring in different models is variable between 16 to 69 percent. The minimum of scouring depth was seen in a model with closest position of slot toward tip, and its maximum was seen in a model with farthest position of the slot.

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INTRODUCTION

Spur dike are structures to regulate the river and are used in a range of different conditions. They can be used individually or in series and by diverting the stream lines from the edibility walls to the inner parts of the river and reducing the flow velocity, they decrease the velocity of the water hitting the walls and increase the ability of the flow sedimentation process. One important issue in designing the spur dikes is the phenomenon of their tip local scouring which is due to narrowing the cross-flow and the strong eddy flows. Down flows and the initial vortex in the upper corner of the spur dike with the secondary vortex and wake vortex in the middle part and downstream corner of spur dike cause the interaction between water flow and the bed materials and this is the major cause of scouring around the spur dike. The combination of these factors leads to the removal of bed materials from around the spur dike, and in the long term it creates large holes in the spur dike tip and is likely to damage the structure. For this reason, by controlling and protecting the structure against the scouring and providing appropriate methods to scouring reduction, this damage can be prevented.

In some locations dikes are constructed higher than the high water level, which are called emerged dikes. In rivers with unsteady flow conditions, spur dikes can serve as emerged in ordinary state or submerged during flood. The area behind the dike is either a dead zone during emerged conditions or a slow flow zone during submerged flow conditions.

The flow field at a spur dike is coupled with a complex 3D separation of approach flow upstream and a periodic vortex shedding downstream of the spur dike. The complexity of flow increases with the development of the scour hole. Outer banks of river bends are usually associated by scour. As a result lateral migration of channel may take place. The scour depth estimation has attracted considerable research interest, and different prediction methods exist at present.

Local scour around the spur dike foundations failure spur dikes. In recent years, flood waters have closed many highways and local roads as well as interstate highways, and caused scour that damaged many spur dikes and even resulted in loss of life.

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Estimation of the depth of scour in the vicinity of spur dikes has been the main concern of engineers for years. Therefore, knowledge of the anticipated maximum depth of scour for a given discharge is a significant criterion for the proper design of a spur dike foundation. In current practice, the design scour depth is chosen to be the maximum equilibrium scour depth achieved for steady flow under the design flow conditions. A number of studies have been performed with a view to determining the equilibrium scour depth for clear-water scour conditions. In these studies, the maximum scour depth under steady flow conditions is related to the hydrodynamic and sediment parameters, Froude number and spur dike location and among others. The scour in channel bend has been studied extensively by different researchers.

Chiew (1987) examined the parameters such as width, height and position of slots on the bridge pier. The results showed that by placing a slot with a width of 0.25 equals to diameter of bridge pier and a hole larger than double of pier diameter, the gaps near the bed and near the water surface reduce the souring depth 20% and 5% respectively.

Kumar *et al*. [5] created slots with a width=0.25 of pier diameter and two height $Y = y_0$ and $Y = y_0 + ds$ (y_0 is depth of uniform flow and ds is depth of local scouring at the bridge pier without slot) in the cylindrical piers. They concluded that by increasing the slot height, scouring depth is decreased and slots with greater height than the flow depth create more reduction in scouring depth.

Oliveto *et al*. [7] studied the temporal evolution of clear-water pier and abutment scour and found that the principal parameter influencing the scour process is the densimetric particle Froude number so suggested an logarithmic formula.

Fazli *et al*. [3] studied the scour and flow field at a spur dike in a 90 degree channel. It is obvious that there is lack of knowledge regarding the scour and flow pattern around the spur dike in a curved channel.

Ghodsian *et al*. [4] studied scour and flow field in a scour hole around a T-shape spur dike in a 90 degree bend. The effects of the length of the spur dike, the wing length of the spur dike and Froude number on the scour and flow field around a T-shape spur dike in a 90 degree bend were investigated in this study. The main results of this experimental study are: At the upstream of the spur dike, a main vortex with anti-clock wise direction is formed in the zone of the spur dike. At section 77.5 degree of the bend a vortex having a clock wise direction is formed between the spur dike wing and the channel wall. The maximum value of the longitudinal velocity component at section 65 degree of the bend is close to the outer wall of the channel and near the water surface. By increasing Froude number the maximum scour depth and the volume of scour whole increases. The dimensions of the scour hole increase as a result of increase in the length of the spur dike. The amount of scour at the upstream of spur dike is much more as compare to that at the downstream of spur dike.

Masjedi *et al*. [6] studied on the time development of local scour at a spur dike in a 180 degree flume bend. Tests were conducted using one spur dike with 110 mm length in position of 60 degree under four flow conditions. In this study, the time development of the local scour around the spur dike plates was studied. The effects of various flow intensities (u*/u*c) on the temporal development of scour depth at the spur dike were also studied. The time development of the scour hole around the model spur dike installed was compared with similar studies on spur dikes. The results of the model study indicated that the maximum depth of scour is highly dependent on the experimental duration. It was observed that, as flow intensities (u*/u*c) increases, the scour increases. Measuring time and depth of scouring based on experimental observation, an empirical relation is developed with high regression coefficient 97%.

MATERIALS AND METHODS

All of the experiments were conducted in a flume located at hydraulic laboratory of Islamic Azad University of Ahvaz. The flume channel was conducted in a recirculation flume, with central angle of 180 degree, central radius of Rc=2.8m and width of B=60cm. Relative curvature of bend was Rc/B=4.7 which defines it as a mild bend. The test area of the flume is made up of an aluminum bottom and Plexiglas sidewalls along one side for most of its length to facilitate visual observations. At the end of this flume a controlling gate was designed to adjust the water surface height at the desired levels (Figure 1).

Donat, [2] maximum length of spur dike should be between 10 to 20 percent of the width of channel. In the present research, the supposed model is a kind of spur dike with vertical wall, length of spur dike is La=12 cm (i.e. La = 20% of the channel width) and spur dike width is Ba=1cm (Figure 2). To do experiments, a slot with a height of $Y = y_0$ in four different positions from spur dike tip was used in which y_0 is water flow depth.

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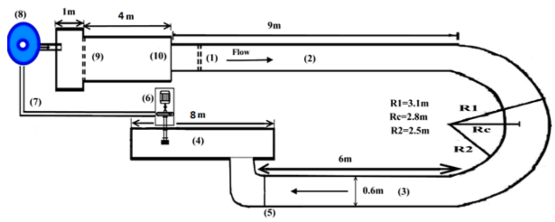

Fig. 1: The experimental setup (Plan).

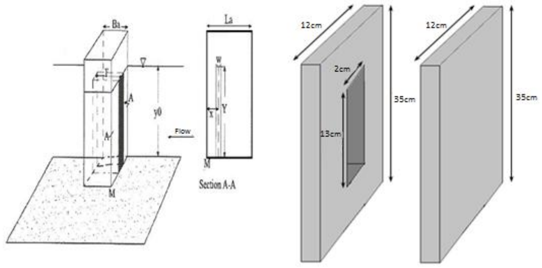

Fig. 2: Schematic illustration of a shape spur dike with slot.

All experiments were performed by installing the physical model of flat spur dike at a position with an angle of 70 degree at 180 degree bend with four discharges in clear water. According to Chiew and Melville [1] with a constant flow depth of 13cm the relation y_0/La>1 is dominant, because in this situation the water depth do not reduce the created cavity. Four discharges of 17, 20, 23 and 27 liters per second were chosen in a way in which according to the fixed depth, the Froude number in all experiments was less than one and flow was the subcritical condition.

According to Raudkivi and Ettema [9], to prevent the formation of ripple, the average diameter of particles should be larger than 0.7 mm and to eliminate the effect of sediment size on scouring depth, the standard deviation of particles must be less than 1.3. The used sediment in experiments has an average size of 2 mm and the standard deviation is 1.3. Table 1 show the characteristics of physical hydraulic model.

Table 1: Characteristics of physical hydraulic model .

Slot height (cm)	$\frac{X}{La}$	X slot distance from the tip ((cm)	Model		Row
-	1	-	Ao	Testifier	1
13	0.25	3	$A1$	Slotted spur dike	2
	0.42	5	$A2$		3
	0.58	7	$A3$		4
	0.75	9	$A4$		5

The following procedure was used for each experimental run. Before the experiment with the spur dike model in place, the sediment bed surface was leveled with a scraper blade mounted on a carriage that rode on the steel rods. After the bed was completely wetted and drained. The flume was then filled with water to obtain the desired depth. Before the pump was started an initial set of transects of the anticipated scour region was collected. At the completion of each test, the pump was shut down to allow the flume to slowly drain without disturbing the scour topography. The flume bed was then allowed to dry, during which time photos of the scour topography around the pier were taken, and the final maximum scour depth was recorded using the point gauge having an accuracy of ±0.01mm (Figure 3).

Results:

Figures (4) and (5), the longitudinal and transverse profiles of scouring in front tip of spur dike in the different discharges of experiments 17,20,23 and 27 Lit/s and in slot distance X/La = 0.25, 0.42, 0.58 and 0.75 from front tip with a fixed slot width and the height of slot $Y = y_0$ has provided in statues with and without slot. The results of the chart show that the slot in the body of spur dike reduces scouring around it. In any discharge, the lowest scouring at X/La = 0.25 and its highest scouring at X/La = 0.75 distance in

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comparison to other distances is observed. Since the collision of flow to spur dike occurs at tip, so the slot near the spur dike tip and the passing of flow reduce the eddy flows in the front tip of spur dike.

Fig. 3: Scour pattern at the end of a test. (A) Model A1 (B) Model A4.

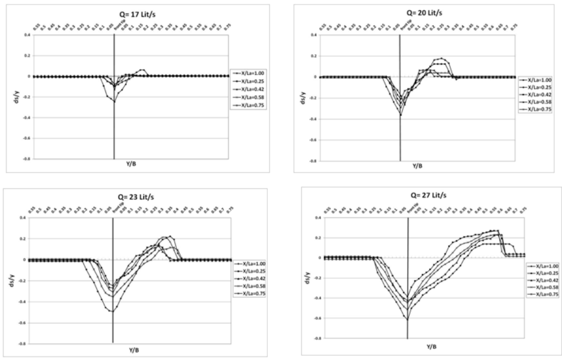

Fig. 4: Comparison of longitudinal profiles at different distances of slot for the different discharges .

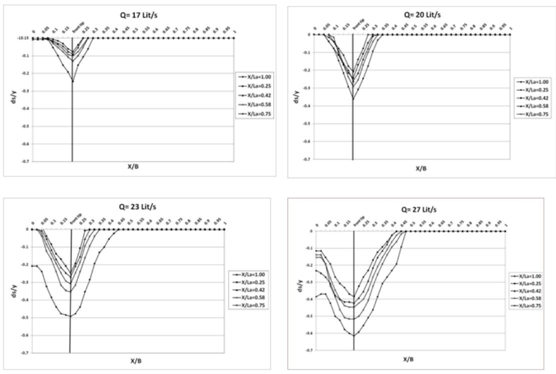

Fig. 5: Comparison of transverse profiles at different distances of slot for the different discharges.

Figure (6) shows the effects of slot in reduction of scouring at different Froude numbers of 0.19, 0.23, 0.26 and 0.31 and at four slot distances from tip X/La = 0.25, 0.42, 0.58 and 0.75 with fixed slot width and the height of the slot ($Y = y_0$). The results of diagrams show that by increasing the slot distance from the tip, the percentage of the slot effects in reduction of scouring is decreased. Due to the collision of flow with spur dike, the power of eddy flows near the tip is more, but it is decreased by creating slot near the tip and passing of eddy flows, then scouring around the tip will be decreased. The larger the slot distance from the tip, passing of eddy flows is decreased and their power will be increased.

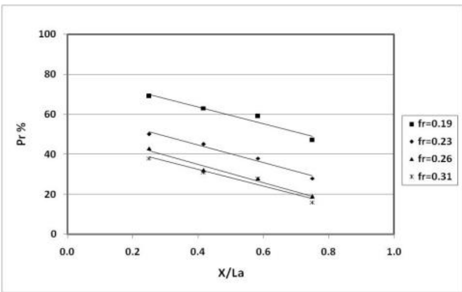

Fig. 6: The effects of slot distance from the tip in scouring around the spur dike.

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