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Original Article

The Effect of the Spur Dike Wall Angle on Controlling Scour Around It in Straight Path

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Abstract

Spur dikes are structures used with the aim of deviation of flow from erodible coast of river, creating suitable path to conduct the flow, controlling flood, external protection of bend and plans to modify river path. In this study, the effect of wall angle on controlling scour around the spur dike in direct path is investigated. Through placement of 4 types of spur dike with angles of 60, 70, 80 and 90 under the effect of 4 types of discharge, the scour around the spur dikes in pure water is analyzed. The results obtained from the study showed that existence of slop in body of spur dike could decrease the dimensions of scour around it. Moreover, the amount of scour around spur dike was created with angle of 60º and its maximum was created around the spur dike with angle of 90º and the dimensions of scour hole were increased with the increasedFroude number.

Key words: Spur dike, Spur dike wall angle, Scour, Pure water

INTRODUCTION

When a structure is located in bed of the river, it creates some changes in river flow, which could increase capacity of transferring sediments in the fluid and could lead to scour. Spur dikes are river structures, which are mainly applied to prevent erosion of river sides. Recently, various environmental uses of spur dikes in rivers have gained attentions. Among various methods of indirect protection of walls, construction of spur dikes is one of the most common methods, which is today one of the most applicable approaches in river engineering. One of the most common methods of controlling side erosion and protection of river sides is using Epi or Spur dike. Summary of relevant works in field of flow pattern and scour in rivers is presented as follows:

Ahmad (1951, 1953) has investigated the flow pattern and scour around the single spur dikes. For this purpose, the author placed some spur dikes under different angles of 30-150º to upstream in leggy direct river and observed that increase in the said angle from 90 has led to relative decrease in flow. McCoy et al (2006) investigated the fields of flow around and between two vertical spur dikes in a direct open channel. They used Large Eddy Simulation method and reported that in main stream,unsteady horseshoe vortices are created in foundation of spur dikes and in upstream. Ezzeldin et al (2007) conducted some studies on blade spur dike with different angles of 30, 60 and 90 to downstream of the adjacent coast of spur dike and various effective lengths (4, 7 and 10cm) and uniform materials d50=0.6mm in a channel with width of 0.4 and length of 12m. The study showed that increase in constriction could increase sour hole and the upstream length of scour hole is about two times larger than effective length of spur dike. Moreover, the study showed that the upstream and downstream length of scour hole in this spur dikes is respectively about 2 and 3 times higher than maximum depth of scour. This study showed that spur dike with angle of 30º is the best item in terms of depth of scour and protection of coasts. Teraguchi et al (2011) presented experimental investigation of turbulent flows and bed changes around spur dike. In this study, 3 types of spur dikes includingPermeable, impermeable and Bandal-Like spur dikes were used and a 3-D model was used to analyze the distribution of velocity and sedimentation around the structure in two submerged and non-submerged modes. The results of examinations showed higher maximum depth of scour in nose of impermeable spur compared to permeable spur.

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Vaghefi (2009) conducted some studies in T-shaped spur dike in river bend and found that with the increase in spur dike length, maximum scour depth is increased and with the decrease inFroude number of flow, the dimensions of scour hole is reported. Zomorodian and Asadi (2015) presented numerical simulation of turbulent flow pattern and positional scour around the Ghaem angled spur dike (30 and 60) with Flow-3D numerical model. The results showed that maximum depth of scour in head of spur dike with angle of 90º in vitro was equal to 8.82cm and using the Flow-3D software, maximum depth of scour was obtained instandard two-equation turbulence models, normalized group and large eddy simulation respectively to 9.1, 8.9 and 9.1cm. The two-equation turbulence model of normalized group with about 9% error showed better consistency compared to standard two-equation turbulence model and large eddy simulation. Moreover, in the simulation related to spur dike of 60 and 30º, maximum depth of scour in head of spur dikes was respectively equal to 8.75 and 6.5cm. Asadzadeh et al (2016) conducted an experimental study on the flow pattern around spur dike with sloped wall. To this end, the 3-D hydrodynamics around the straight spur dike with slopped wall of 75º was studied experimentally and in a straight channel with rigid bed. The information of flow was analyzed with extraction of turbulence parameters around the spur dike by means of point three-dimensional speedometer (ADV). Behind the spur dike, with decrease in flow velocity leading to formation of static region, the flow velocity could be increased in middle points. Hence, the flow was divided to two parts and a part of flow was moved upward and the other part was moved downward with lower pressure. The downward flow could be the factor for creation ofhorseshoe vortices. Two points of intensification of velocity are created: the first one is associated with intensification of velocity in main core of the flow caused by reduced flow passing width and the other point is associated with positional intensification of velocity in downstream of spur dike in outer area of shear layer.[1-8]

METHODS AND MATERIALS

Dimensional Analysis

In the science of Fluid Mechanics, majority of phenomena are depended on numerous variables and their analysis using the main sample and these variables is time and cost consuming and this problem has been solved by dimensional analysis. In this field, instead of using each variable, the dimensionless numbers are obtained and they are used. As a result, the number of variables is decreased. On the other hand, using the law of similarity caused by dimensional analysis, a data related to a small model could be changed into designing data of a real time sample.

To determine dimensionless, various methods are available and the most common method is Buckingham method. Various parameters could affect scour around the spur dike. In this study, regardless of constant parameters and with regard to constant flow and steady properties of fluid, the equation 1 is created for the parameters affecting scour around the spur dike in equilibrium state:

$$F_1(L, B, \theta, h, S_0, V, g, ds, \phi, \rho_s, \mu, \rho_w, X)=0 \quad (1)$$

Where; L refers to spur dike length; b is width of spur dike θ is the lateral slope of body, h is flow depth, S0 isflume bottom slope, V is the flow velocity, ds is scour depth, is special mass of sediments, g is gravity acceleration, is internal friction angle of bed particles, is fluid viscosity, Pw is water special mass, B is channel width and X is the longitudinal coordinates of channel.

Regardless of constant parameters in equation 1, equation 2 is obtained:

$$F_1(B, \theta, h, V, g, ds, \rho_w, X)=0 \quad (2)$$

Using Buckingham theory, the eq. 2 has changed into dimensionless equation as follows:

$$F_1\left(\frac{X}{B}, Fr, \frac{d_s}{h}, \theta\right)=0 \quad (3)$$

Procedure

The experiments in this study are performed in a flume with length of 8m and width of 6cm and height of 50cm in the hydraulic laboratory of Kurdistan University. Flow measurement was done using sharp-edged rectangular overflow in downstream of flume after the relaxing pool. The type of frame, floor and walls was respectively of iron, glass and Plexiglas. The junction of Plexiglas of wall and wall glass was filled byadhesive for the aquarium to prevent water leakage. The channel used in the experiment was equipped with an entrance reservoir conducting the flow through a convertor to the channel (Figure 1).

In this study, to perform experiments, materials with diameter of d_{15}= 1.3 are used in the bed. According to the Figure 2, the experiments were performed on 4 types of spur dike with upper width of 2cm and length of 1cm and height of 50cm with wall angle of 60, 70, 80 and 90º of type Plexiglas under the effect of 4 types of discharge (15, 19, 23 and 27) with constant depth of 10cm and Froude numbers of 0.250, 0.383, 0.316 and 0.450.

The procedure is as follows: after equilibrium of scour, for topography purpose, the pump was turned off and water was discharged with very low speed from the end shaft. After

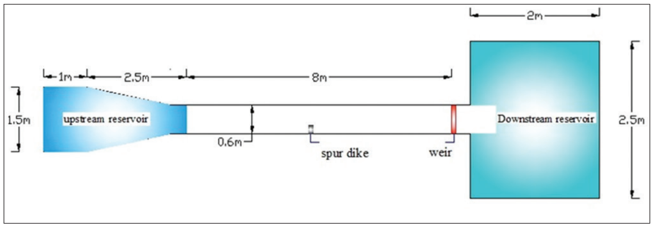

Figure 1: The plan of straight channel and position of installation of spur dike

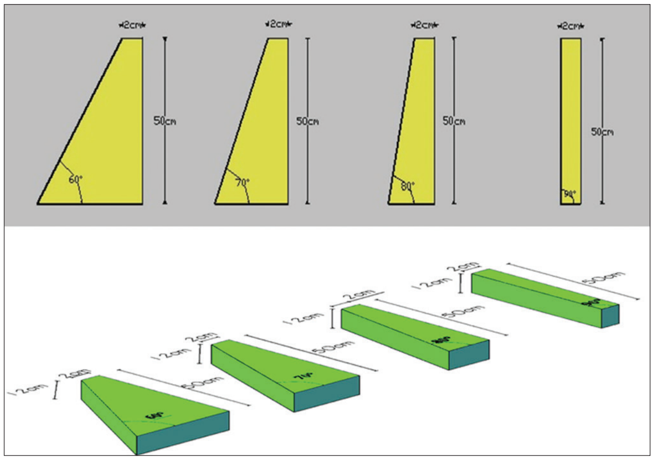

Figure 2: Plan and lateral view of spur dikes in angles of 60, 70, 80 and 90°

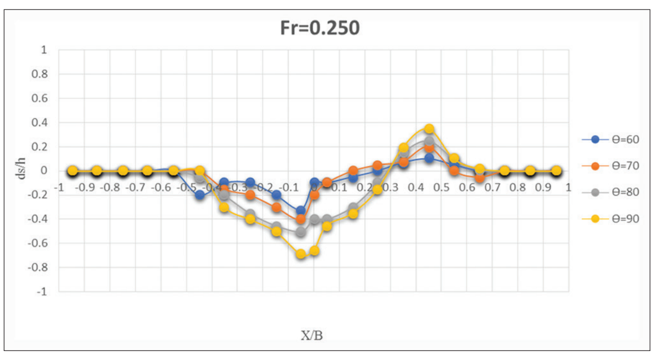

Figure 3: Longitudinal profile of scour of spur dike in Fr=0.250 and angles of 60, 70, 80 and 90

about half an hour and complete discharge of water from channel, adepth gauge with millimeter accuracy was used to measure and take the bed profile (Figure 4-6). The device was embedded on side rails in longitudinal and transverse direction. For careful analysis of the changes taken in bed in longitudinal direction, the space if taken points was considered to 1.5cm and the topography of bed around the spur dike was taken in different positions and rates.

The Effect of Spur Dike Wall Angle on Scour Around it in Different Froude Numbers

In the figure 3, longitudinal profile of scour in front head of the spur dike is illustrated in 4 body angles of 60,

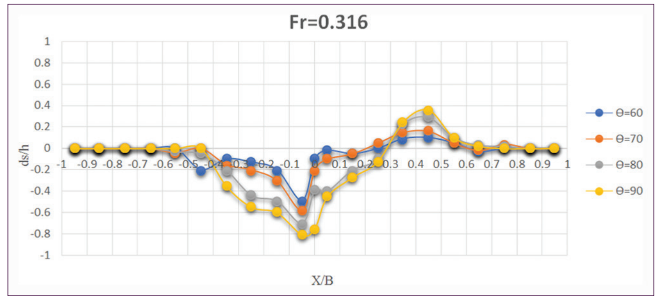

Figure 4: Longitudinal profile of scour of spur dike in Fr=0.316 and angles of 60, 70, 80 and 90

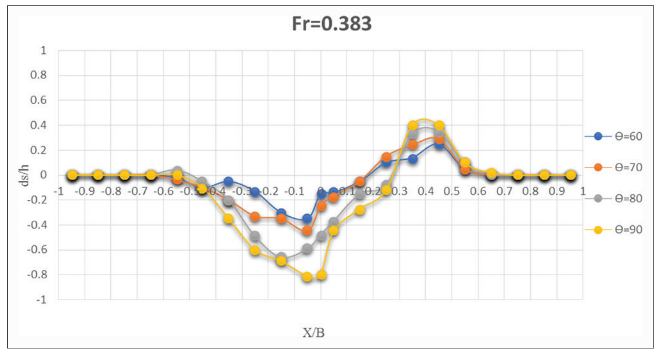

Figure 5: Longitudinal profile of scour of spur dike in Fr=0.383 and angles of 60, 70, 80 and 90

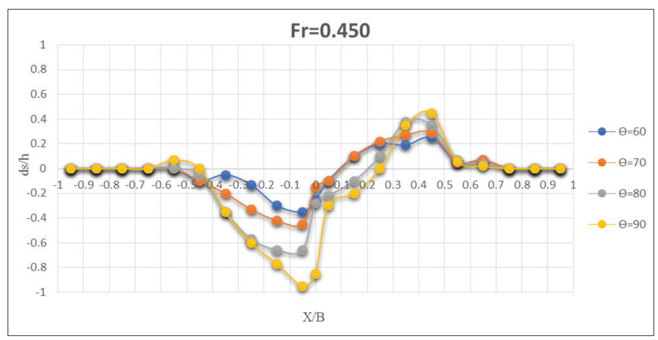

Figure 6: Longitudinal profile of scour of spur dike in Fr=0.450 and angles of 60, 70, 80 and 90

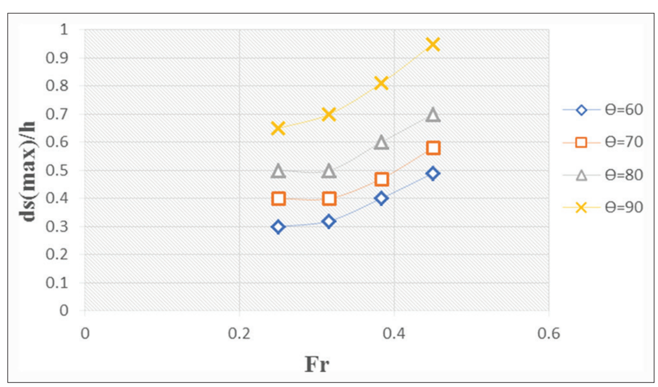

Figure 7: Analysis of the effect of wall slope of spur dike on maximum depth of scour in different Froude numbers

70, 80 and 90 and in Froude numbers of 0.250, 0.383. 0.316 and 0.450. The results obtained from diagrams show that:

1. Maximum depth of scour in all spur dikes is observe din upstream and near the head of spur dike
2. Minimum and maximum scour in the spur dike happens with lateral angle of 60 and 90º
3. With the increase in spur dike wall angle, elongation and progress of deposition in downstream is increased, so that in wall angle of 60º, the lowest and in angle of 90º, the highest elongation and progress of deposition in downstream is happened

With the increase in body angle of spur dike (90º), the encounter of flow lines with the spur dike wall is increased and as result, Eddy currents are increased around the spur dike and this could lead to more displacement of sediments towards downstream and increased dimensions and elongation of deposition in downstream. In other words, the more the structure is beveled (goes toward angle of 60º), the less the direct contact of flow would be and hence, the less scour would become.

Analysis of The Effect of Spur Dike Wall Angle on Maximum Scour Depth in Different Froude Numbers

In figure 7, maximum scour depth is illustrated in 4 angles of 60, 70, 80 and 90º and in Froude numbers of 0.250, 0.316, 0.383 and 0.450 and the results show that:

Increase in Froude numbers in total body angles could increase maximum depth of scour.

In all Froude numbers, minimum scour was observed in angle of 60 and maximum scour depth was observed in angle of 90.

CONCLUSION

In this study, the effect of wall angle on controlling scour around the spur dike in straight direction of spur dike is investigated. The results obtained from the study showed that slope in spur dike body could decrease the dimensions of scour hole around it. Moreover, minimum scour around the spur dike was observed with angle of 60 and maximum scour was observed with angle of 90º. With the increased Froude number, dimensions of scour hole were increased. With increase in wall angle of spur dike, elongation and progress of deposition to downstream was increased, so that in wall angle of 60º, the lowest elongation and progress of deposition and in angle of 90º the highest elongation and progress was to downstream could be observed.

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