Investigation on Scour Hole Around Spur Dike in a 180 Degree Flume Bend

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Abstract: Investigation on scour and determination of hole of scoring are among the most important issues in spur dike designation with model spur dike was measured in a laboratory flume with 180 degree bend under clear-water. Experiments were conducted for different locations with various Froude number. In this study, the time development of the scour hole around the spur dike plates was studied. The results of the model study indicated that the maximum depth of scour is highly dependent on the experimental duration. It was observed that, with increasing time development the greatest hole of the scour was associated with 75 degree spur dike. With increasing Froude number the maximum scour length, width and depth increases.

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1. Introduction

Spur dike is hydraulic structure and widely constructed in alluvial rivers all over the world. Spur dikes are build perpendicular or at an angle to the channel bank or revetment, protruding into the watercourse. Impermeable spur dike is built of local soil, stones, gravels, rocks or gabions. Protruding of a structure such as a spur dike to a channel leads to changes on the flow patterns and bed configurations. These changes usually initiate a scour process, involving turbulent flow, sediment transport and erodible boundaries.

The scour occurring at a spur dike is divided into three categories, general scour, constriction scour and local scour. Local scour results directly from the impact of the spur dike on the local flow pattern.

The flow past the spur dike may be divided into three zones: a main flow zone from the head of the spur dike to the opposite side of the channel, a wake zone behind the spur dike and a mixing zone in-between them (Fig. 1).

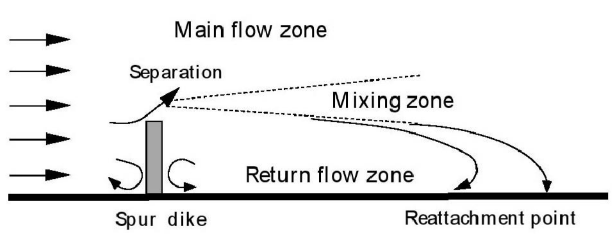

Figure 1. Flow around spur dike

The flow in local scour generally shows obvious 3D characteristics. This 3D flow may be divided into several components. In front of the spur dike, there exists a bow wave near the water surface and a downflow towards the channel bed due to the stagnation of approaching flow. As the result of the flow separation, a horseshoe vortex develops in the local scour hole and a wake vortex system forms behind the spur dike (Fig. 2).

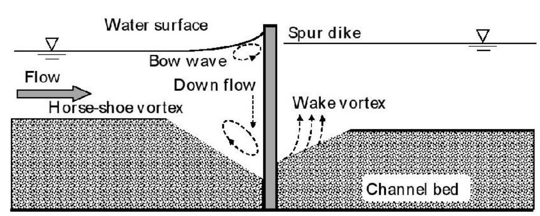

Figure 2. Flow in a scour hole

Estimation of the length, width and depth of scour in the vicinity of spur dikes has been the main concern of engineers for years. Therefore, knowledge of the anticipated maximum scour hole for a given discharge is a significant criterion for the proper design of a spur dike foundation.

Garde et al. [3] suggested that the maximum scour depth was greatest for a spur dike with an inclination angle of 90 degree and smaller for all other inclinations upstream and downstream.

Kothyari and Ranga Raju [5] noticed that scour process around a spur dike was similar to that around a pier except that the boundary layer effect induced by the channel wall might cause less scour in the spur dike case.

Uijttewaal et al. [9] conducted physical scale model experimentals in a 20m-long and 3m-wide channel with a series of embayments. According to their result, reducing the main channel velocity had no effect on the flow pattern in the embayment, whereas lowering the water level did.

Fazli et al. [2] 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. Also the characteristics of flow pattern have been shown to be affected by the location of spur dike. It was found that: Bed topography in the bend is influenced by location of spur dike in the bend. When the spur dike is located in the second half of the bend, deposition is occurred near the outer bank at the exit of the bend. When spur dike is located in the first half of the bend erosion occurred in this region. Diversion of water by the spur dike cause a narrow zone of degradation in the channel from upstream stagnation zone up to downstream of standing eddy zone. Froude number is an important parameter and has a direct relation to maximum relative scour depth and height of point bar. By increasing the Froude number these parameters increases. By increasing the length of spur dike, the scour depth increases. New empirical equation for estimation of maximum scour depth is presented.

Ghodsian and Vaghefi [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 hole 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%.

Masjedi et al. [7] studied on reduction of local scour at single T-shape spur dike with wing shape. The study was conducted using in a 180 degree laboratory flume bend. Experiments were conducted for different wing shapes of T-shape spur dikes at the bend with various Froude number. In this study, the time development of the local scour around the T-shape spur dike plates was studied. The time development of the scour hole around the model T-shape 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 Froude number increases, the scour increases. All Froude numbers, oblong wing at location of 60 degree results maximum reduction in scour depth. Measuring depth of scouring based on experimental observation, an empirical relation is developed with high regression coefficient 95%.

Characteristic of flow in bend is different than in straight channel. Since in bend the general helical current induced by the balance of centrifugal force and the gravity force will force the water surface layers move toward the outer bank and the lower layers moved toward inner bank. Such flow pattern can redistribute the flow velocity and shear stress at the bed. The maximum flow velocity and shear stress occur at the outer bend. Therefore it is the principal objective of this study is to carry out experimental tests on the effect of scour hole around a spur dike in a 180 degree bend.

2. Materials and Methods

The experiment reported herein was conducted in a recirculation flume, with central angle of 180 degree. Relative curvature of bend was Rc/B=4.7 (Rc= Central radius and B=Flume width) 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 3).

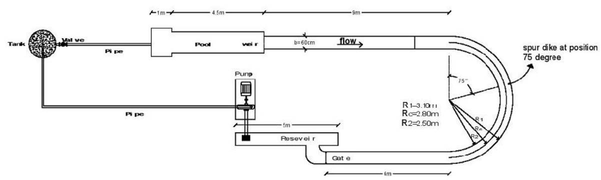

Figure 3. The experimental setup (Plan)

In this study to maintain the clear water condition without formation of ripple, uniform sediment with median size of *d*50 = 1.3 mm, and geometric standard deviation of σg ~ 1.4 were used [1] was used with a thickness of 0.17 m and covered the total length of channel. The spur dikes were made of Plexiglas in plan and located at sections 30, 45, 60 and 75 degree in the bend. The spur dikes were of 10 mm thick and 0.50 m high.

The experiments was carried out using one length for spur dike (i.e. L =20% of the channel width) was used [8]. Figure 4 shows a schematic illustration of a spur dike and scour hole in flume.

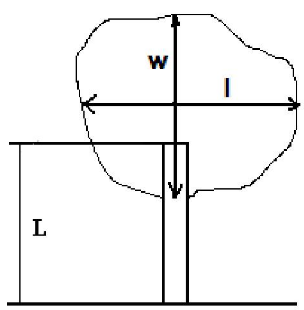

Figure 4. A spur dike and scour hole (Plan)

In this study the experiments were performed under clear-water conditions at four Froude numbers of 0.20, 0.23, 0.26 and 0.28 were applied in order to investigate the effect of flow conditions on the scouring.

Equilibrium scour occurs when the scour depth does not change appreciably with time. In clear-water scour, scour depth is approached asymptotically with time and may take an infinite amount of time for the equilibrium scour hole to develop, while in live-bed scour the scour develops rapidly and then fluctuates in response to the passage of bed forms.

Experiments were run under clear water scour regime for a period of more than 24 hrs when movement of sediment from scour hole was almost negligible and equilibrium state of scour reached (Fig. 5). As it can be seen approximately 94% of scouring occurs during the first 3 hours. Therefore in all remaining of our experimental tests, duration of 3 hours was selected for each test. Therefore in all our experiments, the scour depth 3 hours after the start of each test was recorded and considered here as maximum scour depth.

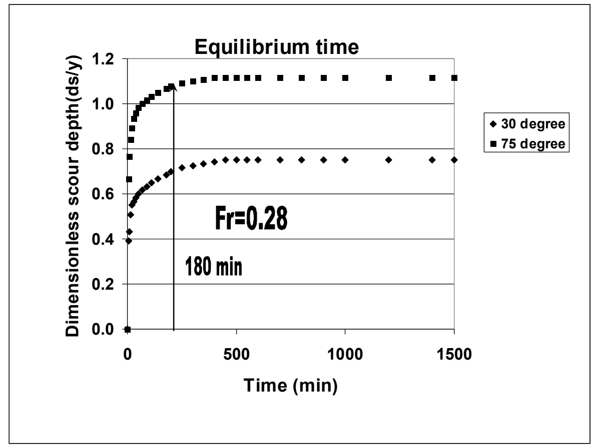

Figure 5. Equilibrium time in the different position for a spur dike

At during test time, scour length (l), scour width (w) and scour depth (ds) were recorded using the point gauge having an accuracy of ±0.01mm (Fig.6).

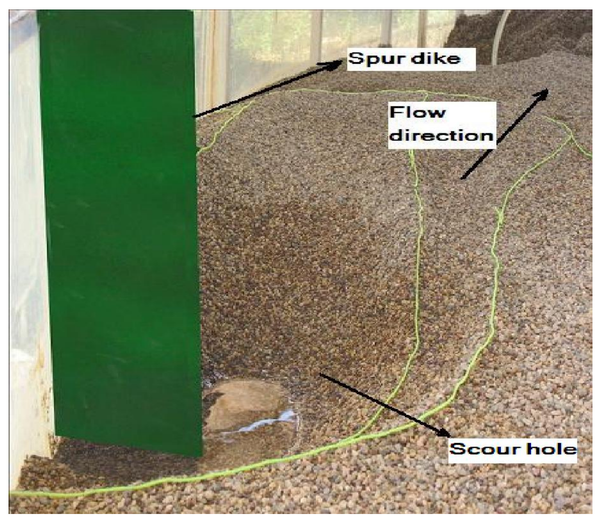

Figure 6. Scour pattern at the end of a test

3. Results and Discussion

3-1. Effect of Froude Number on the Scour Hole

Figure 5 shows effect of Froude number on the time development for relative scour depth (ds/y), scour length (l\y) and scour width (w/y) at location 75 degree in the bend. Four different Froude numbers 0.20, 0.23, 0.26 and 0.28 were applied in order to investigate the effect of flow conditions on the scouring. Increasing Froude number is associated by increase in the flow velocity, as a result the scour depth (ds/y), scour length (l\y) and scour width (w/y) increases with scour time.

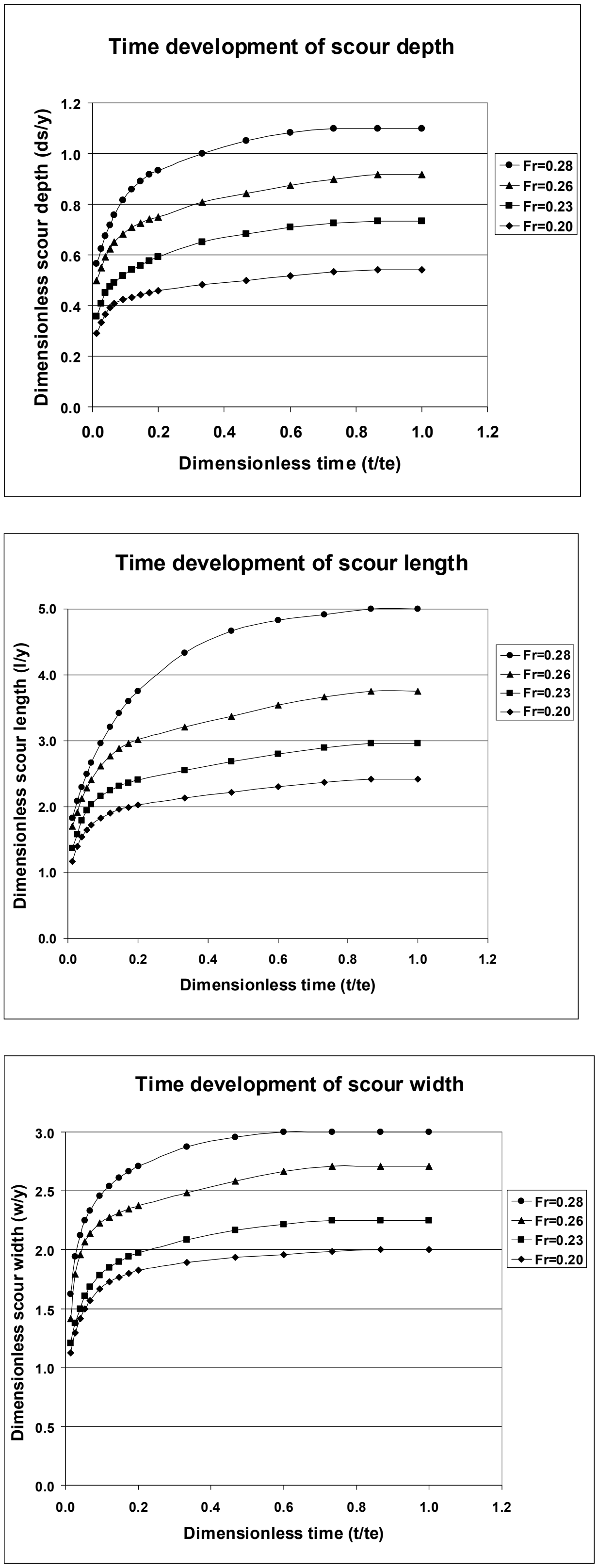

Figure 5. Time development of scour hole for different Froude number

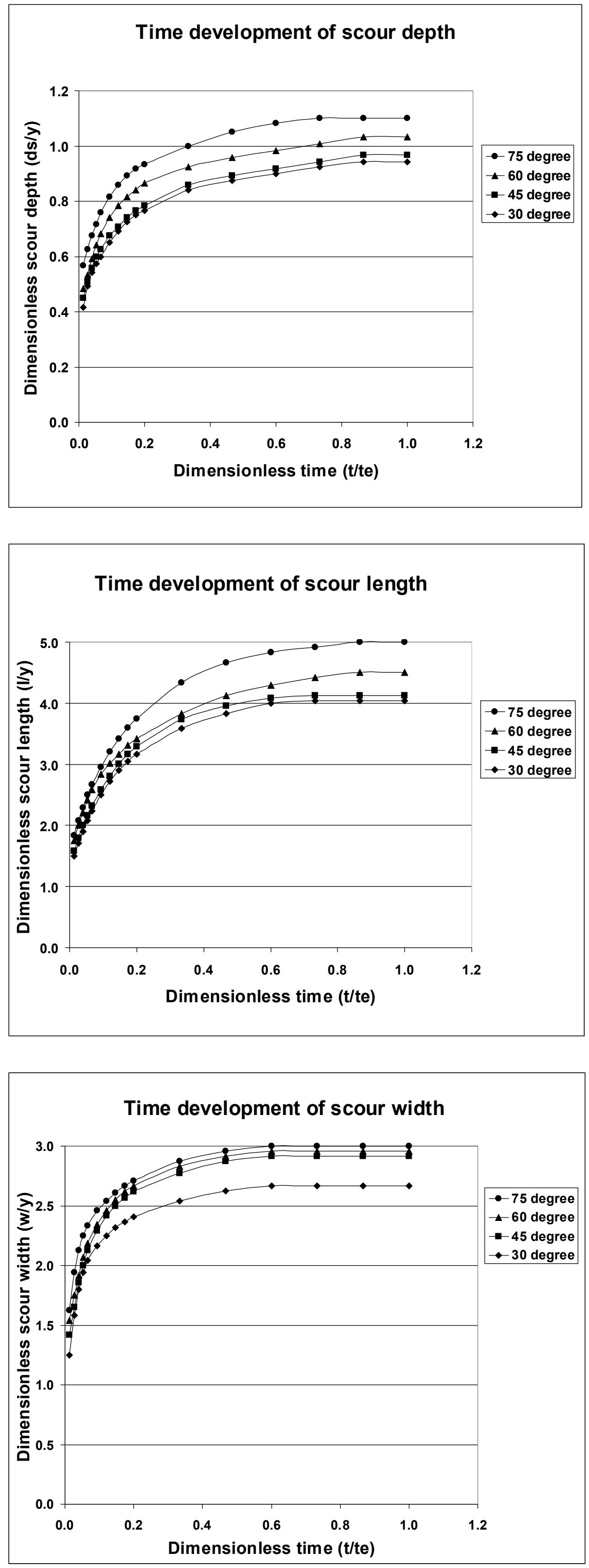

Figure 6. Time development of scour hole for different locations

The main reason of such finding is that with increases in Froude number, occurs increases in vortex. This finding also is in agreement with the results of and Masjedi et al. [8] and Ghodsian and Vaghefi_[4] which they found that , as Froude number increases, the vortex and scour increases.

3-2. Effect of Location of Spur Dike on the Scour Hole

Figure 6 show typical dimensionless graphs for the relative scour depth (ds/y), scour length (l\y) and scour width (w/y). This figure corresponds to Fr =0.28 and for four location 30, 45, 60 and 75 degree in the bend. As it can be seen from Figure 6, for scour depth, length and width, at location of 75 degree results maximum increases in scour depth, length and width. It is clear that the location of the spur dike increase at bend, the maximum scour depth, length and width increase. The main reason of such finding is that at location of 75 degree of the bend a maximum increases in vortex. This finding also is in agreement with the results of Ghodsian and Vaghefi [4] which they found that 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.

4. Conclusions

The effects of Froude number and location of spur dike on the scour depth, length and width around a spur dike in a 180 degree bend were investigated in this study. It was found that:

- By increasing Froude number the maximum scour depth, length and width increases.
- Increases scour depth, length and width increases occurs at location of 75 drgree.

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