Control of local scour at single L-shape spur dike with wing shape in flume bend

Alireza Masjedi [1] , Abdolmajid Nadri [2] , Amir Taeedi [3], Iman Masjedi [4]

[1.] Assist. Prof., Islamic Azad University Ahwaz Branch, Ahwaz, Iran, (Email:Drmasjedi.2007@yahoo.com)
[2.]MSc Student, Khuzestan Science and Research Branch, Islamic Azad University, Ahwaz, Iran
[3.]MSc Student, Shahid Chamran University, Ahwaz, Iran, (Email:Taeedi@yahoo.com)
[4.]P.S, Islamic Azad University Shoushtar Branch, Shoushtar, Iran, (Email:Flyiman@Gmail.com)

Abstract: In this study, investigation of effect of wing shape on control of local scour at a L-shape spur dike in a 180 degree flume bend are presented. Spur dikes are structures constructed in rivers to maintain a suitable measures for bank protection and flood control. In this study, the time development of the local scour around the L-shape spur dike plates was studied. The study was conducted using in a 180 degree laboratory flume bend. Experiments were conducted for three wing shapes of L-shape spur dikes (Rectangular, Oblong, Rectangular chamfered) at the bend with various Froude number. 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. [Journal of American Science 2010;6(10):893-897]. (ISSN: 1545-1003).

Key words: Local scour; Wing shape; L-shaped spur dike; Froude number; Time development

1.Introduction

A spur dike may be defined as a structure extending outward from the bank of a stream for the purpose of deflecting the current away from the bank to protect it from erosion. In addition to bank protection, spur dikes have also been used to enhance aquatic habitat by creating stable pools in unstable streams (Klingeman et al. 1984).

Designers of bank stabilization structures should, where possible, select spur geometry which stabilizes the bank and provides the largest scour volume subject to cost constraints.

The volume of local scour in the vicinity of a spur dike is difficult to estimate accurately. Most investigations in this field have just measured the maximum depth of scour and not the geometry of the scour hole. Few studies have been made which measured the velocity distribution associated with spur dikes and scour holes (e.g. Rajaratnam and Nwachukwu 1983), and none to our knowledge which measure the velocity distribution as the scour hole evolves.

Local scour around the spur dikes foundations failured 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.

Result of spur dike construction against flow, there will be a difference in hydrostatic pressure at upstream and downstream of the construct which will cause a whirlpool disturbance around it. These whirlpool flows account for the main local scoring mechanism which in long term, produce large vortexs at spur dike head and this lead to construct failure. One of the important indictors in determining specifications of scoring and predicating the position and expanding range is maximum scoring depth.

The scour in channel bend has been studied extensively by different researchers. Coleman et al. (2003) studied clear-water scour development at bridge abutments and suggested an logarithmic formula. Recently Ghodsian and Mousavi (2006) correlated the maximum scour depth in a channel bend to densimetric Froude number, relative bend radius and relative depth of flow.

Fazli et al. (2008) 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 and Vaghefi (2009) 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. (2010) 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%.

As it can be seen from the forgoing paragraphs, fast majority of researches on scour at spur dike are conducted at a straight flume. In practice there are many examples where the spur dike the flume bend. In such a case the flow patterns which are mostly the cause of scour would not be the same as the case of straight flume and therefore it is the principal objective of this study is to carry out experimental tests on the effect of wing shape on time development of scour at L-shape spur dike in location of 60 degree in a 180 degree flume bend.

The scour geometry around an L-shape spur dike in a bend depends on channel geometry (channel width, channel radius and bed slope), spur dike characteristics (length and wing spur dike, wing form, angle with bank, location in bend), flow conditions (approach depth and discharge or velocity), sediment properties (specific gravity, grain size, friction angle), and fluid parameters (density and viscosity). Therefore for depth of scour ds one can write:

(1) $ds = f(L, l, \alpha, \theta, y, B, S_0, V, g, d_{50}, R, \rho_s, \phi, \rho, \mu, \lambda, t)$

in which L is length of spur dike,l is wing of spur dike, α is angle of spur dike with bank, θ is location of spur dike in bend,y is approach flow depth, B is channel width, S_0 is bed slope,V is approached flow velocity, g is gravitational acceleration, d_{50} is median grain size, R is radius of bend, ρ_s is density of sediment, ϕ is friction angle of sediment, ρ is density of fluid, μ is viscosity of fluid, λ is coefficient of wing form and t is time of scour. Using dimensional analysis, Eq. (2) can be written as:

$$\frac{ds}{y} = f\left(Fr, \theta, \alpha, S_0, \phi, \mathrm{Re}, \frac{L}{B}, \frac{l}{L}, \frac{R}{B}, \frac{L}{d_{50}}, \frac{\rho_s}{\rho}, \frac{R}{L}, \frac{t}{te}, \lambda\right) \quad (2)$$

in which Fr is approach Froude number, Re is Reynolds number and te is maximum of time development of scour. After simplification of above equation and eliminating the parameters with constant values, one can have:

$$\frac{ds}{y} = f\left(Fr, \frac{t}{te}, \lambda\right) \quad (3)$$

2. **Materials and Methods**

All of the experiments were conducted in a flume located at hydraulic laboratory of Islamic Azad University of Ahwaz. 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 (Fig. 1).

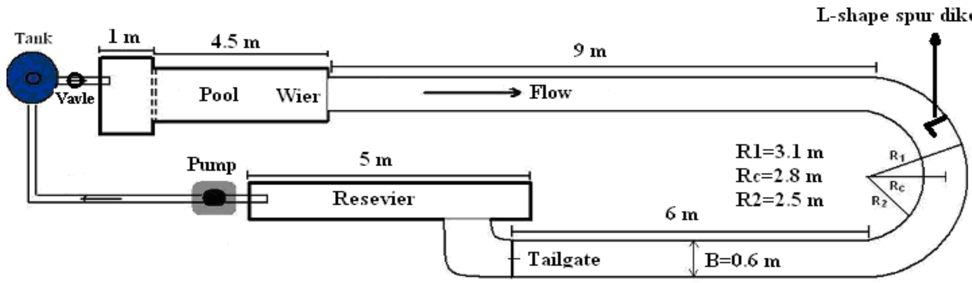


Figure 1. The experimental setup (Plan)

In this study to maintain the clear water condition without formation of ripple, uniform sediment with median size of *d*50 = 2 mm, and geometric standard deviation of σg ~ 1.7 were used (Dey et al., 1995) was used with a thickness of 0.2m and covered the total length of channel. The spur dikes were made of Plexiglas L-shape in plan and located at section 60 degree in the bend. The L-shape spur dikes were of 1 cm thick and 60 cm high.

The experiments was carried out using one length for spur dike (i.e. L = 20% of the channel width), one wing length of spur dike (i.e. *l* = 100% of the spur dike length) (Donat ,1995) and three different wing shapes of oblong, rectangulat chamfered and rectangular were used (Fig.2).

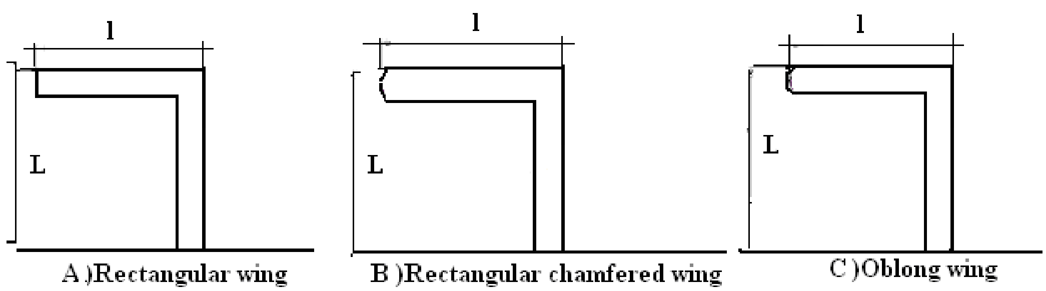


Figure 2. Schematic illustration of a L-shape spur dike with different wing shapes

In this study the experiments were performed under clear-water conditions at four different flow intensities (u*/u*c) of 0.61,0.68,0.74 and 0.85 corresponding to a shear stress levels of 37%,48%,57% and 78% of the critical shear stress level based on Shields stress, respectively. The symbols u* and u*c are the shear velocity and the critical shear velocity, respectively.

Four Froude numbers of 0.23,0.26,0.28 and 0.32 were applied in order to investigate the effect of flow conditions on the scouring. All the experimental tests where conducted under the same flow depth and in two location of 60 degree in 180 degree flume bend.

In this study, a long time experiment was conducted at a Froude number of 0.34 and location of 60 degree for an L-shape spur dike of rectangular wing. The results are shown in Fig.3. 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.

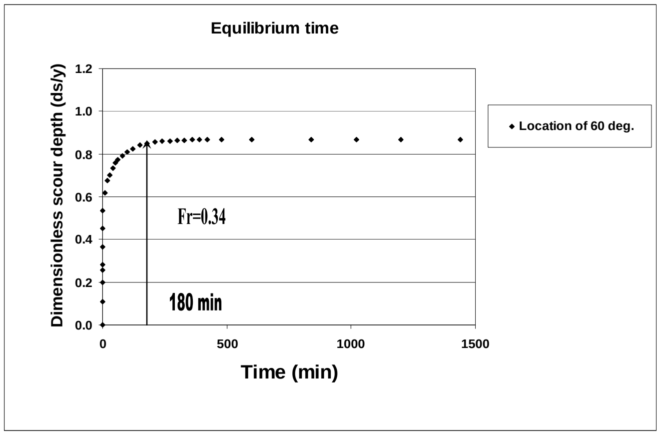


Figure 3. Equilibrium time in the location of 60 degree for an L-shape spur dike of rectangular wing

The following procedure was used for each experimental run. Before the experiment with the L-shape 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 (Fig.4).

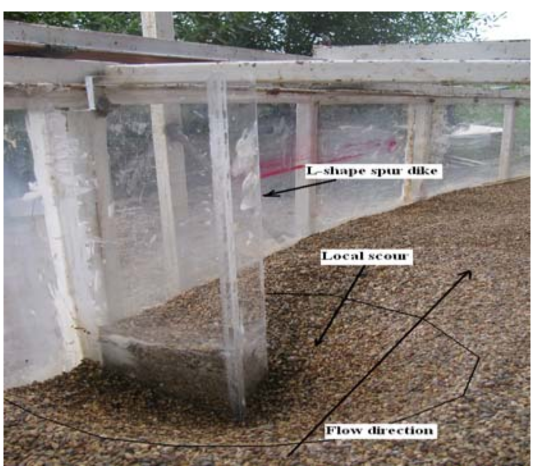
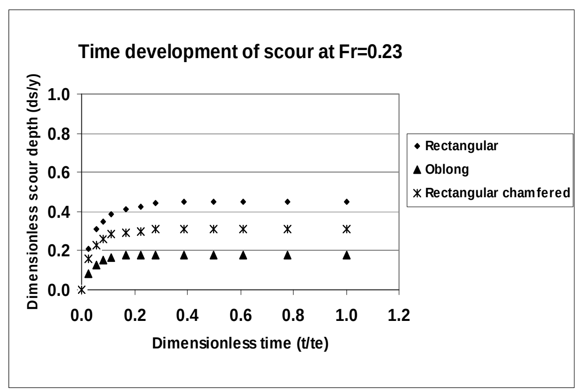
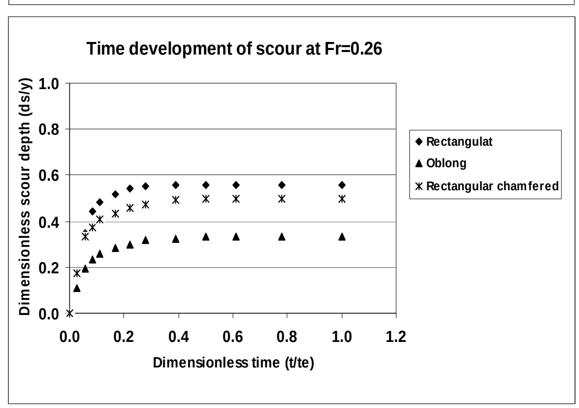


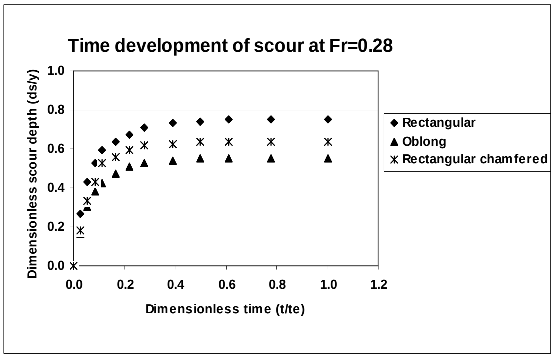
Figure 4. Scour pattern at the end of a test

3. **Results**

Figure 5 shows the time development of the local scour around the L-shape spur dike for three different wing shapes were used at location 60 degree in flume bend. In all Froude number, at wing shape of oblong results maximum reduction in scour depth and gives a maximum reduction in scour depth and at wing shape of rectangular results minimum reduction in scour depth and gives a minimum reduction in scour depth. The main reason of such finding is that minimum value of vortex at wing shape of oblong and maximum of vortex at wing shape of rectangular.







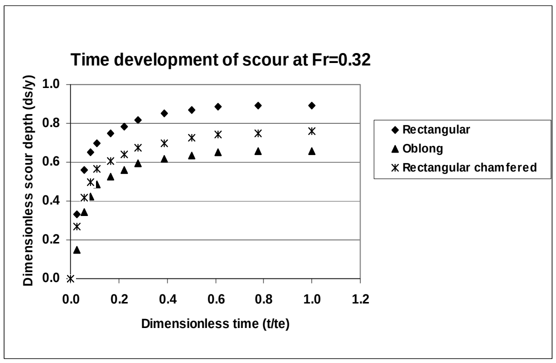


Figure 5. Time development of scour for different wing shapes

4. Discussions

In this study, investigation on the time development of local scour on around a L-shape spur dike with three different wing shapes in a 180 degree flume bend are presented. The experiments was carried out using one length for spur dike (i.e. L = 20% of the channel width), one wing length of spur dike (i.e. *l* = 100% of the spur dike length) were used. Experiments were at location 60 degree in flume bend with four Froude numbers of 0.23,0.26,0.28 and 0.32. The characteristics of the scour hole have been shown to be affected by the shape of spur dike in the bend and Froude number. It was found that:

- Wing shape of Rectangular results maximum in scour depth.
- By increasing the Froude number, the scour increases.
- Maximum depth of scour occurs for the Fr=0.34.
- Wing shape of oblong results maximum reduction in scour depth and gives a maximum reduction in scour depth.

Acknowledgements:

Author thankfully acknowledge the financial support provided by Islamic Azad University Ahwaz Branch and Khuzestan Science and Research Branch, Islamic Azad University.

Corresponding Author:

Assist. Prof., Alireza Masjedi
Islamic Azad University Ahwaz Branch
Ahwaz, Iran
Email: Drmasjedi.2007@yahoo.com

References

1. Coleman, S.E., Lauchlan, C.S. and Melville, B.W. 2003. Clear-water scour development at bridge abutments, Journal of Hydraulic Engineering, No.41, pp.521-531.
2. Dey S., Bose S. K., and Sastry G. L. N. 1995. Clear water scour at circular piers: a model. Journal of Hydraulic Engineering, Vol. 121, No.12, pp. 869–876.
3. Donat, M .1995. Bionengineering techniques for streambanj restoration: A review of Central European practices, watershed restoration project report No.2, University of British Colombia,Austria.
4. Fazli M., Ghodsian M., and Salehi S. A. A. 2008, Scour and flow field around a spur dike in a 90o bend. International Journal of Sediment Research. Vol.23, No.1, pp. 56–68.
5. Ghodsian, M. and Mousavi S. K. 2006. Experimental study on bed scour in a 90o channel bend. International Journal of Sediment Research, Vol. 21, No. 4, pp. 321-328.
6. Ghodsian, M. and Vaghefi, M.2009. Experimental study on scour and flow field in a scour hole around a T-shape spur dike in a 90° bend, International Journal of Sediment Research, Vol. 24, No. 2, pp. 145–158
7. Klingeman, P. C., Kehe, S. M., and Owusu, Y. A. 1984. Streambank erosion protection and channel scour manipulation using rockfill dikes and gabions. Rep. No. WRRI-98, Water Resources Research Institute, Oregon State Univ., Corvallis, Ore.
8. Masjedi, A., Shafai Bejestan, M. and Moradi, A. 2010. ҁExperimental study on the time development of local scour at a spur dike in a 180 degree flume bend. Journal of Food, Agriculture & Environment, Vol.8 (2): 904-907.
9. Rajaratnam, N., and Nwachukwu, B. A.1983. Flow near groin-like structures. J. Hydraul. Eng., 109(3), 463–480.
10. Oliveto, G. and Hager, W.H. 2002. Temporal evaluation of clear-water pier and abutment scour. Journal of Hydraulic Engineering, ASCE. 128(9): 811-820.

7/11/2010