Scour Around a Spur Dike at a 90^o Bend

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Abstract

The special feature of bend flow may cause scouring of the bed and bank. For protection of outer bank, spur dike may be used. But in this case the local scour around the spur dike may form.

In this paper preliminary result of experiments around a single spur dike in a 90 degree bend is reported. Experiments were conducted in a 0.6m width and 0.7m height flume with 90 degree bend at its end.

INTRODUCTION

Scouring in the bend ways leads to deep sections at the toe of the outer bank of the bend. The presence of secondary currents and the greater depths at the outer bank cause high velocity along the outer bank. The high velocity and shear stress along the outer bank, causes scour to form at the outer bank. Secondary currents transport bed material toward the inner bank of the bend. When the outer bank is rigid or when it is protected, the width of channel will not change and the deepening or scouring of the bed may observed. It is expected that when the banks are rigid, the amount of scour is more. However Harvey and Sing (1989) indicated that rigidity of the bank had no effect on maximum flow depth in the bend.

It is required to predict the amount of bed scour in order to design stable bank protection. The amount of scour depends on channel geometry (i.e. slope, cross section and plane form), hydraulic forces, bed and bank material, flow and sediment characteristics.
One of the early studies on scour in bend is that due to Shukry (1950) who performed experiments in 90 degree and 180 degree bends in rectangular channels with different values for ratio of width of flow to depth of flow and ratio of radius of the bend to width of flow. The scour and deposition pattern at a 90 degree bend was measured by Hooke (1974). The flow in bends with rigid banks on erodible bed was studied theoretically by Engelund (1974), Kikkawa et al. (1976), Zimmermann and Kennedy (1978) and Odgard (1981). Varshney (1973) analyzed laboratory and field data and an empirical equation for the maximum scour depth at the bend in a rectangular channel.

Apman (1972) investigated the effects of water surface width and outer radius of the bank on the relative depth of flow. Chatley (1931) related the scour depth at bend to depth of flow, radius of channel curvature and with of flow. Alvarez (1977) studied the scour in the channel bend using limited field data and related *Dmb* to the maximum depth of flow in the upstream straight channel and ratio of width of flow to centerline radius of bend *W/Rc*. Galay et al. (1987) studied the scour in the gravel bed rivers and related the relative depth of flow to ratio of width of flow and bend angle. Thorne (1988) related the scour depth at a bend to depth of flow and ratio of channel curvature to channel width.
Watanabe et al. (1990) related the scour depth to width of flow, centerline radius of the bend, mead depth of flow, slope and friction factor.

Maynord (1996) by using large number of field data related the scour depth to depth of flow, centerline radius of curvature of channel and width of flow.

Review of literature shows that most of research on scour in a bend flow is related to experiments on bed scour without using spur dike. The available literature, to the knowledge of authors, doesn't provide any procedure for computation of scour around spur dike at a bend. However, extensive experiments were conducted to study the scour around spur dike in a straight channel, for example Ahmad (1951,1953); Garde et al. (1961); Gill (1972); Richardson and Stevens (1975); Rajaratnam and Nwachukwu (1983); Perzedwojiski (1992); Lim and Chiew (1992) and Shields et al. (1995) and

Kuhnel et al. (1999) who studied the scour associated with spur dike when the flow depth was greater than the groin height. Subramanya (1976) studied the scour around slotted permeable groin and obtained equation relating the maximum scour depth to approach Froude number and opening ratio of groin.

In this paper result of experiments on bed scour around a spur dike in a rectangular channel with a 90 degree bend is presented.

EXPERIMENTS

Experiments were conducted in a re-circulating rectangular flume having 0.6 m width, 0.7m height with a 90 degree bend at it end. The flume was designed such that its 90 degree bend could be changed to have different radius of curvature (i.e. R = 1.2m, 1.8m and 2.4m). Figure 1 shows a schematic view of flume. The bed and sides of flumes was made of glass supported by metal frame. Measurement of discharge was done by a calibrated orifice set in the supply pipe. Depth of flow was measured by a digital point gauge having an accuracy of ±0.01mm. Bed profile was recorded using a bed profiler. Water was supplied from a sump in to the entrance tank and water level in the flume was controlled by a tail gate situated at the end of flume. Uniform sediment with median size d50 = 1.4mm was used with a thickness of 0.2m and covered the total length of flume. Spur dike was made of Plexiglas with a thickness 1cm and length of 20cm fixed to the side of flume at section 45 degree. Period of experiments was kept equal to 8hrs at witch maximum scour occurs.

Initially for a particular value of bend curvature supply valve was opened slowly, the discharge increased to a predetermined value so that no scour occurs at the straight section of flume. Discharge and flow depths were recorded for each experiment. At the end of each experiment, the bed topography was measured. Experiments were conducted for discharge 20 and 30 L/s. Two different values for relative bend radius i.e. R/W = 2 and 3 was tested.

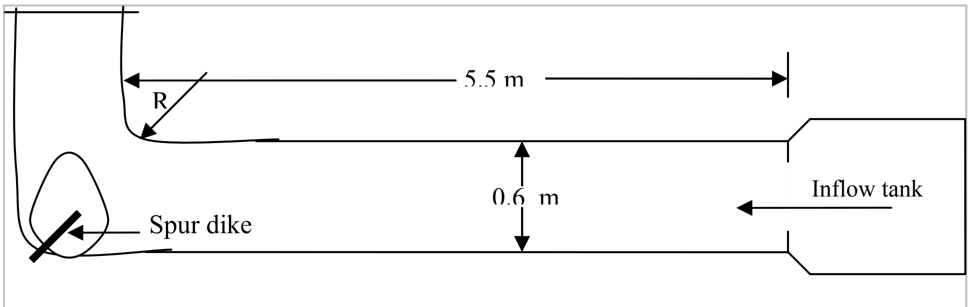

Figure 1. Schematic view of 90 degree flume

RESULTS

Figures 2 and 3 show typical bed topography for Froude number Fr =0.4 and relative bend radius of R/W =2. Figure 2 is for discharge Q = 20 L/s while Figure 3 is for discharge Q = 30 L/s. It is clear that for both values of discharges (20 and 30 L/s), the scouring is concentrated at the nose of spur dike and sedimentation is observed at about same distance downstream of spur dike. Figure 3 (which is for Q= 30 L/s) shows that scour dimensions is greater than that of Figure 2 (which is for Q= 20 L/s). This means that the higher the discharge is, the larger the scour dimensions are. The effect of discharge on dimensions of sedimentation downstream of spur dike is also noticeable from Figures 2 and 3. The pattern of sedimentation in both cases is different. For Q = 20 L/s, some sedimentation is occurs at the outer bank in the downstream of spur dike, while more sediment is transported by flow and deposited

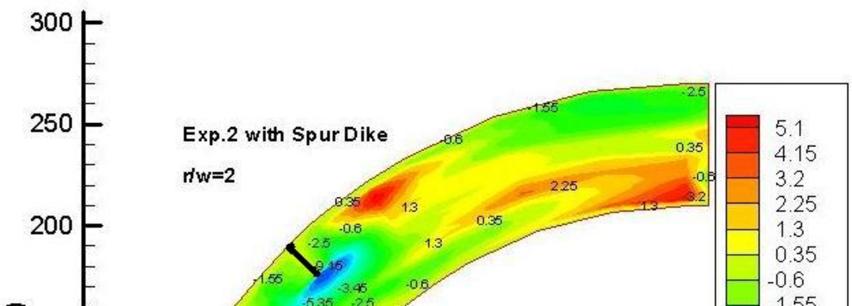

Figure 2. Scour pattern around spur dike for Q = 20(L/s) and Fr = 0.4 with R/W=2

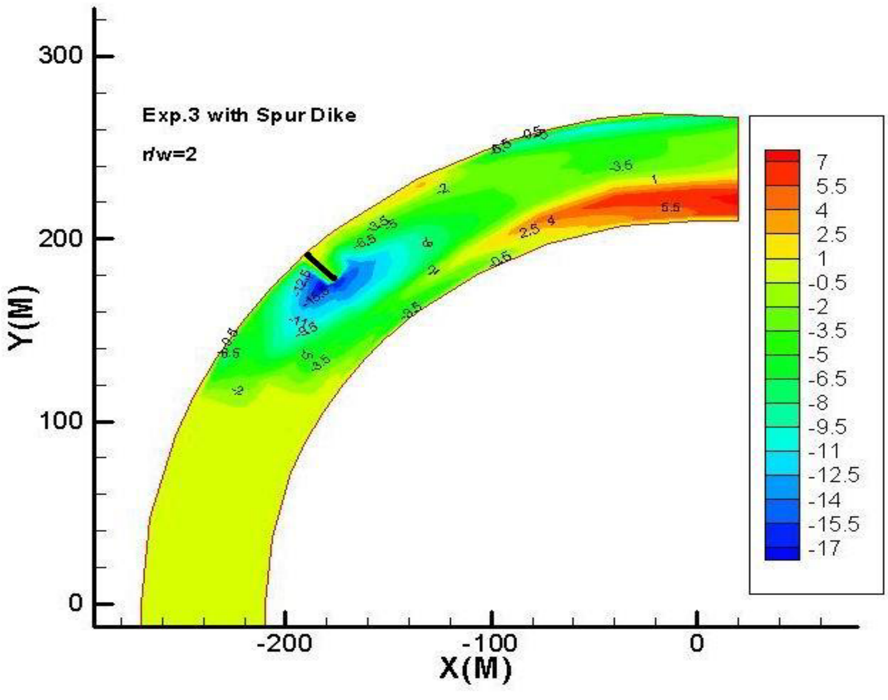

Figure 3. Scour pattern around spur dike for Q = 30(L/s) and Fr = 0.4 with R/W=2

in the inner bank. For Q = 30 L/s most of the scoured material is transported to the downstream and deposited at the inner bank.

Figure 4 shows a typical variations of effect of discharge on lateral bed slope for Froude number Fr = 0.4 and R/W = 2 at sections 45, 50 and 60 degree. The solid line is for Q = 20 L/s while the doted line is for Q = 30 L/s. This figure shows that maximum depth of scour occurs at the nose of spur dike (i.e. at section 45 degree). Moreover, the amount of scour for Q = 20 L/s is less than that for Q = 30 L/s. At sections downstream of spur dike (i.e. at sections 50 and 60 degree) maximum depth of scour is reduced and height of sedimentation at the outer bank is increased. Depth of scour for Q = 30 L/s is more than that for Q = 20 L/s. The effect of discharge on the variations of bed level at the midwidth of flume and on the outer bank is more pronounced.

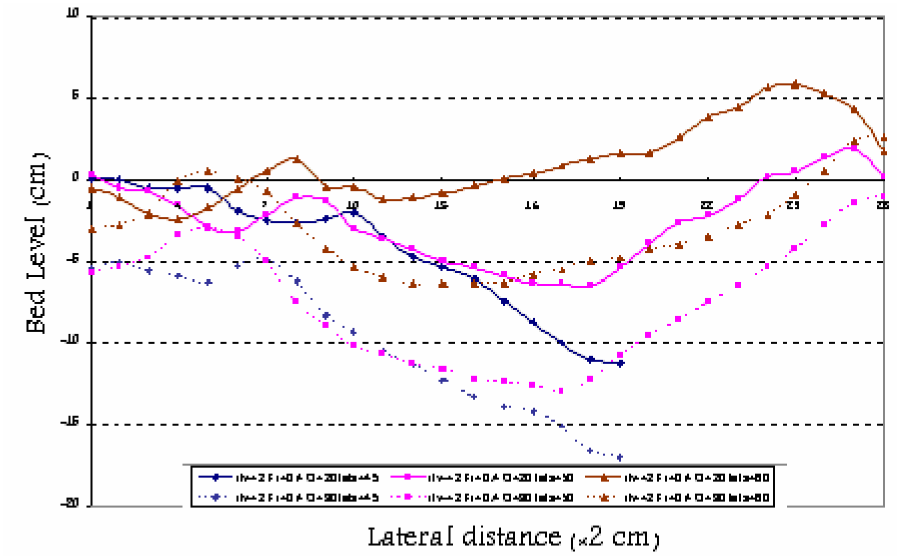

Figure 4. Variations of lateral bed slope for Q=20 and 30 (L/s), Fr = 0.4 and R/W=2 for sections 45, 50 and 60 degree

Figure 5 shows a typical bed topography for Froude number Fr =0.4, relative bend radius of R/W = 3 and discharge Q = 30 L/s. The variation of bed slope in this figure is almost similar to that of Figure 2. In this case also the scour is concentrated at the nose of spur dike. The pattern of sedimentation is also similar to that of Figure 3. The amount of scour and sedimentation is less for R/w =3 than that for R/w =2.

Figure 6 shows the effect of relative bend radius R/W on lateral bed slope of channel at the upstream of spur dike (at section 40 degree), at the nose of spur dike (at sections 45 degree) and further downstream (at section 50 degree) of spur dike. Moreover it is evident that by increasing the R/W, the amount of scour decreases. The variation of bed level at the inner bank is much less than that at the right bank.

CONCLUSION

The main conclusions from this experimental study are:

- By increasing the discharge, dimensions of scour hole and sedimentation increases.
- By decreasing the relative bend radius R/W, dimensions of scour hole increases.
- By decreasing the relative bend radius R/W, height of sedimentation at the section 60 degree decreases.
- By decreasing the relative bend radius R/W, the location of sedimentation moves to the downstream

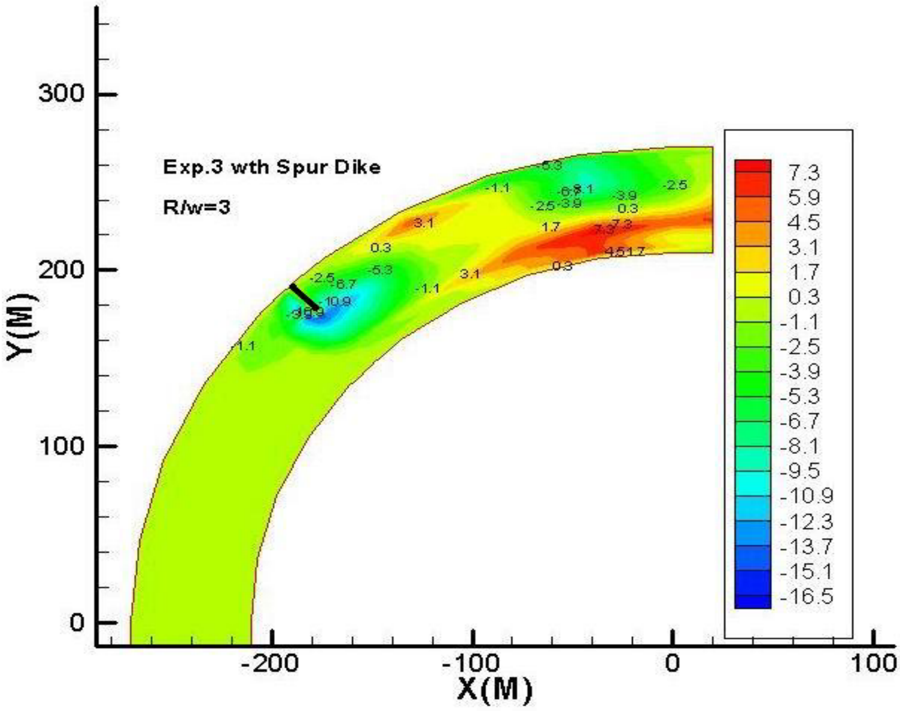

Figure 5. Scour pattern around spur dike for Q = 30(L/s) and Fr = 0.4 with R/W=3

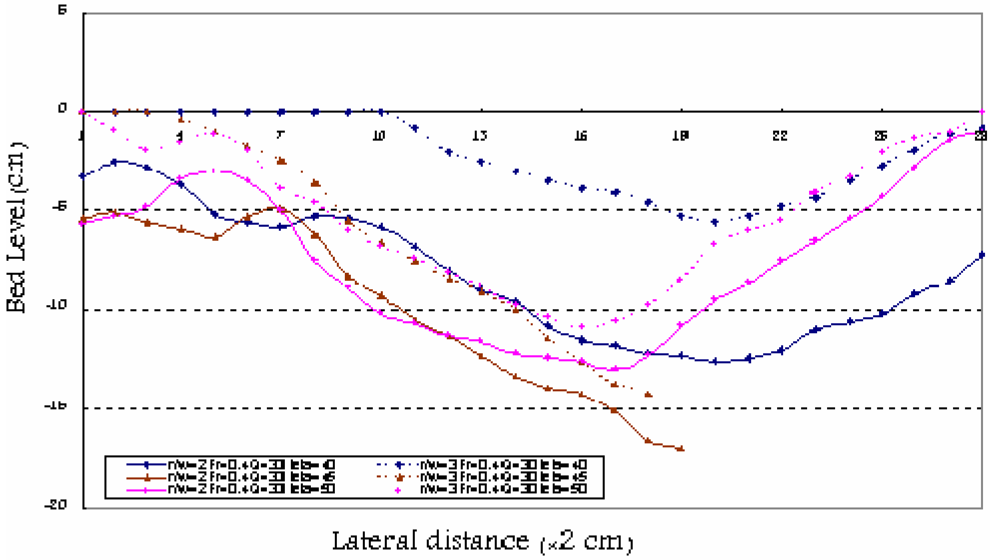

Figure 6. Effect of R/W on lateral bed slope for Q= 30(L/s), Fr = 0.4 for sections 40, 45 and 50 degree

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