Hydro Science & Marine Engineering
https://ojs.bilpublishing.com/index.php/hsme

ARTICLE

Effects of Locations of Spur Dyke on Bed and Scour around Bridge Piers in Meandering Channel

M. Athar[1*] Farha Naz[1] Humaira Atahr[2]

1. Civil Engineering Department, Aligarh Muslim University, Aligarh, U.P., India
2. Innovative Building Materials Division, CSIR- CBRI, Roorkee, Uttarakhand, 247667, India

ARTICLE INFO

Article history
Received: 21 February 2022
Accepted: 23 March 2022
Published Online: 01 April 2022

Keywords:
Spur dykes
Bridge piers
Angular displacement
Scour and deposition

ABSTRACT

Spur dykes are the structures which are used to protect the eroding bank of rivers. They are sometimes also used to safeguard the life of many structures such as bridge piers, abutments etc. The efficiency of spur dykes has been checked in straight channels by conducting model tests in laboratories by many investigators. Very few studies were done in curved channels. In present work an attempt has been made to study the effect of location of spur dyke on bed and scour around bridge pier in curved open channel (bend angle $\emptyset = 80^o$) with time. Experiment has been carried out in 80^o channel bend at constant discharge (3.5×10^{-3} m^3/s) and bridge pier is located at angular displacement $\Theta = 60^o$. Here Θ is the angle the line drawn at the inlet of any bend to the line joining the centre of curvature and any point on the outer portion of the bend. It is found that maximum scouring occurs at $\Theta = 0^o$ and 20^oalong inner wall and at $\Theta = 60^o$ and 80^o along outer wall. It is also found that scouring around bridge pier is more in the vicinity of pier and decreases with increase in distance from pier. The most suitable location for spur dyke to protect bridge pier is at angular displacement $\Theta = 20^o$. Scour developed rapidly during initial time and then rate of scouring decreases with elapse of time.

1. Introduction

Dikes are the hydraulic structures which are mainly used for river training and erosion protection of the river bank. Primary objective is to improve the navigability of a river by providing a sufficient depth of flow and a desirable channel alignment. With respect to erosion protection, spur dikes can be designed to protect both straight reaches and channel bends.. Although the use of spur dykes is extensive, no definitive hydraulic design criteria have been developed. Design continues to be based primarily on experience and judgment within specific geographical areas.

Garde et al. [1] (1961) pointed out that the maximum scour depth occurs at 90° inclination and smaller for other inclinations of spur dykes. Zhang & Nakagawa [2] (2009), examined the flow behavior and concluded that the maximum influenced flow around spur dyke depends on ap-

*Corresponding Author:
M. Athar,
Civil Engineering Department, Aligarh Muslim University, Aligarh, U.P., India;
Email: matharalam58@gmail.com

DOI: https://doi.org/10.30564/hsme.v4i1.4462

proach velocity and length of spur dyke. Vaghefi et al. [3] (2009) conducted an experimental study on a T- shaped spur dike in a 90° channel bend and concluded that maximum scour depth and the scour hole volume increases with increase of the length of spur dike. Masjedi et al. [4] (2010) found that the depth of scour increases with the increase in approach Froude number and length of the spur dike whereas the same was found to decrease with an increase in wing length of spur dike. Masjedi et al. [5] (2011) carried out series of experiments on scour depth around a L-shape dike, in a laboratory flume with 180° bend under clear water. It was found that by increasing the length of spur dike, the maximum depth of scour increases, and with increase in Froude number, the maximum scour depth increases. Koken & Gogus [6] (2015), studied on effect of spur dyke length on the horseshoe vortex system and observed that the main horseshoe vortex disappears over a much shorter distance in the flow direction for the short spur dyke than those of medium and long spur dykes. Pandey et al. [7] (2015), noticed that the maximum influenced on scour length depends on flow characteristics around spur dyke. Przedwojski [8] (2015) did field investigations of bed topography and local sour at spur dykes in two bends of the Warta River. A new equation for a maximum scour depth prediction at spur dyke located along an outer bank of a bend is introduced. Nishank et al. [12] (2019) observed that when spur dyke was located at location 1 (at Θ = 0°), this affects the bed till Θ = 40° after that spur dyke's effect reduces on bed. When spur dyke was installed at location 2 (Θ = 40°), scouring near (Θ = 60°), reduces. When spur dyke installs at location 3 (Θ = 60°), scouring reduces at (Θ = 80°).

After critically reviewing the available literature on spur dikes, it is concluded that lot of work has been done on the spur dikes in straight and curved channel. Effects of channel geometry, sediment characteristics, flow characteristics, spur dikes shapes, size, location and orientation etc. have been fully reviewed in literature. Certain co-relations for evaluating depth of scour around the dikes and the areal extent have been proposed. A very few literature is available where the effects of spur dyke location on bed topography as well as any hydraulic structure like spillway, bridge piers etc. have been studied. Hence in this paper an attempt has been made to critically examine the channel bed variation and change in scour hole developed around bridge piers by installing spur dykes at various locations.

Dimensional Analysis

Many variables such as flow velocity (v), flow depth (y), particle size (d_{50}), mass density (ρ), viscosity (μ), acceleration due to gravity (g), angular displacement (θ), which is the angle the line drawn at the inlet of any bend to the line joining the centre of curvature and any point on the outer portion of the bend, width of channel w, width of spur dyke b, thickness of spur dyke t_1 and time of scour t were supposed to influence the scour and deposition (river bed variation) d_s, in straight and curved open channels.

Thus,

$$d_s = f\{v, \rho, y, \theta, d_{50}, \mu, g, b, w, t_1, T\} \quad (1)$$

Carrying dimensional analysis using Bukingham's Pi – theorem method, following equation may be written.

$$d_s/w = f\left(y/w, b/w, t_1/w, \theta, d_{50}/w, \rho v w/\mu, v/\sqrt{gw}\right) \quad (2)$$

Dropping those dimensionless variables which are invariant in present study, the final equation can be written as:

$$d_s/w = f\left(\theta, \frac{l}{L}, x/w\right) \quad (3)$$

These will form the basis for the analysis of the data collected in the present work.

2. Methods and Materials

The data on scour and deposition around the spur dyke have been collected carefully in the model of a meandering channel. The various hydraulic and geometrical data regarding flow, spur dykes, piers and bends etc are mentioned in Table 1.

Table 1. Parameters used in Present Study

S. No.	Parameter	Symbol	Unit	Range
1.	Width of spur dyke	B	m	0.075
2.	Sediment size	d	mm	-
3.	Averaged sediment size	d_{50}	mm	0.27
4.	Depth of channel	D	m	0.43
5.	Dimensionless scour or deposition	ds/w	-	-
6.	Longitudinal spacing	l	m	-
7.	Length of channel	L	m	10.5
8.	Dimensionless spacing	l/L	-	0 - 1.0
9.	Radius of curvature of bend	Rc	m	0.705
10.	Curvature ratio	Rc/w	-	2.014
11.	Time of scour	t	sec	-
12.	Total time at equilibrium scour	T	hours	6
13.	Thickness of spur dyke	t_1	cm	1.3
14.	Lateral spacing	x	cm	3 to 6
15.	Width of channel	w	cm	35
16.	Transverse dimensionless spacing	x/w	-	0 - 1.0
17.	Bend Angle	$\emptyset$	-	80°
18.	Angular Displacement	θ	-	20° to 80°

Schematic diagram and photographic view of the experimental setup are shown in Figures 1 and 2.

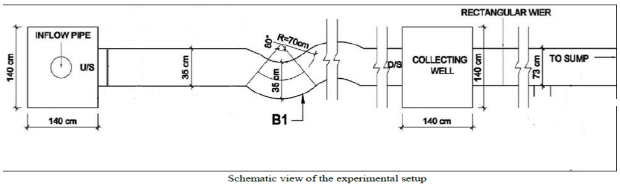

Figure 1. Schematic view of Experimental Set-up

Figure 2. Photogramatic view of Experimental Set-up

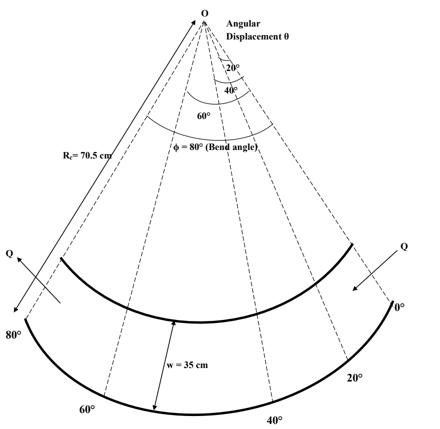

Figure 3. Showing the angular displacement θ

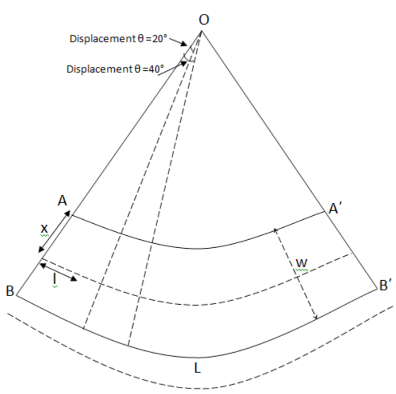

Figure 4. Sketch showing the studied parameters transverse distance x, longitudinal spacing l, total length L, width of channel w and angular displacement θ.

Figure 5. (Photometric view of bed, when spur dyke installed at angular displacement ϴ = 0°)

Figure 6. (Photometric view of bed, when spur dyke installed at angular displacement ϴ = 20°)

Figure 7. (Photometric view of bed, when spur dyke installed at angular displacement ϴ = 4 0°)

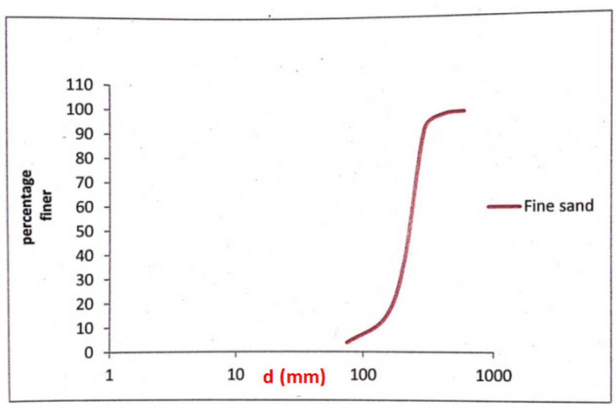

Figure 8. Particle size Distribution Curve

Experimental Procedure

The bed of the meandering channel was first prepared using well graded wet sand (d_{50} = 0.27 mm) using uniform compaction technique. After insuring that test bed is fully prepared, a discharge of 3.5×10^{-3} m^3/s is allowed to pass over the bed for about 4 hours. After 4 hours of run, the discharge is stopped and the bed variations in both straight and curved reaches of the channel are carefully recorded. In second phase, the spur dyke of designed shape and size was installed at particular location. Same discharge was passed and observations were made. The data for scour and deposition were collected for many locations of spur dyke under similar hydraulic and geometric conditions.

3. Analysis of Data, Results and Discussion

3.1 Bed Variation along Longitudinal Direction

Figure 9 shows variation of scour and deposition along the longitudinal direction in meandering channel without installing spur dyke for a flow rate of Q = 3.5×10^{-3} m^3/s. Along inner wall maximum scouring occurs at angular displacement Θ = 0° and maximum deposition occurs at Θ = 80°.Scouring decreases from Θ = 0° to Θ = 40° and then at Θ = 60° and Θ = 80°, there is deposition. Along outer wall maximum deposition occurs at Θ = 0° and maximum scouring at Θ = 80°.

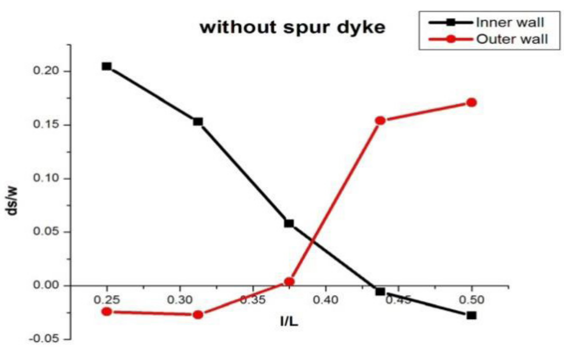

Figure 9. Bed variation along longitudinal direction without spur dyke

Figure 10 shows variation of scour and deposition along the longitudinal direction when spur dyke installed at angular displacement Θ = 20°. Along inner wall maximum scouring occurs at location 2, Θ = 20° and minimum scouring at Θ = 80°. From Θ = 0° to Θ = 20°, scouring increases then from Θ = 20° to Θ = 80° it decreases. Along outer wall maximum deposition occurs at Θ = 0° and maximum scouring occurs at Θ = 60°. Scouring increases from Θ = 20°to Θ = 60° and then decreases from Θ = 60°to Θ = 80°. The data of scour and deposition are shown in Tables 2(A) and 2(B).

Table 2(A). Spur Dyke at Θ = 0°, Inner Wall

Spur Dyke at Θ = 0°				
Inner Wall				
l (m)	L (m)	ds (m)	l/L	ds/w
0.984	3.936	0.018	0.2500	0.3085
1.23	3.936	0.0536	0.3125	0.1531
1.476	3.936	0.0467	0.3750	0.1334
1.722	3.936	0.0309	0.4375	0.0882
1.968	3.936	0.0235	0.500	0.0671

Table 2(B). Spur Dyke at Θ = 0°

Spur Dyke at Θ = 0°				
Outer Wall				
l (m)	L (m)	d_s (m)	l/L	ds/w
0.984	0.3936	0.0116	0.2500	0.0331
1.230	0.3936	0.036	0.3125	0.1028
1.476	0.3936	0.059	0.3750	0.1685
1.722	0.3936	0.0679	0.4375	0.1940
1.968	0.3936	0.0598	0.5000	0.1708

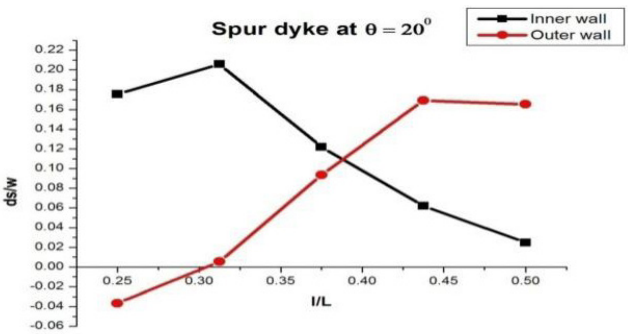

Figure 10. Bed variation along longitudinal direction spur dyke at location 2 (Θ =20°)

3.2 Bed Variation along Transverse Direction

Transverse direction is the direction in which distance x is measured normal to flow from inner to outer bank of the bend as shown in Figure 4.

Figure 11 shows bed variation along the transverse direction at angular displacement Θ = 0° for various location of spur dyke (Θ = 0°, 20°, 40° and without spur dyke). Maximum scouring occurs at x/w = 0 at Θ = 0°.This figure shows more scouring from x/w = 0 to 1 when spur dyke installed at angular displacement Θ = 0° in comparison to when spur dyke installed at Θ = 20°, 40° and without spur dyke. Scouring decreases from x/w = 0 to 1 in all cases. This figure shows that there is no effect of spur dyke on bed variation.

Figure 12 shows bed variation along the transverse direction at Θ = 60° for various locations of spur dyke (Θ = 0°, 20°, 40° and without spur dyke). Maximum scouring occurs at x/w = 1 when spur dyke installed at ϴ = 40°. From this figure it is clear that there is more scouring from x/w = 0 to 0.5 at angular displacement ϴ = 0° in comparison to when spur dyke installed at ϴ = 20°, 40° and without spur dyke. Maximum deposition occurs at x/w = 0 when ϴ = 40°. Scouring increases from x/w = 0 to 1 in all cases.

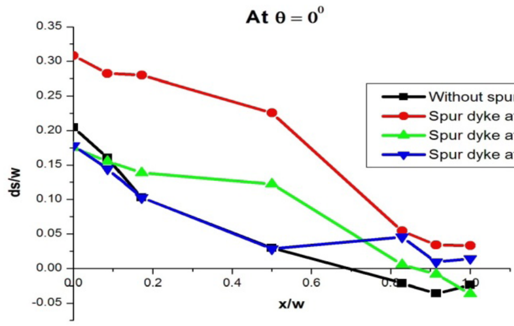

Figure 11. Bed variation along the transverse direction at location 1($\theta = 0°$)

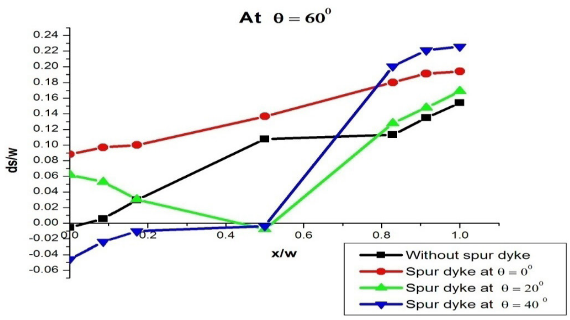

Figure 12. Bed variation along the transverse direction at location 4 ($\theta = 60°$)

Figure 13 shows bed variation along transverse direction at ϴ = 40°. Near inner wall maximum scouring occurs at ϴ = 0° and maximum deposition occurs at ϴ = 60°. This figure shows at ϴ = 40°, maximum scouring occurred at mid of channel. Near outer wall maximum scouring and deposition occur at ϴ = 60° and ϴ = 20° respectively.

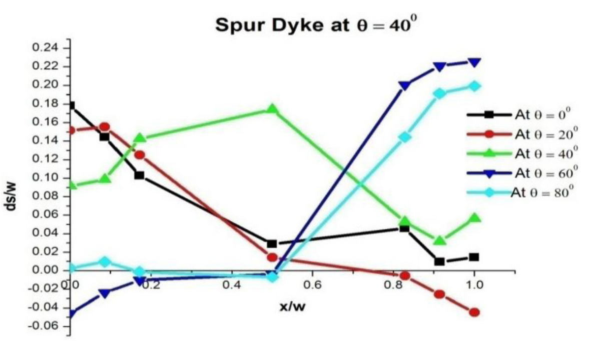

Figure 13. Bed variation along the transverse direction at location 3 (ϴ = 40°)

3.3 Bed Variation with Time along Longitudinal Direction

Figure 14 shows bed variation along the longitudinal direction with time at ϴ = 0°. Scour developed rapidly during initial time then rate of scouring decreases. The scour increases with time. Scouring developed rapidly during initial 10 minutes then rate of scouring decreases, and maximum scour hole depth occurred time t = 90 minutes.

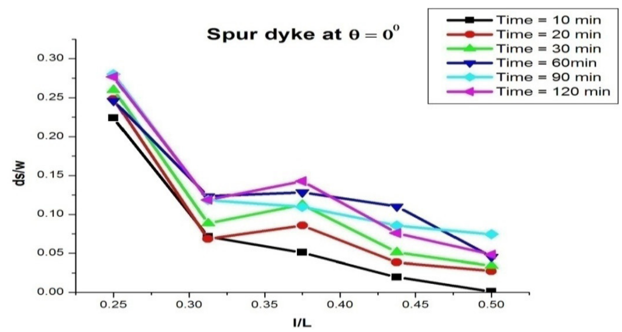

Figure 14. Bed variation along the longitudinal direction with time at location 1(ϴ = 0°)

Figure 15 shows bed variation along the longitudinal direction with time along inner wall for spur dyke location 2 (ϴ = 20°). Scour developed rapidly during initial 40 minutes then rate of scouring decreases. Maximum scour hole depth developed at t = 90 minutes for ϴ = 20°.

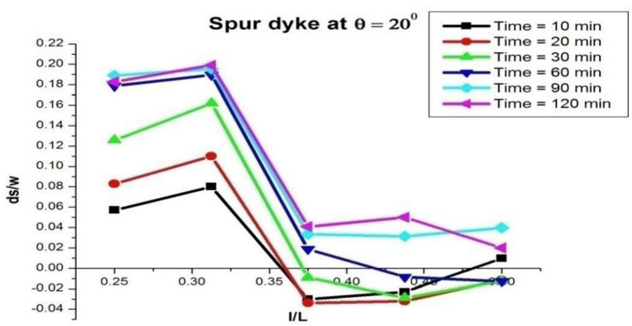

Figure 15. Bed Variation along the longitudinal direction with time, at the inner wall at location 2, (ϴ =20°)

Figure 16 shows bed variation along the longitudinal direction with time along outer wall for ϴ = 20°. Scour developed rapidly during initial 10 minutes at ϴ = 80°, then rate of scouring decreases. Maximum scour hole developed at t = 90 minutes at ϴ = 80°.

Figure 17 shows bed variation along the longitudinal direction with time along inner wall when spur dyke installed at ϴ = 40°. Scour developed rapidly during initial 10 minutes, then rate of scouring decreases. Maximum scour hole depth developed at time t = 20 minutes at ϴ = 0° displacement.

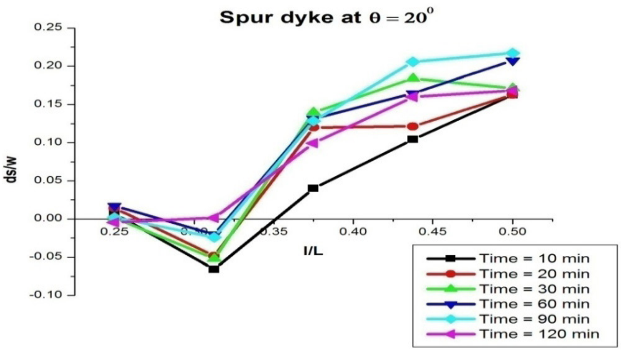

Figure 16. Bed variation along the longitudinal direction with time, along the outer wall at location 2, Θ =20°

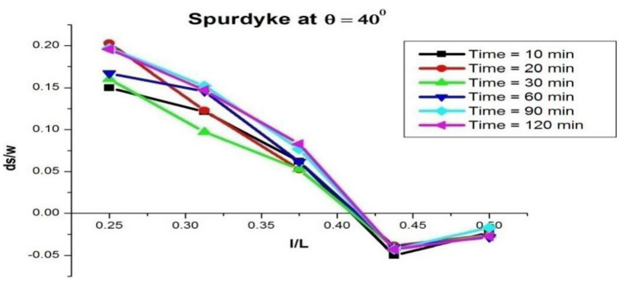

Figure 17. Bed variation along the longitudinal direction with time, along the inner wall at location 3, Θ =40°

Figure 18 shows bed variation along the longitudinal direction with time along outer wall at Θ = 40°. Scour developed rapidly during initial 10 minutes, then rate of scouring decreases. Maximum scour hole depth developed at time t = 60 minutes and at Θ = 60.

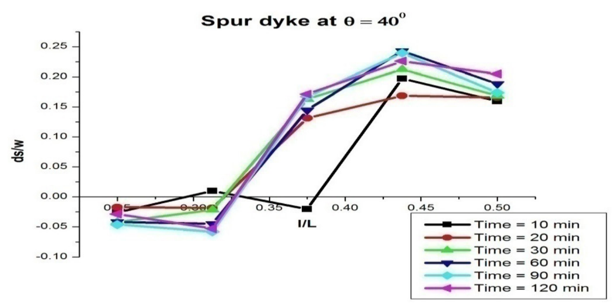

Figure 18. Bed Variation along the longitudinal direction with time, along the outer wall spur dyke is located at location 3, Θ = 40°

3.4 Bed Variation around Bridge Peirs

Figure 19 shows that at the downstream side of bridge pier at x = 3 cm (from bridge pier) scour is more at angular displacement Θ = 0° in comparison to no spur dyke. But at Θ = 20°, less value of scour is observed in comparison to no dyke and but at Θ = 40°, it shows deposition. At the upstream side of bridge pier at x = 3 cm (from bridge pier) scour is more when spur dyke installed at Θ = 0°, 20° & 40° in comparison to no dyke was used.

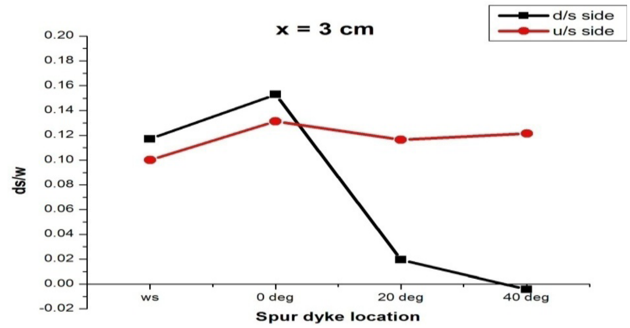

Figure 19. Bed variation around bridge pier for different location of spur dyke at x = 3 cm

Figure 20 shows that at the downstream side of bridge pier at x = 6 cm (from bridge pier), scour is more when spur dyke is installed at = 0° in comparison to no dyke is being used. But at = 20° scour is less in comparison to no dyke. Also when spur dyke is installed at = 40°, it shows deposition. At the upstream side of bridge pier at x = 6 cm (from bridge pier) scour is more at = 0°, 20° & 40° in comparison to no dyke.

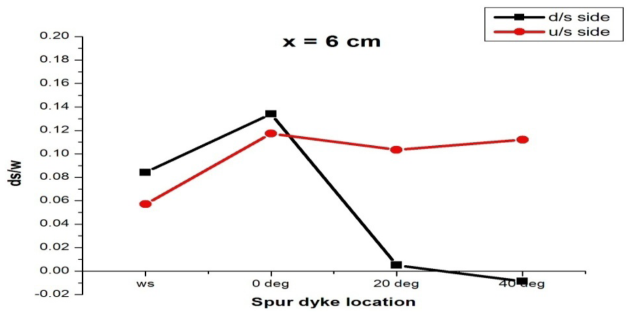

Figure 20. Bed variation around bridge pier for different location of spur dyke at x = 6 cm

4. Conclusions

Following are the main conclusions when test were performed in curved open channel (bend angle ∅ = 80°).

1) In curved portion both scour and deposition occur but for same hydraulic conditions, no such things were observed in straight portion.

2) Along the inner wall maximum scouring occurs in between Θ = 0° to 20° and along the outer wall it occurs in between Θ = 60° to 80°. But along the inner wall maximum deposition occurs in at Θ = 60 to 80° and along the outer wall maximum deposition occurs at Θ = 0° to 20°.

3) Maximum scouring occurs around the spur dyke in between at Θ = 0° to 20° and maximum scour depth occurs at Θ = 60° near outer wall.

4) Scouring around the bridge pier is more at Θ = 0° in comparison no spur dyke and it is less when at Θ = 20° in

comparison to no dyke.

5) Scouring around the bridge pier is very less at Θ = 40° in comparison when no dyke is installed. It causes more scouring at Θ = 60° near outer wall which is very close to bridge pier. Scour hole developed at the tip of the spur dyke and its length increases with time and reaches very close to the bridge pier .This can affect the stability of the bridge pier.

6) To protect bridge piers and similar hydraulic structures, the best location of spur dykes is at Θ = 20°. Spur dykes in no case should be located very close to these structures.

7) Scour develops rapidly during initial time then rate of scouring decreases. Scouring increases with time.

Author Contributions

The work presented in this manuscript is purely based on the M. Tech. dissertation of second author under the supervision of first author. The work is basically comprises with the rigorous experimentation work followed by plotting of graphs and analysis of results. The third author contributed in the preparation of the figures/tables etc and also checked the draft. The main author supervised other two authors to prepare the text in the guide lines given by editor.

Conflict of Interest

Authors declare that there is no conflict of interest.

Acknowledgments

All authors fully acknowledge the help and facilities rendered by the chairperson of Civil Engineering Department, A.M.U., Aligarh. Also thankful to other colleagues of the hydraulic section who gave valuable suggestions during the experimentation. The technical help obtained by lab staffs is highly acknowledged.

References

[1] Grade, R.J., Subramanya, K., Nambudripad, K.D., 1961. Study of scour around spur dikes. Journal of Hydraulics Division, ASCE. 87(6), 23-38.

[2] Zhang, H., Nakagawa, H., Mizutani, H., 2012. Bed morphology and grain size characteristics around a spur dyke. International Journal of Sediment Research. 27, 141-157.

[3] Zhang, H., Nakagawa, H., 2009. Characteristics of local flow and bed deformation at impermeable and permeable spur dykes. Annual Journal of Hydraulic Engineering, JSCE. 53, 145-150.

[4] Vaghefi, M., Ghodsian, M., Salehi Neyshaboori, S.A.A., 2009. Experimental study on the effect of a T-shaped spur dike length on scour in a 90^0 channel bend. Arabian Journal For Science And Engineering. 34(2), 337.

[5] Masjedi, A., Bejestan, M., Moradi, A., 2010. Experimental study on scour depth in around a T-shape spur dike in a 180 degree bend. Journal of American Science. 10(6), 886-892.

[6] Koken, M., 2011. Coherent structures around isolated spur dykes at various approach flow angles. Journal of Hydraulics Resource. 49(6), 736-743.

[7] Pandey, M., Ahmad, Z., Sharma, P.K., 2017. Scour around impermeable spur dikes, ISH Journal of Hydraulic Engineering. 36(6), 663-676.

[8] Przedwojski, B., 2015. Bed topography and local scour in rivers with banks protected by Groynes. Journal of Hydraulic Research. 33(2), 142-161.

[9] Akash Parashar, Dr. N.K. Tiwari, 2014. M. tech dissertation, Experimental study of spur dykes, Department of Civil Engineering, NIT Kurukshetra.

[10] Teraguchi, H., 2011. Study on hydraulic and morphological characteristics of river channel with groynes structure, Ph.D Thesis, Kyoto University.

[11] IS 8408, 1994. Planning and design of groynes in alluvial river-guidelines. Bureau of Indian Standards Manak bhavan, 9 Bahadur Shah Zafar margnew Delhi10002.

[12] Athar, M., Mansoor, T., Agrawal, N., 2021. Effects of Spur Dyke's Orientation on Bed Variation in Channel Bend. Journal of Hydro Science and Marine Engineering. 3(2), 1-9.

[13] www.nptel.com, Lesson 1, River training and river bank protection work, IIT Kharagpr.