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The Effect of length of a T Shape Spur Dike on Flow Patterns in 90° Bend Channel with Support Structure

[1]Mohamad Vaghefi, [2]Arash Ahmadi, [3]Behroz Faraji,[4]Mitra Javan,[5]Afshin Eghbalzadeh
[1] Department of Civil Engineering, Persian Gulf University, Bushehr, Iran
[2,3,4,5] Water Civil Engineering , Razi University, Kermanshah, Iran
Vaghefi@pgu.ac.ir

Abstract— ***Spur dike is kind of protection structure. In this paper, flow patterns around T shape spur dike and a support structure evaluated by variation of the length of T shape spur dike. After that, some of the hydraulic parameters such the power of secondary flow obtained from each simulation output.***

Keywords—T shape spur dike, support structure

I. Introduction

Spur dike is one of the common structures in hydraulic science that was protecting river morphology. Due to complex situation in bend channel especially around spur dike, a lots of investigation done to analyzed flow pattern in meandering rivers. Flow passed through meandering channels and spur dike is obviously a three-dimensional nature, so it is required a three dimensional hydrodynamic model to accurately simulate flow in meandering channels. Mesbahi (1992), Ghodsian and Mosavi (2004), Fazli et al (2007) and Forghani et al (2008) investigated on scour around spur dike in curved channel, experimentally. Dey and Barbhuiya (2006) studied the condition of flow patterns around vertical wall abutment. Vaghefi .et.al (2009 and 2012) used T-shaped spur dike located at section 75° in a bend worked on many parameters such as length and position of to a lesser extent to scour. Masjedi (2010) .et.al worked on T shape spur dike, which located in 45 and 60 degrees in outer bank of 180° bend. The number of numerical studies regarding the flow pattern around the spur dike in a curved channel is not enough. Soliman (1998) determine morphology of Nile channel around groyne by two-dimensional method. Giri et.al in (2004) determine flow pattern around spur dike in meandering channel with numerical and experimental model. Olsen .et.al (2009) used a numerical to analyze flow pattern in meanderings channel, and main purpose of their study was about effects of the bed surface roughness on flow characteristics. Because of the a few studies, which related on support structure in bend channel, so in this paper the effect of support structure accompanied the variation of length of T shape spur dike on hydraulic parameters evaluated by numerical method?

II. Material and Methodology

According to the most of the numerical method, Flow-3D software has used momentum and continuity equation. Equation (1) shows continuity relation, which is relinquishing compressibility of fluid and Cartesian coordinate (x, y, z) directions. Momentum formulas show from equations 2 up to 4.

$$V_F \frac{\partial(\rho)}{\partial t} + \frac{\partial}{\partial x}\left(uA_x\right) + \frac{\partial}{\partial y}(vA_y) + \frac{\partial}{\partial z}(wA_z) = \frac{R_{SoR}}{\rho} \qquad (1)$$

$$\frac{\partial u}{\partial t} + \frac{1}{V_F}\left(uA_x\frac{\partial u}{\partial x} + vA_y\frac{\partial u}{\partial y} + wA_z\frac{\partial u}{\partial z}\right) = -\frac{1}{\rho}\frac{\partial p}{\partial x} + Gx + fx \qquad (2)$$

$$\frac{\partial v}{\partial t} + \frac{1}{V_F}\left(uA_x\frac{\partial u}{\partial x} + vA_y\frac{\partial u}{\partial y} + wA_z\frac{\partial u}{\partial z}\right) = -\frac{1}{\rho}\frac{\partial p}{\partial y} + Gy + fy \qquad (3)$$

$$\frac{\partial w}{\partial t} + \frac{1}{V_F}\left(uA_x\frac{\partial u}{\partial x} + vA_y\frac{\partial u}{\partial y} + wA_z\frac{\partial u}{\partial z}\right) = -\frac{1}{\rho}\frac{\partial p}{\partial z} + Gz + fz \qquad (4)$$

Here (u, v, w) are velocity components in (x, y, z) directions, and (Ax, Ay, Az) are fractional areas open to flow in the subscript directions, (Gx, Gy, Gz) are gravitational force in the subscript directions. F is part of fluid volume that is including to one and zero .one utilize when cell combine with fluid and zero use in vacant condition. By equation five, the amount of the F obtained which is a show as below.

$$\frac{\partial F}{\partial t} + \frac{1}{V_F}\left(\frac{\partial}{\partial x}(FuA_x) + \frac{\partial}{\partial y}(FvA_y) + \frac{\partial u}{\partial z}(FwA_z)\right) = 0.0 \qquad (5)$$

In this model, from figure 1, four computational mesh blocks used to simulate all of the models. Two mesh block

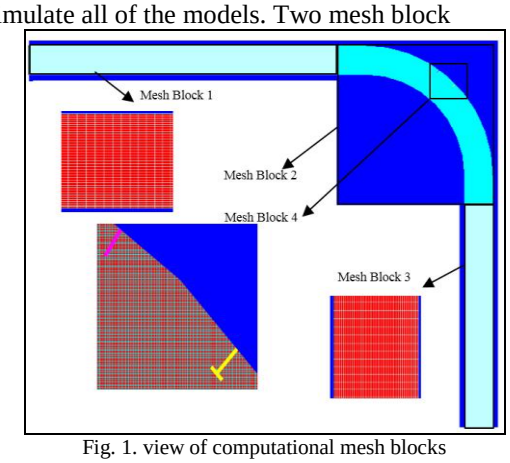


Fig. 1. view of computational mesh blocks

Experimental data, which used in numerical model, carried out at the Hydraulic Laboratory of Tarbiat Modares University, Tehran [11]. The main channel consisted of 7.1m long upstream and 5.2m long downstream straight reaches. A 90° bend channel located between two straight reaches. The channel included rectangular cross section with 0.6m in width, 0.7m in height and 2.5m radius of bend to the centerline. The bed and sides of channel were made of glass that supported by a metal frame. Channel has 0.001 slope and ratio between radius and channel wide equaled to four.

III. Results and Tables

Accuracy of the numerical result is the most important parameter of each simulation Therefor the numerical and the experimental data for model with single T shape spur dike have compared in this paper. Figure 2 Mean velocity profiles at 50-degree cross section. It can take that the difference of the both

model are minimum, so it can expected that numerical model can simulate such this physical model by high accuracy.

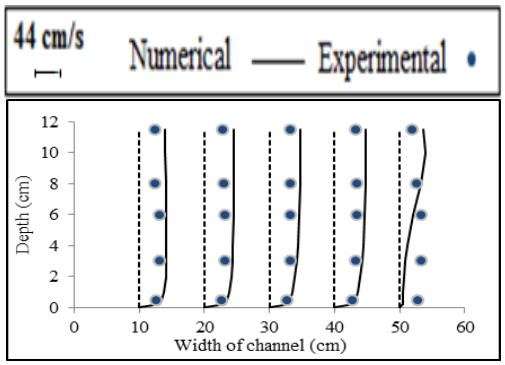


Fig. 2. Mean velocity profiles at 50-degree cross section

In this paper, the effect of a support structure on the flow patterns around T shape spur dike in 90-degree bend channel analyzed by flow-3D model. For this purpose the support structure, which made with nine centimeters length (L), and a centimeter thickness (t), located on upstream of T shape spur dike. Fig. 3 shows geometry of numerical and physical case studies field. In recent study, distance of support structure is 5 times bigger than the length of T shape spur dike (L) in the upstream of it.

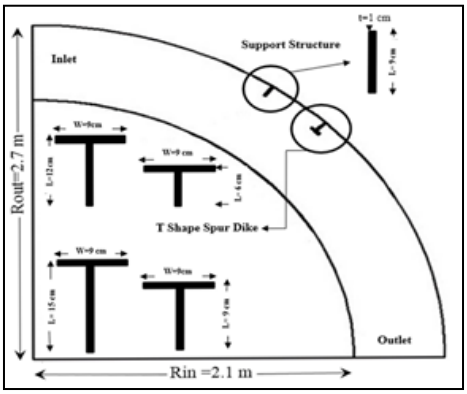


Fig. 3.View of geometry of numerical and physical case studies field

One of the purpose of spur dike is that reduce the power of secondary flow in sensitive section of channel. support structure decrease the amount of the power of secondary flow more than 50 percent around T shape spur dike, so it can predict if channel bed moveable after that this phenomena can preserve bed and banks of channel from scouring. As the result shows that peak point of the power of secondary flow occurred around first structure.

The power of secondary flow demonstrated some differences between both models. In this paper from equation (6) the power of secondary flow obtained by dividing lateral kinetic energy with total kenotic energy in each section in 90 degrees bend channel.

$$S = \frac{K_{latral}}{K_{total}} = \frac{(v_r)^2 + (w_z)^2}{(U_\theta)^2 + (v_r)^2 + (w_z)^2} \qquad (6)$$

Where K_{Latral} is lateral kinetic energy and K_{Total} is total kinetic energy in each section, and u_θ, v_r and w_z are tangential, radial and vertical velocity components respectively. Figure 4 indicated that if a single T shape spur dike located in bend channel then the power of secondary flow increase in section with 2.5 times bigger than distance from upstream of spur dike exponentially until the wing of T shape spur dike. After the spur dike position the power of secondary flow plunge since section with 5 times bigger than distance with downstream of T shape spur dike rapidly because channel width increase after this section

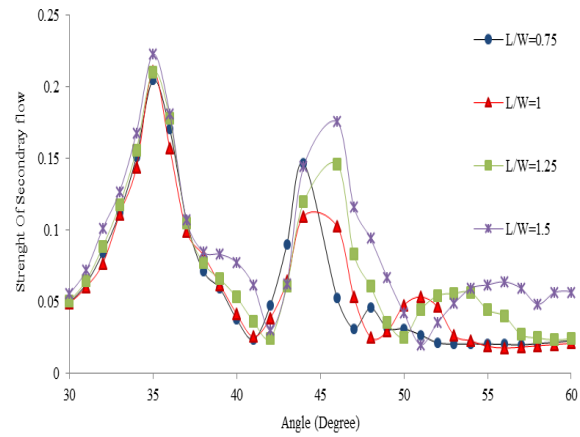


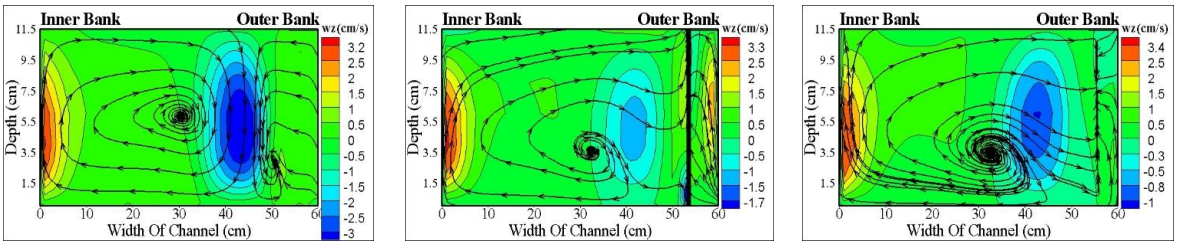
Fig. 4- The power of secondary flow in 90 degrees bend channel

Totally, Streamline directions changed as pressure and velocity components varied in every section of channel. If both streamline direction and velocity magnitude analyzed together than flow patterns around dikes investigated with high precision. Either streamline patterns or perpendicular velocities counter's (wz) indicated in Figures (5) to (8) for 40, 44.5 and 46.5 degrees cross sections. From all figures, it can be understand that streamline directions move down whereby velocity component (w_z) has negative amount and streamline directions move up to water surface in which velocity component (w_z) has positive amount.

From figures (5-a) to (8-a), which were indicate cross section in 40 degree of channel, it can be seen that a clockwise vortex created in more than half of the channel width approach to inner bank beside this vortex negative velocity of Wz cause another flow patterns which is behaved from outer bank to middle of channel width. This situation were occurred for all ratio of L/W. by approaching to T shape spur dike position, flow patterns changed completely, as figure (5-b) to (8-b) show, flow a main clockwise vortex exist between wing of T shape spur dike and inner wall of channel. The most significant differences in all of models related to distance between outer bank and wing of T shape spur dike.

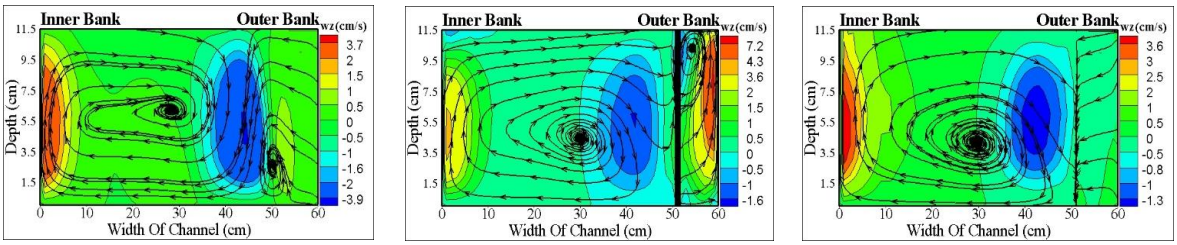
By the way, in both ratio of W/L equaled to 0.75 and 1 up flow pattern existed, but in models with 1.25 and 1.5 ratio of W/L the streamline moved from wing of T shape spur dike to outer bank because of large anti-clock wise which was created between support structure and T shape spur dike. This kind of patterns can scour outer wall of channel. The positive value of w_z velocity component, which was existed near outer bank of channel, can deflect streamline to water surface. Maximum value of w_z velocity component occurred in model with unit ratio of W/L that was intensified angle of deflection on up flow pattern. Figures (5-c) to (8-c) show cross section in 46.5 degree of bend channel what is located in downstream of T shape spur dike. Center of

anti- clock vortex moved from nose of T shape spur dike to inner wall of channel when length of T shape spur dike increased. Down flow pattern created just in model with unit ratio of W/L while others model existed up flow pattern. In downstream of T shape spur dike, it is preferable that down flow pattern create because it can be predicted that this kind of pattern protect bed of channel from local scouring. Finally, it can be determined that model with unit ratio between length and wing of T shape spur dike can preserve bend channel from scouring better than other models.



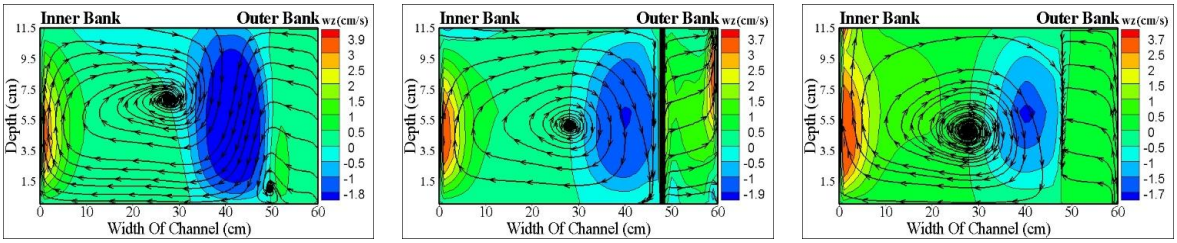
(a) (b) (c)

Fig. 5- View of streamline and w_z velocity component in cross section with (a) 40, (b) 44.5 and (c) 46.5 degrees for L/W=0.75



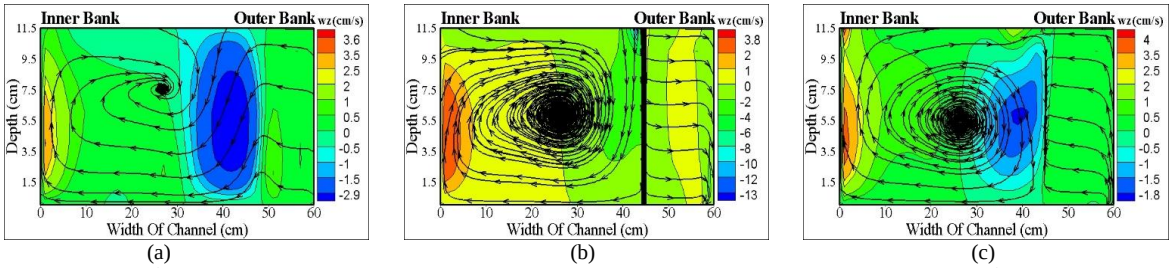
(a) (b) (c)

Fig. 6- View of streamline and w_z velocity component in cross section with (a) 40, (b) 44.5 and (c) 46.5 degrees for L/W=1



(a) (b) (c)

Fig. 7- View of streamline and w_z velocity component in cross section with (a) 40, (b) 44.5 and (c) 46.5 degrees for L/W=1.25



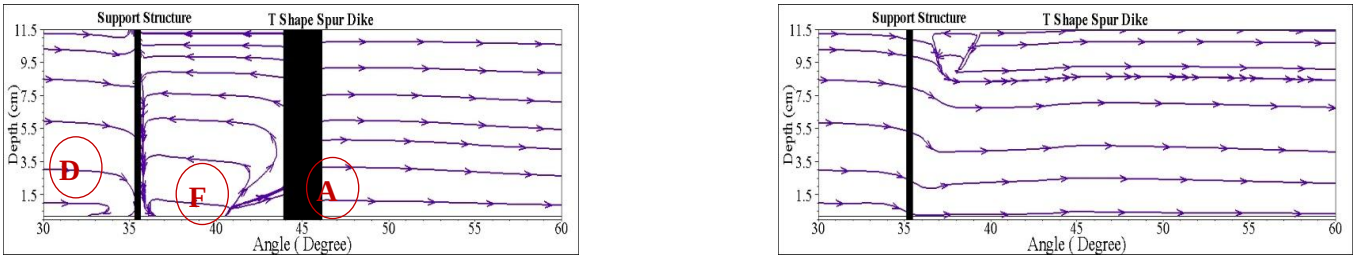
(a) (b) (c)

Fig. 8- View of streamline and w_z velocity component in cross section with (a) 40, (b) 44.5 and (c) 46.5 degrees for L/W=1.5

In this paper from figures (9) to (12), streamline in longitudinal section with (a) 10 and (b) 15 percent of channel width from outer bank. From figures (9) to (12), in area, which named D, some of the streamline were down flow. The angle of deflection in model with unit ratio of W/L was less than other model. In model with ratio of W/L equaled to 0.75, streamline directions have been parallel with main flow at A zone. However, for other models, Anti-clockwise vortex created both streamline direction. One of them has parallel direction with main flow and another one has opposite direction with main flow. It can obtain that if the length of spur dike increased than center of vortex receded from T shape spur dike. From figure (15-b), two kind of streamline flow patterns created which were named as B and C. up flow pattern occurred in B zone this kind of

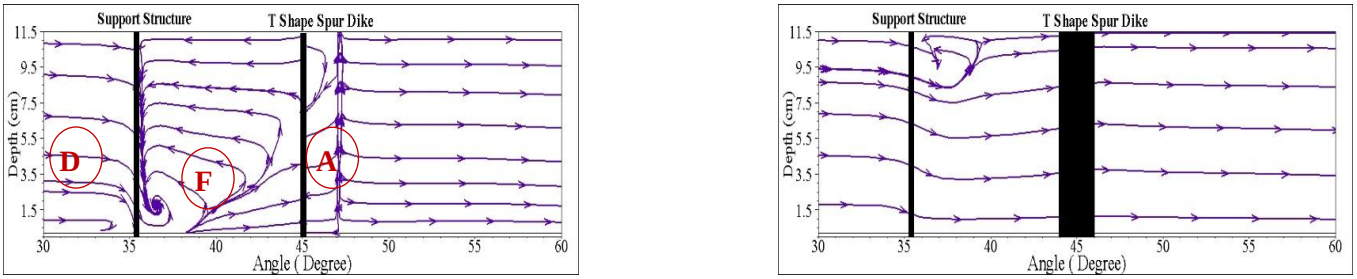
flow pattern was not positive for stability of channel bed. At middle of Support structure and T shape spur dike distance, parallel streamline with main flow created in models with ratio of W/L equaled to 0.75 and 1 but complex flow patterns occurred in models with ratio of W/L equaled to 1.25 and 1.5.

C zone demonstrated three streamline directions. Majority of streamlines, which created around support structure, have anti-clockwise rotation, so it can be negative for preserving channel bed. figures (9-a) to (12-a) indicate that some of the streamline which were existed in F zone, have up flow patterns in vicinity of T shape spur dike for models with ratio of W/L equaled to 0.75 and 1. However, this kind of flow pattern was not creating in both models with ratio of W/L equaled to 1.25 and 1.5.



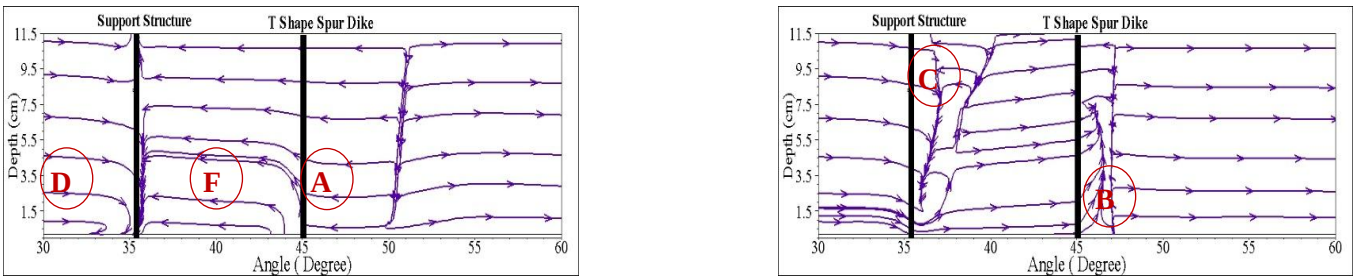
(a) (b)

Fig. 9- Streamline in longitudinal section with (a) 10 and (b) 15 percent of channel width from outer bank for W/L=0.75



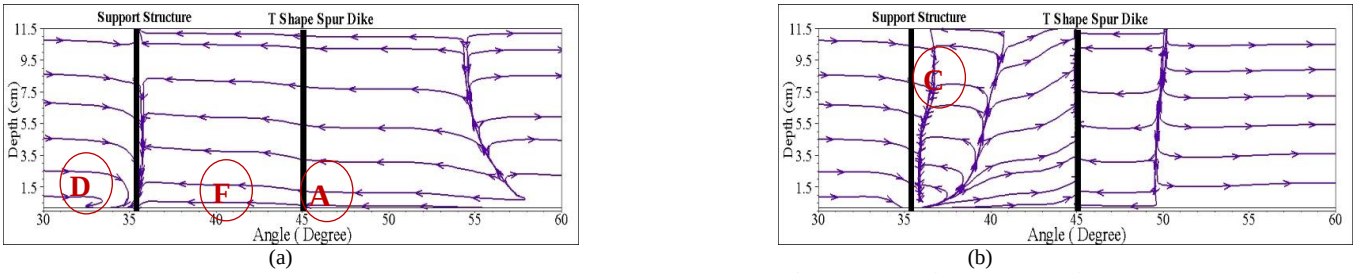
(a) (b)

Fig. 10- Streamline in longitudinal section with (a) 10 and (b) 15 percent of channel width from outer bank for W/L=1



(a) (b)

Fig. 11-Streamline in longitudinal section with (a) 10 and (b) 15 percent of channel width from outer bank for W/L=1.25



(a) (b)

Fig. 12- Streamline in longitudinal section with (a) 10 and (b) 15 percent of channel width from outer bank for W/L=1.5

IV. Conclusion

Flow-3D model can simulated flow pattern around T shape spur dike and support structure with high accuracy. Totally, it can predict if bed of channel covered with moveable material than model with unit ratio between length and wing of T shape spur dike can protect more efficiently than other models.

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