УДК 631.63:556.16

ESTIMATING SHEAR STRESS WITHIN AL- DIWANIYAH RIVER(IRAQ) BEND USING EXPERIMENTAL WORK AND FIS MODEL

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Introduction. In the rivers, shear stress may be considered as one of the most important parameters for estimating the sediment load. Measurement of the shear stress in the rivers is not an easy task and it cannot be measured directly, however it can be measured indirectly by observing the hydraulic characteristic and geometry of the river. Analysis of the shear stress and studying any parameters in bend zone of the river is difficult compared with straight river. The cross sectional shape, secondary flow, and variation of roughness of the channel perimeter are all affect in the estimating of the shear stress on bed river even for simple cases [1].

The head losses are very large when bends in rivers become too tight, which leads to raise the water level at outer bank on one hand and lowering it at inner bank on the other hand. Moreover, the fluctuation of water level at bank causes problems such as erode at outer bank and sedimentation at inner bank [2]. Shukry has presented an experimental study on the bend and the results have shown that the highest velocities at bends are at close to outer bank in the beginning, close to the inner bank at middle and close to the inner bank at the end of bend [3]. Vaghifi *et al.* (2014) [4] have been presented different methods for calculating shear stress parameters and used the depth-average method for estimating the shear stress in a 180^{o} laboratory bend, their results have shown that the peak shear stress took place near the beginning, 40^{o} cross section, and close to the inner wall.

Kabir and Nasir (1996) [5] have used the precise velocity profile "Jamuna" of the river to determine bed shear stress of the bed by using different logarithmic equations. Islam (2008) has discussed the mechanisms and methods of predictions the bank erosion and suggested sustainable strategies of different bank protection measures including the economic analysis [6]. In addition, Nama A.H. (2015) has studied the distribution of shear stress in the meanders of Tigris River in Baghdad city. The geometric data of Nama’s study was obtained using HEC- RAS software and then used to estimate the shear stress. The results have shown that the effect of meandering would increase the maximum shear stress [7].

Karthik *et al.* (2014) were used the Computational Fluid Dynamic (CFD) to solve flooding and modeling of alluvial roughness in the complex and dynamic domain. The river migration and the effect of pre-scour hole around the hydraulic structure were all solved. Simulation of the multi-phase flows with a free boundary including possible phase transitions in flooding was discussed [8] as well. Limnol O., (2001) was described the use of tube of Preston Static for estimating the local shear stress in Mountain Rivers. The results have indicated that the local shear stress could be quickly measured at lower costs in the field [9].

Booij R., (2003) was used the 2-D horizontal model and showed that due to deferential advection main flow momentum is advocated from the region of low velocity at the inner of bend to the region of high velocity at the outer bend and so the negative eddy viscosity is required while in the 3-D the advection effect is included in the computation [10].

Al Amin *et.al.*, (2013) has conducted an experimental study in a compound meandering channel. The results have shown that the shear stress increases with increasing the ratio of depth to width and minimum shear stress occurs at the outer bed while the location of high stress is at the inner of the bed for the compound meandering channel [11]. Kardan *et.al*, (2012) have described the bed shear stress distributions around and downstream of cylindrical bridge pier using various turbulence model. A large number of numerical simulations have been carried out to predict the bed shear stress of vortex shedding behind the pier using the Fluent and Gambit software [12].

Afzalimehr *et al.*, in (2006) [13] were studded the effect of a gravel bed in a compound bend of a natural river (case study in Iran) to measure the velocity using current meter and flow resistance analysis. The results showed that the flow depth was effected to the size of gravel and the Froude number have less impact on the estimation of flow resistance. Elsaeed *et. al.*, (2015) [14] have studied the effect of releasing peak flow discharges on bed shear stress meandering river reach at Kafr El-Zayat City by using a two dimensional numerical model "SMS" and a hydrographic measurement. The results showed that the shear stress at bed reduces near the banks. In addition, Lai and Greimann (2010) [15] investigated the adequacy of 2-D depth averaged model for modeling the contraction scour. The model was adequate for estimating the contraction scour and it was also adequate compared with three dimensional model except for the estimating the aggradation at the downstream channel.

Experimental study.

A. Case study

The selected case is a bend in Al-Diwaniya River which is located in Barshawiya city as a part of Al- Qadisiyah governorate, Iraq. Al- Barshawiya city shown in Figure 1 located on the border between Al- Diwaniya and Al-Muthana governorates in Iraq with a total area of 2794 km^2 [16].

Figure 1 – Location of Al-Barshawiya city, Iraq [16]

B. Measurement of hydraulic parameters using M-9 device.

In this study, a field and experimental study have been conducted to evaluate the shear stress and to determine the maximum shear stress path of a bend in Al-Diwaniyah River, Al-Qadisiyah Governorate, Iraq. A specific bend was selected and divided into several curvature zones using an angle of 40^o. Different hydraulic characteristic parameters such as: cross section, the bend radii, the bent width, the bend depth, and the velocity were measured by using the M-9 device as shown in Figure 2. Samples of bed and side soil were collected for a sieve analysis which is conducted in soil laboratory at college of Engineering, University of Al- Qadisiyah. Thereafter, the d_{50} was obtained and the Manning coefficients calculated for each section using Manning- Strickler equation.

Figure 2 – The M-9 device.

C. Collection of data from the field

As mentioned before, the bend has been divided into several 40^o angle sections using GIS as shown in Figure 3. The data were obtained by using the M-9 device for each angle. Each section was subdivided into 5-meter curvature zones a cross the river width and hydraulic parameters such as: mean velocity, depth of water, and the bend radii were collected for each sub-cross section. Figures 4 and 5 represent the collected data for each section and the cross section at some angles of bend respectively collected by the M-9 device. Samples of soil for each sub-cross section were collected from bed of river for sieve analysis and then the d_{50} was obtained for each sub-cross section.

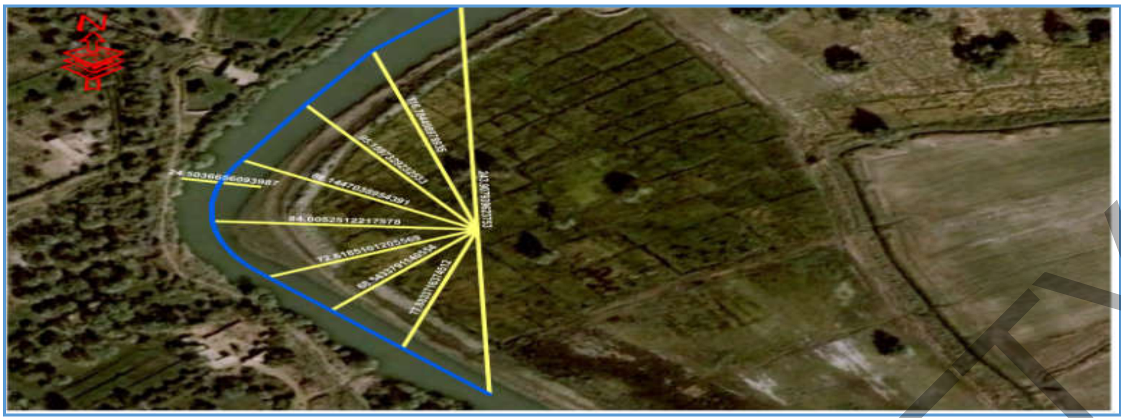
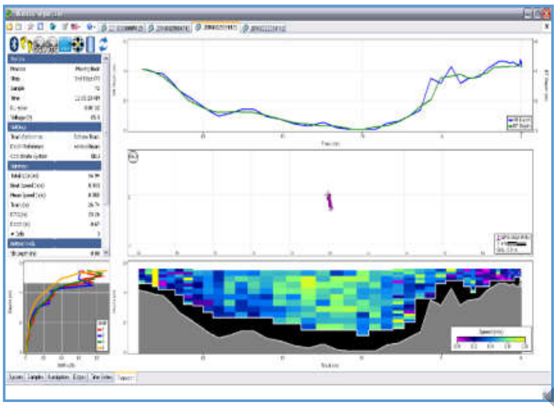


Figure 3 – The bend used in the study and its angled zones

a)



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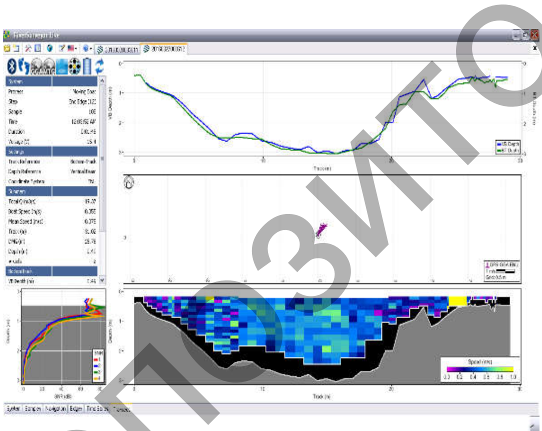

c)

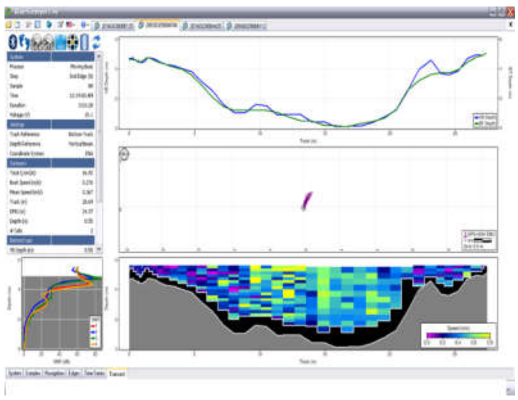

Figure 4 – Cross section at some angles of bend a) at 0^o angle b) at 160^o angle c) at 280^o angle.

Figure 5 – Collection of data in the field using M-9 device

Theoretical study. The following equations have been used for calculating the experimental collected data of the bed and the side shear stress for each curvature zones of the bend [7].

$$\tau_b = cf .\rho. V^2 \qquad \dots (1)$$

$$cf = (n^2.g)/y^{(1/3)} \qquad \dots(2)$$

$$\tau s = Kb. \tau b \qquad \dots (3)$$

$$n = (d_{50}{}^{(1/6)})/21.1 \qquad \dots(4)$$

$$Kb = 2.0 \qquad \text{if } Rc/Tw \le 2$$

$$Kb = 1.05 \qquad \text{if } 10 \le Rc/Tw$$

$$Kb = 2.38 - 0.206\, Rc/Tw + 0.0073\, [(Rc/Tw)]^2 \quad \text{if } 2 < Rc/Tw < 10$$

Where: τ_b: shear stress at bed of bends (N/m^2); ρ: Mass density of water (kg/m^3); V: velocity of water (m/s); *n*: Manning coefficient (can be calculated from Manning – Strickler equation, Eq.4); g: gravity acceleration (m/s^2); y: depth of water (m); τs: shear stress at side in bend (N/m^2); Kb: coefficient (dimensionless); Rc: Radii of bend (m); Tw: Width of river (m).

Figure 6 represents the path at the largest shear stress which was calculated according to the method described in paragraph C of section II. It can be seen from this figure that the path was close to the inner near the beginning of the bend and close to the outer at the middle. It was close to the outer at the end of the bend. Based on the sieve analysis conducted in the soil laboratory, the d_{50} was obtained for each sub-section. The Manning coefficients were calculated by using the Manning – Strickler equation (Eq. 4) and the results showed that the Manning coefficient at the bed of the bend was about 0.027 while at the sides was about the range (0.038-0.042).

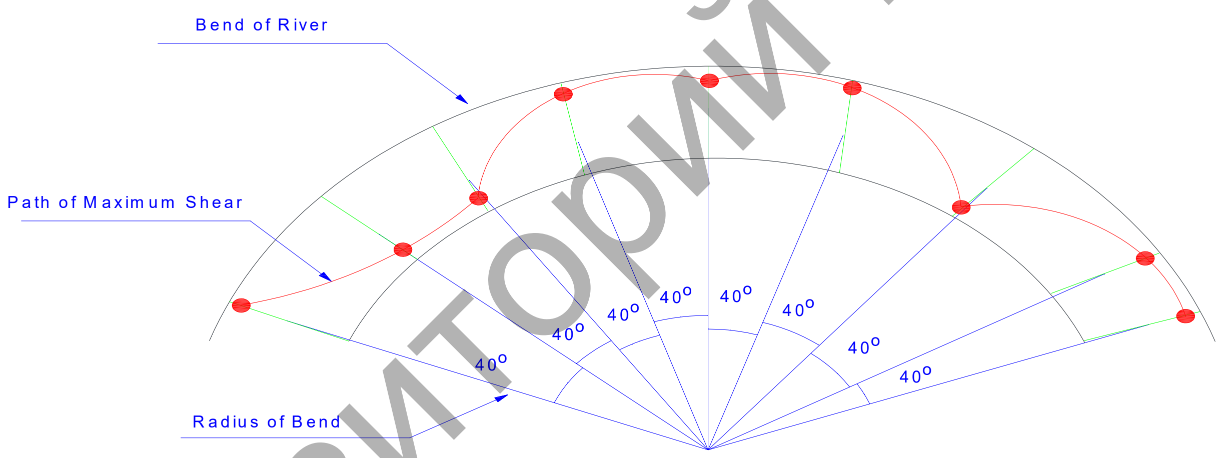

Figure 6 – Path of maximum shear stress in bend.

FIS Model. The Fuzzy approach concept has firstly been introduced by Zadeh (1965) [17] and widely used in various fields of technology and science. Using of fuzzy logic in modeling of water resources field is relatively new. Fuzzy model is similar to the ANN and the ANFIS. In fuzzy modeling, the basis is using the directly knowledge of an experienced expert directly. Firstly, the fuzzy sets of the inputs and the outputs have to be created. Secondly a set of rules are to be used to combine the inputs with the outputs. The basic form of the system for the fuzzy inference (FIS) is transforming the data to membership functions, then the input for membership function transformed to rules. Then, the rules transform the output data to output membership functions and finally transform the output membership function to a crisps output.

Membership function used to show the input. The aim of using this function is to transform the crisp data to interval data and to weight the inputs [18]. Rules used for input data and then used the membership functions, then give the output [18]. In MATLAB software, two methods can be used to generate of the initial fuzzy inference system. Firstly, the grid partitioning and secondly the subtractive clustering. The number of membership functions must be determined when the grid partitioning is method used [19].

Fuzzy logic representations have found to represent the uncertainty in engineering problems. A Fuzzy set may be explained in a mathematical form (is the assigning each possible individual in the universe of discourse in an understandable clause), by a value representing its grade of membership in the fuzzy set. The transforming the input data to an output using fuzzy logic is called the fuzzy inference.

FIS Model application for estimating shear stress in bend. In this study, a new model was presented to estimate the shear stress in bend at Al- Diwaniya River. To prepare the FIS model, 80% of all data have been used as an establishing data (chosen randomly), while the 20 % remaining data were used for verification of the FIS model. The parameters involved in the establishing of FIS were: angle of curvature, radius of bend, width of river, depth of water, Manning coefficient, and velocity of flow as input data and the shear stress τ at bend as output data.

Five membership functions have been used in this paper which are available in MATLAB, which are: pi curves (pimf), Gaussian (gaussmf), Gaussian combined (gauss2mf), Difference of two sigmoid (dsigmf), and Product of two sigmoid (psigmf). Mean Square Error (MSE) was used for determining the best membership function that represents the data. Results show that data with Gaussian membership function can estimates shear stress in bend better than the other as shown in Table (1). Also, by ignoring the effect of curvature, equations 1 to 4 can be applied for Al-Diwaniya river since the error was very little (MSE = $3.945*10^{(-3)}$) as shown in Table (1). This paper presented a novel study to implement FIS model to river bend.

Table 1 – Membership functions and its performance.

Membership function	**Performance for training data**	**Performance for testing data**
	MSE*10$^{(-3)}$	**MSE*10$^{(-3)}$**
gaussmf	3.984	3.945
gauss2mf	15.581	15.581
pimf	188.38	61.68
dsigmf	21.985	21.985
psigmf	21.985	21.985

Figures 7 and 8 represent FIS editor with the variables and shape function, and the rules using MATLAB R2011b, respectively.

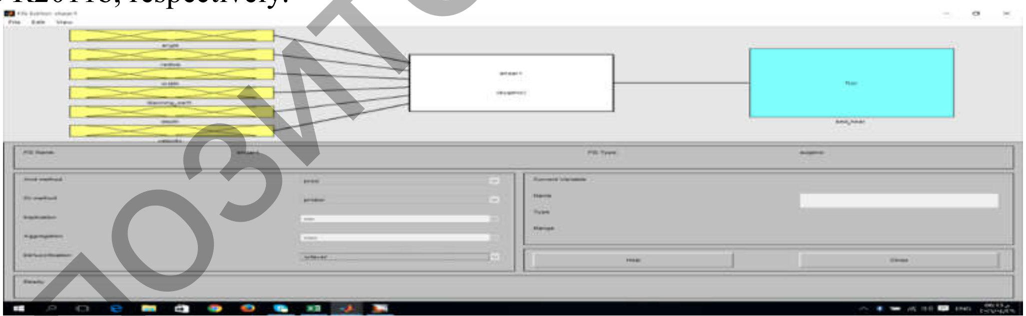

Figure 7 – FIS Editor

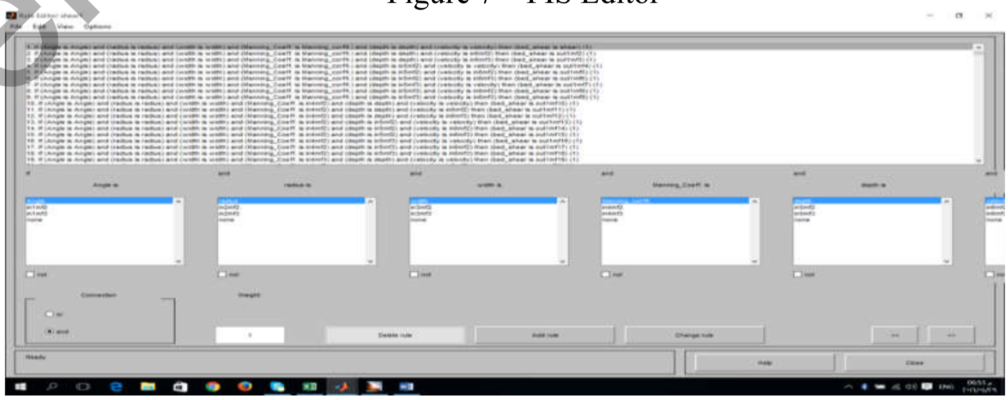

Figure 8 – Rules of the FIS Model.

Figures 9 and 10 show the output of the FIS Model and the surface of angle- velocity- shear at bend, respectively.

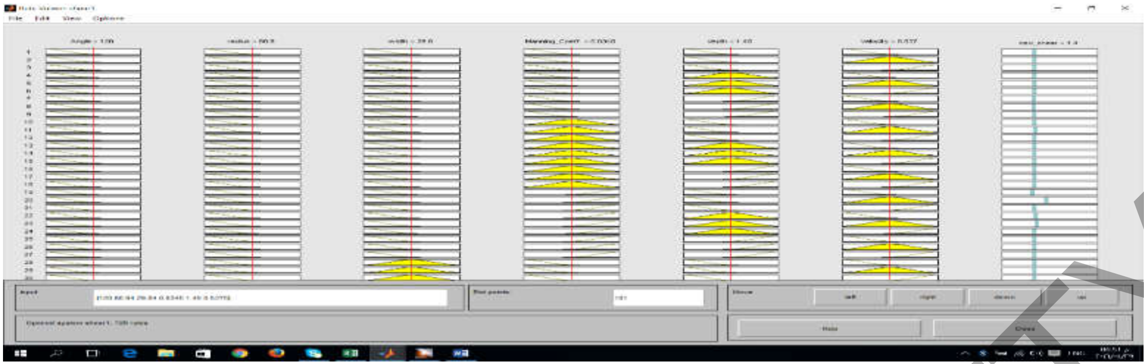

Figure 9 – The output of the FIS Model.

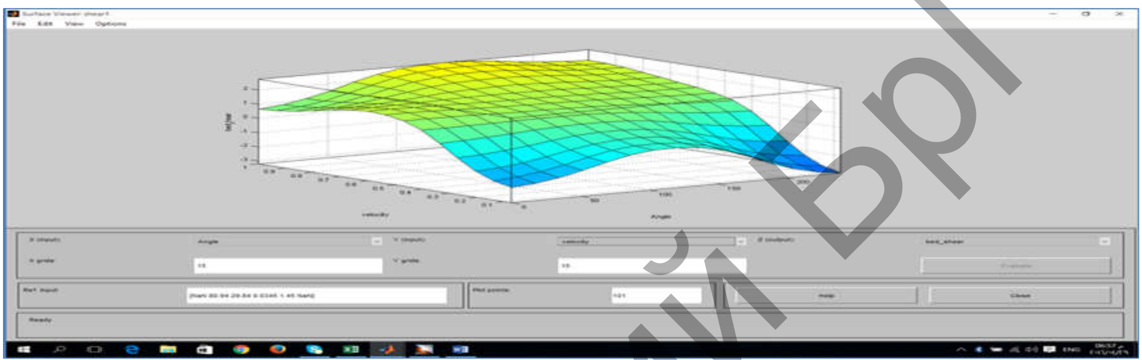

Figure 10 – The surface of angle- velocity- shear stress at bend.

Conclusion. A new model based on an experimental collected data has been derivate in this paper to compute the shear stress through a bend within Al- Diwaniya River, Al-Qadisiyah Governorate, Iraq. Each 40^{o}-angled zone has been subdivided into sub-division with 5 m in length crossing the river's width. This paper experimentally measured the hydraulic parameters and then theoretically calculated the shear stress path at the bend. It can be seen that the path was close to the inner near the beginning of the bend and close to the outer at the middle. It was close to the outer at the end of the bend. In addition, this paper gives the efficiency of (FIS) model to estimate the shear stress in bend at Al- Diwaniya River, Al-Qadisiyah Governorate, Iraq. The FIS model indicated that the equations 1 to 4 can be applied for Al-Diwaniya River ignoring the effect of curvature since the error between the equation and FIS model was very little.

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