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ORIGINAL ARTICLE

# ESTIMATE OF THE VELOCITY DISTRIBUTION IN COMPOUND CHANNEL WITH USING SKM TWO-DIMENSIONAL MODEL

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**ABSTRACT:** To obtain the velocity distribution in compound channels, the SKM two-dimensional method based on Navier-Stokes Equation, has been used. Generally, in the compound channels due to strong secondary flows caused by changes in bed roughness distribution, existing methods for estimating the velocity distribution have errors than actual results. In this study, with using the SKM method and compares that with experimental results can be observed that; by adding the secondary flows parameter, the maximum error is measured about 4 % that proposed in the composite section to fit the velocity obtained from the experimental data. By comparing the DEBI–ASHEL curves can be shown that; in the non-homogeneous section, because varying in the roughness of floodplains, the non-interfere flow depth of secondary flow coefficient ‹increases the 21% error in the calculations. This error becomes greater with increasing flow depth.
**Keywords:** secondary flow, SKM two-dimensional model, the velocity distribution.

## INTRODUCTION

Todays, with expansion of cities, water use has increased a lot, transferring the water from one place to another for irrigation and water supply is an essential consideration. Among the various methods of transferring water ‹Using gravity and moving water to form free-surface flow in channels, Commonly used in water supply, irrigation, drainage or collecting and transmitting surface water. Therefore, in open channels, Identify the flow various quantities, such as deep mean velocity profile and transverse velocity distribution, DEBI and secondary flow in the flow section is important For optimal design, and prevents potential risk. Evaluating of secondary flows is important due to their impact on the hydraulic flow. Despite the negligible secondary flows, than the base flows due to the effect on the flow resistance of the composite section, their study is very important [1]. lateral Stream transferred of the main channel to the flood zone, and This will increases the transmission capacity during flooding.[2]According to Figure(1), compound Channel, is the combination of a basic deep section and wide flood plains, that On most days of the year, flood plains is lifeless and roughness coefficients are higher than the basic section.[6]

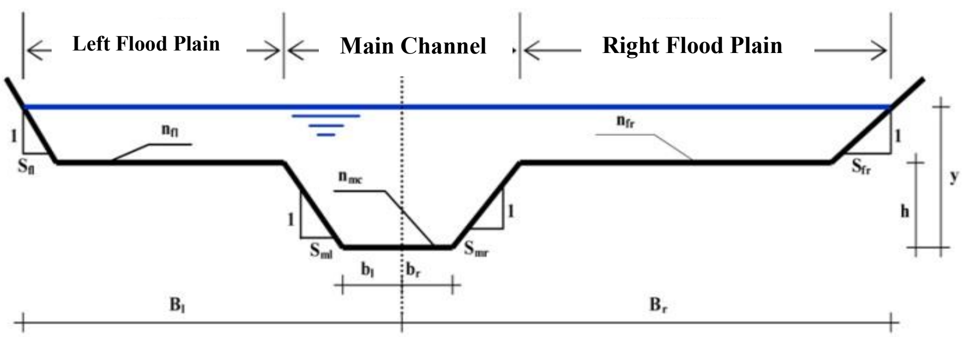



**Figure 1 -**schematic of the compound channel with the floodplain zone [1]

During floods, water fills the main channel and entered to the flood plains. In this case, because of the difference in flow depth and roughness coefficient in the main channel and floodplains, considerable friction is established in the connection boundary. In flood conditions, lateral section of the river are typically includes two flood plains and one main channel that flow In the main channel, have high deep and velocity but flow in the Flood plain have low depth and

velocity. Therefore, the most important stage of the flow hydraulic calculations in the Flood Rivers, is dividing the river to the floodplains and main channel [3].
The main source of these currents, caused by the shear stress difference between the fluid layers.In the compound Channel, because of the flow velocity difference between main channel and flood boundary, shear stress is created in the fluid layers, which leads to the formation of secondary flows in this region [4]. Significant flow velocity difference between the flood plains and main channel causes a middle zone in the border between two regions that causes exchange of mass and momentum, and energy dissipation considerably decreases. Figure (2) at the entry point of the main channel to the flood plain, showed the effect of secondary flow on the Transverse velocity [6]

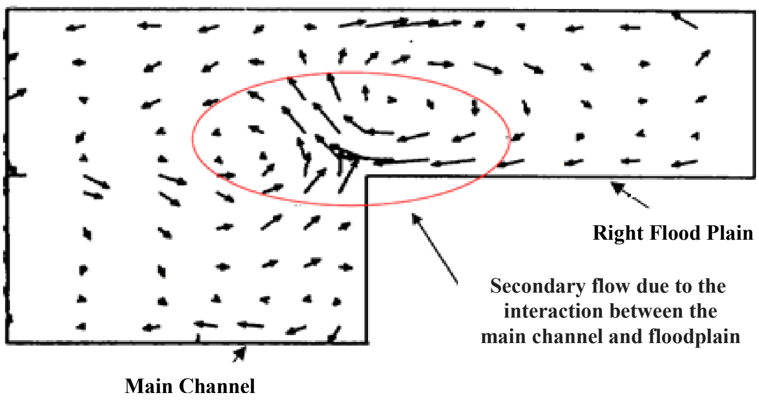



**Figure 2-** Secondary flow between the main channel and floodplain sections [6]

## RESEARCH HISTORY

In the Hydraulic books, of the flow hydraulic reference in the compound Channel, studied that compound Channel, analyzed to the partial sections (main channel and flood plains) and then the flow rate in each of these sections is calculated with using the Manning equation. Finally the total flow rate is obtained from partial flow rates. While the results of various studies show that the flow rate obtained by this method in comparing with the actual amount have 40% error[7].For the first time in 1964, Sellin, find that Interaction phenomenon and reduce the flow cross-section rate is caused by the disturbance between partial sections[8]. Since then, numerous studies have been made on the modified conventional methods to calculate the flow rate due to the momentum transfer. The most important study of these studies was the constitution of a central laboratory equipped in Hydraulic Research, Wallingford at 1985. The purpose of creating such facilities, Recognition flow hydraulic and compound Channel sediment with using precise data from laboratory precision.
With using the experimental results of this center, researchers, provided several methods for momentum transfer interfere in calculating composite sections in order to modify the hydraulic flow. The results of this research will lead to significant improvements in calculating Debi- ashel relationship between laboratory and river composite sections. These methods include one-dimensional, two-dimensional and three-dimensional methods that are called Corrective methods.
Because the adjustment methods provided with assume a steady and uniform flow conditions, Their use considerate (e.g,determine the Debi-ashel relationship , calculating the transverse distribution of velocity and boundary shear stress, determine the critical depth, and estimating sediment transport) under the same flow conditions .
More research works has been done on laboratory channels with compound Channel. While hydraulics and river engineering studies are done for floodplains better management of the natural rivers, important point in the present study is investigating of Shiono and Knight Method (SKM) in compound channels. In 1988[9].an analytical - two dimensional model based on Navier - Stokes Equation provided for solving the transverse velocity and shear stress distribution in simple and compound Channel. In

this Mathematical model, the effect of secondary flow was removed. The results of the mathematical model, in experimental and river compound Channel, was shown that; Secondary flow, have an important role, especially in determining the distribution of transverse shear stress. Numerical solving of this Two-dimensional model is presented with using the finite difference method [3] and finite element [10] Using of numerical methods in flood routing in homogeneous compound channel, has provided the same results [11].

In1999One-dimensional method was presented to calculate the flow rate of main channel and floodplains that was called Exchange Discharge Method (EDM)[12]. In 2004, with using two-dimensional numerical model [14] and the Coherence method (COHM) [7], the method was presented for calculating the DEBI - ASHEL relationships of Non -homogeneous regular and river compound Channel [15]. In this way, the secondary flow Coefficient of main channel in the case of non-homogeneous compound is modified as a third degree function of the relative roughness.

**MATERIALS AND METHODS**

There are too many two-dimensional hydraulic methods; that is developed By Shiono and Knight (1989),Vark et al (1990), Lamber and Sellin (1996), Irwin and colleagues (2000) and progeny (2005) [16] .Several studies in large-scale is performed with above methods on the data available in Flood Channel Facility (FCF). In this study with using SKM methods (1989,1991) to evaluate the performance of two-dimensional secondary flows in compound channels, used of complex experimental data obtained from the University of Birmingham[1].Maybe Navier - Stokes Equation ought to be considered in the form of equation (1) for a fluid flow element in the momentum equation combined with the continuity equation:

$$\rho\left[V\frac{\partial u}{\partial y}+w\frac{\partial w}{\partial z}\right]=\rho g\sin\theta+\frac{\partial \tau_{yx}}{\partial y}+\frac{\partial \tau_{zx}}{\partial z} \qquad (1)$$

The physical meaning: secondary flows =Weight force and Reynolds stress (lateral + vertical), Where u, v and w are local velocity and x is the longitudinal direction, and y is the transverse direction and z is the perpendicular direction.$s_\circ = sin\theta$ is the Slope; $\tau_{xy}$ and $\tau_{yz}$ are Reynolds stresses in the floor; In general, whenever v and w velocity components are important along the transverse and vertical velocity components, secondary flow is created And significantly affects the hydraulic compound Channel[4]. SKM (1988, 1989) presented the average depth velocity equation with the Integration of the flow depth (H), on the dissenting viscosity flows according to (2) [2] equation regardless of the secondary flows [17].

$$\rho g H S_0 - \frac{1}{8}\rho f U_d^{\,2}\left(1+\frac{1}{s^2}\right)^{1/2} + \frac{\partial}{\partial y}\left\{\rho\lambda H^2\left(\frac{f}{8}\right)^{1/2} U_d \frac{\partial U_d}{\partial y}\right\} = 0 \qquad (2)$$

In the above equation: $U_d$ is the Average velocity in depth (the value of d is the average depth values.); ρ is the Density of water, g is the Acceleration of gravity, λ is the viscosity Dimensionless coefficient (turbulent flow) ؛ which is obtained Based on turbulent flow data and after determine the average depth Reynolds stress. $f$ Is the Darcy –Weisbach Friction Factor dimensionless coefficient; H is the Flow depth at any point;$s_o$ is the channel bottom slope; and y is the Transverse direction of channel [11]. Equation (2) only used when the secondary flow is not considered [18]. If the interference caused by the secondary flows effects is very important; and with negligible vertical component of flow velocity (the H is assumed constant); SKM 1991; amended the Differential equation (2) into equation (3) [1].

$$\rho g H S_0 - \frac{1}{8}\rho f U_d^{\,2}\left(1+\frac{1}{s^2}\right)^{1/2} + \frac{\partial}{\partial y}\left\{\rho\lambda H^2\left(\frac{f}{8}\right)^{1/2} U_d \frac{\partial u_d}{\partial y}\right\} = \frac{\partial}{\partial y}\left[H(\rho UV)_d\right] \qquad (3)$$

In the following equation, s is the main channel lateral side slope.

## DATA USED FOR THE TWO-DIMENSIONAL MODEL

For implementing two-dimensional mathematical model, in the laboratory and natural rivers sections, different data is required. Most of these data are data, that the most common one dimensional mathematical model needs them in river engineering projects. For this reason, these data are available in most rivers, particularly in the hydrometric stations area. Data that are specific for mathematical model are the measured Values of flow velocity transverse distribution. They measured in rivers with using the mulineh. In Table (1), the required data listed for the implementation and calibration of two-dimensional mathematical model.

**Table1-** data and required Statistics for implementing two-dimensional mathematical model in rivers

| Information required | Stage used | |
|---|---|---|
| | Run Model | Calibration |
| Transverse sections of the river | ✓ | ✓ |
| The longitudinal slope of river or water surface slope | ✓ | ✓ |
| Manning roughness coefficient | ✓ | - |
| Manning scale river flow within the normal flow and flood | - | ✓ |
| Flow velocity distributions measured at various depths | - | ✓ |

## ANALYSIS OF SECONDARY FLOW COEFFICIENT

The original definition of K presented by Literature is used to express the relationship between $(UV)_d$ $U_d^2$ , with assuming that and temporary average velocity components (U,V),are public medium speed items. Analytical description for flow Transverse velocity is by Ikeda presented in equation (4)

(4)

$$\frac{V}{U_*} = \frac{6\delta}{k\pi^2} Sin(\frac{\pi y}{H}) \left[ 2Cos(\frac{\pi z}{H}) - \pi(\frac{2z}{H} - 1) Sin(\frac{\pi z}{H}) \right]$$

In which $U_*$ is the shear velocity. K is the Von Karman's Constant (k = 0.415) and δ is the Perturbation amplitude size, in this case, according to equation (4), transverse velocity V can be both positive and negative. As a result, we found that the average depth $UV$ ,$(UV)_d$ can be both positive and negative.

$$\rho g H S_0 - \frac{1}{8}\rho f U_d^{2}\left(1+\frac{1}{s^2}\right)^{1/2} + H\frac{\partial}{\partial y}\left\{\rho\lambda\left(\frac{f}{8}\right)^{1/2} H U_d \frac{\partial u_d}{\partial y}\right\} = \frac{\partial}{\partial y}\left[H(\rho UV)_d\right]$$

(5)

(6)

$$\Gamma = \frac{\partial H(\rho \bar{U}\bar{V})}{\partial y} = \frac{\partial}{\partial y}[H(\rho UV)_d] \quad ; UV = kU_d^2$$

Where k is the proportionality coefficient. This coefficient is a function of depth and roughness of floodplain channel. We replaced the equation (6) in equation (5).The equation number (5) can be changed to ordinary differential equation (7).

$$\rho g H S_0 - \frac{1}{8}\rho f U_d^{2}\left(1+\frac{1}{s^2}\right)^{1/2} + H\frac{\partial}{\partial y}\left\{\rho\lambda\left(\frac{f}{8}\right)^{1/2} H U_d \frac{\partial U_d}{\partial y} - \rho K U_d^2\right\} - \frac{\partial H}{\partial y}\rho K U_d^2 = 0$$

(7)

According to the analysis above sections, the value of k in the main channel are often negative and in floodplain are positive And even in some cases, this value is greater than 0.50 percent. This value can be positive for the flow moves clockwise,(along the flow) and This value can be negative for counter-clockwise flow. As demonstrated by Liu et al (2008)[20]shown in this study is consistent.

## RESULTS AND DISCUSSION (COMPARISON OF MODEL CALCULATIONS AND EXPERIMENTAL DATA)

In Figure (3) most important parameter are presented for calibration of flow hydraulic mathematical model of channels, geometry and flow characteristics in comparison with experimental data. Specified data, included water level data and cross-sectional geometry. Transverse velocity Distributive values for the experimental data, in large-scale is obtained from laboratory studies conducted at the University of Birmingham. Velocity distribution obtained from experimental data should be consistent with the transverse distribution of the proposed model velocity in composite channels.

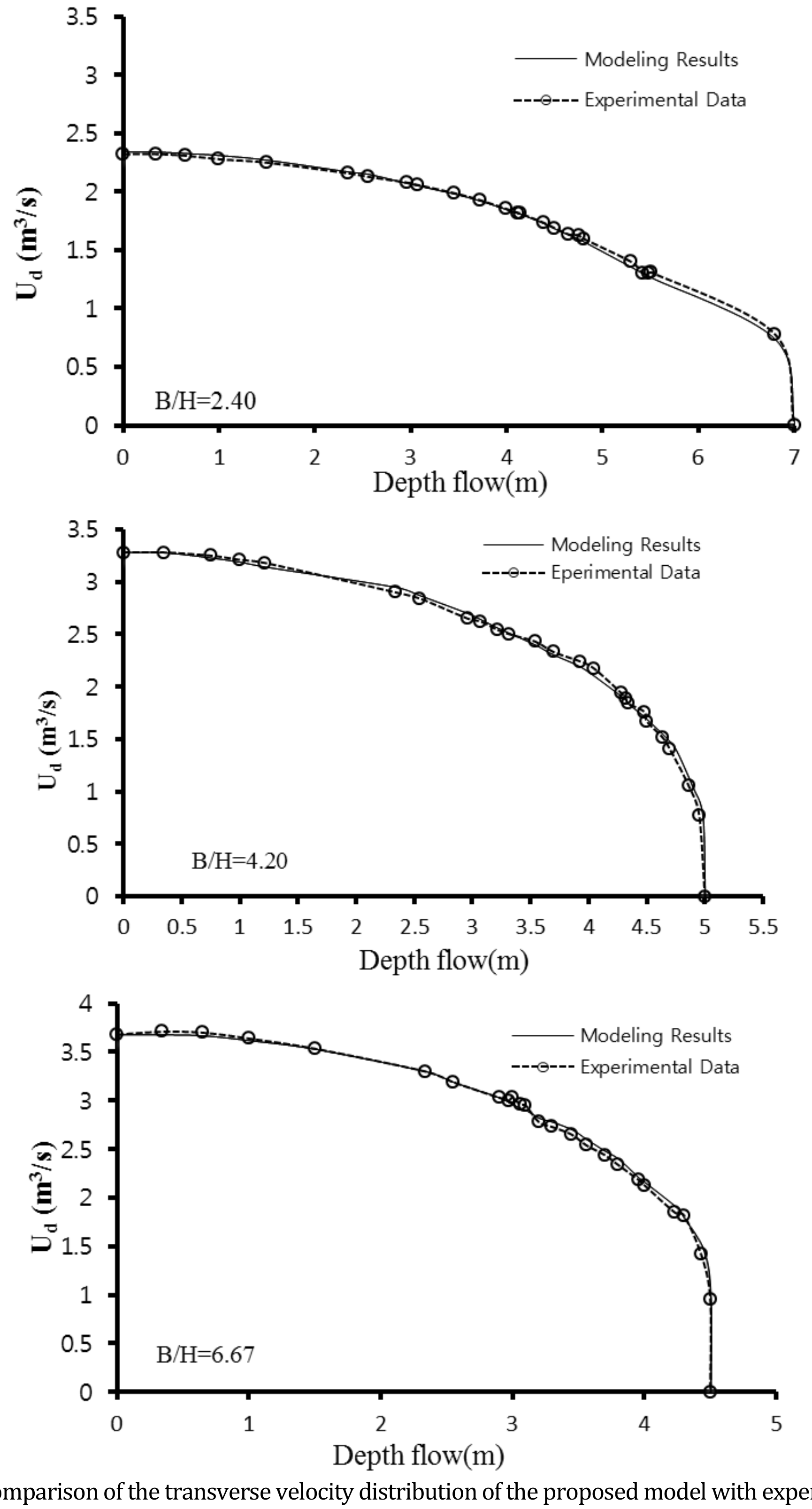
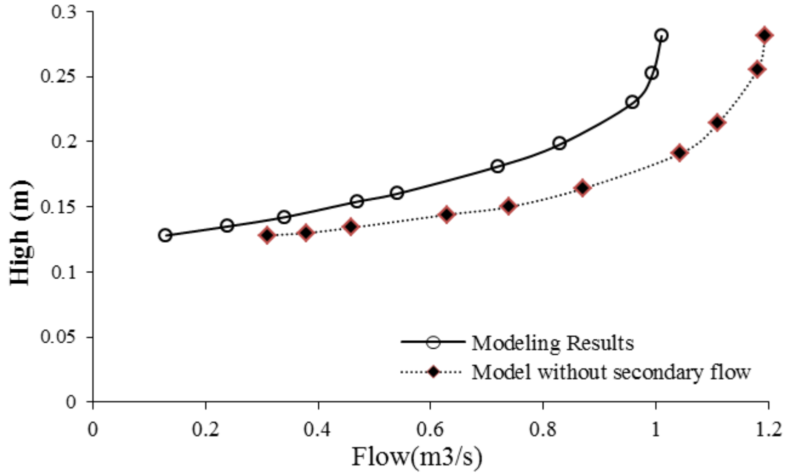
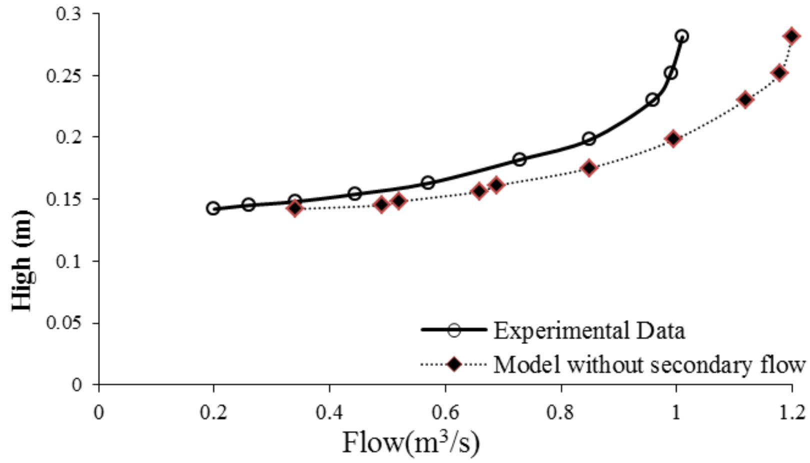



**Figure 3-** Comparison of the transverse velocity distribution of the proposed model with experimental data

According to Figure (3), we can say that the proposed model is similar to the experimental results; therefore it is a good estimate of the transverse velocity distribution. Our results indicate that, the maximum error of the proposed two-dimensional model in compound channel is measured about 4 % for velocity rate obtained from model and experimental data. By comparing the DEBI-ASHEL curves obtained from the two models showed in Figure (4) that have good performance in homogeneity section, And excluding the effect of secondary flow ، There is no high error, However, in non-homogeneous section, due to the variable nature of floodplains roughness, depth of flow and non-interference of the secondary flow, the error in the calculation is increased about 21% which become greater With increasing depth of flow.




A- Non-homogeneous




B- Homogeneous

**Figure 4-** Comparison of DEBI-ASHEL curves in compound channel

## DEBI-ASHEL curves

The most important unreliable part of the rivers analysis is the accurately predict of the channel flow carrying capacity with floodplain. With Calculating the transverse velocity distribution in the main channel and river floodplains, better conditions will be provided for flood management, pollutants distribution and river sediment transport. According to the results achieved from transverse velocity distribution at any flow depth, flow can be calculated by numerical DEBI integration. In figure (5), computing Debi showed with using of the DEBI-ASHEL curve ،which Indicating the high accuracy of the estimated flow two-dimensional model, even in torrential conditions.

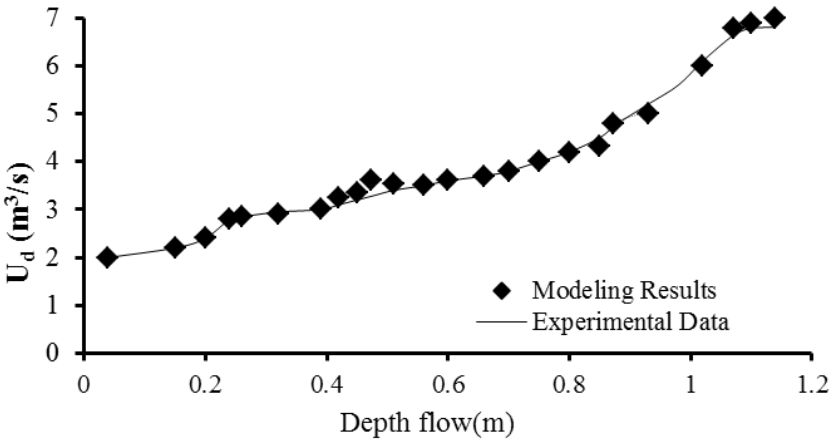



**Figure 5-** Comparison of calculating DEBI with using a two-dimensional model with DEBI-ASHEL curve

## ASSESSING ERROR RESULTS OF TWO-DIMENSIONAL MATHEMATICAL MODEL

After obtaining numerical model, to ensure proper operation of the model, and verify the validity of results, the errors resulting from the numerical solution of the mathematical model, is evaluated in calculating the transverse distribution of velocity and Debi flow rate. Figure (6) percent error rate and Figure (7) compares the speed of 3.6 m in depth research on the two-dimensional mathematical model for calculating more accurate flow velocities in the main channel and the floodplains. Using a two-dimensional scatter slightly toward the line bisector 45 degrees. For a more detailed assessment of these results, the coefficient of determination ($R^2$) is calculated.

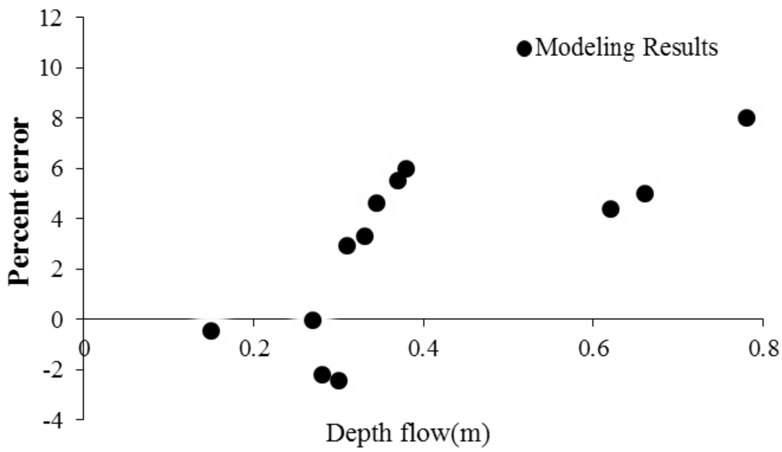



**Figure 6-** Comparison of calculating flow DEBI error Percent

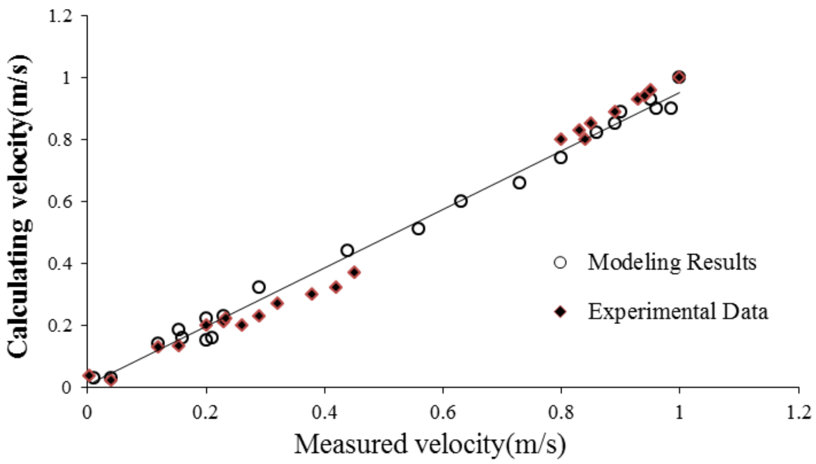


**Figure 7-** Comparison of the measured velocity than calculating velocity, at a depth of 3.6 m.

## CONCLUSIONS

According to the results obtained from the two-dimensional model to estimate the transverse velocity distribution and Comparison these with the results of experimental data can be referred to the following conclusions:

1) Comparison proposed model two-dimensional computational method with experimental data to estimate the distribution of the transverse velocity (average velocity in the depth) with the effect of the secondary flow coefficient indicates the validity of the mathematical two-dimensional model in channels.
2) Benefits of two-dimensional mathematical model, is to estimate the secondary flow coefficient, in estimating DEBI flow rate for each depth of the stream, with using the distribution of transverse velocity profile that provided satisfactory results, in Estimating DEBI-ASHEL curve, with a relative error of 0.076%.
3) Due to roughness coefficient changes in channel width and also with flow depth changes, Considering a constant roughness coefficient are not possible, Therefore, due to the relationship between changes in flow depth and roughness coefficient for a several DEBI-ASHEL, for The main channel and floodplains, and with Considering the minimum error in estimating the transverse distribution of Computational and observational and relational velocity ،Manning roughness coefficient in the main channel and floodplains, was measured with linear variations with depth.

The results of the proposed mathematical model and the experimental results of the transverse velocity distribution showed that ؛the hypothesis of Erwin and Knight (2004), greatly improve the model results. Also The DEBI-ASHEL curve of these sections showed that; in compound homogeneous Section, non-interference of the secondary flow effect is not included an error in computing; and the results are in good agreement with the experimental values. But in the case of non-homogeneous compound Channel, secondary flows have an important role. Regardless of the effect of the secondary flow, in the homogeneous compound Channel, created Maximum, 0.076 % error in calculating the total DEBI flow; however, in non-homogeneous compound Channel, the maximum error rate is about 21 %. In this study, secondary flow coefficient with geometric shapes, based on the best process analyzed with experimental data SERC-FCF. Finally, the following conclusions can be derived from this analysis:

i. With increasing depth in the floodplain ، velocity distribution in the cross section is more heterogeneous and homogeneous and Secondary flow coefficient gradually increases.
ii. By reducing the width of the flood plain, the value K, (k Based on the percentage) increases in the flood plain ،while the values of K; gradually decrease in the main channel and side slope domain.
iii. When the flood plain is rough; the speed change become larger. , between the main channel and flood plain. Therefore, momentum transfer, become stronger and secondary flow coefficients in cross-section, become greater.

The above results indicate that; Determination of K, in each area, to modeling the velocity distribution, in open compound channel is extremely important.

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