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EXTENDED ABSTRACT

Analytical Study of Flow Field in Non-Prismatic Compound Channel with Converging Floodplains Using Modified SKM

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1. Introduction

Prediction of flow filed in compound channel is an important task for hydraulic researches because of three-dimensional nature of flow. The complexity of the problem increases, significantly, when floodplains geometry changes from prismatic to non-prismatic form. In non-prismatic compound channels with converging floodplains, the main feature consists of the mass and consequent momentum exchange between the floodplains and the main channel. In the present work based on the depth-averaged Navier-Stokes equation an analytical method is proposed and used to predict the depth-averaged velocity and boundary shear stress distribution in non-prismatic compound channels with converging floodplains. In order to consider the effect of the secondary flows in the depth-averaged Navier-Stokes equation, temporal mean velocity components are assumed to be a portion of the depth-averaged velocity. Also, since the flow condition is not uniform; the flume bed slope has been replaced by the energy line slope. The results of the proposed analytical method are then compared with the experimental data, the modified SKM suggested by Rezaei and Knight (MSKM) and the SKM method. The study shows that there are good agreement between the results of the new analytical method and the experimental data.

2. Methodology

Based on two-dimensional approach, the Lateral Distribution Method (LDM) was developed to study the velocity distribution in prismatic compound channels (see Wormleaton, 1988; Knight et al., 1989; Wark et al., 1990; Wormleaton, 1996). The depth-averaged momentum equation for steady non-uniform flow in compound channel with non-prismatic floodplains can be written as follows;

$$\rho g S_e H - \rho \frac{f}{8}\sqrt{1+s^2}\,\overline{U}_d^2 + \frac{\partial}{\partial y}\left(\rho \lambda H^2 \sqrt{\frac{f}{8}}\,\overline{U}_d \frac{\partial \overline{U}_d}{\partial y}\right) = \frac{\partial}{\partial y}\left[H(\rho \overline{V}\overline{U})_d\right] \tag{1}$$

Where ρ=water density, g=gravitational acceleration, Se = energy line slope, H=flow depth, s=side slope, Ud = depth-averaged velocity, λ=dimensionless eddy viscosity, f=Darcy-Weisbach friction factor, and $H(\rho\overline{V}\overline{U})_d$ = shear stress due to secondary flow. According to Ervine et al. (2000), it is assumed that temporal mean velocity components ($(\overline{V}\overline{U})_d$) are a fraction of the depth-averaged velocity $(K\overline{U}_d^2)$ and therefore

$$\rho g S_e H - \rho \frac{f}{8}\overline{U}_d^2 + \rho \lambda H^2 \sqrt{\frac{f}{8}}\frac{1}{2}\frac{\partial^2 \overline{U}_d^2}{\partial y^2} = H\rho K \frac{\partial \overline{U}_d^2}{\partial y} \tag{2}$$

Analytical solution of Equation (2) is as follow:

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$$\overline{U}_d = \left[A_1 e^{\gamma_1 y} + A_2 e^{\gamma_2 y} + \kappa\right]^{1/2} \tag{3}$$

Where $k=(8gHS_e)/f$; and γ_1 and γ_2 may be written

$$\gamma_1, \gamma_2 = \frac{(-K) \pm \sqrt{(-K)^2 + 2\lambda\left(\frac{f}{8}\right)^{3/2}}}{\sqrt{\frac{f}{8}} \cdot \lambda H} \tag{4}$$

The parameter K in the proposed model has to be characterized. Equation (3) is applied to compound channel with converging floodplains. In the initial test runs the value of K is estimated but successfully refined until it gives a best fit with the depth-averaged velocity data. For example in the middle of converging part of the flume, the K values near the floodplains were chosen 0.08 and 0.04 wall for experimental tests of ONPC2-0 and ONPC6-0 respectively. However, by moving from floodplain walls to the main channel, the K values would be changed to the 0.001 and 0.0005 (for non-prismatic compound channel with convergence angles of 11.31o and 3.81o).

3. Results and discussion

The results of the analytical modeling in the middle of converging part of the flume for two experimental tests of ONPC2-0-0.4 and ONPC6-0-0.4 are shown in Fig. 1. The figures indicate that to compare with the Modified Shiono and Knight Method (MSKM) (Rezaei and Knight, 2009), there are good agreement between the experimental data and the depth-averaged velocity and boundary shear stress, modeled by the new Analytical method (Analy). The mean absolute percentage errors (MAPE) calculated for the depth-averaged velocity and boundary shear stress indicate that the accuracy of the proposed analytical model are almost two times of those for Rezaei and Knight (2009) method.

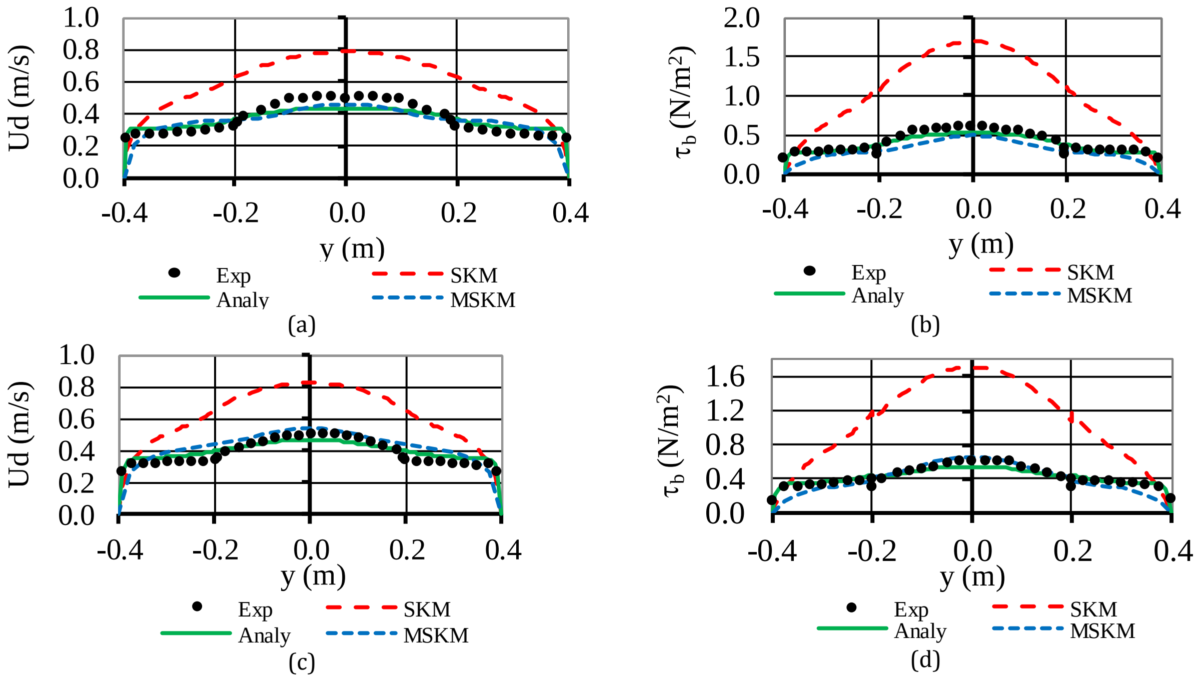

Fig. 1. Comparison between depth- Averaged velocity and boundary shear stress modeled using the new Analytical method (Analy), the Modified Shiono and Knight Method (MSKM) (Rezaei and Knight, 2009), the SKM and the experimental data for experimental test of (a), (b) ONPC2-0-0.4 and (c), (d) ONPC6-0-0.4

4. Conclusions

The velocity and boundary shear stress distributions in compound channels with converging floodplains were simulated using a new Analytical method. The results of numerical modeling were then compared with the Modified Shiono and Knight Method (MSKM) (Rezaei and Knight 2009), the ordinary Shiono and Knight Method (SKM), and the experimental data. The results of modeling indicate that the ordinary (SKM), always, overestimate the depth-averaged velocity and boundary shear stress in non-prismatic compound channel with converging floodplains. Also, the Mean Absolute Percentage Errors (MAPE) calculated for the velocity and boundary shear stress distributions, show that accuracy of the proposed analytical method is more than the Modified Shiono and Knight Method (MSKM) (Rezaei and Knight, 2009).

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