Journal of
Applied Research in Water and Wastewater

Journal homepage: www.arww.razi.ac.ir

Original paper

Hydraulic analysis of compound open channel

Abbas Parsaie *, **Amir Hamzeh Haghiabi**

Department of water Engineering, Lorestan University, Khorramabad, Iran.

ARTICLE INFO

Article history:
Received 12 April 2015
Received in revised form 25 June 2015
Accepted 28 June 2015

Keywords:
Stage-discharge relationship
Flow discharge
Velocity distribution
Energy and momentum coefficients

ABSTRACT

Distribution of velocity of flow in compound open channel due to interaction of floodplains and main channel is strongly non-uniform. Defining the distribution of flow velocity is an important factor in calculation of sediment transport and estimation of flow discharge. One of the correction factors in calculation of flow discharge and shear stress are momentum(β) and energy (α) coefficients. In this study, the effect of β and α coefficients on Froude number and specific energy are assessed. Stage-discharge relationship in compound open channel was assessed using some empirical formula including Single-Channel Method (SCM), Divided-Channel Method (DCM), and modified divided-channel method (MDCM) and compared with together. When the discharge only flows in main channel all the empirical has a same result whereas by increasing the discharge and covering the floodplains by flow the results of them are different. The highest value of outcome of empirical formula is related to the SCM. Results indicated that considering the energy and momentum coefficients have significant effect on distribution of Froude number and specific energy.

1. Introduction

Estimation of flow discharge in the rivers is one of the main parameters in flood management projects (Parsaie et al. 2015a). Prediction of flow discharge in rivers have welcomed to insurance companies. Prediction of flow discharge leads to evaluate the flow depth in streams, using those parameters is necessary to evaluate the risk of insurance of projects located on floodplains (Parsaie and Haghibia. 2014a). Therefore, they have attempted to develop a damage function proportion of flow discharge and flow depth. To estimate the flow discharge in streams the compound open channel as accurate idea has been proposed (Whyte. 2012). Fig. 1 shows different types of cross section of compound channel. As shown in Fig. 1, the compound open channels cross section includes a main channel and floodplains.

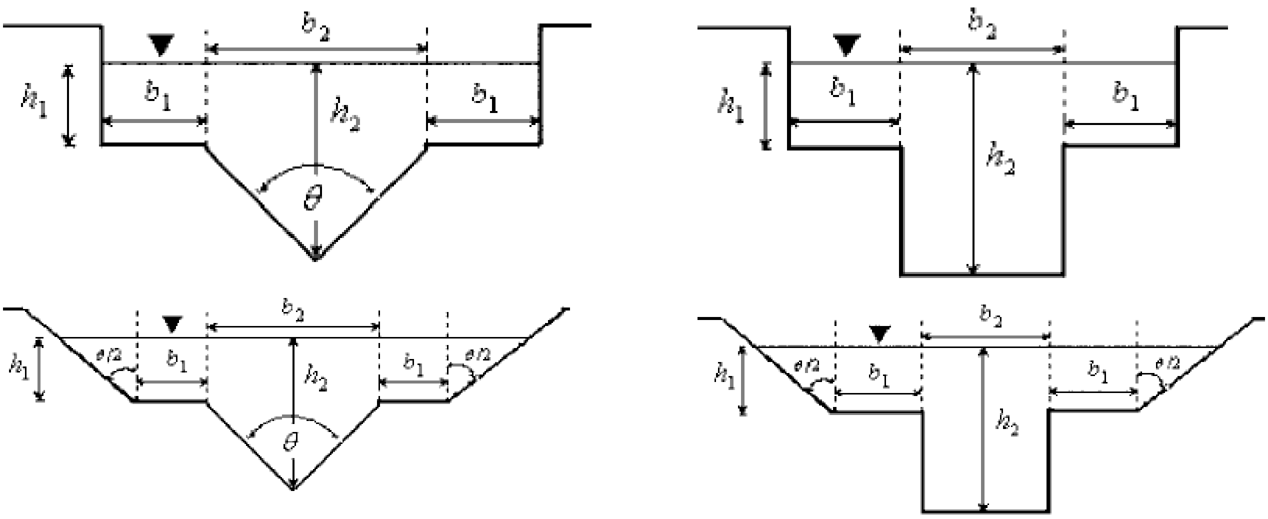

Fig. 1. Compound open channel cross sections.

where, b mc is the main channel width, n mc: main channel roughness, h mc: main channel depth, b fpl: floodplain width, n fpr: floodplain roughness and h fpr: floodplain depth. Several ways as analytical approaches such as Single-Channel Method (SCM), Divided-Channel Method (DCM), modified divided-channel method (MDCM) have been proposed to estimate the discharge of flow in

Corresponding author Email: Abbas_Parsaie@yahoo.com

compound open channel (Al-Khatib et al. 2013; Al-Khatib et al. 2012; Bousmar and Zech 1999; Huthoff et al. 2008; Khatua et al. 2012; Liao and Knight 2007; Mohanty and Khatua. 2014; Myers. 1987; Naot et al. 1993; Prinos et al. 1985; Seckin. 2004; Seckin et al. 2009; Stephenson and Kolovopoulos. 1990; Tang et al. 1999; Unal et al. 2010). Recently, intelligence techniques such as artificial neural network (Moasheri et al. 2013; Parsaie and Haghiabi. 2015a; Parsaie and Haghiabi. 2014a; Parsaie and Haghiabi. 2014b; Parsaie and Haghiabi 2015b; Parsaie and Haghiabi 2015c; Parsaie and Haghiabi. 2015d; Parsaie et al. 2015b), Genetic Programing (GP) (Azamathulla and Zahiri 2012; Najafzadeh and Zahiri. 2015; Zahiri and Azamathulla. 2014) and Multilayer perceptron neural network (MLP) have been proposed to calculate or predict the flow discharge in compound open channel (Azamathulla and Zahiri. 2012; Najafzadeh and Zahiri. 2015; Sahu et al. 2011; Zahiri and Azamathulla. 2014). Due to interaction of floodplains and main channel the distribution of flow velocity is highly non-uniform. The aim of this study is defining the hydraulic properties of compound open channel such as distribution of energy coefficient, momentum coefficient, is calculated and their effects on the specific energy, Froude number and calculating the head discharge curve by analytical approaches are evaluated.

2. Material and methods

The Bernoulli equation is the basic formula for open channel hydraulic studies. Distribution of hydraulic component such as energy coefficient, momentum coefficient is calculated by equation (1 and 2) which derives from Bernoulli equation and also the specific energy equation by considering the energy coefficient is given in equation (3).

$$\alpha = \frac{\int V^3 dA}{V_m^3 \int dA} \approx \frac{\sum_{i=1}^{N}\left(V_i^3 A_i\right)\cdot\left(\sum_{i=1}^{N} A_i\right)^3}{\left(\sum_{i=1}^{N} V_i A_i\right)^3} \tag{1}$$

$$V_m = \frac{\sum_{i=1}^{N} V_i A_i}{\sum_{i=1}^{N} A_i}$$

$$\beta = \frac{\int V^2 dA}{V_m^2 \int dA} \tag{2}$$

$$E = y + \frac{\alpha Q^2}{2gA^2} \tag{3}$$

where, i subscript is related to subsections, V is the flow velocity and A is the area of the subsections respectively. It is notable that the energy and momentum coefficients as seem in equations (1 and 2) are functions of flow discharge, flow depth and cross section area. Calculating the flow discharge by classical formula such as manning formula cases of appear incredible error in compare to measured data so researchers try to improve the accuracy of computation by modifying the manning formula. In the fallow, two main of analytical approaches which was used by investigators in many compound open channel studies are presented. To understand more detail about the hydraulic component of compound open channel an example of hydraulic channel is considered. This example was designed based on the literature section which stated that the roughness of floodplains and main channel usually is different. Table 1 presents the value of cross section of compound channel which considered in example. In other to the aim of this research is defining the effect of compound cross section of canal and different roughness between the floodplains with main channel on the hydraulic components such as head discharge curve, specific energy distribution and so on.

Table 1. Summary of geometry properties of example compound open channel.

b mc	n mc	h mc	b fpl	n fpl	h fpr	n fpr
0.25	0.012	0.15	1	0.022	1	0.022

2.1. Single channel method (SCM)

The compound open channel cross section has been considered as a unique cross section in the Single channel method (SCM) and there is not any difference between the normal and compound channel. The main point in the SCM is calculating the equivalent roughness for compound channel by prevalent methods such as Horton and Einstein formula (equation 4) and then discharge is calculated by equation (5). The weakness of the SCM is related to calculate the transport capacity, because when the water level increases and flow covers the floodplains especially in the lowest depth of flow at the floodplains, wet perimeter is more increases in compare to the wet area so transport capacity is calculated small and at the end the flow discharge which are calculated by SCM are smaller than the actual values. Increasing the flow depth on the floodplains the accuracy of the SCM may be improved.

$$n_e = \frac{\left[\sum_{i=1}^{N}\left(P_i n_i^{\frac{3}{2}}\right)\right]^{\frac{2}{3}}}{P^{\frac{2}{3}}} \tag{4}$$

$$Q = \frac{1}{n_e} A R^{\frac{2}{3}} S^{\frac{1}{2}} \tag{5}$$

2.2. Divided channel method (DCM)

The Divided Channel method (DCM) divides the compound channel to some sub sections. The DCM is based on the uniform velocity in the subsections. In this method the compound channel section is divided to the main channel and floodplains and total discharge is calculated by adding the sub sections discharge. The discharge in subsections calculates by equation (6). as shown in this equation the classical equation such as manning is used for calculating the discharge and i subscription is related to the discharge in each sub sections. The separation line between the main channel and floodplains as shown in the Fig. 1 may be considered as vertical, diagonal or horizontal. Some modification has been conducted on the divided channel method and in this regards the divided channel method with horizontal division lines which are excluded within the calculation of wetted perimeter (DCM (h-e)) can be mentioned.

$$Q_t = \left(\sum_{i=1}^{N} \frac{A_i R_i^{\frac{2}{3}}}{n_i}\right) S_0^{\frac{1}{2}} \tag{6}$$

3. Results and discussion

The momentum and energy coefficients were calculated from equations (1 and 2) and distribution of them gives in Fig. 2.

As shown in

Fig. ***2*** the momentum and energy coefficients are constant versus the flow depth until the discharge flows only in the main channel. By increasing the flow depth, the value of the momentum and energy coefficients are increased rapidly and the rate of energy coefficient is much more than the momentum coefficient.

Please cite this article as: A. Parsaie, A.H. Haghiabi, Hydraulic analysis of compound open channel, Journal of Applied Research in Water and Wastewater, 2(1), 2015, 137-142.

This change in distribution is related to intense non-uniformity in distribution of velocity and entering the properties of floodplains such as area and flow depth in computation process of momentum and energy coefficients. as shown in Fig. 1 and equations (1 and 2), when the flow depth is increased especially when the flow depth increased a modicum value then the main channel, the discharge flows in floodplains and the area of flow increased suddenly, so the value of momentum and energy coefficients increased rapidly. As shown in Fig. ***2*** by increasing the flow depth the distribution of momentum and energy coefficients decreases after it's suddenly increase. The reason of this reduction is regulation of velocity distribution and reduction the effect of floodplains on the hydraulic characteristic of compound open channel. The results of discharge calculation in compound open channel by analytical approaches are given in the Fig. 3.

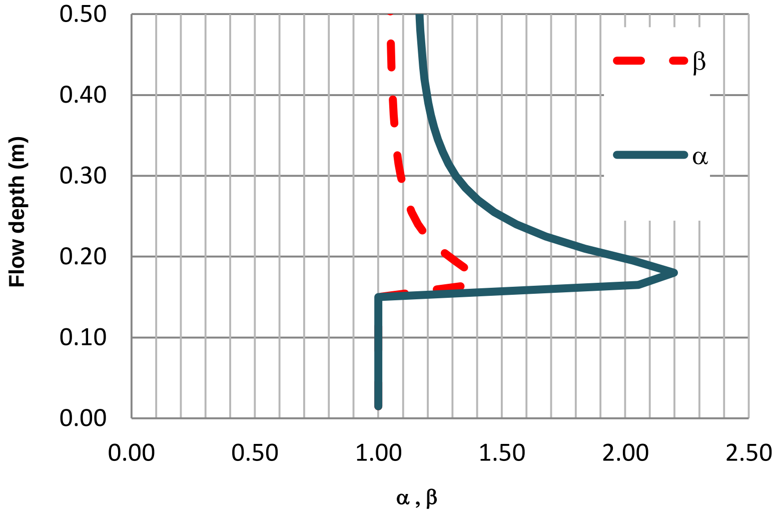

Fig. 2. Distribution of energy and momentum coefficients versus the flow depth.

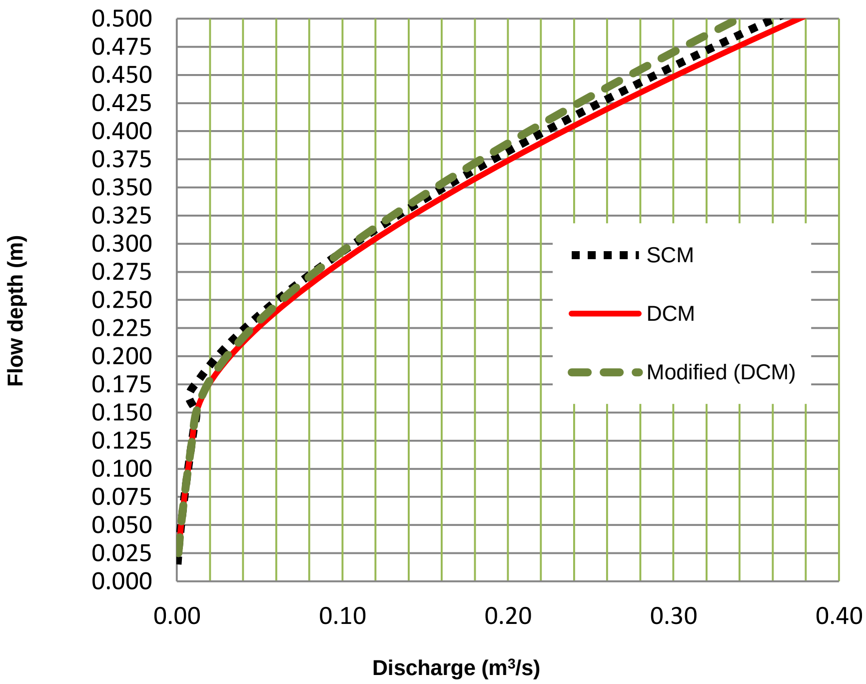

Fig. 3. Result of analytical approaches for calculation of discharge versus the flow depth.

As shown in Fig. 3, the results of the all analytical approaches are similar when the discharge flows in the main channel only. by increasing the flow depth event more than the main channel depth as shown in the Fig. 3 there is no change in the rate of results of the DCM and MDCM methods but the SCM method when the flow depth a lite increased more than main channel, the SCM method results shows a reduction in flow discharge calculation. As shown in the Fig. 3 the results of SCM is more the other analytical approaches. Figs. 4 and 5 show the distribution of Froude number versus the flow depth.

Fig. 4 shows the distribution of Froude number versus of flow depth by considering the energy coefficient in Froude number whereas the Fig. 5 shows the Froude number distribution versus the flow depth

Please cite this article as: A. Parsaie, A.H. Haghiabi, Hydraulic analysis of compound open channel, Journal of Applied Research in Water and Wastewater, 2(1), 2015, 137-142.

without considering the energy coefficient. As seems in both Figs. 4 and 5 by increasing the discharge of flow the flow depth is increased at the constant Froude number. Considering the energy coefficient to calculate the Froude number cases of appears more Froude number in constant flow depth.

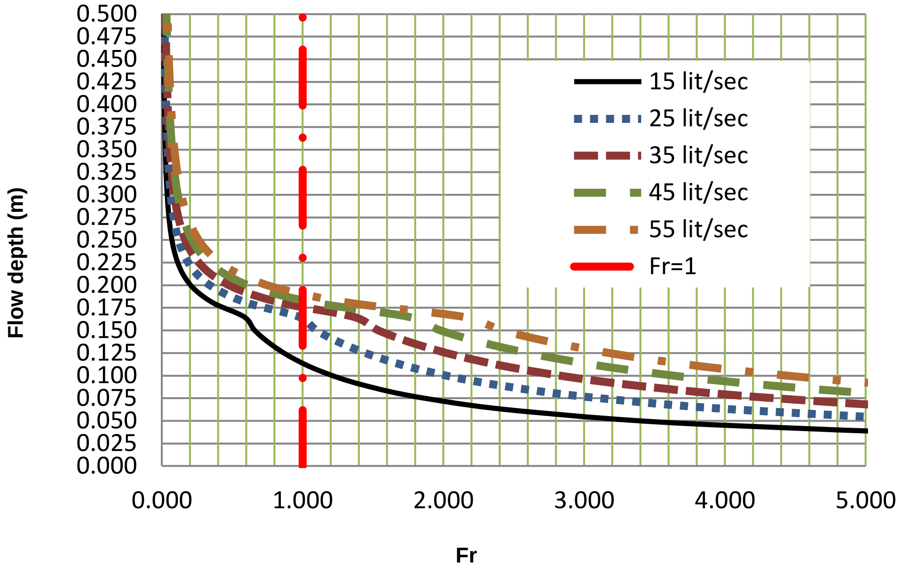

Fig. 4. Distribution of Froude number versus flow depth with energy coefficient.

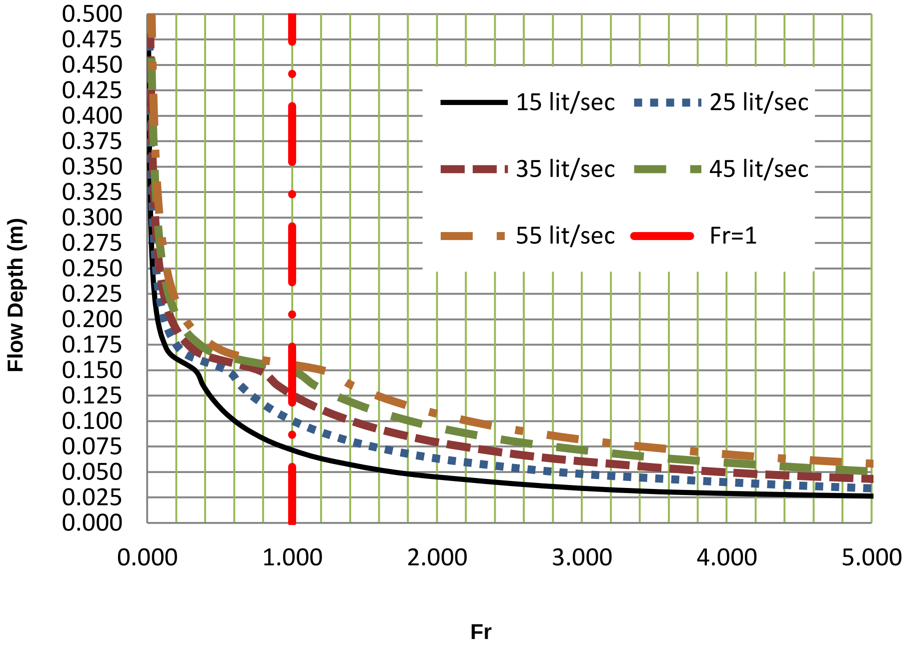

Fig. 5. Distribution of Froude number versus flow depth without energy coefficient.

Both of Figs. 6 and 7 show the distribution of specific energy versus the flow depth. Specific energy increases by increasing the discharge of flow.

Fig. 6 is showing the specific energy by considering the energy coefficient whereas the Fig. 7 is showing the specific energy without the energy coefficient. The energy coefficient is more effective on the specific energy curve especially when the discharge coefficient is increased.

4. Conclusion

In this paper a theoretical hydraulic analysis conducted on the hydraulic components of compound open channel. The result of this study showed that the compound section for open channel cases to non-uniformity in velocity distribution especially when the flow depth is increased in values a lite more than the main channel depth so the energy and momentum coefficients is more variation especially at flow depth values lite more than the main channel depth. Calculation of flow discharge in compound open channel by modified divided-channel method (MDCM) shows the more values in compere to other analytical approaches. Considering the energy coefficient is more effect on the distribution of specific energy versus the flow depth especially is more effective by increasing the discharge.

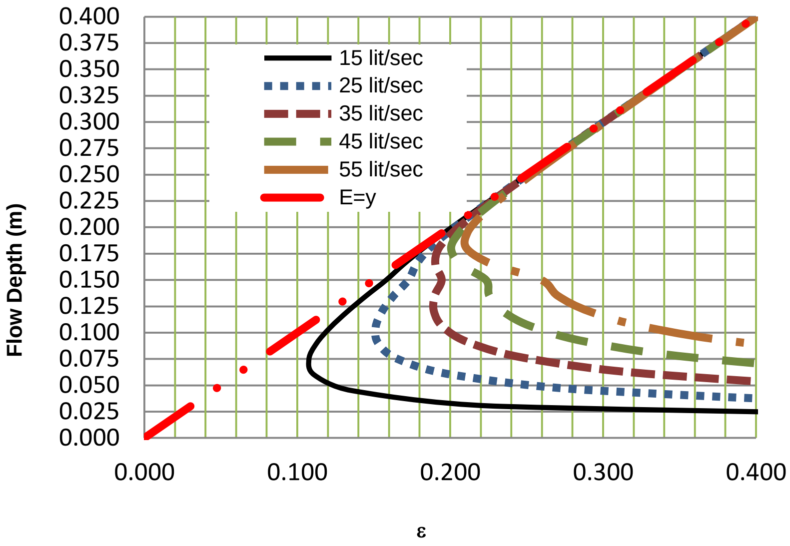

Fig. 6. Distribution of Froude number versus flow depth with energy coefficient.

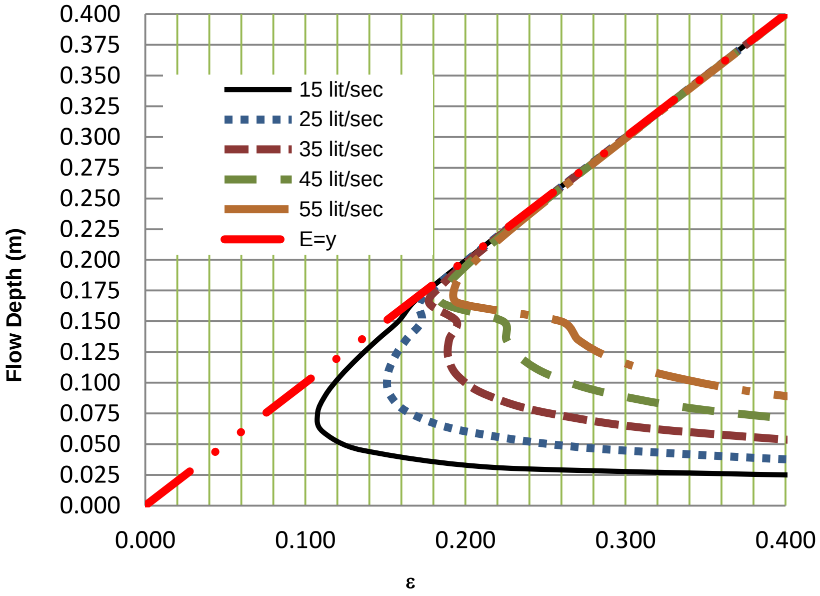

Fig. 7. Distribution of Froude number versus flow depth without energy coefficient.

References

Al-Khatib I., Hassan H., Abaza K., Application and Validation of Regression Analysis in the Prediction of Discharge in Asymmetric Compound Channels, Journal of Irrigation and Drainage Engineering 139 (2013) 542-550.

Al-Khatib I.A., Dweik A.A., Gogus M., Evaluation of separate channel methods for discharge computation in asymmetric compound channels, Flow Measurement and Instrumentation 24 (2012) 19-25.

Azamathulla H.M., Zahiri A., Flow discharge prediction in compound channels using linear genetic programming, Journal of Hydrology 454–455 (2012) 203-207.

Bousmar D., Zech Y., Momentum Transfer for Practical Flow Computation in Compound Channels, Journal of Hydraulic Engineering 125 (1999) 696-706.

Huthoff F., Roos P., Augustijn D., Hulscher S., Interacting Divided Channel Method for Compound Channel Flow, Journal of Hydraulic Engineering 134 (2008) 1158-1165.

Please cite this article as: A. Parsaie, A.H. Haghiabi, Hydraulic analysis of compound open channel, Journal of Applied Research in Water and Wastewater, 2(1), 2015, 137-142.

Khatua K., Patra K., Mohanty P., Stage-Discharge Prediction for Straight and Smooth Compound Channels with Wide Floodplains Journal of Hydraulic Engineering 138 (2012) 93-99.

Liao H., Knight D., Analytic Stage-Discharge Formulas for Flow in Straight Prismatic Channels, Journal of Hydraulic Engineering 133 (2007) 1111-1122.

Moasheri S.A., Goshki A.S., Parsaie A., "SAR" Qualities parameter persistence by a compound method of geostatic and artificial neural network (Case study of Jiroft plain), International Journal of Agriculture and Crop Sciences 6 (2013) 157-166.

Mohanty P.K., Khatua K.K., Estimation of discharge and its distribution in compound channels Journal of Hydrodynamics, Ser B 26 (2014) 144-154.

Myers W., Velocity and Discharge in Compound Channels Journal of Hydraulic Engineering 113 (1987) 753-766.

Najafzadeh M., Zahiri A., Neuro-Fuzzy GMDH-Based Evolutionary Algorithms to Predict Flow Discharge in Straight Compound Channels, Journal of Hydrologic Engineering 20. (2015).

Naot D., Nezu I., Nakagawa H., Calculation of Compound-Open-Channel Flow Journal of Hydraulic Engineering 119 (1993) 1418-1426.

Parsaie A., Haghiabi A., The Effect of Predicting Discharge Coefficient by Neural Network on Increasing the Numerical Modeling Accuracy of Flow Over Side Weir, Water Resources Management 29 (2015a) 973-985.

Parsaie A., Haghiabi A.H., Evaluation of Selected Formulas and Neural Network Model for Predicting the Longitudinal Dispersion Coefficient in River, Journal of Environmental Treatment Techniques 2 (2014a) 176-183.

Parsaie A., Haghiabi A.H., Predicting the side weir discharge coefficient using the optimized neural network by genetic algorithm Scientific Journal of Pure and Applied Sciences 3 (2014b) 103-112.

Parsaie A., Haghiabi A.H., Calculating the Longitudinal Dispersion Coefficient in River, Case Study: Severn River, UK, International Journal of Scientific Research in Environmental Sciences 3 (2015b)199-207.

Parsaie A., Haghiabi A.H., Computational Modeling of Pollution Transmission in Rivers, Applied Water Science (2015c)1-10.

Parsaie A., Haghiabi A.H., Predicting the longitudinal dispersion coefficient by radial basis function neural network, Modeling Earth Systems and Environment 1 (2015d) 1-8.

Parsaie A., Haghiabi A.H., Moradinejad A., CFD modeling of flow pattern in spillway's approach channel, Sustainable Water Resources Management 1 (2015a) 245-251.

Parsaie A., Yonesi H.A., Najafian S., Predictive modeling of discharge in compound open channel by support vector machine technique, Modeling Earth Systems and Environment 1 (2015b) 1-6.

Prinos P., Townsend R., Tavoularis S., Structure of Turbulence in Compound Channel Flows, Journal of Hydraulic Engineering 111 (1985) 1246-1261.

Sahu M., Khatua K., Mahapatra S., A neural network approach for prediction of discharge in straight compound open channel flow, Flow Measurement and Instrumentation 22 (2011) 438-446.

Seckin G., A comparison of one-dimensional methods for estimating discharge capacity of straight compound channels, Canadian Journal of Civil Engineering 31 (2004) 619-631.

Seckin G., Mamak M., Atabay S., Omran M., Discharge estimation in compound channels with fixed and mobile bed Sadhana 34 (2009) 923-945.

Stephenson D., Kolovopoulos P., Effects of Momentum Transfer in Compound Channels Journal of Hydraulic Engineering 116 (1990) 1512-1522.

Tang X., Knight D.W., Samuels P.G., Variable parameter Muskingum-Cunge method for flood routing in a compound channel, Journal of Hydraulic Research 37 (1999) 591-614.

Unal B., Mamak M., Seckin G., Cobaner M., Comparison of an ANN approach with 1-D and 2-D methods for estimating discharge capacity of straight compound channels Advances in Engineering Software 41 (2010) 120-129.

Whyte D., River Flow: New and Selected Poems (Revised). Many Rivers Press (2012).

Zahiri A., Azamathulla H.M., Comparison between linear genetic programming and M5 tree models to predict flow discharge in compound channels, Neural Comput & Applic 24 (2014) 413-420.

Williams S.C., Beresford J., The effect of anaerobic zone mixing on the performance of a three-stage bardenpho plant, Water Science and Technology 38 (1998) 55-61.

Yamaguchi T., Ishida M., Suzuki T., Biodegradation of hydrocarbon by Prototheca zopfii in rotating biological contactors, Process Biochemistry 35 (1999) 403-409.

Please cite this article as: A. Parsaie, A.H. Haghiabi, Hydraulic analysis of compound open channel, Journal of Applied Research in Water and Wastewater, 2(1), 2015, 137-142.