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EXTENDED ABSTRACT

Discharge Estimation in Compound Channels with the Use of Diagonal Dividing Lines

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Introduction

Based on the previous research, the flow rate estimation by the DCM method has been widely used in compound channels and many computational models have been developed accordingly. Therefore, a compound channel dividing into sections according to the most accurate method is a requirement that all researchers agree. While vertical lines are used in models for dividing the compound channel into the main channel and floodplain, some researchers maintain that vertical lines have an inaccurate performance compared with horizontal and diagonal lines, especially for low discharge (Khatua et al., 2013, Mohaghegh and Kouchakzadeh, 2008, and Ozbek et al., 2004). However, the methods for discharge estimation based on the shear stress calculation uses vertical lines (Ackers, 1993, Shiono and Knight, 1991, and Bousmar and Zech,1999). In this research, it has been attempted to present the best angle of the dividing line, which results in a 0% error rate calculated by comparing the effect of dividing lines with different angles on the calculation of the discharge of the compound channel.

Methodology

The research was carried out using published data from the large-scale channel. Flood Channel Facility (FCF) that has been constructed at Hydraulics Research Ltd at Wallingford with measures 56m in length by 10m in width. In this study, the first series of data was used that provided for the study of a straight compound channel with uniform roughness set at a longitudinal bed slope of approximately 0.001, and the cross-section of the compound channel is networked, and the velocity values for each node are measured for different flow rates. Using these data, the flow through the channel can be calculated and compared with the measured flow rate. For this purpose, the compound channel was divided into three sub-sections: a main channel and two floodplains on the sides of the main channel. The diagonal lines were used at different angles for dividing the cross-section. The first angle in each experiment was chosen so that the division line reaches the intersection of the flood plain and the water surface and the last hypothetical line to the intersection of the water surface and the central channel of the compound channel. According to the DCM methods, the discharge in sub-sections was calculated using the flow resistance equations, such as Manning and the sum of calculated discharge for sub-sections was considered as the total flow. In order to calculate the wetted perimeter, four methods were considered: including or excluding within the calculation of wetted perimeter of main channel or floodplains. In order to compare the performance of these different methods, the rate of error was calculated using the following equation that the Q_m and Q_c are the measured and calculated discharge, respectively (Khatua et al. 2011):

$$Error\% = \frac{Q_c - Q_m}{Q_m} \times 100 \quad (1)$$

Results and Discussion

In this study, the error of the estimated discharge using Manning's equation was calculated, and the effect of the angle of division line on the error was investigated for different flow rates. As shown in Fig.1, the application of two methods (I) and (III) can lead to satisfactory results due to the convergence on both sides of the curves and the decreasing error rate. The methods of the wetted perimeter calculation in subsections are different for figs. (a) to (d). Methods (I) and (II) are including the division line length in the main channel and floodplains respectively for the calculation of wetted perimeter and methods (III) and (IV) are including the division line length in both of the main channel and floodplains and none of them respectively. According to the Fig.1, in the upper discharge and angles in the range of 30 to 140 degrees, the error rate is less than 5 percent, so the application of the vertical line and diagonal in this range can be accurate, but in lower discharge, angles in this range results in an error up to 40 percent. So, very small or very large angles but not horizontal lines should be chosen for the low discharge. The study of the apparent shear stress distribution at interfaces of the compound channel with different angles confirmed these results, and the maximum of apparent shear stress is on the vertical interface for all discharges and reduced by decrease and increase of the angle. It is observed that 10 to 30% of the flow resistance is assigned to the apparent shear force, and it reached 50% by the decrease of the angle, and the horizontal division lines have the lowest percentage of shear force. This confirms the previous studies.

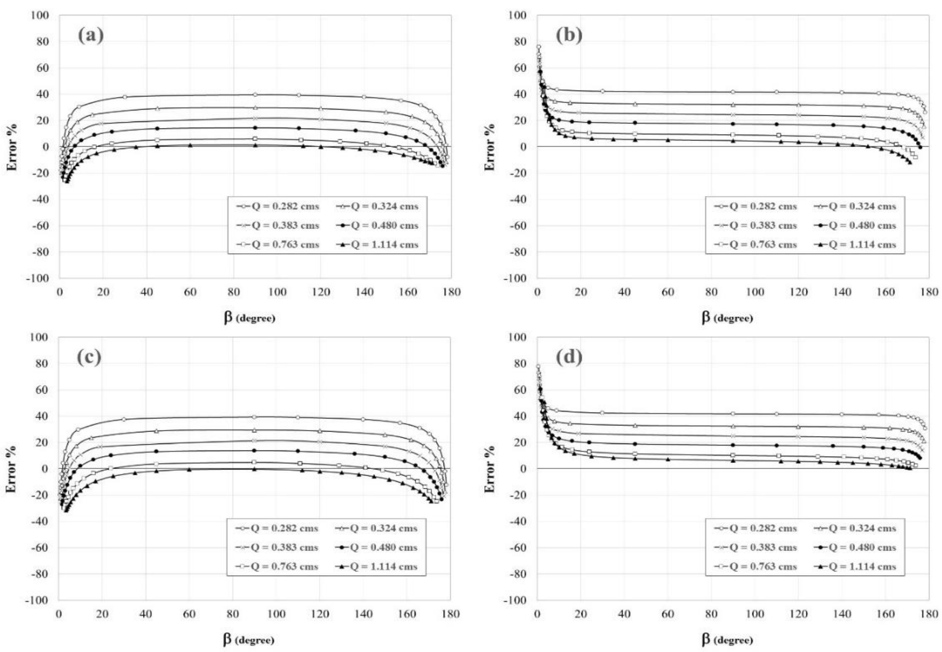

Fig. 1- The effect of the angle of the division line by the estimated discharge error for the methods of the wetted perimeter calculation:(a) method I, (b) method II, (c) method III, and (d) method IV

So based on the results of the application of the Manning equation, the optimal angle of the division line in the form of the following equations was obtained using the nonlinear regression method. (Fig.2)

$$\sin\beta^* = Exp\left(\frac{Dr - 0.506}{0.094}\right) \quad (\beta^* < 90°) \quad (2)$$

$$\sin\beta^* = Exp\left(\frac{Dr - 0.506}{0.117}\right) \quad (\beta^* > 90°) \quad (3)$$

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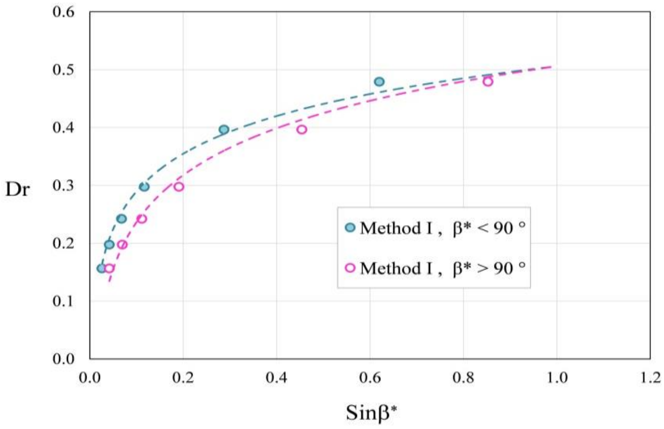

Figure 2- The curve of the best angle of the division line at different depth ratios

In these equations, Dr is the depth ratio and β^* is the best angle for the division line. β is 0 to 90 degree for Eq.2 and 90 to 180 degree for Eq.3. The apparent shear force is 10 to 25% of the flow resistance on the diagonal interfaces with the optimum angle according to the results of this study.

Conclusion

In this study, the best angle for the interface is determined in such a way that makes zero the discharge computational error by the Manning method compared with the data collected from the large channel facility (FCF) at Wallingford. Finally, equations and graphs are recommended to determine the optimum angle to depth ratio.

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