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Stage Discharge Prediction in a Prismatic Compound Channel

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Abstract

In river channel analysis, the major area of uncertainty is to predict the discharge carrying capacity of the main channel along with the floodplain. Prediction of discharge is required to establish the stage discharge relationship, which is useful for flood analysis and river engineering studies (sediment transport, bank protection etc). The traditional discharge prediction methods such as SCM, DCM fail to give accurate discharge as they don't consider the effect of momentum transfer occurs at the junction between floodplain and main channel. This momentum transfer makes the discharge prediction difficult. Therefore some new models are developed which make the discharge prediction more accurate than the traditional method by considering the effect of momentum transfer. In this paper computation of discharge is found out through the traditional approaches as well as with a newly developed method of IDCM. It describes the effect of momentum transfer on discharge prediction. The experimental data reported by other investigators as well as the data from the present series of experiments are used through DCM and IDCM to evaluate the discharge estimation approaches.

Keywords: Discharge estimating methods, Hydraulic model, Flow pattern, Momentum Transfer, Apparent shear stress, Interface stress.

1. Introduction

During normal periods, water generally flows in the main channel, but during high stages the level of water goes over bank and inundates the floodplains, resulting a compound channel flow section. Due to higher roughness in the floodplain, the velocity in the floodplain is less as compared to the main channel that leads to the formation of vortices at the interface of the main channel and floodplain. This leads to continuous transfer of momentum between the two sections. This momentum transfer makes the discharge prediction inaccurate. Initially the single channel method of analysis was used for discharge calculation. Later, the divided channel method was being developed which gives better result than single channel method. But still they don’t make the discharge prediction accurate as both the methods don’t consider the effect of momentum transfer occurring at the interface. Selin (1964) has shown that the formation of vortices at the interface between the main channel and the floodplain. Other investigators considered the momentum transfer effect and tried to form different mathematical formulae that gave good results for discharge and interacting divided channel method (Hutoff 2007) is one of them. This method quantifies momentum transfer in terms of shear stress.

2. Methodology

2.1 Divided Channel Method

This method is most widely used for predicting discharge in an open channel. In this method the channel is divided into suitable subsections and area of each sub section and subsequent velocity are being found out using Manning’s or Chezy’s equation. By multiplying these two the discharges for each sub-section are computed. Further, addition of the segmental discharges gives the total discharge of the compound channel. When the discharge is computed by dividing the channel using horizontal interface, then it is called as horizontal interface plain and when discharge is computed by dividing the channel using vertical interface, then it is known as vertical interface plain. Cross section of a two-stage channel having symmetric identical floodplains and asymmetric with one side floodplain are shown in Fig 1. The three commonly used interfaces are shown in Fig. 2. The discharge of the compound channel can be estimated using equation (1).

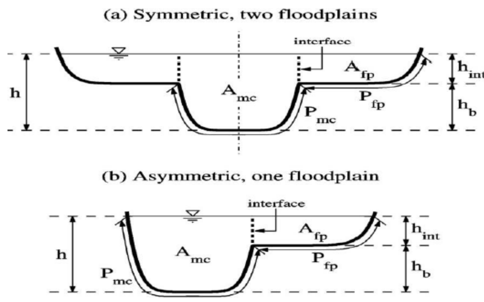


Fig. 1: Cross section of a two-stage channel: (a) symmetric with two identical floodplains (b) asymmetric with one side floodplain.

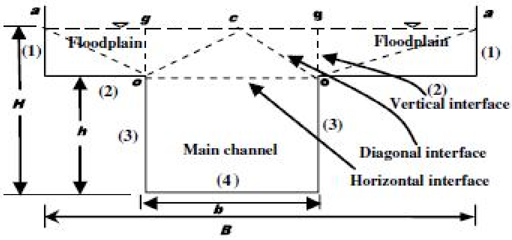


Fig. 2: Shows the vertical, horizontal, diagonal interface of a prismatic compound channel.

(1)

where Q = Discharge through the compound channel, = Area of the main channel and floodplain respectively, = perimeter of the main channel and floodplain respectively, = Bed slope of the channel, = manning's co-efficient for main channel and flood plain respectively.

2.2.2. Interacting divided channel method

This method developed by Fredrik Huthoff in the year 2007 considers the effect of momentum transfer in terms of interface stress (τ_{int}). The following equations have been developed to find out the velocity of the main channel as well as flood plain given as

(2)

(3)

(4)

where & are the velocities of main channel and the flood plain. = number of flood plains. = velocities of the main channel and flood plain when . =interface stress developed at the interface of the main channel and flood plain.

(5)

where are co-efficient of friction. are the area for main channel and flood plain respectively. = difference between the water depth and the full bank level.

After finding out the velocities the discharge (Q) of the total section can be predicted through inter acting divided channel method by using equation (6).

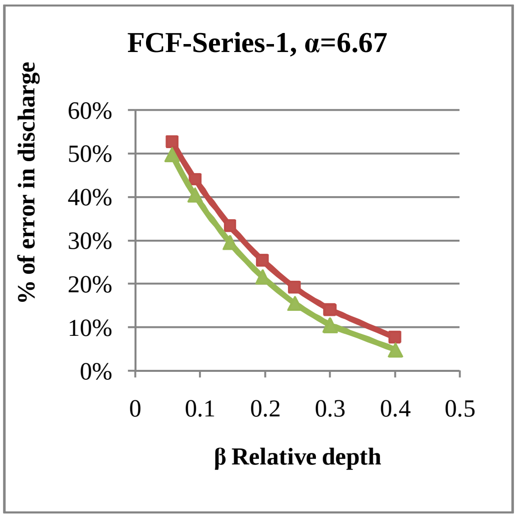
(6)

3. Data Collection

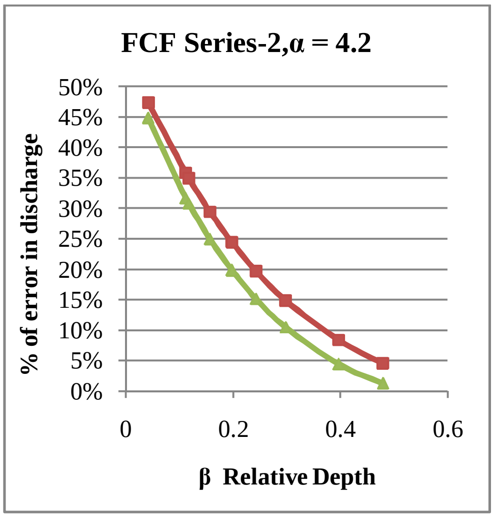
Discharge data has been collected from FCF Series data(S-1, S-2, S-3, S-8, S-10) and Kinght & demetriou data with varying width ratio (*B/b*). Then discharge is calculated by using Divided channel method as well as interacting divided channel method. The results of the both method is then compared with the actual discharge of the collected data set.

4. Results and Discussion

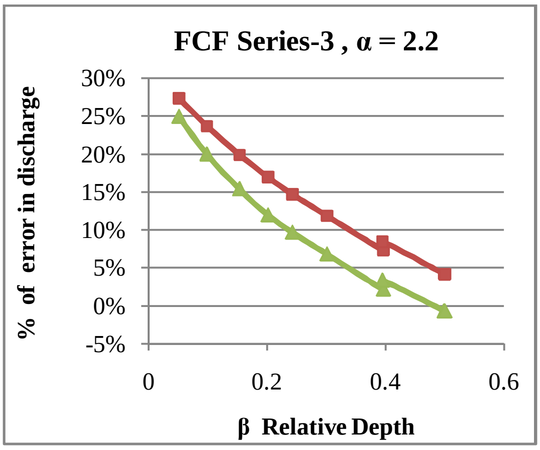
By using the equations of both the models, discharge is being computed for each channel cross section with varying depth with different width ratio (B/b). Here the graphs are plotted between relative depth (β) and percentage of error in the discharge. At lower depth both the methods gave poor discharge measurement but as the depth of water goes on increasing both the models performed well.



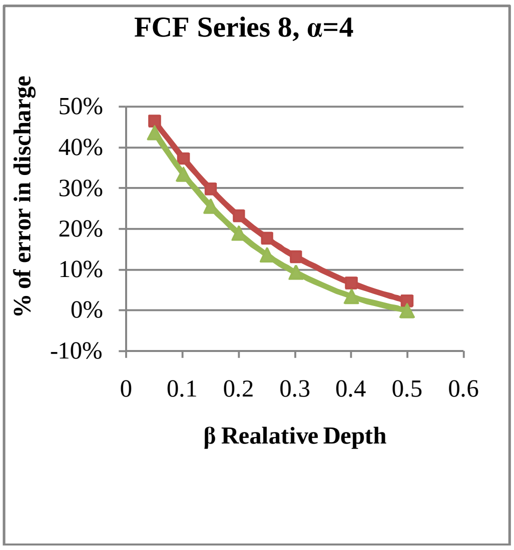
(a)



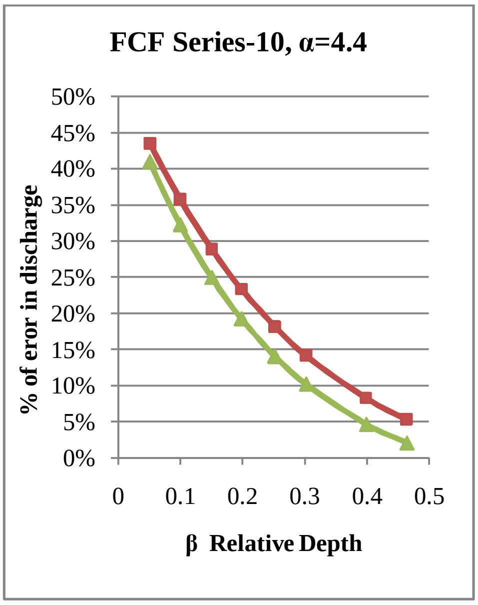
(b)



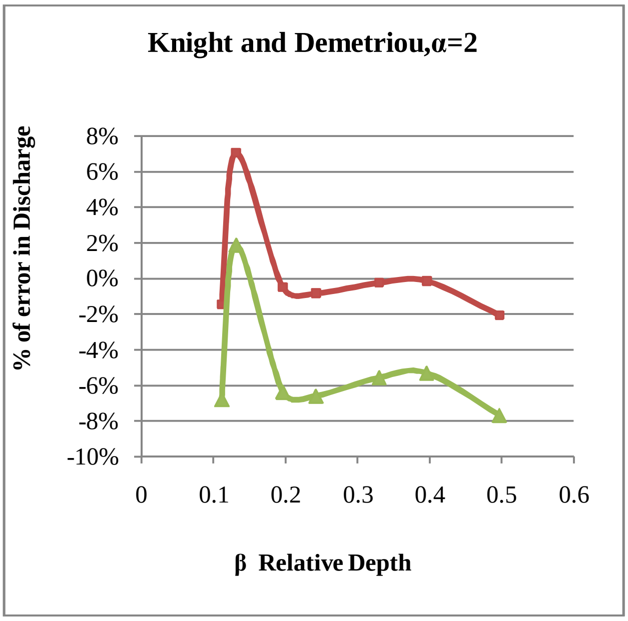
(c)



(d)

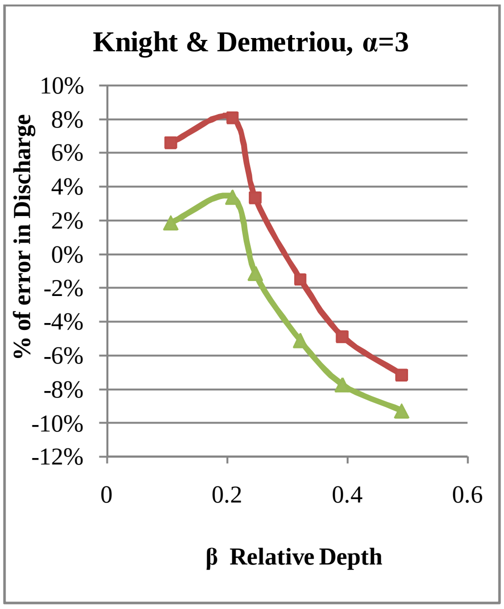


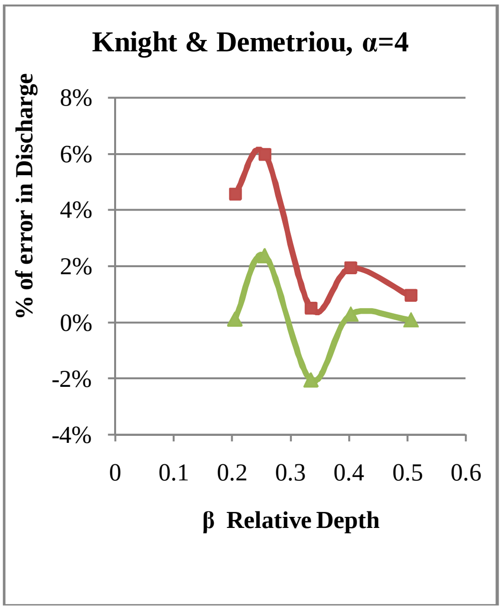
(e)



(f)

By using the equations, discharge is being computed for each channel cross section with varying depth. From the graph it is clearly visible that divided channel method is giving less accurate result than interacting divided channel method (IDCM). IDCM is giving more or less 5% error whereas DCM is giving around 10% error. Here positive error shows the over estimation of discharge while negative error shows the under estimation of discharge with respect to actual discharge.





(g) **(h)**

Fig. 3 (a),(b)(c)(d)(e)(f)(g)&(h) show the graph between the relative depth and % of error in discharge with respect to actual discharge.( ) shows the % of error in DCM(vertical interface),( ) shows the % of error in IDCM. α=width ratio=B/b. B= bottom width of the compound channel, b= bottom width of the main channel.

5. Conclusion

By considering different channels with varying cross section with different width ratio, discharge has been computed through two methods. The results are compared with the actual data that has been collected from different sources. From the comparison study we got that IDCM do better discharge prediction as compared to DCM as IDCM considers the effect of momentum transfer in terms of interface stress at the junction of the main channel and the flood plain.

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