Flow computation in symmetric and asymmetric compound channels by Separate channel methods

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Abstract— In compound channel flow, due to strong interaction between the main channel and floodplain flows, the discharge at different interfaces of the compound sections varies greatly. There are many reports found in literature related to compound channel with symmetrical flood plains and very few are found for asymmetrical cases. In a symmetrical compound channel the momentum transfer occurs from both sides of the channel to the flood plains uniformly. In case of a compound channel with asymmetrical floodplains, there is a stronger interaction between main channel and flood plains occur as compared to the symmetrical case. Many investigators have studied and modeled in predicting the flow variables of the compound channel which are generally applicable for symmetrical cases. In this paper, some approaches for predicting flow in such channels are described. The approaches were also applied to a number of experimental data sets and the results were compared well. Six different division methods have been used for predicting discharge in four different channel cross sections with varied geometric dimensions. The discussed approaches are generally based on location of vertical, horizontal and inclined interfaces of the channel. The applicability and improvement of the methods to such channels are discussed and these methods have been compared to their corresponding experimental values using error analysis.

Keywords-*compound channel, asymmetric, width ratio, relative depth apparent shear, interface plains, overbank flow*

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I. INTRODUCTION

Mostly compound channels are consisting of a main river channel and flanked by one or two-side floodplains. The first case is known as symmetrical compound channel where both flood plains are equal otherwise the channel is said to be asymmetrical whether it is flanked by either side. The design of such channel is very important for environmental, ecological, and design issues. Therefore, it is very essential for a hydraulic engineer to estimate discharge through the channel after simulating or measuring stage in compound channel. It is a task to hydraulic people to understand the flow behavior and mechanism of rivers in both their in bank and overbank conditions. Generally in dry seasons of low water levels, normally the main channel conveys the entire flows. When flood occur, the flow rate for a particular river may change drastically that the over bank flow condition is breached and inundates the surrounding floodplain area. Then the important issue to ensure adequate water supply to the community, routing of flood, flood mitigation and flood prediction during extreme rise of water level. Because the secondary flow plays a vital role and the flow becomes more complex.The common works of floodplains are mainly to convey the additional flows during the floods [6]. Symmetric compound channels of rectangular or trapezoidal shape have been extensively studiedand satisfactory equations have been derived for their analysis and design[2]. Uniform flow formulas such as Chezy or Manning are used to calculate the flow in simple channel. But having the complex geometrical cross section, the SCM, DCM, and MDCM methods are widely usedin compound channels, due to the momentum transfer between the main channel and flood plain produces a transverse shear layer influencing the flow at junction. So some methods are developed by researchers named as separate channel method to estimate the discharge capacity compound channels. Separate channel methods are simple in manipulation and give a reasonable accuracy for discharge calculations. The aim of this study is to evaluate the separate channel methods for discharge computation in asymmetric rectangular compound channels for six different models. The satisfactory application of the manning's equation is required for main channel along with the flood plain. Appropriate flow resistance factor or manning's coefficient is used in the application of the formula.

II. THEORY OF APPLICATION

In straight compound channels, the longitudinal velocity in the main channel is generally faster than that on the floodplain. This causes a shear layer at the interface between the main channel and the floodplain [9]. Three imaginary interface vertical, horizontal and inclined divide asymmetric and symmetrical compound channel into main channel and floodplain as suggested by Wormleaton et al. [11,12]. Vertical, horizontal and inclined division planes are used for dividing the compound channel to estimate the capacity. However some assumptions are there for making of subdivision which make different in this six methods regarding the location of the imaginary interface plane. The most chosen location of that subdivisions are shown in Fig. 1and 2, where B is the width of total compound channel, b is the bottom width of main channel, bf is the width of floodplain, H is the total depth of main channel and Z is the main channel bank full depth.The uniform flow equation i.e. manning's equation is adopted for finding out the flow rate in every sub divisional cross section and the equation for main channel and flood plain are

$$Q_{mc} = \frac{A_{mc}}{n_{mc}} R_{mc}^{\frac{2}{3}} S_0^{\frac{1}{2}}$$
$$Q_f = \frac{A_f}{n_f} R_f^{\frac{2}{3}} S_0^{\frac{1}{2}}$$

Floodplain;Q_f = Rate of flow of the flood plain; A_f=Area of the flood plain; Rf = Af / Pf = hydraulic radius of the flood plain; S_0=bed slope

Then the total discharge capacity for an asymmetric compound channel is found out by adding the flow through main channel and flood plain.

$$Q = Q_{mc} + Q_f$$

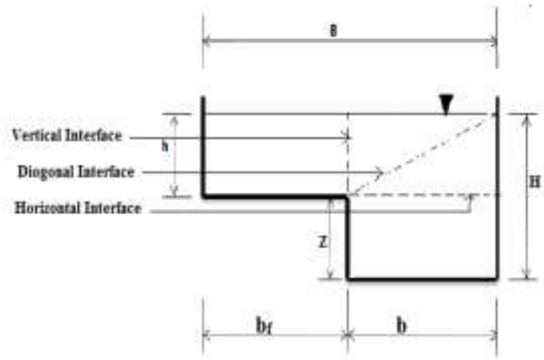

Fig 1: Asymmetric compound channel with interface

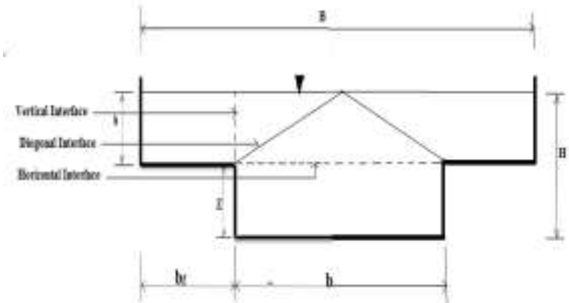

Fig 1: Symmetric compound channel with interface

DIVISION METHODS

When bank full condition occurs, it has been observed that the singe channel method underestimates the discharge as it considers the whole cross section as one unit. Sometimes it is seen that the manning's equation overestimate the discharge. Reduction in hydraulic radius underestimates the carrying capacity as it takes the whole cross section as a unit. So six divided channel methods (DCMs) are used as a standard discharge calculation method in which the symmetric and asymmetric compound channel of different width ratio are simply divided by vertical or horizontal or inclined interfaces planes as shown in Fig[1] and [2]. In calculation procedure the main channel and flood plain are separately taken. The three interface plane are both excluded andincluded in the wetted perimeter of the main channel. But these planes are not considered in the flood plain case. It is the main difference in these methods whether the interface is included to or excluded from the wetted perimeter of the main channel. Once the individual discharges in the main channel and floodplain subsections for any assumed interface are computed, they are summed to obtain the total discharge of the compound channel. To perform the analysis, six different discharge calculation methods will be used as follows: EVDM, EHDM, EIDM, IVDM, IHDM, and IIDM. From the notation of name,E represents whether the interface is excluded from the wetted perimeter and I represents if the interface is included to the wetted perimeter of the main channel. On the other hand, V, H and I represent vertical interface, horizontal interface and inclined interface respectively. DM stands for division method.

Where:Q_{mc} = Rate of flow of the main channel; A_{mc}=Area of the main channel; R_{mc} =hydraulic radius of the main channel;n_{mc} = Manning's roughness coefficient of the main channel; *nf*=Manning's roughness coefficient of the

III. CALCULATION

Asymmetric channel for EVDM, Amc= bH, Af= bf h , Pmc= (H+b+Z), Pf = bf +h ; for EHDM, Amc= bZ, Af= Bh, Pmc= (b +2Z), Pf = bf +2h; for EIDM, Amc= b(Z +H)/2, Af= h(bf + B)/2, Pmc= (H +b+ Z), Pf = bf +h; for IVDM, Amc= bH, Af= bf h , Pmc= (2H + b), Pf = bf + h ;For IHDM Amc= bZ, Af= Bh, Pmc= (2b+2Z), Pf = bf +2h ; for IIDM, Amc= b(Z +H)/2, Af= h(bf +B)/2, Pmc= H+b+Z+$\sqrt{(b^2 + h^2)}$, Pf = bf +h .

Symmetric channel for EVDM, Amc= bH, Af= 2bf h , Pmc= (Z+b+Z), Pf =2(bf +h) ; for EHDM, Amc= bZ, Af= Bh, Pmc= (b +2Z), Pf = 2bf +2h; for EIDM, Amc= bZ+(bh)/2, Af= h(bf +0.5B), Pmc= (Z+b+ Z), Pf = 2(bf +h);for IVDM, Amc= bH, Af= 2bf h , Pmc= (2H + b), Pf = 2(bf +h);For IHDM Amc= bZ, Af= Bh, Pmc= (2b+2Z), Pf = 2bf +2h ; for IIDM, Amc= bZ+(bh)/2, Af= h(bf +0.5B), Pmc= Z+b+Z+2$\sqrt{(0.5b^2 + h^2)}$, Pf = 2(bf +h).

IV. EXPERIMENTAL APPARATUS AND PROCEDURE

In this presentpaper,4 series of experiments were considered for the analysis. Two series of the asymmetrical experimental data(width ratio 1.5 and 3)are taken which are conducted on the flume at the fluid mechanics laboratory, Mechanical Engineering Department, Birzeit University [3]. This asymmetricalglass-walled horizontal laboratory flume is 7.5 m long, 0.30 m wide and0.3 m deep with a bottom slope of 0.0025. The manning's n is assumed as 0.015. From the other two symmetric cross sections, one is of width ratio 1.8, the data are taken from [4] in which experiments had been conducted in prismatic compound channels with non-prismatic case after half length of the channel. This channel is built inside a concrete flume measuring 15m long ×.95m width × 0.55mdepthwith a roughness coefficient of 0.011.

TABLE-I DIMENSIONS OF CHANEELS

Channel type	b(m)	z(m)	bf(m)	B(m)	B/Z	B/b	bf/b
Asymmetric(A)	0.20	0.06	0.10	0.30	5.00	1.50	0.50
Symmetric(A)	0.50	0.10	0.20	0.90	9.47	1.80	0.40
Asymmetric(B)	0.10	0.06	0.20	0.30	5.00	3.00	2.00
Symmetric(B)	0.12	0.12	0.16	0.44	3.66	3.66	1.33

The other symmetric channel is of width ratio=3.66 hasbeen taken from [7].This straight experimental symmetric compound channel is fabricated inside tilting flumes in the Fluid Mechanicsand Hydraulics Engineeringat theNational

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Institute of Technology, Rourkela, India. This straight compound channelhas equal flood plain of at both sides of the main channel.From the series of data, four data set series are considered for the analysis. The required experimental values with dimensions of the models used in the experiments are given in Table I. The values of varying width ratio 1.5, 1.8, 3.0 and 3.66 are taken for calculation.

V. RESULT AND DISCUSSION

In the subsequent sections, the variations of relative depth and discharges (measured and calculated) of different symmetric and asymmetric series of data of varying non dimensional parameter are graphically presented in Figs. 3–6. The relative depths in abscissa with discharge value in ordinate are taken in each figure. The ranges of width ratio (α), depth ratio (β),$b/z$of different compound channels along with the error analysis are presented in table 2.From thosegraphs, it is clearly seen that excluded methods givegoodagreement with the measured dischargesfor both symmetric and asymmetric methods. For asymmetric channel of $\alpha = 1.5$ and 3.0,both including as well as excluding methods give good results. For asymmetriccompound channel of $\alpha = 3$ the included horizontal (IHDM) and inclined(IIDM)methodsgive better results.For asymmetric (A)channel of lower width ratio the EVDM, IVDM over-estimate the flow and IHDM, IIDM under estimate the flow. But the error comes minimum for all method except IIDM. From the fig 4, it is observed that all methods are under estimating where as EVDM shows minimum error for symmetric channel of 1.8width ratio. From the error analysis it is analyzedthat all excluded methods gives good agreement for symmetric channel of width ratio 3.66.The included methods are generally under estimating the flow values as the wettedperimeter takes the interface value in the calculation.Due to wetted perimeter of the main channel, the included methods give always lesser discharges than the same method of excluding the interface.

TABLE II ERROR ANALYSIS AND BEST DISCHARGE COMPUTATION METHODS FOR MODEL

Channel type	Width Ratio B/b	b/Z	Relative Depth (h/H)	Percentage Error Analysis						Suitable Method	The best prediction method
				EVDM	EHDM	EIDM	IVDM	IHDM	IIDM		
Asymmetric(A)	1.50	3.33	0.188-0.512	4.30	7.00	2.60	6.20	9.30	14.60	EIDM	EIDM
Symmetric(A)	1.80	5.26	0.05-0.51	9.34	11.50	12.10	12.50	26.50	31.80	EVDM,EHDM	EVDM
Asymmetric(B)	3.00	1.66	0.26-0.562	6.10	6.10	5.70	8.30	3.90	4.90	IIDM,IHDM	IHDM
Symmetric(B)	3.66	1.00	0.12-0.46	2.30	2.60	1.40	7.50	7.30	10.90	EVDM,EHDM	EVDM

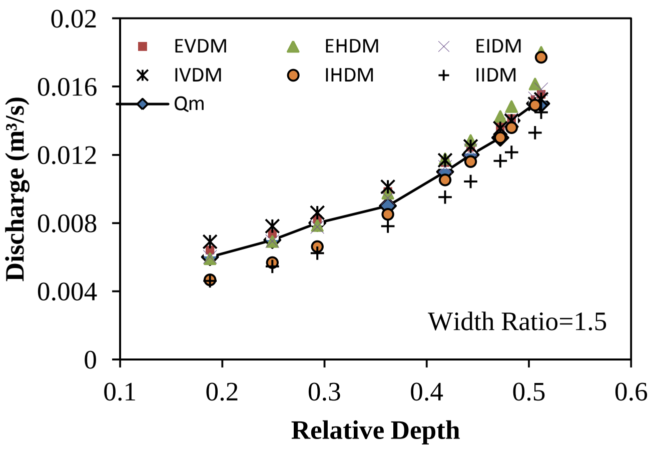

Fig 3.Comparison of methods in Asymmetric channel

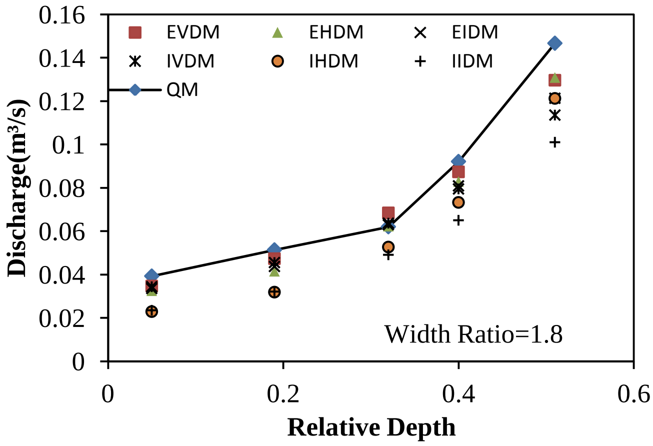

Fig 4.Comparison of methods in Symmetric channel

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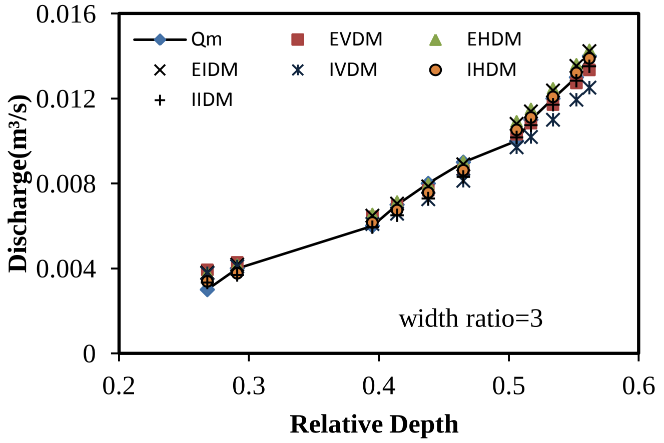

Fig 5.Comparison of methods in Asymmetric channel

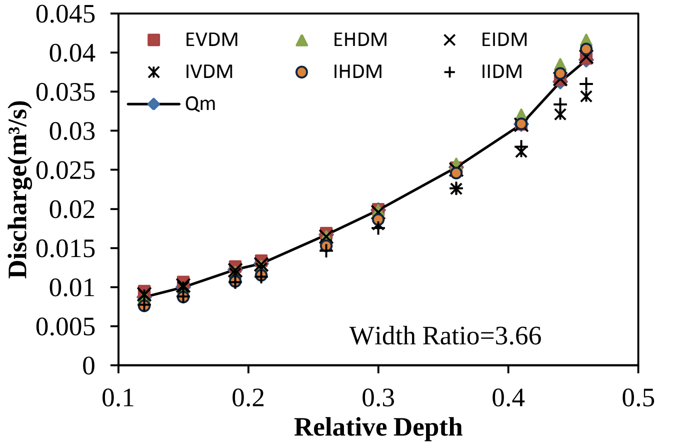

Fig 6.Comparison of methods in Symmetric channel

VI. CONCLUSION

Experimental data sets have been taken to study the effect of flow variables in symmetric and asymmetric compound channels. In this study, four series of laboratory experiments with different width ratio were considered for analysis. Flow characteristics in each standard model were observed and corresponding error analysis is done for a wide range ofdischarge. From the error analysis of the results, it was observed that selected methods should be used to estimate discharges. One should keep in mind that for the specified range of relative value (h/ H) value this best predicted method should be applied accurately. The best calculation methods with the validity ranges of h/H ratios for different channel geometries are given in Table II. It is seen that for asymmetrical case both excluded and included methods predicts the flow well where as for symmetrical cases excluded methods should be preferable.

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