Prediction of mixing layer in symmetric and asymmetric compound channels

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ABSTRACT: It is technically exigent task to solve depth integrated Navier Stokes equation for finding out the depth averaged velocity and boundary shear distribution in a compound channel with symmetric and asymmetric flood plains.Due to complexity of the flow structure at junction of main channel and flood plain, there is a certain level of uncertainty to predict the accurate depth averaged velocity and boundary shear distribution exceptionally at the shear layer region, appearing near the junctions due to enormous turbulence. Experiments have been conducted to study the dependence of shear layer width with independent geometric and hydraulic parameters. As the shear layer width is directly depend upon the mean velocity ratios of the sub sections therefore an effort has been made to develop reliable expressions to predict the mean velocity ratios for both symmetric and asymmetric compound channels. Through multi linear regression analysis, generalised expressions for enumerating the quantification of shear layer width of compound channels of homogenous roughness are presented. The depth integrated Navier Stokes equation can be refined for predicting the variables in the shear layer region.

1 INTRODUCTION

Modeling the overbank flows of water that inundates the adjoining area over flood plain is an onerous task due to the position and strength of the several numbers of longitudinal secondary flow cells. The maximum level of flood depends on flow rate and resistance to flow exerted by bed friction and other loss mechanisms (Ervine et.al. 2000).Due to the distinctive shape of the cross sectional geometry and diverse roughness distribution, the secondary flow cells are controlled (Knight 2007) (Figure.1). The friction factor can be obtained from Darcy-Weisbach formula which renders a single value for main channel and another single value for the flood plain depending upon relative depth and bottom roughness (Fernandes 2014).The gradient of velocity between the flows of flood plain and main channel creates large scale turbulent structures at the junction (Sellin 1964). Thus for high stage flow, understanding the level of turbulence at junction of main channel and flood plain is crucial to success in predicting the flow parameters of that location. Many researchers stated that secondary flows vary from compartment to compartment of a compound channel which depend upon bottom roughness (Fernandes 2014) and the variability of lateral flow depths. Depending on the flow depth, one or two longitudinal vortices may also be developed near the junction of main channel and flood plain due to the turbulence anisotropy originated at the fixed boundary and the interface (Tominaga 1991).The two vertical structures constitute a complex 3D flow structure at the junction where momentum transfer between the main channel and the flood plain can easily be identified (e.g., Nezu, Nakayam 1997). There are quasi 2D models or depth integrated model proposed by various researchers e.g., SKM model by Shiono& Knight (1988 & 1990); LDM model by Wark et al (1990), model of Ervine et al (2000) and EDM model of Bousumar and Zech (2002). Most of the models are used in flow computation considering the 2-D flow effects needing the calibration coefficients which depend on the experimental and field observations. In forward step, even an advanced Reynolds depth averaged turbulence model cannot consider and reproduce the plan form vorticity, as it is primarily excluded from RANS equation (Knight 2007). Further these models are found to give unsatisfactory results of flow predictions near the shear layer regions. Therefore, there is a need of a model comprising expressions for evaluating and quantifying the shear layer width where modifications to any numerical model for evaluating the flow parameters can be implemented with an acceptable accuracy.

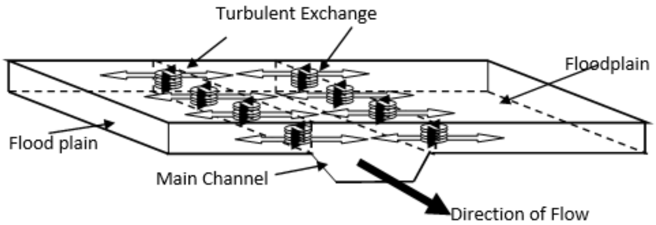


Figure.1 Schematic view of momentum transfer between main channel and floodplain of a symmetrical compound channel

2 THEORETICAL CONSIDERATIONS

A shear layer in a compound channel can be described as a mixing layer at the junction where two horizontal orthogonal dimensions of flow are much larger than the third dimension of flow (Van Prooijen et.al 2005).In a shallow depth of flow, this layer becomes more active in the determination of depth averaged velocity and boundary shear stress. Although shear is present in between two parallel layers of flow in vertical direction, from research point of view the main focus can be on large gradient of shear in the transition region. This layer extends both towards floodplain zone and main channel zone. The extent of this layer somewhat also scales with size of macro vortices and accurate quantification of its magnitude under a variety of geometry (aspect ratio $\delta'$and width ratio α) and flow conditions (relative depthβ) needs to be investigated. Where,δ' is the ratio of main channel bottom width to bank full depth,α is the ratio of total width of compound channel to the bottom width of main channel andβ is the ratio of flow depth over flood plain to the total depth of water over main channel. Some investigators defined the shear layer width and it's nature in different way Approaches for finding the shear layer width are based on the assumption of plain mixing layer along with some modifications to take into account the effect of uneven bottom and the finite width of the flow section. A sketch of half cross section of a symmetrical compound channel with lateral profile of depth averaged velocity showing the mixing layer region is graphically represented in Figure2.

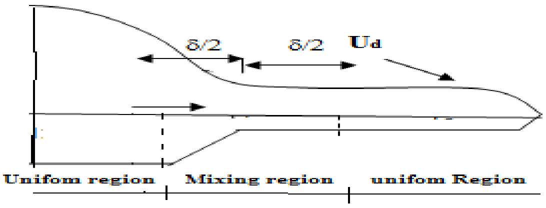


Figure.2. Sketch of half cross section of compound channel with lateral depth average velocity

According to Van prooijen et al (2005) the width of mixing layer is quantified as twice the distance between the position $y_{25\%}$ and $y_{75\%}$ (Figure 1). Where $y_{25\%}$ is the lateral distance corresponding to $U_{(25\%)}$ and $y_{75\%}$ is the distance corresponding to$U_{(75\%)}$.

Again

$$U_{(25\%)} = U_f + 0.25(U_c - U_f) \qquad (1)$$

$$U_{(75\%)} = U_f + 0.75(U_c - U_f) \qquad (2)$$

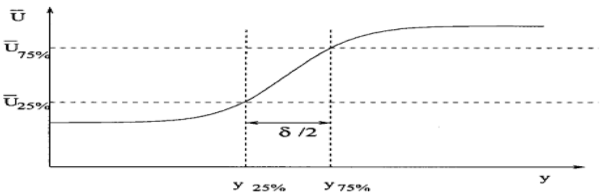


Figure 3. Definition sketch for determination of width of mixing layer (Van Prooijen et al, 2005)

So the shear layer width is determined as twice the distance between the position of$U_{(25\%)}$and$U_{(75\%)}$. Where U_c and U_f are defined as depth averaged mean velocities in the main channel and floodplain far from mixing region respectively. In this region the momentum exchange takes place due to the movement and contribution of horizontal coherent structure. Flow distribution is mainly influenced by the shear layer generation due to the interaction between main channel and flood plains. This shear layer width is an important parameter which needs to be modelled properly so that the depth averaged velocity distribution and boundary shear distribution in this regions can be improved. Many advance softwares like CES, LDM provide error in estimating depth averaged velocity distribution and boundary shear distribution in these regions. To predict the shear layer width of both symmetric and asymmetric compound channel equation 1 and 2 can be used in the depth averaged velocity distribution plots of compound channels of different flow and geometry conditions. FCF and NITR channels are providing a series of compound channels having ranges of width ratio and flow depths. Far from mixing region Depth averaged mean velocities in the main channel(U_c) and in the floodplain(U_f) are found approximately equal to the respective mean velocities in the subsections. So in the present analysis this assumption has been considered. Flow resistance due to momentum transfer and asymmetricity in flood plain geometry and other factors are responsible for unequallity in velocity or flow distributions in the subsections. The flow distributions do not linearly vary with the corresponding sub sectional areas. In smooth compound channel Myer 1987 and Khatua et.al 2009 have shown that the carrying capacity of the main channel and floodplain subsectionsare functions of geometry and flow conditions only i.e.,Q_{mc}or $Q_{fc} = \mathrm{F}(\alpha, \beta)$.Knight and Demetrious (1983) for their straight channel data have presented an empirical equation for flow carried by the main channel$\%Q_{mc}$separated by vertical interface plane of a compound section as

$$\%Q_{mc} = \left[\frac{100}{\{(\alpha-1)\beta+1\}}\right] + 108\left[\frac{\alpha-1}{\alpha}\right]^{\frac{1}{4}}[3.3\beta]^{\frac{4}{\alpha}}e^{-9.9\beta} \qquad (3a)$$

Khatuaand Patra(2009) developed a generalised equation for $\%Q_{mc}$for width ratio up to 4.0 as

$$\%Q_{mc} = 1.2338\left[\frac{100}{\{(\alpha-1)\beta+1\}}\right]^{0.9643} \qquad (3b)$$

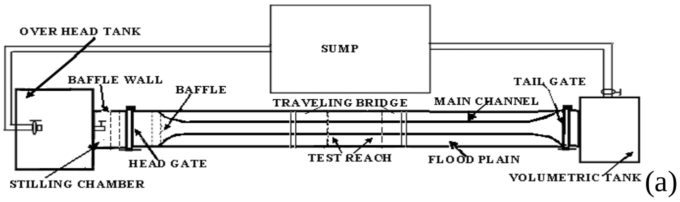
Mohanty and Khatua (2014) developed equation to predict the sub sectional flow using the expression of average velocity in the subsections for width ratio up to 12and provided expressions

$$U_{mc} = \sqrt{\frac{\%S_{mc}gAS}{12.5P_{mc}f_{mc}}} \text{ and } U_{fp} = \sqrt{\frac{\%S_{fp}gAS}{12.5P_{fp}f_{fp}}} \qquad (3c)$$

Then percentage of flow carried by the main channel $(\%Q_{mc})$and percentage of flow carried by the flood plain $(\%Q_{fp})$ can be evaluated by multiplying the corresponding area and taking the percentage from total discharge. These equations are meant for smooth and symmetrical or unsymmetrical compound channels for some specific ranges of width ratios. For an asymmetrical compound channels there is more complex flow phenomenon as compared to symmetrical compound channel. The previous equations (3a, b, c) do not follow properly for asymmetrical flood plain and symmetrical flood plain cases with higher width ratio. So there is need to improve the equations and to form generalized expressions for higher ranges of width ratio i.e., 15.75 for symmetrical and 5.1 for asymmetrical compound channels. For the present analysis a step has been taken to develop suitable expressions to predict sub sectional mean velocities U_c and U_f for both symmetrical and asymmetrical compound channels.

3 EXPERIMENTAL INVESTIGATION

In this present work to find the magnitude of shear layer width of symmetric and asymmetric compound channels and to study it’s variation with its geometrical and hydraulic parameters, experimentations have been conducted inthree combinations of asymmetric compound channels at the hydraulic engineering laboratory of National Institute of Technology, Rourkela, India. The asymmetric compound channels are having one flood plain at right side of it making the total width of the compound section 168, 145, 120respectively creating 3 different width ratios. The main channels are trapezoidal in cross section with 1:1 side slope having 33cm bottom width and 11cm at bank full depth. The longitudinal bed slope of the channel is found to be 0.001. The roughness of the flood plain and main channel are kept same and estimated to be 0.01. The experiments have been carried out in a glass flume made up of MS bars, plates and angles, fitted with all accessories. Water was supplied through three numbers of centrifugal pumps (each 15 hp capacity) discharging into a large RCC overhead tank. The water is made to flow to the stilling tank of flume from the overhead tank by regulating valves. Baffle walls arrangement have been made inside the stilling basin to reduce the turbulence. Water is made to flow under gravity from the head gate end to the tail gate of the flume. At the downstream end there is a measuring volumetric tank followed by a large underground sump which feed the water to the overhead tank through pumping. This is an arrangement of complete recirculation system of water for the experimental channels.



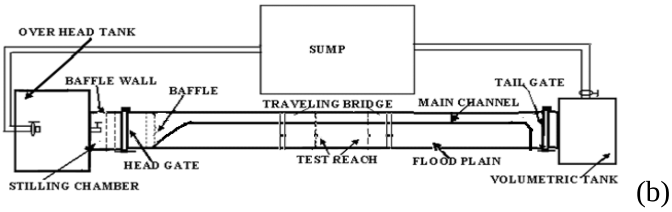


Figure 4. (a and b) Plan view of experimental set up of the NITR symmetric and asymmetric channel

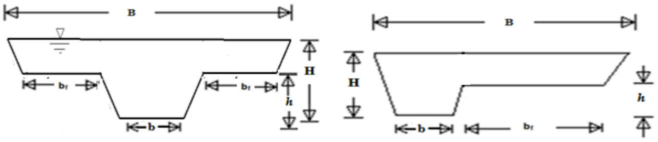


Figure 5. Sectional view of experimental symmetric and asymmetric compound channels

Figure 6.Photo of symmetric and asymmetric compound Channels fitted with instruments (NITR Series)

Figure4 shows the plan view of experimental sections of the symmetric and asymmetric channels with flood plains and Figure.5shows the sectional view of experimental channels. Figure 6 shows Photos of compound Channels fitted with instruments. Velocity measurements have been performed by the three probes Micro-ADV which uses the Doppler shift principle to measure the velocity of small particles, assuming that the velocity is same as that of velocity of fluid. There are some remaining points in the flow cross section to be measured for which a standard Prandtl type Micro-Pitot tube in conjunction with a manometer of accuracy 0.12 mm is used for measuring the point velocity at the desired locations. Further, the asymmetrical data set of large channel facility channel, UK is added with present experimental data sets for the analysis.

Table.1 Geometrical and flow parameters of the symmetrical compound channels

Test channel	Cross sectional geometry	Total channel width (B)in m	Main channel width (*b*)in m	Bank Slope (n)	Main channel depth (*h*)in m	Longitudinal slope (*S*)	Width Ratio(α)	Aspect Ratio(β)
FCF-series1	Trapezoidal	10.005	1.5	01:01	0.15	0.001027	6.67	10
FCF-series2	Trapezoidal	6.3	1.5	01:01	0.15	0.001027	4.2	10
FCF-series3	Trapezoidal	3.3	1.5	01:01	0.15	0.001027	2.2	10
FCF-series8	Rectangular	6	1.5	_	0.15	0.001027	4	10
NITR1	Trapezoidal	3.95	0.33	01:01	0.065	0.0011	11.97	5.07

NITR2	Rectangular	0.44	0.12	_	0.12	0.0019	3.67	1
NITR3	Trapezoidal	1.89	0.12	01:01	0.08	0.00311	15.75	1.5
K & D1	Rectangular	0.304	0.152	_	0.076	0.000966	2	2
K & D2	Rectangular	0.456	0.152	_	0.076	0.000966	3	2
K & D3	Rectangular	0.61	0.152	_	0.076	0.000966	4	2

Table.2 Geometrical and flow parameters of the Asymmetrical compound channels

Test channel	Cross sectional geometry	Total channel width (B)in m	Main channel width (b)in m	Bank Slope	Main channel depth (h)in m	Longitudinal slope (S)	Width Ratio(α)	Aspect Ratio (β)
FCF 6	Trapezoidal	4.05	1.50	01:01	0.15	0.001027	2.70	10
NITR (Asym)1	Trapezoidal	1.68	0.33	01:01	0.11	0.001	5.09	3
NITR (Asym)2	Trapezoidal	1.45	0.33	01:01	0.11	0.001	4.40	3
NITR (Asym)3	Trapezoidal	1.20	0.33	01:01	0.11	0.001	3.65	3

For analysis of symmetrical compound channel, 3nos of experimental data sets from NITR, India, 4 nosof large channel facility channel, UK data and 3nos of data sets from Knight and Demetriou (1983) have been considered. The depth averaged velocity data from point to points along the wetted perimeter of both symmetric and asymmetric compound channels have been acquired experimentally to study the variation of shear layer width with different geometrical and hydraulic conditions.

4 RESULT AND DISCUSSIONS

4.1 *Assessment of Discharge Distribution*

The carrying capacity of main channel, flood plain subsection and the total carrying capacity of the compound channels are the functions of channel geometry only (Myer, 1999) and (Khatua, 2009). The ratio of carrying capacities of main channel or floodplain subsection to the total is proportional to the dimensionless channel geometry only. In a compound channel, the two significant dimensionless channel geometries are width ratio (α) and relative depth (β) which influence the flow variables. For a compound channel with homogenous surfaces under uniform conditions, the percentages of flow in main channel can be written as;

$$\%Q_{mc} = \emptyset(\alpha,\beta) \tag{4}$$

Many investigators have expressed the flow distribution expressions as a function of α and βwhich have already been demonstrated through Equation3. They have utilised a short ranges of data sets in developing these models which are generally relevant for symmetrical compound channels and provide sizeable errors for all flow depths of compound channel with asymmetrical flood plain of large flood channel facility data sets (i.e., FCF 6) owing to its difference in geometry .For establishing better predicting models applicable for larger width ratio for symmetrical and asymmetrical channel, wide ranges of data sets have been employed. So experiments have been performed on channels with asymmetric flood plains of different width ratio (α=5.1, 4.4 and 3.6). For better predictability of the flow distribution model, large Flood Channel Facility data sets, Knight and Demetriou (1983), Khatua&Patra (2009) and Mohanty and Khatua (2014) have been utilised as provided in Table1. The variation of $\%Q_{mc}$with percentage area of main channel $\%A_{mc}$ have been plotted for all flow depths of this channels asdemonstrated in Figure 7. The best fit betweenQ_{mc} and $A_{mc}$for present models follow power relationship when the percentage flow in main channel $(\%Q_{mc})$ are expressed as function of percentage area of main channel$(\%A_{mc})$. The equation for $\%Q_{mc}$for symmetricalcompound channels with high regression coefficient (0.94)are demonstrated by the following equation

$$\%Q_{mc} = 1.715\{\%A_{mc}\}^{0.9} \tag{5a}$$

$$\%Q_{mc} = 1.715\left\{\frac{100\delta^{*}\left(\delta^{'}+n+n\beta\right)}{\delta^{*}\left(\delta^{'}+n\right)+n\beta\left(\delta^{'}-2\delta^{*}\right)+\delta^{*}\delta^{'}\beta(\alpha-1)}\right\}^{0.9} \tag{5b}$$

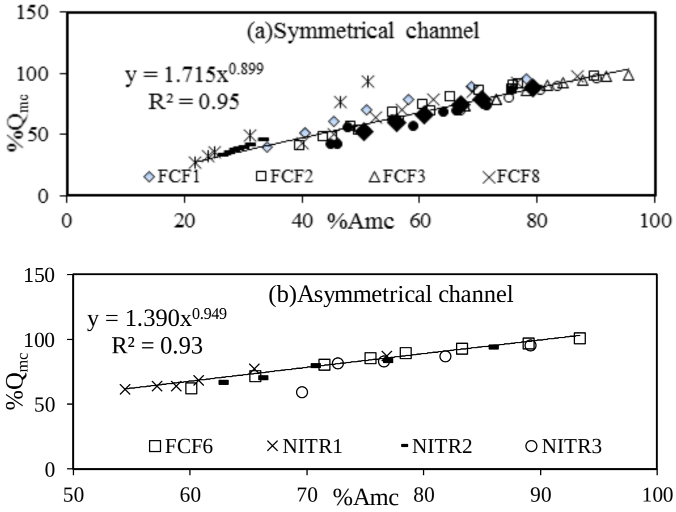


Figure7.Variation of$\%Q_{mc}$ with $\%A_{mc}$for (a) Symmetrical compound channel (b) Asymmetrical compound channel

Similarly, the dependency of $\%Q_{mc}$of asymmetrical compound channels with their area ratio$\%A_{mc}$have been found to be power function and modelled as

$$\%Q_{mc} = 1.4\left\{\frac{100\{\delta'(\delta^{*}+n)-0.5n\beta(\delta'-\delta^{*})\}}{\delta'(\delta^{*}+n)+\beta\delta^{*}(\alpha\delta'-\delta'-2n)}\right\}^{0.95} \tag{6}$$

Where α=width ratio(B/b), β =relative depth$((H-h)/H)\delta^{*}$=flow aspect ratio(b/H), δ' is the aspect ratio of main channel(b/h), b= bottom width of the main channel, h= maximum height of the main channel and n is the value of side slope of the trapezoidal main channel and flood plain $(1{:}\,n{::}V{:}\,H)$.

4.2 *Evaluation of Shear layer Width*

Previously, the complex mechanism of momentum transfer at the junction of a compound channel has been noticed by many researchers and analysed the horizontal coherent structure in both laboratory and field study. The experimental evidence of occurrence of such structures in the transition region is shown in Figure8 (a, b).

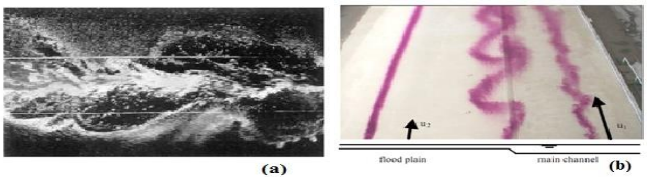
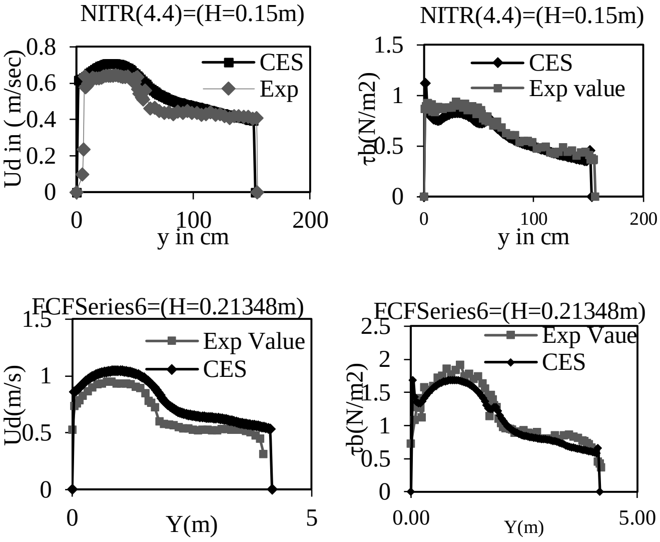


Figure 8 (a). Macro vortices in transition region (b) large coherent structures in mixing layer made visible by dye injection (Van Prooijen.2005)

Shear layer in a compound channel has been usually analyzed as a plane of mixing layer in a shallow flow. This shear layer width extends both towards floodplain zone and main channel zone. Most popular models in determination of stage discharge relationship for compound channel flows are quasi 2D models or depth integrated models (SKM model, Shiono& Knight, 1988& 1990; LDM model,Wark et al,1990; Model of Ervine et al,2000; EDM model of Bousumar&Zech, 2002). Accurate estimation of shear layer width can suggest possible modification of these models. The extent of this layer somewhat also scales with size of macro vortices and accurate quantification of its magnitude under a variety of geometry (width ratio)and flow conditions (relative depth) is a matter of investigation .In the present work an attempt has been made to estimate the shear layer width of a compound channel for both symmetric and asymmetric flood plain cases. Depth averaged velocity distribution for all experimental channels (Figure 9) along the lateral direction(y) are analysed to estimate the shear layer width using equation 1 and 2.



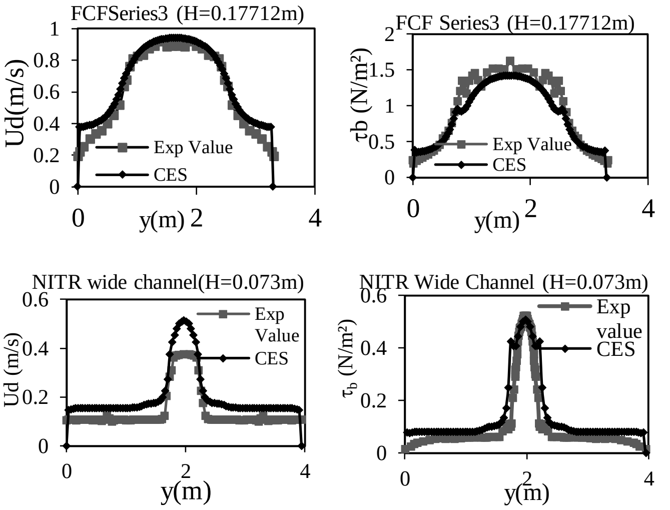


Figure 9. Depth averaged velocity distribution Measurements for symmetric and Asymmetric compound channel

The measured shear layer width (δ) is normalised by dividing total depth of flow (H).The variation of $\left(\frac{\delta}{H}\right)$with relative depth(β) and width ratio (α) for symmetrical flood plain cases are depicted in Figure 10(a) and (b).The best functional relationships indicate exponential function and in form of $\frac{\delta}{H} = Ae^{B\beta}$and $\frac{\delta}{H} = Ce^{D\alpha}$. As it can be seen from both the figures, the general trend of $\left(\frac{\delta}{H}\right)$ for different (β) and $(\alpha)$are similar in nature of falling with increase in relative flow depth and width ratio, that means there is a clear bulging of shear layer width towards the shallow depth of flow and small width ratios would be expected. It is a characteristic of compound channel flow where intense exchange of momentum occurs particularly in shallow depth as compared to the deep flow. It is obvious that the shear layer width is strongly correlated with α and β. The analysis is also done for asymmetric compound channels as presented in Figure11 (a) and (b) for independent (β) and(α) values respectively. The highest possible coefficient (R^2) of best fit curves have been generated for all the channels and for all flow depths using the program provided in Microsoft Excel. For asymmetric channels the best fit curves have been generated as power function represented by $\frac{\delta}{H} = E\beta^F$and $\frac{\delta}{H} = G\alpha^H$ where *A, B, C, D, E, F, G, H*are coefficient. The values of these regression coefficients (R^2) as presented in Figures 10-13 are generally high ranging greater than 0.93. Single variable models have been developed considering the values of $\left(\frac{\delta}{H}\right)$ as dependent on the non-dimensional mean velocity ratios $\left(\frac{U_c-U_f}{U_c}\right)$for different asymmetric compound section configurations as demonstrated by previous researchers. Reverse trends of ascending have been noticed when plotted against the independent parametersβ andα. It is clearly seen that no single trend of $\frac{\delta}{H}$ is observed for all values of$\left(\frac{U_c-U_f}{U_c}\right)$. But the variations of $\left(\frac{\delta}{H}\right)$ with $\left(\frac{U_c-U_f}{U_c}\right)$have been found out dissimilar for different configurations. As the variation is different for different width ratios, soregression analysis have been attempted for symmetric compound channel to develop multi variable model depending upon both $\frac{U_c-U_f}{U_c}$ and α with high regression coefficient more than 0.90 (equation 7a). Also for asymmetric compound sections, a generalised multi variable regression model has been attempted showing the dependency of non-dimensional shear layer width$\frac{\delta}{H}$ with non-dimensional mean velocity ratio $\frac{U_c-U_f}{U_c}$and with width ratio α with high regression coefficient of 0.96 (equation 7b).

$$\frac{\delta}{H} = -1.63 + 0.8526e^{2.143\frac{U_c-U_f}{U_c}} + 36.228e^{-1.05\alpha} \qquad (7a)$$

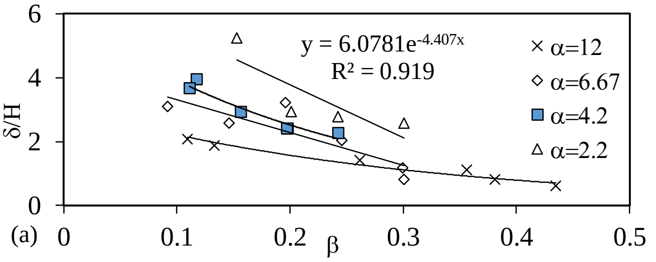
$$\frac{\delta}{H} = -0.7 + 0.1752e^{2.936\frac{U_c-U_f}{U_c}} + 3.7386e^{-0.09\alpha} \qquad (7b)$$

For a given channel dimensions and flow depth, shear layer width (δ) can be estimated using equation 7 if the value of $\frac{U_f}{U_c}$ can accurately be predicted. This Shear layer width shows the ability to reproduce the proper length of shear layer region at junction which is mainly depending upon the mean velocity ratios of the subsections. For a given flow depth and geometry of a compound channel, the mean velocity ratios between the flood plain and main channel of both symmetrical and asymmetrical cross sections respectively have been modelled as

$$\frac{U_f}{U_c} = \left[\frac{100}{\%Q_{mc}} - 1\right] * \frac{\delta^*(\delta'+n+\beta)}{\beta\left(\alpha\delta'\delta^* - \delta'\delta^* - 3n\delta^* + n\delta'\right)} \qquad (8a)$$

$$\frac{U_f}{U_c} = \left[\frac{100}{\%Q_{mc}} - 1\right] * \frac{\{\delta'(\delta^*+n) - 0.5n\beta(\delta'-\delta^*)\}}{\beta\delta^*(\alpha\delta'-\delta'-2n) + 0.5n\beta(\delta'-\delta^*)} \qquad (8b)$$

These expressions are helpful to evaluate the mean velocity ratios of the subsections which in terms help to predict the shear layer width of a compound channel. Advanced numerical model like SKM and LDM can be improved in shear layer region of compound channel to refine depth averaged and boundary shear distribution results to incorporate the eddy viscosity and intense turbulence effects.



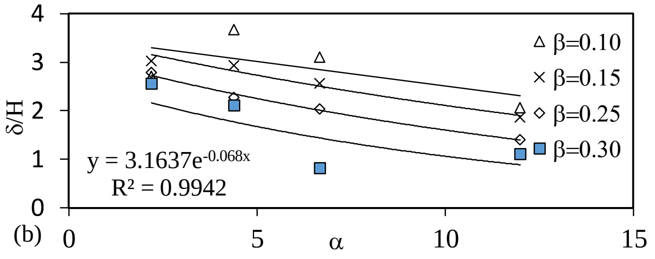


Figure10 (a and b).Variation of $\frac{\delta}{H}$withβ and with α (Symmetrical compound channel)

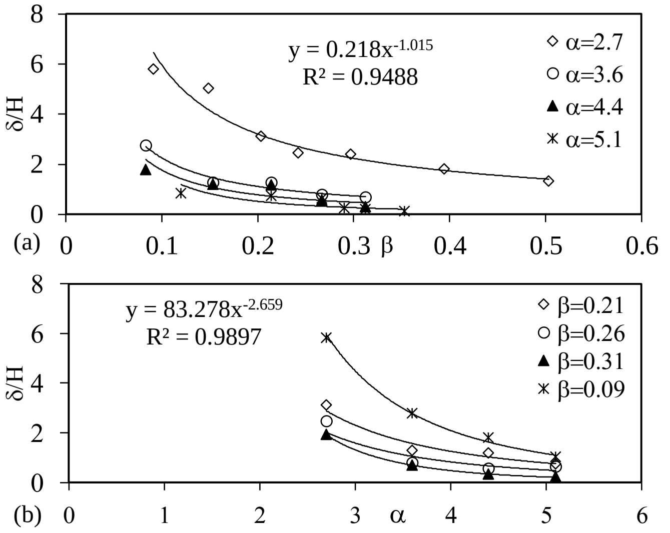


Figure 11 (a and b).Variation of $\frac{\delta}{H}$with α and β (asymmetrical compound channel)

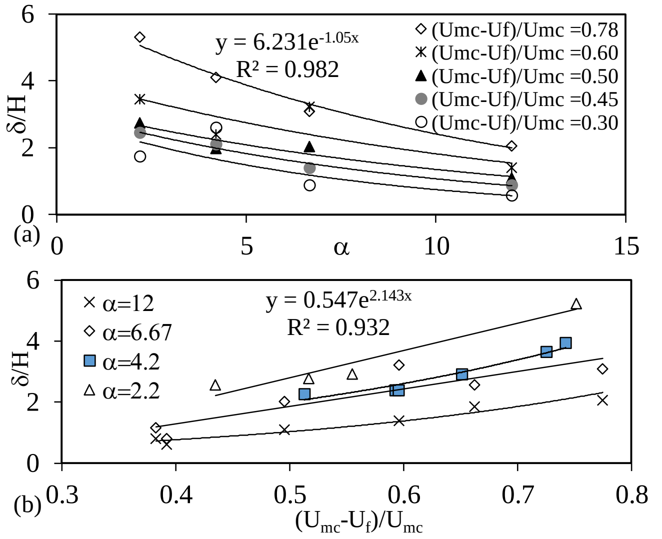
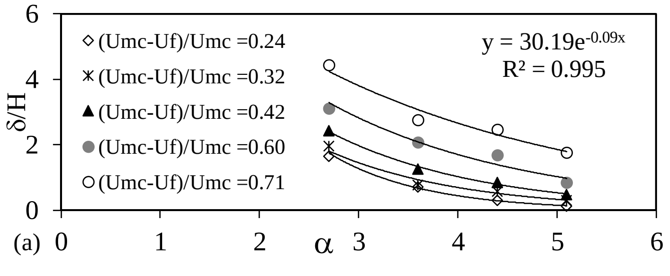


Figure12(a and b).Variation of $\frac{\delta}{H}$ with α and relative mean flow velocity (Umc-Uf)/Umc(Symmetrical compound channel)



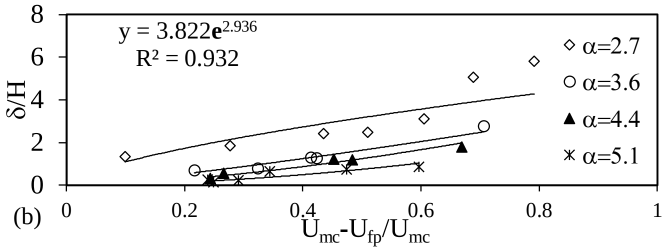


Figure 13(a and b).Variation of (δ/H) with α and relative mean flow velocity $(U_{mc}-U_f)/U_{mc}$(asymmetrical compound channel)

5 VALIDATION OF THE RESULTS

The present work can be divided into two parts. First one investigation on flow distribution of a compound channel and the second one examines the evaluation of its shear layer width for both symmetric and asymmetric flood plains. The strength of the developed flow distribution equations have been verified with the present experimental channels, FCF channels and channels of other investigators. Figure 14 (a and b) shows the scatter diagram for measured and predicted percentage main channel discharge $(\%Q_{mc})$ both for symmetrical and asymmetrical compound channels. For comparingthe strength ofpresent model, three standard approaches were applied to compute the percentage for flow on main channel$(\%Q_{mc})$. The present expressions for$\%Q_{mc}$have been found to well matching with the measured value as compared to the other models. It can be clearly observed from the Figure14 (a) that all the models suitably prophesy the percentage flow in main channel for symmetrical cases with minimum errors. However for asymmetrical channels, all the three models are providing poor distribution of flow in main channel as compared to present expression. Figure 15 provides the distribution of errors of all the method s in terms of mean absolute percentage errors given by the equation 9.

$$\text{MAPE} = \frac{1}{n}\sum 100\frac{|computed-mesured|}{mesured} \qquad (9)$$

From Figure 15, it can be noticed that the model of Mohanty and Khatua (2014) provides less errors as compared to the Knight and Demetriou (1983) and Khatua and Patra (2009) models. Also it can be well examined that the models of Mohanty and Khatua (2014) over estimates the distribution in asymmetrical channels and other two models are under estimating from the observed values for both types of the compound cross sections. However the present model provides the minimum error as compared to all the approaches. In the next part of the work, the shear layer width can be predicted using the expression 7. Figure 16 provides the scatter diagram of the predicted shear layer width verses measured shear layer width for both symmetrical and asymmetrical compound channel case showing the efficacy of the present models.

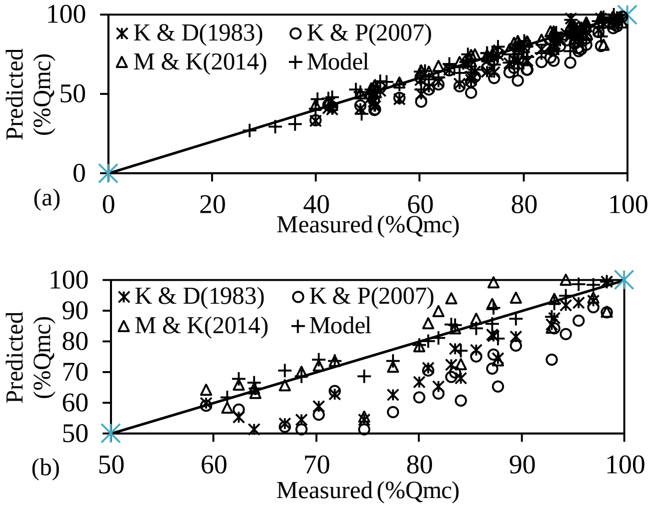


Figure14. Scatter Diagram for Measured and Predicted percentage Main channel Discharge for (a) symmetrical compound channels (b) asymmetrical compound channels

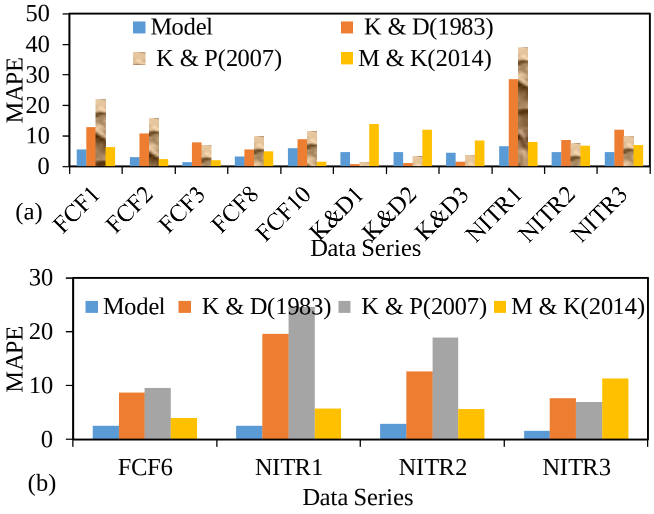


Figure15. Mean absolute percentage error in flow prediction in main channel subsections for (a) symmetrical compound channels (b) asymmetrical compound channels

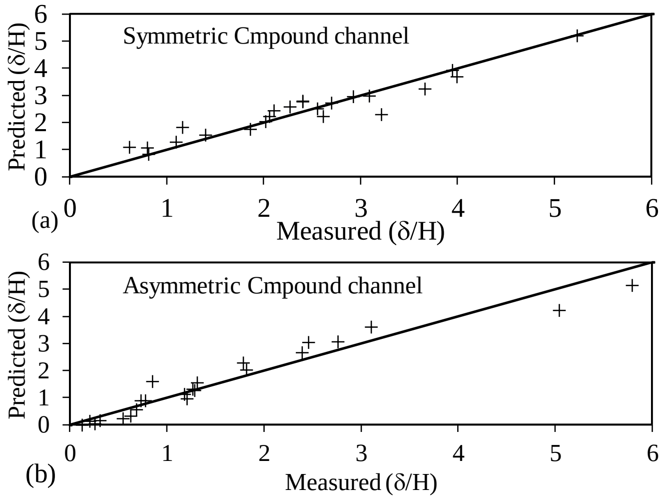


Figure16. Scatter Diagram for Measured and Predicted normalized shear layer width for (a) symmetrical compound channels (b) asymmetrical compound channels

6 CONCLUSIONS AND FUTURE WORK

1. An experimental investigation concerning the depth averaged velocity, boundary shear stress and flow distribution in three asymmetric compound channels has been done to study the variation and impact of this structure in flow modelling.The exchange of momentum creates large gradients of depth averaged velocity near junction of main river channel and its adjoining flood plains creating a shear layer width. The magnitude of shear layer width are found to depend on flow distribution between these subsections.
2. Depending upon the non-dimensional parameters, expressions for estimating the precise flow distribution in main channel have been developed for both symmetrical and asymmetrical compound channelswhich directly help to estimate the shear layer width.The model of Mohanty and Khatua (2014) over estimates the percentage of flow in main channel particularly in asymmetrical channel.
3. Advanced numerical model like SKM and LDM provides deficient results for depth averaged and boundary shear distribution in shear layer region of compound channel. This is because of role of intense turbulence near the junction of the subsections. The shear layer width has been found to be influenced by mean velocity distribution of a compound channel and width ratio resulting from the non-dimensional parameters..
4. A multi linear analysis is applied to derive empirical equations to predict shear layer widths in both symmetrical (forα up to 12 and β up to 0.5) and asymmetric compound channels(α up to 5.1 and β up to 0.51).It can be stated that the new model will be helpful for improvement of the depth averaged velocity and boundary shear stress distribution of shear layer width.
5. Because of the simplicity of the present model to implement, their utilisationfor successfully quantifying the shear layer width should be assessed in any compound section configuration. Improvements to the models can be made by incorporating more datasets on differential roughness in the main channel and flood plain.

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