Interfacial compound section transverse flow variation in symmetric and asymmetric compound open channel flow

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Abstract

An experimental analysis of symmetrical and asymmetrical channels is considered over three depth ratios varying from small to large. In this study, shear stress contributes to Reynolds stress and spanwise advection due to transverse current are experimentally explored.

Keywords: Reynold shear stress; secondary currents, compound open channels

Introduction

Apparent shear is a measure of the net effect of viscous shear, turbulence together with the action of vortices induced between main-channel and floodplain(s) (Singh and Tang, 2020a, b). Two components of large-scale motions, namely advective dispersion ($\boldsymbol{\rho}(\overline{\boldsymbol{u_x u_y}})$ and the transverse current ($\overline{\boldsymbol{\tau_{yx}}}$), where $\boldsymbol{\rho}$ is the density of fluid and $\overline{\boldsymbol{u_x u_y}}$ is the time-averaged product of streamwise and lateral velocities, are key characteristics to measure momentum exchange in any compound channel (Proust and Nikora, 2020). This paper presents a study of uniform flow, which is explored experimentally over two sets of compound channels.

Methods

Six test runs were undertaken (see Table 1), and three-dimensional velocities were measured using side and down-looking Acoustic Doppler velocimeter (ADV). Figure 1 shows the normalized depth-averaged velocity distribution for two cases with an accuracy of $\pm\mathbf{1}$ to $\mathbf{3}\%$ of the measured mean velocities

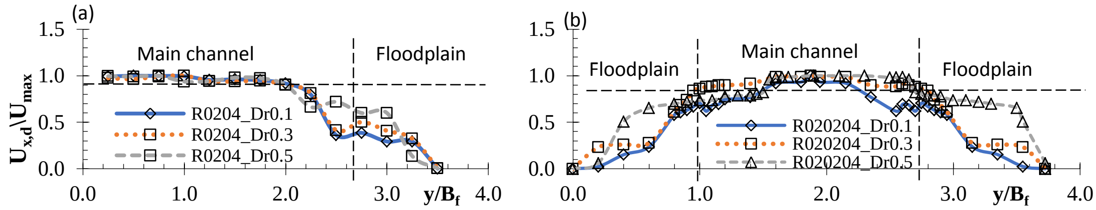

Figure 1. Distribution of normalized depth average velocity using maximum velocity over the cross-section for configurations (a) R0204; (b) R020204.

Table 1. Summary of the flow conditions, where R denotes rectangular, the next numeral signifies floodplain width (20cm), and the last numeral is bankfull height (4cm).

	Case	$\boldsymbol{D_r}$ (H-h/H)	Aspect ratio	Width ratio	Q_t (l/s)	U_{mc} (m/s)	U_{fp} (m/s)	λ
	R204	0.1			16.83	0.4146	0.0978	0.6183
Asymmetric	R204	0.3	13.625	1.4	21.14	0.4564	0.1390	0.5331
	R204	0.5			35.23	0.5208	0.2509	0.3497
	R20204	0.1			5.03	0.2846	0.1133	0.4307
Symmetric	R20204	0.3	8.625	2.2	10.16	0.4449	0.1779	0.4288
	R20204	0.5			20.42	0.5945	0.3046	0.3223

Each point measurement in the cross-sections was taken at an interval of 2.5-5 mm in the vertical direction and an interval of 10 to 50 mm in the lateral direction.

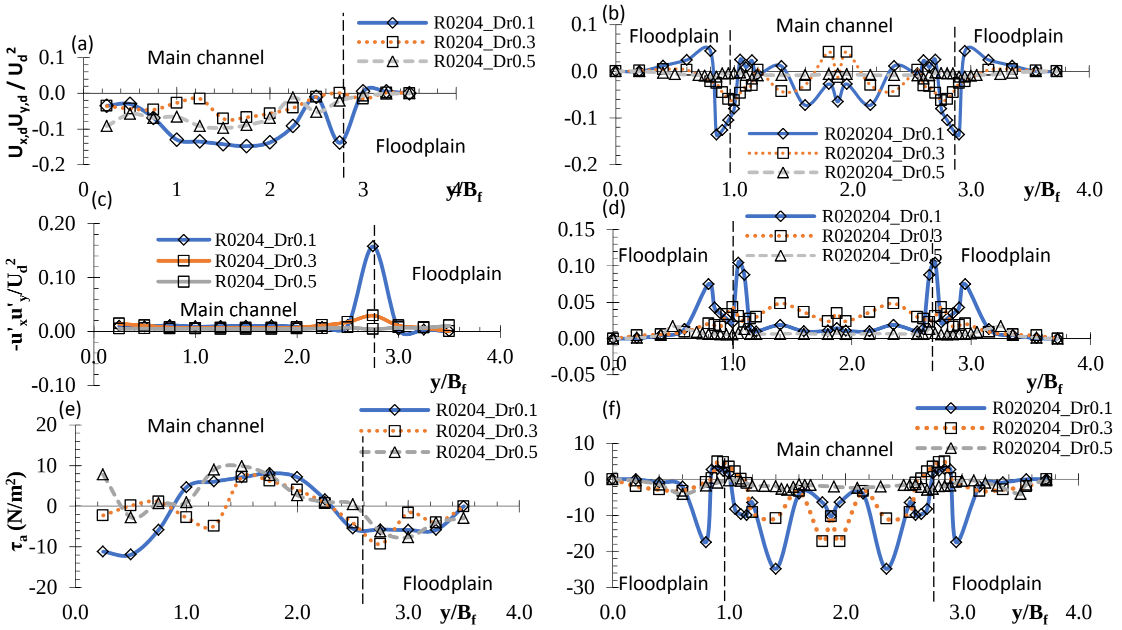

Figure 2. Cross sectional distribution of (a-b) transverse currents (c-d) Reynolds stress ($\overline{-u'_x u'_y}$) & (e-f) apparent shear stress (τa).

Results

The strong anisotropy of the turbulence near the junction is commonly noticed. However, the effect of Reynold shear stress (Fig. 2 a-b) and transverse current (Fig. 2 c-d) in the asymmetric channel with the same floodplain width is higher than that in symmetric channels (see Fig. 2). The apparent shear effect (Fig. 2 e-f) thus catapults in the asymmetric channels with maximum advect momentum transfer near the interface. In addition, dimensionless shear $\boldsymbol{\lambda} = (\boldsymbol{u_{mc}} - \boldsymbol{u_{fp}})/(\boldsymbol{u_{mc}} + \boldsymbol{u_{fp}})$ is higher in the asymmetric channel (R204) than the symmetric channel (R20204) (Table 1). This increase in $\boldsymbol{\lambda}$ is due to an increase in maximum velocity in the main channel of asymmetric channels where geometric difference and proximity of wall resistance exist, which is higher in symmetric channels.

Conclusions

The study of turbulence statistics and normalized mean flow velocity difference shows that the channels having the same floodplain width and bankfull height (h) but having different main channel width (b), behaves differently on Reynold shear stress and transverse current near the interface. The effect of these parameters increases for asymmetric channels than symmetric channels.

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