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EXTENDED ABSTRACT

Experimental Study of the Effects of Skew Angle on Flow Field in Skewed Compound Channels with Inclined Floodplains

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1. Introduction

During a flood, water flows out of the main channel and enters the floodplains. In nature, due to the influence of local topographic conditions, rivers have often irregular and non-prismatic shape. In non-prismatic compound channels, because of the effect of changing in cross-sectional area along the channel, the flow structure is more complex than prismatic compound channels. Therefore, it is important to study the flow characteristics in such channels and it can help researcher to better understand the flow behavior in rivers, especially during floods. In the present study, the flow characteristics in a compound channel with inclined and skew floodplains has been investigated experimentally. The experiments were performed at three relative depths of 0.2, 0.3 and 0.4 and for two skew angles of 11.31° and 3.81°. The water surface profile, lateral distributions of velocity and boundary shear stress along the skew part of the flume have been measured and reported. The results of experiments indicate that the lateral distributions of velocity and boundary shear stress in skewed compound channels with inclined floodplains are non-uniform and asymmetric. Also, the flow velocity and boundary shear stress in diverging floodplain are always higher than its value in converging floodplain. By increasing the skew angle of the floodplains from 3.81 to 11.31 degrees, the boundary shear stress and flow velocity in the main channel and on the floodplains increase.

Each river in the natural world has unique shape. Some gently curve, others meander, some are relatively straight and others become braided. However, one thing can be said for the vast majority, is that they are usually compound i.e. have at least one floodplain with a deeper main channel. Much work has been carried out on compound channels with prismatic and non- prismatic floodplains (Chlebek, 2009). It is believed that James & Brown (1977) were to be the first to carry out experimental research into skewed channels. They tested the effect of skewing the main channel relative to the floodplain for three skew angles of 7.2°, 11.0° and 24.05°. Flow on the diverging floodplain was found to accelerate whereas on the converging floodplain the flow decelerated. Elliott (1990) and Elliott & Sellin (1990) also carried out further works on the skewed compound channels at the Flood Channel Facility (FCF); it was revealed that flow exchange between the skewed floodplains and the main channel had significant effects on the flow characteristics such as the velocity and bed shear stress. Chlebek (2009) managed to conduct some extra experimental studies on a compound channel with skewed floodplains and compared the obtained results with the FCF work of Elliott (1990).

2. Methodology

Experiments were conducted by using an 18-m flume at the Bu-Ali Sina University, Department of Civil Engineering. A compound channel of simple rectangular cross-section with inclined floodplains was selected and all experiments were performed in a straight flume, 18 m long, almost 1,200 mm wide, 600 mm deep, and with the average bed slope of S_0=1.63×10^{-3}. Using PVC material, rigid and smooth boundaries were constructed,

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both for the main channel of 400 mm width and 50 mm depth, as also for the floodplains 400 mm wide with side slope of 1:13.3 (V:H), see Fig. 1. Experiments were performed in skewed compound channels with two skew angle of 11.31° and 3.81° and three relative depth ($D_r = \overline{H_{fp}}/H$, where $\overline{H_{fp}}$ is the average water depth on floodplains and H is the total flow depth) of 0.2, 0.3, and 0.4. Also, as seen in Fig. 1, the main channel and floodplains were isolated using L-shaped iron profiles to make different skew angles of θ. Using a tailgate, the uniform flow in upstream prismatic part of the flume were adjusted.

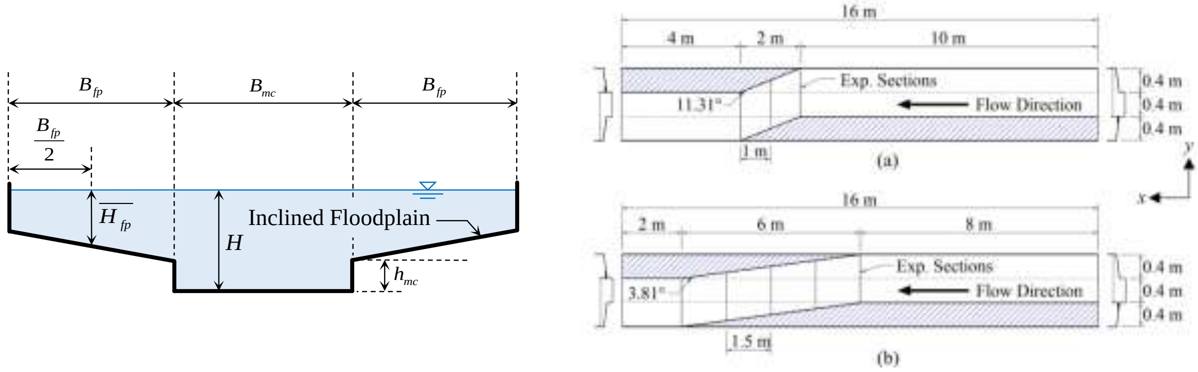


Fig. 1. Plan view and cross-section view of skewed compound channel with inclined floodplain

The velocity distributions were measured across the whole cross-section at selected sections along the skew part of the flume (three section for skew angle of 11.31° and five section for skew angle of 3.81°). For all experiment cases, the local velocities were recorded across the whole cross-section, laterally every 20mm and vertically every 10mm. Also the lateral distributions of boundary shear stress were measured around the wetted perimeter at 10mm vertical and 20mm horizontal interval, using a Preston tube of 4 mm outer diameter at the same sections where the velocity distributions were tested.

3. Results and discussion

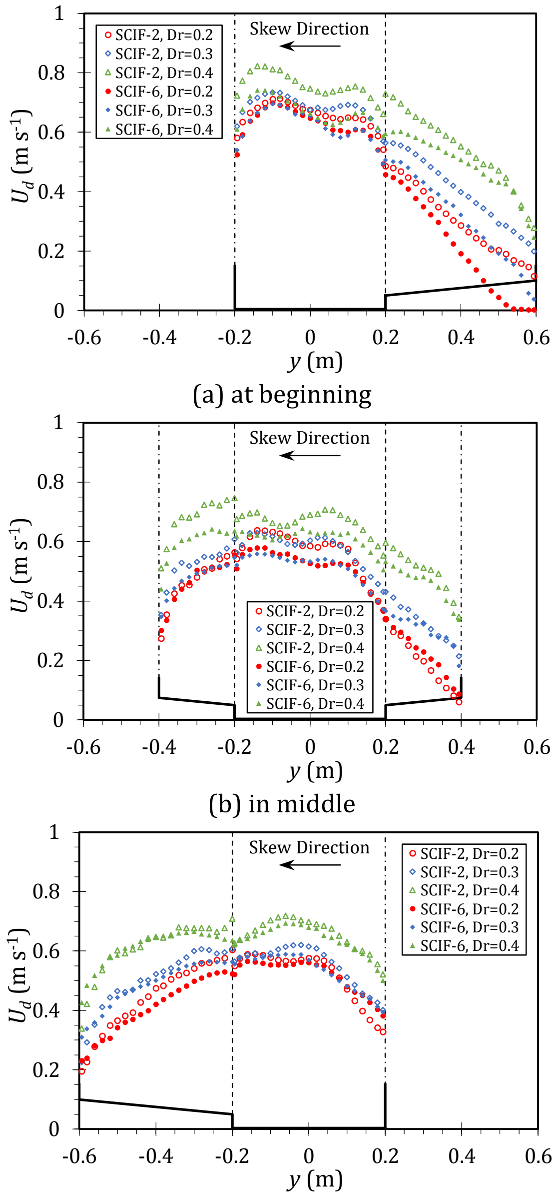
The depth-averaged velocity (U_d) distribution in a cross-section at different experimental sections was calculated by numerical integration of the point velocity measurement over the flow depth (see Eq. (1)).

$$U_d = \frac{1}{h}\sum u_i \, \Delta h_i \tag{1}$$

In which, h is the local flow depth, u_i is the point velocity data, and Δh_i is the height of surrounding subareas. The depth-averaged velocity distribution at three selected sections (at the beginning, in the middle, and at the end of skewed part of the flume) for two skew angles of 11.31° and 3.81° are shown plotted in Fig. 2. From the Fig. 2, it can be seen that the depth-averaged velocity in the diverging floodplain is always bigger than its value in the converging floodplain. In the middle of the skew part of the flume, where the flume cross-section is symmetric, the velocity distributions are asymmetric. Also by increasing the relative depth and skew angle, the depth-averaged velocity along the skewed portion increases and get close to uniform distribution. The boundary shear stress distributions is another task which experimentally have been investigated. The results of measurement at selected sections for two skew angles of 11.31° and 3.81° and three relative depth of 0.2, 0.3, and 0.4 are shown in Fig. 3. From figure 3 it be seen that similar to the depth-averaged velocity, the boundary shear stress distributions are not symmetric at the middle of the skew part of the flume. Also, compared to converging floodplain, the boundary shear stress in diverging floodplain is greater.

4. Conclusions

The velocity and boundary shear stress distributions in compound channels with inclined and skew floodplains for two skew angles of 11.31° and 3.81° were experimentally investigated. The results of experimental measurements indicated that both the depth-averaged velocity and boundary shear stress in the middle of skewed part of the flume are not symmetric. Also, in general the velocity and bed shear stress in the diverging floodplain are bigger than the converging floodplain. Moreover, by increasing the skew angle and relative depth, both velocity and shear stress along the skew part of the flume increase.

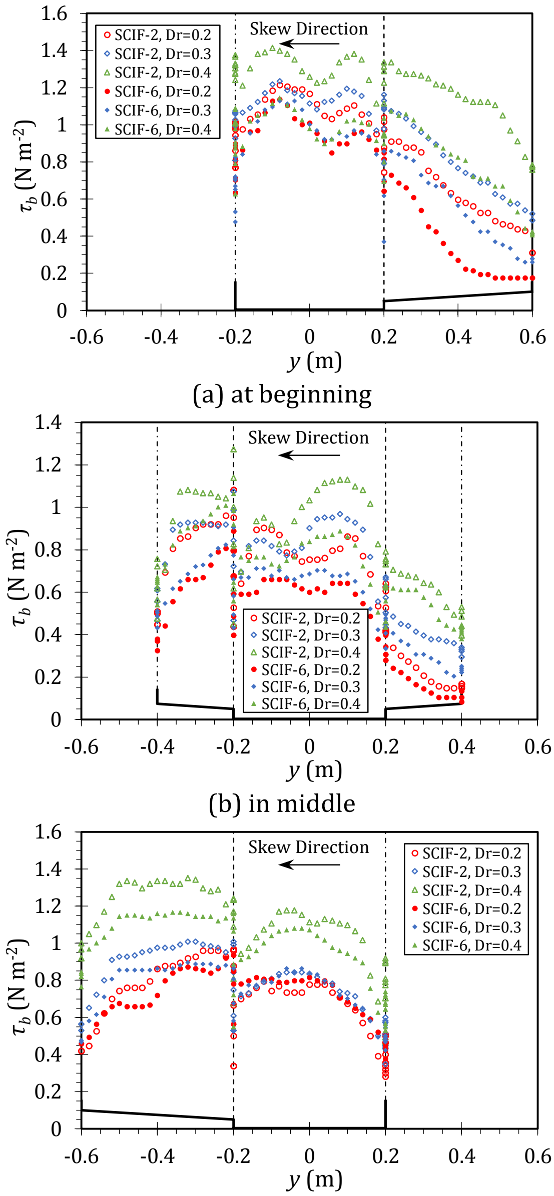


(a) at beginning

(b) in middle

(c) at end

Fig. 2. Deph-averaged velocity distribution at three experiment sections for two skew angles of 11.31° and 3.81° and different relative depths



(a) at beginning

(b) in middle

(c) at end

Fig. 3. Shear stress distribution at three experiment sections for two skew angles of 11.31° and 3.81° and different relative depths

5. References

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