The Impact of Double-layered Rigid Vegetation on Flow Structure

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Abstract

Flow structure in vegetated channels is highly three-dimensional. This study focuses on the characteristics of flow through the mixing layered vegetation partially covered in an open channel. A series of experiments were conducted to investigate the velocity distributions in the vegetated zone under different flow conditions. Reynolds shear stress was calculated based on 3D measurements using ADV (Acoustic Doppler velocimeter). Observed results show that the flow has distinct features in three layers: the lower, mediate, and upper layer. A prominent shear stress layer is found at the upper edge of tall vegetation, indicating strong momentum exchange in this transition region.

Keywords: Reynolds stress; vegetated channel; double-layer vegetation; mixing layer

Introduction

Aquatic vegetation has a great impact on the flow structures of natural rivers. Additional resistance generated by the vegetation retards the velocity, which will result in reduced channel capacity and sediment deposition (Tang & Knight, 2001; Gunawan et al. 2010). Furthermore, the shear layer caused by vegetation affects the boundary shear stress distributions, which is of great importance in bank protection and bed stability.

Typically, in vegetated channels, a strong momentum exchange occurs at the vegetation top, resulting in significant Reynolds stress in this region (Tang and Knight, 2008; Tang et al., 2010, Tang 2019). Despite the dominant role of drag force of vegetation in the vegetated flow, shear stress distributions in double-layered, partially vegetated channels remain unclear. This paper gives a brief description and reasonable explanations of the shear layer flow structure.

Methods

Plastic dowels of 10cm and 20 cm height were used to simulate rigid vegetation in this study. The double-layered vegetation was arranged to cover half width of 40 cm wide channel. The details of the experimental setting and measurements was given by Tang et al (2021). Summary of the experiment parameters is listed in Table 1.

Table 1. Summary of experimental parameter

Case	vegetation density	tall vegetation height (cm)	short vegetation height (cm)	water depth (cm)	flow rate (L/s)
R1	0.0315	10	20	9	8.24
R2				12	11.38
R3				22	2.20
R4				25	24.80

Reynolds shear stress is calculated from Equation (1).

$$\tau_{yx} = -\rho\overline{u'v'} \#(1)$$

Results

Take measurement points w4, w8, w12, w14 and w18 for example. The point of w4 is behind the short vegetation, while the location w8 is behind the tall vegetation. Measurement point w12 and w14 is at the interface between vegetated zone and free flow zone. The results in Figure 1 show the vertical variation of the Reynolds stress cross the channel. The flow field in the short vegetation zone has more obvious fluctuation than in the tall vegetation zone under submerged conditions (scheme R4). At the near-bottom layer and the upper edge of the short vegetation, the curve shows a sharp turning point, indicating a strong momentum exchange occurring at this location.

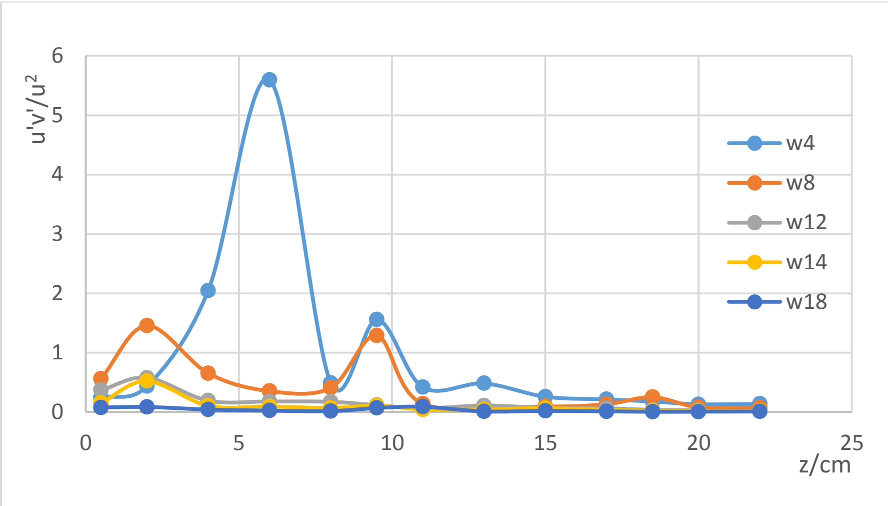

Fig.1 Relationship between dimensionless Reynolds stress and vertical locations

Conclusions

The existence of vegetation has a great impact on the channel flow field. The vegetation height is one dominant factor affecting the velocity profiles and stress field. Reynolds shear stress in the double-layered vegetation zones shows more obvious fluctuations than that in the free flow zones. Strong momentum exchange often occurs near the bed or at the upper edge of the vegetation.

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