NUMERICAL SIMULATION OF OPEN-CHANNEL FLOWS OVER SMOOTH-ROUGH BED STRIPS

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The movement of the sediment particles in open-channel flows over a movable bed is affected intensively by secondary currents. This leads to the spanwise variation of bed roughness. Now, the spanwise heterogeneity of bed roughness changes the pattern of secondary currents. When the bed roughness is varied periodically in the spanwise direction, the secondary currents can be characterized by a pair of circular flow cells. These cells observed in wide open-channel flows are called cellular secondary currents, of which the upflow occurs over the smooth bed strip and the downflow over the rough bed strip. Vanoni (1946) commented that the spanwise distribution of sediment concentration is varied periodically because of the cellular secondary currents. McLelland et al. (1999) reported that the bedload transport rate over the rough bed strip is about 20% greater than over the smooth bed strip. The cellular secondary currents are important in hydraulic engineering because they affect the mean flow and turbulence structures, the sediment transport rate in the spanwise direction, and the formation of various types of sand wave on the riverbed.

The purpose of the present study is to present a 3D model for the numerical simulation of the turbulent open-channel flows over smooth-rough bed strips (see Figure 1). The Reynolds stress model (RSM) is used for the turbulence closure. Using the developed model, the mean flow and turbulence structures are simulated and the results obtained are compared with experimental data by Muller and Studerus (1979). Comparisons reveal that the developed Reynolds stress model successfully predicts the cellular secondary currents (see Figure 2) and turbulence structures of open-channel flows over smooth-rough bed strips. The mechanism by which secondary currents are generated was investigated by performing a budget analysis of the streamwise mean vorticity equation (see Figure 3). It was found that production by anisotropy of turbulence plays a key role in the vicinity of the wall and the production by Reynolds shear stress is important in the region more distant from the wall. Therefore, the balance between two production terms generates the stable secondary currents.

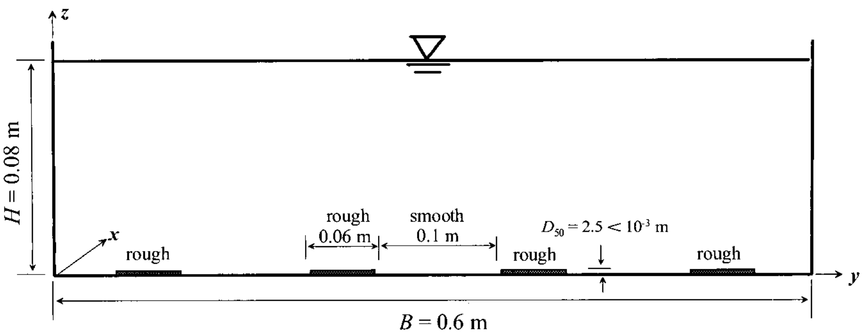
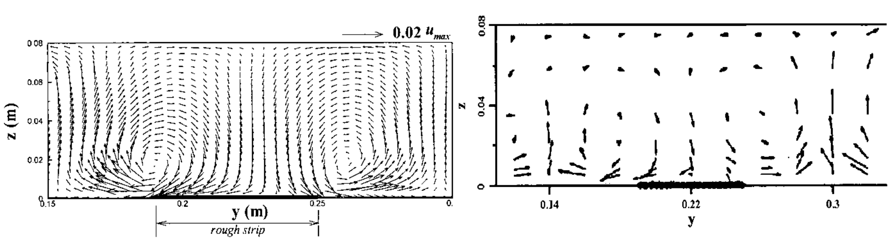
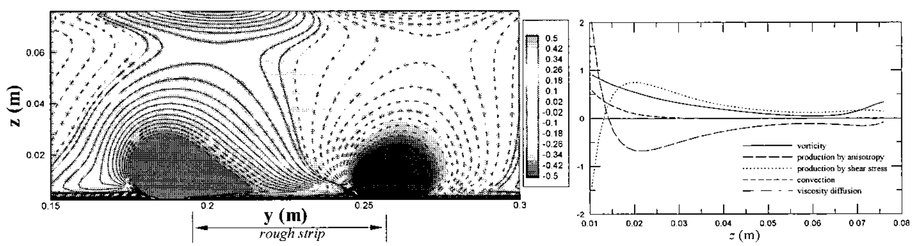


Fig. 1 Flow Configuration for Computation



(a) RSM (b) Muller and Studerus (1979)

Fig. 2 Secondary Current Vectors



(a) Streamwise vorticity contour (b) Budget analysis at y =0.2 m

Fig. 3 Streamwise Mean Vorticity and Budget Analysis

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