FLOW DYNAMICS OVER A GRAVEL RIVERBED

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The present research on natural gravel-bed river flows concerns the flow around a bed protuberance. Flows around obstacles are an important subject in geophysical fluid mechanics, because of their effect on turbulent mixing and transport processes. In shallow gravel-bed rivers, the mean velocity in the lower layers of the flow may show two kinds of profiles, logarithmic and s-shaped (Marchand et al., 1984 and Bathurst, 1988). The wake effect formed by the bed forms and boulders is responsible for the deviations observed in the velocity profile of gravel-bed rivers (Nelson et al., 1993, Baiamonte et al., 1995 and Buffin-Bélanger and Roy, 1998). Nikora and Smart (1997) referred to a 3D inner layer of the flow called the roughness sublayer ($z<Z_{RL}$) where deviations from the log-law are expected. Flow over gravel riverbeds may be compared to atmospheric canopy flow where a continuous inflection of the velocity profile occurs in the inner layer (Katul et al., 2002). It is thus essential to understand the turbulent mechanism involved in the transition between different velocity distributions.

This paper analyzes one streamwise plane where the transition log-s-2xlog exists due to an individual bed perturbation scaling with D_{84}. The coexistence of s and log velocity profiles in gravel-bed rivers was observed on the present measurements and the dynamics of gravel-bed river flows was explained (Fig. 1). One streamwise plane was analyzed where a transition in the velocity distribution of the type log-s-2xlog exists. A double log boundary layer exists in the transition from s to mono-logarithmic profiles. Three different regions of flow related to the presence of a bed obstacle were identified: (1) convergence, (2) separation and (3) redistribution. Each of these regions corresponds to a log, s and double log velocity profile, respectively and they were investigated in terms of mean velocity, mean turbulence and coherent structures.

The s-profile may be described by a tanh function, parameterized with a reference velocity u_o which is equal to half the constant velocity in the outer "potential layer" and a geometric parameter of the same order of magnitude as the mean size of the larger coherent structures present inside the roughness sublayer ($L \approx \bar{L}_{\text{int}}(z < Z_{RL})$). The low momentum inner layers in region (1) are laterally conveyed into the lee of the obstacle by the mean spanwise field, creating the inner log law layer in the downstream profile (region (3)). In region (2) one finds a "quasi" 2D potential flow above the roughness sublayer and the outer boundary layers where a 2D potential flow approximation is possible. The shear zone in the second logarithmic layer (region (3)) is mainly due to the form drag caused by the upstream obstacle. There is turbulence enhancement due to the existence of coherent structures caused by Kelvin-Helmholtz type instability formed along the wake line (Fig. 6). In the wake of the bed protuberance, a recirculation zone is formed where the mean velocities are low; there is a shielding effect and turbulence reaches lower levels. Inside the wake, the outward and inward interactions aligned with the wake delimitation direction are dominant; the Reynolds shear stress in the inner layer of region (2) is positive. The instantaneous vertical shear component increases with the vertical, and appears to be higher in the s-profile than in the others, eventually due to the extra vertical momentum resulting from the upstream flow convergence.

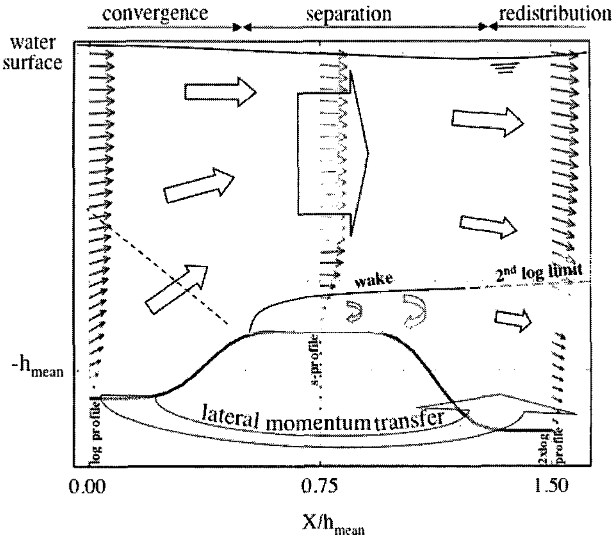

Fig. 1 Interpretation of investigated the flow field.

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