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Flow Resistance and river bed stability of natural river beds at low relative submergences

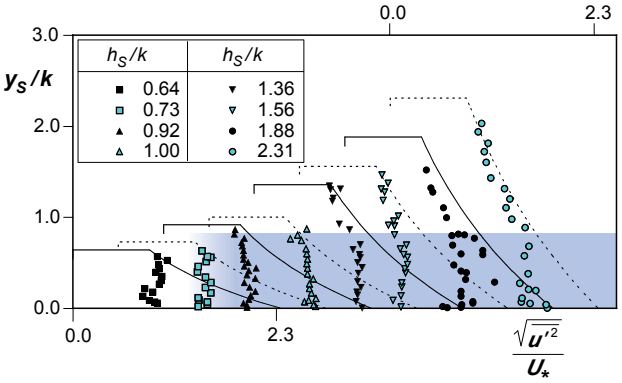

Fig. 1: Turbulence intensities above plane bed of uniform grains for different relative submergences hs/k in comparison with the empirical distribution functions found for smooth beds. Data of DONG ET AL. (1991). The shaded area marks the roughness sublayer.

An essential characteristic of mountain rivers is small relative submergences, i.e. even during floods the flow depth is of the same order of magnitude as the characteristic grain size of the bed material. The assessment of flow resistance and river bed stability by means of conventional approaches derived for channel flows with large relative submergence is, however, problematic and often yields unreliable results.

Experimentally determined distributions of turbulence intensities and turbulent shear stress show that above the roughness elements of a hydraulically rough bed, a layer exists, within which the flow is strongly influenced by the flow separations from the individual grains. Within the roughness sublayer the turbulence intensities and the turbulent shear stress are almost constant. Near the bed, the distribution of turbulent shear stress thus deviates from the triangular distribution, and the value of turbulent shear stress at the bed is smaller than the bed shear stress determined by the product of flow depth and the longitudinal slope. The suppression of turbulent shear stress near the bed can be explained as a consequence of smallscale secondary flows caused by flow separation from the individual grains.

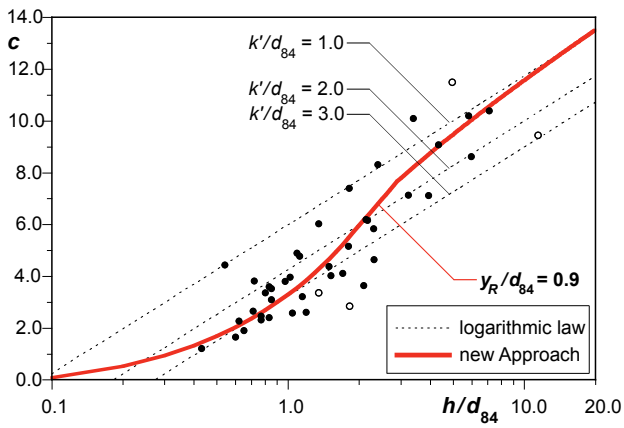

Fig. 2: The new approach in comparison with the log law of NIKURADSE and the prototype flow resistance data of JARRETT (1984), where h: flow depth, d_{84}: characteristic diameter of bed material, c: Chézy coefficient, k': equivalent sand roughness, y_R: thickness of roughness sublayer.

On the basis of a simple turbulence model – the mixing length approach of PRANDTL – a new model for the velocity distribution in turbulent flows is proposed. The main element of this model is the assumption that not the total shear stress, but only the portion of turbulent shear stress controls the mean motion. Additionally, the thickness of the roughness sublayer is introduced as a roughness parameter.

Comparison with existing data from laboratory experiments and field measurements confirm the applicability of this new model. The thickness of the roughness sublayer used as a roughness parameter, in contrast to the already existing approaches, is not dependent on relative submergence. This circumstance facilitates the determination of explicit roughness values for given roughness configurations.

Due to the influence of relative depth, the flow velocity in the vicinity of the grains decreases with decreasing relative submergence. Thus, the forces acting on the single grains are also reduced. From the analysis of data obtained from experiments on the initiation of erosion at small relative submergence, it emerges that the reduced hydraulic stress determined on the base of the new proposed model for velocity distribution allows a more precise prediction of river bed stability.

Keywords:	Flow resistance, initiation of motion, riverbed stability, mountain rivers, turbulence
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