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Development of a device for direct bed shear stress measurement in a gravel bed river

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The temporal and spatial bed shear stress distribution represents an important link between turbulent flow conditions and sediment transport. Hence bed shear stress is a fundamental parameter to describe and predict morphodynamic processes, e.g. sediment transport patterns, scour, deposition or morphological changes. Though literature is rich in the descriptions of various indirect methods dealing with the evaluation of bed shear stress and shear velocity by measuring flow velocity or turbulence it is, however, difficult to estimate these variables accurately, particularly in large rivers. Furthermore these indirect techniques are only capable of estimating mean values of bed shear stress and shear velocity. Thus it is worthwhile to measure the fluctuating bed shear stress, in order to obtain not only mean values, but also variability, minima and maxima of this parameter, to draw conclusions in terms of critical shear stress and the initiation of motion, respectively.
Compared to indirect shear stress estimations the main advantage of direct measurement techniques is the acquisition of temporal bed shear stress variations. However, due to their complexity and requirement of careful calibration direct techniques are rarely applied. So far there have been no reported successful attempts to apply direct bed shear stress measurements using a shear plate in gravel bed rivers, though they could give substantial progress in process understanding concerning sediment transport, turbulent flow conditions and the statistical characteristics of bed shear stress.
Therefore the aim was the design, construction and a functional test of a device for direct measurements of the instantaneous bed shear stress which can be used in a gravel bed river. The principle of the adopted measurement technique is to allow a shear plate covered with roughness elements to move freely in horizontal directions under the forces exerted by the flowing water and to measure the forces acting on the plate.
The shear plate covered with roughness elements is 0.5 m long, 0.5 m wide and mounted in a steel frame, which acts as a carrier for the whole measurement system. The shear device is approximately 0.1 m in height and surrounded by a streamlined shape, also covered with roughness elements to ensure an undisturbed approaching flow. The forces occurring are measured with two strain stress transducers, which are oriented perpendicular to each other, in order to measure the forces acting on the shear plate in and lateral to the flow direction. They are mounted underneath the shear plate and are fixed to a load transmission, which is aligned in the center of the shear plate, and to the carrier of the measurement frame. The shear device is able to measure the instantaneous bed shear stress up to about 40 N/m^2.
In a laboratory flume test the functionality of the approaching flow device was confirmed and a validation of the directly measured bed shear stress was in good agreement with calculated and modelled independent data sets. Moreover a resonance frequency analysis as well as statistical analyses of the directly measured bed shear stress were performed.