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Experimental modelling of marginal bed-load transport in an alpine mountain river

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The presented work deals with experimental transport modelling of bed-load over a self-stabilized channel bed, as it is often observed in alpine mountain streams. A reach of the Gurgler Ache, a mountain river situated in the Oetztal valley in Tyrol (Austria), was reproduced within a physical scale model (1:20) in the hydraulic engineering laboratory at the University of Innsbruck. The investigated river reach features a length of 280 m, a mean channel slope of 0.03 m/m, a bankful channel width of roughly 14 m, and a channel bed surface with a d84 of approximately 0.3 m.

Experimental modelling was based on Froude's similarity law. At the lower end of the flume the bed was artificially fixed. Further, the lower boundary condition featured supercritical flow conditions as the water dropped into a tank, which was mounted on load cells. Ensuring an invariable relation of water level and volume in the tank the increase of weight is thus attributable to the bed-load leaving the flume.

To ensure similar conditions as observed in the field, a bulk sediment mixture, corresponding to the sub-surface material of the Gurgler Ache, was set to a certain bed-level and a discharge (about one third of the mean annual peak flow) was applied until the bed-load transport decreased to virtually zero. With it, the observed mean bed slope as well as the characteristics of the bed surface could be configured. This was the initial condition of each experimental series. A series itself consisted of several experimental runs, each at a steady discharge, where 50 kg of sediment was added manually at the upper boundary of the flume. The sediment feeding was best possibly tried to be done at a constant rate. Once the 50 kg were fully added, the experimental run was continued for one third of the feeding duration. While for each experimental series a different grain size were added, the runs within one series differed in the discharges applied and were done successively, starting with the lowest one (which was far beyond the discharge of self-stabilization). Within three experimental series nearly uniform sediments with mean grain sizes of 1.3 to 4.4 mm (model scale) were added. To distinguish the fed grains from bed sediments the former were coloured beforehand. In the fourth experimental series a sediment mixture was used, each grain size was coloured differently therein.

The continuous measurement of bed-load accumulation at the downstream end allowed for the identification of different stages within each experimental run: (i) a certain lag time with nearly zero bed-load transport at the beginning, followed by (ii) a discontinuous increase of the transport rate until (iii) a certain equilibrium condition was reached. Depending on the applied discharge, (iv) a decrease of transport rate to zero was observed as sediment feeding stopped. Due to the colouring of the admitted sediment, the origin of the collected material could be assessed proportionally. Additionally, photographs from the bed-surface at the end of each run allowed further quantifications on deposited patches on the bed-surface.