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Formula for Motion Threshold per Grain Size for Graded Sediments in Steady Flows

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It's important to be able to determine precisely the point at which deposited sediment moves in fluids. These criteria have been well understood for decades for the limiting case of a uniform particle size in steady water flows. Previous studies on the motion threshold of graded sediment (with a particle size distribution) have shown that the response exhibited by grain size at a given shear stress is different from what it would be if the bed were of uniform size. Previous parameterisations for the effects of the distribution have been unsatisfactory.

Contrary to previous approaches which evaluate the distribution effects based on inferred transport rates, here an alternative approach is outlined which is based on the measured particle size-distribution of the mobilised sediment. We present arguments for why this approach is physically less uncertain than previous approaches.

We have re-analysed fractional mobilisation data from 12 sets of experiments, totalling 81 different mixed sand and gravel beds and flow conditions (grain Reynolds numbers between 1 and 10,000). Non-linear optimisation of a simple equation for mobilisation of sediment mixtures is used to find the optimal form of a weighting (so-called 'hiding') function used to modify critical entrainment criteria to provide the best possible fit with the data.

The analysis reveals, for the first time, that the effects of distribution on critical threshold scale with excess shear stress. A secondary dependence is found on the ratio of particle sorting to mean grain size. We therefore propose a new predictive relation (a simple deterministic equation, in non-dimensional form) for critical shear stress of any grain size in graded sediment which is applicable to all situations. Evaluated using a Brier Skill Score approach, the new formula outperforms existing formulas in 11 out of 12 data sets, on average, in aggregate, and with an expected root-mean-squared error of +/- 20%.