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Bed load transport above a bimodal sediment bed

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Despite several decades of investigations, accounting for the effect of the wide range of grain sizes composing the bed of rivers on bedload transport remains a challenging problem. We investigate this problem by studying experimentally the influence of grain size distribution on bedload transport in the simple configuration of a bimodal sediment bed composed of a mixture of 2 populations of quartz grains of sizes $D_1 = 0.7 \pm 0.1mm$ and $D_2 = 2.2 \pm 0.4mm$, respectively. The experiments are carried out in a tilted rectangular flume inside which the sediment bed is sheared by a steady and spatially uniform turbulent flow. Using a high-speed video imaging system, we focus on the measurement of the average particle velocity and the surface density of moving particles, defined as the number of moving particles per unit surface of the bed. These two quantities are measured separately for each population of grains as a function of the dimensionless shear stress (or Shields number) and the fraction of the bed surface covered with small grains. We show that the average velocity and the surface density of moving particles obey the same equations as those reported by Lajeunesse [2010] for a bed of homogeneous grain size. Once in motion, the grains follow therefore similar laws whether the bed is made of uniform sediment or of a bimodal mixture. This suggests that the erosion-deposition model established by Lajeunesse [2010] for a bed of uniform sediment can be generalized to the case of a bimodal one. The only difference evidenced by our experiments concerns the critical Shields number for incipient sediment motion. Above a uniform sediment bed, the latter depends on the particle Reynolds number through the Shields curve [Shields, 1936]. In the case of a bimodal bed, our experiments show that the critical Shields numbers of both populations of grains decrease linearly with the fraction of the bed surface covered with small grains. We propose a simple model to account for this observation.