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Compositional analysis of Stress History effects on the stability of a graded sediment bed

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Antecedent flow strongly influences the stability of graded sediment beds in gravel-bed rivers. Results of flume-based investigations are discussed that illustrate the underlying process(es) responsible for promoting stability specifically in terms of detailed quantitative compositional analysis. Thirty-three experiments, including repetitions, were undertaken using a bimodal sediment bed of D_{16} = 1.8mm, D_{50} = 4.8mm, D_{84}= 7.8mm and σ_g = 2.08. The effects of antecedent duration were determined using shear stresses of 56% and 79% of the critical value for entrainment of the D_{50} (τ_{c50}) for 30, 60, 1440 and 5760 minutes. The influence of antecedent shear stress was examined using 1440 minutes of applied shear stress 56%, 79%, 82% and 93% of τ_{c50}. The stability of each antecedent bed was analysed by measuring the bedload, bedload composition and bed surface composition during a subsequent 240 minute period of flow at 119% of τ_{c50}.

Compositional data indicated that the stability of the graded bed was reduced using flows of higher antecedent shear stresses due to the increased winnowing of fines from the bed surface. Increasing the antecedent shear stress from 56% to 93% of τ_{c50} increased the selective entrainment of 1.4-5.6mm grains by up to 58.3%, causing progressive coarsening of the bed surface (up to 91.7%) by the exposure of heavier immobile gravels. Erosion of the fine supporting matrix reduced particle interactions and the packing density of the bed surface; this reduced the bed stability.

With increasing antecedent duration the graded bed became more stable, independent of compositional change to the bedload or bed surface. Visual analysis of the surface indicated the reorientation of all fractions in the bed surface into more stable posi-

tions by pivoting around an axis. Vertical settling of fines generated a tighter packing configuration such that larger gravels were increasingly exposed to fluid forces. Consequentially, this caused the coarser material to pivot, disturbing the surface fines into a tighter packing arrangement around the base of the gravel particle; this cycle of positive feedback generated a more stable bed.

Analysis of the competitive effects of antecedent duration and shear stress magnitude indicated that particle rearrangement acted on a shorter timeframe and was of greater relative importance than compositional change. This highlights the crucial importance of antecedent flow duration for delaying entrainment to higher shear stresses and changing the pattern of sediment transport during a flood event. Overall the research demonstrates the significance of antecedent flow conditions for hydraulic engineering and research; including the modelling of bedload transport and the need for standardising flume-based experimental procedure