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Effect of Bed Porosity on Momentum Exchange in Gravel-Bed Rivers

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Momentum exchange between a rough, porous gravel substrate and the overlying turbulent flow is a key control of fine sediment ingress, pollutant exchange, spawning success and hyporheic flows. The surface topography and porosity of the substrate are known to be important controls on the near-bed hydraulics and momentum transfer mechanisms. However, previous attempts to examine the effect of bed porosity on sediment-water exchange mechanisms have either been undertaken over idealised roughness elements, or over water-worked gravel beds where it has not been possible to isolate the influence of bed porosity from that of surface topography.

In the present study, a series of flume experiments have been undertaken that examined the near-bed flow dynamics over porous and non-porous gravel beds that exhibited the same surface topography. Using different grain-size distributions and sediment feed rates, a number of water-worked, porous beds with differing surface topography were created within the flume. A novel casting technique was used to produce non-porous facsimiles of each of the porous beds that faithfully replicated the topography of the original surfaces. The near-bed hydraulics over these beds were measured using Particle Image Velocimetry and used to deduce the temporal and spatial characteristics of the flow. Using these data, we compared the Reynolds and form-induced stress contributions to the momentum budget for the porous and non-porous beds. The experiments provided an evaluation of the link between bed porosity and fluid momentum transfer across sorting and bed structure gradients, thereby overcoming a major limitation in existing understanding of sediment-water exchange mechanisms.

Early results from this work reveal (1) porous and non-porous beds differ in the relative role of Reynolds stress, and thus turbulent fluid exchange, in momentum transfer; (2) within the roughness layer, the total fluid stress is distributed differently in the vertical; and (3) the effects of bed porosity vary with surface topography and can be related to the arrangement of surface grains. These advances underpin the development of more realistic characterisations of sediment-water exchange mechanisms, which are vital for the continued development of fine sediment deposition and pollutant transfer models.