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The pore structure of the river bed

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Bank collapse and local scour during extreme events often result in large, sudden inputs of sediment to the river. These sediment inputs may lead to morphological changes within the channel (affecting navigation and flood water levels), but this is not necessarily the case. If the supplied sediment is fine enough, it will fill the pores between the larger bed grains without causing a rise in bed level. The discrimination between sediment grains that infiltrate in the pores of the bed grains (here called pore-filling load) and the grains that do not infiltrate in the pores of the bed grains (here called bed structure load) is therefore of practical importance for morphological predictions.

In this study, a new method is proposed to estimate the cut-off grain size that forms the boundary between pore-filling load and bed-structure load. The method evaluates the pore structure of the river bed geometrically. As input only detailed grain-size distributions of the river bed are required. A preliminary validation shows that the calculated porosity and cut-off size values agree well with experimental data. Application of the new cut-off size method to the river Rhine demonstrates that the estimated cut-off size decreases in downstream direction from about 2 to 0.05 mm, covariant with the downstream fining of bed sediments. Grain size fractions that are pore-filling load in the upstream part of the river thus gradually become bed-structure load in the downstream part. The estimated (mass) percentage of pore-filling load in the river bed ranges from 0% in areas with a unimodal river bed, to about 22% in reaches with a bimodal sand-gravel bed. The estimated bed porosity varies between 0.15 and 0.35, which is considerably less than the often-used standard value of 0.40.

The predicted cut-off size between pore-filling load and bed-structure load ($D_{c,p}$) is fundamentally different from the cut-off size between wash-load and bed-material load ($D_{c,w}$), irrespective of the method used to determine $D_{c,p}$ or $D_{c,w}$. $D_{c,w}$ values are in the order of 10^{-1} mm and mainly dependent of the flow characteristics, whereas $D_{c,p}$ values are generally much larger (about 10^{0} mm in gravel-bed rivers) and dependent of the bed composition. Knowledge of $D_{c,w}$ is important for the prediction of the total sediment transport in a river (including suspended fines that do not interact with the bed), whereas knowledge of $D_{c,p}$ helps to improve morphological predictions, especially if spatial variations in $D_{c,p}$ are taken into account. An alternative to using a spatially variable value of $D_{c,p}$ in morphological models, is to use a spatially variable bed porosity, which can also be predicted with the new method.

In addition to the morphological benefits, the new method also has sedimentological applications. The possibility to determine quickly whether a sediment mixture is clast-supported or matrix-supported may help to better understand downstream fining trends (especially gravel-sand transitions), sediment entrainment thresholds and variations in hydraulic conductivity of soils.