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Porosity and Void Structure of Riverbed Materials

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1. Introduction

Riverbed materials can have a variety of different vertical structures depending on the bed-material particle-size distribution, the supply of transportable sediment in the streambed, and the interaction with the hydraulics of flow. In conventional riverbed deformation calculations, void ratio in riverbed materials had been assumed unquestioningly to be a constant (0.3-0.5), regardless whether particle size distribution of riverbed materials was uniform or not. Fixing the void ratio is insufficient to simulate practical sediment movements in the riverbed such as the removal of sand from a gravel bed by the flushing flow or intrusion of fine sediment into gravel bed, since no doubt that the void ratio changes depending on the particle size distribution.

The void of bed–sediment is a major component of habitat for aquatic lives, such as fishes and insects. In particular, a variety of natural sediment transport processes such as floods or debris flows induced by heavy rainstorm, and also human interfere such as construction of dams or sediment flushing from reservoirs affect seriously on the voids change in riverbed. To integrally manage both sediment controls and ecological conservations through a whole river system, it is essential to consider the changes of voids in riverbed depending on the particle size distribution.

2. Method

In this study, a spherical particle packing simulation model was developed as a fundamental framework for analysis of the voids in the riverbed deformation calculation. A hypothetical cubic vessel is assumed for particle packing. The diameters of particles that will be pack into a hypothetical vessel are determined from the grain size distribution using a set of random number. The particles were filled into a hypothetical cubic vessel one by one as low a position as possible until the vessel would be full. The validity of the model was assessed by a particle packing experiment. To visualize the void structure within the packed particles, the hypothetical vessel was cut using horizontal cross-section, and the circles that appear on the cross-section were drawn in 2-dimensions in the plan view.

3. Results

Simulations were carried out to elucidate the dependency of void ratio on lognormal-type particle size distribution. The results indicated that void ratio decreased with an increasing size distribution mainly due to the reduction of the open space by large particles. The simulated void ratios were less than 0.2 when $\ln \sigma > 1.0$, much smaller than the constant void ratio 0.4, which is generally, assumed in conventional riverbed deformation calculations. The size of the voids did not change with the particle size distributions, if the mean particle diameters were identical. Further simulations comparing different types of particle size distributions (i.e., lognormal, Talbot, and other type) indicated that even thought range of size distributions were identical the void ratios varied depending on the types of distributions.

4. Conclusion

These simulations confirmed the importance of the changes in void ratio within riverbed for the integrated sediment management of the sediment controls and ecological conservations.