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Internal Erosion Behaviors in Upward Seepage under Isotropic and Anisotropic Stress Conditions

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Internal erosion is one of the main reasons initiating failures of embankments and dams. To estimate the risk of failures, understanding the mechanism of internal erosion under different stress conditions is crucial. With a stress-controlled apparatus, experiments are conducted, in which suffusion is induced by step-wise increasing hydraulic gradients under the isotropic and the anisotropic stress conditions. Based on the results, a low critical hydraulic gradient (LCHG) and a high critical hydraulic gradient (HCHG) are defined, corresponding to the local and the global mobilizations of fine particles, respectively. It is found that the critical hydraulic gradients under isotropic and anisotropic stress conditions are remarkably different. Under the isotropic stresses, the critical hydraulic gradients increase monotonously with the confining stress. Whereas, under the anisotropic stress conditions, the critical hydraulic gradients increase at first and then decrease after reaching a maximum value. The continuous erosion is triggered by rising the water head difference to a target value higher the HCHG. The results show that the amount of the eroded particles gradually increases with the erosion time under isotropic stress states. The final accumulative particle loss approaches a constant if the erosion time is sufficiently long under a given erosion gradient. The process of particle loss under anisotropic stress states is similar to that under the isotropic stress states, as long as the amount of the particle loss is small. However, if the erosion amount is high enough to reach a critical value, the specimen collapses and undergoes significant volumetric deformation. Based on these erosion behaviors, an analytical expression of the erosion rate is developed for quantifying the erodibility of the cohesionless soils. Moreover, an energy-based model is used to interpret the erodibility of soils. The mechanism of the effects of the stress state on the erosion behavior, especially the collapse of specimens, is explained. It is concluded that the evolution of the strain-stress behaviors and the rearrangements of the microstructure are the main reasons causing the differences between the erosion behaviors under the isotropic and the anisotropic stress conditions.