EGU24-9914, updated on 09 Dec 2024
https://doi.org/10.5194/egusphere-egu24-9914
EGU General Assembly 2024

High-fidelity modeling of landslide dam overtopping failure using SPH-DEM method

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Abstract: Overtopping failure of landslide dams is a complex process that involves strong soil-water coupling and structural failure. Physically based numerical models are needed for breach mechanism as well as failure process and flood prediction. In this study, we establish an SPH-DEM dam-break model that considers the combined effect of seepage and overflow. The key feature of the proposed high-fidelity dam-break model is that both solid and fluid phases are solved simultaneously in two different sets of Lagrangian particles using their own governing equations. In the numerical framework, the water phase is modeled as weakly-compressible Newtonian fluid using the SPH method, and the soil phase is modeled using the DEM method. The interactions between these two phases including drag force, buoyancy and adhesion. The capillary force generated by the meniscus between two soil particles is solved to characterize the saturated and unsaturated processes of soil. The model is validated by three benchmarks including the simulations of seepage through an earth dam, a small-scale dam-break test and the whole progress of dam profile erosion. In a small-scale dam break test, the calculation error of overtopping peak flow is 3.5%. Simulation results predicted by the SPH-DEM dam-break model show good agreements with the finite element method and experimental results. Furthermore, the high-fidelity dam-break model is able to simulate many other soil-water coupling processes, such as reservoir water infiltration, dam slope erosion and collapse, breach development, and dam failure. In the future, the proposed SPH-DEM soil-water coupling framework could be applied to the modeling of geohazard chain triggered by rainfall-induced landslides, blocking river and dam outburst flood.

Keywords: landslide dam; overtopping modeling; SPH-DEM; soil-water coupling