Simulating dynamic disaster evolution of soil flowslide triggered by earthquakes

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Abstract

Earthquakes induced soil flowslide, such as landslide, debris flow, liquefaction and so on, can lead to serious damage and casualties. It is significant to perform analysis of soil flowslide to understand the dynamic disaster evolution of these phenomena. The authors established hazard-formation theory of soil flowslide based on field investigation and dynamic laboratory tests. Moreover, high-performance SPH method for soil flowslide was developed and applied to practical engineering.

Through field survey of soil flowslide caused by Wenchuan earthquake, it was found that the characteristics of soil flowslide include: destruction of soil structure, continue deformation and complicated flow state. However, it is difficult to record the flow process of soil flowslide in reality considering the abruptness and uncertainty of them. A creative experimental device, static and dynamic multi-functional model tests device, was developed to reproduce the flow process of soil flowslide. This device can record the time history of runout, velocity, impact force and excess pore water pressure during co-earthquake and post-earthquake stages. To illustrate the mechanical properties of soil flowslide, extensive dynamic laboratory tests including dynamic triaxial tests and ring shear tests were conducted. It was concluded that Bingham fluid model was suitable to describe the dynamic features of soil flowslide.

The flow soil was regard as viscous fluid and the numerical model based on computational fluid dynamics were established to reproduce the dynamic process of soil flowslide. Equivalent viscosity model and Mohr-Coulomb model were introduced into Bingham fluid model to develop a constitutive model for flow soil. Smoothed particle hydrodynamics (SPH), which is a pure Lagrange, meshless method, was introduced to solve the governing equations. SPH can conquer deficiency of mesh method in soil flowslide and can easily capture the free surface of soil flowslide. Considering the practical situation of soil flowslide, multi-phase coupled model, dynamic erosion model, fluid-structure coupled model and 3D parallel SPH models were developed in high-performance SPH model and verified using experimental and theoretical results. The three phases of soil, gas phase, liquid phase and solid phase, is essential for soil flowslide. Hence, multi-phase coupled model is applied to consider the interaction between different phases. During the propagation of soil flow, the loose material along the way will be eroded by shear strength of flow soils. This phenomenon is reflected using dynamic erosion model. As we mentioned above, soil flowslide can cause serious damage to structure and infrastructure. It is significant to make out the fluid-structure interaction. Hence, fluid-structure coupled model is contained in high-performance SPH method. 3D parallel SPH model can be applied to complicated 3D topography and large scale regional problems, which is common in real engineering problems. This high-performance SPH method was successfully applied to simulate soil flowslide in practical engineering.

The dynamic disaster evolution of soil flowslide was reproduced and the constitutive model for largely deformed soil was established. The high-performance SPH method containing pivotal model solution algorithm system was developed and applied to practical engineering.

Keywords: Dynamic disaster evolution; soil flowslide; SPH; earthquake; computational fluid dynamics;