Applicability of a coupled MPM-VOF analysis to seepage failure problems in the ground

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Abstract

Seepage failure of earth structures and natural ground caused by water flow under high hydraulic gradients leads to serious disasters such as earth dam failures and debris flows. When developing a numerical analysis method for seepage failure and sediment runoff phenomena, it is essential to consider the large deformation of soil, the free surface flow of water inside and outside of the soil, and their interaction. The authors have developed a coupled analysis method using the Material Point Method (MPM) and the Volume of Fluid (VOF) method to analyze these phenomena. In the coupled MPM-VOF analysis, sediment motion and deformation are analyzed using MPM, which is one of the methods for large deformation analysis of continua, while the free surface flow of fluid is calculated using the VOF method. A weakly coupled scheme is employed in which information on velocity, pressure, and porosity is exchanged through the computational grid of the MPM and the VOF method, and they are computed alternately. To validate the developed method, seepage failure analysis due to boiling in a one-dimensional upward seepage flow field and seepage failure analysis due to seepage flow around sheet piles in a two-dimensional field were conducted to investigate the applicability of the developed method to seepage failure problems in the ground. The results showed a decrease in effective stress due to an increase in the hydraulic gradient and the boiling phenomenon, confirming the validity of the MPM-VOF.

Keywords

MPM-VOF, seepage failure, boiling