Peridynamics for Soil Desiccation Cracking Simulation: Coupled Hygro-mechanical Model, Staggered and Monolithic Solution

Xin Gu[1*], Panyong Liu[1], Xiaozhou Xia[1] , Qing Zhang[1]**

[1] Department of Engineering Mechanics, College of Mechanics and Materials, Hohai University, Nanjing, 211100, China
xingu@hhu.edu.cn, lxzhangqing@hhu.edu.cn

The soil desiccation cracking attributed to moisture loss will significantly weaken the mechanical properties of soil and cause various potential natural disasters. The numerical simulation of soil desiccation cracking remains challenging within the framework of classical continuum mechanics. To avoid the limitation of classical continuum mechanics and corresponding numerical methods, peridynamics has been proposed and developed for dealing with damage accumulation and crack evolution problems.

The hygro-mechanical peridynamic model and numerical method is developed for this classical hygro-mechanical coupled problem. Specifically, a bond-based peridynamic diffusion equation is constructed by using the peridynamic differential operator. In addition, an improved prototype micro-elastic brittle (PMB) model is adopted with high precision attenuation kernel function and discretized micro-modulus. For the numerical implementation, both staggered and monolithic schemes are developed for the coupled hygro-mechanical problem. The direct integration method of explicit dynamics with an artificial damping term is adopted for the staggered scheme. While the matrix equations are assembled and solved in the monolithic scheme with the boundary conditions imposed by Lagrange multiplier method. Furthermore, the method of controlling the maximum number of bond breakage for non-convergence is explored in the monolithic scheme. For modeling of soil drying and cracking, two-dimensional soil rings, and two- and three-dimensional soil strips are simulated and demonstrated. The soil ring model verifies the accuracy of the coupled hygro-mechanical bond-based peridynamic model and reveals the development mechanism of the number of penetrating cracks. The stress distribution and redistribution law are explored, and the curling phenomenon is captured in the soil strip model.

Summarily, the coupled hygro-mechanical peridynamic model provides a potential strategy in soil desiccation cracking investigation for real-scale simulation and fine mechanism exploration.

References

[1] Panyong Liu, Xin Gu, Yang Lu, Xiazhou Xia, Erdogan Madenci, Qing Zhang. Peridynamics for mechanism analysis of soil desiccation cracking: coupled hygro-mechanical model, staggered and monolithic solution. Computer Methods in Applied Mechanics and Engineering. 2023;406: 115896.