Multiscale modeling of saturated granular materials in concurrent second-order computational homogenization method

†*Xikui Li, Songge Zhang, and Qinglin Duan

[1]Department of Engineering Mechanics, Dalian University of Technology, China.

*Presenting author: xikuili@dlut.edu.cn
†Corresponding author: xikuili@dlut.edu.cn

Abstract

A generalized Hill's lemma for meso-macro homogenization modeling of saturated porous gradient Cosserat continua is derived in the frame of the average-field theory. In light of the derived generalized Hill's lemma the downscaling rule for multiscale modeling of saturated granular materials in the frame of concurrent second-order computational homogenization method is specified. The macroscopic hydro-mechanical response variables are downscaled to the meso-scale via the proper presentation of boundary conditions attributed to each of meso-structural representative volume element (RVE) so that the satisfaction of the Hill-Mandel energy condition is ensured.

A discrete particle – continuum model is developed for modeling the coupled hydro-mechanical behavior within the RVE of saturated discrete particle assembly. The motion of interstitial fluid is described by the continuum scheme governed by the averaged Darcy's law at the meso-scale. The averaged relative velocity between the solid and fluid at a local solid particle is evaluated by the velocity of the center of solid particle and the velocity of the fluid at the time instant when the fluid is superposed to the center of solid particle. The solid-fluid interaction force acting on the solid particle and fluid that superposed to the solid particle is expressed in terms of the averaged relative velocity.

In addition to the macroscopic effective stress measures, the incremental non-linear effective stress–strain constitutive relation for the solid phase, the macroscopic effective pore fluid pressure and the meso-mechanically informed Darcy's law for current incremental step at a local material point, to which the RVE is assigned, in the macroscopic porous gradient Cosserat continuum are determined from the volume average of the mesoscale solutions within the meso-structured RVE and upscaled to the macroscale.

A mixed finite element procedure for the hydro-mechanical modeling of saturated porous gradient Cosserat continuum is developed in the frame of concurrent second order computational homogenization method. Numerical example and results demonstrate the performance of the proposed method.

Keywords: **Saturated granular material, concurrent computational homogenization method, Wet discrete particle assembly model, Saturated porous gradient Cosserat continuum model, Generalized Hill's lemma, Meso-hydro-mechanically informed macroscopic constitutive relations.**