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Multiscale Analyses of Granular Media at Finite Strains Based on Micro-Macro Transitions with Different Boundary Constraints

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We consider a homogenized macro–continuum with locally attached discrete microstructure that may be represented by granular particles in soil mechanics or atoms in nanoscale mechanics of metals. Specific micro–macro transitions are derived by a consistent transfer of the discrete micro–variables to macroscopic field variables on a continuous macrostructure. On the microscopic side, the classical boundary conditions of homogenization theory of continuous structures are consistently transferred to their discrete counterparts. We show that those for linear displacements and uniform tractions on the surface yield upper and lower bound characteristics for the periodic boundary constraints with regard to the particle aggregate stiffness. Special attention is paid to the definition of the representative volume element which leads to specific constraints for both the displacements and rotations of the granules on the defined boundary frame. On the macroscopic side, the homogeneous problem is solved by a finite element method where the material model is implemented by directly evaluated micro–macro transitions based on the discrete microstructures for the case of periodic boundary constraints. The two–scale simulations are linked by solving coupled boundary–value problems on both the micro- and macroscales. Numerical examples are finally discussed which clarify the proposed method.

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