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Computational Multiscale Modeling of Granular Media for Integrated Civil Engineering Analysis and Design

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Abstract: Granular media are ubiquitous on the earth and intimately related to our daily life. They are the second most processed materials (next to water) in the world. Granular media are typical porous, discrete media and exhibit intricate behaviours of both solids and fluids depending on the loading conditions. Understanding of the mechanics and physics of granular media plays a pivotal role for analysis and design in geotechnical and structural engineering and concrete materials. This talk introduces the latest advances in computational multiscale modelling of granular media that potentially form a paradigm shift for us to simulate and understand of granular media as an engineering science. We show that a granular material in an engineering setting can be rigorously and effectively simulated by a general-purpose continuum-discrete coupling framework which combines the advantages and strengths of both conventional continuum modelling approaches and purely discrete-based numerical methods. It helps avoid the necessity of assuming continuum phenomenological constitutive models in conventional continuum analysis while providing straightforward cross-scale links of key granular responses and phenomena in an engineering scale, including strain localization, liquefaction, large deformation, and failure. The framework is highly adaptable to include latest developments in both continuum and discrete modelling approaches for enrichments, including consideration of complex grain shape, grain crushing, particle-fluid interactions which can find wide, important engineering relevance in civil, mining, chemical, coastal and offshore engineering, agriculture and pharmaceutical industry. The talk will cover developments of prevailing computational methods such as finite element method (FEM), material point method (MPM), discrete element method (DEM), nonlinear contact dynamics (NLCD), physics engine (PE), and computational fluid dynamics (CFD). We also show how the granular media based multiscale modeling approach can help to provide an integrated framework for prediction and analysis across multiple subareas in civil engineering, including geotechnical, structural, and material engineering.