Granular micromechanics: bridging grain interactions and continuum descriptions

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Granular solids are ubiquitous and impact diverse areas of engineering and science ranging from material development to biomaterials to geophysics. These materials span the spectrum from highly consolidated dense solids formed of particulate precursors to soft membranes formed of cell aggregations to confined packings of non-cohesive particles. In all their forms, they represent a unique case of material system that have posed intractable challenges to the description of their behavior. The grain-interactions play a paramount role in determining their physical behavior. Thus, any mathematical description of their mechanical response begins from the conception of grain-interactions. From this point of departure, either discrete or continuum descriptions can be elaborated. Discrete models of granular materials aim to describe their behavior by tracking grain trajectories in simulated grain assemblies according to formulated equations of motions. Continuum models of granular materials, on the other hand, aim to describe their behavior in an average sense while exploiting the paradigm of continuum mechanics. For granular materials, however, success of these continuum models is predicated upon how they treat grain-interactions and grain kinematics within the formulation. Discrete simulation and continuum modeling are in this sense two competing/complementary methods for analyzing the behavior of granular assemblies. With the aid of examples drawn from discrete simulations and continuum models, and novel grain-scale experimental measurements, this presentation will show why/where traditional approaches are not successful and challenge us to seek innovations. The presentation will emphasize simplicity over complexity and primarily follow energy and variational principles to deduce tractable and plausible models and explanations. More than 2 decade old measured kinematics (displacements and rotations) in disk assemblies [1] and new experiments with controlled grain interactions, will be utilized as basis to motivate the granular micromechanics approach. This approach provides a paradigm that bridges the discrete models to appropriate continuum model, and obviates the need for extensive mechano-morphological parameters required for discrete models. Through this approach, a micromorphic continuum model connected to the grain-scale can be deduced [2] which shows on one hand the type of information lost and on the other the advantages gained when deriving this type of continuum model. The obtained model provides interesting predictions for granular media. These include damage and failure in cementitious materials [3], wave dispersions and frequency band gaps [4-5], and ability to design granular metamaterials [6]. This presentation will discuss specific examples of findings based upon the granular micromechanics continuum model (including those in [7-9]).

References

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Short biography of Dr. Anil Misra, Professor of Civil Engineering

Anil Misra received his bachelor's degree in civil engineering from the Indian Institute of Technology, Kanpur, India, and his M.S. and Ph.D. degrees from the University of Massachusetts at Amherst. He is currently a Professor in the Civil, Environmental and Architectural Engineering Department of the University of Kansas, Lawrence. He also serves as Associate Director of the University of Kansas Institute for Bioengineering Research (KU-IBER). Dr. Misra has a broad research interest that spans topics covering both basic and applied aspects of mechanics of geomaterials, interfaces and biomaterials, including analytical, computational and experimental granular micromechanics, particle and atomistic methods, multi-scale modeling, constitutive behavior, micro-macro correlations, and multi-modal material characterization using high resolution techniques. He has co-edited four books; guest edited four journal special issues; and authored more than 300 papers in journals, edited books and conference proceedings. He has made more than 170 presentations of his research results at national and international fora. His research has been funded by a variety of sources, including the United States National Science Foundation, National Institute of Health, and private industry. He is active in various professional societies where he has been honored with election to the grade of fellow. He serves as reviewer and editorial board member of a number of journals as well as for funding agencies. He has been honored with the 2017 Eugenio Beltrami Senior Scientist Prize, various research and teaching awards at his home institutions, and Chair/Visiting Professorships at a number of international universities. (webpage: http://people.ku.edu/~amisra/).