UNIVERSITÀ DEGLI STUDI DELL'AQUILA
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MATHEMATICS AND MECHANICS
OF COMPLEX SYSTEMS

Anil Misra is currently a Professor at the University of Kansas, Lawrence. He previously served as a faculty member at the University of Missouri-Kansas City. He received his bachelor's degree in civil engineering from the Indian Institute of Technology, Kanpur, India in 1985, and his M.S. and Ph.D. degrees from the University of Massachusetts at Amherst in 1988 and 1991, respectively. His broad research interest span topics covering basic and applied aspects of engineering mechanics, materials engineering and geo- and bio-mechanics. His primary research has been in the micro-mechanics of granular materials. He has pioneered the method of granular micromechanics with which he seeks to develop generalized continuum model of a range of granular materials and materials with granular texture, including geomaterials, biomaterials, polymers, and architectured/metamaterials bHis research into granular materials began in his graduate studies wherein his Ph.D. dissertation dealt with method to treat the effect of non-affine motions in random grain packings on their macro-scale behavior. This early work formed the foundation of his desire to develop methods that can capture the impact of micro-scale in materials of complex microstructures; structures that occur over a range of spatial scales, are too numerous to characterize and are largely inaccessible through purely experimental techniques. This research has resulted in development of several novel and alternative concepts cutting across analytical, computer simulation and experimental methods.

In an innovative experimental work performed in early 1990s, he measured grain displacements and grain spins in 2D grain packing published in

- Misra, A. and Jiang, H. (1997), "Measured Kinematic Fields in the Biaxial Shear of Granular Materials," Computer and Geotechnics 20(3/4), 267-285.

These measurements showed that displacement fluctuations in these materials organize spatially into finite sized clusters, typically, spanning a few grains. The work remained one-of-a-kind till revisited in 2012 as noted in Richefeu et al. (2012) Geotechnique Letters 2, 113–118.

In more recent works on granular materials he has engaged in micro-macro correlations termed by him as "granular micromechanics". He has applied this approach to develop governing equations, and constitutive relationships for rocks, concrete, soils, asphalt concrete, biological materials, polymers and rock fractures including derivations of higher-order continuum mechanics theories from discrete (particulate/atomistic) descriptions. Among these works are the thermomechanical derivation of rate-dependent damage and plasticity constitutive relations.

- Misra, A. and Singh, V, (2014) "Thermomechanics based nonlinear rate-dependent coupled damage-plasticity granular micromechanics model," Continuum Mechanics and Thermodynamics, 27(4–5), 787–817.
- Misra, A., and Poorsolhjouy, P. (2015) "Granular Micromechanics Model for Damage and

Plasticity of Cementitious Materials Based upon Thermomechanics," Mathematics and Mechanics of Solids, (doi: 10.1177/1081286515576821).

These derivations present some interesting findings with respect to relationship of Cauchy stress and grain-pair forces in granular systems.

To address problems of interest to engineering practice, the derived constitutive relations have been applied to failure of concrete/ cementitious materials and for analysis of permanent deformations of asphalt pavements, see for example

- Poorsolhjouy, P. and Misra, A., (2017) "Effect of Intermediate Principal Stress and Loading-Path on Failure of Cementitious Materials Using Granular Micromechanics," International Journal of Solids and Structures, 108, 139–152
- Misra, A. Singh, V, and Darabi, M. (2017) "Asphalt pavement rutting simulated using granular micromechanics based rate dependent damage-plasticity model," International Journal of Pavement Engineering, (doi: 10.1080/ 10298436.2017.1380804)

Interesting extensions of the "granular micromechanics" homogenization is its application to the derivation of micromorphic model of granular materials which includes the effect of grain spins, discussed in publications such as

- Misra, A., and Poorsolhjouy, P. (2016) "Granular Micromechanics Based Micromorphic Model Predicts Frequency Band Gaps," Continuum Mechanics and Thermodynamics, 28, 215–234 (doi: 10.1007/s00161-015-0420-y).
- Misra, A., and Poorsolhjouy, P. (2015) "Identification of Higher-Order Elastic Constants for Grain Assemblies based upon Granular Micromechanics," Mathematics and Mechanics of Complex Systems; 3(3):285-308. doi:10.2140/memocs.2015.3.285.
- Misra, A., and Poorsolhjouy, P. (2016) "Elastic Behavior of 2D Grain Packing Modeled as Micromorphic Media based upon Granular Micromechanics," Journal of Engineering Mechanics, ASCE, (doi: 10.1061/(ASCE)EM.1943-7889.0001060).
- Misra, A., and Poorsolhjouy, P. (2017) "Grain- and Macro-scale Kinematics for Granular Micromechanics based Small Deformation Micromorphic Continuum Model," Mechanics Research Communications, 81 (2017) 1–6

Many of his works are pioneering and among first forays into the subject matter. Worthwhile to mention along these lines is the study of failure behavior of single crystals from first principle atomistic simulation. It was which shows interesting local deformation

- Misra, A., and Ching, W.Y. (2013) "Theoretical nonlinear response of complex single crystal under multi-axial tensile loading", Scientific Reports, 3, 1488

Although, the atomic system and granular system described above may seem distant from each other, they clearly show that for their continuum modeling similar considerations need to be applied to account for the micro-deformations (or inner motions) of a volume element or a continuum material point. As another example he introduced in an early paper contact orientation as an additional measure of roughness in contact mechanics of rough solids, an aspect which was derived in a more recent paper by considering contact of gaussian rough surfaces

- Misra, A. (1997), "Mechanistic Model for Contact between Rough Surfaces," Journal of Engineering Mechanics, ASCE, 123(5), 475-484.
- Huang, S. and Misra, A., (2013) "Micro-macro shear displacement behavior of contacting rough solids," Tribology Letters, Vol. 51(3), 431-436

In an experimental innovation Misra along with his research collaborators introduced the concept of 'homotopic' measurements to address the data interpretation from non-destructive high-resolution location-dependent complementary measurement of physical, chemical and mechanical properties. See publications

- Marangos, O., Misra, A., Spencer, P., Bohaty, B. and Katz, J.L. (2009) "Physico-mechanical Properties Determination using Microscale Homotopic Measurement: Application to Sound and Caries Affected Primary Tooth Dentin," Acta Biomaterialia, 5, 1338-1348.
- Marangos, O., Misra, A., Spencer, P., and Katz, J.L. (2011) "Scanning acoustic microscopy investigation of frequency-dependent reflectance of acid-etched human dentin using homotopic measurements," IEEE Transactions UFFC, Vol. 58, No. 3, 585-595.
- Misra, A., Marangos, O., Parthasarathy, R., Spencer, P., (2013) "Micro-scale analysis of compositional and mechanical properties of dentin using homotopic measurements", in Biomedical Imaging and Computational Modeling in Biomechanics, Lecture Notes in Computational Vision and Biomechanics, 4, 131-141

He has a deep interest in interdisciplinary research at the intersection of mechanics and material science motivated by the principle that the fusion of knowledge from traditionally separated disciplines will lead to creative approaches for solving problems. His ability to reach out across disciplines meaningfully is attested by his having co-authored with researchers in material physics, dental materials, polymer chemists, see for example works below that introduce new ideas or collect state-of-the-art works:

- Dharmawardhana, C.C., Misra, A., and Ching, W.Y. (2014) "Quantum Mechanical Metric for Internal Cohesion in Cement Crystals", Scientific Reports, 4, 7332
- Singh, V., Misra, A., Parthasarathy, R., Ye Q, Park JG, and Spencer, P. (2013) "Mechanical Properties of Methacrylate Based Model Dentin Adhesives: Effect of Loading Rate and Moisture Exposure," Journal of Biomedical Materials Research Part B, 2013:101B:1437–1443
- Misra, A., Parthasarathy, R., Ye, Q., Singh, V., Spencer, P. (2014) "Swelling equilibrium of dentin adhesive polymers formed on the water-adhesive phase boundary: Experiments and micromechanical model", Acta Biomaterialia, Vol. 10, No. 1, pp. 330-342
- Spencer, P., Misra, A. Eds. (2016) Material-tissue interfacial phenomena Contributions from reconstruction of oral tissues, Elsevier Science, The Netherlands

His ability to transcend basic and applied research is clear. He has collaborated with geotechnical engineers (field of his training in graduate school) to solve problem of uncertainty in the design of deep foundation, and the application of coal combustion products to soil stabilization for which he earned a partnership award from the United States Environmental Protection Agency. He has been a key component of many other successful collaborative engagements. His accomplishments can be seen at his website http://people.ku.edu/~amisra/.

For all exposed reasons the committee, entrusted by the Scientific Committee of the International Research Center MEMOCS with the responsibility of awarding the International Eugenio Beltrami Prize unanimously proposes Professor Anil Misra as recipient of the 2017 edition.