The Raymond D. Mindlin Lecture

Department of Civil Engineering & Engineering Mechanics, Columbia University
Engineering Mechanics Committee, ASCE Metropolitan Section
Engineering Mechanics Institute, ASCE

Challenging the Paradigm of Critical State Soil Mechanics: The Role of Fabric

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Abstract: The paradigm of Critical State Soil Mechanics (CSSM) postulates that at critical state, signified by continuing shear deformation at fixed volume and stress, the stress and void ratios reach appropriately defined critical values with no reference to orientational aspects of the soil fabric, such as particles long axes, contact normal directions or void vectors statistical orientations. However, several soil mechanical response characteristics associated with fabric anisotropy cannot be adequately or even correctly described within the existing theory, while experimental and numerical studies indicate the presence of a strong fabric orientation at critical state.

This presentation will constructively challenge the CSSM paradigm by introducing the hypothesis that an evolving soil fabric tensor must also acquire a critical value for critical state to occur, motivated by relevant 2D DEM measurements of fabric evolution for dry granular assemblies. Relating the evolving fabric tensor to the loading direction by an appropriately defined scalar-valued fabric anisotropic variable A, a dilatancy state parameter ζ is defined in terms of A that characterizes the contracting or dilating trends of the current state. At critical state, A=1, and the ζ becomes identical to the well-known state parameter ψ. Static liquefaction is obtained when ζ=0 with the stress ratio reaching its critical value, but the void ratio and the fabric being far from critical. Simulations of sand response by a triaxial model developed within the new theoretical framework, illustrate the effectiveness of the novel fabric-enhanced critical state theory. The much-debated question of uniqueness of the critical state line in the void ratio - confining pressure space is answered by the new theory in conjunction with Gibb's principle of thermodynamic equilibrium. Effects on practical applications, future research directions and remaining unanswered questions will be briefly discussed.

Biosketch: Yannis F. Dafalias received the diploma in Civil Engineering from the National Technical University of Athens (NTUA) in 1969, the M.Sc. in Engineering Mechanics at Brown University in 1971, and the Ph.D in Engineering Sciences at the University of California at Berkeley in 1975. Currently he holds a joint appointment as Professor at the University of California at Davis and the NTUA. His major field is Continuum Mechanics, with application in the areas of solid and structural mechanics, soil mechanics, and biomechanics. The particular focus of his research is in the plasticity of metals and soils, finite elastic-plastic deformations, inherent and evolving anisotropy, and more recently in turbulence and biomechanics.

He is the recipient of the Walter L. Huber Civil Engineering Research Prize, awarded in 1987 from ASCE, the Foreign Researcher Shield Plate by the Japanese Society of Soil Mechanics and Foundation Engineering in 1991, and the Nathan M. Newmark Medal awarded in 2012 by the EMI and SEI of ASCE. He was invited to deliver the Mindlin Lecture at Columbia University in 2012. In 2011 he was awarded a prestigious IDEAS advanced grant for research from the European Research Council.

He has been invited as visiting Professor, guest lecturer, plenary and keynote speaker in various Universities, Institutions, conferences and workshops. He served as Chair of the Inelasticity Committee of the J. Eng. Mechanics of ASCE and Chair of the Department of Mechanics and Director of the Laboratory of Strength of Materials at the NTUA in 2006-07. He was the Ph.D dissertation advisor, teacher and mentor of students who now hold faculty positions in several Universities, or high-ranking positions at National Labs and international companies. He continues the scientific collaboration with several of them and considers the success of his students as one of his proudest achievements.

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The Department of Civil Engineering and Engineering Mechanics established the Mindlin Lecture to honor the pioneering contributions of Prof. Raymond D. Mindlin to the field of applied mechanics. His research encompassed photoelasticity and experimental mechanics; classical three-dimensional elasticity (e.g., Mindlin's problem); generalized elastic continua (strain-gradient and couple-stress theory); frictional contact and granular media; waves and vibrations in isotropic and anisotropic plates (Mindlin's Plate Theory); wave propagation in rods and cylinders; theory of electro-elasticity and piezoelectric crystal resonators, and crystal lattice theories.

A member of the National Academy of Engineering and the National Academy of Sciences, Prof. Mindlin received the National Medal of Science for applied mechanics and mathematics in 1979. He had been awarded the Medal for Merit in 1946, by President Harry S. Truman, for his work in developing the radio proximity fuse, a detonator for weapons used in offensive warfare that was a significant factor in World War II. ASCE created the **Mindlin Medal** in 2009.