Tsinghua University Seminar Series on Rock Mechanics

清華大学 土木水利学院
SCHOOL OF CIVIL ENGINEERING
TSINGHUA UNIVERSITY

Schedule (Zoom ID: 806 403 8955 / Code: 287 696)

Beijing Time	Speakers	Titles
Dec 11, 2020 8:00 AM	Prof. Chandrakant S. Desai	DSC constitutive and computer modeling in geomechanics
Dec 15, 2020 10:00 AM	Prof. Alexander H-D Cheng	Intrinsic material constants for poroelastic rocks
Dec 17, 2020 4:00 PM	Prof. Jean Sulem	Multiphysics processes during seismic slip: Field observations and modelling
Dec 18, 2020 4:00 PM	Prof. Charlie Chunlin Li	Stabilization of high engineering rock slopes – passive or active ground support?
Dec 20, 2020 4:00 PM	Prof. Robert W. Zimmerman	Failure of anisotropic rocks such as shales, and implications for borehole stability

Chair: Prof. Qiang Yang Secretary: Dr. Zhihong Zhao (zhzhao@tsinghua.edu.cn), Dr. Yuedu Chen (reading0901@tsinghua.edu.cn)

Chandrakant S. Desai

Regents' Professor (Emeritus), University of Arizona, Tucson, AZ, USA
The Founding President of the International Association for Computer Methods and Advances in Geomechanics (IACMAG)

He has made original and significant contributions in basic and applied research in material-constitutive modeling, laboratory testing, and computational methods for a wide range of problems in civil engineering (Geomechanics, structural dynamics, earthquake geotechnical engineering), engineering mechanics, flow through porous media, and mechanical engineering (electronic packaging). One of the main topics of Dr. Desai's research involves development of the innovative and unified disturbed state concept (DSC) for constitutive modeling of materials and interfaces/joints, e.g. soils, rocks, glacial tills, concrete, asphalt, metals, alloys, silicon with impurities, polymers and lunar. He has authored/edited about 24 books, 20 book chapters, and has been author/coauthor of about 345 technical papers in refereed journals and conferences. He has been the founding General Editor of the International Journal for Numerical and Analytical Methods in Geomechanics (1977-2000). He is the founding Editor-in-Chief of the International Journal of Geomechanics (2001-2008. Dr. Desai has the unique honor for receiving two prestigious awards from Geo-Institute (Terzaghi award), and Engineering Mechanics and Structural Engineering Institutes (Newmark medal), ASCE, recognizing his interdisciplinary contributions.

DSC Constitutive and Computer Modeling in Geomechanics

Chandrakant S. Desai (University of Arizona)

Abstract:

(1) Importance of Constitutive Modelling for geomaterials and interfaces/joints

(2) A brief outline of various constitutive models and their limitations,

(3) Need for advanced and appropriate models

(4) Detailed description of the Unified Disturbed State Concept (DSC) with HISS plasticity

(5) Applications, specifically in rock mechanics: (I) Underground Cavities, and (II) Wellbore stability in rocks

(6) Conclusions

Alexander H.D. Cheng

Emeritus Dean of School of Engineering, University of Mississippi
Chair of Department of Civil Engineering, University of Mississippi
Former president of Engineering Mechanics Institute of ASCE
Former Vice President of Academic Affairs of American Institute of Hydrology

He authored and coauthored 5 books, including *Poroelasticity*, *Modeling Groundwater Flow and Contaminant Transport*, and *Trefftz and Collocation Method*. He also edited 4 books, including *Seawater Intrusion in Coastal Aquifers*, and published over 180 journal articles. He is the Editor-in-Chief of Engineering Analysis with Boundary Elements (Elsevier), Associate Editor of Transport in Porous Media (Springer), and Journal of Mechanics (Cambridge). He was the recipient of the George Green Medal, the Maurice A. Biot Medal, the Walter L. Huber Civil Engineering Research Prize of ASCE, and the Basic Research Award of U.S. National Committee for Rock Mechanics.

Intrinsic Material Constants for Poroelastic Rocks

Alexander H.D. Cheng (University of Mississippi, USA)

Abstract: Biot and Willis (1957) performed micromechanical analysis on isotropic poroelastic materials and presented three material constants, the jacketed compressibility, the unjacketed compressibility, and the coefficient of fluid content, to characterize the volumetric deformation. Nur and Byerlee (1971) and Rice and Cleary (1976) recast them into a drained bulk modulus K, an unjacketed bulk modulus K's, and an unjacketed pore modulus K"s. The constant K"s is tied to the storage capacity of porous medium; hence is highly important in petroleum and geosequestration applications. It is, however, difficult to measure in the laboratory due to the lack of a direct way to observe pore volume deformation.

In this work, a physics based approach is used to explore these micromechanical constants. Three intrinsic material constants that isolate the physical mechanisms, an unjacketed solid bulk modulus Ks, a drained pore modulus Kp, and a micro inhomogeneity and anisotropy modulus $K\psi$, are presented to characterize the porous material. Bounds on material constants are developed based on thermodynamics and elastic stability requirements. Past attempts in measuring K"s using direct or indirect approaches are compiled. Most of the efforts failed to satisfy the theoretical bounds. Only those attempted to measure the change in pore volume passed the test. The intrinsic constants are used to interpret the bulk material constants, such as the drained and undrained bulk modulus, the storage and Skempton pore pressure coefficient. The total volume change and the storage capacity can be partitioned into those attributed to the solid, pore, and fluid compressibilities, and the microinhomogeneity effect. A published data set on stress dependent Skempton pore pressure coefficient and bulk modulus is analyzed. The data are matched by the intrinsic material constant model through the calibration of a single $K\psi$ value.

Jean Sulem

Professor and Research Director at Ecole des Ponts ParisTech
Director of Laboratoire Navier
Past-President of the French Society of Rock Mechanics
Editor-in-chief of Rock Mechanics and Rock Engineering (Springer)

His research interests are related to Bifurcation Theory applied to stability and strain localisation analyses, Constitutive Modelling of geomaterials, Experimental Rock Mechanics, Thermo-Hydro-Mechanical Behaviour of Geomaterials with applications to Tunnelling, Petroleum Engineering, Deep Geological Storage, Fault Mechanics. He has published 110 papers in peer-reviewed journals and 3 books (Vardoulakis, I. and Sulem, J. , 1995, *Bifurcation Analysis in* Geomechanics, Taylor & Francis, Hatzor Y., Sulem J., Vardoulakis I. 2009, *Meso-scale Shear Physics in Earthquake and Landslide Mechanics*, Taylor & Francis, M. Panet & J. Sulem, 2020, *Le calcul des tunnels par la méthode convergence-confinement*, Presses des Ponts et Chaussées). In 2018, Jean Sulem received the Vardoulakis lecture Award from the University of Minnesota.

Multiphysics processes during seismic slip: Field observations and modelling

Jean Sulem (Laboratoire Navier, Ecole des Ponts ParisTech, Université Gustave Eiffel, CNRS, France)

Abstract: Field observations of exhumed mature faults and outcrops, i.e. faults that have experienced a large slip, have evidenced that shear deformation is often localized in very narrow slip zones. This strain localization is seen as the result of various weakening mechanisms induced during seismic slip. These weakening mechanisms may correspond to a mechanical degradation of the rock properties (micro-cracking, grain crushing and grain size reduction…), but various other physical processes can be responsible for it. The effect of shear heating in a fluid saturated fault zone leads to pore-fluid pressurization due to the discrepancy between the thermal expansion of water and solid grains. Chemical reactions such as dissolution/precipitation, mineral transformation at high temperature (dehydration of minerals, decomposition of carbonates, …) affect the solid phase of the rock, sometimes release a new fluid phase in the system and can induce a positive feedback in the progressive mechanical degradation. The width of the deforming zone is actually a key parameter, as narrow deforming zones concentrate the frictional heating, which leads to large temperature rises and thus to more rapid weakening. It also controls the multi-physics couplings which occur during dynamic slip. Thermo-chemo-mechanical couplings are nowadays more and more identified as factors that play a central role in the mechanical behavior and the evolution of localized deformation zones. Important challenges and questions are still open, which span from the qualitative understanding of the main phenomena to their quantitative description and observation. In this talk, we will present some recent results on analytical and numerical modelling of strain localization processes under multi-physical couplings and discuss the geophysical implications of these instabilities for earthquakes nucleation.

Charlie Chunlin Li

Professor in rock mechanics at the Norwegian University of Science and Technology, Norway

member of the Norwegian Academy of Technological Sciences (NTVA)

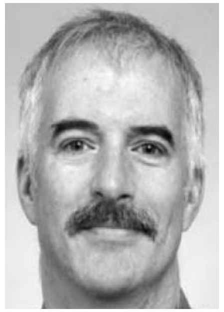
ISRM Vice-President for Europe (2015-2019)

His work experience includes research associate and associate professor in LUT, ground control engineer in Boliden Mineral Ltd., Sweden, chief technical officer in Dynamic Rock Support AS, Norway, and professor in NTNU. His expertise is in stability analyses of underground spaces and ground control. In the last two decades, his research interest has been focused on the performance of rockbolts and rock support in difficult rock conditions. He invented the D-bolt that has been worldwide used for rockburst control in deep underground mines. He published a book entitled Rockbolting – Principles and Applications in 2017.

Stabilization of high engineering rock slopes – passive or active ground support?

Charlie Chunlin Li (Norwegian University of Science and Technology, Norway)

Abstract: Reinforcement of engineering rock slopes is expensive and has to be carried out selectively when necessary. Now and then in the past practice critical sliding planes were not reinforced or inappropriate methodologies were employed, which led to collapses of the rock slopes and even caused casualties. In the lecture, the presenter will first demonstrate a few relatively large-scale slides of engineering rock slopes in Norway as well as the misjudgments in stability analysis and the inadequate reinforcement measures. One of the slide cases occurred in high road cut of a busy highway nearby the capital city Oslo in the end of 2019. The slide triggered a nationwide concern how to improve the rock support of high engineering rock slopes excavated in competent rock mass. The performance of the major reinforcement devices (rockbolts and cablebolts) in the rock slope ground is then presented, which is helpful to understand how rockbolts/cablebolts should be installed in order to most effectively reinforce the rock slopes. Finally, the consequences of passive and active reinforcement are discussed and the advantages of the active reinforcement are illustrated.



Robert W. Zimmerman

Professor of Rock Mechanics at Imperial College in London

Editor-in-Chief of the International Journal of Rock Mechanics and Mining Sciences (2006-)

MTS Visiting Professor of Geomechanics at University of Minnesota (2011)

He conducts research on the hydromechanical behaviour of fractured and porous rocks, fluid flow in porous media, and rock failure and fracture, with applications to petroleum engineering, underground mining, radioactive waste disposal, and carbon sequestration. He is the author of the monograph Compressibility of Sandstones (Elsevier, 1991), the co-author, with JC Jaeger and NGW Cook, of Fundamentals of Rock Mechanics, 4th ed. (Wiley-Blackwell, 2007), and the author of the textbook Fluid Flow in Porous Media (World Scientific, 2018). In 2010 he was awarded the Maurice A. Biot Medal for his “outstanding contributions in applying poroelasticity to rock mechanics and fluid flow in fractured media.” He has given plenary keynote lectures at numerous international conferences, most recently the 1st International Conference on Geomechanics, Geo-energy and Geo-resources (Melbourne, 2016), the 9th International Conference on Porous Media (Rotterdam, 2017), and the 9th Asian Rock Mechanics Symposium (Singapore, 2018).

Failure of anisotropic rocks such as shales, and implications for borehole stability

Li Robert W. Zimmerman (Imperial College, London)

Abstract: In anisotropic rocks such as shale, the value of the maximum principal stress required to cause shear failure depends not only on the other two principal stresses, but also on the angle β between the maximum principal stress and the normal to the bedding plane. According to Jaeger's plane of weakness model, for β near 0° or 90° , failure will occur at a stress determined by the failure criterion for the "intact rock", and the failure plane will cut across the bedding planes. At intermediate angles, failure will occur along a bedding plane, at a stress determined by the strength parameters of the bedding plane. Data were analyzed from a set of triaxial ($\sigma_2 = \sigma_3$) compression tests conducted on a suite of shale samples, at different confining stresses, and a range of angles β, and it was found that the data could be fit reasonably well with the four-parameter plane of weakness model. Based on these results, a model has been developed for the stability of boreholes drilled in shales. The fully anisotropic Lekhnitskii-Amadei solution is used to compute the stresses around the borehole wall. The Mogi-Coulomb failure criterion is used for the strength of the "intact rock", and the plane of weakness model is used for the strength of the bedding planes. The model can be used to predict the minimum mud weight required to avoid shear failure, for arbitrary borehole orientations and anisotropy ratios. The results show the importance of using a fully anisotropic elastic model for the stresses, and a true-triaxial failure criterion, in borehole stability analysis.

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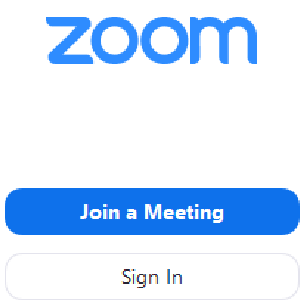

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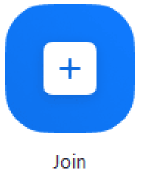

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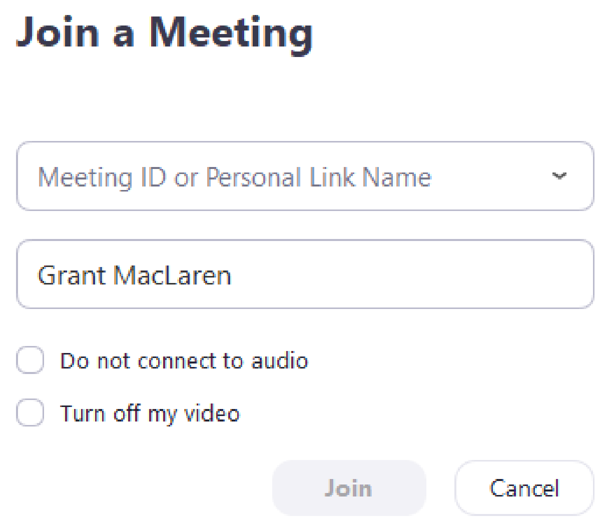

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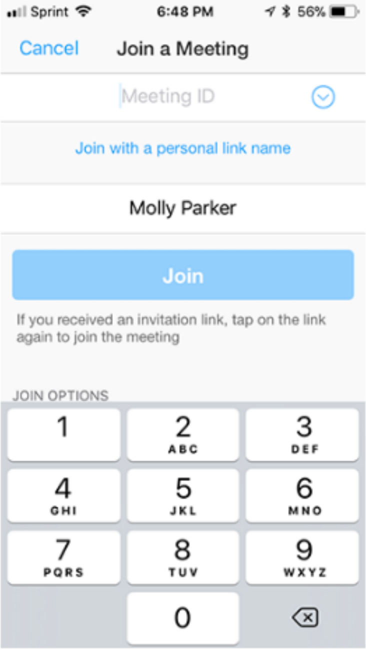

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