
The Geo-Institute Rock Mechanics and Engineering Technical Committee will live-stream the *session* *<u>"Emerging Applications of Rock Mechanics and Engineering"</u>* on Tuesday, December 9, at 11 AM EST. The talks include:

**Talk #1: *<u>Shales as barriers in geoenergy projects</u>* (Presented by Dr. Roman Makhnenko, Ph.D.)**

*Claystones or shales are the most abundant sedimentary rocks in the shallow subsurface. While formations with 10-30% clay content are explored for unconventional petroleum purposes, the materials with higher clay content are considered as barriers for fluid flow in geo-energy projects, such as CO2 and H2 storage or deep disposal of nuclear waste. The appropriate shale formations should have dominant pore sizes on the order of nanometers and their sealing capacity is determined by high non-wetting fluid entry values, low permeability, high ductility, which varies with mechanical, thermal, and chemical disturbances over time. The potential leakage can happen through diffusion or permeation through faults, fractures, or pore spaces. The characterization of the hydro-mechanical behavior of shales is involved even when saturated with just one fluid because of very long experimental times and high sensitivity to environmental factors such as temperature or pore fluid chemistry. The unsaturated poromechanical properties are even more difficult to measure because the solid, pore, and fluid compressibility cannot be neglected and the degree of saturation should be controlled. On top of that, natural shales are anisotropic and often times heterogeneous even at core scale, which has a strong effect on their mechanical and especially flow properties such as permeability and non-wetting fluid entry pressure. Despite the long duration of the characterization procedures for coupled processes in shales (weeks to months at the laboratory scale and months to years at the field scale), these tasks need to be undertaken enabling building of realistic models and making accurate predictions for geoenergy projects. In this presentation, the results of a comprehensive laboratory study of shale-like materials are discussed. Eau Claire Shale and Maquoketa Shale formations serve as caprocks for CO2 storage in Illinois Basin, while Upper Ironton/Galesville is under consideration to be a sealing layer for the hydrogen storage. Opalinus Clay is being investigated as a host rock for nuclear waste disposal. Experimental methods are developed to characterize the short- and long-term effect of thermo-hydro-mechanical loading on shales, while controlling their degree of saturation to measure the poromechanical and multi-phase flow parameters. The effect of mineral composition and presence of heterogeneities, including fractures, on the mechanical response and sealing capacity is investigated under varying effective mean stress, pore pressure, and temperature. The implications of using shales as barriers for advective and channeled fluid flow, including CO2 injection, are presented for representative in-situ conditions. The upscaling to the underground lab (meter scale) and pilot field CO2 storage projects (kilometer scale) are achieved through a combination of high-performance finite element modeling and machine learning.*

**Talk #2: *<u>Determination of elastic constants and crack propagation thresholds of brittle rocks: Insights across elastic and plastic regimes</u>* (Presented by Dr. Hua Yu, Ph.D., P.E., M.ASCE)**

*Elastic constants and crack propagation stress thresholds of brittle rocks are important mechanical properties for engineering applications. However, these properties are currently determined using methods with subjective interpreting* *procedures, which create cognitive biases leading to a higher degree of uncertainties. In this study, triaxial compression tests were conducted on Weber Sandstone collected from the Rock Springs Uplift, Wyoming. Nine rock specimens were treated in different geochemical conditions and tested for three different confining pressures at an in-situ pore pressure and temperature. A new method is proposed to systematically determine elastic constants and crack stress thresholds using linear and cubic regression functions to describe the linear and nonlinear stress-strain elastic behaviors, respectively. The statistical approach implemented in this new method eliminates bias due to the subjective interpretation of the nonlinear stress-strain data. The proposed method improves the consistency of elastic constant determinations by considering the linear elastic boundary of rocks and unambiguously determines the crack initiation threshold using the cubic regression function. Eliminating the subjectivity in data analysis, the new systematic method is beneficial for studying the nonlinear rock behavior and facilitating engineering applications.*

**Talk #3: *Rock mechanics for underground hydrogen storage* (Presented by Ehsan Dabbaghi, S.M.ASCE and Dr. Kam Ng, Ph.D., P.E., M.ASCE)**

As the world accelerates toward a low-carbon future, hydrogen has emerged as a critical energy carrier, but how and where we store it is just as important as how we produce it. One promising solution is the underground. This presentation will provide a comprehensive overview of underground hydrogen storage (UHS), exploring why it's vital for large-scale, long-term hydrogen deployment. We'll begin with a general introduction to UHS, followed by a discussion of its key benefits, such as energy security, decarbonization support, and balance in energy sources. The session will then explore where UHS can be implemented, including suitable geological formations like salt caverns and porous media, and highlight global case studies and recent research efforts in this field. Attendees will also gain insight into experimental approaches used to simulate subsurface storage conditions, including a look at specialized equipment and testing conducted in the lab. Finally, we'll consider future directions, and research needs to help scale and optimize this technology. This presentation will show how UHS connects scientific research with real-world energy needs, and how our civil engineering communities can support a cleaner, more reliable energy future.

**Talk #4: *Instability mechanisms in jointed rock slopes concerning the pattern of the natural fracture network* (Presented by Dr. Shahrzad Roshankhah, Ph.D., P.E.)**

The stability of jointed rock slopes is essential for maintaining the sustainability and resilience of civil infrastructure and nearby communities. The mechanical behavior of these slopes is controlled by complex interactions among the natural fracture (NF) network, the intact rock matrix, and external boundary conditions. Environmental factors such as weathering gradually weaken both the rock matrix and the NFs, potentially leading to the progressive collapse of the entire slope. Traditional numerical methods for slope stability analysis—specifically the strength reduction method—typically assume that shear strength properties (cohesion and friction) only degrade uniformly across both the fractures and the rock matrix. However, this study demonstrates that such assumptions tend to overestimate the factor of safety (F.S.) and underestimate the potential impacts of failure, including runout distance, displaced material volume, and runoff velocity. In reality, all strength parameters—including cohesion, friction, tensile strength, and fracture toughness—of the rock mass deteriorate over time. Our findings further indicate that the contributions of the NFs and the rock matrix to slope stability differ and are strongly influenced by the internal structure of the rock mass, i.e., the pattern of the natural fracture network.