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Understanding Fracture Processes in Heterogeneous Rock Systems

Dr. Lie Kong, The University of Manchester

Physical and mechanical properties of the tectonic basin located at the subduction zone

Dr. Nana Kamiya, Kyoto University

Genetic Discrete Fracture Network Modeling for High-Fidelity Network Representation

Dr. Jineon Kim, Seoul National University

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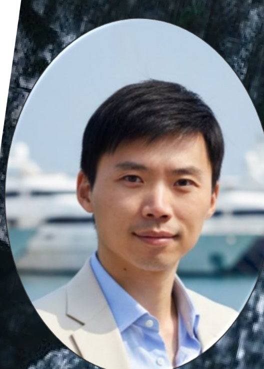
Understanding Fracture Processes in Heterogeneous Rock Systems

Abstract

Heterogeneity is a defining characteristic of natural rock systems and plays a fundamental role in controlling fracture evolution and failure. From grain-scale mineral variations to larger-scale discontinuities, heterogeneity governs the mechanical and hydraulic behaviour of rocks and influences subsurface engineering performance. This talk explores how material and structural heterogeneity govern fracture processes through numerical investigations of fluid-driven fracturing and shear rupture. A coupled hydro-mechanical grain-based discrete element modelling (Hydro-GBM) framework has been developed to explicitly represent rock heterogeneity and capture the coupled evolution of deformation, fluid flow, and fracturing. Case studies include fluid-driven fracture processes in heterogeneous rocks under varying hydraulic and mechanical conditions, and the shear rupture of heterogeneous fault veins are presented. These examples demonstrate how heterogeneity influences fracture complexity, damage localisation, fluid transport, fault slip behaviour, and associated micro-seismicity. The talk concludes with perspectives on advancing predictive fracture geomechanics through improved representation of geological heterogeneity and its implications for geo-energy and subsurface engineering systems.

Speaker

Dr Lie Kong is a Postdoctoral Research Associate at The University of Manchester, UK. He holds a PhD in Civil Engineering from Monash University, Australia. His research aims to understand how geological heterogeneity governs fracture processes and coupled multi-physical behaviour in subsurface systems. Combining physics-based numerical modelling, laboratory experimentation, and advanced characterisation, he develops predictive frameworks for fracture evolution, coupled multi-physical processes, and subsurface system behaviour. His research contributes to addressing fundamental and applied challenges in geo-energy and subsurface engineering systems. Dr Kong has published in leading journals including JGR: Solid Earth, Engineering Geology, International Journal of Rock Mechanics and Mining Sciences, and Rock Mechanics and Rock Engineering, with two papers recognised as ESI Highly Cited Papers. He currently serves as a Guest Editor for the Journal of Rock Mechanics and Geotechnical Engineering and holds editorial roles with several international journals. His research has been supported through competitive funding and access to national research facilities. He is also actively engaged in international research collaborations and professional activities within the geomechanics and subsurface engineering communities.



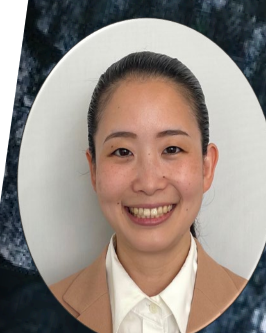
Physical and mechanical properties of the tectonic basin located at the subduction zone

Abstract

My motivation of this research comes from the question which is “How does consolidation progress at the subduction zone?” The consolidation is advanced by the overburden pressure at the silent depositional basin; however the lateral compression stress would relate to consolidation at the tectonic basin. Therefore I’m interested in the consolidation process under these complex conditions. I have performed the consolidation test using sedimentary soft rocks to answer this questions and discuss the tectonic process. Additionally, anisotropy of the physical and mechanical properties were measured to understand the development the micro structure related to the meso and macro scale tectonics. Consolidation yield stress reflects the burial processes even if sedimentary soft rocks. Furthermore, I found that information such as excess pore pressure during the development of tectonic basin is recorded in the sedimentary soft rock. When I compare the anisotropy of the properties between tectonic and non-tectonic basin, there is clear difference related to the paleo-maximum stress. I expect that a deeper understanding of complex consolidation mechanisms will lead to new insights into mass transport within rock masses.

Speaker

Dr Nana Kamiya is an Assistant Professor at the Department of Urban Management, Graduate School of Engineering, Kyoto University. She holds a MSc in Earth Sciences from Nihon University, and a Ph. D. in Resource Engineering from Kyoto University, Japan. Her research focuses on the physical properties and mechanical properties to understand the tectonics at the subduction zone. Her main focus includes consolidation test using sedimentary soft rocks taken from the outcrop and/or drilled core.



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Genetic Discrete Fracture Network Modeling for High-Fidelity Network Representation

Abstract

Fracture networks control the hydraulic and mechanical behavior of rock masses, with direct implications for nuclear waste disposal, geothermal energy, and groundwater management. Conventional Poisson-based discrete fracture network (DFN) models generate unrealistic topologies dominated by X-shaped crossing intersections, whereas natural systems exhibit Y-shaped abutting intersections. This misrepresentation can introduce significant errors in predicting flow and transport behavior. To address this, a genetic DFN (G-DFN) modeling framework is developed that incorporates simplified kinematic growth rules to generate high-fidelity networks while remaining practical at the field scale. Drawing on field evidence for Charles's law growth and contact-driven arrest, a polygon-based algorithm is developed in which fractures grow and arrest upon contact with larger fractures, allowing realistic topologies to emerge without imposed truncation or target sizes. Model parameters are linked to observable trace map features through a two-stage calibration scheme. Applied to the Korea Underground Research Tunnel (KURT), a generic research site for nuclear waste disposal, the G-DFN and Poisson DFN approaches produce distinct geometries despite identical calibration data, with G-DFN models more accurately reproducing the magnitude and variability of field-observed hydraulic conductivity and exhibiting stronger flow channeling toward large fractures. These results support G-DFN modeling as an alternative to conventional DFN frameworks.

Speaker

Dr Jineon Kim is a postdoctoral researcher at the Rock Mechanics & Rock Engineering Laboratory, Department of Energy Systems Engineering, Seoul National University. He holds a B.S. in Energy Resources Engineering and a Ph.D. in Rock Mechanics from Seoul National University, where he graduated with distinction. His research focuses on high-fidelity discrete fracture network modeling, rock discontinuity analysis, and automated fracture surveying using computer vision and deep learning.