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EVALUATION OF RAINFALL-INDUCED SLOPE STABILITY USING PHYSICS-INFORMED NEURAL NETWORK (PINN) APPROACH

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Assoc Prof Geoff Chao
President, SEAGS

3 NOVEMBER 2025
4.00PM

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MGS Webinar - Assoc Prof Geoff Chao

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SYNOPSIS

Rainfall-induced slope failure is one of the most challenging natural hazards that commonly occurs after intense rainfall events in mountainous areas. Rainfall intensity, soil/rock properties, and configuration of the slope have been widely accepted as the key controlling parameters in rainfall-induced slope failure. From a geotechnical perspective, failure could occur when heavy rainfall increases infiltration, reduces soil suction in unsaturated soils, and consequently lowers slope stability. The relationship between suction and water content is defined as the soil-water characteristic curve (SWCC), which links hydrologic changes to mechanical response. Thus, if rainfall-driven changes in soil water content can be predicted, slope stability can be assessed.

This study develops and evaluates a physics-informed neural network (PINN) that embeds Richards' equation and assimilates observations to predict soil-moisture profiles in unsaturated slopes under rainfall. Laboratory experiments used a physical slope model filled with red clayey sand and white sandy clay, subjected to controlled rainfall intensities (10, 50, and 90 mm/h) and slope angles (0°, 15°, 30°). Soil properties, including SWCCs, were determined experimentally, and finite-element method (FEM) simulations were calibrated to the observations. The PINN was first trained using observations only, then extended to a hybrid scheme that combined FEM outputs with observations. The observation-only PINN captured overall infiltration trends but produced smoother, less accurate wetting fronts, especially at greater depths. In contrast, the hybrid PINN improved accuracy, resolving infiltration dynamics and wetting-front propagation more effectively, with lower error metrics and closer agreement with both observations and FEM results. These findings suggest that denser sensor networks and richer observational data could further enhance PINN performance and support real-time landslide hazard assessment.Overall, the study shows that PINNs can reasonably predict soil water content and thereby enable stability evaluation for various rainfall events.

SPEAKER BIODATA

Geoff Chao, Ph.D., P.E. has over 30 years of geotechnical and construction engineering experience. He received his Master and Ph.D. degrees from Colorado State University, Fort Collins, Colorado, USA in 1995 and 2007, respectively. He is currently the Department Head of the Civil and Infrastructure Engineering at the Asian Institute of Technology (AIT) in Bangkok, Thailand. He is also currently the President of the Southeast Geotechnical Society. Before joining AIT, he was the Vice President of Engineering Analytics, Inc., a geotechnical and environmental engineering consulting company in Fort Collins, Colorado, USA. Dr. Chao has extensive experience in the areas of geotechnical and reclamation engineering design, construction and design defect investigations, ground improvement, construction remediation and mitigation, construction oversight experience on a diversity of projects. His technical specialties include expansive and collapsible soils evaluation, unsaturated soil modeling, soil/ground improvement methods, landslide/debris flow investigation, soil-foundation interaction, soil behavior under dynamic loadings, and mining reclamation. Dr. Chao was an Adjunct Professor at Colorado State University. He is the co-author of a textbook titled "Foundation Engineering for Expansive Soils." Dr. Chao has authored over 50 technical papers, many of them dealing with structures on problematic soils.

CONTACT US

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