ID 169: An Analytical Model for Consolidation in Unsaturated Two-Layer Soils

10:10 AM – 10:30 AM

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This study develops analytical solutions for consolidation in an unsaturated two-layer soil system subjected to a time-invariant surface stress. Within the framework of unsaturated poroelasticity, the governing equations are formulated to describe the coupled behavior of the solid skeleton, pore air, and pore water phases. The model captures the evolution of excess pore air pressure, excess pore water pressure, and the associated time-dependent total settlement of the soil system. Continuity of pore pressures and fluid fluxes is imposed at the interface between the two soil layers to ensure consistency of the coupled hydro-mechanical processes.

The governing equations consist of coupled partial differential equations describing the interactions between the solid deformation and the pore-fluid pressures in partially saturated soils. To facilitate analytical treatment, appropriate normal-coordinate transformations are introduced to decouple the system into independent modes. The transformed equations are subsequently treated using Laplace transformation in time and Fourier expansion in space. Through this procedure, the boundary-value problem is reduced to a set of ordinary differential equations that admit closed-form solutions.

The resulting analytical framework provides explicit expressions describing the spatial and temporal evolution of pore pressures and total settlement within each soil layer. The solutions establish a theoretical basis for investigating consolidation behavior in layered unsaturated soils and provide a useful benchmark for verifying numerical models developed for coupled hydro-mechanical processes in partially saturated porous media.

Speaker

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ID 178: Experimental investigation of the behaviour of a shallow energy wall in a PCM-improved ground

10:30 AM – 10:50 AM

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Energy geostructures represent an innovative type of earth-contact structures capable of simultaneously fulfilling structural and energy-related functions by integrating load-bearing elements with the exploitation of shallow geothermal energy. By avoiding dedicated drilling operations, these systems facilitate the deployment of renewable energy solutions in dense urban environments. Despite their potential, the widespread application of energy geostructures for heating and cooling applications and underground thermal energy storage is still limited by several challenges. In particular, installations at shallow depths are strongly affected by seasonal temperature fluctuations, while the close proximity of more geothermal systems in urban settings may lead to thermal interferences, resulting in progressive efficiency losses.

To address these issues, a prototype of a shallow energy wall, named Geothermskin, has been developed at the Politecnico di Torino to investigate underground heat exchange and storage through energy geostructures. The prototype includes six thermally activated geothermal modules grouped in pairs to obtain three independent experimental fields separated by thermal insulating panels, to prevent the occurrence of thermal interactions between adjacent systems.

In one of the three experimental fields, phase change materials (PCMs) were distributed into the soil layers facing the energy wall with the objective of enhancing the heat storage capacity and thermal inertia of the geomaterial. By exploiting latent heat storage, the geomaterial mixed with PCM is expected to mitigate the temperature fluctuations induced by heat extraction and to reduce thermal depletion of the ground reservoir to maintain the efficiency of the shallow geothermal system. An experimental campaign is currently underway, which includes both daytime heat extraction and nighttime underground heat storage operations.

This contribution presents the results of some selected tests from the ongoing experimental campaign carried out to understand the role of PCM on the thermal performance of the energy wall and its impact on the heat transfer process in the ground. The preliminary findings provide insights into the role of PCM-enhanced geomaterials in coupled thermo-hydraulic processes relevant to energy geotechnics and highlight the potential of the integration of PCM as a strategy to improve the thermal performance of energy geostructure and the ground for energy applications.

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