DIPARTIMENTO DI INGEGNERIA
STRUTTURALE E GEOTECNICA

SAPIENZA
UNIVERSITÀ DI ROMA

DOTTORATO IN
INGEGNERIA STRUTTURALE E GEOTECNICA

Course for the Doctoral Program in
Structural and Geotechnical Engineering

Failure and Instability in Geomaterials and Geosystems

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ABSTRACT

This 3-day course introduces, at the post-graduate level, the basic principles of material stability analysis, with specific reference to geomaterials such as soil and rock. First, an introduction to the definition and use of different metrics of material instability is given, including second-order work and controllability indices. Analytical techniques to differentiate localized and diffuse failure are then discussed, along with an examination of the implications of shear banding for the numerical analysis of geotechnical problems and examples of possible computational remedies. Afterwards, diffuse instabilities of the liquefaction type and the role of the pore fluids on their initiation are addressed, stressing the role of transitions from unsaturated to saturated conditions. Finally, the relevance of geomaterial instability in the context of landslide geomechanics is addressed. Examples of application spanning from rapid shallow landslides of the flow type to deep-seated creeping landslides are shown, with the goal to highlight the feedback between material instability, inelastic deformation, and the temporal dynamics of landslide motion.

PROGRAM

Fundamentals of geomaterial instability
Definition of failure in plastic geomaterials. Drucker's stability. Hill's stability. Second-order work criterion. Application to geomaterials and limitations. Theory of controllability. Critical hardening moduli. Advantages and disadvantages of different methods.

Strain localization analysis
Experimental observations. 1D examples of strain localization in a layer. Bifurcation theory. The acoustic tensor. Application to elastoplastic constitutive laws. Computational challenges and regularization strategies. Discussion of field-scale events: compaction zones in porous rock.

Liquefaction instability
Experimental observations. Instability domains for soil liquefaction. Role of plastic non-normality. Analytical determination of the instability line. Application to critical state constitutive models. Discussion of field-scale events: underwater flowslides.

Effect of fluid saturation
Basic notions of hydraulic and mechanics of unsaturated soils. Second-order work principle for three-phase porous media. Extension of controllability theory. Use in conjunction with constitutive laws for unsaturated soils. Discussion of field-scale events: rainfall-triggered shallow landslides.

Dynamics of landslide motion
Effects of soil instability on pore pressure dissipation. Feedback between consolidation and runout. Role of the constitutive law on the post-failure landslide dynamics. Application to flowslides: role of plastic flow and critical state on landslide mobility. Application to creeping landslides: role of soil dilatancy and past stress history on seasonal velocity. Final remarks.

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