ED 398 Géosciences, Ressources Naturelles et Environnement
Proposition de sujet de thèse pour la rentrée universitaire 2021-2022

Les glissements et les instabilités de pente du plateau du Larzac : intégration de la géologie structurale dans la modélisation mécanique des massifs rocheux

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Landslides and incipient slope instabilities of the Larzac plateau : structural geology integration into rock mechanics modelling

Description du projet de thèse

The southern border of the Larzac plateau (Lodève site, Lergue river valley) is affected by widespread rock falls along carbonate cliffs, areas with incipient slope failures and several active (slow) deep-rooted landslides at a rate of a few mm/year (Denchik et al., 2019). Despite the slow motion, these landslides constitute an important hazard due to their close location to bridges, human dwellings, agricultural lands and roads, as the A75 motorway, often disrupted by rock falls and sliding. No historical records exist of the initial activity but according to the geomorphology they would be post Wûrm (Denchik et al., 2019).

Most of the landslides share a common geological context: their headwall scarps outcrop on the Jurassic (Hettangian and Bajocian/Bathonien) carbonate series (Larzac plateau) lying ontop of Jurassic (Toarcian) or Triassic (Norian) clays, where sliding surfaces develop. Karstification of the carbonate series is important, with the formation of sinkholes, which seems facilitate cliff formation, rock falls and toppling, as in the Pas de l'Escalette. The carbonate cliffs present along the several valleys (Lergue river, Laurounet river...) are rooted in the mechanical contrast between the Jurassic (hard) carbonate series and the (weak) Toarcian and Norian clays. Moreover, the Larzac plateau is affected by a dense network of joints formed during the tectonic events that affected the area, including the Jurassic and Oligocene extensions and the Pyrenean compression.

An important effort in monitoring of the most active landslide (Pegairolles de l'Escalette) undertaken by the OMIV has revealed the presence of two slip zones localising deformation within evaporite rich levels. Evaportites would act as preferential water pathways, recording rapid transfer of hydraulic pressure during large rainfall events (Denchik et al., 2019). The particular hydrology of the area characterised by seasonal heavy rainfall events (*cevenols*) imposes a complex interaction of potential geological factors (contrasted lithologies, fractures/joints) with the hydrogeology of the Lodève site.

The main goal of this PhD project is to constrain the causal factors of the landslides and incipient instabilities affecting the southern border of the Larzac plateau. The methodology implemented will include field work and slope stability analyses (through numerical simulations) and will illustrate the relevance of integrating structural geology in rock mechanical analyses. In order to achieve the aim of the project, the following working hypothesis are suggested:

Are head scarps and sliding surfaces controlled by joints? An important characteristic for understanding landslide mechanics is the geometry describing the slope failure. In order to reconstruct the pre-slide conditions, the structural control of the geometry will be addressed.

How many family of joints affect the southern border of the Larzac plateau? According to the tectonic context, two main families are present. A comprehensive field work to characterise the structural geology needs to be carried out to identifythe geometry of the joint network and quantities parameters of jointing within the the investigated series.

What is the most suitable mechanical model to describe the observed active landslides? Classical Mohr-Coulomb failure criteria used for slope stability analyses enables the integration of structural observations. Quantitative description of discontinuities is fundamental in rock mass characterization and slope stability analyses (Mahé et al., 2014). Furthermore, hard carbonates do not show the same mechanical (frictional) behaviour than soft clays or soft clays with evaporites (viscoelastic). The PhD work will investigate the best model to describe failure mechanisms characterizing geological medium with rheology.

Which are the mechanical properties of the involved lithologies? According to the failure criteria considered, the properties involved in the slope stability analyses may vary. A field approach based on strength measurements using a Rockschmidt hammer will be used to estimate Rock Mass Rating and others parameters to qualify the rock mass as a first attempt. Moreover, discrete measurements of elastic properties on carbonate and clay samples (collected during the field work) will be used to improve the mechanical characteristics selected.

Which are the pore pressures required to increase the landslide motion during heavy rainfall periods? For different rainfall events, the role of pore pressure transfers along discontinuities (lithological or mechanical) on the mobilisation of active landslides will be analysed.

Can we predict the evolution of incipient slope failures? The integration of the structural geology and the slope stability analyses including the hydrogeology will allow to perform probabilistic analyses to predict the critical conditions that would bring incipient failures to evolve into landslides.

The listed working hypotheses will be certainly reviewed according to the experience and critical point of view of the candidate.

References:

Denchik, N., Gautier, S., Dupuy, M., Batiot-Guilhe, C., Lopez, M., Léonardi, V., Geeraert, M., Henry, G., Neyens, D., Coudray, P., & Pezard, P. A. (2019). In-situ geophysical and hydro-geochemical monitoring to infer landslide dynamics (Pégairolles-de-l'Escalette landslide, France). Engineering Geology, 254(January 2018), 102–112. https://doi.org/10.1016/j.enggeo.2019.04.009

Mahé, S., Gasc-Barbier, M., & Soliva, R. (2014). Joint set intensity estimation: comparison between investigation modes. Bulletin of Engineering Geology and the Environment, 74(1), 171–180. https://doi.org/10.1007/s10064-014-0572-1

Compétences et connaissances requises :

Good knowledge in structural geology, rock and soil mechanics. Skills in numerical modelling and slope stability analyses (limit analysis and finite element methods) are welcome. Background in hydrogeology, digital cartography (ArcGIS or QGis) and Matlab (or similar) will be also appreciated.