PhD thesis proposal 2015-2018

Experimental investigation of the impact of the erosion by suffusion on the physical and mechanical properties of soils

Hosting laboratory: Unité de Recherche Ouvrages hydrauliques et Hydrologie, Irstea, Aix-en-Provence, France
Supervisors: Nadia Benahmed (Irstea), Pierre Philippe (Irstea).
Doctoral School: ED 353, Sciences pour l'Ingénieur : Mécanique, Physique, Micro et Nanoélectronique (Marseille).

INTRODUCTION

Internal erosion is a complex phenomenon which represents one of the main sources of risk to the safety of earthen hydraulic structures such as embankment dams, dikes and levees. Its occurrence may cause instability and rupture of these structures with consequences that can be dramatic (Figure 1).

Fig. 1- Failure of Dychow dam (Poland)

In very general terms, internal erosion is characterized by the migration of grains within a hydraulic structure, or its foundations, under the action of a hydraulic flow. The specific situation of the erosion by "suffusion" is the one characterized by the migration of the finest soil particles through the surrounding soil matrix formed mainly of large grains as shown in Figure 2. This type of erosion is governed by several soils' parameters, as grading curve shape, grain size and shape, density of soil, as well as by the hydraulic conditions and in situ stresses.

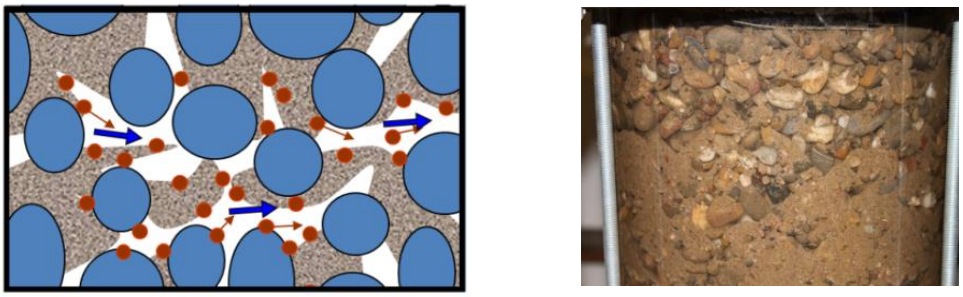

Fig. 2- Suffusion phenomenon (Beguin, 2010).

The occurrence of suffusion usually causes degradation of the initial microstructure and a change in the physical, hydraulic and mechanical characteristics of the soil.

Thus, from the mechanical standpoint, the increase in porosity due to fines migration brings the soil to a looser state that makes it more contractant when subjected to external stresses.

This can also lead to significant settlements that can be very damaging to the structures. When the soil is saturated, excess pore pressure can develop and lead to lower effective stresses, causing possibly rupture by liquefaction.

The fundamental mechanism of suffusion must be studied at the microstructure level, to get a better understanding of this mechanism and identify, at this scale, the physical parameters that can play a key role in either triggering of fines migration or subsequent soil's degradation processes (large settlements, instabilities…). These parameters may subsequently be introduced into constitutive models based on a continuous approach and able to characterize at the macroscopic scale (i.e. structure level), the influence and impact of suffusion on the soil's mechanical response.

GOALS AND METHODOLOGY

The current knowledge of suffusion process and its consequences remains very limited and thus motivates the work proposed in this thesis. Therefore, the aim of this study is to characterize, qualitatively and quantitatively, the suffusion mechanism and its effects in terms of increase of porosity, development of volumetric strains and large settlements, change of the microstructure and degradation of mechanical properties, including soil failure properties such as internal friction angle, peak strength or critical state.

This work will be tackled at first by a preliminary study of post-erosion microstructural characterization through direct visualization of suffusion process by optical techniques. As far as possible, the evolution of the induced microstructure will be quantified by acoustic techniques and micro-tomography X. Specific and original experimental protocols must be developed for this purpose.

Thereafter, the mechanical behavior of intact and eroded soil samples will be characterized to emphasize the effect of suffusion on soil's strength, and correlate the evolution of suffusion with the degradation of these mechanical properties. We will focus in particular on the change in the mechanical parameters at the instability threshold, that is to say when the microstructure is highly degraded and becomes metastable, and at the critical state.

In practice, this study requires the possibility to erode the soil sample first, and then to subject it to mechanical loading in a second time, and this without changing the microstructure resulting from the initial suffusion process. Here again, original protocols will be developed to overcome this technical issue.

CANDIDATE'S SKILLS

The candidate should have a relevant background in geotechnique and soil mechanics, and a strong predilection for experimental work. He should also demonstrate autonomy, personal initiative and capacity for analysis and synthesis as well as good writing skills. A high standard of scientific English is highly desirable

FRAMEWORK AND PARTNERSHIP

The PhD student will integrate the team "Geomechanics and erosion" of the Research Unit "Hydrology and Hydraulic Structures" (Irstea Aix-en-Provence). This work will be done in synergy with the L3SR laboratory in Grenoble, in collaboration and partnership with the Navier laboratory in Marne-la-Vallée and IUSTI laboratory in Marseille.

The PhD student will evolve especially within the “Multi-physics and multi-scale coupling” CNRS Research Group (GOR 3176 Me-Ge4) and ALERT Geomaterials network that brings together the best European laboratories working on geomaterials and related natural hazards.

The contract period is 3 years and the gross salary of about 1.852 €.

CONTACT

- Nadia Benahmed; nadia.benahmed@irstea.fr; Tél. : + 33 4 42 66 99 04 ; IRSTEA, Aix-en-Provence.
- Pierre Philippe; pierre.philippe@irstea.fr; Tél. : + 33 4 42 66 99 55 ; IRSTEA, Aix-en-Provence.