EFFECT OF SHEAR STRAIN IN THE EROSION DEGREE OF SUFFUSED SOILS

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1. INTRODUCTION

Internal erosion is defined as the transportation of finer soil particles from the main structure inside the ground, due to the mechanical action of seepage flow. The result of internal erosion can be observed in the field as chains of macropores parallel to the ground surface. The transportation of fines affects various characteristics of the soil including hydraulic conductivity and mechanical behavior (Schuler 1995). Suffusion, a particular case of internal erosion may have an effect on the mechanical behavior of the soil. Thus, the main objective of this research is to evaluate the mechanical properties of a soil subjected to suffusion. A series of torsional tests were performed to evaluate the effect of shear strain in the erodibility of a soil and the impact of suffusion in the shear strength of a soil.

2. TEST

2.1 Test material

A soil result of the combination of 80% in weight of silica sand No. 5 and 20% of DL-clay (non-plastic silt) was used in the torsional tests (Fig.1). This combination resulted to be highly susceptible to erosion, according to permeability tests made to dense and loose specimens (Santa-Spitia, 2016). The silica sand is colored red and has a mean diameter D_{50} of 0.5mm; it is considered to behave as a *primary fabric* of particles, which supports loads and transfer stresses (Kenney, 1985) (Fig. 2). The DL-clay looks yellowish brown and has a mean diameter D_{50} of 23μm; it is considered as *detached particles*, which are not fixed in position, do not transfer effective stresses and can move within the pores (Fig 2). Two soil conditions were studied: loose soil with relative density around Dr= 50%, and dense soil with Dr= 95%.

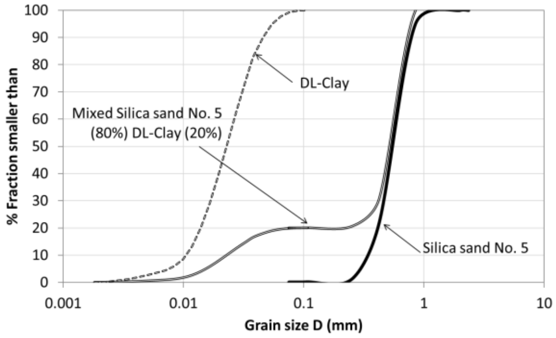

Fig. 1 Grading curves of the soils studied

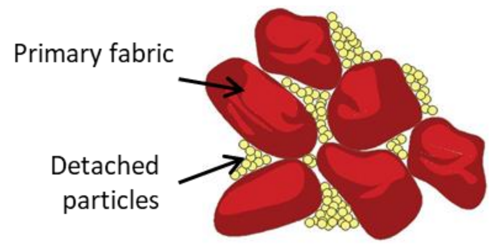

Fig. 2 Schematic illustration of an internally unstable soil

2.2 Apparatus

The hollow cylindrical torsional shear apparatus was used in this study to evaluate the mechanical properties of soil eroded by suffusion. The tests aim to obtain the properties under varied degrees of erosion: non-eroded, eroded before torsional shearing, and eroded before and during torsional shearing; the variation in sample density, and the variation in confining stress: $\sigma_z = \sigma_r = \sigma_\theta = 60$kPa and $\sigma_z = \sigma_r = \sigma_\theta = 150$kPa. The height, outer diameter and inner diameter are 100, 100 and 60 mm respectively (Fig. 4). In addition, two types of pedestals were used: A pedestal with a porous stone was used in the cases without erosion (Figure 3a), in order to drain only the water but no the soil fines (Type 1); and a pedestal with holes of 3mm was used in the cases with erosion (Type 2) (Fig 3b).

(a) Type 1

(b) Type 2

Fig. 3 Pedestal types

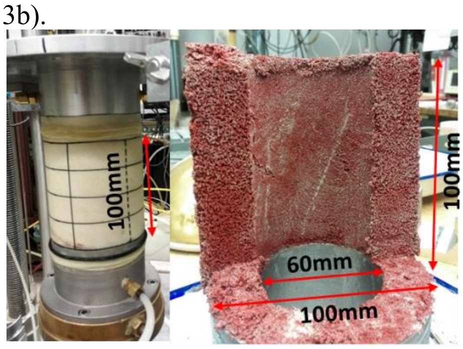

Fig. 4 Specimen dimensions

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2.3 Test procedure

Three kinds of tests were performed: *1) Non-eroded test*: The Type 1 pedestal is used in this test (fig 3a). The specimen was isotropically consolidated to 60 kPa. Small torsional cyclic loadings (STCL) were applied before and after saturation with the purpose of knowing the value of the shear modulus G. During the drained torsional shearing stage, G was measured by STCL at predetermined shear stresses. *2) Test eroded before shearing:* It was followed the same procedure as in the non-eroded test, but this time using the Type 2 pedestal (fig. 3b). After saturation, pressurized water was applied to the upper part of the specimen, and the water and fines eroded were collected from the pedestal with the intention of determine the amount of fines detached and measure the turbidity. Shear modulus was measured in the same way as in the non-eroded test. *3) Test eroded before and during shearing:* The procedure followed was the same as in the test eroded before shearing; in addition, a second stage of erosion was applied during the shearing: After the applying shear strain until the shear stress is equal to 10 kPa, water for erosion was infiltrated. This procedure was repeated for 20, 30 and 40 kPa (fig. 5).

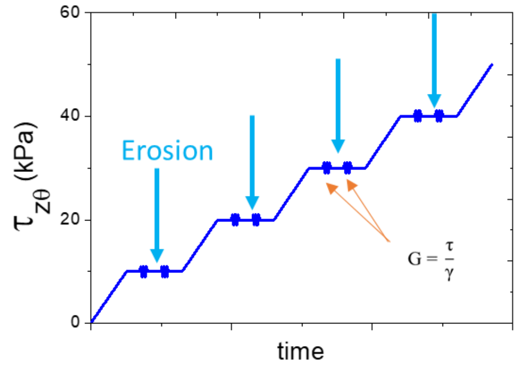

Fig. 5 Schematic illustration of water infiltration during torsional shearing

3. RESULTS

The variation of eroded soil and turbidity for the dense specimen eroded before and during shearing is shown in Fig. 6. Turbidity is higher at the beginning of the erosion and then decreases until reaching a value close to 100 NTU at 7500 ml, resulting in 5% of eroded soil. After this point, torsional shear was applied up to $\tau_{z\theta} = 10kPa$. The turbidity value increases suddenly to 950 NTU with the first cycle of water infiltration (375 ml). The turbidity value decreases in the subsequent cycles of water infiltration until the erosion was regarded insignificant. The specimen was sheared until the next shear stress of $\tau_{z\theta} = 20$kPa, where the same behavior was observed, as well as for $\tau_{z\theta} = 30$kPa and $\tau_{z\theta} = 40$kPa (fig.6). In addition, the specimens subjected to erosion exhibit a reduction in their strength: peak shear stress, and shear modulus (G50 and small strain stiffness G).

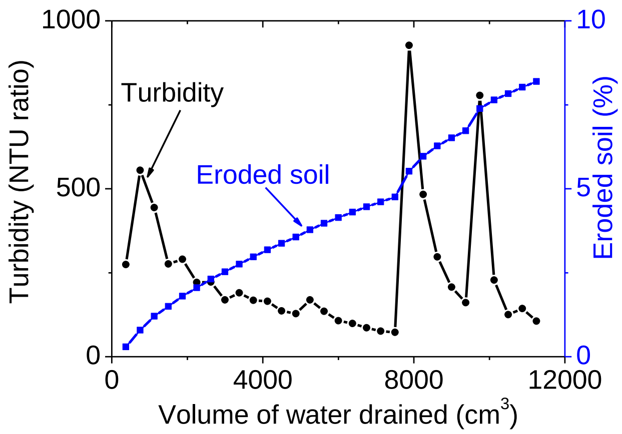

Fig. 6 Eroded soil and turbidity. Loose specimen eroded before and during shearing

4. CONCLUSIONS

- Turbidity is proportional to the amount of eroded particles. It can be measured to estimate the erosion degree.
- The shear strain induces a rearrangement of particles, and hence increases the erosion degree: the increment of eroded particles after the small steps of torsional shearing might be due to a rearrangement of particles induced by the shear strain, allowing the movement of fines through new constrictions.
- Soils with lower relative density and higher confining stress are more susceptible to erosion.
- The peak shear stress, small strain stiffness and shear modulus G50 are reduced by the action of suffusion, not only because a reduction in density, but also because of the destabilization of the structure because of the movement of fines.

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