SHEAR STRENGTH OF SANDS WITH NONPLASTIC FINES SUBJECTED TO SUFFUSION

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1. INTRODUCTION

Internal erosion is an important cause of the failure of hydraulic structures such as levees, dikes and embankment dams. This paper studies particularly a case of internal erosion called suffusion in which the fine particles migrate through the voids between the coarse particles under seepage flow, leaving behind the coarse skeleton. This process may have an effect in the mechanical behavior of the soil. A series of torsional tests had been performed in a highly erodible soil, evaluating the effect of erosion in the shear strength, and the variation of shear modulus at different stages before and during shearing.

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) (Fig 2. (c)). 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 (a)). 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. (b)). Two soil conditions were studied: loose soil with relative density around Dr= 50%, and dense soil with Dr= 95%.

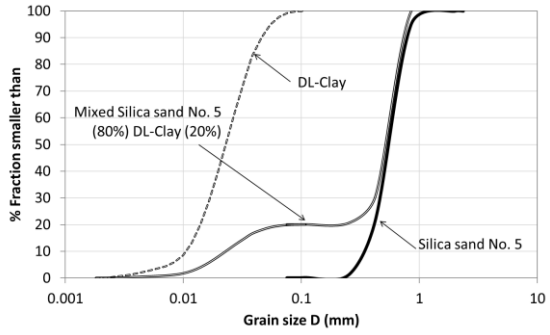
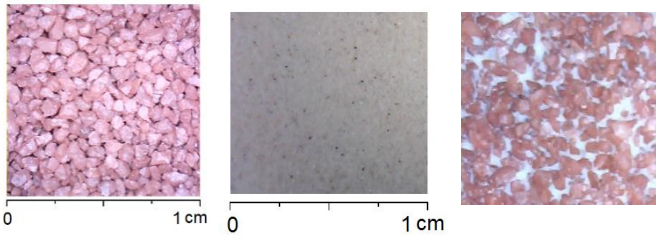


Fig. 1 Grading curves of the soils studied



(a) Silica Sand No. 5 (b) DL-Clay (c) Silica Sand (80%) + DL-Clay (20%)

Fig. 2 Test material

2.2 Apparatus

A high capacity medium size hollow cylindrical torsional shear apparatus was used to investigate the mechanical behavior of specimens with and without soil particles erosion. Specimen size was reduced from the original size in order to achieve in a short period the water dissemination inside it. The height, outer diameter and inner diameter are 100, 100 and 60 mm respectively. In addition, two types of pedestals were used: A pedestal with a porous stone was used in the cases without erosion (Figure 3 (a)), 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 3 (b)). Moreover, a gauze with 1mm opening was placed above the pedestal, in order to drain just the water and the fine particles, and let the primary fabric remain inside the specimen (Fig 3 (b)).

(a) Type 1 (b) Type 2

Fig. 3 Types of pedestals using in the experiments

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2.3 Test procedure

Two kind of tests were performed: *1) Non-eroded test*: The Type 1 pedestal is used in this test. The specimen was erected at isotropic stress of 30 kPa, and then isotropically consolidated to 60 kPa, then, the specimen was saturated. 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 also measured by STCL at predetermined shear stresses (10, 20, 30 and 40 kPa). *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. 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. RESULTS

Specimens with different densities and with various erosion conditions were evaluated. In total, the results for 4 experiments are showed: Non-eroded, and eroded before torsional shearing; each one for loose and dense specimens. In the dense case, the water infiltrated induced a loss of about 3%, and 5% in the loose case.

The dense specimens exhibit a larger shear strength than the one in the loose specimens (Fig. 4). The peak strength in the dense non-eroded case reaches $\tau_{z\theta}$=64kPa, while in the dense specimen eroded, the shear strength decreased to $\tau_{z\theta}$=61kPa. Among the loose specimens, in the non-eroded test the maximum strength is $\tau_{z\theta}$=49kPa, whilst in the test eroded it is equal to $\tau_{z\theta}$=45kPa.

The shear modulus measured by small cyclic torsional loads is also affected by the action of water infiltration. Although the values of G are larger in the dense cases, for both dense and loose specimen G decreases after erosion, and increases during the shearing (Fig. 5). As it may be noticed, the values of G are smaller in the case eroded compared to those in the non-eroded cases.

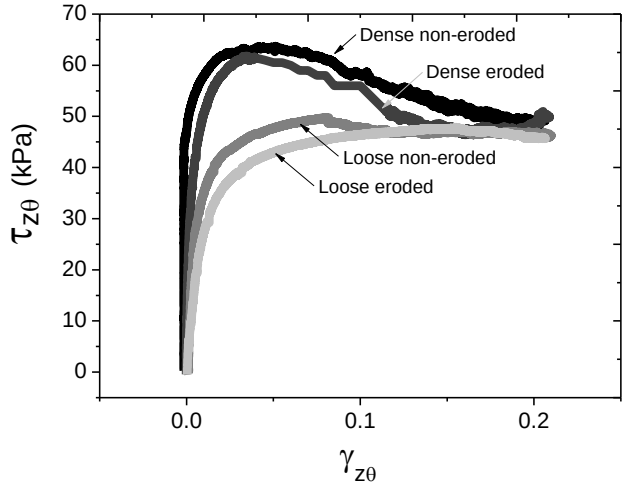

Fig. 4 Shear strain relationship

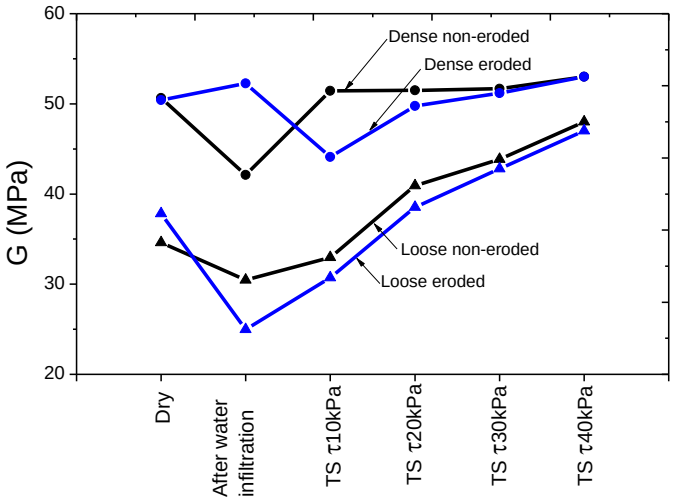

Fig. 5 Variation of the shear modulus G

4. CONCLUSIONS

Using a modified pedestal with large opening in a hollow cylindrical torsional shear apparatus, allows the migration of fine detached particles from the original structure of the soil, leaving behind the soil affected by suffusion.

The curves of the stress-strain relationship are not significantly different between the non-eroded and eroded cases, this can mean that the primary fabric of soil effectively transfer stresses, and the erosion does not strongly affect the mechanical behavior.

The suffusion affects the variation of the shear modulus G measured by small torsional cyclic loadings. G is reduced after every stage of water infiltration and its values remain lower along the experiment, compared with the soils that were not affected by erosion.

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