論 文 の 内 容 の 要 旨

Thesis Summary

Title of Dissertation:

Mechanical properties of soil subjected to internal erosion initiated by suffusion

(細粒分の流出を伴う内部侵食作用を受けた土の力学特性)

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Internal erosion is an important cause of the failure of hydraulic structures such as levees, dikes and embankment dams. This study is focused particularly in 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 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

In this study, red-colored silica sand No.5 (D_{50}=0.5mm) and a non-plastic silt called DL-Clay (D_{50}=23μm) were used. Both soils (Silica sand and DL-clay) were mixed using various percentages combinations based on the study made by Kenney (1985), in which, the author suggested the maximum content of detached particles a granular soil can contain, and therefore the maximum loss possible. According to this, the percentages of Silica sand (primary fabric) and DL-clay (detached particles) were estimated taking into consideration the void ratio and average porosity.

In order to know the influence of water penetration into the ground, a series of permeability tests had been performed, applying water with various hydraulic gradients from the top part of specimens with different densities, and letting fine particles drain out.

As a result of the experiments described previously, it can be concluded that the erodability of a soil not only depends on the particle size distribution, but also depends on density, initial fines content and hydraulic gradient. The results show that the density of the soil is a determining factor for the resistance against suffusion. In dense specimens ($D_r \approx 90\%$), the fines moved out from the matrix are around 10% of the total amount of the soil expelled from the loose specimens ($D_r \approx 50\%$). Regarding to the hydraulic gradient, it has different effects depending on the initial relative density. In loose specimens the eroding effect is proportional to the hydraulic gradient, while in the dense specimens at higher hydraulic gradients the movement of particles is reduced. Also, the turbidity of the water is proportional to the weight of drained particles. It can be measured in order to estimate the degree of erosion.

Additionally, a series of torsional tests evaluating the effect of suffusion in the shear strength, and the variation of shear modulus at different stages before and during shearing. Three types of experimental procedures were used for the drained torsional tests: without erosion (using a pedestal with porous metal), with erosion before shearing, and with erosion before and during shearing (using a pedestal with holes), on the specimens with various density values and confined stress levels.

From these experiments it is concluded that the specimens subjected to erosion exhibit a reduction in their strength: peak shear stress, and shear modulus (G50 and small strain stiffness G), the friction angle is also reduced in the erosioned soils; however, the reduction is larger in the loose specimens compared with the dense specimens, the shear strength of a soil is reduced by the action of suffusion, not only because a reduction in density, but also because of the movement of fines. The reduction of the strength might be due the open channels generated by internal erosion by suffusion. Thus, the detached particles or fines do contribute to the strength of the soil and their internal movements destabilize the structure. In dense specimens the shear strength is mainly derived from the friction along the contacts of primary fabric, the soil strength is reduced in a lesser extent in the dense specimens (compared with the loose specimens), hence, in the dense soils the stress transmission is given mostly (but not totally) by the primary fabric, while in the loose soils the fines play a more important role in the strength. In loose specimens the shear strength is resulting from a combination of friction along the primary fabric contacts and along the detached particles. Nevertheless, at low densities the shear strength is affected by the presence of fines, the primary fabric supports most of the stresses. The contribution of the detached particles in the stiffness is dependent on the confining stress; if the particles are confined at higher pressures the structure of the soil will probably have more influence of the fines. As in the loose specimens the Intergranular contacts are lower than in the dense specimens, the sensitivity to the confining stress is in consequence larger. The shear strain induces a rearrangement of particles, and hence increase 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. The soils with lower relative density and higher confining stress are more susceptible to erosion. The same hydraulic gradient is needed to erode the same amount of particles the specimens confined at different pressures. According to this, it is verified that the transmission of stresses is given only by the large particles and for this reason the fines can be easily moved between pores regardless of the confining pressure.