Pore Fluid Engineering: An Autoadaptive Design for Liquefaction Mitigation

Liquefaction of loose granular soils is an important cause of damage to civil infrastructures during earthquakes. While many factors affect the liquefaction resistance of soils, both laboratory studies and field observations demonstrate that the presence of plastic fines reduces the liquefaction susceptibility. This is the premise for the research presented in this thesis, which addresses the use of bentonite-based thixotropic fluids for liquefaction mitigation.

The thesis focuses on experimental results from resonant column, cyclic and monotonic triaxial tests performed on Ottawa sand specimens prepared with 0%, 3% and 5% bentonite by dry mass of sand. While the bentonite has minimal effects on the static properties of the sand, the cyclic resistance increases significantly. Specifically, for the same skeleton relative density and cyclic stress ratio, the cyclic tests show a marked increase in the number of cycles required for liquefaction with increased bentonite content.

The enhanced resistance to cyclic loading in presence of bentonite is related to the increase in the linear threshold strain observed in the resonant column tests. This behavior is the result of the mechanical properties of the pore fluid formed in presence of bentonite: a concentrated suspension, with gel-like properties. Oscillatory tests conducted with an advanced rheometer show that these materials exhibit elastic response for shear strains as large as 1%. Due to the thixotropic nature of bentonite suspensions, the storage modulus increases with time; this is consistent with the increase in cyclic resistance of the sand-bentonite specimens with aging observed in the cyclic tests.

The research also addresses the results of laboratory permeation tests and rheological tests conducted on bentonite suspensions chemically modified with sodium pyrophosphate. These data demonstrate that the rheology of concentrated bentonite suspensions can be engineered to delay gel formation and enable permeation inside a granular medium, thereby supporting the practical feasibility of the proposed liquefaction mitigation approach. Finally, preliminary results from cyclic triaxial tests performed on sand specimens permeated with 10% bentonite and 0.5% SPP suspension showed an increase in cyclic resistance with time.