Abstract

Microbially induced calcite precipitation (MICP), a bacteria-induced bio-mineralisation process, has been investigated extensively in civil, environmental and infrastructure engineering applications. The produced calcite precipitation preferentially accumulates at particle-particle contacts. Therefore, it contributes to additional cementation at particle-particle contacts (pore throat). Because of this preference of cementation at pore throat locations, large pores are kept relatively open so that the change in permeability is rather small even though the cementation enhances the soil stiffness. These features make MICP a promising solution for erosion-related geotechnical problems.

Earth embankment dams are one of the most commonly encountered hydraulic infrastructures worldwide. The earth core is often constructed using locally available soils, including clay, sand-clay mixtures, sand-silt mixtures, and in some cases, with gravel. Both segregation of fill materials and formation of transverse cracks in the earth cores can result in the fines being dislodged and transported along preferential flow paths to downstream unprotected exits. This process typically works its way backward to the upstream side of the dam until a through-piping forms. Therefore, it is of importance to develop engineering countermeasures to prevent piping and internal erosion.

Sand production is the phenomenon that solid particles (sand in many cases) from weakly consolidated sand or sandstone reservoirs move into the production well along with the oil/gas flow. Sand production leads to serious troubles at all stages of oil/gas production. Normally, sand production is induced by two factors: mechanical degradation and hydraulic erosion. The latter one involves the mobilisation and transport of sand particles under high hydraulic gradient. Preventing sand particles from going into production wells can contribute to higher oil/gas production efficiency as well as operational safety.

The study presented in this thesis firstly investigated the internal erosion control by MICP in sand-clay mixtures. A series of internal erosion tests were conducted using an element-scale rigid-wall column erosion test apparatus. Results show that MICP treatment implemented in this study contributed to an enhanced critical shear stress and a reduced erosion coefficient for sand-clay mixtures with coarse host sand and fine clay. All sand-clay mixtures tested in this study also saw significant reductions in volumetric contraction after

the MICP treatment. The effectiveness of MICP for internal erosion control in sand-clay mixtures was mainly determined by the amount of produced carbonate precipitation.

Then, the efficiency of the MICP treatment for the internal erosion control in gravel-sand mixtures was examined using an up-scale rigid-wall column apparatus. It is found that higher chemical concentration used in the MICP treatment contributed to reduced erosion rate and axial displacement while hydraulic conductivity only reduced marginally. Fines content, axial stress, and MICP implementation method affected the erosional, geomechanical, and hydraulic behaviours of the MICP treated gravel-sand mixtures as well.

After that, MICP was tested for deepwater sand production control. A self-designed high-pressure plane-strain test apparatus was designed, which could reasonably address the stress and flow conditions in the field. The MICP treatment by the injecting method could significantly reduce the sand production rate compared to the untreated specimen, as long as the internal erosion condition could be maintained. It is also found that the enlargement of the upstream cavity was slower in the MICP treated specimens. Meanwhile, the hydraulic gradient dissipation at the inlet end and accumulation at the outlet end were also retarded in the specimens treated by MICP.

Finally, the ureolytic activities of another more anaerobic bacterium (*B. megaterium*) and purified urease enzyme in oxic and anoxic conditions were investigated for their potential application in deepwater sand production control. It is found that the effect of oxygen availability on ureolytic efficiency of purified urease enzyme was marginal. However, the ureolytic activity of *B. megaterium* in anoxic conditions was greater than that in oxic conditions. The ureolytic efficiency of purified urease enzyme was found to be greater than that of *B. megaterium*.