Soil Improvement Potential of Microbially Induced Gas Formation and Carbonate Precipitation

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Microbial induced carbonate precipitation (MICP) has been confirmed to effectively reinforce granular soil by employing biological processes. Biological denitrification is one of these processes, in which the microbes use nitrate to oxidize organic matter and produce nitrogen gas and inorganic carbon, which results in precipitation of calcium carbonate in the presence of calcium ions. Accordingly, MICP via denitrification may stabilize the soil in multiple ways. Besides the strengthening effect of calcium carbonate precipitate crystals, the induced gas phase may enhance the undrained response as the compressible gas may dampen dynamic loads on the soil. The effectiveness of this method has been investigated on different sand types using the triaxial test set-up, at different pressure conditions. During the reaction phase, the water displacement into the back pressure controller was used to monitor gas production. After reaction samples were flushed from bottom to top at a constant head difference. The flow rate was measured to determine permeability. Results of these experiments showed that the volume of produced gas strongly depend on the pressure conditions. The gas storage capacity ranged from 22 to 40% of the total pore volume, depending on grain size. At a pore pressure of 1 bar, the gas storage capacity was exceeded before the reaction was completed and excess gas escaped to the back pressure controller. Gas which remained inside the sample was easily removed during flushing, and the permeability was hardly affected. At higher pore pressure or smaller grain size, the gas phase was well distributed and resulted in a decrease of the permeability after the treatment by 50 to 300%. The drained shear strength of a single batch treatment was not significantly improved, indicating that the amount of calcium carbonate precipitation was not sufficient and suggesting multiple treatments are required to bear an increase of strength. Upon undranied loading the small strain stiffness was significantly improved, but the peak undrained strength was reduced. The results indicate that controlling the gas formation is important in order to optimize this method for field applications.