EXPERIMENTAL STUDIES OF MICROBIOLOGICALLY INDUCED IMPROVEMENT OF FINE SANDS

General abstract

Microbially Induced Carbonate Precipitation (MICP) is a promising technique for soil biocementation, involving biological and chemical processes that facilitate the precipitation of carbonates, thereby improving soil properties by binding soil particles within the matrix. There are two different approaches in MICP: bioaugmentation, which involves introducing non-native bacteria directly into the soil, and biostimulation, which optimizes the growth environment for native bacteria. The MICP process can be classified into ureolytic and non-ureolytic, depending on the bacteria's ability to break down urea or use other metabolic pathways for carbonate production. Several factors influence the effectiveness of MICP, including soil type and grain size, bacterial strain, optical density, and the source and concentration of metal ions (calcium/magnesium). Additionally, the method of bacteria and precursor application plays a critical role in determining the overall success of the biocementation process. These factors need careful consideration when scaling the process for larger applications such as infrastructure projects, slope stabilization, and erosion prevention. The aim of this work was to investigate the potential of MICP for various geotechnical applications. By focusing on optimizing bacterial densities, chemical composition, and injection procedures, this research aimed to maximize the mechanical properties of cemented soils. Furthermore, statistical analyses were conducted to evaluate the effects of MICP treatments on soil strength and carbonate precipitation. Key methods included microstructure analysis, measurement of shear wave velocity (Vs), and unconfined compressive strength (UCS) tests, all aimed at quantifying improvements brought by MICP. Bacterial strains such as *Bacillus subtilis*, *Sporosarcina pasteurii*, and *Arthrobacter* sp. were utilized, alongside cementation solutions containing urea, calcium chloride, and magnesium chloride. Optimization studies examined how variations in chemical and bacterial concentrations influence carbonate precipitation, with a focus on enhancing the cementation process through bioaugmentation and biostimulation methods of the ureolytic pathway with non-ureolytic support, as well as non-ureolytic pathways. The potential advantages of both techniques and pathways, particularly biostimulation, were explored in the context of improving overall cementation efficiency. Another primary focus of this research was evaluating MICP's capacity to mitigate wind erosion by forming a protective biocemented crust on soil surfaces. The study measured parameters

such as carbonate precipitation, erosion depth, and crust thickness to assess the method's effectiveness. In summary, the novelty of this study lies in the direct comparison of the ureolytic pathway, supported by non-ureolytic mechanisms, with the non-ureolytic pathway, examined under both bioaugmentation and biostimulation approaches, which provides new insights into how application methods affect soil cementation. Overall, the findings indicate that MICP, when implemented via both pathways, has the potential to serve as a sustainable and adaptable technology for soil improvement, erosion control, and broader geotechnical engineering applications.