# Effect of Fines Type on Biological Improvement of Sandy Soil

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## Extended Abstract

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**Introduction**

In many areas of the world, the mechanical properties of soils for utilization of land are not sufficient. For improvement of these lands, soil stabilization such as compacting, installation of nails, elders of piles, mixing soil with lime or cement before or during constructions on the surface or inside of the ground can be useful. Microbially induced carbonate precipitation (MICP), due to its versatility and stable performance, has been recently attracted the attention of many researchers in the field of the geotechnical engineering around the world. MICP is a biological technique that is naturally caused to create a cementation agent, which is known as calcium carbonate or calcite by controlling the metabolism of bacteria. Although there are many biological processes that can be lead to MICP, but the using of urea hydrolysis by bacteria is commonly used more. In this method, aerobic bacteria with the enriched urease enzymes inject into the soil. Hydrolysis of urea occurs when the bacteria speeds up the hydrolysis reaction to produce ammonium and carbonate ions. In the presence of soluble calcium ions, carbonate ions are precipitated and formed the calcium carbonate crystals. When these crystals are formed on a grain of soil or like a bridge between them, they prevent the movement of grains and thus improve the mechanical and geotechnical properties of the soil.

**Material and methods**

In the present study, the effect of increasing fines on the improvement of Anzali sandy soil, and soil resistance parameters for improving the clean sand and its mixtures with a fine grained cohesive soil and a fine grained cohesionless soil separately in a percentage weight of 30 by MICP and using a small scale of direct shear test (6×6) have been investigated. In the present study the sandy soil was collected from the coast of Bandar Anzali Free Zone and for the preparation of samples of clayey sand and silty sand, Kaolinite clay soils and Firouzkooh broken silt were used, respectively. Anzali sand is poorly graded and had a rounded corner with an average particle size of 0.2 mm, somewhat, sharpening cores are also found in its granulation. In addition, its fine grained content is very small (less than 1%). The Kaolinite clay is also labeled with a liquid limit of 40, a plastic limit of 25, and a plasticity index of 15 as an inorganic clay (CL). The used microorganism in this study is urease positive Sporosarcina pasteurii, which is maintained with the number of PTCC1645 at the Center Collective of Industrial Microorganisms of Iran Scientific and Research Organization. The bacterium was cultured in a culture medium containing 20 g/l yeast extract and 10 g/l ammonium chloride at pH 9 under aerobic conditions in incubator shaker machine at 150 rpm and temperature of 30 °C. The organism was grown to late exponential/early stationary phase and stored at 4 °C before injection in samples. A solution of calcium chloride and urea with a molar ratio of one is also used as a cementation solution. With the direct shear test (6cm×6cm) as a benchmarking of the shear strength in the before and after improvement steps, molds fitted with a shear box made of the galvanized sheet with a thickness of 0.6 mm and it consists of two main parts, the body, in the middle of which an exhaust pipe was embedded in the injector waste fluid. At the bottom of the samples, a layer of filter paper was placed in order to prevent soil washes, and then all samples with a thickness of 2 cm, with a relative density of 30% at the same weight and height were pressed. In the upper part of the samples, a layer of filter paper is similarly used to prevent the discontinuity of soil particles when injected biological materials are used. Biological solutions are injected from the top to the specimens and allowed to penetrate under the influence of gravitational and capillary forces in the sample and discharge the inhaled fluid from the exhaust pipe. The criterion for determining the volume of the solution to inject into each sample is the pure volume (PV) of soil. The preparation process of the samples was initiated by injection of a PV water unit, followed by a two-layer mixture of bacterial suspensions and cementation solutions, each with a volume of one PV, and then for biological reactions, 24 hours to the sample at laboratory temperature (25 ± 2) is given. After the time of incubation, the solution of cementation is injected into the sample for a period of three days and every 24 hours. The processing time of samples is also considered 28 days. In this study, optical density (OD) was selected as a benchmark for estimating the concentration of bacterial cells in the culture medium, and in all stages of development, and precisely before injection of bacteria suspension into soil samples, it was measured by a spectrophotometer device at 600 nm ($OD_{600}$) wavelength, which was obtained for all bacterial suspensions in the range of 1.7 to 2 before the injection. To determine the activity of urea bacteria, 1 ml of bacterial suspension was added to nine milliliters of 1.11 molar urea solution, and by immersing the electrode of the electrical conductivity in the solution, its conductivity was recorded for 5 minutes at 20 ± 2 ° C. The rate of urea activity in the pre-treatment stage for all specimens was in the range of 0.8 to 1.23 mS $min^{-1}$. In order to evaluate the shear strength parameters of soil samples, before and after the improvement operations, a direct shear test was used based on the ASTM D3080 standard. This test was performed for all samples under stresses of 50, 100 and 150 kPa in undrained conditions at a loading speed of 1 mm/min up to a strain of 15%. Also, samples of soil with a moisture content of 7% and a relative density of 30% (as already mentioned) have been restored. SEM analysis was carried out to determine the distribution of sediment between soil particles and EDX analysis in order to identify carbonate calcium sediment formation elements in improved soil samples, by scanning electron microscopy on Anzali sandy soil samples in before and after improvement conditions.

**Conclusions**

The effect of the increasing cohesive and cohesionless fines on the bio-treated process of sandy soil is the main subject of this research. For this purpose, three samples of clean sand, sand containing 30% clay and sand mixture with 30% silt in a relative density of 30% were treated with MICP method and their shear strength parameters were evaluated by direct shear test after 28 days of processing. Using the direct shear test and analyses of SEM and EDX data, the results are represented as below:

1. The microbial sediment of carbonate calcium has greatly improved the resistance properties of all three soil samples.
2. A sample of clayey sand, in spite of a higher improvement compared to the other samples with an average shear strength of 113.7% in comparison to ~~to~~ its untreated state, it has the lowest shear strength among the three improved samples.
3. Increasing the clay content of 30% increases the soil voids. On the other hand, it reduces the friction angle and shear strength of the soil in the pre-treated state and also facilitates easier movement of the bacteria between the pores in the soil. More favorable distribution of sediment calcium carbonate was occurred and, as a result, increased adhesion between soil particles.
4. The increase of cohesionless fine particles creates more bonding points between sand particles and, therefore, calcium carbonate crystals form shorter distances between the soil bridges. As a result, with the end of the improvement process, the shear strength parameters of the sandy soil containing 30% of the silt compared to the clean sand have a higher value.
5. SEM images of the clean sand in both before and after improvement show that the calcium carbonate precipitation occurred with a uniform and thin layer that surrounds sand grains and another part of the sediments formed in the joint of grains.
6. Cube-shaped crystalline sediments confirm that the sediment formed in the soil is a stable type of calcite and that the relative increase in the

friction angle of the improvement samples can be attributed to solid particles and multifaceted sediments. Also, the elements of carbon, oxygen, and calcium, which are the main components for the formation of calcium carbonate deposits, have been found in the EDX analysis of improvement sand samples.

**Keywords:** Biocementation, clayey sand, soil improvement, microbially induced carbonate precipitation (MICP), silty sand.

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