University of Tabriz

Journal of Civil and Environmental Engineering
Volume 52 (2022), Issue 1 (Spring), 203-215

EXTENDED ABSTRACT

Evaluation of Nano Silica Performance on Biological Stabilization of Two Types of Sandy Soils (Poorly Granulated and Silty)

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Received: 02 January 2020; **Accepted:** 28 September 2020

Keywords:
Soil improvement, Microbial induced calcite precipitation, Shear strength, Bacteria, Sand.

1. Introduction

The increasing population of the world indicates the development of urban areas, and consequently the use of appropriate methods to improve sandy soils in these areas, led engineers to think of inventing methods to improve the properties of sandy soils. One of these efficient methods to modify the behavior of unsuitable soils in geotechnical engineering is to change the properties of problematic soils, which is called improvement. In this regard, sandy soil is improved by adding materials to improve mechanical properties (compressibility, hardness, shear strength, permeability, etc.). In this study, the undeniable role of nanoparticles in the improvement of sandy soil and the effect of nanosilica along with bacteria in the biological improvement of soil samples that have not been tested, was investigated (Dejong et al., 2010). Controlling the distribution at the site of bacterial and reactant activity and the results of calcium carbonate distribution and related engineering properties below the soil surface is a major challenge for future improvements, especially if bioremediation in a surface or deep soil system (To replace the method of deep soil improvement with artificial lime). In order to commercialize the bioremediation process, further optimizations in the performance of the biological deposition process (improving the effective use of bacteria, reactants and reducing heterogeneity) should be done (Sharma et al., 2016). Therefore, the aim of this study was to investigate the compatibility of nanosilica with bacteria in order to be able to use minerals to increase the strength of biologically improved soil properties.

2. Methodology

2.1. Selection and culture of bacteria

Preliminary studies were performed on the identification of urease-producing bacteria and the ability of bacteria to produce enzymes, and the bacterium Sporosarcinina urea (PTCC=1642) was selected as the reaction agent (Kilic and Canakci, 2015).

2.2. Select Nano Silica

Due to the fact that some nanoparticles, such as copper, silver, zinc, and titanium nanoparticles have strong antibacterial properties. In this study, we tried to use nanoparticles, which have a neutral reaction on bacterial function or very weak antibacterial properties, to improve the soil properly. After studying different nanoparticles, nanosilica was finally selected because of its ability to bond with a wide range of molecules and

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polymers and its effect on increasing the shear strength of sandy soils (Karimabadi and Shoush Pasha, 2016) and in proportion. The mixture (0.02% by weight of soil) was injected into the samples with bacteria. Properties of nano-silica used in this study, which was purchased from Iran Nano Silica Industries Manufacturing Company (ID: 10840449455).

2.3. Injection of cementation solution

In this study, to evaluate the strength, adhesion and internal friction angle of the soil and according to the limitations mentioned in ASTM D3080, molds with geometric characteristics similar to the direct shear test were used as a laboratory pilot (Canakci, 2014).

2.4. Electronic analysis (SEM)

To determine the type of sediment formed to describe its shapes, to determine the locations of deposited $CaCO_3$ and to investigate the bonding behavior between the sand grains of the tested sand and the cementation factors, Scanning Electron Microscope analysis was performed on the improved samples. In addition, all microscopic specimens were dried at 60 °C for 24 hours before microscopic testing. Electron imaging was performed using an electron microscope (PHILIPS XL20 Eindhoven, Netherlands)

2.5. Direct cutting test

The molds were opened after processing and removed from the mold with the help of grease impregnated droplets. Due to the proportional dimensions of the samples with the cutting box of the machine without any interference and change in its appearance, they were immediately prepared for a direct cutting test. This test was performed according to the ASTM D3080 standard and by applying a constant shear strain at a speed of 1 mm/min at the vertical stress levels of kPa (60, 120 and 240) for soil-shaped cylindrical specimens (Vander Star et al., 2011). The authors are also aware that changing the cut-rate can be an effective parameter, but this research has not addressed this issue. To further investigate this issue, refer to the article on the effect of strain rate on stabilized soil in direct shear experiments (Dey. A, 2015).

3. Results and discussion

3.1. Investigation of changes in shear strength of loose sandy soil improved with different amounts of molar cementation solution

Shear stress versus shear strain changes for sand samples improved for mol/L cementation solutions (0.25, 0.5 and 0.75) at three different time intervals (3,7 and 14 days) and under vertical stresses (60, 120 and 240 kPa). As shown in Figure 9, the change in the behavior of the samples improved with the 0.25 mol/L cementation solution was clearly visible, so that the improved specimens showed compacted soil-like behavior in all vertical stresses. Also, the maximum shear strain in the improved specimens was reduced, which indicates a reduction in the deformation of the improved sand compared to the non-improved sand due to its significant hardening. The shear strength of the improved samples also showed a more than 2-fold increase for the improved samples and the effect of processing time on the increase in strength was on average about 10%. Examining the results of the shear strength test, we found that the adhesion parameter in the improved specimens has increased significantly, so that with increasing processing time, its value increases to some extent. The amount of internal friction angle also increased by 10%. With these interpretations, it can be concluded that mainly the shear strength of improved sandy soils is mainly provided by the adhesion parameter and the internal friction angle has little effect on it. Fig. 1 shows the time-shear changes of improved specimens with different concentrations of cementation solution at different stresses. As can be seen, the trend of increasing shear strength of the improved specimens with mol/L cementation solution (0.25, 0.5 and 0.75) continued at 3 and 7 day intervals, but the maximum stress of the specimens of 7 specimens continued. And the 14-day period changed close to each other, due to the complete penetration of the bacteria during the 7-day processing time, and therefore the enzyme activity was significantly reduced over a 14-day period.

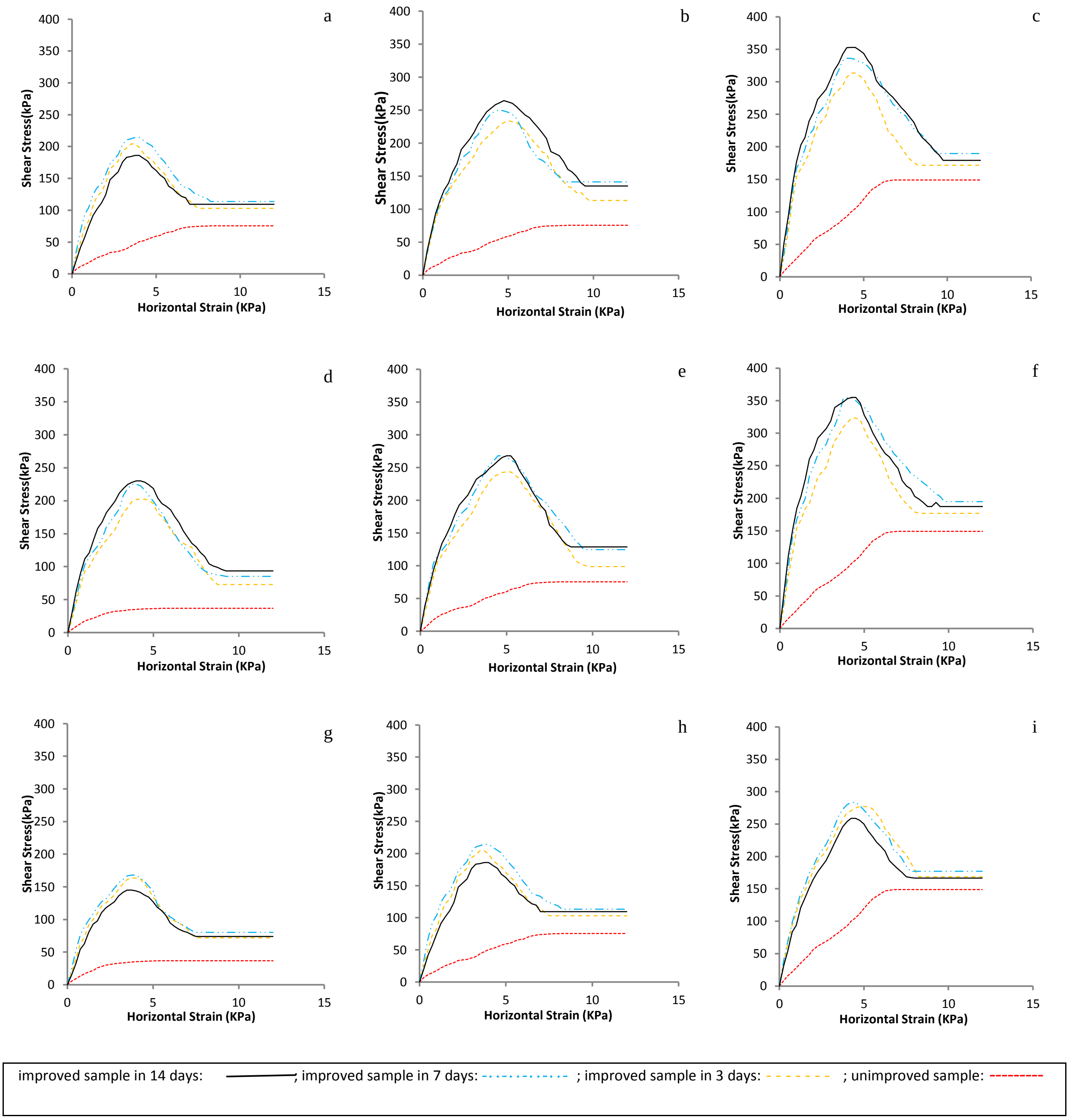

Fig. 1. Shear stress changes - Shear strain of loose sandy turquoise soil with mol / L solution (0.5, 0.5 and 0.75) cementation, under loads

kPa, 60M 0.25= a kPa, 120M 0.25=b kPa, 240M 0.25= c 0.5 kPa, 60M = d 0.5 kPa, 120M = e

i= 0.75 kPa, 240M h= 0.75 kPa, 120M g= 0.75 kPa, 60M, f=0.5 kPa, 240M

3.2. Investigation of shear strength changes of improved sand soil samples with different amounts of silt

In order to improve these samples, cement solution with a concentration of 0.5 mol/L (due to better performance than other concentrations) with 0.2% nanosilica and shear strength of soils at three vertical stresses (50, 100 and 200 kPa) was used and measured. Columbine mohair cover in improved samples was higher than in unmodified samples, which showed the positive effect of this improvement method in all three soil samples. According to Table (1), The main effect of biological improvement on the angle of internal friction and adhesion was observed in 15% silt sample after 14 days. This maximum effect is evident in 30% silt sample for the internal friction angle parameter after 28 days and for adhesion parameter in 14-day sample.

Table 1. Cohesion and internal friction angle for samples containing 15%, 30% and 45% silt in a direct shear test

Percentage of sample containing silt		Processing time (days) 0	7	14	28
15%	Cohesion (kPa)	23.92	24.85	33.5	18.74
	Internal friction angle (°C)	35.64	37.86	38.75	41.7
30%	Cohesion (kPa)	25.62	35.86	48.36	60.4
	Internal friction angle (°C)	35.86	40.88	43.19	38.35
45%	Cohesion (kPa)	27.77	31.05	37.99	33.87
	Internal friction angle (°C)	31.22	34.67	35.84	36.95

4. Conclusions

In this study, nano-silica and calcium carbonate microbial deposition methods, which is a sustainable and environmentally friendly improvement method, were used to improve sandy soils. In this method, urea in the environment is hydrolyzed by the bacterium Sporosarsina urea and formed by a network of biochemical reactions of calcium carbonate deposition, which increases soil resistance. Factors studied in this study included the concentration of reactants, curing time, changes in silt percentage on sandy soil behavior and the possibility of bacterial compatibility with nanosilica. In this study, the results showed that the soil shear strength parameters were improved by the combined effect of bacteria and nanosilica, and in the presence of nanosilica, the shear strength of biologically improved sand increased up to 4.5 times. The adhesion rate in sandy soil increased from 0.1 to 186 kPa and the soil friction angle reached about 35.6 degrees, which compared to loose sand, the internal friction angle increased by about 12%. In silty sand samples, the maximum strength also increased. And for the soil sample with 30% silt, the maximum shear strength at 50 kPa stress was observed with an increase of up to 81%, also the maximum increase in shear strength at all stresses occurred for the sample containing 30% silt. In addition, the main effect on the internal friction angle in the 30% silt sample was obtained after the 14th day of curing.

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