**Effect of sodium silicate on the unconfined compressive strength of sand dune**

1Evan Emad, Mahmood D. Ahmed, and Ammar A. Sheikha
1Civil Engineering Department, University of Baghdad, Baghdad, Iraq
Email: evanemaad800@gmail.com

**Abstract.** Sand dunes are spread in multiple places in the world especially in a desert area as a result of economic development and construction processes, there was a need to study the behavior of sand dunes and make it suitable for construction. This paper aims to study the effect of adding sodium silicate on the cohesion strength of sand dune and its behavior. The results show that the cohesion strength increase as a percentage of sodium silicate increase (addition 8% Sodium silicate show the higher cohesion) and the cohesion between sand dune particles increase excepted when using 10% sodium silicate the cohesion began to decrease. However, the effect of curing time is significant and shows that as the curing time increases the cohesion strength of sand dune increases.

**Keywords:** Soft clay, sand dune, sodium silicate, unconfined compressive strength, soil cohesion, improvement.

1. **Introduction**

The desert area occupies less than half the land of Iraq with a total sand dunes area of about 10 percent of the whole area. The sand dunes area is separated in many parts of Iraq as shown in Figure (1) such as Salaaldien Governorate, AL-Anbar area. Also, the sand dunes occurred at Najaf Governorate, and in Diyala Governorate, west Imarah Governorate and west of Basrah Governorate, which may cause many problems to cities, roads, infrastructures, etc. [1]

Sand is well defined by engineers as the particles of soil that have a diameter that ranges from 0.06 mm to 2.00 mm, while geologists define sand as any particle of soil which are light sufficient to be moving by the wind but very heavy it cannot be suspended in the air. very fine particles that can be held in suspended in the air are known as clay or silt (dust), while heavy particles that are not affected by the wind can be classified as pebbles and gravel) [2,3].
Many researchers studied the sand dunes area like Mainguet [4] in which he defined the dune as “an accumulation of loose particles, deposited or a wind reformulation, with diameters range from 2 mm to tens of micrometers”. It has been argued that accumulations of loose particles are deposited or reformulated in fluvial environments (in lakes, seas, or river streams) cannot be considered as dunes because of there are no sharp tops. And Ahmad [5] studied the effect of soil chemical stabilizers including polyvinyl alcohol, ferquatac resin emulsion RB-50, bitumen emulsions Al-35, and aquapol resin35-0019, on the infiltration rate of Baiji dune sand. The results indicated that only the first stabilizer increased the infiltration rate. At the present time, it is difficult to get such a stabilizer in suitable quantities. Asi and Al-Abdul Wahhab [6] found that the stabilizing agents can be used to improve both the shear strength and resistance of tested soils to water damages. Moreover, they proved that additive, like Portland cement was more effective than the lime.

The use of stabilizing agents like Portland cement had brought up material with the most acceptable engineering characteristics [7]. Also using polypropylene fibers to reinforce dune sand reduces permanent deformation of sand specimens. It is believed that sand can be easily reinforced with Synthetic fibers to increase its stiffness and load-carrying capacity [8]. The use of petroleum mixtures also useful to stabilize the sand dunes in which it forms large amount of non-erodible aggregates and reduction of the erodible aggregates. Treated samples also, showed good stability against breakdown under repeated sieving, and the effect of cyclic freezing and thawing. One shortcoming is the possible toxicity to plants and the environment [9]. Bentonite powder can also be used to stabilize dune sand, the mixing and compaction method gave the best result in the improvement of the measured engineering properties before the treatment [10]. Permeability coefficient (k), is greatly affected by bentonite addition, as reported by Ameta and Wayal (2008). That permeability (k) was reduced from 10 cm/s to 10 cm/s after the addition of 10% bentonite by weight with compaction at the maximum dry density and the optimum moisture content. And a percentage of bentonite for stabilization should be 12% to 15 %, reduces the hydraulic conductivity to less than 10 cm/s, with "good" shear strength [11].

Al-Hillo [12] used the dune sand in improving the behavior of weak soil and the studied behavior of foundation supported by the dune sand column beneath the foundation. The results showed that there is good improvement in bearing capacity. It was about 892% in some (thickness of column/width of footing) ratio. Also, a reduction in the settlement was observed. Using dune sand itself in improvement works seems to be a good idea as it can be made available at economical costs.
2. Methodology

2.1. Sand dune
Sand dune used in this study was brought from Alshnafia desert (45 km from Diwaniyah city and 238 km south east Baghdad). It is classified as poorly graded sand (SP). The physical and chemical properties of sand dune are shown in Table 1 and the particle size distribution of sand dune is shown in Fig. 2.

Figure 2. (a) Site location of sand dune, (b) A map shows the study location

Figure 3. Particle Size Distribution of Sand dune
Table 1. Physical and Chemical Properties of Sand dune

| Index Property                  | Index Value |
|--------------------------------|-------------|
| Max. Dry Unit Weight (kN/m³)    | 17.4        |
| Min. Dry Unit Weight (kN/m³)    | 15.7        |
| D₁₀ (mm)                       | 0.17        |
| D₃₀ (mm)                       | 0.32        |
| D₆₀ (mm)                       | 0.42        |
| Coeff. of Uniformity (Cᵤ)     | 2.45        |
| Coeff. of Curvature (Cᵥ)       | 1.43        |
| Gravel (%) (G)                 | 0           |
| Sand (%) (S)                   | 89.4        |
| Fines (%)                      | 10.6        |
| Classification                 | SP          |
| Specific Gravity (Gs)          | 2.68        |
| Organic Material (%) (O.M)     | 1.22%       |
| (%) (TSS)                      | 11.32%      |
| SO₃ Content (%)                | 3.45%       |

2.2. Silicate Sodium

Liquid sodium silicate use in this study. The properties of sodium silicate are presented in Table 2.

Table 2. Properties of sodium silicate

| Index Property  | Index Value    |
|-----------------|----------------|
| Appearance      | Colorless liquid|
| Melting Point   | 0°C            |
| Boiling Point   | 100°C          |
| Density         | 1.37 g/ml      |
| PH              | 11-12.5        |

2.3. Test procedure

A laboratory test of unconfined compressive strength was performed on the sand dunes (at loose and dense state) with different percentages of sodium silicate (4%, 6%, 8%, 10%) and cured for 3, 5, 7, and 14 days. UCS for all samples was performed according to ASTM D-2850. A mould with 8.5cm height and 3.5cm was used. The specimens were prepared by mixing sand dune with different percentage of sodium silicate and then the specimen was compacted in the mold in three-layer after that the specimen was kept for curing before testing. Samples preparation and failure shape of the specimen are shown in Fig 4 and Fig 5.
3. Results and Discussion

The effects of adding sodium silicate to sand dunes are presented in Fig 6 to Fig 10 as a geotechnical properties improvement. The cohesion strength of sand dune after 3, 5, 7 and 14 day curing time is improved very quickly and the samples started to go on hardening a few hours after mixing. A good improvement noticed at 8% of sodium silicate and also for dense state and the appropriate time for treatment can be chosen at 7 days as a good improvement can be achieved.
Figure 6. Sodium silicate effect on the cohesion strength of sand dune after 3-day curing time

Figure 7. Sodium silicate effect on the cohesion strength of sand dune after 5-day curing time

Figure 8. Sodium silicate effect on the cohesion strength of sand dune after 7-day curing time
4. Conclusions
   - The reaction of sand dune with sodium silicate was very quickly and the samples started to go on hardening for a few hours.
   - The higher value of the cohesion of sand dune obtained by adding 8% of sodium silicate
   - The cohesion of sand dune at dense state is higher than at loose state when adding sodium silicate.
   - Through results, it was found that the value of cohesion of sand dune with 8% sodium silicate at 7 days and 14 days was very close, so the appropriate time for treatment can be chosen at 7 days because the most appropriate in terms of time.
   - As a curing time increased the cohesion of sand dune with 8% of sodium silicate increases.
   - The cohesion of sand dune increased as a percentage of sodium silicate increasing except when using 10% sodium silicate, the cohesion began to decrease.
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