Effect of sea water in grout on the mechanical behavior of cement stabilized marine sand

Mojgan Geravand[1], Hamed Bayesteh[2*], Mahdi Sharifi

[1] Graduated student, Department of civil engineering, University of Qom
[2] Assistant professor, Department of civil engineering, University of Qom
[3] Assistant professor, Department of civil engineering, University of Qom

ABSTRACT

One of the challenges in the field of geotechnical engineering is the sustainable development of soil improvement methods in marine environments due to severe environmental conditions such as high salinity. Implementation of soil-cement columns using deep mixing method and jet-grouting methods is an effective way to deal with problems caused by low resistance of coastal problematic soils. What is common in the implementation of these columns in the engineering community is the need to use fresh water to make the grout used in these columns. This, both from the point of view of its supply and transportation costs, and from the lack of fresh water in many areas, imposes high costs on projects and time delays. However, prior to the final cement retention, the saline water present in the environments of the columns was mixed with the fresh water in the grout as they were built deep in the soil. Investigating the feasibility of using sea water in mixing these columns and evaluating the behavior of soil-cement samples in marine conditions has received little attention. In this study, it has been attempted to investigate the effective factors in the grout mixing scheme including water salinity, cement percentage, water-cement ratio and processing time on uniaxial compressive strength and sand-cement tensile strength. SEM images were also microstructurally evaluated for sample behavior. The results show that in the 15% to 25% cement content, the use of sea water in grout production does not decrease the strength of sand-cement samples in marine environment. The obtained compressive strength range for sand-cement samples made with seawater is approximately (1.5 to 6) MPa and the tensile to compressive strength ratio of these samples is in the range (0.15 to 0.3).

KEYWORDS

Soilcrete, Seawater, Marine sand, UCS, Grout

(Corresponding author: Hamed Bayesteh: h.bayesteh@qom.ac.ir)

1. Introduction

One of the soil improvement methods that have become common in recently in Iran is the soil-cement columns using deep mixing method or Jet grouting, which is an effective way to deal with problems caused by soft soil in the marine environments [1]. Although the study of soil-cement behavior with different approaches has been of interest to researchers, most of these studies have been neglected the salinity effects of water and the environment and have been performed by fresh water. The previous studies indicated that in the range of 20 to 30 percent of cement in the preparation of soil-cement, the use of seawater does not have a negative effect on the resistance parameters of clay-cement samples [2]. In some cases, the use of water with relative salinity also has a positive effect on clay-cement samples, which is also specified by Kitazomi [3]. However, from an engineering point of view, the use of fresh water in the construction of the soil-cement columns has become common in the engineering community. This has led to high project costs and delays due to the lack of fresh water in many areas, especially the coastal area. Studies that have examined the effect of water salinity on sand-cement resistance [2, 4, 5] have generally used salts with specific ions and generally artificial salinity instead of the direct use of seawater in making samples. While the chemical compounds in seawater as well as soil-forming minerals are different. In this study, the effect of salinity of water used in preparing of the soilcrete, on the physical and microstructural properties of sand-cement will be investigated.

2. Methodology

One of the objectives of the study is to study sandy soil in natural marine conditions, the studied soil has been prepared from the northern coasts of Iran in the port of Anzali port which is classified in the Unified classification system (USCS) as bad granulation sand (SP). To investigate the effect of salinity in seawater on the mechanical behavior of sand-cement, a combination of fresh water and seawater in different concentrations has been used. The criterion for measuring salinity is the electrical conductivity of the soil (EC), which is generally expressed in the technical literature as mmho / cm. Accordingly, three modes of fresh water, medium salinity water (50% fresh water and 50% seawater) and seawater, which have electrical conductivity of 0.6, 9.2 and 16.5 mmho/cm, respectively have been used to make samples that indicate different salinity values. To obtain the electrical conductivity, the immersion electric sensor was immersed in distilled water (to avoid contamination), and the amount of electrical conductivity was obtained. Selected mechanical tests include unconfined compressive strength (UCS) and indirect Brazilian tensile strength according to ASTM-D 2166-00 and ASTM-D 3967-95a. In the mixing plan, the first group of fresh water (L), the second group of a mixture of seawater and fresh water were used equally (medium saline water) (M) and the third group of seawater (H) were used. In order to classify the information obtained from the mechanical behavior of soil-cement samples, four-part name such as L-15-0.75-07 was used. In this nomination method, the first letter indicates the salinity of water, the second number indicates the percentage of cement, the third number indicates the ratio of water to cement, and the fourth number indicates the curing time. For example, in a sample called L-15-0.75-07, L indicates fresh water, 15% of cement by weight of dry sand, 0.75% of water to cement ratio, and 7 days of curing time, respectively. The sample mixing plan was prepared in accordance with FHWA relationships [6]. To mold the soil-cement mixture, the samples are poured into 6 equal layers and each layer is compacted 30 times by a rod with a diameter of 2 cm.

3. Discussion and Results

The effect of salinity on the modulus of elasticity and compressive strength in different percentages of cement (15, 20 and 25) for the water to cement ratio of 1.25 at the age of 90 days has been studied at different ages are depicted in the Figure 1. It is observed that there is no significant change with increasing salinity of the modulus of elasticity. However, due to the formation of a dense structure in some samples, minor differences are observed. Generally, the modulus of elasticity decreases with increasing salinity (samples made with seawater) due to the formation of salt crystals.

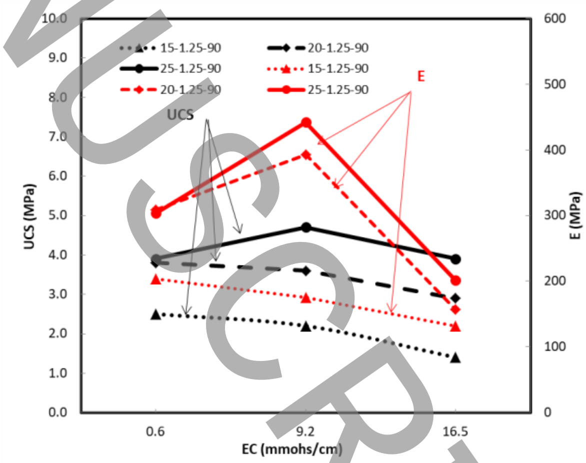

Figure 1. Effect of water salinity on the UCS and modulus of elasticity (E) of soilcrete

In order to investigate the effect of salinity on compressive strength of the samples tested at different ages, a coefficient called alpha (α) was defined, which indicates the compressive strength at each age compared to 7 days of age.

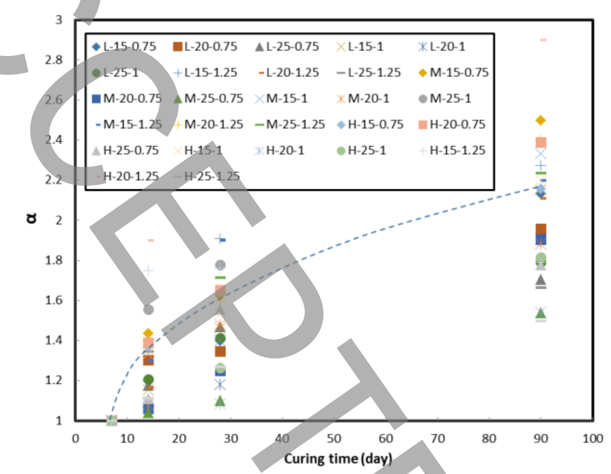

Figure2. Effect of water salinity on the strength of soilcrete vs. curing time

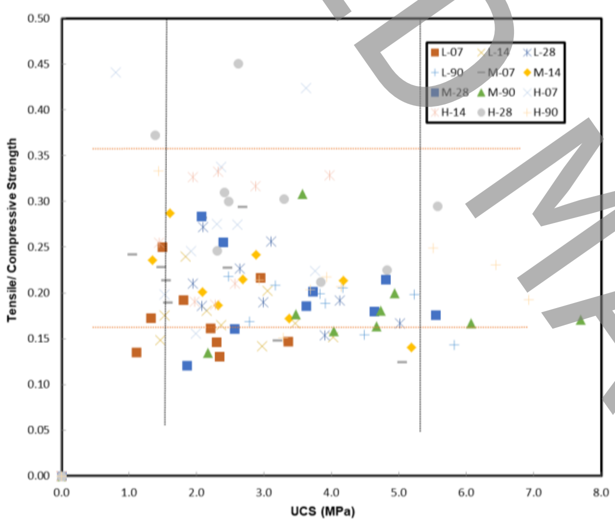

Figure 3. Relation between UCS and tensile strength in soilcrete

Figure 2 shows the changes in this coefficient at different times. It is observed that the highest percentage of increase in 90-day strength compared to 7 days in the water to cement ratio of 0.75 is related to the seawater. The ratio of the increase in 90-day resistance to the 7-day strength of the prepared sample with brackish water specimens is in the middle. This indicates that despite the salinity (medium and high) of sand-cement samples, they continue to increase their strength at an older age, and there is no concern about the use of water-soluble in long-term resistance of samples. It is observed that with increasing time, the strength has an upward trend and over time, the samples have shown a strength increase of up to 2.5 times compared to the 7-day resistance.

To analyze the strength behavior of sand-cement samples and use its results in studies related to the design of sand-cement columns, an attempt has been made to establish the relationship between tensile strength and compressive strength of sand-cement samples. The ratio of tensile strength to compressive strength of samples made with different waters at the ages of 7, 14, 28 and 90 days is shown in Figure 3. The compressive strength range of the samples is equal to 1.5 ~ 6 MPa.

4. Conclusions

- The use of seawater instead of fresh water in the design of mixing sand-cement samples is not prohibited. The increase in salinity has not had a significant negative effect on the compressive strength of the samples. This result is 15 to 25 percent for the cement range in the mixing scheme.

- The range of compressive strength to tensile strength ratio for samples made with seawater, medium salinity water and fresh water is equal to (0.16 to 0.35), (0.14 to 0.3) and (0.13 to 0.25). The average compressive strength of the samples in the laboratory conditions of this study is in the range of 4 MPa.

5. Refrences

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