Sulfate Resistant Cement and Barium Components Effects on Soil-Cement Strength under Sulfate Attack –A Laboratory Study

Shaham Atashband[1], Mohsen Sabermahani[2*], Hamidreza Elahi[3]

1. Department of Civil Engineering, Arak Branch, Islamic Azad University, Arak, Iran
2. School of Civil Engineering, Iran University of Science and Technology, Tehran, Iran
3. Department of Civil Engineering, Iran University of Science and Culture, Tehran, Iran

Received: 10 Jul. 2020 Accepted: 6 Oct. 2020

(Paper pages 177-206)

Abstract

In coastal industrial areas, in addition to the presence of loose soil, sulfate attack on soil improvement elements, such as soil-cement, is a double problem. Generally, the use of type V cement is recommended as one of the methods to reduce the detrimental effects. Considering the limited resources of this type of cement, firstly to determin the relationship between the cement content and the strength obtained in sulfated environments is one of the important engineering question in this field and secondly, as an alternative option, the use of type II cement which is more available, is suggested to use in combination with suitable additives. The present study pursues the above two goals by making cylindrical soil-cement specimens with sand, water and Portland sulfate resistant cements. Sodium sulfate is used as the sulfate in soil and water. In the research, first of all, the relation between type V cement content and unconfined compressive strength of soil-cement is obtained at 0% to 5% sulfate concentration, which results in a cement content of 400 kg/m^3 completely limited the sulfate attack effects in a sulfate concentration of 2%. Secondly, the combination of type II cement with barium chloride and hydroxide was tested. The related results show that the combination of type II cement with barium chloride and hydroxide had higher strengths, about 2.7 to 3.3 times, respectively (in 362 days), than the soil-cement containing type V cement.

Keywords: Soil improvement, soil-cement, barium chloride and hydroxide, sulfate resistant cement, unconfined compressive strength.

Extended Abstract

Introduction

The soil mixing method is an effective ground improvement technique that has been used to improve a wide range of problematic soils having different particle-size grades. In coastal industrial areas, in addition to the presence of loose soil, sulfate attack on soil improvement elements, such as soil-cement, is a double problem. The effects of sulfate attack can include extensive cracking, expansion, loss of the bond between the cement paste and aggregate, alteration of the paste composition during the monosulfate phase, causing the formation of ettringite and gypsum. The effect of these changes will be the overall loss of concrete or soil cement strength. Researchers have cautioned worldwide the use of cement in sulfate enriched environment or in marine soil containing sodium sulfate. Generally, the use of type V cement is recommended as one of the methods to reduce the detrimental effects. Considering the limited resources of this type of cement, firstly determining the relationship between the cement content and the strength obtained in sulfated environments is one of the important engineering question in this field and secondly, as an alternative option, the use of type II cement which is more available, is suggested to use in combination with suitable additives.

Material and methods

Cylindrical soil-cement specimens are used in this research. The material includes sand (Firoozkuh #161), tap water and Portland sulfate resistant cements (II and V types). Sodium sulfate (Na_2SO_4) is used as the sulfate in soil and water. Three sulfate concentrations of 0%, 2% and 5%. The lab mixing method performed in this research is based on ASTM 163. Polyvinyl chloride (PVC) cylindrical molds having an internal diameter of

3.5±0.02 (cm) and a height of 7.0±0.02 (cm) were used to mold the specimens for the unconfined compressive strength (UCS) tests. An adequate volumetric energy was selected to remove the air bubbles from the specimens using blows of a tamper. The specimens were cured by soaking in the corresponding tap water and/or sulfate solution. UCS tests were performed on the specimens according to ASTM D1633 at 1, 3, 7, 28, 42, 63, 91 and 362 days. A loading machine with a moving head operating at approximately 1.0 mm/min was assembled to operate automatically with a maximum capacity of 30 (kN) and an accuracy of 1 (N). In the research, first of all, the relation between type V cement content and unconfined compressive strength of soil-cement is obtained at 0% to 5% sulfate concentration. Secondly, the combination of type II cement with barium chloride and hydroxide was tested. Moreover, morphological assessments were carried out using scanning electron microscopy (SEM). A VEGA II LSH was used to study the morphology and elemental composition of the specimens.

Results and discussion

Graphs and equations such as those presented in the first part of the study can help designers to select an appropriate cement content to achieve the desired UCS (q_u) in soil cement structures exposed to sulfate attack. The equations provided in the first part of this study demonstrate the logarithmic relationship that exists between the UCS (q_u) and time (t) in which the coefficients are functions of the cement factor (α) and sulfate concentration (S%). The trends show that, in addition to q_u, f_c, CSL also follows logarithmic relationships over time. The results demonstrate that a cement content of 400 ($^{kg}/_{m^3}$) (type V) completely limited the sulfate attack effects in a sulfate concentration of 2%. According to SEM images, the mixture containing 400 ($^{kg}/_{m^3}$) cement (type V) shows no ettringite present. Observation of the microstructure confirms the results of the unconfined compressive strength trends. The related results obtained in the part two of this research show that the combination of type II cement with barium chloride and hydroxide had higher strengths, about 2.7 to 3.3 times, respectively (in 362 days), than the soil-cement containing type V cement.

To explain another result, barium hydroxide for up to 91 days has resulted in greater resistances than soil-cement composition containing 300 ($^{kg}/_{m^3}$) type 5 cement and no sulfate (control samples). Thus, as an additive to cement type II, barium hydroxide has better control of sulfate performance than barium chloride (with the same mixing ratio); in 362 days the CSL level is limited to less than 10%, while in barium chloride this value is about 30% and the trend of decreasing resistance is still progressing.

Conclusion

The following conclusions are drawn from this research:

-As observed, to limit the effects of sulfate attack for sulfate concentrations up to 2%, it is necessary to increase the SRPC-type V cement content to more than 400 ($^{kg}/_{m^3}$).

-Additives of barium hydroxide and barium chloride to type II cement show stronger performance than type V cement (alone). Meanwhile, barium hydroxide additive can significantly outperform other groups in 362 days in reducing the effects of sulfate.

-The SEM results clearly indicate that the structure of the stabilized sand containing more SRPC cement is denser. Also, the use of more SRPC cement result in a decrease in the amount of ettringite and other degradation products. Similar results are obtained in combination of type II cement and barium chloride or hydroxide.

*Corresponding Author: msabermahani@iust.ac.ir