Smart Geotechnics for Smart Societies – Zhussupbekov, Sarsembayeva & Kaliakin (Eds)

Stabilization of organic soil with CSA cement

Nazerke Sagidullina, Aiym Muratova, Jong Kim, Alfrendo Satyanaga & Sung-Woo Moon
Nazarbayev University, Nur-Sultan, Kazakhstan

ABSTRACT: Problematic soils, especially organic soils, are not usually suitable for engineering construction purposes due to their high compressibility. The infrastructures built on organic soil can be easily damaged by causing many problems, such as foundation settlement, cracking in the structure, and corrosion. Therefore, this study aims to investigate the effectiveness of CSA cement for the stabilization purposes of organic soil by conducting comprehensive laboratory work for the improvement of organic soil properties. For this purpose, Unconfined Compressive Strength (UCS) and free swell testing were performed on the stabilized soil specimens cured for 3, 7, and 14 days. Samples were prepared at optimum moisture content using different cement content, 0%, 10%, 15%, and 20%. Overall, the use of CSA as a stabilizer for silty would be useful to achieve sufficient strength and meet the requirements subgrade.

1 INTRODUCTION

The problematic soil, especially in severe weather conditions of Kazakhstan, is usually not applicable for geotechnical engineering purposes. Therefore, investigating the characteristics and performance of problematic soil is of great importance. Generally, the soil stabilization method is adopted to improve ground properties. For the treatment of problematic soil properties, chemical soil stabilization has been implemented for several decades due to a potential reduction in the construction and maintenance costs of pavement infrastructure built on problematic grounds. Chemical stabilization generally involves mixing or injecting the soil with a chemical stabilizer (Güllü &Fedakar 2017, Yilmaz &Fidan 2018, Bazarbekova et al. 2021, Subramanian et al. 2023). Cement and lime stabilization are commonly used methods for improving ground properties among the existing soil stabilization techniques.

Ordinary Portland Cement (OPC) is popularly used as a binding admixture, whose behavior has been well investigated by many researchers. On the other hand, using OPC poses environmental problems due to the significant emission of CO_2. Hence, considering global warming and climate change, there has been a strong need for replacing OPC with low CO_2-emitting binders.

Calcium Sulfoaluminate cement (CSA), which releases less carbon than OPC cement, can be used to treat problematic soil since several research works were carried out to assess CSA binder effectiveness. The previous research results showed the rapid strength gain of CSA-treated soil (Ocheme et al. 2022, Bisserik et al. 2021, Subramanian et al. 2018, Vinoth et al. 2018, Moon et al. 2020). Also, the effect of cyclic freezing and thawing was tested, where the addition of CSA cement considerably reduced the effect of cyclic freezing and thawing by improving the performance (Jumassultan et al. 2021, Sagidullina et al. 2022). Therefore, the CSA cement will be tested for the treatment of organic soil by conducting different experimental tests, such as unconfined compressive strength (UCS) and free swell tests.

DOI: 10.1201/9781003299127-73

2 EXPERIMENTAL WORK

2.1 *Materials*

The materials used in this experimental work are natural soil, calcium sulfoaluminate (CSA) cement, gypsum, and water. Table 1 shows the main physical properties of natural soil, which was received from the open-cut excavation in Nur-Sultan. Natural soil is defined as organic soil since it contains 18% of organic matter. The organic content of the soil is determined based on ASTM D2974 standard (2000). Applying the USCS classification, the soil type is classified as poorly graded sand with silt [SP-SM]. The gypsum was used to partially replace CSA cement since previous research by Subramanian et al. (2019) has shown that CSA cement with 30% of gypsum will have a high strength gain in treated soil.

Table 1. Physical properties of the soil.

Property	D_{10} (mm)	D_{30} (mm)	D_{60} (mm)	C_c	C_u	Organic content (%)	LL (%)	PL (%)	PI (%)	USCS
Value	0.08	0.18	0.45	0.90	5.63	18	83.99	74.01	9.99	SP-SM

2.2 *Sample preparation*

The received organic soil is oven dried for 24 hours at 105ºC to be further used in cement-soil mixtures. The mixture should be prepared at the optimum moisture content (OMC) and maximum dry density (MDD) conditions. These conditions are defined by the standard Proctor test, conducted according to ASTM/D698 standard (2007). The results of the testing for 0, 10, 15, and 20% CSA content mixture are given in Table 1. From the results of the Proctor test, it can be seen that with the increase of cement content, the maximum dry density decreases, and optimum moisture content increases. Using the OMC, soil mixtures were prepared, and samples were placed into the mold applying the undercompaction technique in three layers, where each layer was compacted 25 times. Mold with a diameter of 50 mm and a height of 100 mm was used. After the sample preparation step, the samples were cured at room temperature for 3, 7, and 14 days.

Table 2. Standard proctor test results.

Cement Content	0%	10%	15%	20%
OMC	36.0%	41.0%	44.0%	45.5%
MDD	1.148	1.114	1.101	1.062

2.3 *Experimental methods*

After each curing period, samples were tested for expansion and strength by conducting free swell and UCS element tests. A one-dimensional free swell test was performed according to ASTM D4546 standard (2008). The 1-D free swell test was conducted to observe changes in the volume of cement-treated soil. Problematic soils, especially expansive soils, with the change of moisture content, could have considerable changes in volume, which leads to the development of wide cracks with the decrease of moisture and swelling with the increase of moisture. The samples were assembled in an oedometer and inundated until the value of the dial gauge becomes constant. This wetting-induced deformation was measured continuously by setting the dial indicator. As the samples were already in the optimum moisture, content precautions should be applied to avoid test water absorption. The dial gauge reading was taken after 0.5, 1, 2, 4, 8, 15, 60, 120, 240, 480, 960 minutes, and so on until the dial gauge showed constant value over a significant period.

A UCS test was conducted to evaluate the cement-soil mixture's mechanical properties (ASTM/2166 2003). The samples were compressed at 1 mm per minute until the sample breakage. Five samples were tested for each cement content and curing time to get more reliable data.

3 RESULTS AND DISCUSSIONS

Figure 1 illustrates the UCS test results for 3, 7, and 14 days cured samples. It can be observed that the strength of the treated soil sample increases with the increase of cement content, mainly after 7 and 14 curing days. For example, in the case of samples treated with the 10% CSA cement, the compressive strength increased only by 18%, from 3 to 14 curing days, whereas samples with 15% and 20% cement content showed an 82% and 106% increase in strength, respectively.

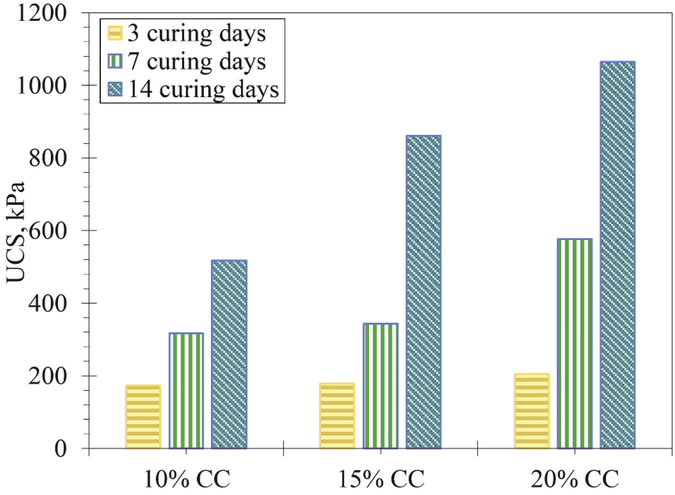

Figure 1. UCS test results.
Note: CC – cement content.

Figure 2 shows the results of 1D free swell testing for the 3, 7, and 14 curing days. Figure 2 shows that with the addition of more cement, the swelling percentage considerably decreased.

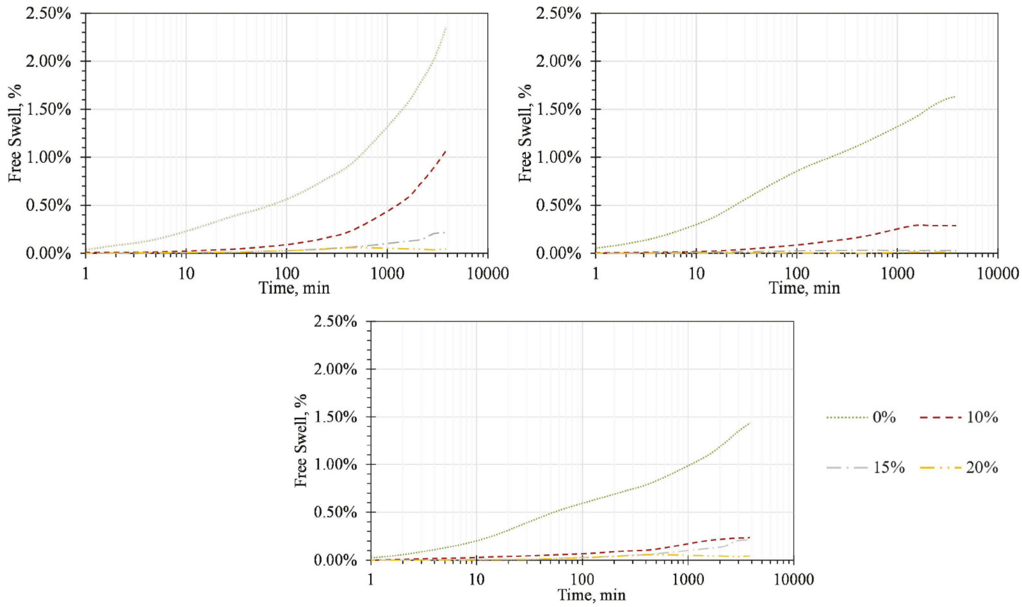

Figure 2. Free Swell test results: (a) 3 curing days, (b) 7 curing days, (c) 14 curing days.

For example, in the free swell test results after 3, 7, and 14 curing days, the swelling percentage decreased from 2.36% to 0.04%, from 1.63% to 0.01%, and from 1.44% to 0.04%, respectively.

Moreover, an increase in the curing period showed a reduced swelling percentage. For the untreated sample, the free swell value decreased by 61% from 2.4% to 1.4% when the curing period increased from 3 to 14 curing period. Overall, the CSA cement effectively reduced the swelling percentage of the soil. The decrease of free swell value depends on the percentage of additive and curing period.

4 CONCLUSIONS

This study is conducted to evaluate the effect of CSA cement used to stabilize problematic soil, categorized as expansive soil with organic content. For the assessment of the CSA cement treatment method, 1-D free swell and UCS tests were performed. The main findings of the research are listed below.

– Adding more cement improved the soil performance and cement-treated soil samples gained more strength with the increase of the curing period.
– The reduced swell percentage of soil can be achieved with an increase in cement content.

Further research will include assessing other parameters of stabilized soil, such as 3-D volume expansion and shear velocity. SEM pictures of soil will also be taken to see the changes in the microstructure of soil. Moreover, the long-term performance of CSA-treated soil will be tested. In addition, the determination of the efficiency of the soil stabilization technique with the CSA cement and other traditional chemical additives will be tested.

REFERENCES

Astm 2000. Standard test methods for moisture, ash and organic matter of peat and other organic soils, method ASTM D2974-00. ASTM International.

Astm, D. 2008. 4546, Standard Test Methods for One-Dimensional Swell or Collapse of Cohesive Soils. *ASTM International, United States.*

Astm/2166 2003. Standard test method for unconfined compressive strength of cohesive soil *American Society for Testing and Materials*. Philadelphia.

Astm/D698 2007. Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort. *American Society for Testing and Materials*. Philadelphia, PA.

Bazarbekova, A., Shon, C.-S., Kissambinova, A., Kim, J. R., Zhang, D. & Moon, S.-W. Year. Potential of limestone powder to improve the stabilization of sulfate-contained saline soil. *In:* IOP Conference Series: Materials Science and Engineering, 2021. IOP Publishing: 012016.

Bisserik, A., Kim, J., Satyanaga, A. & Moon, S.-W. Year. Characterization of CSA cemented-treated sands via discrete element method. *In:* AIP Conference Proceedings, 2021. AIP Publishing LLC: 030001.

Güllü, H. & Fedakar, H. I. 2017. Unconfined compressive strength and freeze-thaw resistance of sand modified with sludge ash and polypropylene fiber. *Geomechanics and Engineering*, 13: 25–41.

Jumassultan, A., Sagidullina, N., Kim, J., Ku, T. & Moon, S.-W. 2021. Performance of cement-stabilized sand subjected to freeze-thaw cycles. *Geomechanics and Engineering*, 25: 41–48.

Moon, S.-W., Vinoth, G., Subramanian, S., Kim, J. & Ku, T. 2020. Effect of fine particles on strength and stiffness of cement treated sand. *Granular Matter*, 22: 1–13.

Ocheme, J. I., Khamitov, R., Satyanaga, A., Kim, J. & Moon, S.-W. Year. Triaxial Test Behavior of CSA-treated Sand with High Confining Pressure. *In:* The 2022 World Congress on Advances in Civil, Environmental, & Materials Research, 2022.

Sagidullina, N., Abdialim, S., Kim, J., Satyanaga, A. & Moon, S.-W. 2022. Influence of Freeze–Thaw Cycles on Physical and Mechanical Properties of Cement-Treated Silty Sand. *Sustainability*, 14: 7000.

Subramanian, S., Khan, Q., Moon, S. W. & Ku, T. 2023. A Review of Mix Design Terminologies for Cement-Admixed Sandy Clay. *8th International Symposium on Deformation Characteristics of Geomaterials*. Porto, Portugal.

Subramanian, S., Moon, S.-W. & Ku, T. Year. Effect of Gypsum on the strength of CSA treated sand. *In:* 16th Asian Regional Conference on Soil Mechanics and Geotechnical Engineering, 2019.

Subramanian, S., Moon, S.-W., Moon, J. & Ku, T. 2018. CSA-treated sand for geotechnical application: microstructure analysis and rapid strength development. *Journal of Materials in Civil Engineering*, 30: 04018313.

Vinoth, G., Moon, S.-W., Moon, J. & Ku, T. 2018. Early strength development in cement-treated sand using low-carbon rapid-hardening cements. *Soils and Foundations*, 58: 1200–1211.

Yilmaz, F. & Fidan, D. 2018. Influence of freeze-thaw on strength of clayey soil stabilized with lime and perlite. *Geomechanics and Engineering*, 14: 301–306.