Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 52(4) (2020) 239-242
DOI: 10.22060/ceej.2018.15100.5829

Laboratory study on stabilization of kaolinite clay with cement and cement kiln dust

S. Ghavami[1], H. Jahanbakhsh[2], F. Moghadas Nejad[2]

[1] School of Civil Engineering, Iran University of Science and Technology, Tehran, Iran.
[2] Department of Civil Engineering and Environmental, Amirkabir University of Technology, Tehran, Iran.

ABSTRACT: Considering the geotechnical problems caused by low strength, clayey soils are important in construction projects. Chemical stabilization with additives such as cement is a common method to improve the engineering properties of clay soils. In spite of the acceptable effects of cement on the strength of soils, the cost of this additive and its destructive effects on the environment should be of concern. This has led the researchers to use by-products and waste materials. Cement Kiln Dust (CKD) is a powdery byproduct of the Portland cement manufacturing process. In this paper, the geotechnical parameters of cement and cement kiln dust stabilized kaolinite clay are compared. For this purpose, Atterberg limits, standard proctor, unconfined compressive strength, and California bearing ratio tests were conducted on specimens containing 5, 10 and 15% cement and CKD (by dry weight of the soil). The results show that the cement and cement kiln dust increase soil strength. It was seen that the unconfined compressive strength of the specimen with 15% CKD is equal to the specimen with 10% cement after 28 days of curing. It is evident from the scanning electron microscopy analysis of specimens containing cement and CKD that calcium silicate and aluminate hydration products reduce the volume of the void spaces and join the soil particles, leading the strength to increase.

Review History:

Received: 10/7/2018
Revised: 11/3/2018
Accepted: 12/17/2018
Available Online: 12/17/2018

Keywords:

Soil Stabilization
Cement
Cement Kiln Dust
Geotechnical Parameters
Scanning Electron Microscope

1. INTRODUCTION

Traditional chemical stabilizing additive such as Portland cement is often used to improve the engineering properties of clay soils with low strength [1-2]. In spite of the acceptable effects of cement on the strength of soils, utilizing a considerable amount of energy, and emission of the massive quantity of air pollutants especially greenhouse gases during the production of cement has led the researchers to use by-products and waste materials such as cement kiln dust (CKD).

Cement kiln dust is a by-product of the cement manufacturing process that collected from electrostatic precipitators during the production of cement clinker [3]. The presence of free lime (CaO), the high alkali content, and the high fineness of CKD make it potentially valuable material for soil stabilization [4].

Kaolinite clay considered as soil with poor properties through low strength [5]. Previous studies have shown that CKD can be used for soil stabilization as an alternative to cement [4, 6, 7]. However, the study on the comparison of the effect of cement and CKD on the geotechnical parameters of kaolinite clay, and statistical analysis of results has not been done so far. Also, this paper will determine how much CKD can be used as an alternative to cement for improving the strength of kaolinite clay.

2. MATERIALS AND METHODS

In this study, commercial kaolinite clay was utilized as raw soil. The geotechnical properties of the clay were measured according to ASTM standards and are summarized in Table 1. Type II Portland cement and CKD were obtained from the Shahroud cement factory. The compositions of the CKD and cement consist primarily of CaO, SiO_2, Al_2O_3, and Fe_2O_3.

Atterberg limits, standard Proctor, unconfined compressive strength, and California bearing ratio tests were conducted on specimens containing 5, 10 and 15% cement and CKD (by dry weight of the soil). Also, changes in microstructures of soil were observed using SEM analysis.

Table 1. Geotechnical properties of kaolinite clay.

Properties	Value
Liquid limit (LL), %	29.5
Plastic limit (PL), %	21.5
Plasticity index (PI), %	8
Soil classification (USCS)	CL
Specific gravity	2.65
Maximum dry density, kN/m^3	17
Optimum moisture content (%), %	16.2
Unconfined compressive strength, kPa	129
Soaked California bearing ratio, %	3

*Corresponding author's email: email

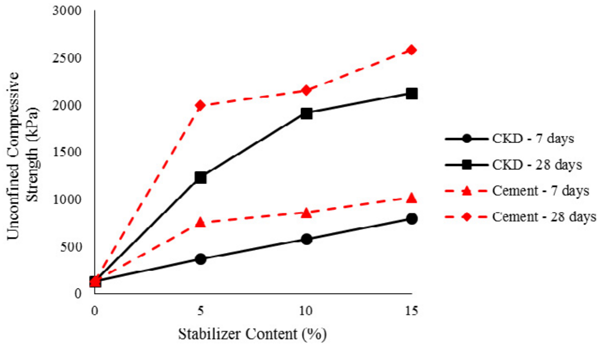

Fig. 1. Effect of addition of cement and CKD on UCS of kaolinite clay after 7 and 28 days curing

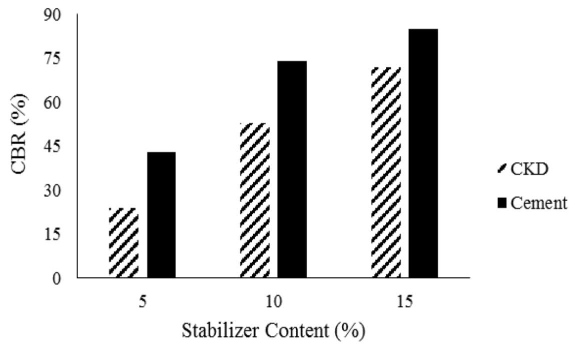

Fig. 2. Variation of CBR of specimens

3. RESULTS AND DISCUSSION

3.1. Atterberg limits

The addition of cement and CKD to soil lead the liquid and plastic limit of stabilized soil to increase. The increase in plastic limit may be attributed to the quantity of water used should be just sufficient to satisfy hydration requirements. Since the plasticity index of kaolinite clay is low, it appears not to change very much due to the addition of cement and CKD.

3.2. Compaction test

Regarding the compaction curve, by increasing the amount of cement and CKD, the maximum dry density (MDD) decreases and optimum moisture content (OMC) increases. The increase in OMC is due to the water-loving nature of the calcium oxide. The MDD appears to decrease because the aggregation of particles due to stabilizer results in larger macropores within the soil. The reduced MDD might also result from the replacement of soil of higher specific gravity with the stabilizer of lower specific gravity.

3.3. Unconfined compressive strength

The effect of cement and CKD on the unconfined compressive strength of the soil at curing periods of 7 and 28 days is shown in Fig. 1. It can be argued that the increase in strength in specimens containing cement is much higher than that of CKD. So that the UCS of the specimen with 15% CKD is approximately equal to the UCS of the specimen with 10% cement after 28 days curing.

During the pozzolanic reaction, high pH environment due to an interaction of stabilizer containing alkalis with soil in the presence of water, causes silica and alumina to be dissolved out of the structure of the clay minerals and to combine with the calcium to form calcium silicate hydrate (C-S-H) or calcium aluminate hydrate (C-A-H). These products in the treated soil were presumed to be the major factor contributing to strength improvements. SEM images also showed the formation of a dense matrix in specimens with cement and CKD resulting from cementitious products.

By the addition of cement and CKD, corresponding strain to peak axial stress decreased. Therefore, treated soils are more brittle compared with raw soil, which can be problematic in dynamic loading. Due to the higher production of C–S–H gel in the soil-cement mixture than the soil-CKD mixture, specimens with cement display much more brittle behavior.

3.4. California bearing ratio

The soaked California bearing ratio of specimens after 7 days of curing illustrated in Fig. 2. The CBR value of soil improved from 3% to 43, 74 and 85%, resulting from the addition of 5, 10 and 15% cement after 7 days curing time. The addition of 15% CKD increases CBR 24 times relative to untreated soil. The increment in CBR of specimens with cement and CKD may be attributed to the formation of cementitious compounds resulting in bonding between the stabilizer and soil particles.

3.5. Statistical analysis

In this study, a statistical analysis is performed to check if the parameters and their interactions are statistically significant in the performance of cement and CKD treated soils. To this end, the multi-way analysis of variance (ANOVA) with replication was conducted using Minitab 2018 software. Atterberg limits, UCS, and CBR results with three replicates were selected as response variables to study the effect of stabilizers on the geotechnical responses. Also, a significance level of 0.05 ($a = 0.05$) was selected to investigate the null hypothesis. Moreover, the Tukey-Kramer method is used in order to compare all possible pairs of means and find the means that are significantly different from each other. As Tukey-Kramer statistical test says, the UCS and CBR of the specimen with 15% CKD and 10% cement are statistically equal after 28 and 7 days of curing, respectively.

4. CONCLUSIONS

The following conclusions can be drawn from this study:

- The addition of cement and CKD led the liquid and plastic limit to increase. Since the plasticity index of kaolinite clay is low, it appears not to change very much due to the addition of cement and CKD.
- Cement and CKD treatment leads to increase the optimum water content and decrease the maximum dry density of treated soils.
- The addition of cement and CKD enhances unconfined compressive strength and California bearing ratio. The UCS and CBR of the specimen with 15% CKD and 10% cement are statistically equal after 28 and 7 days of

curing, respectively. Therefore, CKD can be used for the improvement of kaolinite clay as an alternative to cement and reduced cement consumption.

- Treated kaolinite clay with cement is more brittle compared to CKD.

REFERENCES

[1] E. Basha, R. Hashim, H. Mahmud, A.J.C. Muntohar, b. materials, Stabilization of residual soil with rice husk ash and cement, 19(6) (2005) 448-453.

[2] M. Asgari, A.B. Dezfuli, M.J.A.J.o.G. Bayat, Experimental study on stabilization of a low plasticity clayey soil with cement/lime, 8(3) (2015) 1439-1452.

[3] R. Siddique, Waste materials and by-products in concrete, Springer Science & Business Media, 2007.

[4] S. Peethamparan, J. Olek, J.J.C. Lovell, c. research, Influence of chemical and physical characteristics of cement kiln dusts (CKDs) on their hydration behavior and potential suitability for soil stabilization, 38(6) (2008) 803-815

[5] A.J. Alrubaye, M. Hasan, M.Y.J.I.J.o.G.E. Fattah, Stabilization of soft kaolin clay with silica fume and lime, 11(1) (2017) 90-96.

[6] Z.A.J.E.S. Baghdadi, Jeddah, Scientific Publication Center, King Abdul Aziz University, Utilization of kiln dust in clay stabilization, 2 (1990) 153-163.

[7] G.A. Miller, S.J.C. Azad, b. materials, Influence of soil type on stabilization with cement kiln dust, 14(2) (2000) 89-97.

HOW TO CITE THIS ARTICLE

S. Ghavami, H. Jahanbakhsh, F. Moghadas Nejad, Laboratory study on stabilization of kaolinite clay with cement and cement kiln dust, Amirkabir J. Civil Eng., 52(4) (2020) 239-242.

DOI: 10.22060/ceej.2018.15100.5829