Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 55(12) (2024) 511-514
DOI: 10.22060/ceej.2023.22016.7880

Investigating and studying the effect of Montmorillonite Nanoclay on consolidation and strength behavior of soft and loose fine-grained soil (Case study: fine-grained soil of Kermanshah Faculty of Agriculture)

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ABSTRACT: Using innovative and environmentally friendly materials to stabilize problematic soils is one of the challenges facing geotechnical engineers. Nanoclays are highly reactive due to their high specific surface area, low specific gravity, fine particles, and making them an effective and environmentally friendly stabilizer due to their uniformity with soil materials. In this study, the effect of Montmorillonite Nanoclay on the behavioral properties of Kermanshah's loose fine-grained soil was evaluated. For this purpose, after conducting index and identification tests on the base soil, Nanoclay was added to the soil at 0.5, 1, 2, and 4 percent by dry weight of the soil, and Atterberg limits, consolidation, unconfined compressive strength, and California bearing ratio tests were conducted on samples with curing periods 1, 14, 28 and 60 days. Also, the durability of the stabilized samples was investigated by subjecting them to wet-dry cycles, and the effect of nanoclay on the soil's microstructure was evaluated using scanning electron microscopy on both unstabilized and stabilized samples. The results show that the stabilization performance is significantly dependent on the amount of Nanoclay and curing periods. Based on the results, the optimal amount of Nanoclay is 4%, and the presence of this amount of Nanoclay along with increasing curing periods has increased the plastic index, compressive strength, and soil bearing ratio and decreased the coefficient of consolidation, settlement, compression, permeability, and soil swelling. It is noteworthy that the durability of stabilized soil against environmental conditions has also increased.

Review History:

Received: Dec. 15, 2022
Revised: May, 03, 2023
Accepted: Nov. 14, 2023
Available Online: Nov. 29, 2023

Keywords:

Soil Stabilization
Soft Clay Soil
Nanoclay
Consolidation
Wet-Dry Cycle

1- Introduction

Nanoparticles typically have dimensions ranging from 1 to 100 nanometers. Due to their high specific surface area and reactivity, they have gained significant attention in recent years as stabilizers [1]. Nanoclays, a subcategory of nanotechnology, comprise small and irregular clay sheets. Since they are uniform and compatible with soil materials, their use does not have negative impacts on the environment, and adding these particles on a nano-scale can lead to changes in the behavior and properties of soils [2].

Numerous studies have been carried out to date regarding the stabilization of soils using nanoclay particles; however, only a limited amount of previous research has examined the impact of nanoclay particles on the long-term behavior of soil and the durability of soil against environmental conditions.

This study aims to examine the effects of montmorillonite nanoclay particles on the short-term and long-term behavior of soft clay soil, also since environmental conditions such as wet-dry cycles, in the long run, are one of the most destructive factors and lead to decrease in the strength of soil or may fail due to the spread of fine cracks in the soil [3]. So the effect of nanoclay on the soil durability under wet-dry cycles has been investigated.

2- Methodology

2- 1- Materials

2- 1- 1- Soil and nanoclay

The soil used in this study was taken from the Faculty of Agriculture of Razi University located in the east of Kermanshah from a depth of approximately one meter above the ground. Table 1 presents the characteristics of soil. Based on the index tests performed, this soil is defined as CL and mainly evaluated as fine-grained, soft, and loose.

The nanoclay used in this research is montmorillonite in powder form, a product of the Sigma Aldrich Factory with a purity of 99%.

2- 2- Method

First Montmorillonite nanoclay was mixed with soil at 0.5, 1, 2, and 4 percent by dry weight of the soil. Then based on maximum dry density and optimum moisture, samples were prepared and sealed in a double-layered plastic wrap and kept in a room with the temperature maintained at 20±2°C under various curing times (1, 14, 28, and 60 days). After completion of curing time, Atterberg limits, one-dimensional consolidation, uniaxial compressive strength (UCS), California bearing ratio tests, and wet-dry cycles were

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Table 1. Geotechnical properties of studied soil.

Characterizes	Value
Optimum Moisture (%)	22.1
Maximum Dry Density (gr/cm^3)	1.62
Gs	2.67
Liquid Limit (%)	46.64
Plastic Limit (%)	21.23
Plasticity Index (%)	25.41

conducted on samples. To achieve the optimal amount of nanoclay, the samples containing higher amounts of nanoclay (8% of the dry weight of the soil) were also examined in the consolidation and UCS tests. Also, to perform a wet-dry cycle, the cured samples were first immersed in distilled water at room temperature (20±2 ◦C) for 5 h. Once removed, the samples were placed in an oven at 71±2 ◦C for 42 h. Finally, to investigate the effect of nanoclay on the soil's microstructure, scanning electron microscopy (SEM) was performed on unstabilized and stabilized samples.

3- Results and Discussion

3- 1- The effect of nanoclay on plasticity properties

With increasing the amount of nanoclay from 0 to 4% of soil dry weight and curing time from 1 to 60 days, the liquid limit, plastic limit, and plasticity index increased. This increase is due to the high specific surface of nanoclay, which increases the water absorption of stabilized samples and consequently raises the Atterberg limits of stabilized samples.

3- 2- The effect of nanoclay on consolidation

Based on the results, with the presence of nanoclay up to 4% of weight, and with increased curing times, the compression index, consolidation coefficient, settlement, permeability, and soil swelling index decreased. By adding 4% nanoclay and a curing period of 60 days the compression index, consolidation coefficient, settlement, permeability, and swelling decreased by 58%, 59%, 55%, 69%, and 62% respectively compared to the base soil, and the sample became overconsolidated up to 0.6 kg/cm2 compared to base soil which is normally consolidated. It is noteworthy that the reaction speed of nanoclay with soil was very high in the initial 14 days. It can be said that the presence of nanoclay particles in the soil increases the contact surface between soil particles so that a part of the existing voids between soil particles are filled, resulting in decreased soil settlement against applied loads. Also, the reduction in permeability is due to the decrease in voids between soil particles. Furthermore, the reduction of soil swelling is attributed to the high water absorption of montmorillonite nanoclay particles, which absorb most of the water in the sample. On the other hand, when nanoclay was increased to 8% by weight, the compression index, consolidation coefficient, settlement, permeability, and soil swelling index increased. This is because, in this case, the sample's behavior is influenced more by the nanoclay particles.

3- 3- The effect of nanoclay on UCS

According to the results with increasing the curing periods and amount of the nanoclay, the compressive strength of samples increased and the peak of the UCS of stabilized soils occurred at a lower strain compared to the unstabilized soil. The most compressive strength was obtained in the presence of 8% nanoclay after a curing period of 60 days which compressive strength increased by 750% and the strain values decreased by 36% compared to the base soil. However, it should be noted that the presence of nanoclay at 8% by weight had no significant effect on the compressive strength of the soil compared to 4% by weight. So optimum amount of nanoclay for the soil being studied based on consolidation and UCS test results is 4%.

3- 4- The effect of nanoclay on CBR

The addition of an optimal amount of nanoclay increases the bearing ratio of the soil. With the increase in curing periods, this parameter has shown an upward trend. For instance, after the 60-day curing period, the CBR value of the stabilized sample with 4% nanoclay reached 16.3%, whereas the CBR of the base soil was 3.5%. This increase in the bearing ratio over time is due to the improvement of nanoclay cementation reactions.

3- 5- The effect of wet-dry cycles on stabilized samples

Generally, the samples with longer curing periods and higher amounts of nanoclay additives, up to 4%, demonstrated greater durability and experienced less weight loss during the wet and dry cycles. This is due to the cementation reactions of nanoclay with soil. The unstabilized sample had the lowest durability during these cycles, completely failing in the first wet cycle as a result of water absorption and the dominance of the soil particles' swelling forces over the van der Waals force between the particles. Conversely, the highest durability against wet and dry cycles was observed in samples stabilized with 2% and 4% of nanoclay at the curing periods of 14, 28, and 60 days. These samples withstood 2 wet-dry cycles and then failed during the third cycle.

3- 6- The effect of nanoclay on soil's microstructure

The SEM analysis showed that the stabilized soil with the optimum percentage nanoclay at 60 days curing period had a more homogeneous structure and more uniform surface than the unstabilized sample. Also, nanoclay causes larger pores to be filled and converted into smaller pores.

4- Conclusion

Laboratory tests conducted in this study showed considerable improvement in the soil engineering properties containing montmorillonite nanoclay particles. The main results obtained in this study are as follows:

-By adding nanoclay up to 4% to soil and with curing periods from 1 to 60, the water absorption, and plasticity properties of soil were increased because of the high specific surface of nanoclay. Also compression index, consolidation coefficient, settlement, permeability, and swelling decreased by 58%, 59%, 55%, 69%, and 62% respectively compared to the base soil. But, when nanoclay was increased to 8% by weight, the sample's behavior was influenced more by the nanoclay particles, and consolidation parameters were increased.

-The compressive strength of samples increased and the peak of the UCS of stabilized soils occurred at a lower strain compared to the unstabilized soil with increasing the curing periods and amount of the nanoclay. The presence of nanoclay at 8% by weight had no significant effect on the compressive strength of the soil compared to 4% by weight. So the optimum amount of nanoclay for the soil being studied based on consolidation and UCS test results is 4%.

-The CBR value of the stabilized sample with the optimum amount of nanoclay after the 60-day curing period reached 16.3%, whereas the CBR of the base soil was 3.5%.

-With the presence of nanoclay up to 4% of weight, and with increased curing times, the soil durability under wet-dry cycles has been increased. The highest durability against wet and dry cycles was observed in samples stabilized with 2% and 4% nanoclay at the curing periods of 14, 28, and 60 days. These samples withstood 2 wet-dry cycles and then failed during the third cycle.

-Based on SEM analysis stabilized sample had a more homogeneous structure, less porosity, and a more uniform surface than the unstabilized sample.

References

[1] A. Kalhor., M. Ghazavi., M. Roustaei., and M. Mirhosseini., 2019. "Influence of nano-SiO2 on geotechnical properties of fine soils subjected to freeze-thaw cycles". Cold Regions Science and Technology, 161.

[2] M.R. Taha., 2009. "Geotechnical Properties of Soil-Ball Milled Soil Mixtures", in: Nanotechnology in Construction 3, Berlin, Heidelberg: Springer Berlin Heidelberg, pp. 377-382.

[3] H.R. Akbari., H. Sharafi., and A.R. Goodarzi., 2021 "Effect of polypropylene fiber and nano-zeolite on stabilized soft soil under wet-dry cycles". Geotextiles and Geomembranes, 49(6), pp. 1470-1482.

HOW TO CITE THIS ARTICLE

R. Fathi, M. R. Elyasi, J. Khazaei, Investigating and studying the effect of Montmorillonite Nanoclay on consolidation and strength behavior of soft and loose fine-grained soil (Case study: fine-grained soil of Kermanshah Faculty of Agriculture), Amirkabir J. Civil Eng., 55(12) (2024) 511-514.

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