

Laboratory Evaluation of the Effects of Temperature and Nano-magnetite on the Physical and Mechanical Characteristics of Clayey Soil (Case Study: Rasht Clay)

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Abstract

In geotechnical engineering, using additives to improve soils is very important. This research aims to investigate the effects of Temperature and nano-magnetite on the physical and mechanical properties of clayey soil. The selected percentages for nano-magnetite as 0, 0.5, 1, 1.5, and 2% in standard curing conditions (1, 28, and 90 days) and under different temperatures (3 days at 20, 40, and 60°C) to evaluate the physical and mechanical characteristics of the samples, atterberg limits, standard compaction, unconfined compressive strength (UCS), direct shear test (DST), and ultrasonic pulse velocity (UPV) were used. The results of this research show that by adding 1% of nano-magnetite to clayey soil at a temperature of 60°C, the UCS of clayey soil increased by about 175%, and further, according to the DST, it can be seen that the parameters of cohesion and Internal friction angle have increased by 115% and 77% respectively. Also, the UPV was the highest due to the addition of 1% nano-magnetite, which can confirm the results obtained for mechanical tests.

Keywords: *Nano-magnetite, Clayey soil, Physical properties, Mechanical properties, temperature.*

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Extended Abstract:

1. Introduction

The purpose of soil stabilization and improvement is to increase the bearing capacity and reduce settlement and deformation. Soil stabilization and improvement methods can generally be divided into three categories: mechanical, chemical, and physical. To stabilize and improve the soil, waste materials, fibers, cement, and various additives have been used to improve the shear strength parameters of clayey soil (Eshghi and Jafary, 2022; Changizi and Haddad, 2017). In continuation and with the advancement of technology, nanomaterials can also be used as new additives, and the main purpose of using them in geotechnical engineering is to improve the physical and mechanical properties of soils by adding these materials. Nanoparticles significantly affect soil engineering properties due to their specific surface area, high cation exchange capacity, and participation in chemical reactions, even when only a small amount is added to the soil (Majeed and Taha, 2013; Liu et al, 2023; Krishnan et al, 2019). In the field of geotechnical engineering, most of the studies have been done with nano-silica (Ghasabkolaei et al, 2016; Soleimani Kutanaei and Janalizadeh Choobbasti, 2017; 2018; Kalhor et al, 2019; Gu et al, 2022, Eshghi et al, 2022) and nano-clay (Khalid et al, 2015; Sharo and Alawneh, 2016; Arabani et al, 2023). In other words, fewer studies have been done on other nanomaterials. In the current research, the effect of nano iron oxide on some geotechnical characteristics of clayey soil has been investigated. The selection of nano iron oxide as a new material has been little research on the strength of soil, especially nano-magnetite, and also because of its compatibility with the environment with filler and catalytic properties, as well as the acceptable distribution of this material from the mineral point of view. which is considered with high abundance, in case of providing positive results on the studied soil compared to other nanomaterials, it can be cost-effective and also compatible with the environment. Based on this, this research has been investigated by emphasizing the curing and the effect of temperature parameters on the curing of samples, the effect of additives on the physical and mechanical characteristics of clayey soil, as well as the effect on the UPV.

2. Materials and Methods

2. 1. Materials used

The soil used in this research is of clay type and classified as CL with $G_s=2.75$ and it was prepared from Rasht city located in the north of Iran. Also, the nano iron oxide used in this research is nano-magnetite with the chemical formula Fe_3O_4 and it is also used in solution with a concentration of 300 gr/lit for better distribution of nanoparticles in this research.

2. 2. Laboratory Methods

In this research, the sample is coded as CxN, where C indicates clayey soil, x indicates the percentage of nano-magnetite, and N indicates nano-magnetite. Also, the introduction of curing conditions at different temperatures is in the form of Ty, where T represents the temperature and y represents the desired temperature. Next, to investigate the effect of nano-magnetite on the physical and mechanical characteristics of clayey soil, the values of nano percentages have been chosen as 0.5, 1, 1.5, and 2 percent. Also, the optimum moisture content for mixing the samples is 15% according to the optimum moisture content of the studied soil.

3. Result and Discussion

The results of investigating the effect of nano-magnetite on the Atterberg limits and compaction characteristics of clayey soil samples and samples containing different percentages of nano-magnetite are given in Table (1). As Table (1) shows, with the addition of nano-magnetite, the liquid limit has a decreasing trend and finally, the plastic limit is always on the rise. Due to the addition of nano-magnetite to clayey soil and the higher density of nano-magnetite compared to clayey soil, the maximum dry unit weight (MDUW) of the sample containing 1 percent nano-magnetite compared to clayey soil had an increasing trend. From 1 percent onwards, it was a decreasing trend. Next, the optimum moisture content (OMC) of mangroves increased due to the addition of nano, and the largest increase was due to the addition of 2 percent nano-magnetite to the soil, which increased from 15 percent to 16.5 percent.

Table 1. Values related to Atterberg limit and standard compaction tests

Mix Code	Atterbeg Limits			Standard Compaction	
	LL	PL	PI	MDUW (KN/m ³)	OMC (%)
C0N	38	19	19	17.2	15
C0.5N	36.9	19.5	17.4	17.9	15.4
C1N	35.1	20.2	14.9	18.5	16.1
C1.5N	34.9	20.3	14.6	18.3	16.2
C2N	34.8	20.3	14.5	17.8	16.5

The results of this research show that by adding 1% of nano-magnetite to clayey soil at a temperature of 60°C, the UCS of clayey soil increased by about 175%, and further, according to the DST, it can be seen that the parameters of cohesion and Internal friction angle have increased by 115% and 77% respectively. Also, the UPV was the highest due to the addition of 1% of nano-magnetite, which can confirm the results obtained for mechanical tests.

4. Conclusion

- As a result of adding nano-magnetite to clayey soil, the plasticity index of the samples containing nano-magnetite (0.5, 1, 1.5, and 2 percent) decreased by 8.1, 21.5, 22.9, and 23.5 percent respectively. Also, it can be seen that from the combination of 1% of nano-magnetite with soil, the slope decreases and practically more effect is shown in 1%.
- Due to the addition of nano-magnetite to clayey soil and the higher density of nano-magnetite compared to clayey soil, the maximum dry unit weight of the sample containing 1 percent nano-magnetite compared to clayey soil had an increasing trend. From 1 percent onwards, it was a decreasing trend. Next, the optimum moisture content of mangroves increased due to the addition of nano, and the largest increase was due to the addition of 2 percent nano-magnetite to the soil, which increased from 15 percent to 16.5 percent.
- Due to the addition of 1% of nano-magnetite, the maximum UCS has occurred, which is the highest value in the standard conditions of 90 days and applying a temperature of 60°C, which has increased by about 110% and 155%, respectively, in the ratio of clayey soil, which is the reason This increase in resistance can be specifically searched for in the filler and catalytic properties of nano-magnetite.

- The maximum UPV in the sample with 1% by weight of nano-magnetite was measured under the standard 90 days curing conditions and accelerated curing condition with a temperature of 60°C, which has increased by about 47% and 56%, respectively, compared to clayey soil, which practically shows the density above are the examples in the physical part and the formation of strong bonds due to the application of heat.
- The changes in cohesion values for nano-magnetite in standard conditions of 90 days and accelerated at 60°C compared to clayey soil were about 83% and 115%, respectively. In the following, the changes in the values of the internal friction angle for nano-magnetite in standard conditions of 90 days and accelerated at a temperature of 60°C are about 72% and 77%, respectively.

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