Iranian Journal of Engineering Geology
Winter 2022, Vol.14, No.4

Laboratory Evaluation of polypropylene fibers and nano-SiO2 on geotechnical properties of clayey soils

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Abstract

Improvement of problematic soils, as an inevitable issue, has an important role in the construction projects. Adding some additive materials to the soil, has been considered as one of the effective procedure in improving characteristics behavior of soils. In this study, the effect of polypropylene fibers and nano-SiO_2 in combination with clay was investigated, as a novel method, in order to refining mechanical properties of the soil. The purpose of this research is to investigate the effect of nano-SiO_2 and polypropylene fibers on the properties of low plasticity clay by applying Unconfined Compression Test. Three different mixtures of the proportion of polypropylene fibers(0.25 %, 0.5%, and 1% of dry weight of clayey soil) and nano-SiO_2 (0.5%, 0.75%, and 1% of dry weight of clayey soil) has been used. The results of this study show that adding the mixture of polypropylene fibers and nano-SiO_2 into the clay soils, leads to 4.69% and 4.17% increment of unconfined compressive strength and modulus of elasticity, respectively, in comparison to the untreated clay. Also adding nano-SiO_2 to the soil, causes more failure of samples occur respect to the case in which the soil is getting mixed with fiber, though by increasing the amount of fibers, the failure mechanism of refined samples changes, thus the failure strain increases.

***Keywords**: Soil stabilization, Nano-SiO2, PP fibers, Unconfined compressive strength, modulus of elasticity.*

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Extended Abstract:

1. Introduction

Stabilization using additives is one of the common methods for improving these soils, the most common of which are cement and lime, which are traditionally used in various projects. However, the use of new additives to achieve optimal performance has been considered in recent years. On the other hand, technological advances have introduced new materials such as nanomaterials for soil improvement that can be used alone, or in combination with traditional additives. The use of additives such as nano and fibers into the soil, improves the parameters of shear strength, unconfined compressive strength and geomechanical properties of soils. Recently, much researches have been carried out on soil stabilization by adding nanomaterials and also reinforcing soils with fibers. (Ahmadi et al., 2020, Anagnostopoulos et al., 2013, Changizi and Haddad, 2015,Changizi and Haddad, 2017).
In this study, preliminary tests in accordance with ASTM standards for the studied soil have been performed in order to obtain the initial soil parameters and then by using nano-SiO_2 and synthetic polypropylene fibers, both individually and in a combination with together, the unconfined compressive strength test was performed to determine the compressive strength and modulus of elasticity (E_{50}). Also, in order to investigate the liquid limit and plasticity index, Atterberg limits tests was used, and the standard compaction test has been used to evaluate the changes of maximum dry density and optimum moisture content. It is noteworthy that in this study, due to the importance of improving problematic soils in geotechnical engineering, nano-SiO_2 has been used as a new material and polypropylene fibers to stabilize and reinforce clay.

2. Materials and methods

The studied clay is prepared from Rasht, located in the north of Iran, which is a type of clay with low plasticity(CL) and the soil is classified according to ASTM D-2487 standard. nano-SiO2 and polypropylene fibers have also been used to improve the studied clay. Therefore, in order to evaluate the effect of nanosilica and polypropylene fibers on the samples, to determine the compressive strength and modulus of elasticity, the unconfined compressive strength test according to ASTM D-2166 standard has been used. Laboratory tests were performed with different percentages of polypropylene fibers (0.25, 0.5, and 1% of dry weight of clayey soil) and nanosilica (0.5, 0.75, and 1% of dry weight of clayey soil) where three experiments were performed for each sample during UCS tests and the mean of which was entered as the result. In addition, in order to evaluate the amount of plasticity index and standard compaction parameters of clay, Atterberg limits tests in accordance with ASTM D-4318 standard and standard compaction tests in accordance with ASTM D-698 standard have been used, respectively.

3. Result and Conclusion

In this study, after conducting the Atterberg limits tests and standard Proctor tests, the unconfined compressive strength test was performed on four types of samples including natural clay, clay containing polypropylene fibers, clay containing nanosilica and clay containing a

combination of nano-SiO2 and polypropylene fibers. The result of the unconfined compressive strength test is given in Table (1).
Among the important results of this research, the following can be mentioned:

Table 1. Effect of Nano-SiO2 and PP Fiber on the UCS of clay

NO	Name of specimens	Nano-SiO2(%)	PP Fiber(%)	UCS test result		
				$q_u\ (kPa)$	$c_u\ (kPa)$	$E_{50}\ (kPa)$
1	C0F0N	0	0	130	65	1625
2	C0F0.5N	0.5	0	190	145	2375
3	C0F0.75N	0.75	0	218	109	3114
4	C0F1N	1	0	286	143	3575
5	C0.25F0N	0	0.25	158	79	1975
6	C0.5F0N	0	0.5	178	89	2225
7	C1F0N	0	1	264	132	2640
8	C0.25F0.5N	0.5	0.25	236	118	2950
9	C0.25F0.75N	0.75	0.25	374	187	4158
10	C0.25F1N	1	0.25	452	226	5022
11	C0.5F0.5N	0.5	0.5	310	155	4429
12	C0.5F0.75N	0.75	0.5	468	234	5850
13	C0.5F1N	1	0.5	496	248	6200
14	C1F0.5N	0.5	1	394	197	4925
15	C1F0.75N	0.75	1	582	291	6467
16	C1F1N	1	1	610	305	6778

- The results of standard compaction test showed that by increasing the weight percentage of polypropylene fibers and nano-SiO_2 in the clay, the optimum moisture content increases and the maximum dry specific weight decreases.
- According to Atterberg limits test, with increasing the percentage of polypropylene fibers, due to more water absorption by the fibers the soil liquid limit increases by 16% and the soil plasticity index decreases by about 24% due to limited soil compaction. However, with increasing weight percentage of nano-SiO_2 in clay, both parameters of liquid limit and plasticity index increase.
- Adding polypropylene fibers leads to improve the ductility of the soil and its compressive strength, which increases the strain of failure in the soil.
- The addition of nano-SiO_2 causes more failure of the samples than the composition of the soil with polypropylene fibers, but with increasing amounts of polypropylene fibers, the failure mechanism of the modified samples changes and as a result, with increasing amounts of polypropylene fibers, the failure strain increases.
- The combination of 1% by weight of polypropylene fibers and nano-SiO_2 with natural clay increases the uniaxial compressive strength and the modulus of elasticity, which causes a growth of 4.69 and 4.17 times compared to natural clay, respectively.

In this study, the stabilization and reinforcement of clay with nano-SiO_2 and polypropylene fibers was carried out, which is a practical method for soil improvement for use in foundations and roadbeds. It is also worth mentioning that this method of soil improvement can be considered a practical and executive method in civil engineering projects.

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