Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 52(11) (2021) 689-692
DOI: 10.22060/ceej.2019.16472.6242

Effect of Water-Soluble Polymers and Nanoparticles on Physical, Mechanical, and inflationary Properties of Clay

G. Moradi[1,*] , S. Abbasi[2], A. Abbasnejad[3]

[1] Associated Professor, University of Tabriz, Tabriz, Iran.
[2] MSc in Geotechnical Engineering, University of Tabriz, Tabriz, Iran.
[3] Assistant Professor, University of Tabriz, Tabriz, Iran.

ABSTRACT: In the present study, to investigate and compare the effect of Nanosilica nanoparticles and water-soluble polymer of cationic polyelectrolyte on a set of physical, mechanical and chemical properties of CL clay, a series of laboratory tests were performed on untreated soil samples, treated with Nanosilica and treated with cationic polyelectrolyte. Nanosilica was added to soil with 0.5, 1, 2 and 3% dry weight of soil and cationic polyelectrolyte with concentrations of 3, 6, 9 and 12 gr/liter based on optimum water content and their effects on the soil details have been investigated in 3,7,14 and 28 days of processing. Despite the differences in the effectiveness mechanisms, these materials showed similar effects on the variety of soil samples characteristics in this study. By adding of both materials to the soil, optimum water content, liquid limit, unconfined compressive strength, and water retaining potential of soil have been increased and Maximum dry density and free swelling percentage of soil decreased remarkably. On the other hand, regarding small changes of plastic limit and increasing of liquid limit, plasticity index increases. Also, for various amounts of additives, there is no significant change in soil pH.

Review History:

Received: 2019-06-02
Revised: 2019-06-25
Accepted: 2019-10-03
Available Online: 2019-10-12

Keywords:

Clay
Cationic polyelectrolyte
Nano-silica
Physical and Mechanical specifications
Swelling

1. INTRODUCTION

Soil stabilization is a collective term for any physical, chemical, or biological method, or any combination of such methods, which is employed to improve certain properties of a natural soil to make it adequately serve an intended engineering purpose over the service life of an engineering facility [1]. Nontraditional soil stabilizers can be classified as one of three types [2]:

- Ionic stabilizers, reported to work through cation exchange within the clay mineral
- Enzyme stabilizers, described as consisting of various organic catalysts
- Polymer stabilizers, comprised of various organic and inorganic polymers

Effect of various organic and inorganic polymers on different properties of varies soils has been investigated in many studies [3,4], also according to studies in recent years on usage of Nanoparticles in soil stabilizing, Nanoparticles also can be regarded as the fourth group of soil stabilizers [5,6]. Although these materials are not cohesive but it is expected to enter the soil and decrease the distance between soil particles and finally make it reinforced in Nano scale [7].

In this paper, the effects of cationic polyelectrolyte and Nano-silica as soil stabilizers were investigated and compared. Nano-silica was added to soil with 0.5, 1, 2 and 3% dry weight of soil and cationic polyelectrolyte with concentrations of 3, 6, 9 and 12 gr/liter based on optimum water content. Then the effect of different percentages of these materials on compaction, Atterberg limits, unconfined compressive strength, stiffness, free swelling, pH and soil moisture preservation potential was investigated.

2. MATERIALS AND METHODS

In the present study, a set of materials including soil and chemicals have been used, and their specifications are presented respectively. Basic characteristics of the clay used in this experiment are presented in Table 1.

Technical details of cationic polyelectrolyte or Polyacrylamide (PAM) are presented in Table 2, and chracteristics of Nano-silica are presented in Table 3 and Table 4.

Nano-silica was added to soil with 0.5, 1, 2 and 3% dry weight of soil and cationic polyelectrolyte with concentrations of 3, 6, 9 and 12 gr/liter based on optimum water content. Then the effect of different percentages of these materials on compaction, Atterberg limits, unconfined compressive strength, stiffness, free swelling, pH and soil moisture retaining potential were investigated. All of tests conducted according to ASTM standards.

3. RESULTS AND DISCUSSION

3.1 Compaction

According to Figure 1(a) with the addition of Nano-

*Corresponding author's email: gmoradi@tabrizu.acc.ir

Table 1. Engineering Properties of Clay

Specific gravity (G_s)	2.75
Liquid limits, (%)	46
Plastic limits, (%)	22
Plasticity index, (%)	24
Optimum Moisture Content, (%)	20
Maximum dry unit weight, (kN/m^3)	17.42
USCS	CL
pH	7.32

Table 2. Properties of Cationic polyelectrolyte

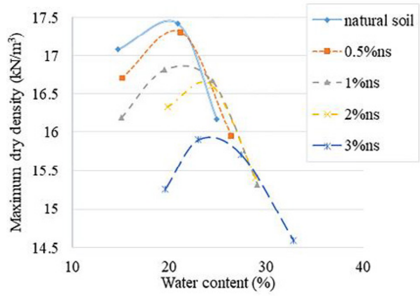
Characteristics	Off white, granular powder
Degree of charge	medium
pH (5% solution)	3.0 – 5.0
Bulk density	750 ± 50
Viscosity @ 25°C/77°F	
0.10 %	180 cps
0.25 %	400 cps
0.50 %	800 cps
1.00 %	2000 cps

Table 3. Properties of Nano-silica

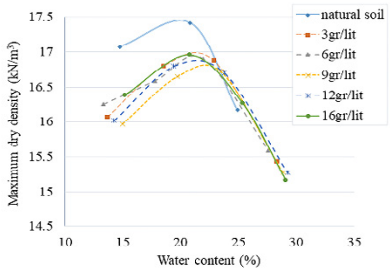
Purity	+99 %
APS	11-13 nm
SSA	200 m^2/gr
Color	white
Bulk density	<0.10 gr/cm^3
True density	2.4 gr/cm^3

Table 4. Chemical Composition of Nano-silica

Compound	Magnitude
SiO_2	>99%
Ti	<120ppm
Ca	<70ppm
Na	<50ppm
Fe	<20ppm

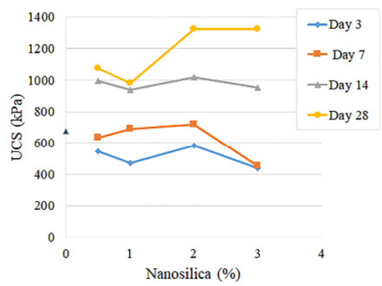


(a)

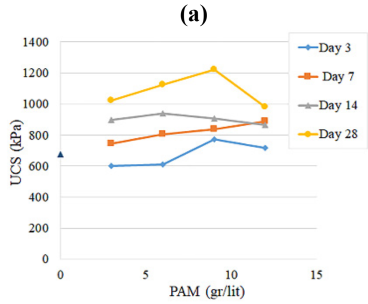


(b)

Fig. 1. soil density diagrams for different percentages of (a) Nano-silica and (b) cationic polyelectrolyte.



(a)



(b)

Fig. 2. compressive strength changes diagram by changing amounts of (a) Nano-silica and (b) PAM.

silica, soil maximum dry density decreased, and optimum moisture content of the soil increased. One of the reasons for decreasing the maximum dry density due to the addition of Nano-silica to the soil is the high density of soil particles relative to the Nano-silica particles. This reduction also can be stem from increasing of fine-grained materials and consequently increasing of soil specific surface area and more water absorption by soil and Nano-silica mixture. On the other hand, as shown in Figure 1(b) It is observed that adding PAM causes a decrease in maximum dry density and an increase in optimum moisture. The main reason for increasing optimum moisture is the hydrophilic property of PAM, which is led to absorb much water and consequently rising of optimum moisture. Absorbed water losses a part of the applied energy, and thereby the maximum dry density of PAM stabilized soil reduces.

3.2 Atterberg limits

By increasing Nano-silica amount, both liquid limit and plastic limit of soil increase. however, liquid limit increment rate is more than the plastic limit, and soil plasticity index which is liquid and plastic limit difference increases a little. On the other hand, with increasing PAM to the soil, the liquid and plastic limits of the soil increase. The hydrophilic property of PAM polymer is the main reason for rising Atterberg limits [8].

3.3 Unconfined compressive strength

Unconfined Compressive strength of control sample (not modified) is equal to 674.5 KPa which is marked with a blue triangle on the vertical axis in Figure 2. According to Figure 2(a), by increasing of the percentage of Nano-silica in the soil to an optimal value of 2%, the strength of the samples is increases and decreases again for 3%. The reason for the loss of UCS of the specimens after an optimal 2% is that, with the excessive increase in the nanoparticles, they begin to accumulate together and form masses in the soil, and due to the low weight of the nanoparticles in comparison with soil particles, Reduces the volumetric density of the soil. On the other hand, according to Figure 2(b), UCS of the polymer containing specimens increases with increasing concentration of the solution to an optimum amount of 9 gr/lit, and then interrupts and decreases. it is especially evident about 28-day specimens.

4. CONCLUSIONS

The test results can be summarized as follows:

• By increasing the amount of Nano-silica and PAM in the soil, the maximum dry density gradually decreased and optimum moisture content of the soil increased.

• Both Nano-silica and PAM increased the liquid and plastic limits. Nano-silica also increased the plasticity index with a significant increase in the liquid and plastic limits.

• Both materials had a positive effect on the UCS of the soil and, for optimal values, soil strength increased about 100%. Regarding the stress-strain curves of the samples, Nano-silica, in spite of increasing soil strength, increased stiffness. Although PAM had little effect on the strain, the PAM also increased soil stiffness by increasing the strength of the samples.

• Both materials had a positive effect on the swelling of the clay and reduced the percentage of soil free swelling.

• For various amounts of additives, there was no significant change in soil pH.

• Natural soil samples lost 30% of their moisture after 28 days, while samples containing nano-silica, 8-10% and samples containing PAM lost 13-18% of their moisture after 28 days.

• In order to reduce inflation and increase soil resistance, 2% Nano-silica and 9 gr/lit PAM were obtained as the optimal amount.

5.

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HOW TO CITE THIS ARTICLE

GH. Moradi, S. Abbasi, A. Abbasnejad, Effect of Water-Soluble Polymers and Nanoparticles on Physical, Mechanical, and inflationary Properties of Clay, Amirkabir J. Civil Eng., 52(11) (2021) 689-692.

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