# Effect of Adding Nanoclay on the Geotechnical Behavior of Fine-grained Soft Soils

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## Extended Abstract

(Paper pages 225-246)

### Introduction

Soil has always been a major material in civil projects. Due to progress in science, different studies on the behavior of soil and its engineering characteristics have been conducted. As mentioned, there are different types of soil in nature; a small change in their structure and fabric under different environmental conditions or loading causes high deformation and settlements, which result in a reduction of strength and bonding between soil particles. Also, in this regard, some soft soils exist that are mostly composed of clay particles, with small shear strength and big settlement under low stress. With respect to the above-mentioned characteristics, these soils are referred to as problematic soils. The problematic soils consist of a silicate combination, whose major parts are clay minerals formed under weathering of rocks. Additionally, the precipitation of some soils and ground activity near the surface causes them to become problematic (Beckwith and Hansen [1]). Principally, in engineering, those soils on which construction is not safe, and which are affected by different environmental conditions, are defined as problematic soils. Collapsible soils are some of the most important of these problematic soils. The collapsibility phenomenon is defined as a sudden collapse of soil caused by the loss of the shear strength of soils. The collapsible potential depends on the initial void ration of soils. A few silty strata that are exposed to arid weather are susceptible to considerable volume decrease or collapse under soil saturation. Therefore, it is possible that surface water penetration in an irrigation form, pipe leakage and rise in ground water level may lead to great settlement.

In the last decade, the use of nanotechnology based on the science of production and nano-scale particles usage has become prevalent in many sciences. It can be said that nanoparticle application has made considerable progress, apart from nanotechnology, in recent years and has been one of its main aspects of this study. In this regard, the variety of nanoparticle depends on different applications.

The use of nano-materials has drawn the attention of various researchers in geotechnical engineering. One of the important nano-materials is nanoclay which, with respect to its characteristics, has had a wide range of applications in soil improvement techniques. Taha and Taha [2] and Majid et al. [3] have studied the effects of nano-materials, such as nanoluminum, nanocopper and nanoclay, on the swelling and shrinkage behavior in fine grain-size soils. Also, the compressive strength and permeability of soils increase and decrease with the addition of nanoclay, respectively, and are subjected to change of elastic to plastic behavior (Burton et al. 2009 [4], Gallagher and Lin [5], Persoff et al. [6]).

In this research, the main objective is to investigate the addition of nanoclay on the behavior of fine grain-size soil with experimental studies and to evaluate the different parameters on the soils' modification mechanisms.

**Material and methods**

Given the importance of this subject and the practical use of the results of this research in the improvement of problematic soils, as well as the field assessment conducted, it was observed that, in many parts of the main irrigation channels of Gonbad dam in northeastern Iran, which is an arid and semi-arid region of Iran, due to the specific geotechnical conditions and loess soils, large and non-uniform subsidence of soil has occurred around dewatering channels. This has caused large cracks to occur in the concrete channel coverage and subsoil and the surrounding wall soil, which ultimately will lead to the destruction of large parts of the channel mentioned above. Remarkably, given the nature of loess soils in the study area, dangers such as collapsibility, dispersivity, landslides, sinkholes and subsidence can be noted. In order to evaluate the effect of soil improvement with the help of nanoclay in field conditions, all the tests and geotechnical studies on soil samples located in the channels were performed under valid standards. In this regard, a number of exploratory boreholes were bored in the walls and floors of the considered channel. During this procedure, sampling was carried out in different depths of layers of soil in order for laboratory tests to be carried out and for identification of the soil. The undisturbed samples were also taken by a Shelby Tube Sampler for necessary tests. In order to determine the initial physical and mechanical properties of the used soils, various tests such as particle size analysis, Atterberg limits, specific gravity and standard compaction were conducted. Table 1 summarizes the characteristics of the used soils.

**Table 1. Soil specifications**

| Soil Properties | Gonbad Area | Incheberon Area |
|---|---|---|
| Unified soil classification system | CL-ML | CL-ML |
| Particle specific gravity | 2.54 | 2.55 |
| Plastic limit (%) | 16 | 18 |
| Liquid limit (%) | 22 | 23 |
| Plasticity index (%) | 6 | 5 |
| Passing No. 200 sieve (%) | 95 | 86 |
| Average particle size ($D_{50}$) (mm) | 0.006 | 0.04 |
| Optimum water content (%) | 15 | 16 |
| Maximum dry unit weight (g/cm$^3$) | 1.54 | 1.60 |

The nano-materials used in this study have comprised nanoclay prepared by Sigma-Aldrich Company Ltd with the brand clay montmorillonite K(10).

## Results and discussion

By adding nanoclay to the soil, it is observed that the liquid limit and plasticity limit of samples gradually increases as can be seen in Figure 1.

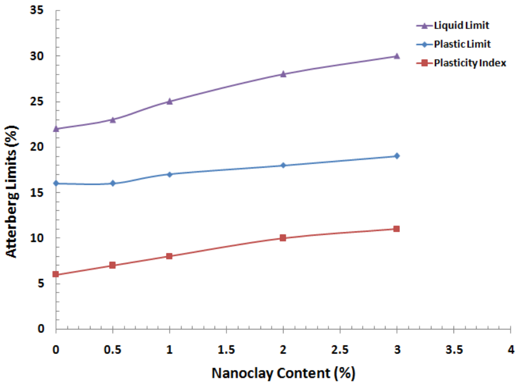


**Figure 1. Effect of nanoclay addition on the Atterberg limits test of soil samples**

Based on the obtained results by adding different amounts of nanoclay to the soil, the maximum dry density and optimum moisture content decreased and increased, respectively. By adding nanoclay to the soil, strain increases at the moment of failure due to increased plasticity and changes in soil structure. It is worthy to note that the unconfined compressive strength in samples stabilized with nanoclay has been increased in comparison with the plain soil. Plain and improved soil samples were tested with different amounts of nanoclay under unconsolidated undrained conditions at different confining pressures.

To study the impact of nanoclay on the collapsibility potential of the soil, double consolidation tests were conducted to determine the deformation of plain and stabilized samples with various amounts of nanoclay under different vertical pressures. The test results showed that adding nanoclay has reduced the collapsibility potential of samples.

## Conclusions

Due to existence of large areas of collapsible soils in Iran, improvement of these soils is necessary in civil projects. With considering the advances of nanotechnology sciences, in this research aiming to understand the impacts of different amounts of nanoclay on above mentioned soils have been studied. The soil samples used in experiments were collected from Golestan province including Boston dam of Gonbad and Incheboron near Gorgan city. In order to assessment of geotechnical behavior of soils, samples were mixed with varying percentages of nanoclay and different tests such as Atterberg

limits, standard compaction, unconfined compressive strength, unconsolidated undrained triaxial and double consolidation were conducted. The results showed that nanoclay particles have a significant effect on the plasticity and strength behavior of used soils. Also, it was found that collapsibility index of soils decrease with adding nanoclay and it depends on the type of soil.

**Keywords:** Nanoclay, Collapsibility, Improvement, Fine-grained Soils.

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