**Improvement of Collapsible Soils in the North of Hamadan Province by Silica Nanoparticles**

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**Abstract:**

The risk of engineering construction on collapsible soils is a challenge for geological engineers because when the soils get wet in these soils, the volume decreases. Identifying and improving collapsible soils can significantly reduce hazards and prevent problems around structures. This study aims to investigate the use of silica nanoparticles in improving the behavior of collapsible soils in the north of Hamadan province. For this purpose, Nano Silica particles with different percentages (0.4, 0.8 and 1% soil dry weight) were added to the above soils. The presence of insignificant amounts of nanoparticles had dramatic effects on soil engineering properties. Tests of Atterberg limits (determination of liquid limit and of plastic limit), Proctor compaction, unconfined Compressive strength, Single oedometer and triaxial compression strength were performed. The experimental results showed that with a slight increase of Nano silica in improved soils, plasticity indices (liquid and plastic limit), optimal moisture and maximum dry density, and modulus Elastic and in most cases the shear strength parameters increase significantly. The resistance remains unchanged and strain at the moment of failure, collapsing potential and pore pressure show a decreasing trend. Decrease in pore pressure leads to increase the expandability of soil samples, due to the locking and non-release of improved soil grains. Finally, the reason for changes in the geotechnical properties of soil samples is discussed.

**Key Words:** collapsible soils, silica Nanoparticles, Soil Stabilization, North of Hamadan, engineering properties

1. **Introduction**

Collapsible soil is susceptible to a large and sudden reduction in volume upon wetting. Collapsible soil deposits share two main features (1) they are loose, cemented deposits, and (2) are naturally quite dry (Day, 2000). It can withstand a large applied vertical stress with a small amount of compression, but then show much larger settlement upon wetting, with no increase in vertical stress (Jenning and Knight, 1975).

 Natural soils, do not have suitable mechanical and geotechnical properties for engineering projects, and with the reduction of available land, engineering constructions are being carried out on loose and problematic soils. Therefore, it is necessary to perform some improvement methods to achieve the desired conditions on these soils. A suitable method to achieve this goal is to change the mechanical properties of the soil, considered as soil improvement techniques (Choobbasti et al (2015), Kutanaei and Choobbasti (2015). Improving the performance of soil is an important factor in choosing soil improvement (Arabani and Veis Karami, (2007), Nikookar et al., (2012)). Soil improvement techniques can be broadly divided into three categories (i.e. mechanical methods, chemical methods, and physical methods).

In recent years, Nano technology has been implemented in geotechnical engineering, especially for soil remediation (Taha and Taha (2012)). Nanoparticles of usually 1 to 100 nm are the smallest particles in soil environments which are in three different forms: nanoplatelets, nanowires or nanotubes, and nanodots. Recently, engineers have used Nano scale stabilizers as additives to improve soil properties (Edalati et al. (2016), Choobbasti et al. (2018), Anvari et al. (2017)). Applying nanomaterials for soil improvement showed that even a small amount of nanomaterial could bring significant changes in physical and chemical properties of soil. SiO2 nanoparticles have particular physical, chemical, and optical properties leading to their wide use in soil stabilization. Nano sio2 and Nano clay are the major additives used in soil stabilization (Lin et al. (2008), Butron et al. (2009), Mohammadi and Niazian (2013), Bahmani et al. (2014) , Gholami and Shiva (2015), Changizi and Haddad (2017), Baziar et al. (2018)).

This study investigates the effect of silica nanoparticles on the behavior of collapsible soils in the north of Hamadan province. For this purpose, Nano Silica particles with different percentages (0.4, 0.8 and 1% soil dry weight) were added to the soil samples. Finally, the reason for changes in the geotechnical properties of soil samples due to the presence of silica nanoparticles is discussed.

1. **Material and methods**

In this study the improvement of collapsible soils was investigated using Nano Silica particles. The samples were obtained from sinkhole in north of Hamadan province. Original soil was collected at shallow depth after removing the top 0.5m depth of ground surface. Nano silica particles with different percentages (0.4, 0.8 and 1% soil dry weight) were added to the above soils. A series of laboratory tests including Atterberg limits, compaction, unconfined compressive strength, single Oedometer, and triaxial compression strength were conducted on the original soil and soil mixed with Nano silica. Finally, the effect of the nano-SiO2 on the behavior of collapsible soils was evaluated.

1. **Results and discussion**
	1. **Effect of Nanosilica on consistency limits:**

Figures 1 to 3 show the effects of nanomaterial contents on the Atterberg limits. The liquid limit and plastic limit increased as the nanomaterial content increased. The results show initially plasticity index (PI) increased and then decreased as the nanomaterial content increased. Reductions in the plasticity index are indicators of soil improvement. Thus, addition of Nano Silica particles to soil, even at low doses, can enhance its properties.