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Investigation the use of nanoclays on the modification of Aeolian Sand

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ABSTRACT

Nano-clays are a broad class of naturally occurring inorganic minerals in the form of plate-like of aluminosilicate layers with thickness between 1 nanometer to 10 micrometers. Due to the very small sizes of nanoparticle, they provide a large specific surface area which capable them to absorb water and fill the voids within the soil particles.

The aim of this paper is to investigate the use of nano-clays for modifying the engineering properties of aeolian sand. The aeolian sand covers a large areas in Central Iran and their movements affect directly on the performance and stability of infrastructures such railways and roads networks of the region.

The mineral composition of the sand mainly consists of quartz grains and the soil type is classified as poorly graded materials. In order to evaluate the effect of micro and nano clay on modification the geotechnical properties of the sand, different percentage of 0.5%, 1%, 2% and 4% of micro and nano clays were mixed with the sand and number of tests such as compaction test, direct shear test are conducted on the samples. The result shows that maximum dry unit weight and lowest optimum moisture content were obtained when 4% nano-clay mixed with the sand. It was also was noted that the increment of nano-clay and micro-clay causes gradual increases and gradual decreases of the shear strength of the sample, respectively.

الخلاصة :-

نانو الطين هي فئة واسعة من المعادن غير العضوية التي تحدث بشكل طبيعي في شكل لوحة طبقات ألومينوسيليكات مع سماكة بين 1 نانومتر إلى 10 ميكرومتر. نظرا لأحجام صغيرة جدا من جسيمات متناهية الصغر، أنها توفر مساحة كبيرة التي قادره على امتصاص الماء وملء الفراغات داخل جزيئات التربة. والهدف من هذه الورقة هو للتحقيق في استخدام النانو الطين لتعديل الخصائص الهندسية للرمال. يغطي الرمال على مناطق واسعة في وسط إيران وتحركاتهم تؤثر بشكل مباشر على أداء واستقرار البنى التحتية مثل هذه السكك الحديدية، شبكات الطرق، المزارع و الأحياء السكنيه في المنطقة. الرمال من ناحية التركيب المعدنى، يتكون أساسا من حبيبات الكوارتز ويصنف نوع التربة كمواد متشابه الأجزاء. من أجل تقييم تأثير الطين الجزئي ومتناهية الصغر (النانو) على تعديل خصائص الجيوتقنية من الرمال، نسب مختلفة من 0.5٪، 1٪ و 2٪ و 4٪ من الطين الجزئي ومتناهية الصغر اختلطت مع الرمل و تم اجراء عدد من الاختبارات مثل اختبار الضغط، اختبار القص المباشر على العينات. وتظهر النتيجة أن الحد الأقصى وحدة الوزن الجاف ومحتوى الرطوبة الأمثل أدنى مستوى تم الحصول عليها عند 4٪ النانو الطين مختلطة مع الرمل. وأيضا لوحظ أن الزيادة النانو الطين و الطين الجزئي تسبب زيادات تدريجية وانخفاضات تدريجية لقوة القص من العينة، على التوالي.

Keywords: Aeolian sand, Kaolinite, Micro-clay, Nano-clay, Soil modification

1. Introduction

Ground modification techniques have become a major part of civil engineering practice in recent years, and their use is growing rapidly as infrastructural development demand for land reclamation and utilization of soft or unusable soils. Soils are recognized as most abundant natural resources and are used in constructing many engineering projects such as embankment dams, road basement and retaining walls. They deserves to be treated to gain suitable requirement needed for the proposed projects. The application of nanoparticles for reinforcing the strength of soft soil is regarded as suitable technique of ground modification.

The application of nano-clay in soil treatment has been in the interest of many researchers in recent years. For example, the stabilization of soft soil with nano-materials was investigated in some construction site [1]. The use of nano-materials for improving the strength and geotechnical properties of soft soil was studied in Penang, Malaysia [2]. Nan-clay was also used in Esfahan, Iran to control soil erosion [3]. The applications of nano-clay were evaluated for stabilizing and controlling the behavior of soft soils [4]. The influence of nanoclays on compressive strength of earth bricks was investigated by Niroumand et al. [5].

The aim of this paper is to investigate the effect of micro and nano clay particles on modifying the engineering properties of aeolian sands. This type of sand is most abundant in large part of central desert of Iran and along the coast line in the north and south part of the country where the stability of many construction could be affected by the presence of this type of soils.

2. Material properties

2.1 Aeolian Sand

Aeolian sand is a type of quartzite sand that formed by the action of wind blow in desert and coastal areas. This type of sand is almost cohesionless, granular and its grain has spherical shape. The soil is defined as very loose materials with low shear strength. The physical properties of the sand used in this paper is summarized in Table 1. The particle size distribution curve of the pure sand is presented on Figure 1.

Table1. Physical properties of the aeolian sand

water	coefficient of		void ratio		specific
content	uniformity	curvature	max.	min.	gravity
w%	C_u	C_c	e_{max}	e_{min}	G_s
0.032	2.28	1.75	0.71	0.44	2.73

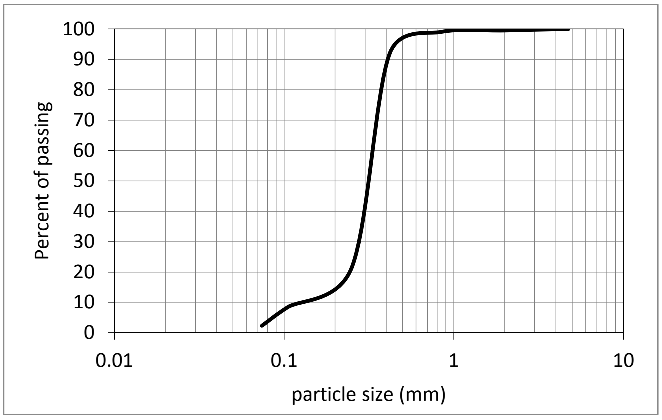


Figure 1, Particle distribution curve of the pure sand

Clay Material

Clay materials studied in this paper are a type of Kaolinite with mineralogical composition derived from XRD analysis as shown in Table 2. The liquid limit and plastic index of the clay were 60% and 45% respectively. The particle size distribution curve of the clay is shown on Figure 2.

Table 2, mineralogical composition of clay material

Mineral type	Kaolinite	Quartz	Calcite	Others
Composition	64 ± 0.2	27 ± 2.0	2.1 ± 0.5	6 ± 1

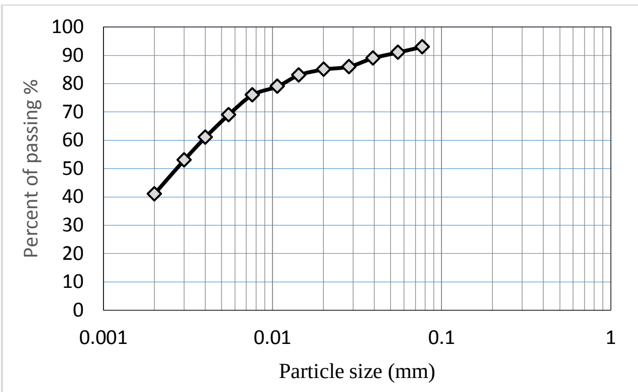


Figure 2, Particle distribution curve of Kaolinite

Nano-clay production:

There are different methods to produce fine grain materials in the size of nano-particles. In this research a planetary ball mill was used to grind the clay materials in to the size of nano-clay. The performance of the equipment is based on rotation of different sizes of balls at high speed (600 rpm) in steel cup container with two types of transition and circular rotation. The grinding balls in the grinding jars are subjected to superimposed rotational movements. The difference in speeds between the balls and grinding jars produces an interaction between frictional and impact forces, which releases high dynamic energies. The interplay between these forces produces the high and very effective degree of size reduction of the planetary ball mill. The clay specimens were loaded in small amounts in the ball mill. Then 20 sintered corundum balls with diameter of 5 mm used for grinding were added. The milling time to prepare each batch was 6 hours while water was added to sample during the operation to decrease the heat. An electronic microscope, FESEM, is then used to analysis the images of nano particles in their natural state. It was also used to measure the size and to scan the morphology of the fine particles. A general feature of ball mill equipment and an example of FESEM image of nano-clay are shown on Figure 3a and 3b, respectively.

Figure 3a, general view of ball-mill equipment

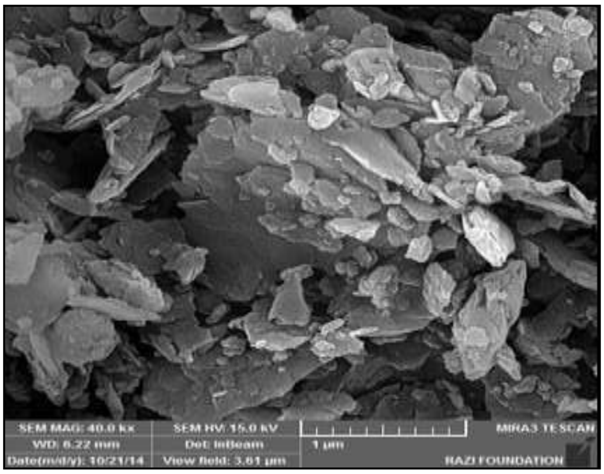


Figure 3b, an example of FESEM image of nano-clay (Kaolinite)

Sample preparation:

In order to evaluate the effect of micro-clay and nano-clay on the mechanical behavior of pure sand, three types of soil samples were prepared for this research. The samples were prepared as in the following set up:

1. Pure aeolian sand without any additive.
2. Pure sand mixed with 0.5%, 1%, 2% and 4% of micro-clay.
3. Pure sand mixed with 05%, 1%, 2% and 4% of nano-clay.

Two ways of mixture were examined in the laboratory including spraying nano-clay into pure sand and using mechanical device for this purpose. It was found that the mechanical mixture produce more homogeneous sample. Example features of nano-clay with sand taken by FESEM Microscope from two ways of mixture are shown on Figures 4a and 4b respectively. All the samples were undergone two series of laboratories tests including standard proctor compaction test and direct shear tests.

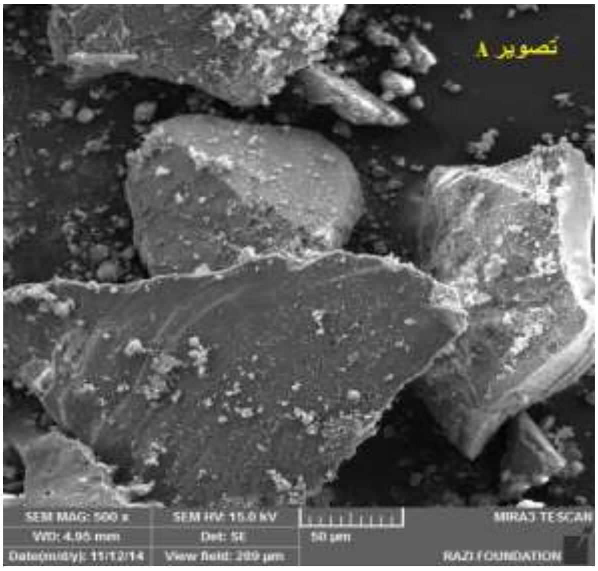


Figure 4a, SEM images of sand mixture with nano-clays using spray method

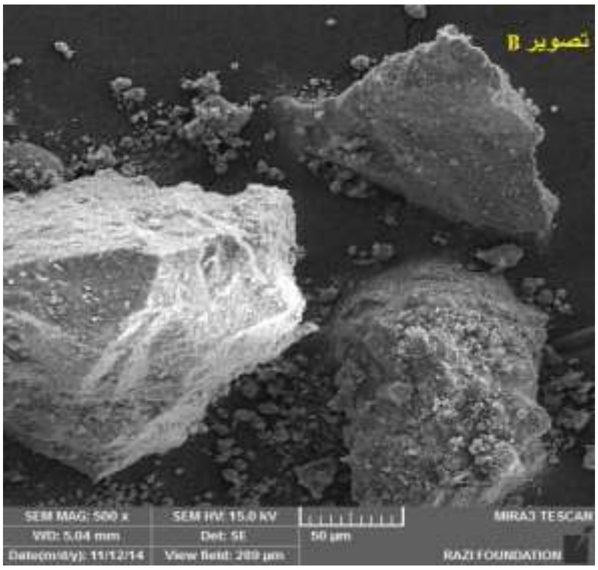


Figure 4b, SEM images of sand mixture with nano-clays using mechanical method

Compaction Test Analysis

A series of standard compaction tests in accordance with ASTM D698 were perform on three types of samples, including, pure aeolian sand, mixture of sand with micro-clays (with different percentage) and mixture of sand with nano-clays (with different percentage). The relationship of dry density and moisture content for all samples are plotted on Figure 5. A comparison of the test results are also presented on Figure 6. The results indicate that the maximum dry density for pure sand is lowest with higher percentage of moisture content. The compactibility of the mixture of sand with micro-clay show no special trend. On the other, as the percentage of nano-clay increase the maximum dry density of the samples increases very sharply. It can be explained that due to the large specific surface area of nano-clay particle with large specific surface area is suitable for enhancing the strength of pure aeolian sand.

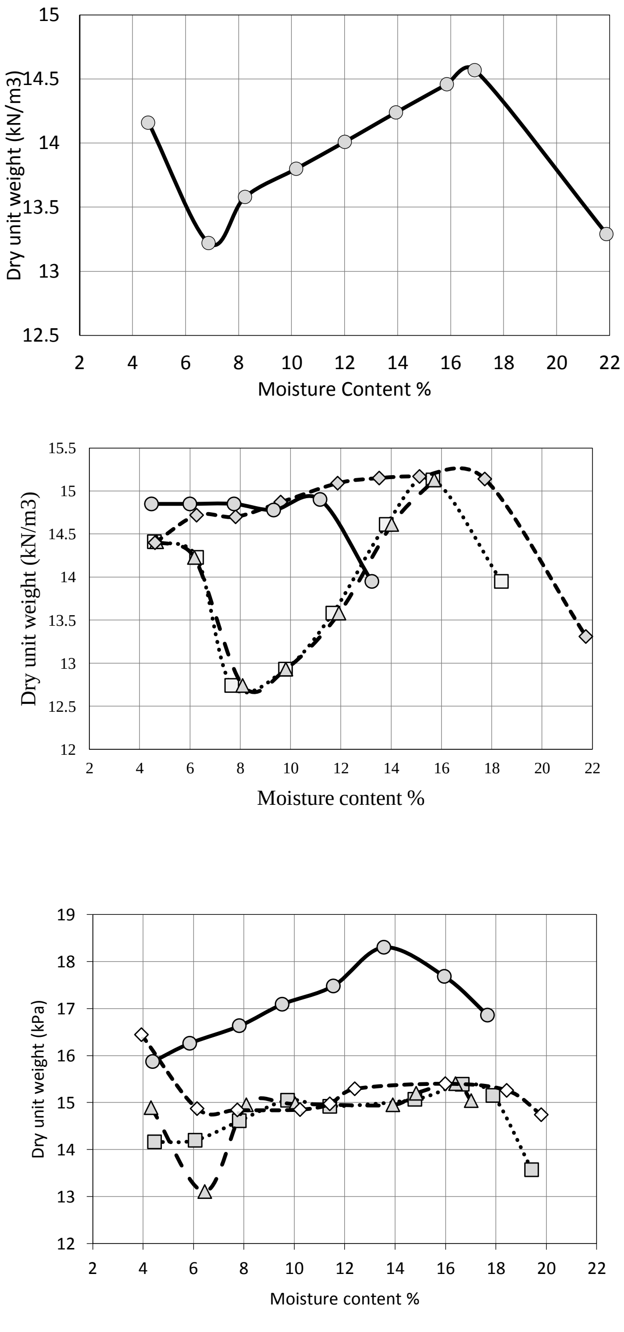


Figure 5, Plots of compaction test results

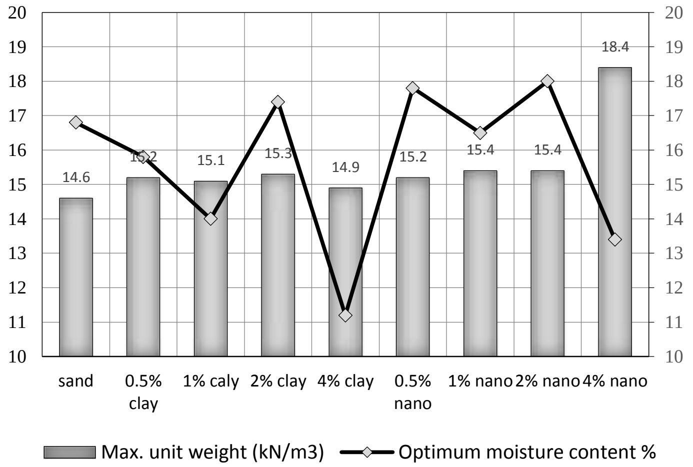


Figure 6, Comparison of compaction test results

Direct shear test

The shear strength of the prepared samples was evaluated by conducting the direct shear test (ASTM D3080) on pure sand sample and sand mixed with different percentage of micro and nano clays. The tests were performed on cylinder shape samples with radial and height of 6 and 2 cm respectively. The samples were tested under three constant normal stresses of 35, 70 and 105 kN/m^2. Plots of shear strength results for pure sand, mixture of sand and micro-clay and mixture of sand and nano-clay are presented on Figures 7a, 7b and 7c, respectively.

A list of shear test results is also summarized in Table 3. The shear strength of the pure sand records shows the lowest value of 24.3 kN/m^2. For sand mixed with micro-clay, the shear strength decreases as the percentage of micro-clay increase, in contrast, the shear strength increases as the percentage of nano-clay increase. A comparison of shear strength values of all samples and their internal friction angle (Ø) and amount of cohesions (c) are illustrated on Figure 8a and 8b respectively. It can be noted that, although addition of more micro clay cause an increase in cohesion but at the same time reduces the internal friction angel. On the other hand, the increment of nano-clay increases both the cohesion and the internal friction angel which result in an increase the overall shear strength of the sample.

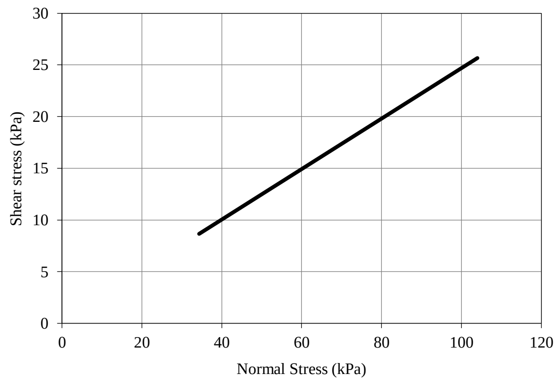


Figure 7a, Plots of direct shear test for pure sand

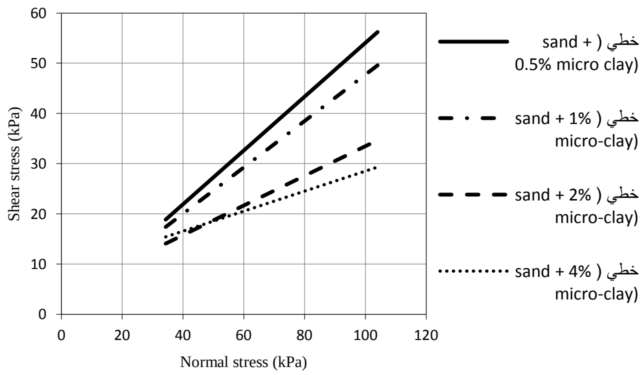


Figure 7b, Plots of direct shear test for mixture of sand and micro clay

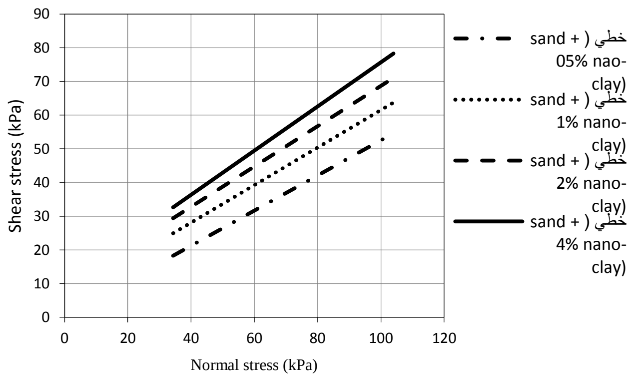
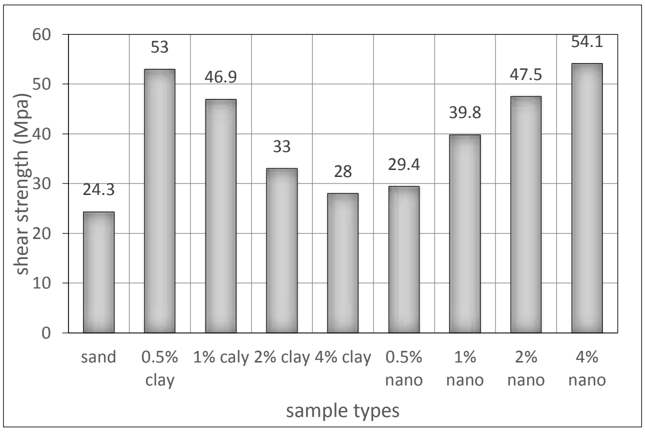


Figure 7c, Plots of direct shear test for mixture of sand and nano clay

Table 3, Summary of shear test results

Sample type		shear strength kPa	cohesion kPa	friction angle (Ø°)
Pure sand	-	24.3	0.3	14
Sand and micro-clay	0.5%	53.0	0.41	28
	1%	46.9	1.50	25
	2%	33.0	3.86	17
	4%	28.0	8.56	11
Sand and nano-clay	0.5%	29.4	0.33	27
	1%	39.8	05.8	29
	2%	47.5	08.9	31
	4%	54.1	10.2	33



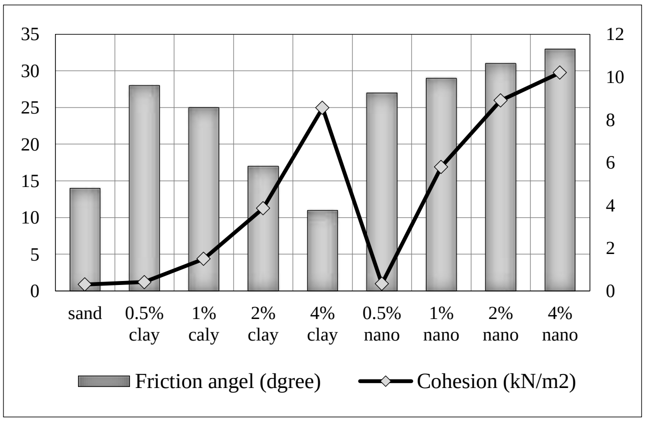


Figure 8, Comparison of shear strength of samples

Conclusions

The following conclusion can be derived from this paper:

1. A ball mill is a suitable equipment to produce nano-clay for laboratory scale samples.
2. The use FESEM Microscope to analysis and imaging of particles can be recommended for the procedure of preparing the nano-particles.
3. Additive materials such as micro-clay and nano-clay improve the geotechnical properties of aeolian sands.
4. The mixture of micro and nano clays with sand shows an increase of compactibility of the pure sand and the best effect is obtained when the sand is mixed with4% of nano-clays.
5. The gradual increment of micro-clay additive to the pure sand show a gradual decrease of their shear strength. In contrast, the gradual addition of nano-clay causes a gradual increment of their shear strength parameters.
6. In general the nano-clay admixture with aeolian sand can be considered as a suitable method for improving the engineering properties of soft soils.

References:

[1] Majeed, ZH. Taha, MR. and Jawad IT. (2014) Stabilization of soft soil using nanomaterials, Research Journal of Applied Sciences, Engineering and Technology 8(4): 503-509.

[2] Majeed ZH. and Taha, MR. (2013) Effect of nanomaterial treatment on geotechnical properties of Penang soft soil, Journal of Asian Scientific Research, vol.2 (11), pp: 587-592.

[3] Padidar, M. Jalalian, A. Abouss, M. Najafi, P. Honarjoo, N. and Fallahzade, J. (2014) Effect of nanoclay on soil erosion control. Proceedings of NANOCON conference, Brno, Czech Republic.

[4] Neethu, SV. And Remya, S. (2013) Engineering Behavior of nanoclay stabilized soil, proceeding of Indian Geotechnical Conference. Boorkee, pp: 1-7.

[5] Niroumand, H, Zain, MF. And Alhosseini SN. (2013) The influence of nano-clays on compressive strength of earth bricks as sustainable materials. Procedia-Social and Behavioral Sciences, vol.89, pp: 862-865.