Kufa Journal of Engineering
Vol. 12, No. 1, January 2021, P.P. 1-14
Received 20 June 2020, accepted 27 July 2020

EFFECT OF NANOMATERIALS ON SHEAR STRENGTH OF GYPSEOUS SOIL

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HTTP://DX.DOI.ORG/10.30572/2018/KJE/120101

ABSTRACT

A Gypsum soil is an example of problematic soils and susceptible to large volumetric deformations when they become saturated. Various structures for instance: roads, spread foot, different kinds of building, expressways, as well as dams are damaged due to the swell and collapse of soils, this make such structures unqualified for using. The damage in the construction works built upon collapsing soil may happen due to unexpected and frequently huge prompted settlement as saturating and that can be consider the problem statement such kind of soil following the constructing. Experimental works were conducted to checking the effect of using nanomaterials in the improving and stabilization of gypseous soil. In this study, the gypseous soils were collected from a site in Al-Najaf city in Iraq. The gypsum content was 30%. The experimental work was conducted to study the performance of collapsible soil improved by adding nanomaterials as Nano-clay and Nano-silica with different percentages. Direct shear test is used to determine the cohesion and angle of friction of the soil sample before and after adding the nanomaterials. The outcomes showed that when the Nano-clay and the Nano-silica are added to the soil, there will be a considerable increase in the value of cohesion and also increase of the angle of friction.

KEY WORDS: Collapsible soil, Shear strength, Direct shear test, Nanomaterials.

1. INTRODUCTION

Collapsing soil occurs broadly within the United States, Australia,Thailand, and another parts of the world. This Collapsing soil is type of low value of dried units weight plus normal water contents. In Iraq the collapsible soils cover about 20% of the area (Barzangi, 1986).

Gypseous materials are the principal origin of sulfates within soils, and the soils that contain gypseous materials are called gypseous soils (Abdi, 1992). Such kinds of soils can't be utilized in the area of development because of temperamental conduct brought about by varieties in dampness. A few building issues were experienced worldwide with these soils because of their high water affectability (stage change and dissolvability) with varieties within waters (Yilmaz, 2001).

Some of the transportation structures and the buildings, communication and utility networks are vulnerable to damage from a variety of geologic dangerous, such as volcanoes and earthquakes. But when the soils are sucked by water occur to the hazards therefore it is considered from the problematic soils.

When the dam's foundation contains dissolvable mineral, at that point waters leaking through it, can make holes. soils or rocks, which contain solvent minerals and are pieces of hydraulically made structure, for example, dams, repository, channels, or passages, perhaps suspects to collapsing. Already dried fissured rocks later exposed to significant water-powered inclinations would in general lose materials, and leakage stream ratios might increase quickly to inadmissible level. Grounds having the minerals in certain structures might endure insufferable settlement, and combinations established with them may miss quality.

Numerous experimental researches in the world and Iraq motivated on remedial measures of collapsible gypseous soils. Al-Saoudi et al., (2013) reported a brief survey on the remedial techniques for gypseous soils; all of these techniques are focusing on governing the volume change and decreasing the permeability coefficient or inhibiting any interaction of moisture between the gypseous soil and water source to reduction the gypsum agent dissolution. In general, the treatment measures of gypseous soils can be summarized as:

- Chemical treatment: in which the remedial materials recommended are primarily cement, lime and crude and/or west oil products
- Physical treatment: these measures are based upon improvement the geotechnical features of gypsum soil to control the consequences of gypseous dissolution.

Dynamic compaction was utilized to decrease the collapse potential by Fattah et al. (2012) while grouting with acrylate liquid was adopted as a chemical agent for treatment of collapse by Fattah et al. (2013, 2015).

The study of Alsafi et al. (2017) concentrated on impacts of characteristic sulfates within gypsum soils on their collapsing ability potential as settled with fly debris geopolymer fastener. Appropriately, pressure and collapsing ability testing was conducted upon the fastener and the settled soils, separately. XRD (X-ray powder diffraction is a rapid analytical technique primarily used for phase identification of a crystalline material and can provide information on unit cell dimensions. , and SEM (A scanning electron microscope is a type of electron microscope that produces images of a sample by scanning the surface with a focused beam of electrons).

Testing was likewise directed to follow changing because of geopolymerizating and sulfates assault when introduction at various periods of as long as 90 days. The outcomes demonstrated the arrangement of geopolymer gels (A-S-H) having high quality and additional sulfates resisting compared to Portland concrete glue in the fastener. Besides, joining of KOH (12 M) initiated flied debris within gypsum soils registered the least collapsing potential and factor of porousness till 90 days of exposing.

Processing gypsum soil with lime or concrete might actuate observable swell, bringing about the weakening of asphalt subgrade otherwise another establishment layer. To alleviate such swell, two industry side-effects, carbide slag (CS) and ground granulated impact heater slag (GGBS), had been used by Li et al. (2019). The CS get utilized to initiate the GGBS, which was utilized to treat a fake gypsum soils with various folio substances and CS: GGBS proportions, contrasted with common Portland concrete. The processed soil was drenched following a 7-day relieving time. A progression of testing had been conducted to look at the features for the processed soil, together with expanding, quality, and water contents. It had been discovered that the CS-GGBS processed soil witnessed somewhat higher swell (0.2%–1.0%) compared to the concrete processed soil (0.1%–0.3%) through the 7-day relieving time. Be that as it may, the accompanying drenching process altogether expanded the swell of the concrete processed soil (>5.0%), causing breaks upon the example surface, and diminished the quality, while the swell of the CS-GGBS-processed soil subsequent to splashing was a lot of lower (< 0.3%), no split was watched, and the lessening in the dousing instigated quality was considerably less.

Verma along with Maheshwari (2017) stated that several kinds of Nano- material for instance Nano silica (SiO_2), Nano Titanium oxide (TiO_2) are there. They carried out experiment in which a mix of the Nano silica was made with soil's specimens having various ratios of (0.0%, 0.25%, 0.50%, 0.75% and 1.0%) for testing the geotechnics features of soils. The outcomes explained that the unconfined compressive strength and CBR soil features increase when the proportions increase up to 0.75 % of Nano SiO_2, after that a regular decreasing was obtained.

Changizi and Haddad (2017) investigated the impact of utilizing Nano-silica materials to enhance the mechanic features of clay soils having little and large fluid limit. Nano-silica to soil proportions of 0.5, 0.7 and 1.0% had been utilized. Both as far as possible and California bearing proportion value enhanced with expanding nano-silica content. Expanding proportions prompted a decrease in the pliancy record and an expansion in as far as possible. The decrease in soil settlement was ascribed to a gooey gel in the dirt added substance collaboration, which brought about an expansion in the pre-union worry of the balanced out soils.

With the current work, A try was done to examine the potentials of nanomaterials to suppress the adversative influences of treating upon the collapse potential and shear strength of gypsum soils. With the purpose of achieving the goal, in depth collapse oedometer and direct shear testing has been conducted to define the collapsibility and shear strength of the soil before and after treatment.

2. LABORATORY WORK

2.1. Material

The soil specimens of this study had been brought from a site located in Bahar Al-Najaf city in Iraq at a depth (1.5-2.5) m. The soil represents disturbed regular collapsible soil (gypseous soils).

2.2. Soil properties

The classification of the soil is SP (Poorly evaluated clean sands). Typical testing had been conducted to decide the physic and chemic features for the sands. Table 1 records the features information. Research center testing completed on the soils incorporated the accompanying:

- Grain size distributing.
- Explicit gravity.
- Direct shear testing.

The British specification (BS 812: Part: 1988) is followed for the chemic features. The chemic and physic soil's features are shown in Table 1.

Sieve analysis had been conducted by ASTM D422–00. Grain size distributing of the soils utilized related 95.5% sand as appeared in Fig. 1. The soils are grouped, as per the Unified Soil Classification System, as SP type (Poorly graded sands).

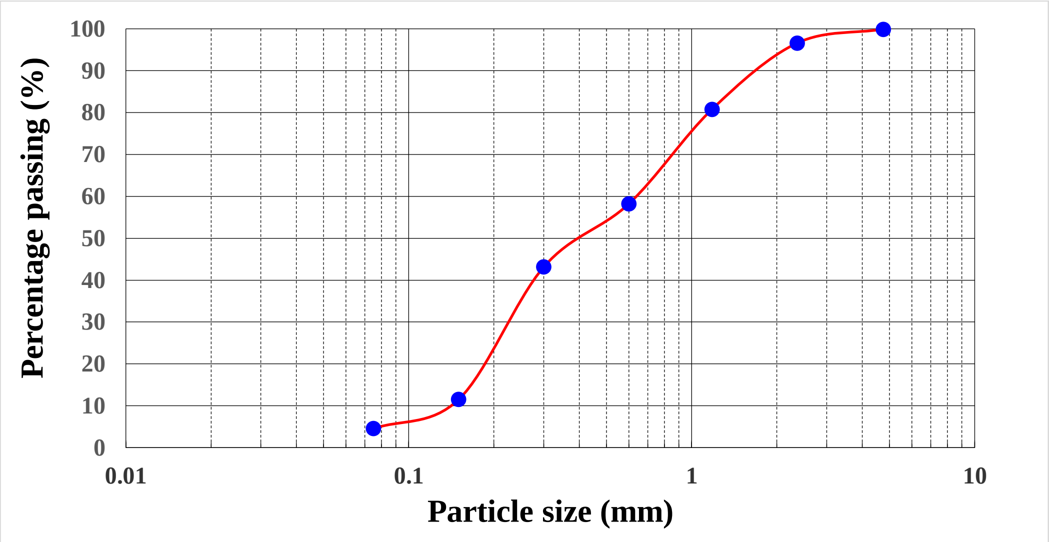

Fig. 1. Grain size soil distributing.

Explicit gravity testing was acted as per ASTM D854 (2010) norm. Refined water is regularly utilized for explicit gravity determining, nevertheless, kerosene can be suggested instead of the refined water as soon as the soil's specimens have a noteworthy part of the natural issue or gypsum materials (ASTM D854, 2010). Explicit gravity testing demonstrated a diminishing in Gs with the expansion in gypseous contents. This part of gypsum soil is significant, in light of the fact that Gs is straightforwardly connected with the unit weight of soil which can be fundamental to all major geotechnics measurements.

Maximum plus minimum density tests were performed in accordance with ASTM D4253-93.

The gypseous contents are established as stated by Al-Mufty and Nashat, (2000). According to such technique, the soils get oven-dried at (45°C) so as to make the specimen weight constant. Then the verification for the specimen weight at (45°C) gets done. At that time, the drying for sample is made by (110°C) so as to make the weight constant along with recording it. The calculation for gypseous contents can be done consistent with the coming equation:

$$\chi = \left[\frac{W_{45^oc} - W_{110^oc}}{W_{45^oc}}\right] x4.778x100 \quad (1)$$

As: χ = gypseous contents (%),

$W45°C$ = the specimen weight by (45ºC),

$W110°C$ = the specimen weight by (110°C), and

4.778 = inversing rate of molecular weight of hydrating water to molecular weight of gypsums.

The samples were prepared at the field dry unit weight of 15.2 kN/m^3 by making a gentle tamping on sample in a compaction mold.

The specification of ASTM D 3080-04 was utilized to perform the direct shear box testing. There are several particle sizes to box sizes needs for direct shear box experimentation as to prepare the experimentation sample. The width of mini sample must not be ten times fewer than the maxi the width of particle sizes, while the thickness of mini primary sample mustn't be six times fewer than the width of maxi particles. Table 1 lists the value of Index Properties as the Specification.

Table 1. The physical and chemical properties of nanomaterials.

Index Property	Value	Specification
Gypsum content, %	31.47	
Specific gravity(Gs)	2.55	ASTM D-854
D10	0.15	ASTM D 422-00
D30 (mm)	0.24	ASTM D 422-00
D60 (mm)	0.65	ASTM D 422-00
Coefficient of uniformity (Cu)	4.34	ASTM D 422-00
Coefficient of curvature (Cc)	0.59	ASTM D 422-00
Maximum dry unit weight (kN/m^3)	17.25	ASTM D 4253-16
Minimum dry unit weight (kN/m^3)	12.27	ASTM D 4254-16
Field unit weight (kN/m^3)	15.20	ASTM D1556 - 07
Soil Classification according to (USCS)*	SP	
Friction angle, ϕ (°)	34.07	ASTM D 3080-04
Cohesion (kN/m2)	10.11	ASTM D 3080-04
Total sulphate content (SO_3)%	13.45	B.S 1377. Part 3
pH value	8.27	

* Unified Soil Classification System.

2.3. Nano materials

Nanomaterials are defined as particular kind of matter with uniform properties and can be measured by nanometer unit. At least one dimension of Nano materials is less than approximately 100 nanometers, where the nanometers are approximately (1000000) of mm, Nanomaterials are classified into three types (Jaison et al., 2018):

1. One-dimensional materials.

2. Two- dimensional materials.

3. Three- dimensional materials.

The Nano-clay is one of the types of the nanomaterials, it represents a novel generating of treated clays for a wide-ranging of well performing concrete Nano composites (Hakamy et al., 2015). Based upon morphological as well as chemic structure of nano clay, numerous categories for instance illites, halloysites, bentonites, kaolinites, montmorillonites, hectoliters, and chlorites could be identified (Pavlidou and Papaspyrides, 2008).

The Nano-silica is classified as Nano-SiO_2 (11-13) nm and can be defined as a hydrophilic fumed silica with a specific surface area 200 nm. Silica is used in preparation of dental nanomaterials

3. RESULT AND DISCUSSION

3.1. Direct Shear Test Results without Nanomaterial

The direct shear testing showed that the values of the cohesiveness equal to 10 kPa and the angle of friction is 34.2° for water content equal to 5%. Fig. 2 illustrates the results of stress-strain and values of shear strength without additives after soaking the soil sample for 48 hrs. The results show the cohesiveness as well as angle of internal friction are reduced upon soaking to become 4.05 kPa and 27.51°, respectively. Fig. 3 illustrates the outcomes of direct shear testing upon the soaked soil specimens.

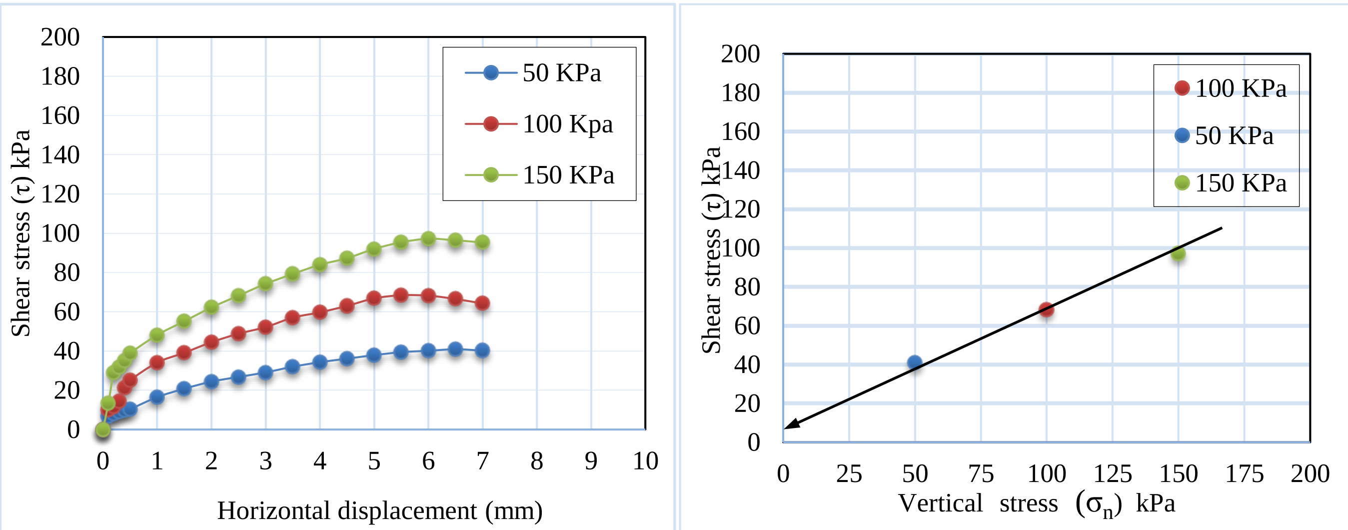

Fig. 2. Results of direct shear test on untreated soil with 5% water content.

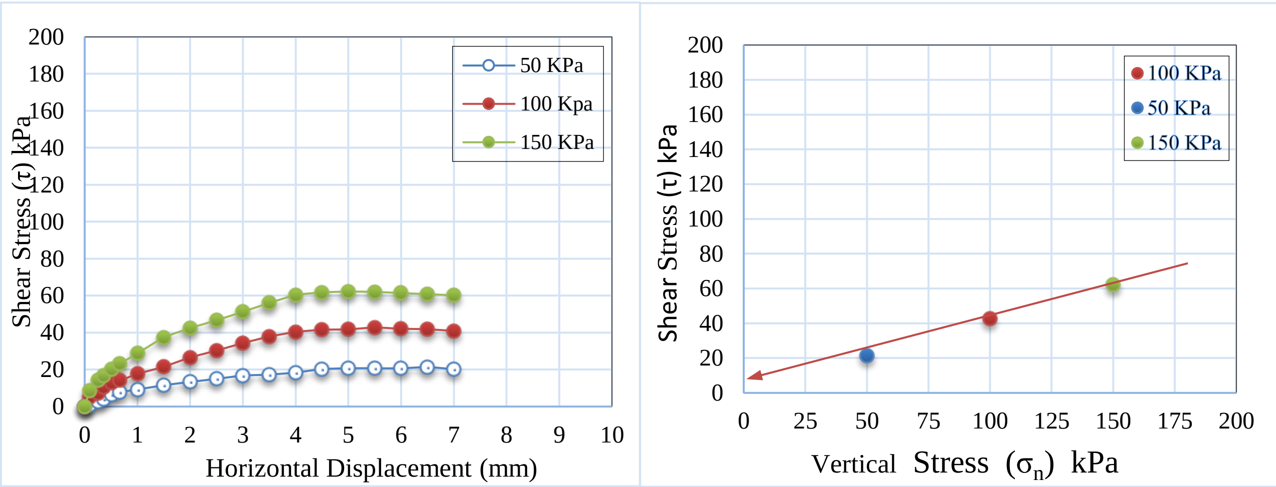

Fig. 3. Direct shear results for soil sample without nanomaterials and soaked for 48 hour

3.2. Direct Shear Test Results with Nanomaterial

3.2.1. Nano-clay

Nano-clay (C) was added with different percentages (2.5%, 5% and 10%) to the gypseous soil soaked for 48hr and the results showed that the addition of Nano-clay up to (5%) leads to increase in the cohesion by about 780% and the angle of friction (ϕ) value increased by only (5%) as indicated in Figs. 4 to 6.

The effect of adding 2.5% of the Nano-clay to the soil are shown meanwhile the result which that the friction angle increased from 27.5o to 35.8° and the cohesion also increased from 4.05 kPa to 28 kPa as a ratio 270% as presented in Fig. 4.

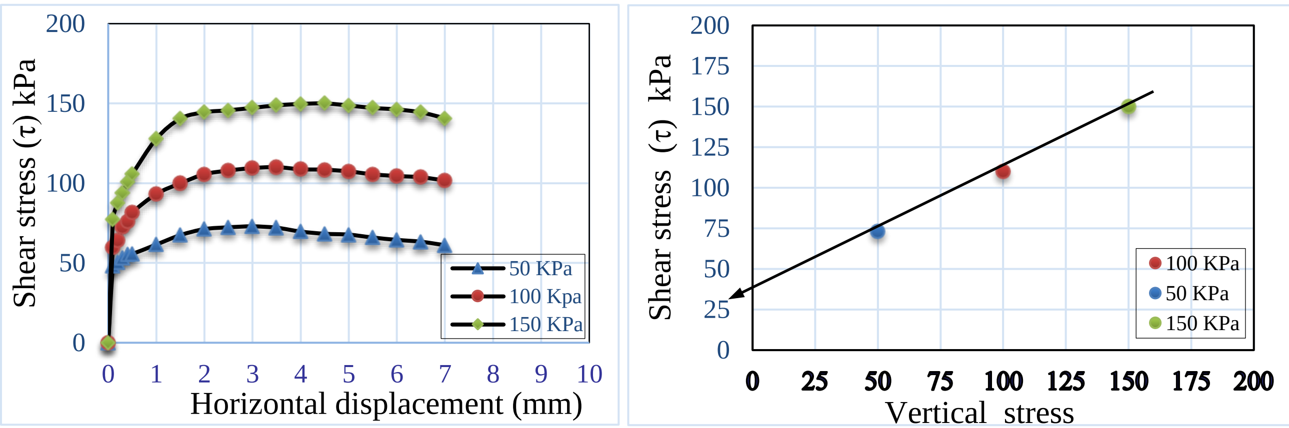

Fig. 4. Results of direct shear test on gypseous soil treated with 2.5% nanoclay.

The effect of adding 5% of the Nano-clay to the soaked soil sample appears in the results where the friction angle increased from 27.5o to 36o and the cohesion also increased from 4.05 kPa to 55 kPa as explained in Fig. 5.

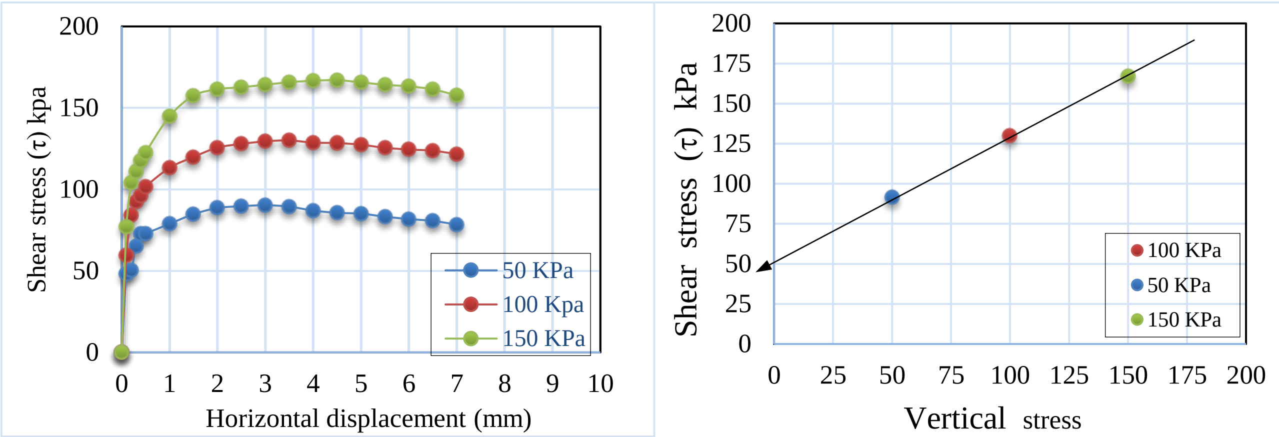

Fig. 5. Results of direct shear test on gypseous soil treated with 5% nano clay.

The adding of 10% nano-clay to the soaked (48 hr.) sample of gypseous soil affects the cohesion as its value increases from 4.05 kPa to 64 kPa and also leads to increasing the friction angle from 27.5o to 35° as illustrated in Fig. 6.

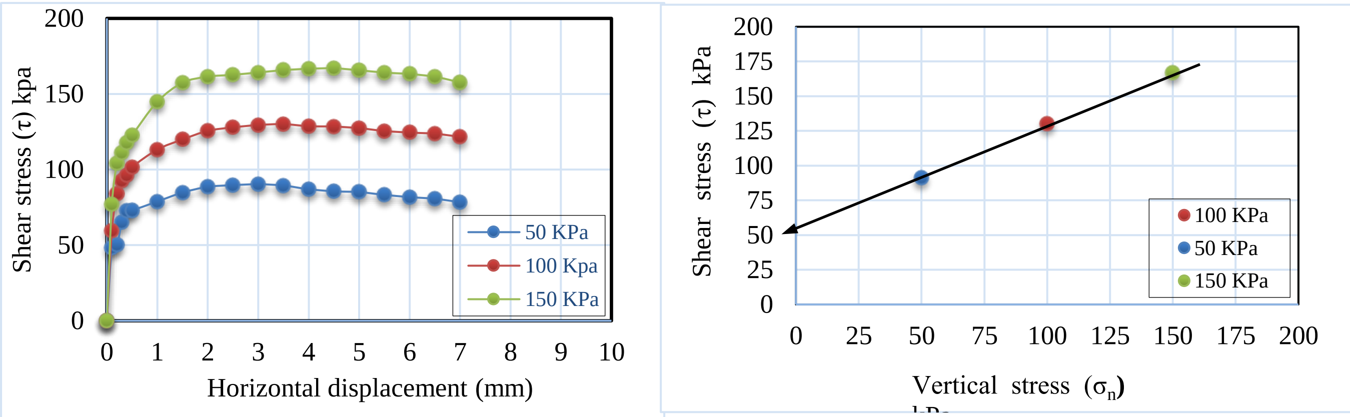

Fig. 6. Outcomes of direct shear testing on soaked gypseous soil treated with 10% Nano clay.

Table 2 summarizes the results of direct shear test on treated and untreated samples. The adding of nanomaterials (Nano-clay) to the gypseous soil is doing as a favorable agent for treatment the weak soils occur to the effect of the cohesion force and the angle friction which increasing with high portion.

Table 2. Results of direct shear test with Nano-clay.

Without treatment		**Treated with Nano-clay**					
		Cohesion, kPa	Angle of friction, ϕ	Cohesion, kPa	Angle of friction, ϕ	Cohesion, kPa	Angle of friction, ϕ
C, kpa	Φ, °	2.5%		5%		10%	
4.05	27.5	28	31.6	55	32.7	64	35

3.2.2 Nano-silica

Nano-silica was added with different percentages (0.5%, 1%, 2% and 3%) to the gypseous soil and the outcomes from the direct shear test showed that the adding Nano-silica up to (1%) leads to increment within the cohesion by about 490% and the angle of friction (ϕ) value increased by only (320%) as indicated in Figs. 7 to 10.

The effect of adding 0.5% of the Nano-silica material to the specimen of the soaked soil are shown meanwhile the outcomes which that the friction angle are increased from 27.50 to 34.50 and the cohesion force also increased from 4.05 kPa to 14.1 kPa as a ratio 350% as illustrated in Fig. 7.

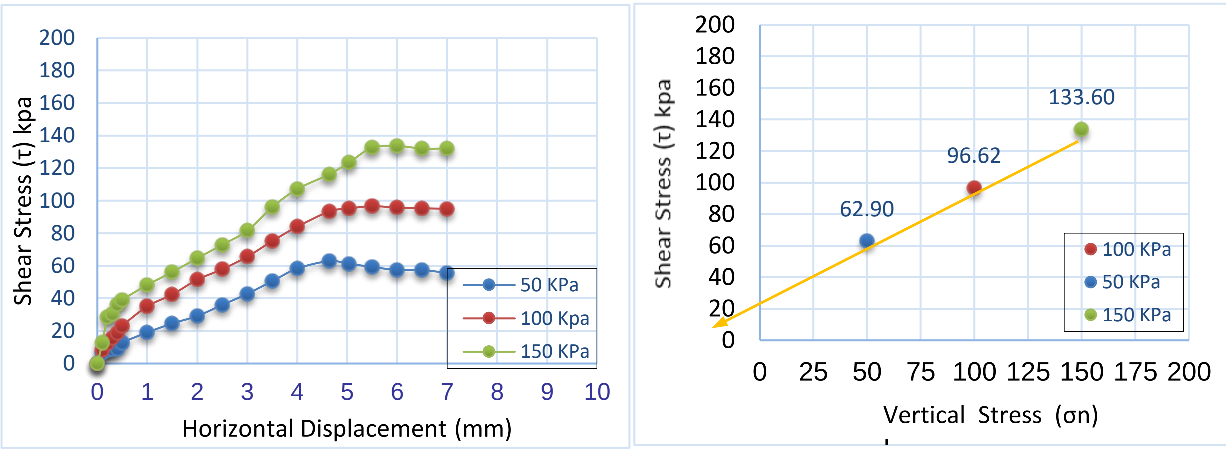

Fig. 7. Direct shear results for soil sample with Nano silica (0.5%) and soaked for 48 hours.

Fig. 8 shows the results of adding (1%) of the Nano-silica to the sample of the soaked gypseous soil effect on the cohesion force as increment the value of it from 4.05 kPa to 20 kPa and also leads to increasing the friction angle from 27.5oto 36° degree.

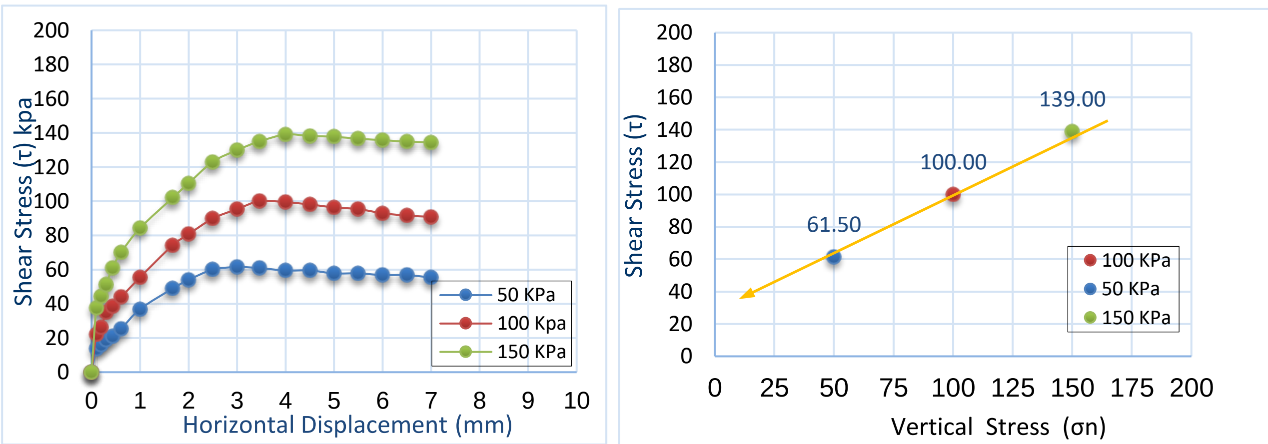

Fig. 8. Direct shear results for soil sample with nanosilica (1%) and soaked for 48 hours.

The adding (2%) of the Nano-silica material to the sample of the Gypseous soil effect on the cohesion force as increasing the value of it from 4.05 kPa to 19.3 kPa and also leads to increasing the friction angle from 27.5° to 38° degree

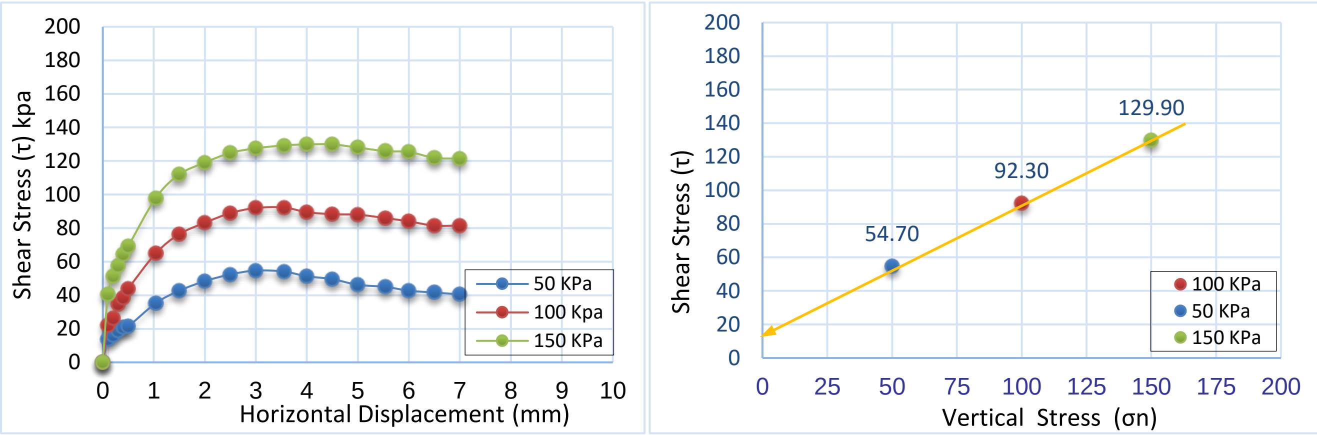

Fig. 9. Direct shear results for soil sample with nanosilica (2%) and soaked for 48 hours.

The adding(3%) of the Nano-silica material to the sample of the soaked gypseous soil effect on the cohesion force as increasing the value of it from 4.05 kPa to 23.5 kPa and also leads to increasing the friction angle from 27.5o to 38o degree. Fig. 10 explains results of direct shear testing upon the soaked soil specimens.

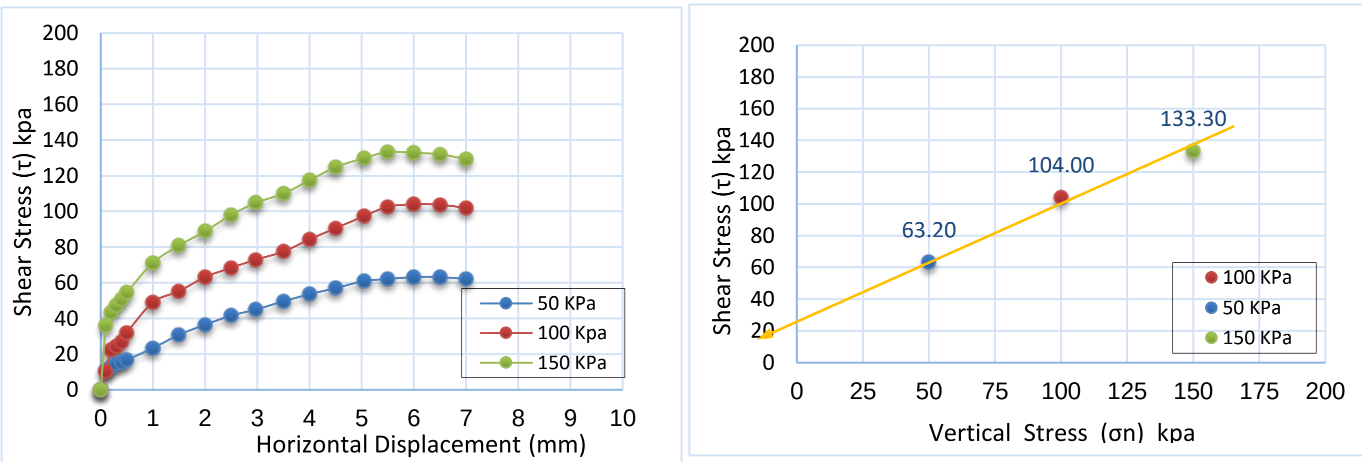

Fig. 10. Direct shear results for soil sample with Nano silica (3%) and soaked for 48 hours.

Table 3 summarizes the outcomes of direct shear tests on treated specimens and explain the effect of mixed (0.5%, 1%, 2% and 3%) from the nano-silica with the gypseous soil.

Table 3. Results of direct shear test with Nano-silica

Without treatment		**Treated with Nano-silica**							
		Cohesion, kPa	Angle of friction, o	Cohesion, kPa	Angle of friction, o	Cohesion, kPa	Angle of friction, o	Cohesion, kPa	Angle of friction, o
c (kpa)	Ø°	0.5%		1%		2%		3%	
4.05	27.5	14.1	34.5	20	36	19.3	٣٥	23.5	38

4. CONCLUSIONS

I. The optimum percentage of Nano-clay is 5% where the increase shear strength properties in the soil where the friction angle increased from 27.5o to 36o and the cohesion also increased from 4.05 kPa to 55 kPa, this means that the Nano-clay as additive modifies the geotechnical properties of the soil.

II. The optimum percentage of Nano-silica is 1% where the increase shear strength properties in the soil at this portion were as the friction angle increased from 27.5o to 36o and the cohesion also increased from 4.05 kPa to 20 kPa, Then can be say that the Nano-silica as additive modifies the geotechnical properties of the soil.

III. The effect of adding of nano-clay and nano-silica to the soil are shown by the results as ncreasing the cohesion force (C) from 4.05 kPa to 55kpa when adding 5% of nano-clay and from 4.05kpa to 20 kPa when added 1% of nano-silica and these changes are consider modifying in the geotechnical properties of the soil and also the increment of the internal friction angle (Ø) value when adding the nanomaterial.

IV. From the percentage of the nanomaterials(additives) that are using were added to the soil before and after the soaking it is found that one of the important benefits are decreasing the amount of the replacing soil because of the effect of the added nano particles.

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