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Some geotechnical properties and damping ratio of clay nanocomposites

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ABSTRACT

Natural clays soils are commonly used in dams, landfills, nuclear plants, etc. as an impermeable component or protecting liner. However, there could be permanent damage in structural elements due to the problems such as swelling, settlement, and heaving of these soils because of varieties in water contents over time. To remove these issues, stabilization of natural clay soils by the use of chemical additions is a prevalent subject of research. Recently, clay polymer interactions are commonly used for the improvement of nanocomposites. In addition, hydrophobic organoclays are preferred to eliminate the water affinity of clay nanocomposites. In this research, to improve damping ratio of clay liners, clay-nanocomposites are obtained from a hydrophobic organoclay, interacting with different concentrations of the latex polymer. Some geotechnical properties of these nanoclay-composites such as specific gravity, compaction parameters, unconfined compressive strength, and swelling pressure have been investigated. Additionally, damping ratios of these clay-nanocomposites are determined with a computer-based and multi-channel analysis system, pulse vibration measurement system. The test results found that specific gravities, maximum dry unit weights, unconfined compressive strengths, and swelling pressures of clay-nanocomposite samples decrease with the increase in latex concentration. On the other hand, damping ratios of samples are increased with latex concentration. The obtained results indicate that the damping ratio for provided nanocomposite in dry mode and in wet mode was increased from 1.08% (without additives) to 7.14% (including 20% Latex) and from 5.06% (without additives) to 8.47% (including 20% Latex), respectively.

Keywords: Clay-nanocomposites; contact angle; damping ratio; geotechnical properties; hydrophobic organoclay; unconfined compressive strength.

INTRODUCTION

Clay minerals are important components of a soil and are characterized by their fine grained natural composition with foil-like structure (Silvestre et al., 2015). As a consequence of the substantial difference between the specific surface area of clay minerals and other sand particles, the existence of even a little percentage of clay minerals in a soil mass can significantly affect the engineering properties of that mass (Holtz & Kovacs, 1981). Common usage of clayey soils is for earth dams' core, solid waste disposal landfills, nuclear plants, etc. Because of having large specific surface and high ion exchange capacity, clay minerals are strongly influenced by encounter of water. The change of water content impresses the plasticity of clay and changes occurred in Atterberg limits and indicates this influence (Holtz & Covacs, 1981; Cernica, 1985). Natural clay minerals is of low price with high absorption properties (Monvisade & Siriphannon, 2009).

By considering this matter, smectite minerals (especially montmorillonites) have many uses in industrial applications (Carrado, 2000; Powell & Beall, 2006; Gunister et al., 2007). Because of these properties of clay minerals, the geotechnical properties such as shear strength, swelling, and compaction parameters of clay minerals change gradually.

Clay minerals usually have gained negative specifications because of the change of clay properties due to the clay-water interaction. The volume of clays has changed with the increase in swelling or decrease in settlement and this phenomenon could negatively affect the stability of clays. Stabilization of clays by using chemicals has been studied by researchers to decrease the negative features that could affect the stability of clays (Vichan & Rachan, 2013;

Zhao et al., 2014; Turkoz et al., 2014; Latifi et al., 2015). Additionally, with the development of polymer technology, researchers focused on polymers and surfactants to reclaim clay soils for amending their engineering properties (Akbulut et al., 2010; Esfahani et al., 2012; Akbulut et al., 2013; Azzam, 2014; Bohnhoff & Shackelford, 2014).

Nanomaterials composed of clay minerals with sheet thicknesses of one nanometer called organosilicates or nanoclays are fine-grained crystalline materials (Schmidt et al., 2002; Nazir et al., 2016). Polymer-clay nanocomposites are known as a new type of composite materials with polymer matrix, which are silicate constituted, and have particles with one or more dimension in the range of nanometer (Anado, 2012; Nazir et al., 2016). Moreover, clay nanocomposites are two-phase materials with polymer matrix reinforced by finely dispersed layered silicate fillers. The smectite class, aluminum silicate clay based filler material is a frequently-used material. It should be stated that the montmorillonite is the most common type of fillers (Nguyen & Baird, 2006). In last years, many researches have been done in this area (LeBaron et al., 1999; Carrado, 2000; Alexandre & Dubois, 2000; Schmidt et al., 2002; Ray & Okamoto, 2003; Schmidt & Malwitz, 2003; Tjong, 2006; Powell & Beall, 2006; Pavlidou & Papaspyrides, 2008; Akbulut et al., 2012; Akbulut et al., 2013; Kurt & Akbulut, 2014; Kurt & Koca, 2016). Another research was conducted by Kurt and Akbulut (2016). Using a hydrophobic organo-clay, polymers such as locust bean gum, latex, glycerin, and vinyl acrylic copolymer and rubber powder developed clay-nanocomposites in order to solve the problems because of the clay-water interaction encountered in the clay liners. They showed that the specific gravities, consistency limits, compaction parameters, and unconfined compressive strengths of clay-nanocomposites change significantly, when compared to those of natural clay and hydrophobic organoclay. According to the reports on specific gravity, provided nanocomposites had enjoyed less specific gravity compared to the natural clay. Also, the reports represent that provided nanocomposite is non-plastic material while the natural clay used for developing nanocomposites in the study was categorized as CH (high plastic clay). Regarding the UCS, the reports showed that the value of unconfined compressive strength for the provided nanocomposite decreased compared to the values obtained from natural clay and hydrophobic oregano-clay. In addition, it is worth mentioning that the void ratio dealing with the provided nanocomposites is greater than that of the natural clay. It was concluded in the mentioned paper that clay-nanocomposites are more porous and lighter than natural clay and hydrophobic organoclay. Also, unconfined compressive strength tests showed that the consistencies of clay-nanocomposites are stiff. They can be used as a liner in waste disposal landfills and dams. All in all, one can say that all changes made were positive.

Soil behavior against the dynamic loading is mostly controlled by the dynamic soil properties containing material-damping ratio (D), shear modulus (G), Poisson's ratio (υ), and shear wave velocity (Vs) (Luna & Jadi, 2000; Aghaei Araei et al., 2010; Bate & Burns, 2012). Dynamic soil properties are also used in many non-dynamic type problems. As an example for this case, Poisson's ratio is one of the main parameters in finite elements analysis within Mohr-Coulomb behavioral model (Brinkgreve & Al-Khoury, 2016). Soil shear wave speed can be used directly to examine the liquefaction potential (Dobry et al., 1982; Bolton & Ignacio, 1983; Andrus et al., 1999) and soil classification (Dobry et al., 2000). Several types of geotechnical engineering problems as machine vibrations, wave propagation, seismic loading, cyclic transient loading, liquefaction, etc. are associated with dynamic loading. It is essential to determine characterization of dynamic soil properties to predict the response of soils to man-made and natural vibration sources (Rix & Meng, 2005; Kumar, 2013). Dynamic properties of clay nanocomposites are investigated by a few researchers. In this content, Bate and Burns (2012) investigated the dynamic properties of organo-bentonites using resonant column tests. Similarly, Kurt and Akbulut (2014) obtained some clay nanocomposites by using hydrophobic clay, some polymers, and additives. They investigated swelling and dynamic properties of the clay nanocomposites in their study. They found that the swelling and dynamic properties of clay nanocomposites can be optimized in order to attenuate the negative effects of dynamic load on clay liners. In geotechnical test field of soil, non-destructive ultrasonic tests were mainly applied to obtain the dynamic strength parameters such as Poisson's ratio, shear modulus, and elastic modulus. Wang et al. (2016) used these methods to investigate the ultrasonic and mechanical properties of clay soil under uniaxial compression by axial and lateral ultrasonic tests.

The zeta potential, electric conductivity, surface area, and contact angles of organoclays were investigated by some researchers (Moraru, 2001; Ece et al., 2002; Akbulut et al., 2010; Bate et al., 2014). Indicating clay wettability and interfacial tension often done by contact angle measurements (Rogers et al., 2005), this method provides an insight into surfactant behavior. Rogers et al. (2005) studied the contact angles of some compatibilizers for polymer-silicate nanocomposites layer. While local montmorillonite surface is hydrophilic, adsorption of a small amount of surfactant on the surface can exhibit it as hydrophobic (Akbulut et al., 2012).

The aim of this study is to modify clay-nanocomposites and to study the effects of latex and glycerin on the geotechnical properties such as specific gravity, compaction parameters, swelling pressure, and unconfined compressive strength and damping ratios of the nanoclay composites and hydrophobic organoclay. The purpose of the study is to improve the damping ratio of clay liners. For doing this, clay-nanocomposites are obtained from a hydrophobic organoclay interacting with different concentrations of an elastomer polymer (Latex). Damping ratios were determined with a computer-based and multi-channel analysis system and pulse vibration measurement system. The experimental results of clay-nanocomposite samples are compared with the experimental results of hydrophobic organoclay. The hydrophobic organoclay is used to eliminate the negative effects of clayey soils when interacting with water.

MATERIALS

Hydrophobic organoclay

Hydrophobic organoclay was used for improving nanocomposites. The preparation of hydrophobic organoclay was undertaken, as the described method by Kurt (2009) and Kurt & Akbulut (2010). In so doing, to provide hydrophobic organo-clay, a cationic surfactant called dialkyl ammonium meta sulfate (DAMS) was used. Initially, 40g of clay was distilled in deionized water and stirred by the stirrer with 1000 rmp for 2 hours. Subsequently, the surfactant solution, which was prepared beforehand (DAMS and deionized water), was added to the clay suspension. The obtained product (hydrophobic organoclay) was desiccated in room temperature. Some engineering properties of hydrophobic organoclay used in this study are collected in Table 1.

Table 1. Some engineering properties of hydrophobic organoclay
(after Kurt, 2009, & after Kurt & Akbulut, 2014).

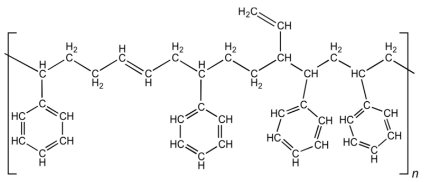
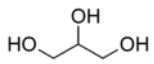
Some Properties			Hydrophobic organoclay
Specific gravity	G_s		2.52
Contact angle		^{o}	88
Cation exchange capacity	(meq./100 g dry soil)		21.62
Optimum moisture content*	w_{opt}	(%)	14
Maximum dry unit weight*	γ_{dmax}	(kN/m^3)	16.67
Unconfined compressive strength*	q_{uu}	(kPa)	998
BET (N_2) surface area		(m^2/g)	5

* The results were investigated from samples compacted with 2597 kJ/m^3 energy level.

Latex and glycerin

In this study, latex and glycerin were used for improving clay-nanocomposites. Latex is an elastomer. To prepare nanocomposites, the presence of glycerin is essential. In some studies on preparing nanocomposites, glycerin was used as plasticizer (de Carvalho et al., 2001; Tang et al., 2008). The chemical structures and properties of latex and glycerin are presented in Table 2.

Table 2. Properties and chemical structures of latex and glycerin (Kurt & Akbulut, 2014).

Properties	Latex	Glycerine
Chemical formula	C_3H_3N	$C_3H_8O_3$
Chemical composition	Styrene Butadiene Emulsion	Glycerol
pH	8-12	7
Viscosity (cps)	-	1200
Density (g/cm^3)	1.015	1.261
Chemical structure		

TESTING PROGRAM

Sample preparation

The clay-nanocomposites interacted to innovate by means of the sol-gel method (Schadler, 2003; Majedi, 2013; Majedi et al., 2013; Kurt & Akbulut 2014; Kurt & Akbulut 2016). Firstly, a mechanic stirrer at approximately 6000 rpm mixed 2.5 liters of water, glycerin, and latex for 10 minutes. While the solution was being stirred, 2500 (gr) of hydrophobic organoclay and 1 (L) of water were added and mixed for 45 minutes. The leach products (clay-nanocomposites) were dried at laboratory standard conditions for a sufficient time. The percentages of latex are 5%, 10%, 15%, and 20%; and the percentage of glycerin is 10% in all samples. The materials used for nanocomposites are given with the percentage of dry hydrophobic organoclay weight (Table 3).

Table 3. Clay-nanocomposite contents.

Sample	Glycerin, %	Latex, %
N0	0	0
N1	10	5
N2	10	10
N3	10	15
N4	10	20

Tests

For determining the electrokinetic properties of clay nanocomposites zeta potential, electric conductivity, Brunauer–Emmet–Teller analysis (BET), and contact angle tests were conducted on the clay-nanocomposite samples. The zeta-potential is a significant characteristic of the electrical double layer and represents a characteristic of electrical indexes of solid/liquid and liquid/gaseous interfaces (Salopek et al., 1992) and is the electric potential in the double layer at the interface between a particle, which moves in an electric field, and the surrounding liquid, and its magnitude was considered a measure of the particle repulsion (van Olphen, 1963). For measuring zeta potentials of clay-nanocomposites, Zeta Meter 3,0+ device was used at the natural pH values of samples. Additionally, electric conductivity values of clay-nanocomposites and hydrophobic organoclays were determined. For the electrical test, some of the prepared samples were dried in an oven at 105˚C. The electrical conductivity values of the samples were determined using a method that involved mixing the dried samples with distilled water in a ratio of 1100/ (solid/water), shaking this suspension periodically for 1 hour then measuring the electrical conductivity of the suspension with a conductivity cell (Akbulut et al., 2010). For determining specific surface areas, BET analyses were conducted on the clay-nanocomposites. The purpose of BET analyze is to estimate specific surface area of nanoscale materials (Lewicka & Colvin, 2013). Additionally, for measuring contact angles, a goniometer was used, which allows measuring the contact angle visually (Akbulut et al., 2012). In this study, the contact angles of hydrophobic organoclay and clay-nanocomposites were measured with a goniometer (CAM 101, KSV Instruments, Finland).

The geotechnical tests that were conducted on the clay-nanocomposite samples were specific gravity, compaction, swelling pressure, and unconfined compressive strength tests. The specific gravities of clay nanocomposites were measured by the method described in ASTM D 4892. The optimum moisture content (wopt) and maximum dry unit weight (γdmax) of clay nanocomposite samples were determined by the method described in ASTM D 1557. The compaction effort of the modified proctor tests was 2597 kJ/m3. The minimum void ratios (emin) are determined from the maximum dry densities (ρdmax) and specific gravities (Gs) of the clay-nanocomposites with Equation 1.

$$G_s . \rho_{dmax} = \rho_{dmax} . (1 + e_{min}) \quad (1)$$

The swelling pressure and unconfined compressive strength tests were, respectively, determined by the method described in ASTM D 4546 Method C and ASTM D 2166. The tests were done on the compacted samples with optimum moisture contents as in the above-mentioned compaction tests. The swelling pressure tests were done on the natural clay, hydrophobic organoclay, and clay-nanocomposite samples compacted with 2597 kJ/m3 on the samples with optimum moisture content and dry samples.

Additionally, damping ratios of clay-nanocomposite samples were determined with a computer-based and multi-channel analysis system and pulse vibration measurement system (Figure 1).

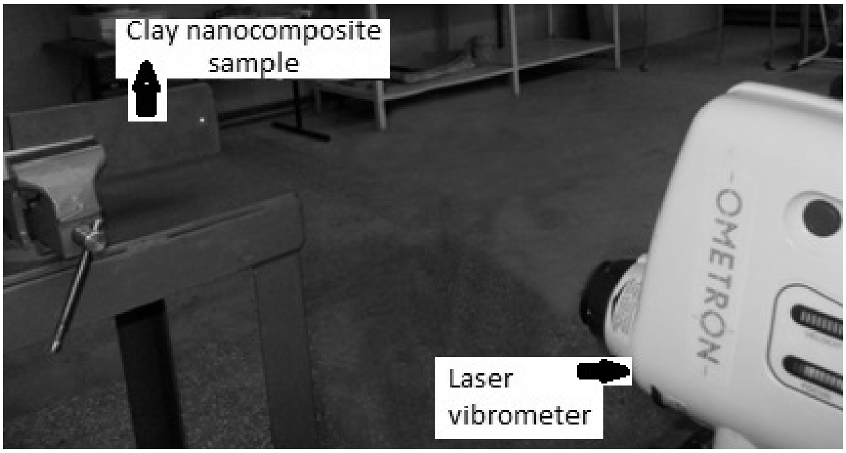


Figure 1. The clay nanocomposite sample and Laser vibrometer.

The propulsion force was applied on the samples at specific points with an impact hammer. Then the response of vibration was measured by a transfer function with a modal analysis (FRF) ME'scope VES (Bolat, 2011; Şakar & Bolat, 2015). This propulsion force was measured with a force transducer (hammer) and the response was measured with a Laser vibrometer.

RESULTS AND DISCUSSION

Electrokinetic properties

The changes of zeta potential amount of clay-nanocomposites with the increasing percentage of latex are given in Figure 2. It is observed that firstly the zeta potential amount of hydrophobic organoclay decreases and then increases while the percentage of latex is 20%.

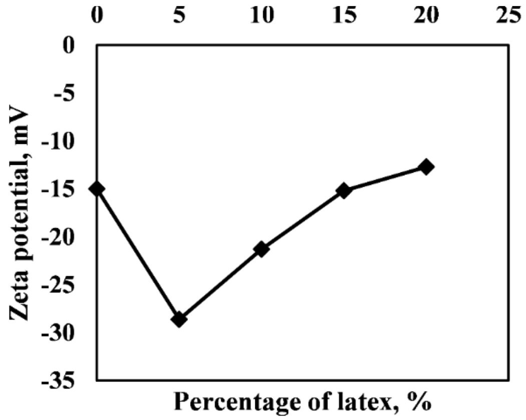


Figure 2. The changes of zeta potentials of clay nanocomposites with the percentage of latex.

The variation of the electric conductivity for the clay-nanocomposites with the percentage of latex obtained from electric conductivity tests is given in Figure 3. It is seen that the electric conductivities generally decrease as the percentage of latex increases and the negative effects of water pollution have been reduced. Akbulut et al. (2010) reported that electric conductivity value of surfactant modified clays slightly decreased as compared with those of virgin natural clay. In the current study, added to the surfactant materials used for obtaining the hydrophobic clay, the Latex polymer has been also used to obtain and produce the clay nanocomposites. As Figure 3 illustrates, the use of latex results in the reduction of electric conductivity among the samples. One can demonstrate that latex has removed higher levels of ions from the clay surface.

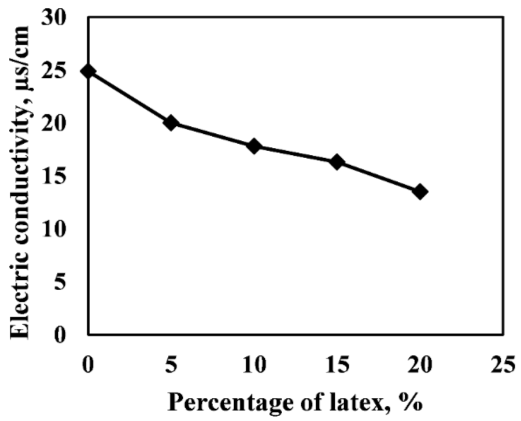


Figure 3. The changes of electric conductivities of clay nanocomposites with the percentage of latex.

Figure 4 shows the change of surface area of clay-nanocomposites with latex percentage. It can be said that increasing latex percentage decreases the surface area of clay-nanocomposites. The decrease of specific surface area in clay results in changes of its properties, which can be categorized by permeability coefficient, plastic properties of clay, and thickness of dual water layer around clay particles (Mitchel and Soga, 2005).

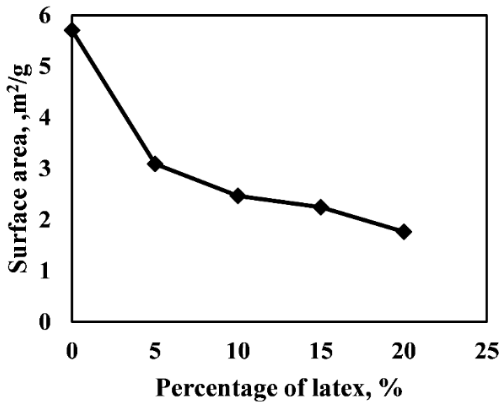


Figure 4. Changing surface areas of clay nanocomposites with the percentage of latex.

Figure 5 presents some images of the smallest contact angle obtained from clay- nanocomposites. Figure 6 indicates the increase in contact angle values of clay-nanocomposites with the increase in the percentage of latex. The contact angle measurements indicated that the clay water affinity decreased by latex polymer and a hydrophobic surface was produced. Increasing latex content caused the increase in the contact angles of the clay-nanocomposites and they became more hydrophobic when compared with the hydrophobic organoclay.

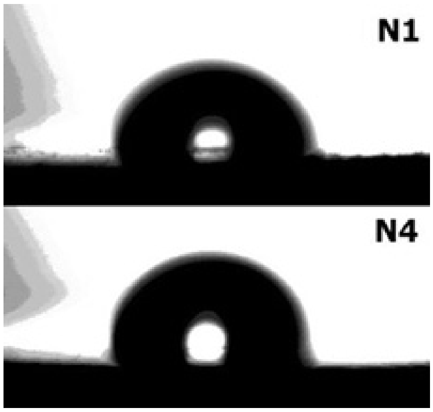


Figure 5. The images of contact angle measurements of N1 and N4 samples.

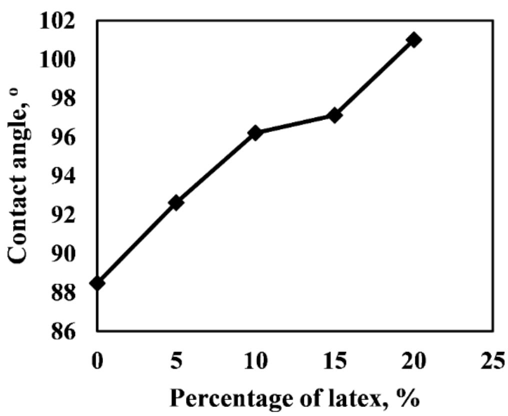


Figure 6. The changes of maximum contact angles of clay nanocomposites with the percentage of latex.

Specific gravities

The test results shown in Figure 7 reveal that the specific gravities of clay-nanocomposites decrease with the increase in the percentage of latex when compared with hydrophobic organoclay. It can be said that the decrease in the specific gravities of clay-nanocomposite samples is caused by the increase in pore ratios (Akbulut et al., 2013). The organoclay with low specific gravity can be attributed to a change in the soil fabric (Denham 1999). Conversely, it can be said that the decrease of specific gravity values is because of the increase of pore sizes and basal spacing of the clay-nanocomposites (Akbulut et al., 2012; Majedi et al., 2013).

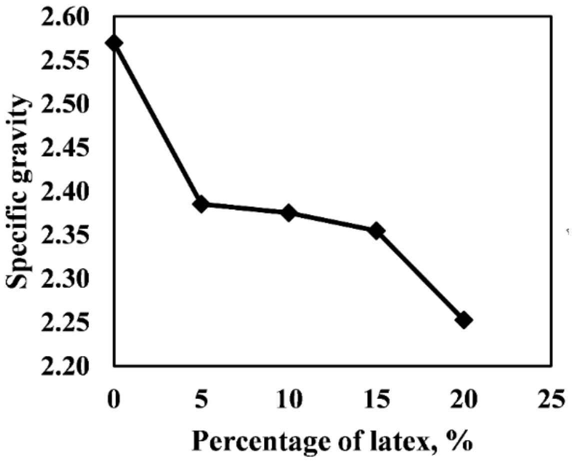


Figure 7. The changes of specific gravities of clay nanocomposites with the percentage of latex.

Compaction results

Modified proctor tests were done on the clay nanocomposite samples to indicate their optimum water content (wopt) and maximum dry unit weight (γdmax) relationships. Because of the hydrophobic property of clay nanocomposites, the compaction tests were done on the clay nanocomposites during the drying process. The compaction test results of the clay nanocomposites (Figures 8, 9) indicated that, by increasing the latex content, the maximum dry densities of samples are decreased. Akbulut et al. (2012, 2013) reported that, due to the low specific gravity of organoclays, maximum dry unit weights (γdmax) decreased with the increase in the quantity of the cationic surfactant. In this sense, it can be said that the decrease in the maximum dry unit weights of clay nanocomposites is related to the lower specific gravities of clay nanocomposites (Figure 7).

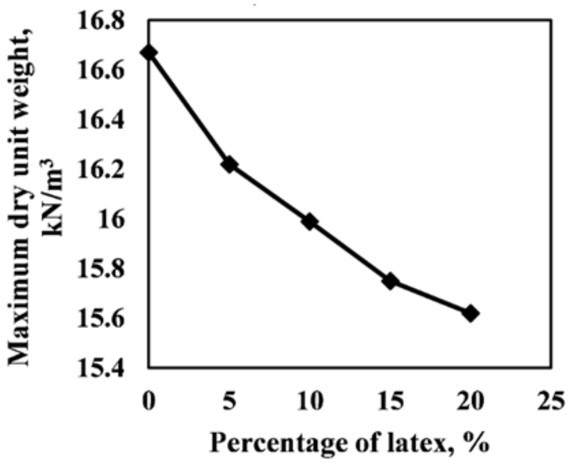


Figure 8. The changes of maximum dry densities of clay nanocomposites with the percentage of latex.

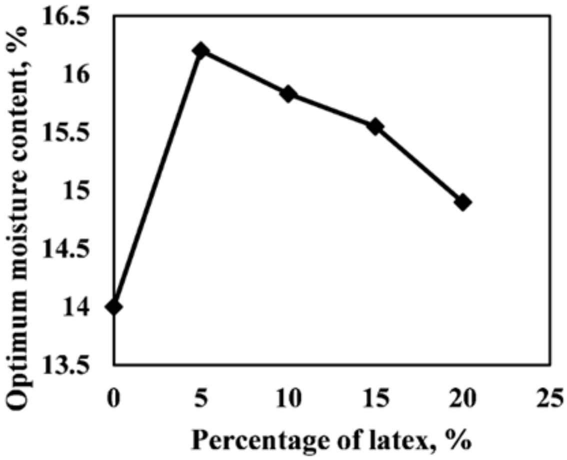


Figure 9. The changes of optimum moisture contents of clay nanocomposites with the percentage of latex.

Akbulut et al. (2010) reported that the surfactants would result in an increase in net repulsive forces when the zeta potential test results put into consideration. They reported that the increasing of repulsive forces also caused dispersion of clay particles. In the current study, the zeta potential tests results showed that the addition of 5% of latex polymer resulted in reduction of zeta potential in prepared clay nanocomposite. The reduction of zeta potential indicates higher levels of scattering concerning the clay particles. Consequently, one needs higher levels of water (moisture) due to the scattering status of clay particles when it comes to compact the produced clay nanocomposites including 5% latex. This value has decreased by the increase of latex level.

Figure 10 shows that the minimum void ratios of clay nanocomposite samples decrease when compared with the hydrophobic clay. The change in the moist unit weights of the clay-nanocomposite samples with the latex percentage has been given in Figure 11. From Figure 11, it can be said that the moist unit weights of the clay nanocomposite samples decrease with the increase in latex content when compared with the hydrophobic organo-clay and natural clay. Based on the study carried out by Kurt & Akbulut (2016), the moist unit weight was obtained as 20.5KN/m^3 for natural clay soil. In the current study, such a value for hydrophobic organo-play is 19.06 KN/m^3.

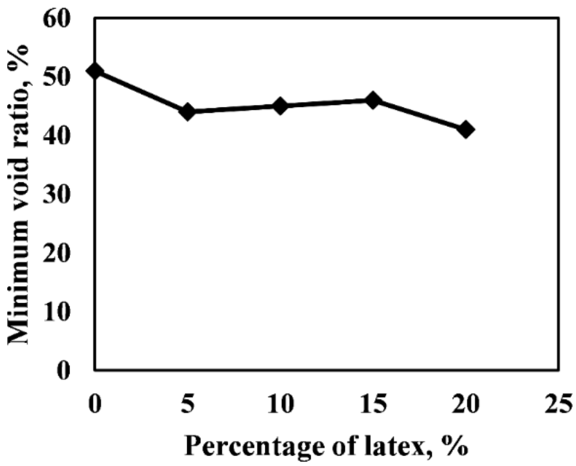


Figure 10. The changes of minimum void ratios of clay nanocomposites with the percentage of latex.

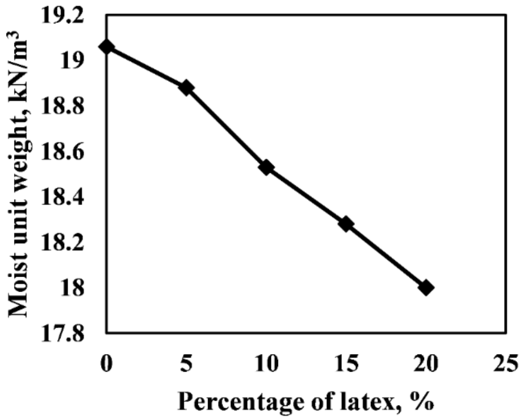


Figure 11. The changes of moist unit weights of clay nanocomposites with the percentage of latex.

Swelling pressure tests

Swelling pressure tests were done on two samples for each clay nanocomposite. One of the samples was prepared with optimum moisture content and the other sample was dried in the drying oven. Both samples were compacted with modified proctor energy. The swelling pressure test results (Table 4) revealed that the swelling pressures of clay nanocomposites decreased when compared with hydrophobic organoclay. Additionally, swelling pressure values of dry clay nanocomposites were zero. It can be said that the decrease in the swelling pressures of clay nanocomposite samples is affected by hydrophobic properties of clay nanocomposites (Akbulut et al., 2012; Akbulut et al., 2013; Majedi et al., 2013; Kurt & Akbulut 2014). The negative effects of clayey soils as swelling were eliminated with the decrease in swelling pressures in clay-nanocomposites.

Table 4. The results of swelling pressure tests.

Sample	Swelling Pressure, kN/m^2	
	Sample with optimum moisture content	Dry sample
N0	78.4	0
N1	1.39	0
N2	1.47	0
N3	1.81	0
N4	2.26	0

Unconfined compressive strength tests

The unconfined compressive strength tests were done on the clay-nanocomposites compacted with 2597 kJ/m3 energy level. The failure planes of clay nanocomposites are shown in Figure 12. The unconfined compressive strengths of the clay nanocomposites decrease with the increase in latex content when compared with hydrophobic organoclay.

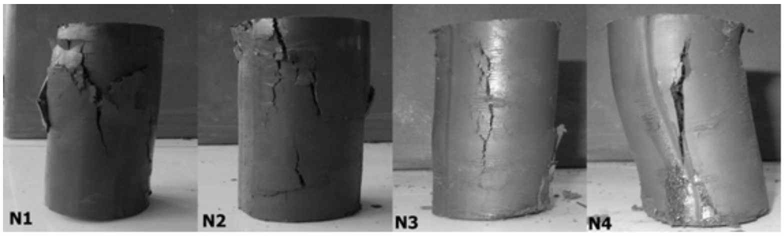


Figure 12. The failure planes of clay nanocomposites.

Figure 13 indicates the change of unconfined compression strength values of the clay nanocomposites with latex percentages. It is revealed that the unconfined compressive strength values depend on many parameters including the composition of the soil particles, the water content of the compacted soil, and the shape and size of soil particles (Kalkan et al., 2009). It can be said that the decrease in the unconfined compressive strength test values of the organoclay samples is because of decrease in specific gravities of clay-nanocomposites and the decrease of maximum dry unit weight as well (Akbulut et al., 2012, 2013; Majedi et al., 2013). The decreasing percentages of unconfined compressive strength values are 56%, 59%, 62%, and 66% for 5%, 10%, 15%, and 15% latex percentages, respectively.

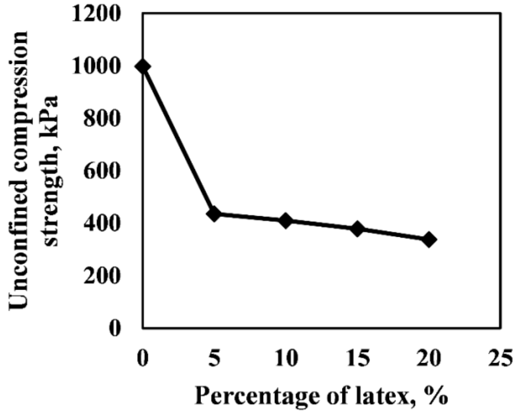


Figure 13. The changes of unconfined compression strengths of clay nanocomposites with the percentage of latex.

Damping ratios

The damping ratios of clay nanocomposites were determined with a computer-based and multi-channel analysis system and pulse vibration measurement system. All of the samples were compacted with modified proctor energy. For this test, two samples were prepared from compacted samples. One of the samples was at optimum moisture content and the other was dried at the drying oven. The samples were rectangular and the dimensions were 7,5x21x1 cm. As Figure 14 illustrates, the use of latex polymer has a considerable role in increasing the damping ratio of nanocomposites due to its elastic behavior. The increasing percentages of damping ratio values for clay nanocomposite samples at optimum moisture content were 39%, 47%, 58%, and %67 for 5%, 10%, 15%, and 20% of latex percentages, respectively. Additionally, the increasing percentages of damping ratio values for dry clay nanocomposite samples are 80%, 92%, 100%, and 106% for 5%, 10%, 15%, and 20% of latex percentages, respectively (Majedi et al., 2013).

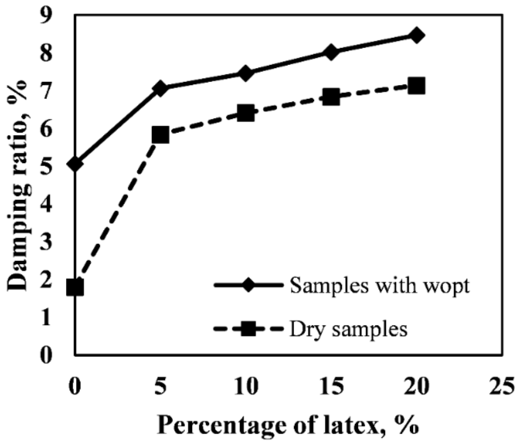


Figure 14. The changes of damping ratios of clay nanocomposites with the percentage of latex.

CONCLUSION

The aim of this study was to investigate some electrokinetic properties (zeta potential, electric conductivity, surface area, and contact angle), geotechnical properties such as specific gravity, compaction, swelling pressure, unconfined compressive strength, and damping ratio values of some clay nanocomposites (hydrophobic organoclay interacted with 5%, 10%, 15%, and 20% latex and 10% glycerin); and the test results were compared with hydrophobic organoclay. From the test results and the discussions presented in this research, the following conclusions were made:

- The zeta potential, electric conductivity, and surface area values of the clay nanocomposites decreased with the increase in latex percentages. The contact angles of the clay nanocomposites increased when compared with hydrophobic organoclay.
- The specific gravities of the clay nanocomposites decreased with the increase in the latex percentage when compared with hydrophobic organoclay.
- The compaction parameters of the clay nanocomposites at the modified compaction energy were determined. The optimum moisture contents of the clay nanocomposites increased at 5% and then decreased at higher latex percentage. In addition, the maximum dry densities of the clay nanocomposites decreased with the increase in latex percentage.
- The minimum void ratio values and moist unit weights determined from the compaction tests showed that the void ratios of the clay nanocomposites decreased when compared with the hydrophobic organoclay samples. Additionally, the moist unit weights of the clay nanocomposites decreased.
- The swelling pressures of clay nanocomposites that were compacted with modified proctor energy level at optimum moisture content decreased when compared with hydrophobic organoclay. However, the swelling pressure values of dry clay nanocomposites were zero.
- The unconfined compressive strength tests of the clay nanocomposites revealed that the unconfined compressive strengths of the clay nanocomposites decreased when compared with hydrophobic organoclay.
- The damping ratio values that were measured by pulse vibration system on the clay nanocomposite samples with optimum moisture content and dry samples increased.

Consequently, it is thought that the clay nanocomposites are more hydrophobic; hence, they could not have interacted with water. Additionally, clay nanocomposite samples have gained highly damping ratio values when compared with hydrophobic organoclay. Therefore, they can be used as a liner and damper in geotechnical applications.

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بعض المواصفات الجيوتكنيكية ونسبة التخميد لمواد النانوكامبوزيت (مواد النانو المركبة) الطينية

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الخلاصة

تتمثل أغلب استعمالات الطين الطبيعي في السدود وأماكن دفن النفايات ومحطات الطاقة النووية وغيرها كطبقة مانعة للتسرب أو طبقة واقية. إلا أن التعرض للماء لفترة طويلة قد يؤدي إلى ظواهر مثل الانتفاخ والهبوط وانجراف الطين الطبيعي، مما يؤدي مع مرور الزمن إلى أضرار دائمة في المنشآت. أصبح تثبيت الطين الطبيعي بواسطة إضافة مواد كيميائية للتغلب على هذه المشكلة أمراً متداولاً وشاملاً في البحوث. ويستخدم التأثير المتبادل للطين والبوليمرات بهدف تحسين جودة مواد النانوكامبوزيت. وفضلاً عن ذلك، تستخدم أنواع نافرة للماء من الطين الطبيعي بهدف التغلب على مشكلة امتصاص المياه من قبل المواد النانوكامبوزيت. سوف نتطرق في هذا البحث إلى استخدام مواد النانوكامبوزيت الطينية النافرة للماء والتي تحتوي على نسبة مختلفة من بوليمر اللاتكس، ودراسة بعض الخصائص الجيوتكنيكية لمواد النانوكامبوزيت الطينيه مثل الوزن النوعي واقصى وحدة كثافة جافة وضغط الانتفاخ ومقاومة الضغط غير المحصور. لقد تم الحصول على معامل تخميد مواد النانوكامبوزيت الطينية هذه بالاستفادة من منظومة التحليل الحاسوبية ومنظومة بالس متعددة القنوات لقياس الاهتزاز. تشير النتائج إلى أن كثافة الحبيبات والوزن النوعي الجاف الأقصى ومقاومة الضغط غير المحصور وضغط الانتفاخ لعينات النانوكامبوزيت الطينية المدروسة قد انخفضت بزيادة تركيز اللاتكس، ومن جهة أخرى فقد ارتفعت نسبة التخميد للعينات بزيادة تركيز اللاتكس. النتائج التي تم الحصول عليها من خلال استخدام مركبات النانو في الحالة الجافة او الحالة الرطبة قد اشارت على ان هنالك زيادة بالمقدار من 1.08 % (بدون استخدام مضاف اللاتكس) الى 7.14 % (باستخدام مضاف اللاتكس بنسبة 20 %) في الحالة الجافة، وفي الحالة الرطبة ازدادت من 5.06 % (بدون استخدام مضاف اللاتكس) الى 8.47 % (باستخدام مضاف اللاتكس بنسبة 20 %).