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Improvement in the Hydraulic Properties of Kaolinite with Adding Nanoclay

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ABSTRACT

Due to special properties of clay, it has widely been used in geotechnical and geoenvironmental projects such as barriers in which very low seepage is required. With advances in nanotechnology, we are witnessing of nanomaterials application to modify material properties in different branches of engineering such as geotechnical engineering. In this study, the hydraulic properties of Kaolinite extracted from Zenuz mine have been investigated experimentally by using nanoclay as an additive. A series of tests, comprising Atterberg limits, standard compaction, one dimensional consolidation and cation exchange capacity test, were conducted on Kaolinite and modified Kaolinite with 1%, 2%, 4%, and 8% nanoclay. According to experimental results, adding 8% nanoclay to Kaolinite increased plasticity index to 184%, and decreased the hydraulic conductivity 300 times when compared with raw Kaolinite. In addition, results of cation exchange capacity test showed that nanoclay caused an increase in cation exchange capacity from 12 to 21 meq/100 gr. This increase was related to a considerable increase in the amount of Na^+.

KEYWORDS:

Nanoclay, Hydraulic conductivity, Kaolinite, One dimensional consolidation test

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1- Introduction

Clay is referred to fine graded clayey minerals. Depending on the types of clayey minerals, its behavior will be different. Being related to the amounts of exchangeable cations, different types of clayey minerals affect their various properties. So far several studies have been conducted to investigate this matter. Monovalent cations in clay can cause an increase in crystals dispersion. The more crystals disperse, the finer clay particles will become and their specific surface extend [1]. This phenomenon can improve the properties of clay such as plasticity, permeability coefficient and the thickness of double layer water [2].

It is important to determine accurately the hydraulic properties of low permeable soils because it plays a vital role in preventing the seepage in hydraulic structures and also to protect the environment against pollutions especially the transmission and spread of dangerous infections.

Barriers are widely used in several geotechnical engineering projects related to preventing water and other liquids seepage. In geoenvironmental cases, barriers must have very low permeability, high capacity in pollutant absorption, good flexibility due to moisture changes, and allowable settlement versus moisture variations and ground movement. For these purposes, clay may be a suitable choice. If local clay doesn't have enough quality for barrier materials and the transportation cost of the large amount of suitable clay is high, the improvement of local soil with additives may be cost effective. Numerous studies were carried out to explore the effects of common additives such as Portland cement, hydrated lime, Bentonite and silica fume [3] on permeability reduction of clay.

In this paper, the different percentages of nanoclay were added and the influence of this additive on permeability coefficient and other physicochemical properties of Kaolinite were investigated experimentally. The Kaolinite extracted from Zenuz mine in Azarbayjanesharghi, Iran. The hydrophilic nanoclay used in this study is MMT/Na+ prepared by ATP Company with the interlayer spacing of 1.2nm.

2- Methodology, Discussion, Results

The experimental investigation involved determining the Atterberg limits, plasticity index, soil compaction specification, permeability coefficient and cation exchange capacity of raw and modified Kaolinite with nanoclay. To achieve these objectives, the following four types of tests were conducted according to the ASTM standard. These are Atterberg limits, standard compaction, one dimensional consolidation and cation exchange capacity (CEC) test.

Nanotechnology gives researchers a decent opportunity to detect the effects of Nanoparticles in the improvement of material properties.

The hydraulic conductivity of Kaolinite is higher than other clay so it was used in this experimental research [4]. The soil was classified as CL in U.S.C.S. and grain size was finer than 0.075mm, sieve no. 200. Nanoclay was added to Kaolinite to improve its hydraulic properties. The amounts of nanoclay selected were 1%, 2%, 4% and 8% of the total dry weight of Kaolinite. The raw Kaolinite was used as a control role for comparison purposes. The process of sample preparation is important to obtain uniformity. The water content of each sample for consolidation test was selected 1.5 - 2 times of its liquid limit. However, it is 1.2 times for samples comprising 4% and 8% nanoclay [4].

In geotechnical projects, high plasticity soils are widely used because they can sustain large deformations without cracking that may cause seepage increase within geotechnical projects [5]. Cracking may be induced by moisture decreasing. Atterberg limits test was conducted to investigate plasticity changes in composite of clay with different percentages of nanoclay.

In this research, the effect of nanoclay on the permeability of Kaolinite was investigated. The permeability coefficient has been calculated indirectly by one dimensional consolidation test results.

Increasing in nanoclay percent resulted in a significant increase in liquid limit while plastic limit changed negligibly. This indicated an increase in plasticity index. For example, adding 8% nanoclay to Kaolinite caused to increase plasticity index to 184%. This phenomenon could be attributed to specific surface of particles in composites which resulted in absorbing more water [1,2].

Furthermore, nanoclay affected the compaction properties of Kaolinite slightly as increase in optimum moisture content and decrease in the maximum dry density of soil.

Changes in the permeability coefficient of each sample versus consolidation pressure are depicted in Fig. 1. The more nanoclay added in samples, the lower

permeability would be obtained. The permeability coefficient of the sample composed with 8% nanoclay was about 10-10 cm/s that indicated a considerable reduction in the hydraulic conductivity of Kaolinite. In other word, permeability reduced 300 times.

The results of cation exchange capacity test are presented in Tab. 1. The amount of cation exchange capacity was increased by adding nanoclay to Kaolinite. This can be attributed to the increase in the ratio of monovalent to divalent cations caused by increasing in the amount of Na^+.

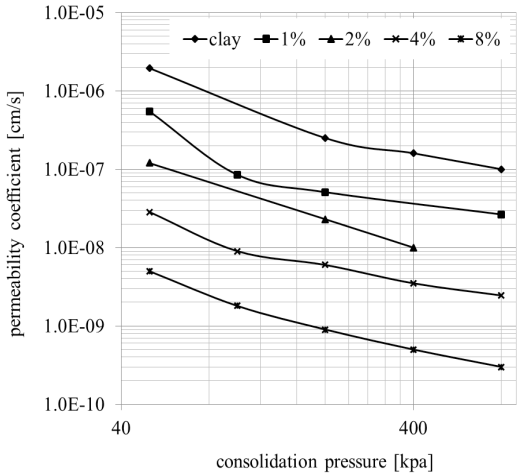

Figure 1. Changes in permeability coefficient versus consolidation pressure

The thickness of double layer water surrounded clayey minerals expands due to increasing in monovalent cations. This causes to extend crystal dispersion and particles become finer consequently which leads to a considerable increase in its specific surface [1,2].

3- Conclusions

Experimental results corroborated that adding 8% nanoclay can improve considerably the hydraulic properties of Kaolinite comprising 184% increase in plasticity index, 300 times reduction in permeability coefficient and an increase in CEC due to increase in the amount of Na+ which caused particles become finer and its specific surface was more. Furthermore, the compaction properties of composite changed slightly.

4- References

[1] Lan, T. and Kaviratna, P. D, "Mechanism of clay tactoid exfoliation in epoxy-clay nanocomposites", Chem Master, pp 2144-2150, 1995.

[2] Mitchel, J. K. and Soga, K, "Fundamentals of soil behavior", John Wiley & Sons, Third edition, 2005.

[3] Francisca, F. M. and Glatstein, D. A, "Long term hydraulic conductivity of compacted soils permeated with landfill leachate", Applied Clay Science, Elsevier, pp 187-193, 2010.

[4] Ohtsubo, M., Anil, K. M., Li, L. and Higashi, T, "Effect of salt solution on the permeability of the mixtures of soil and bentonite", 5th ICEG Environmental Geotechnics, pp 601-607, 2006.

[5] Das, B. M, "Advanced soil mechanics", Taylor & Francis, New York, NY 10016, USA, 2008.

Table 1. The results of cation exchange capacity test

sample	Cations [meq/100 gr]				CEC
	Mg2+	Ca2+	K+	Na+	meq/100 gr
Kaolinite	2.4	8.2	0.8	0.6	12
Kaolinite + 4% nano-clay	2.5	10.4	0.9	4.6	18.4
Kaolinite + 4% nano-clay	2.3	9.5	1	8.2	21