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Microstructure analysis of electrokinetically stabilized peat

Hossein Moayedi [a,*], Ramli Nazir [a], Sina Kazemian [b], Bujang Kim Huat [c]

[a] Department of Geotechnics & Transportation, Faculty of Civil Engineering, Universiti Teknologi Malaysia, Johor, Malaysia
[b] Department of Civil Engineering, Payame Noor University, Tehran, Islamic Republic of Iran
[c] Department of Civil Engineering, Faculty of Engineering, Universiti Putra Malaysia, Serdang, Selangor, Malaysia

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ABSTRACT

In this research, four new chemical grout reagents were used, namely, sodium silicate, calcium chloride, calcium oxide, and aluminium hydroxide. The injection of the chemicals through the soil by using an electrokinetic method was successfully performed. Increase in the shear strength of stabilized soil was higher in the locations near the cathode and the calcium oxide showed the highest increment. The soil microstructure is comprehensively changed due to the change in the pH of the soil, and fluid flow during the electrokinetic application depends upon time and location of samples taken along the cell. The EDX output of natural peat showed the presence of oxygen (46.2%), carbon (29.3%), silica (5.1%), alumina (2.5%), and calcium (3.0%). However, after electrokinetic injection of the sodium silicate, calcium oxide, calcium chloride, and aluminium hydroxide, the concentration of these elements in the soil samples taken adjacent to the anode changed, with the carbon changing to 24.9%, 16.5%, 31.4%, 34%; the oxygen to 47.6%, 41.9%, 53%, 46%; the silica to 12.3%, 4.1%, 4.2%, 4.7%; the alumina to 2.5%, 1.2%, 2.2%, 6.2%; and the calcium to 1.8%, 18.6%, 6.1%, 2.6%, respectively.

1. Introduction

Huat [1] noted that organic matter in soils originates from living plants, organisms and animals. In particular, marine plants and animals contribute a major amount to the formation of organic material in the soil. During the transformation processes of plants, organic products such as coal and peat are created [2]. Peat is a mixture of fragmented organic materials formed in wetlands under appropriate topographic and climatic conditions and is derived from vegetation that has been chemically changed and fossilized [3]. It is often referred to as problematic soil due to its high compressibility, low shear strength, and high water content. Primarily, peats are in an acidic condition and, in turn, the pH value often lies between 4 and 7 [4,5]. For example, West Malaysian peats have very low pH values varying from 3.0 to 5.5. Also, in some cases where sulphide materials are found within the profile, pH values can even be below 3.0 [6].

With the increase in urban construction and construction in mechanically substandard soils, new methods were required to stabilize soft soils with low permeability while minimizing ground movements [7]. While conventional soil grouting can be used to stabilize soils with relatively high permeability (k typically greater than 10^{-5} m/s), other methods need to be applied for improving the strength of fine-grained soils with lower hydraulic conductivity values. These include hydrofracture grouting, artificial ground freezing, and induced consolidation either by applying electric fields or surcharging the soil [8]. EK stabilization is a ground improvement method in which soils are treated without excavation (i.e. disturbing the soil). This is seen as an important advantage over traditional methods. Although electrokinetic injection technology has seldom been employed, the majority of applications have been successful and have proved an economic alternative to traditional ground improvement methods [8,9]. It has been

* Corresponding author. Tel.: +60 0137797925.
E-mail address: hossein.moayedi@gmail.com (H. Moayedi).

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used in several soil improvement categories including consolidation, contaminant removal, dewatering, and stabilization.

There are numerous studies on the strengthening of soft soils using the electro-grouting technique. Alshawabkeh and Sheahan [7] stabilized soft soil by ionic injection under electric fields. The results of their study show that the shear strength increases the soil's baseline strength by up to 560% by adding phosphoric acid. This research was later developed by Alshawabkeh et al. [8] and this has proved that the application of direct current fields to soft soils changes the soil in both its physical and mechanical properties. Shang et al. [10] also investigated the electrochemical cementation of offshore calcareous soil. They used two chemical agents in their electrochemical stabilization experiments. The result of their experiments reveals a 700% increase in the load capacity carried from the soil after 7 days of treatment with an applied voltage of 4 V. Mohamedelhassan et al. [11] explored electrochemical stabilization for offshore model caissons. They used calcareous sand and seawater from the coastline of Western Australia in the study. As a result, the pull-out resistance of the caisson after the electrokinetic treatment was significantly increased. A study performed by Micic et al. [12] focused on electrokinetic improvement of marine deposits surrounding skirted footing of offshore structures. Comparison between the untreated and treated soil reveals that the treated soil has developed preconsolidation pressures with an overconsolidation ratio of 3.7–5 within the treatment influence zone. The results of both the vane shear test and the unconfined compression test indicate increases in the undrained modulus by 7 times.

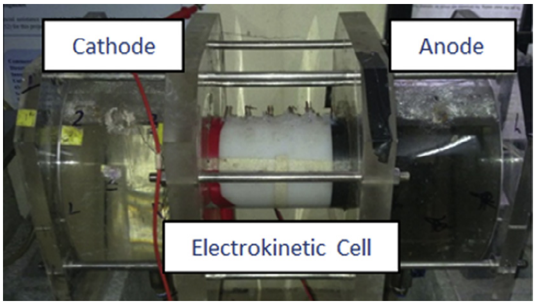

Fig. 1. Schematic diagram of the EK apparatus.

In addition, EK injection has been established as an effective *in situ* ground improvement technique in fine soils, particularly where ground movements need to be minimized. Over the last 40 years, a few hundred different compounds of chemical grout have been introduced. However, in the case of EK treatment only few soil types and chemical stabilizers are highlighted in the literature. This research paper aims to investigate the changes in the microstructure (SEM graph and atomic composition) of possible peat stabilization mixed with several types of chemical reagents. The stabilizer reagents were in-

Table 1
Physicochemical properties of peat samples.

Parameters	Unit	Standard	Values
Moisture content	%	BS 1377-2-3 (1990)	159
Bulk density	kN/m^3	BS 1377-2-7 (1990)	13.2
Specific gravity		BS 1377-2-8.4 (1990)	1.343
Organic content	%	BS 1377-3-4 (1990)	86
Permeability	m/s	BS 1377-6-4 (1990)	3.35×10^{-6}
Fiber content	%	ASTM-1997-91	41.94
CEC	meq 100 g^{-1}	Gillman and Sumpter (1986)	54
pH		ASTM-4972	5.63
Zeta potential	mV	ASTM-4187	−17
Surface area	m^2 g^{-1}	BET technique	51

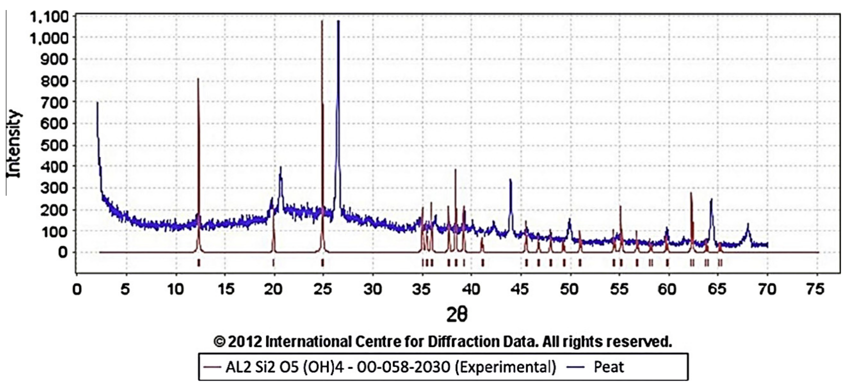

Fig. 2. XRD data of natural soil sample.