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EXTENDED ABSTRACT

An Experimental Study on The Effects of Pore-Fluid Parameters on Microstructural Behavior of Clay Core Materials in Embankment Dams

Mohammad Amiri *, Rahim Zare

University of Hormozgan, Faculty of Engineering, Bandar Abbas, Iran

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1. Introduction

The abundance of saline water at ground level and their progression to freshwater and onshore sources, landfill leachate chemicals, or industrial plant effluents into the soil are factors that can change the amount and type of soil salinity and, as a result, their geotechnical properties (Ouhadi et al, 2015). Also, due to the size of the large dams reservoirs and the impossibility of changing the axis of the dams due to different constraints, it is possible that after the filling, the dam lake water will come into contact with the salt formations and may cause risks such as changing the geotechnical behavior of the clay core, after exploiting embankment dams. Therefore, due to the presence of contaminants, which is sometimes unavoidable, an understanding of basic mechanisms in modifying the physical and engineering properties of soils under the influence of chemicals or chemical salts is essential (Sen et al, 2017). In general, the concentration of ions affects the intermolecular forces of the soil (ie double-layer repulsion and van der Waals attraction) and the structure of the materials (Weimin et al, 2014; Zhu et al, 2015). As a result, such changes in soil structure alter its engineering properties (Yan and Chang, 2015).

According to the extensive studies on the influence of pore fluid on clay soils, however, a comprehensive study from the microstructural perspective with regard to permeability coefficient changes on clay soils has not been conducted. The purpose of this study was to investigate the permeability coefficients and engineering properties of clay soils with a special attitude to clay core in the presence of sodium chloride solution salt as a pore fluid from a microstructural perspective.

2. Materials and methods

Since the materials used in embankment dams core must have a low permeability, sandy clays or high clay sand, and clay sands are commonly used (Rahimi, 2015). Therefore, in accordance with the aforementioned executive points in the construction of the embankment dams core, the soil used in this study was sand clay (SC) with the specifications presented in Table (1). To study the effect of pore fluid concentration on geotechnical and microstructural properties of the studied soil, sodium chloride (NaCl) salt with 8 different concentrations (0, 0.02, 0.04, 0.08, 0.2, 0.4, 0.8, and 1.7 M) were used. The characteristics of the solution concentrations used in the study along with pH and Ec are presented in Table (2). The mechanism of alteration of geotechnical behavior of clay core under the influence of dissolved salts has been investigated with regard to changes in Atterberg limits, permeability coefficients, resistance parameters and probability of divergence phenomena according to ASTM standard.

* Corresponding Author
E-mail addresses: amirii@hormozgan.ac.ir (Mohammad Amiri), zare.rahim1993@gmail.com (Rahim Zare).

Table 1. Some geotechnical properties of the soil used in the study

Physical properties of soil		Quantity measured	References for method of measurement
Percentage of the passage of 200 sieve (%)		45	ASTM D422
Classification		SC	ASTM D422-87
Liquid limit (%)		37	ASTM D4318
Plastic Limit (%)		20	ASTM D4318
Plasticity Index (%)		17	ASTM D4318
Optimum water content (%)		13.5	ASTM D698
Carbonate content (%)		6	ASTM C575
pH (1:10; soil: water)		8.2	ASTM D4972
Electrical Conductivity (ms/cm)		0.48	ASTM D1125-95
CEC (cmol/kg-soil)		2.4	Handershot, 1986
Strenght Parameters	C (kg/cm^2)	0.67	ASTM D3080
	φ^o	24.8	ASTM D3080
Maximum dry density (g/cm^3)		1.9	ASTM D698
Unconfined Compression Strength (kg/cm^2)		2.63	ASTM D2166
Mineral Composition using XRD analysis		Pyrophyllite, Illite, Kaolinite, Quartz	ASTM D2216

Table2. Characteristics of the solution concentrations used in the study

	Distilled water	Fresh Water	Low Salinity	Brackish		High Salinity	Extreme high Salinity	Salt Water
Concentration (M)	0	0.02	0.04	0.08	0.2	0.4	0.8	1.7
pH	7.28	7.62	7.65	7.72	7.81	8	8.5	7.65
EC (ms)	0.13	2.6	4.5	8.3	19.5	38.3	69.8	125

3. Results and discussion

Fig. (1) shows the variations of the Atterberg limits for samples containing different concentrations of sodium chloride (NaCl) as a pore fluid. Based on the results presented, by adding sodium chloride pore fluid to the samples, the liquid limit (LL) and paste limit (PL) were both reduced. The amounts of liquid limit and paste limit for natural soil (combined with distilled water) were 36.94 and 19.57 units, respectively. Increasing the pore fluid concentration from zero to 0.04 M of sodium chloride solution (low salinity water) caused the amounts of liquid limit and paste limit to decrease from 36.94 and 19.57 units to 33.57 and 19.42 units respectively. Increasing the pore fluid concentration to 1.7 M of sodium chloride (brine) caused the amounts of liquid limit and paste limit to decrease to from 36.94 and 19.57 units to 28.07.07 and 17.59 units, respectively. Although the effect of pore fluid chemistry on clay engineering behavior in many cases is still unclear and even controversial in some cases, it can generally be explained by changes in the double layer (Sen et al, 2017). It is also widely accepted that the liquid limit (LL) is essentially the maximum amount of water absorption around a particle, which is directly related to the thickness of the double layer (Tongwei et al., 2019). In fact, the presence of sodium chloride pore fluid in the specimens caused the structure of the soil complex to exist (a decrease in the severity of clay mineral peaks). Hence the decreasing trend of the Atterberg limit can be attributed to the substitution of water molecules by salts which reduces the thickness of the double layer due to the flocculation of the clay particles (Manasseh, 2004).

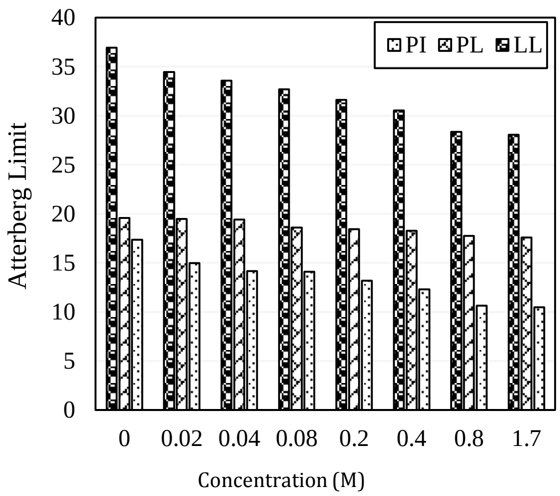

Fig. 1. The effect of different concentrations of sodium chloride pore fluid on the soil Atterberg limit

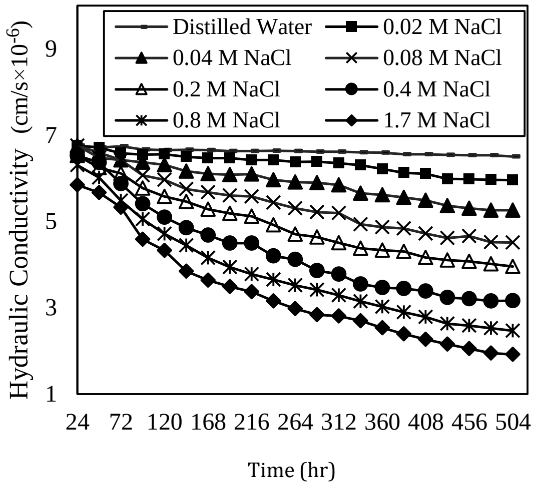

Fig. 2. The effect of different concentrations of sodium chloride pore fluid on soil permeability coefficient over time

In Fig. 2, the results of the permeability test on natural soils over a period of 504 hours under the influence of different concentrations of sodium chloride solution are presented. Based on the results, the permeability coefficient for the soil sample under the influence of distilled water was approximately a constant value of 6.5×10^{-6}cm/s. By increasing the permeable fluid concentration to 1.7 M of sodium chloride (brine), the permeability coefficient decreased by about 70% and reached 1.9×10^{-6}cm/s. It was also observed that about 400 hours after the start of the experiment the permeability coefficient decreased and remained almost constant. In other words, over time, permeable fluid salt particles were deposited between the pores of the soil and reduced the permeability coefficient.

4. Conclusions

1. Overall, although the emergence and dissolution of salts in the reservoir of embankment dams, may reduce the permeability coefficient by about 70% in the short term, but in the long term, it can increase the permeability coefficient by 9 times by changing the salt concentration in the reservoir; this may cause damage to embankment dam and dam inefficiency.
2. Based on the results of the Atterberg limit, the concentration of sodium chloride pore fluid decreased by increasing concentration. But the increase in concentration had little effect on the paste limit. In fact, in suspension mode, the variations were due to the change in the structure, the arrangement of the clay particles, and the thickness of the double layer.

5. References

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