ARTICLE IN PRESS

Egyptian Journal of Petroleum (2016) xxx, xxx–xxx

HOSTED BY

ELSEVIER

Egyptian Petroleum Research Institute

Egyptian Journal of Petroleum

www.elsevier.com/locate/egyjp
www.sciencedirect.com

FULL LENGTH ARTICLE

Effect of salinity of groundwater on the geotechnical properties of some Egyptian clay

Mahmoud M. Abu zeid [a], **Ahmed K. Abd El-Aal** [b,c,*]

[a] *Civil Engineering Department, Faculty of Engineering, South Valley University, Qena, Egypt*
[b] *Civil Engineering Department, Faculty of Engineering, Najran University, P.O. Box 1988, Najran, Saudi Arabia*
[c] *Geology Department, Faculty of Science, Al Azhar University, Assiut Branch, Assiut, Egypt*

Received 4 June 2016; accepted 20 September 2016

KEYWORDS

Clayey soil;
Plasticity index;
UCS;
CBR;
Consolidation test

Abstract This study deals with the effect of salinity of groundwater on some properties of clayey soil. Properties obtained from tests carried out on samples mixed with water containing different salt contents are compared with those obtained from tests carried out on samples mixed with pure water (tap water). The tested samples were taken from the site of the Faculty of Engineering in Qena, South Valley University. Two sets of samples of the clay soil were tested. One was mixed with pure water (pure water clay soil) and the other was mixed with salty water added to it in ratios ranging from 20% to 80% (clay soil mixed with salt). The test results showed the effect of groundwater salinity on the tested samples. The plasticity index decreased from 26 for pure water clay soil to 24.96 for clay soil mixed with 80% salt. The coefficient of consolidation increased from 0.00196 for pure water clay soil to 0.002744 for clay soil mixed with 80% salt. The California bearing ratio increased from 9.75% for pure water clay soil to 10.15% for clay soil mixed with 80% salt. The optimum moisture content increased from 14.25% for pure water clay soil to 16.5% for clay soil mixed with 100% salt. Decrease in the maximum dry density is observed for clay soil mixed with salty when compared with pure water clay soil. A marked decrease was noticed for the value of the unconfined compressive strength. All the tests were carried out in the Soil Mechanics and Foundations Lab, Faculty of Engineering in Qena, South Valley University.

1. Introduction

Clays are important components of soil which evolve mainly from the chemical transformation of minerals. In geotechnical engineering, it is regarded as fine-grained soils [1]. All clays have high affinity for water, yet some clayey soils react mechanically more than others [2]. Swelling clays formed from montmorillonite mineral groups cause serious problems including large settlements under superstructures or becoming hydraulically permeable in the case of change in the pore fluid

* Corresponding author at: Civil Engineering Department, Faculty of Engineering, Najran University, P.O. Box 1988, Najran, Saudi Arabia. Fax: +20 966175428887.
E-mail address: Ahmed_Aka80@yahoo.com (A.K. Abd El-Aal).
Peer review under responsibility of Egyptian Petroleum Research Institute.

http://dx.doi.org/10.1016/j.ejpe.2016.09.003
1110-0621 Production and hosting by Elsevier B.V. on behalf of Egyptian Petroleum Research Institute.

characteristics [3,4]. Such problems mostly arise from changes in the physicochemical state of soil particles, causing changes in the thickness of the diffuse double layer.

Pore fluid chemistry is one of the factors that influence the adsorbed water layer thickness surrounding the clays. That is, strong cation concentration, high cation valence and acidic environment dramatically decrease the double layer thickness around the clay particles [5]. Hence, the performance of earth structures e.g. impermeable clay liners changes dramatically when the pore fluid chemistry of the system changes with time. On the other hand, double layer thickness around non-swelling clays reduces when exposed to chemicals as well [6].

2. Experimental program and materials

The experimental study involves investigating the effect of salinity of groundwater on the various properties of clayey soil, namely plasticity index, unconfined compressive strength, California bearing ratio, optimum moisture content, maximum dry density, and consolidation properties. Tests were performed using samples prepared at optimum moisture content.

The methodology comprised collection of soil, then adding saline water with different ratios of 20, 40, 60, 80 and 100%, by weight. Tap water was considered as pure water and was used as reference water samples. The collected soil was dried, then mixed with water and subjected to laboratory investigations to find their physical and mechanical properties. Dried samples were pulverised then dispersed in water using sodium hexametaphosphate. Dispersing agent can be "sodium polyphosphates glassy" which is a mixture of many polymers for which the CAS number is 68915-31-1, the chemical formula is $Na(x + 2)\ PxO(3x + 1)$, where $x = 6–21$. An alternate CAS number 10124-56-8 is specific for sodium hexametaphosphate, Na6O18P6, molecular weight 611.77. All tests were conducted according to the Egyptian Code for Soil Mechanics and Foundations [7].

2.1. Properties of soil samples

The basic properties of the soil samples are presented in Table 1.

2.2. Propertiesof water samples

The ionic concentrations and salt content of the reference sample and the ratio of salt in water found out through laboratory tested are given in Table 2.

Table 1 Properties of nature soil sample.

Property	Value
Sand content (%)	33
Silt content (%)	26
Clay content (%)	41
Specific gravity	2.64
Water content (%)	7.55
Liquid limit (%)	52
Plastic limit (%)	26
Shrinkage limit (%)	10.75
Free swelling (%)	69
In-situ density (t/m^3)	1.89
pH	7.75

3. Results and analyses

3.1. Atterberg limits

The values of plastic limit, liquid limit and shrinkage limit changes according to salt content in mixing water as given in Table 3.

The liquid limit value of 52 for sample mixed with tap water drops progressively to 34.58 for sample mixed with 80% salt. The plastic limit drops progressively from 26 to 2.15, this causes the plasticity index to change from 26 to 4.85. The shrinkage limit drops progressively from 10.75 to 1.4. Results are shown in Fig. 1.

The change of the prementioned parameters is explained by the fact that when salty water is added to clay, the free ions Al^{3+}, Na^{+}, Mg^{2+} and K^{+} present in the salty water replace the cations of the hydrous layer surrounding the clay particles and reduce the net electrical charge.

3.2. Compaction characteristics

Table 4 presents the change of the compaction parameters of soils resulting from change of salt content. Fig. 2 shows the compaction curves obtained from Standard Proctor Test. Each test was performed 3 times and the average values of the OMC and maximum dry density were taken.

It is shown that the maximum dry density decreases from 1.84 g/cc for sample mixed with tap water to 1.74 g/cc for clay samples treated with 80% salt. The optimum moisture content

Table 2 Ionic concentrations in water.

Mineral	Tap water (meq/L)	Salty water (meq/L) with different ratios (%)			
		20	40	60	80
Calcium	0.54	2.65	5.25	7.85	10.48
Sodium	0.17	85.00	168.00	252.00	335.10
Magnesium	0.36	22.00	44.00	66.00	88.00
Potassium	0.11	2.03	4.00	6.02	8.01
Carbonate	0.65	0.15	0.25	0.40	0.53
Bicarbonate	0.75	0.24	0.45	0.69	0.92
Chloride	1.13	85.00	165.00	250.00	492.00

Please cite this article in press as: M.M. Abu zeid, A.K.A. El-Aal, Effect of salinity of groundwater on the geotechnical properties of some Egyptian clay, Egypt. J. Petrol. (2016), http://dx.doi.org/10.1016/j.ejpe.2016.09.003