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The Effect of Water's Cations on the Consolidation Settlement Process of Clay with Kaolinite

Soheil Ghareh[a] *, Sina Kazemian[b], Seyed Vahid Mojtahed Sistani[c], Ali Shayan Mehr[d]

[a]Associate Professor, Civil Engineering Department, Payame Noor University, I.R. Iran
[b]Assistant Professor, Civil Engineering Department, Payame Noor University, I.R. Iran
[c]MSc in Civil Engineering, Islamic Azad University, Central Tehran Branch, I.R. Iran
[d]MSc in Civil Engineering, Islamic Azad University, Central Tehran Branch, I.R. Iran

Abstract

Due to high effect on stability of construction, settlement is very important factor in construction and foundation engineering. Before implementing any project, we should determine the potential of soil in terms of the amount and type of settlement. In saturated clays, water loss from soil performs after a long time (due to low permeability and high water absorption) causes high settlements which are named settlements of consolidations. In this research, experimental study of changes in the initial consolidation settlement process on kaolinite clay (kaolinite) by oedometertest, with the addition of solved cations with concentrations of 50, 150 and 300 Mg/lit (milligrams per liter) in saturated water. Research findings show that application of aluminum (Al^{+3}), magnesium (Mg^{+2}), calcium (Ca^{+2}), sodium (Na^{+}) and potassium (K^{+}) cations with different concentrations changes the initial consolidation settlement values in appropriation with the concentration and type of cations. The highest reduction in initial consolidation settlement of kaolinite valued at 30.29% related to the sample made with cations magnesium with concentration of 300 Mg/lit.

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Keywords: Consolidation settlement; Clay; Oedometer test; Kaolinite

* Corresponding author. Tel.: +989123842746; fax: +985137620220.
*E-mail address:*ghareh_soheil@pnu.ac.ir

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1. Introduction

In fine grained soils, water loss from soil performs after a long time due to low permeability and high water absorption of clay minerals. In this regard, it is necessary to estimate the settlement occurred in result of consolidation. Obviously in the absence of the prediction, settlement results in irreversible damages. Regarding settlement of saturated cohesive soils when undergoing loads and also due to lowering of underground waters' level, researchers have been searching for approaches to remove initial consolidation settlement process and reducing its values [1-3]. Representing a range of methods including implementation of vertical and horizontal sand drains [4], preloading and dynamic compaction [5,6], the limitation of these approaches deal with the necessary of implementing them before construction of the project. The initial consolidation settlement process of saturated cohesive soils is based on three bases including soil, excess water and overhead. The normal process of the initial consolidation settlement process starts with the completion of these three bases and excess pore water pressure in clay begins its depreciation process. It is to be noted that any changes in the normal process of initial consolidation settlement is possible when being accompanied with changes in each of these three bases [7-9].

In this regard, we tried to improve the normal process of initial consolidation settlement through adding different concentrations of absorbed and dissolved cations in saturated water and performing changes in clay structure toward enhancing the construction of the cohesive saturated clay against initial consolidation settlement and reducing its values.

2. Research Objectives

Continuing researches made by Whitman and Lambe (1902) [10] and Shen and Miura (1999) [11-12], this paper investigates changes in initial consolidation settlement process with the addition of various concentrations of different dissolved and absorbed cations in saturated water, on cylindrical samples of kaolinite clay (kaolinite) with the height of 2 cm and the diameter of 7.5 cm in the standard oedometer device. It should be noted that this paper studies the impact of different parameters including concentration, capacity and hydrated size of cations including aluminum, magnesium, calcium, sodium and potassium on the values of initial consolidation settlement and compaction coefficient (C_c).

3. Construction Materials

Toward research objectives and experimental studies, the effect of different types and concentrations of dissolved and absorbed cations in saturated water was investigated on the natural process of initials consolidation settlement; toward this, kaolinite mineral was applied as one of the most important minerals in clay. Kaolinite used in laboratory studies bear moisture of 18.7%, Dry density of 16.3 kN/m^3 and Specific density of 2.724.

4. Laboratory Studies

Regarding the necessity of performing required changes sutured water, in order to perform laboratory studies of the present research, 16 samples of kaolinite in size of bounding ring, 2 cm in height and 7.5 cm in diameter and 18.7% in humidity, were provided and tested. Cylindrical samples applied for laboratory studies were made in two states and underwent loading and initial consolidation settlement test in standard oedometer device. The first state applied kaolinite mineral and ion-less distilled saturated water and the second state applied kaolinite mineral and saturated water containing cations of aluminum (Al^{+3}), magnesium (Mg^{+2}), calcium (Ca^{+2}), sodium (Na^{+}) and potassium (K^{+}) with concentrations of 50, 150and 300 Mg/lit.

In order to perform laboratory experiments of the present research, we placed clean and wet porous filter papers at the top and bottom of the sample after construction of which and we put the entire series into the bounding ring; then, we placed the sample pack within the standard oedometer loading device; the first loading stage was operated when the sample was immersed in saturated water with vertical pressure of 0.25 kg/cm^2. it is to be noted that values of initial consolidation settlement of any sample in different time intervals were recorded as 0.25, 0.5, 1, 2, 4, 8, 15, 30, 60, 120, 240 and 1440 minutes. The steps set forth for loadings of 0.5, 1, 2, 4 and 8 kg/cm² performed for a term of 24 hours for each increase in load.

After the completion of these processes and completion of initial consolidation settlement up to vertical pressure of 8 kg/cm², unloading processes performed up to vertical pressure of 2 kg/cm², and finally up to vertical pressure of 0.5 kg/cm² for a period of 24 hours. Finally, after completion of loading and unloading processes and recording values of initial consolidation settlement, samples were taken out of oedometer device and put into oven. Moisture of samples was measured after taking them out of the oven.

5. Effective parameters in laboratory test results

Regarding significant impacts of concentration, capacity and size parameters of hydrated cations on the values of the initial consolidation settlement of kaolinite after making laboratory samples and conducting initial consolidation settlement tests, changes of the ratio of porosity against pressure for each of the samples made with ion-less distilled water and also distilled water containing K^{+}, Ca^{+2}, Mg^{+2}, Na^{+} and Al^{+3}cations, with concentrations 50, 150 and 300 Mg/lit, are respectively shown in figures 1 to 5.

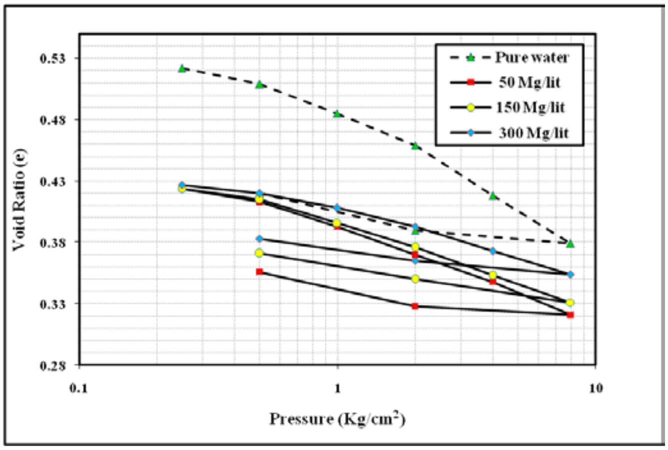

Fig. 1.Changes in the ratio of porosity-pressure for samples made with Al^{3+}.

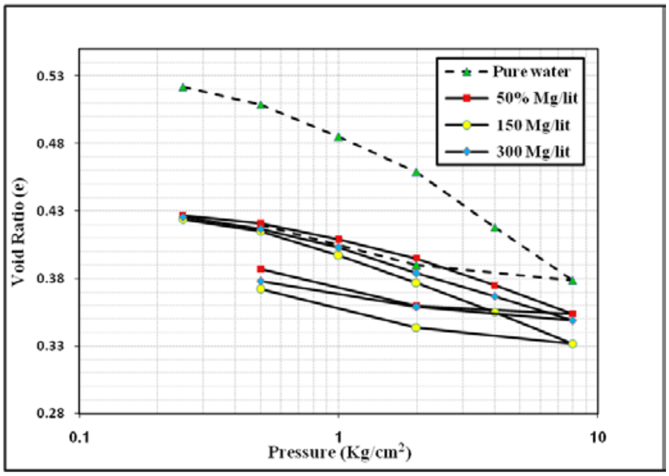

Fig. 2.Changes in the ratio of porosity-pressure for samples made with Ca^{2+}.

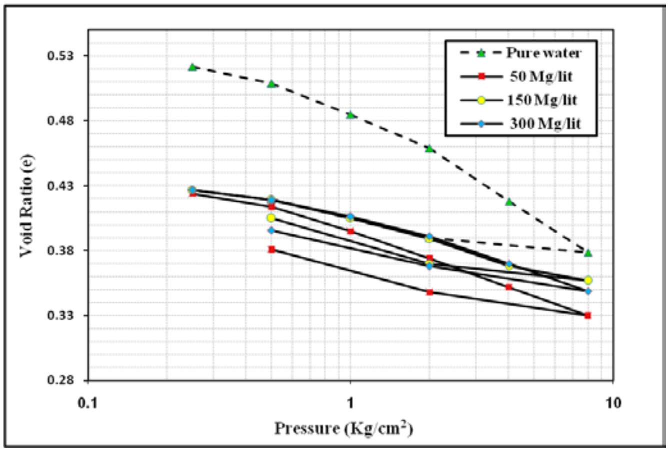

Fig. 3.Changes in the ratio of porosity-pressure for samples made with K^{+}.

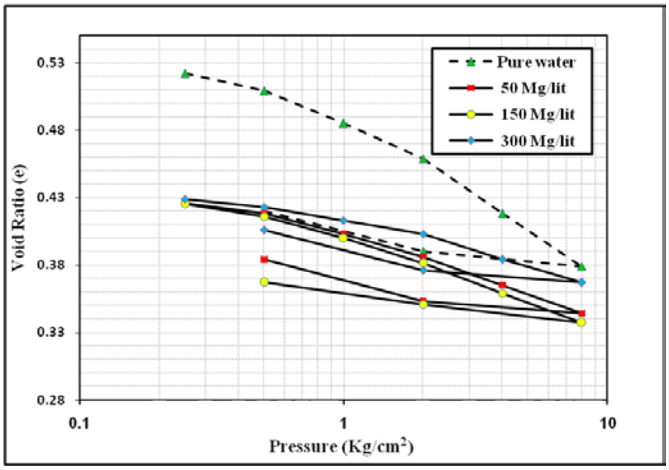

Fig. 4.Changes in the ratio of porosity-pressure for samples made with Mg^{2+}.

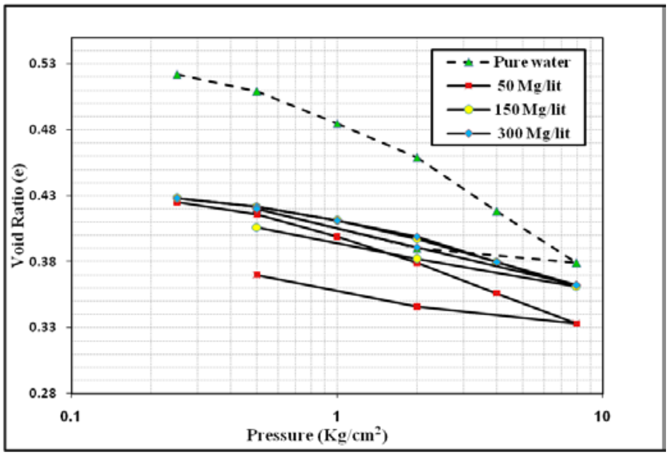

Fig. 5.Changes in the ratio of porosity-pressure for samples made with Na^{+}.

Trend of changes in the ratio of porosity against pressure with changes in cation and its concentration increase from 50 to 300 Mg/lit indicates reduction in C_c values and initial consolidation settlement of kaolinite saturated with cations of K^+, Ca^{+2}, Mg^{+2}, Na^+ and Al^{+3} than kaolinite saturated with distilled water. In addition, changes in the ratio of porosity (Δe) under tensions input respectively reduced upon increase in cations of K^+, Ca^{+2}, Mg^{+2}, Na^+ and Al^{+3} at concentrations of 150 and 300 Mg/lit and consolidation curve slope reduces after pre-consolidation ; where the lowest values are C_c and the initial consolidation settlement relates to Mg^{+2} cation.

5.1. Effect of concentration parameter

Trend of changes in initial consolidation settlement against concentrations of K^+, Ca^{+2}, Mg^{+2}, Na^+ and Al^{+3}cations are shown in Figure 4. In each of the samples made with different cations, values of initial consolidation settlement decreased along with increase in concentration for all dissolved and absorbed cations in saturated water. It is to be noted that upon increase in concentration of dissolved and absorbed cations in saturated water of samples, number of cations increase along with increase of osmotic pressure potential increased in surrounding space of clay cations and resulted in increasing water uptake, increasing distance of clay minerals layers and decreasing ratio of initial consolidation [11, 13].

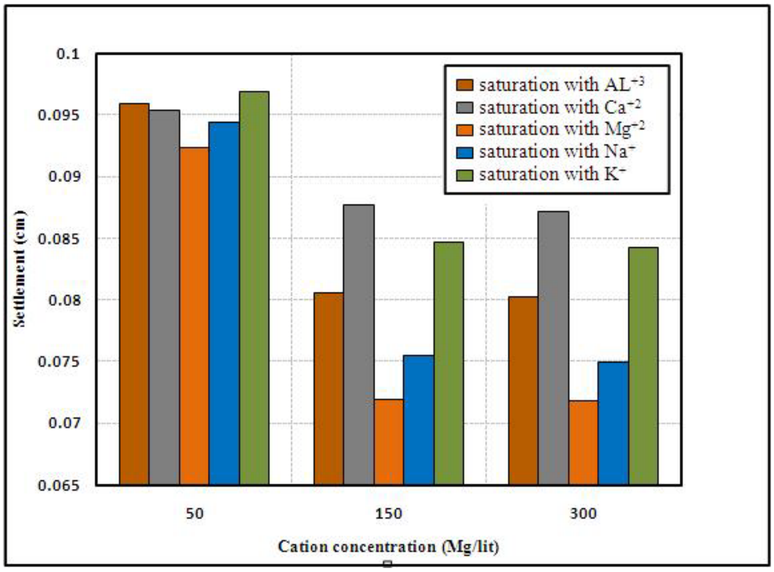

Fig. 6.Changes in initial consolidation settlement- cation concentration

Percentage of reduction in settlement of laboratory samples made with ion concentration of 50 Mg/lit for Al^{+3}, Mg^{+2}, Ca^{+2}, Na^+ and K^+ cations respectively is 6.89, 10.38, 7.37, 8.34 and 5.92. Percentage of reduction in settlement of laboratory samples made with ion concentration of 150 Mg/lit for Al^{+3}, Mg^{+2}, Ca^{+2}, Na^+ and K^+ cations respectively is 21.74, 30.19, 14.85, 26.70 and 17.76. Percentage of reduction in settlement of laboratory samples made with ion concentration of 300 Mg/lit for Al^{+3}, Mg^{+2}, Ca^{+2}, Na^+ and K^+ cations respectively is 22.04, 30.29, 15.33, 27.18 and 18.25.

5.2. Effect of hydrated size parameter

In same conditions, laboratory studies in terms of type of minerals, capacity and concentration of dissolved and absorbed cations, samples with smaller hydrated cations created more initial consolidation settlement. For example, the approximate hydrated size of Na^+ cation and the approximate hydrated size of K^+ cation respectively are 0.36nm and 0.33nm [11]. In same laboratory conditions, K^+ cation created more initial consolidation settlement.

6. Conclusions

In this research, the changes in the initial consolidation settlement process on kaolinite by oedometer test, with the addition of solved cations with concentrations of 50, 150 and 300 Mg/lit in saturated water were studied. The findings showed that:

1. The maximum value of consolidation settlement on kaolinite related to the initial consolidation settlement with deionized distilled saturated water.Upon increase in concentrations of dissolved and absorbed cations in any of the samples, C_c indicating the significant effect of dissolved and absorbed cations in reduction of the consolidation settlement values for kaolinite.
2. In same conditions, laboratory studies in terms of type of minerals, capacity and concentration of dissolved and absorbed cations, value of initial consolidation settlement decreases upon increase in hydrated size of dissolved and absorbed cations.
3. Toward this research, highest decrease in value of the initial consolidation settlement related to the sample made with Mg^{2+}cations with the ionic concentration of 300 Mg/lit which in these samples, value of the reduction in initial consolidation settlement is determined as 30.29%.

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