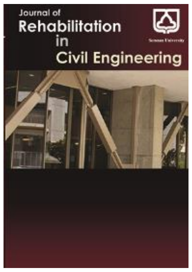
Journal of Rehabilitation in Civil Engineering 4-1 (2016) 55-62



Journal homepage: http://civiljournal.semnan.ac.ir/

Laboratory Study on the Effect of Water Cations' Concentrations on the Bojnord Clay Consolidation Process

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ARTICLE INFO

Article history:
Received: 17 May 2016
Accepted: 15 November 2016

Keywords:
Initial consolidation settlement,
Clay,
Oedometer test,
Bojnord.

ABSTRACT

The initial consolidation settlement process of saturated cohesive soils has been one of the most important issues to geotechnical engineers especially in important and sensitive structures based which are located on saturated clay layer with high thickness. In dealing with initial consolidation settlement process and reducing its negative and destructive consequences, a number of solutions have been presented including but not limited to the implementation of horizontal and vertical sand drainages, pre-loading and dynamic compaction; limitations of these methods include the necessity of implementing them before construction of the project. Furthermore, if the underground water level goes lower than regarded values, no appropriate approach else than the overhead reduction approach has been provided. In present research, with addition of concentrations of 250, 750 and 1250 Mg/lit in saturated water, laboratory study of the changes in initial consolidation settlement process, were investigated by standard Oedometer test device upon the addition of different concentrations of the cations, dissolved in saturated water on cylindrical samples of Bojnord clay with 2^{cm} in height and 7.5^{cm} in diameter. Achieved results represent significant changes in quantities of initial consolidation settlement process upon adding a variety of dissolved cations in saturated water; The results show that application of cations including aluminum (Al^{+3}), calcium (Ca^{+2}), magnesium (Mg^{+2}), sodium (Na^{+}) and potassium (K^{+}) with different concentrations changes the values of initial consolidation settlement values in appropriate with type and concentration of cations that the highest reduction of the initial consolidation settlement of Bojnord clay valued at 24.61% for the sample made with Al^{+3} cation with ionic concentration of 1250 Mg/lit.

1. Introduction

Soil as the most important building materials and the main structural support has been interested by human being in constructions [1-3]. Regarding that initial consolidation settlement occurs upon exiting water from soil and after a long time; 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, representing a range of methods including implementation of vertical and horizontal sand drains [4], preloading [5], dynamic compaction [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 [7-12].

Continuing researches made by Lambe and Whitman (1979) [10], Shen and Miura (1999) [11], In this research, 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

In 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 Bojnord clay with the height of 2 cm and the diameter of 7.5 cm in the standard Oedometer test device. It should be noted that this paper studies the impact of different parameters including concentration, capacity and hydrated size of cations including aluminum (Al^{+3}), calcium (Ca^{+2}), magnesium (Mg^{+2}), sodium (Na^{+}) and potassium (K^{+}) 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, Bojnord clay was applied. Details of Bojnord clay used in laboratory studies are shown in table 1.

Table 1. Details of Bojnord clay used in laboratory studies.

Soil type	**Moisture (%)**	**Dry density (kN/m^3)**	**Specific density**
Bojnord clay	21.9	16.8	2.68

4. Laboratory Studies

4.1. Construction of laboratory samples

In order to perform laboratory studies of the present research, 16 samples of Bojnord clay in size of bounding ring, 2 cm in height and 7.5 cm in diameter and 21.9% in moisture, were provided and tested with regard to the necessity of operating in saturated water.

Cylindrical samples applied for laboratory studies were made in two states and underwent loading and initial consolidation settlement test in standard Oedometer test device. The first state applied Bojnord clay and ion-less saturated pure water and the second state applied Bojnord clay and saturated water containing cations of Al^{+3}, Ca^{+2}, Mg^{+2}, Na^{+} and K^{+} with concentrations of 250, 750 and 1250 Mg/lit.

4.2. Performance of laboratory tests

In order to perform laboratory tests 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 test 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/cm^2 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/cm^2, unloading processes performed up to vertical pressure of 2 kg/cm^2, and finally up to vertical pressure of 0.5 kg/cm^2 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 test 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 Bojnord clay after making laboratory samples and conducting initial consolidation settlement tests, changes of the void ratio against pressure for each of the samples made with ion-less pure water and also pure water containing Al^{+3}, Ca^{+2}, Mg^{+2}, Na^{+} and K^{+} cations, with concentrations 250, 750 and 1250 Mg/lit, are respectively shown in figures 1 to 3.

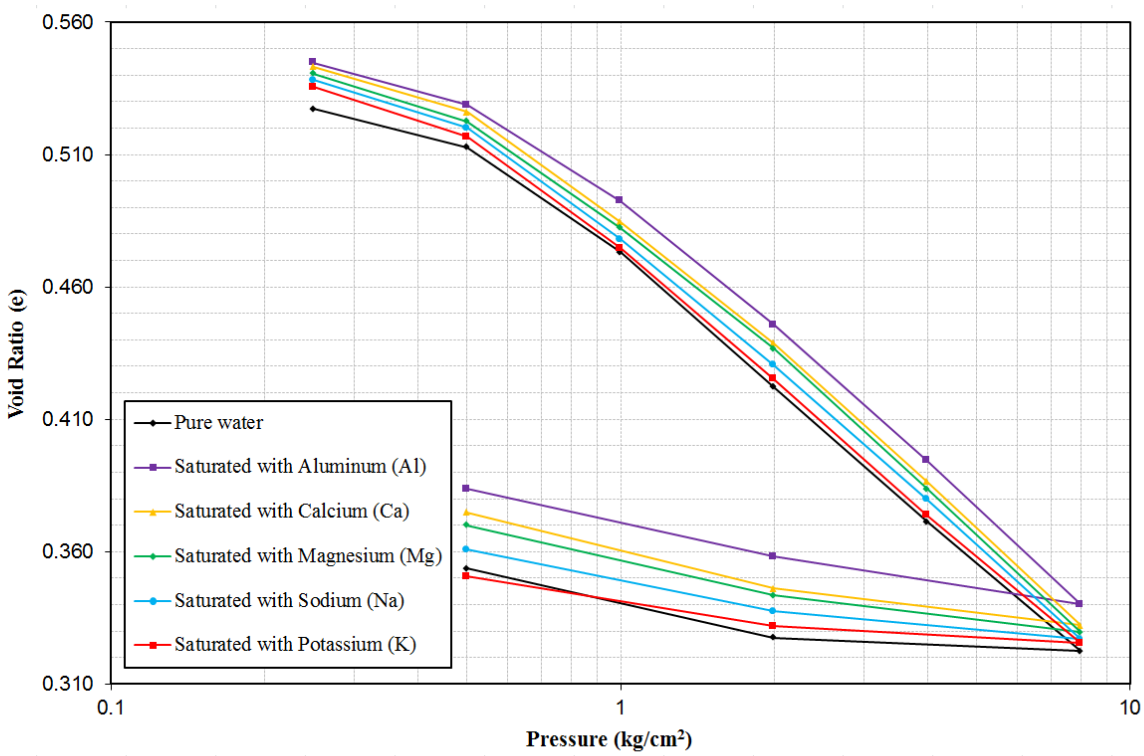

Fig. 1. Changes in the void ratio-pressure for samples made of cations with concentration of 250 Mg/lit.

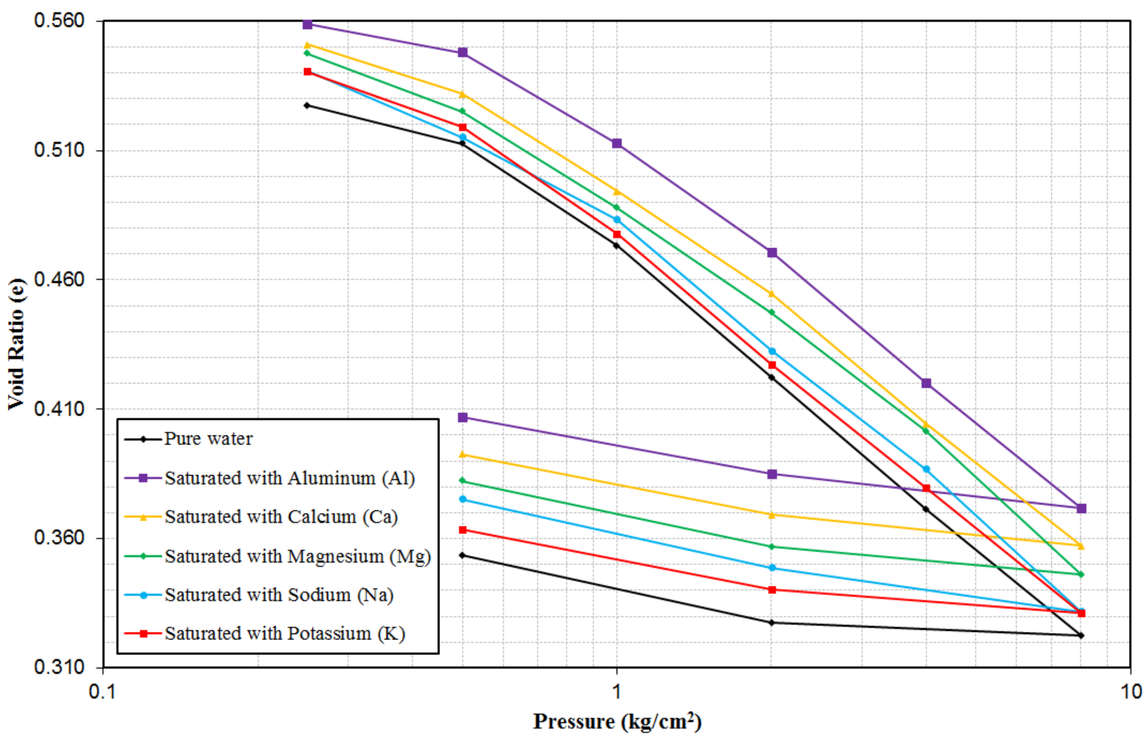

Fig. 2. Changes in the void ratio-pressure for samples made of cations with concentration of 750 Mg/lit.

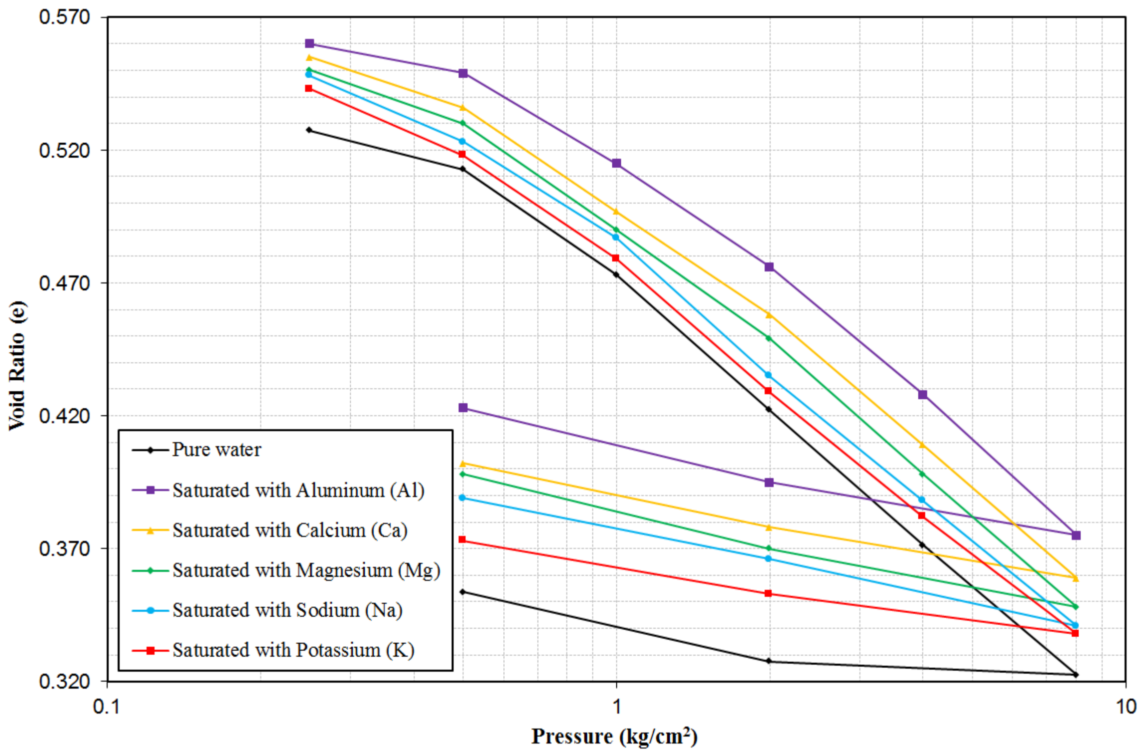

Fig. 3. Changes in the void ratio-pressure for samples made of cations with concentration of 1250 Mg/lit.

Trend of changes in the void ratio against pressure with changes in cation and its concentration increase from 250 to 1250 Mg/lit indicates reduction in C_c values and initial consolidation settlement of Bojnord clay saturated with cations of Al^{+3}, Ca^{+2}, Mg^{+2}, Na^{+} and K^{+} than Bojnord clay saturated with pure water. In addition, changes in the void ratio (Δe) under tensions input respectively reduced upon increase in cations of K^{+}, Na^{+}, Mg^{+2}, Ca^{+2} and Al^{+3} at concentrations of 750 and 1250 Mg/lit and consolidation curve slope reduces after pre-consolidation tension; where the lowest values are C_c and the initial consolidation settlement relates to Al^{+3} cation.

5.1. Effect of concentration parameter

Trend of changes in initial consolidation settlement against concentrations of Al^{+3}, Ca^{+2}, Mg^{+2}, K^{+} and Na^{+} 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 layers and decreasing ratio of initial settlement consolidation [11-13].

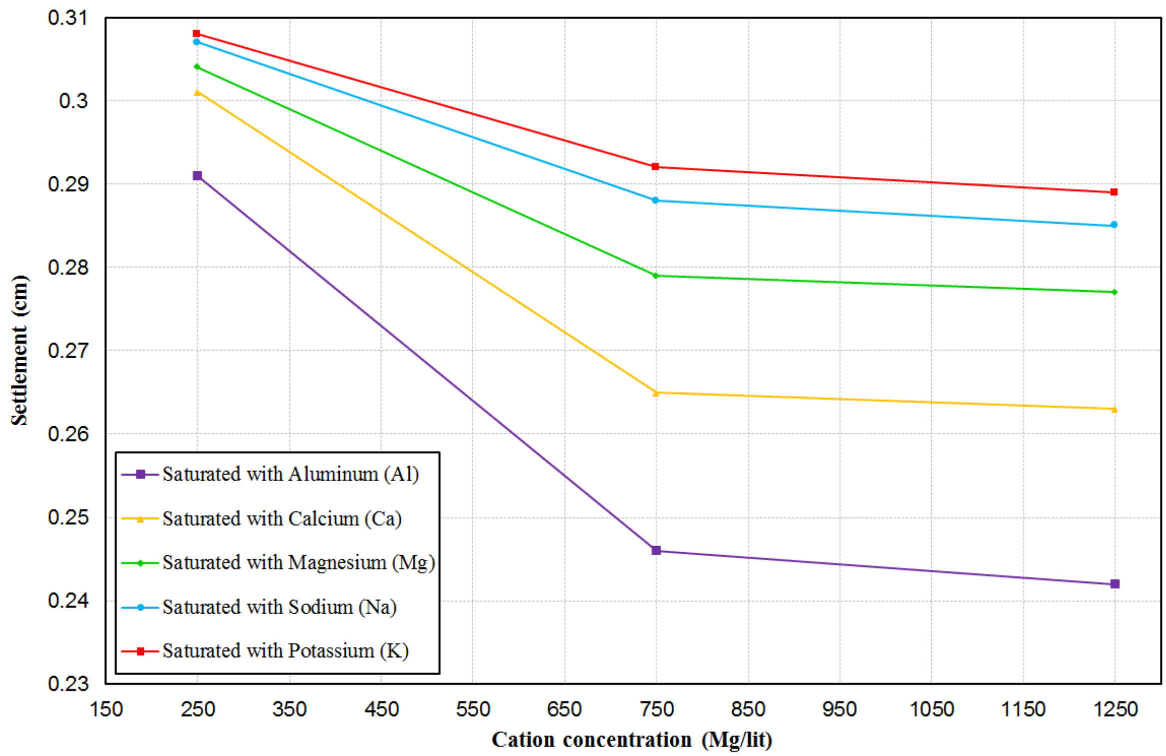

Fig. 4. Changes initial consolidation settlement-cation concentration.

5.2. Effect of capacity parameter

Effect of capacity parameter of dissolved and absorbed cations in saturated water on the initial consolidation settlement of samples is affected by concentration of cations. Laboratory samples made with ionic concentration of 250 Mg/lit amongst dissolved and absorbed cations including Al^{+3}, Ca^{+2}, Mg^{+2}, Na^{+} and K^{+}, the lowest rate of initial consolidation settlement respectively related to tests with Al^{+3}, Mg^{+2}, Ca^{+2}, Na^{+} and K^{+} cations. In this state, due to unsaturation of bivalent environment in terms of osmotic pressure, cations with higher capacity create less initial consolidation settlement. Initial consolidation settlement reduction percent in laboratory samples made with ionic concentration of 250 Mg/lit for Al^{+3}, Ca^{+2}, Mg^{+2}, Na^{+} and K^{+} cations, respectively were 9.34, 6.23, 5.29, 4.36 and 4.04.

In laboratory samples with ion concentration of 750 Mg/lit, the lowest initial consolidation settlement rates respectively relate to experiments with Al^{+3}, Ca^{+2}, Mg^{+2}, Na^{+} and K^{+} cations. In this state, due to unsaturation of dual environment in terms of osmotic pressure, cations with larger capacity have fewer initial consolidation settlements. Percentage of reduction in settlement of laboratory samples made with ion concentration of 750 Mg/lit for Al^{+3}, Ca^{+2}, Mg^{+2}, Na^{+} and K^{+} cations respectively is 23.36, 17.44, 13.08, 10.28 and 9.03.

In laboratory samples with 1250 Mg/lit, the lowest initial consolidation settlement rates respectively relate to experiments with Al^{+3}, Ca^{+2}, Mg^{+2}, Na^{+} and K^{+} cations. In this state, due to unsaturation of dual environment in terms of osmotic pressure, cations with larger capacity have fewer initial consolidation settlements. Percentage of reduction in settlement of laboratory samples made with ion concentration of 1250 Mg/lit for Al^{+3}, Ca^{+2}, Mg^{+2}, Na^{+} and K^{+} cations respectively is 24.61, 18.06, 13.70, 11.21 and 10.

5.3. Effect of hydrated Size parameter

In same conditions, laboratory studies in terms of type of 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 sodium 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. Results

1. The maximum value of initial consolidation settlement on Bojnord clay related to the initial consolidation settlement test with ion-less saturated pure water.
2. Upon increase in concentrations of dissolved and absorbed cations in any of the samples, C_c compaction coefficient decreases.
3. Upon increase in concentrations of dissolved and absorbed cations in any of the samples, the values of initial consolidation settlement reduces.
4. In ionic concentration of 250 Mg/lit, dissolved and absorbed cations of Al^{+3}, Ca^{+2}, Mg^{+2}, Na^{+} and K^{+} the lowest rates of initial consolidation settlement, respectively for tests with Al^{+3}, Ca^{+2}, Mg^{+2}, Na^{+} and K^{+} cations.
5. In ionic concentration of 750 Mg/lit for dissolved and absorbed cations, cations with higher capacity create lower initial consolidation settlement.
6. In ionic concentration of 1250 Mg/lit for dissolved and absorbed cations, the same results with studies for ionic concentration of 750 Mg/lit were gained and cations with higher capacity create lower initial consolidation settlement.
7. The greatest reduction in initial consolidation settlement of Bojnord clay with the value of 24.61% deals with samples made with Al^{+3} cation with ion concentration of 1250 Mg/lit.
8. In same conditions, laboratory studies in terms of type of capacity and concentration of dissolved and absorbed cations, value of initial consolidation settlement decreases upon increase in hydrated size of dissolved and absorbed cations.

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