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Behavior of Swelling Soils Saturated with Magnetized Water

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Abstract

This paper presents an experimental study on the behavior of swelling soils saturated with magnetized water. Parameters investigated were free swelling and swelling pressure of clayey soil saturated in magnetized water with four magnetic intensities (500, 1000, 1500, and 2000). Three specimens (extracted from three different locations in Iraq) were tested in different magnetic intensities and compared with a soil specimen saturated with ordinary water. Magnetized water was produced by passing water through a P.V.C. pipe bounded with a magnetic field. It was found that the value of swelling pressure and free swelling (of the soils saturated with magnetized water) increase with the increase of magnetic intensities. In specific, the value of free swelling and swelling pressure ranging between 26.38% - 59.0 % and 32.16% - 161.16%, respectively.

Keywords: *clayey soils, expansive soils, free swelling, heave, magnetized water, swelling pressure.*

1. Introduction

The issue of swelling has been the focus of researchers due to the problems associated with swelling such as; cracks in wall, roads, airports and railways (Bell & Maud 1998, Khattab & Al-Taie 2006). Swelling of a soil is defined as the changes in the volume of the soil due to increasing or decreasing the percentage of the water content in the soil. This phenomenon is important in aired and semi-aired areas that experience extreme variation in humidity between seasons. In the last few decades, many studies have been published on the characteristics, behavior, stabilization and effects on structures of expansive soil. A review on the behavior of swelling (expansive) soils and its effects on structures can be found in Verma and Maru (2013). Turkoz et al. (2014) evaluated the effect of magnesium chloride ($MgCl_2$) solution on the engineering properties of clay soils. The results showed that the dispersive and expansive of clay soils can be effectively improved using $MgCl_2$ solution as additive. Similarly, Reddy et al. (2015) investigated the influence of three types of additives on stabilization of expansive soils. These additives were used: (a) Cementitious: lime and fly ash (b) Non-cementitious, stone dust, and (c) Chemical additives; $CaCl_2$ and $Na2SiO_3$. It was found that $CaCl_2$ and Na_2SiO_3 exhibited a superior performance over cementitious and non-cementitious additives in reducing the swelling characteristics. Lu, X. (2015) investigated the improvement of expansive soil by adding ionic soil stabilizer (ISS). The results show that after mixing the ISS into expansive soil, free swelling ratio of expansive soil decreases. Ahmed et.al. (2016) studied the effects of glass wool, silica fume, and cement additives on the compressibility and swelling characteristics of soil. The results indicated that these additives caused a significant reduction in swelling of soil. Embaby et.al (2017) introduced an experimental study to mitigate swelling pressure of expansive Tabuk shale in Saudi Arabia. They adopted the removal and replacement technique by using two types of cushion coarse-grained sediments. All the above studies has focused on the influence of additives in reducing the swelling in soil.

Physical properties of water can also affect the swelling rate of soil. The only available study on the physical properties of water is that of Jacinto et.al (2012). Magnetized water is a widely used technique in agricultural research, however, it is limited in civil engineering applications. Magnetized water can also influence the swelling of soils. This study investigates for the first time the effect of magnetized water on swelling soil in terms of free swelling and swelling pressure.

Phenomenon of Swelling: Swelling is a phenomena related to colloidal systems that exhibit an expansion and contraction in soils due to electromagnetic attraction forces for the water layers that bounded the soil particles. The swelling behavior of soil can be attributed to the effect of two overlapped factors. The first factor is the hydration of dried colloidal particles (clay mineral) that called surface hydration which means the absorption of water particles as monolayer on the inner and outer surfaces of soil particles. In this way water absorption leads to diverge the layers of mineral particles away from each other layers. This causes an increasing in the volume of soil by approximately 100 % of the original volume of soil. Examples of these soils are clayey soil formed from montmorillonite that absorbed four layers of water. The second factor of swelling may belong to the repulsion between the double layers of ions of colloidal particles of clay minerals. Such repulsion leads to diverge particles from each other and causes an increase in the volume of soil (swelling). In this phase the swelling pressure called “osmotic pressure”, (Chen, 1988, Nelson & Miller 1992, and Marus, 2013).

2. Materials And Methods

Soil Samples: Three types of expansive soil samples were collected from three cities in Iraq (Baghdad, Mousel and Al-Anbar). All samples were taken from a depth approximately 1 m below natural ground surface. All these specimens were subjected to magnetized water and compared with a reference soil specimen (a soil specimen that subjected to normal water).

Magnetized Water: The magnetized water was produced using a device that fabricated at Al-Nahrain University. This device comprised a water pump, connection pipes of (16) mm diameter, collection tank with capacity of 10 liters and magnet of known magnetic intensity. The water pumped through a magnetic field to the collection tank and from tank to magnetic in a flow cycle. The flow continued for four hours as stated by the manufacturer to reach a completed magnetized water. Fig.1 supported by Plate.1 shows a schematic diagram for this device including the magnets adopted in tests. Magnetic field intensities can be changed by replacing the magnet with another one of different intensity. In this study four types of magnetic intensities were adopted (500, 1000, 1500 and 2000) Gauss (Al-Faoury, 2014).

Tests: The soil specimens (passing through sieve No.4) was dried at 45 C° for (16) hours. The O.M.C. (optimum moisture content) associated to the maximum dry unit weight for all specimens was computed according to ASTM (D 3877). Soil specimen were compacted in the odometer cell at its maximum dry unit weight and O.M.C, and the process of tests for calculating the rate of free swelling and swelling pressure were conducted using natural water and magnetized water. Swelling rate and swelling pressure tests were performed on remolded disturbed soil specimens prepared according to ASTM (D 2216-05). According to ASTM (D 4829-11) the method of free swelling was used to measure swelling rate. Constant volume method was adopted to calculate swelling pressure according to ASTM D4318-93 & ASTM D4829-11.

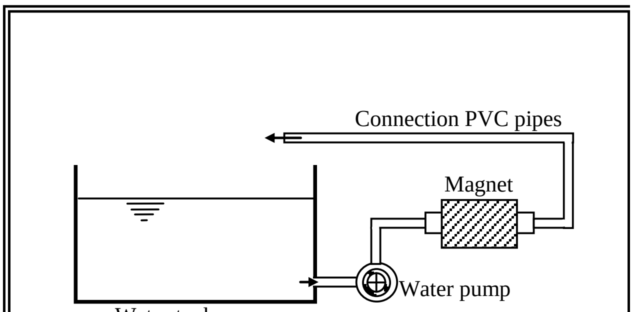

Plate. 1: Image for the magnets used for magnetization of water (500, 1000, 1500 and 2000) Gauss.

3. Results and Discussions

Fig. 2 shows the relationship between moisture content and dry unit weight for the three soil samples. Optimum moisture content with maximum dry unit weight for (Mousel, Al-Anbar, and Baghdad) were found to be (14%, 20%, and 26%) respectively. Atterberg Limits are shown in Table 1. Baghdad and Mosul soil samples can be classified as high plastic soil, while Al-Anbar sample classified as medium plastic soil.

As stated early, free swelling and swelling pressure were computed for the thee soil samples in two cases, the first with natural water and the second with magnetized water in different magnetic intensities. Tests implemented with natural water were adopted as a reference value to investigate changes in swelling behavior when saturated with magnetized water instead of natural water.

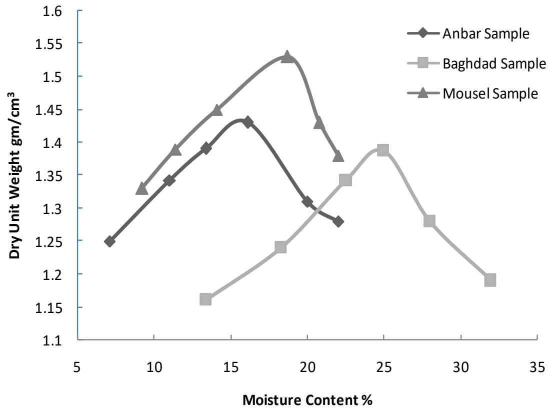

Fig. 2: Relationship between dry unit weight and moisture content.

Table 1: Atterberg's Limits and soil properties.

Soil sample	Al-Anbar	Baghdad	Mosul
Optimum water content	20	26	14
Max. Dry Density gm/cm^3	1.44	1.39	1.53
Liquid limit %(LL)	36.58	48.49	44.84
Plastic limit %(PL)	21.119	17.27	25.5
Plasticity index %(PI)	15.461	31.22	19.34
Specific gravity (Gs)	2.73	2.71	2.76
Gravel %	0.0	0.0	0.0
Sand %	8.0	0.0	10
Silt %	24.0	17.0	21
Clay %	68.0	83.0	69.0

For Baghdad soil sample, the variation of free swelling with water content for different magnetic intensities was shown in Fig.3. Free swelling rate was found to be (13%) when the sample immersed in natural water, while for samples immersed with magnetized water of (500, 1000, 1500, and 2000) gauss were increased up to (16.43%, 17.1%, 18.2%, and 20.67%) respectively. Swelling pressure for the same samples was equal to (37) kPa for natural water, whereas this value increased to reach (48.9, 68.99, 80.0 and 96.8) kPa for samples immersed with magnetized water respectively as shown in Fig. 4.

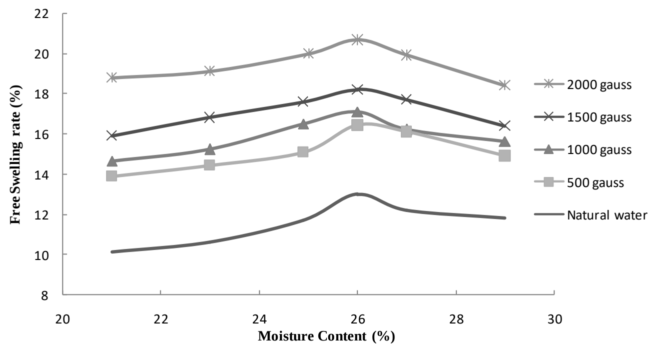

Fig. 3: Free swelling rate vs. moisture content for different magnetic intensities for Baghdad soil sample.

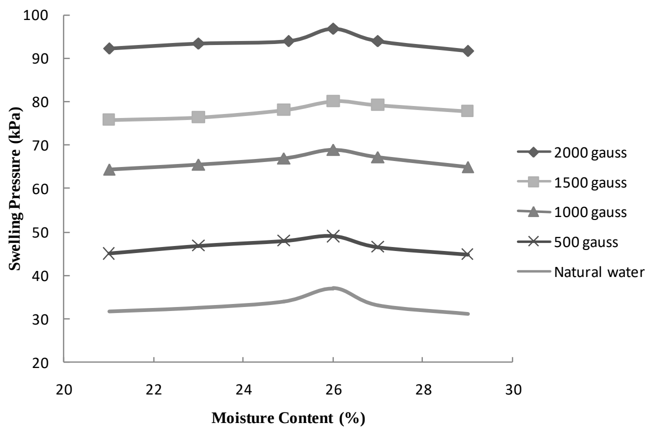

Fig. 4: Swelling pressure vs. moisture content for different magnetic intensities for Baghdad soil sample.

Fig. 5. and Fig. 6. Shows the results for free swelling rate and swelling pressure for Mousel soil samples under the same circumstances that done for Baghdad samples. Mousel soil sample shows a swelling rate less than Baghdad soil sample, where the value of free swelling rate for that immersed with natural water was (7.5%), while for those immersed with magnetized water were (8.8%, 9.95%, 10.42% and 12.64%) respectively with the increasing of the magnetization intensities. Also swelling pressure was equal to (15.6) kPa for the ordinary case and increased to (17.98, 19.5, 21.5, and 23.5) kPa, when, samples soaked with magnetized water intensities of (500,1000,1500, and 2000) gauss respectively.

In the same trend, Al-Anbar soil samples had an increasing in free swelling rate and swelling pressure for samples immersed by magnetized water more than that samples saturated with natural water, as shown in Fig. 7 and Fig. 8. It can be noticed that free swelling rate for the sample immersed with natural water was (6.5%), while

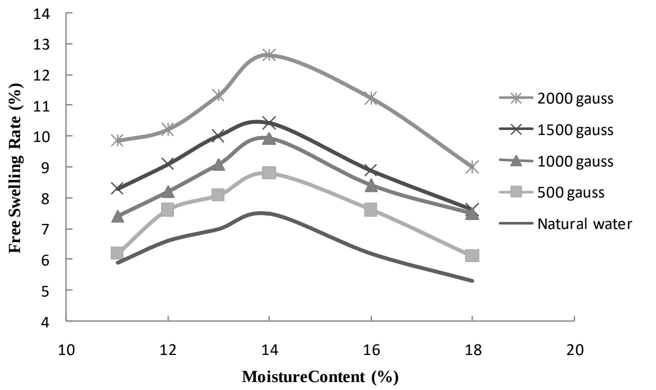

Fig. 5: Free swelling rate vs. moisture content with different magnetic intensities for Mousel soil sample.

for those immersed with magnetized water were (8.8%, 8.9%, 10.42, and 11.6%). Also swelling pressure was equal to (14.7) kPa

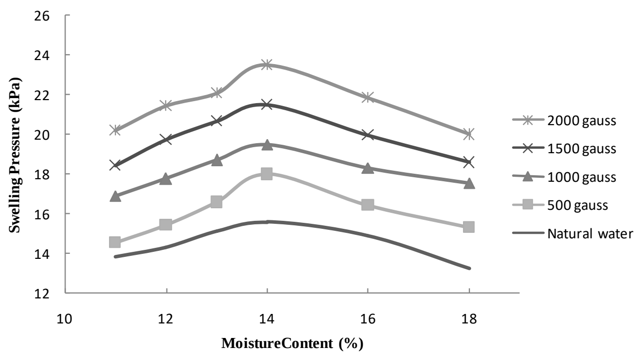

Fig. 6: Swelling pressure vs. moisture content with different magnetic intensities for Mousel soil sample.

with natural water immersing and (16.44, 18.54, 21.5, and 22.0) kPa for samples treated by magnetized water.

The relationship between free swelling rate and magnetization intensity for each sample was shown in Fig.9, whereas the relationship between swelling pressure and magnetization intensity was shown in Fig. 10.

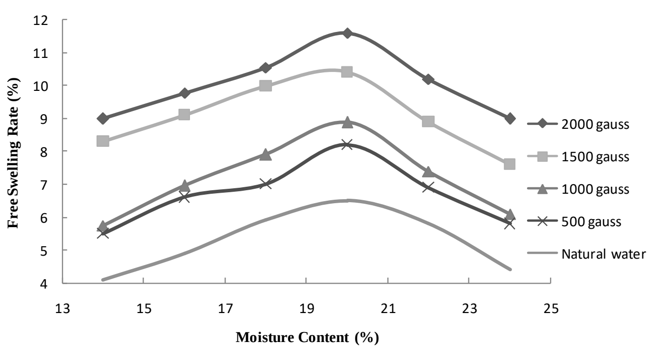

Fig. 7: Free swelling rate vs. moisture content for different magnetic intensities for Al-Anbar soil sample.

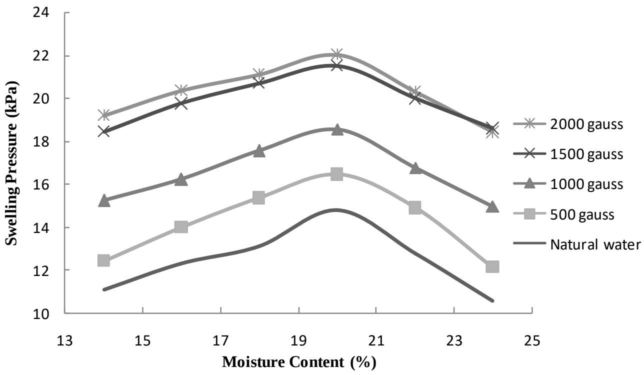

Fig. 8: Swelling pressure vs. moisture content for different magnetic intensities for Al-Anbar soil sample.

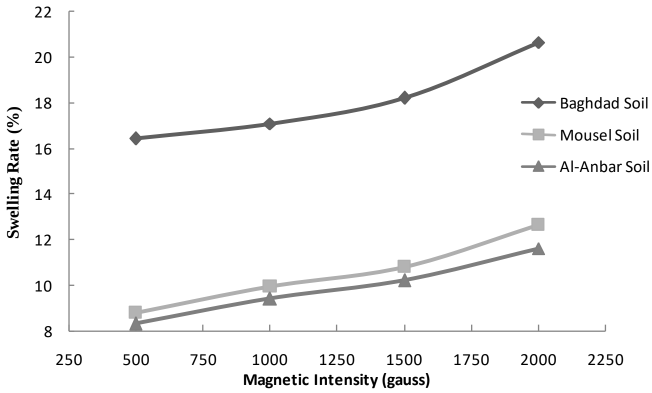

Fig. 9): Swelling rate vs. magnetization intensities of water for different soil samples.

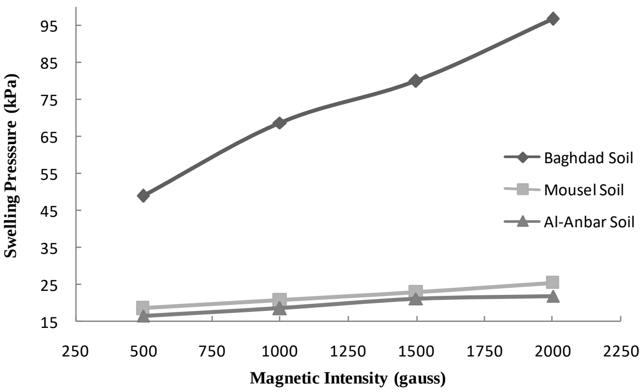

Fig. 10: Swelling pressure vs. magnetization intensities of water for different soil samples.

It can be observed an increasing in swelling rate and swelling pressure with increasing of magnetization intensity for all types of soil sample. Maximum effect was obvious with Baghdad soil sample in other words the sample that had the maximum value of plasticity index. Increasing of swelling pressure and swelling rate can be attributed to the fact that the main component of phenomena of swelling was the repulsion forces between particles due to the electromagnetic field created by surface hydration. So, magnetized water contributes in boosting these forces and increases the repulsion forces between soil particles that cause an increasing in volume of soil and as a result increasing in swelling rate. Same reason stated before explains the increasing in swelling pressure with the increasing of magnetization of water.

There was a major effect observed in the using of magnetized water, whereas for Baghdad soil sample, the percent of increasing in free swelling ranged (26.38% - 59.0 %) and for swelling pressure the increasing ranged (32.16% - 161.16%) with the increasing in magnetic intensities from (500) gauss to (2000) gauss respectively. This increasing was very dangerous on structures constructed on such soils, if taken in consideration the value of swelling computed on natural water only.

From inspection of all figures, it can be noticed that the behavior of soil has the same trend when saturated by magnetized water instead of natural water except the increasing in values of swelling pressure and free swelling. So, an expectation for this effect cannot be distinguished, unless there was a knowledge that the soil may exposed to magnetized water. It is very important to take into consideration the effect of magnetized water on swelling soils especially in the electrical power station, which has a magnetic field that may magnetized the water before seeps to soil.

4. Conclusion

The influence of magnetized water on the swelling soil was examined. Parameters investigated were: (a) free swelling rate (b) swelling pressure (c) magnetic intensities.

A local made device was used to produce magnetized water. Three samples of swelling soil was collected from different cities (Baghdad, Al-Anbar and Mousel) in Iraq were examined. It is mainly concluded that, in general, magnetized water increased the swelling of soil. Maximum rate of free swelling and swelling pressure were observed at the optimum water content of soil specimen. The rate of increasing in pressure and free swelling are directly proportioned to the increasing in magnetization field intensity of water. Maximum rate of increasing in swelling pressure was noticed in Baghdad soil sample, it reaches up to 161.16%, when the sample soaked in magnetized water of a magnetization intensity of (2000) Gauss.

In civil engineering application the value of swelling can be calculated theoretically to consider that value in the construction of foundation. However, when soils subjected to magnetized water the values of swelling rate calculated in traditional methods were not availed and need to be modified.

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