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EFFECT OF SOAKING ON UNSATURATED GYPSEOUS SAND SOILS

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ABSTRACT

This paper shows the different in the volumetric strains between the Oedometer tests with different soaking durations and the unsaturated triaxial tests. The disturbed samples were taken from Al-Najaf city in Iraq. All specimens have the same high gypsum content of 29 %. For Oedometer tests, the specimens are tested in the different soaking durations; the first is in natural moisture content then half hour, one week and two weeks. While in triaxial tests, a wetting induce has been conductive to estimate the volumetric strains under two stress levels (2.5 and 5 kg/cm^2) with presence of matric suction in four levels; initial matric suction (ψo), 0.6 ψo, 0.3 ψo and zero ψ. The results from unsaturated triaxial tests indicate that the volumetric strains are increased as matric suction decreased and the trend of stress-strain curve became steep. While from Oedometer tests, when the specimen is soaked in natural and for a half hour, the volumetric strains are not significantly changed and close to the high matric suction. When the soaking time is increased to a one week, there is relatively increase in volumetric strains. But after two weeks soaking in Oedometer cell, the volumetric strains are very clear in increasing and close to the volumetric strains from unsaturated tests in low matric suction.

Keywords: Oedometer, Unsaturated Triaxial, Matric Suction, Volumetric Strain

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1. INTRODUCTION

The study of gypsum soils from the eighties has attracted the attention of many scholars and scientists. In general, the recognition of problematic soils in terms of engineering geology and geotechnics is a great importance [1]. Gypsum ($CaSO_4.2H_2O$) behaves stable due to the two bonds of water [2]. Sudden collapse can be occurred in gypsiferous soils upon wetting [3]. Gypsum rich soils cover a wide area of the Middle East; they cover large areas of Iraq [4]. Cracks, and may leads to failure, in many structures have been observed in different locations in Iraq [5].

Soil soaking fallouts in volume change and reduction in shear strength and stiffness, the type and amount of this change depend on several factors, such as, soil structure, degree of soaking and stress state and leads to collapse [6]. Many previous researchers have investigated the effect of the gypsum content on the different soil properties. From different sites in Iraq, Al-Khuzaie (1985) [7], Nashaat (1990) [8], Al-Mufti (1997) [4], Salman (2011) [5] and Mahmood (2017) [9] investigate the effect of gypsum content on the shear strength of the soil for different soil samples, while Moula and Al-Saoudi (2010) [10], Razouki and Al-Azawi (2003) [11], Abbas and Muarik (2012) [12], Fattah et al. (2017) [13] Mahmood (2018) [14] and Mahmood et al. (2018) [15] have studied the deformation of the soil due to different processes. All these researchers have stated that with increasing of the gypsum content, there were a decreasing in the shear strength and increasing in the strains.

Al-Najaf city soil is mainly sand with different percentages of the gypsum [16, 17, 18]. Gypsum soils have long been the cause of problems in the city, such as, settlement and cracks in the buildings.

Gypsiferous soils have been studied within the conventional saturated soil mechanics and soil characteristics may be different in unsaturated conditions such are these soil located (Ahmed , 2013). Water infiltration leads to decrease in soil suction and may lead to destabilize the buried services [20]. Many researchers have developed triaxial testing for unsaturated soils, such as, Aversa and Nicotera (2002) [21], Cabarkapa and Cuccovillo (2006) [22], Padilla et al. (2006) [23] and Haeri et al. (2014) [24]. Double walled burettes were controlled and measured the suction, radial strains and the variation of water content in unsaturated tests [21]. High air entry (HAE) ceramic disks, as described by Fredlund and Rahardjo (1993) [25], was used to apply air pressure through.

AlMahmodi (2018) [26] investigated the effect of time-based soaking on the deformation of gypseous sand in Al-Najaf city under different normal stresses using Oedometer testing. The recent paper compared the resulted volumetric strains from the unsaturated triaxial testing on the same soil sample with those from Oedometer testing to verify the main difference in deformations values and behavior.

2. MATERIAL AND WORK METHODOLOGY

The disturbed samples are taken from a district in Al-Najaf city in the southwest of Iraq. The soil samples are mainly sand with more than 80 %. Figure 1 presents the results of a mechanical sieve analysis test. The results of the standard Proctor test are shown in Figure 2. Table 1 summarizes the soil properties of the tested specimens. According to Barazanji (1973) [27], the

soil is classified as high gypsum content. Depending on the Unified Soil Classification System (USCS), the soil is sand well graded (SW).

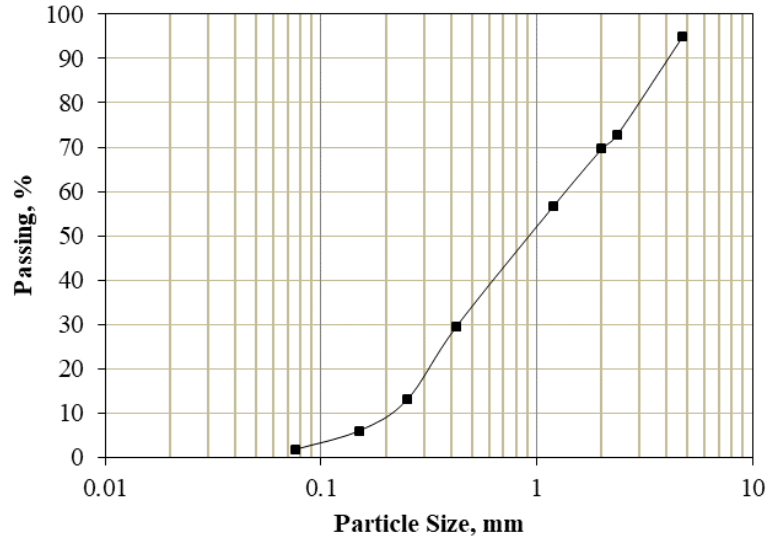

Figure 1 Sieve analysis.

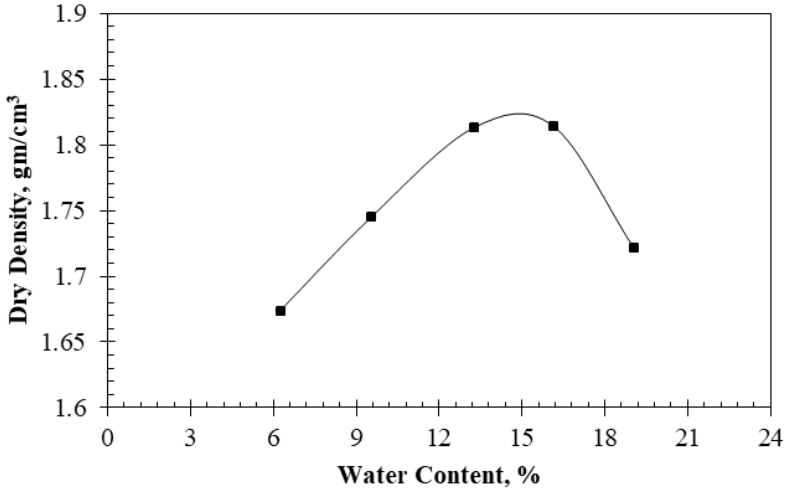

Figure 2 Standard Proctor test.

Table 1 Summarized soil properties.

Tests	Results
Sand, %	86
Soil Classification (USCS)	SW
Specific gravity	2.38
Gypsum Content, %	29
Natural Water Content, %	3
Max. Dry Density, gm/cm^3	1.825
Optimum Moisture Content, %	15

The present research is aimed to investigate the effect of the soaking process on the volumetric strain of the gypseous soil from unsaturated tests with different matric suction using

a modified triaxial test device that has a suction control system. Figure 3 illustrates the tested specimen in the modified triaxial device and it has inner cell (Figure 3(a)) and outer cell (Figure 3(b)). The initial matric suction (in site) was determined depending on the filter paper method according to ASTM D5298-03 and its value is 30 kPa. A High Air Entry (HAE) ceramic disc of 1 bar was selected based on initial matric suction.

(a) Inner cell (b) Outer cell

Figure 3 The modified triaxial device.

The adopted test method was wetting-increase under a specified load. Four matric suctions were performed (initial matric suction; ψo, 0.6 ψo, 0.3 ψo and zero matric suction) to simulate the wetting process in unsaturated soils. Two mean net stresses (Pn) were applied (100 and 200 kPa).

The results of the volumetric strains from unsaturated tests were compared with the results from time-based soaking Oedometer tests that achieved by Al-Mahmodi (2018) [1]. This comparison gives an understanding of the variety of the results from the two methods of testing (unsaturated triaxial test and conventional Oedometer test). The final volumetric strain in the unsaturated test is a summation of diagonal deformation and vertical displacement of the tested specimen. Table 2 summarizes the tests that were performed using unsaturated triaxial test and the compared reference results from Oedometer tests.

Table 2 Estimated volumetric strains.

Stress, kg/cm^2	**Unsaturated Test**				**Oedometer Test [1]**			
	ψo, %	0.6 ψo, %	0.3 ψo, %	Saturated, %	Dry, %	Half hr. Soaking, %	One Week Soaking, %	Two Weeks Soaking, %
1.11	-	-	-	-	-2.9	-3.7	-3.2	-
2.23	-	-	-	-	-4.5	-4.45	-5.15	-12.6
2.5	-1.99	-4.16	-6.45	-8.56	-	-	-	-
4.47	-	-	-	-	-7.15	-7.5	-9.2	-14.37
5	-2.77	-7.58	-12.83	-15.97	-	-	-	-
8.95	-	-	-	-	-10.8	-	-	-

- Not estimated

3. RESULTS AND DISCUSSION

In this research, the results of the unsaturated tests are compared with the conventional Oedometer tests to clarify the effect of the soaking process with and without HAE ceramic disc. The unsaturated triaxial tests were performed with four matric suction levels; initial matric suction (ψo), 0.6 ψo, 0.3 ψo and zero matric suction under two stresses; 2.5 and 5 kg/cm^2. Every test took 8 days (two days for each stage; applying ψo stage, applying 0.6 ψo stage, applying 0.3 ψo stage and applying zero matric suction stage). The two days duration was to ensure there is no volumetric strain in every stage. As shown in Figures 4-7, the volumetric strains of unsaturated tests are increased with increasing stress and decreasing of matric suction. When the specimen is being saturated, the trend of the stress-volumetric strain curve becomes steeper than the previous matric suction level. This behavior may be attributed that the unsaturated testing with presence of HAE represents the natural state (in site) because the tested specimen has air pressure and water pressure as in voids between soil particles.

The first Oedometer test has six stress levels; 0.28, 0.56, 1.11, 2.23, 4.47 and 8.95 kg/cm^2 as shown in Figure 4. In this test, the specimen was examined with the natural moisture content in the site (initial matric suction) [1]. The trend of stress-volumetric strain curve of the first test in Oedometer device (has initial matric suction) approximately is the same curve trend volumetric strain values of the unsaturated test of 0.6 ψo, this means the volumetric strains in the unsaturated test, in the same initial condition, is lower than the conventional test (Oedometer) (Figure 4). When the soaking duration was increased to a half hour in the Oedometer cell, as illustrated in Figure 5, the curve trend becomes steeper than the reference test (natural condition) but there is no significant difference in volumetric strains with respect to the reference test.

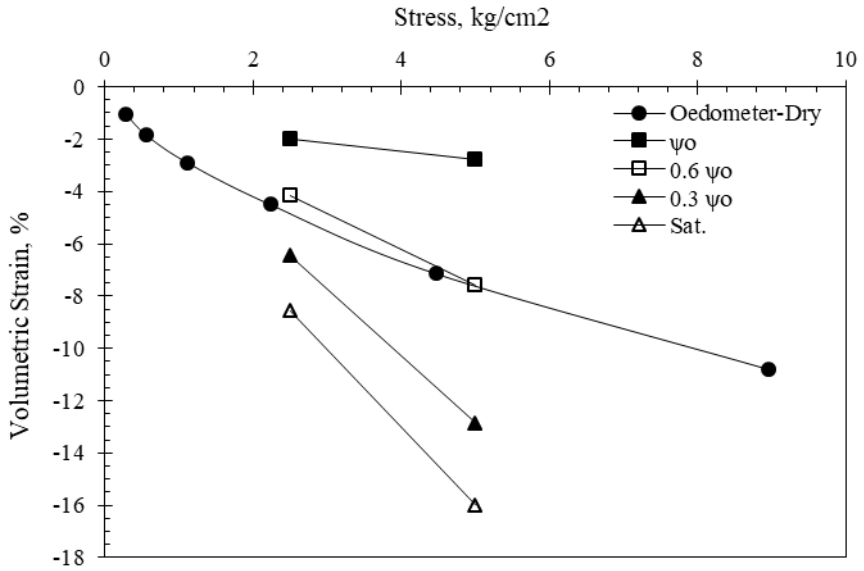

Figure 4 Result comparison of unsaturated triaxial test and dry Oedometer test.

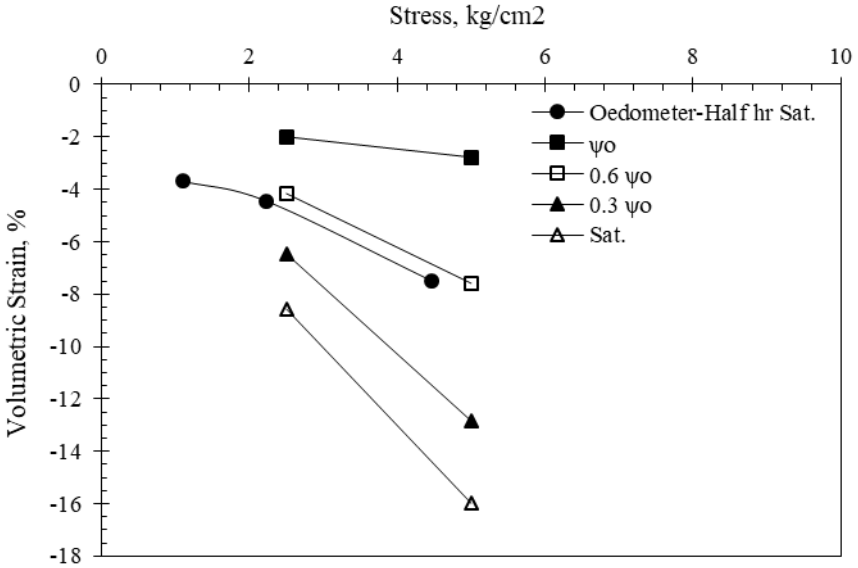

Figure 5 Result comparison of unsaturated triaxial test and half hour soaking Oedometer test.

For one week soaking, the volumetric strains were increased and are approached to the unsaturated test of 0.3 ψo (as in Figure 6), i.e., the unsaturated test achieved approximately same volumetric strains with less time (six days) than the conventional Oedometer test. The final test (two weeks soaking of Oedometer specimen), as shown in Figure 7, indicates that the stress-strain curve of the specimen has lower trend of the volumetric strain than the unsaturated test (the saturated state with zero matric suction). The difference between the unsaturated triaxial tests and the Oedometer tests may be due to of two reasons; the first one is in the triaxial device, the confining stress can be regulated but in the Oedometer device it is constant, and the second reason is the presence of matric suction control system using HAE ceramic disc in the triaxial device which represents real conditions as in site.

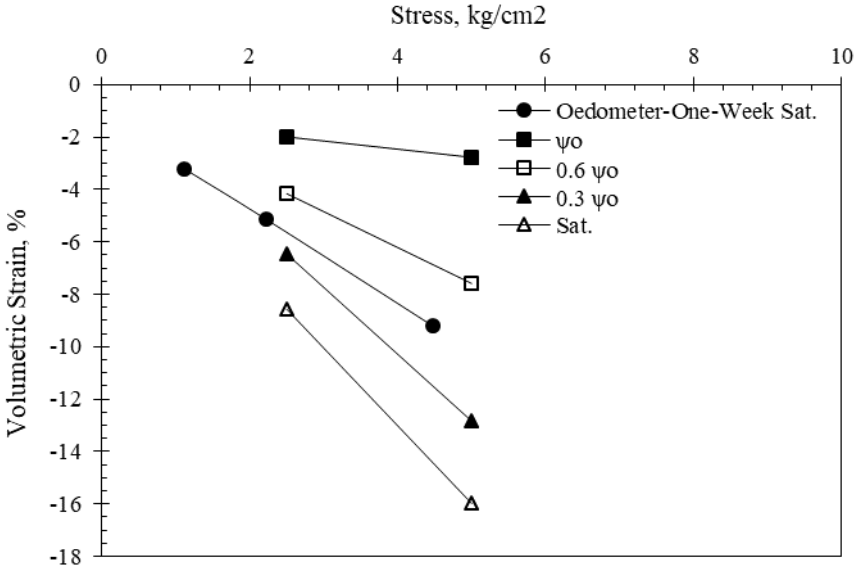

Figure 6 Result comparison of unsaturated triaxial test and one-week soaking Oedometer test.

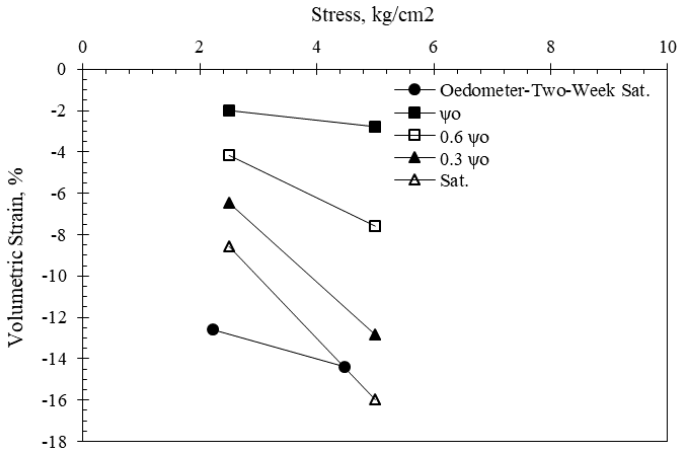

Figure 7 Result comparison of unsaturated triaxial test and two-week soaking Oedometer test.

4. SUMMARY AND CONCLUSIONS

There is a need to investigate the unsaturated gypsum sand soil properties in Iraq because the information is very lake in this region especially when the soil is in the natural state (dry conditions) and the soaking process has been occurred. In dry condition, the gypsum materials work as bonds between soil particles (cementing agent), but when the degree of saturation is increased, these bonds are broken and the shape deformations in the soil will be significant. So, a comparison between Oedometer tests (conventional method) that have been performed by Al-Mahmodi [1] and unsaturated triaxial tests.

The unsaturated tests were done by using a modified triaxial test device that has been developed in Ferdowsi University of Mashhad. This research compared the effect of matric suction on volumetric strains of these soils with conventional Oedometer tests. Four matric suctions were elected under two stress levels of 2.5 and 5 kg/cm^2.

Table 3 summarizes the volumetric strain changes (percent) depending on the Oedometer tests. In the unsaturated triaxial test with initial matric suction (test number 1), the volumetric strains under 2.5 and 5 kg/cm^2 are less than the dry-Oedometer of about 60 % on average. For the 0.3 ψo (six days to reach) is compared with one-week soaking Oedometer test and the volumetric strains have a significant increasing of about 25 % and 40 % under 2.5 and 5 kg/cm^2 stress levels, respectively (test number 2). When the specimen was saturated in the unsaturated triaxial test method, it is compared with the two-week soaking Oedometer test. Under the 2.5 kg/cm^2 stress level test, the volumetric strain is decreased of nearby 32.5 % while it is increased of 11 % under 5 kg/cm^2 as shown in test number 3, i.e., there is a steep trend in strains in the unsaturated test with increasing in the saturation. This situation may indicate a great caution in the estimation of the strains from the soaking process.

Table 3 Volumetric strain changes with respect to Oedometer tests.

Test No.	Test description	Stress level, kg/cm^2	volumetric strain change, %
1	Ψo with respect to dry-Oedometer test	2.5	-55.77
		5	-62.23
2	0.3 Ψo with respect to one-week soaking Oedometer test	2.5	25.25
		5	39.45
3	Sat. with respect to two-week soaking Oedometer test	2.5	-32.53
		5	11.13

From the Oedometer tests, it can be concluded that the soaking duration very affects the soil behavior because when the time is increased, the volumetric strains are increased especially in two-week test, but unsaturated triaxial tests give an indicator that the presence of matric suction control in the test has a major effect on the volumetric strain results. These results give to the designers the soil behavior to estimate the real settlement in such soils.

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