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Settlement assessment of gypseous sand after time-based soaking

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Abstract. This paper investigates the effect of the soaking process on gypseous sand soils. The recent research investigates the time-based soaking method on high gypsum contents (29%) of soil samples. The softening of gypsum materials upon wetting process leads to break the bonds of the soil particles and the settlement of structures will be occurred. The settlement value and rate are the basic problems for the geotechnical engineers. The samples of this investigation have been collected from the selected site in Al-Najaf city in Iraq, then these samples are remoulded to the density of 85% of the maximum dry density from Proctor test and moisture content of 4% in the cell of the computerized Oedometer device and under different stress levels (1.11, 2.23 and 4.47 kg/cm^2). The soil specimen is soaked under three stress levels (1.11, 2.23, and 4.47 kg/cm^2) separately. The results revealed that with increasing of soaking periods and stress level, there is increasing in collapse potential of such soils. The collapse potential was increased from <1% after half-hour soaking to about 8% after two-weeks of soaking.

1. Introduction

Estimation of the soil geotechnical properties is not easy to establish, as in the estimation of tolerable and differential settlement [1]. The settlement value and rate are the basic problems for geotechnical engineers [2]. Collapsible soil is considered as a problematic soil because it is sensitive to moisture and with increasing moisture content, volume reduction occurs. It is considered as a non-elastic deformation [3,4]. The collapsibility of the soil is re-arrangement of the grains of the unsaturation soil state due to the wetting process [4]. Several types of research have been made on the behavior of infiltration of unsaturated soils. Al-Saoudi and Al-Shakerchy, 2010, concluded from field testing that the rate of infiltration illustrated a decreasing trend versus cumulative time [5]. Similarly, Al-Saoudi et al., 2013 and Al-Saoudi et al., 2014 revealed the same condition of infiltration of water into the soil using, also, field testing [6,7]. Al-Shakerchy, 2009, depended on laboratory model, stated that the infiltration and rate of infiltration are changed with respect to time due to the wetting progress of the soil [8].

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 of great importance [3]. The gypsum distributes in Iraq according to Barzanji, 1973 [4]. Many previous researchers have investigated the effect of the gypsum content on the different soil properties. From different sites in Iraq, Al-Khuzaie, 1985 [9], Nashaat, 1990 [10], Al-Mufti, 1997 [4], Salman, 2011 [11] and Mahmood, 2017 [12] investigate the effect of gypsum content on the shear strength of the soil

for different soil samples, While Moula and Al-Saoudi, 2010 [13], Razouki and Al-Azawi, [14], Abbas and Muarik, [15], Fattah, et al, 2017 [16] and Mahmood, 2018 [17] 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 settlement.

Soil wetting fallouts in the change in volume, shear strength reduction and stiffness and type and amount of this change depending on several factors, such as soil structure, the degree of wetting and stress state [18]. The collapse percentage (CP) was defined by Jennings and Knight, 1975, as in Eq. 1, where ≤ 1% is in no problem [18].

$$CP= \Delta e/(1+e) \quad (1)$$

Many buildings have been damaged because of gypsum content within a case of rising of the water table, the softening of gypsum materials that are between the particles of the soil is occurring [19,20]. Al-Najaf city soil is mainly sand with different percentage of the gypsum after Al-Shakerchy, 2007 [21] and Al-Saoudi and Al-Shakerchy, 2010 [22]. Gypsum soils have long been the cause of problems in the city, such as settlement, cracks in the buildings and the destruction of landscapes. The recent paper investigates the settlement of the city sand soil due to short term process at different stress level and different soil relative density and gypsum contents using Oedometer cell. The purpose of this paper is to give a clear and accurate effect of the certain process and gypsum content on the estimation of the settlement value and rate in the Al-Najaf city. Two-weeks of soaking process increased the maximum dry density (MDD) from standard Proctor compaction test corresponding to the initial condition, such as water content. The soil is, according to the increase in MDD, experienced an additional settlement upon the soaking [23]. There were no collapse percentage (CP) in the low gypseous sand soils (<5 %) using Oedometer test after soaking durations according to Eq. 1, but there were increasing in the settlement due to soaking process [24].

The recent paper investigate the effect of soaking process within half-hour, one-week and two-weeks on the settlement value of the sand soils with 29% of gypsum in Al-Najaf city southern east of Iraq using Oedometer test. The settlement is assessed under different levels of normal stress.

2. Methods and materials

The soil samples are taken from one of the northern districts (Al-Jameah) in the province of Al-Najaf city in Iraq. The soil sample is named SW of the highly gypsum contents (29%). Table 1 summarizes the properties of the soil sample. The soil is mainly sand and the max. dry density is obtained from standard Proctor test.

Table 1. Soil Properties of the Tested Samples.

Soil Properties	Value
Sand, %	67.8
Soil Classification, USCS	SW
Natural Water Content, %	3
Gypsum Content, %	29
Max. Dry Density, gm/cm^3	1.825
Optimum Moisture Content (O.M.C.), %	15

56 Oedometer tests are made to estimate the settlement of the soil sample with respect to normal stresses and time. These tests are performed using a computerized multi-cell Oedometer, as in Fig. 1, under six stress levels (0.27, 0.55, 1.11, 2.23, 4.47 and 8.95 kg/cm^2). These tests included soaking process with different periods at three certain stress levels (1.11, 2.23, and 4.47 kg/cm^2). All specimens are investigated with initial density as a percent of the maximum dry density (85%). The tests are started with initial water content (unsaturated), then the soil is wetted to the saturated

condition at the certain stress level and be left for the different soaking periods of half-hour, one-week and two-weeks, then the stress level is re-applied to estimate the collapsibility potential. Figure 2 illustrates the tests program.

Figure 1. Multi-Cell Computerize Oedometer.

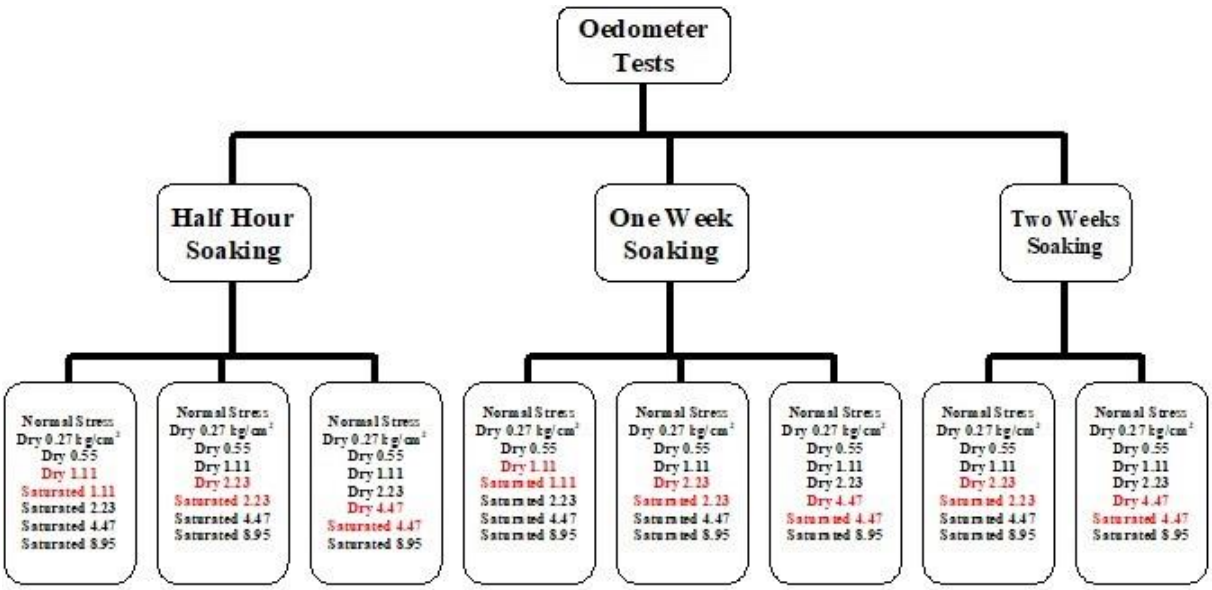


Figure 2. Program of Oedometer Tests.

3. Tests results

Figures 3 to 5 provide the settlement-time relationship under different normal stresses and half-hour soaking process at the three specific stress levels (1.11, 2.23, and 4.47 kg/cm^2) for comparing the collapsibility of the soil specimens. Generally, with increasing the normal stress there are increasing in the settlement due to the rearrangement of the soil particles, as shown in the figures. There are small increases in the settlement, in each stress level, due to the short time (half-hour) soaking process. Table 2 summarizes the settlement values before and after the soaking process and percentage changes at certain stress levels. As can be seen from Table 2, with increasing in the stresses, the percentage change ($(S_{AFTER}-S_{BEFORE})/S_{BEFORE}*100$) is decreased (from about 3% to 2%). This situation of settlement may be attributed significantly by the stress more than the short time soaking process.

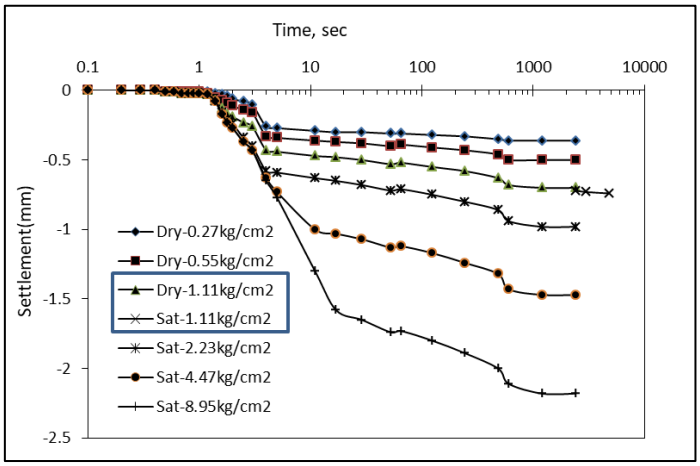


Figure 3. Settlement vs Time under Different Stress Levels with Half-Hour Soaking at 1.11kg/cm^2.

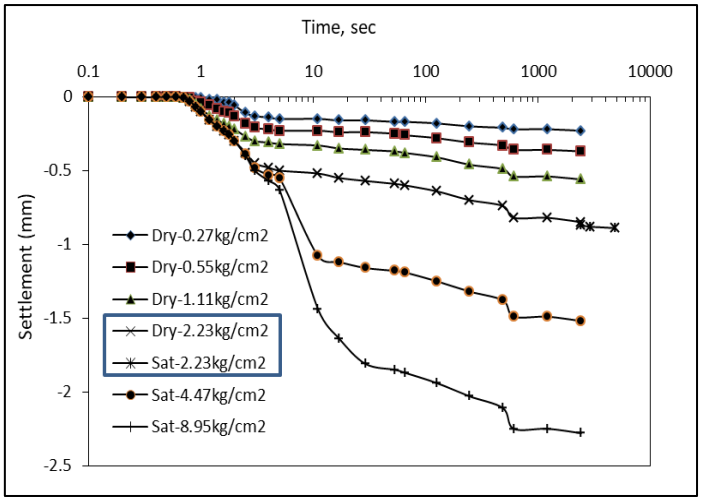


Figure 4. Settlement vs Time under Different Stress Levels with Half-Hour Soaking at 2.23kg/cm^2.

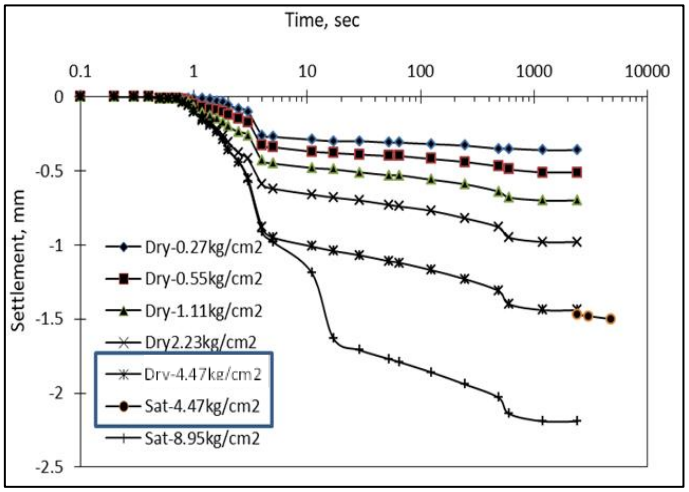


Figure 5. Settlement vs Time under Different Stress Levels with Half-Hour Soaking at 4.47kg/cm^2.

To investigate the effect of soaking periods, same above tests procedure is made on soil specimens with a soaking period of one-week and for the same soil characteristics and loading. Figures 6 to 8 present the settlement versus time under gradually loaded with different normal stresses and soaking process at the same stress levels in previous tests. Compared to half-hour soaking, there is a clear increase in the settlement after the soaking process for one-week under the same specific stress levels (1.11, 2.23, and 4.47 kg/cm^2). Table 3 illustrates the values of settlement corresponding to the soaking process and percentage settlement changes ((S_{AFTER}-S_{BEFORE})/S_{BEFORE}*100). It can be seen from the data in Table 3 that there is a significant increase in a settlement related to the soaking effect. Vice versa from the case of half-hour soaking, the percentage changes in the settlement are increased with increasing the stress level (from about 20% to 36%) and this condition may be due to the effect of one-week soaking is more than the stress effect.

Table 2. Summary of the Specimen Settlement before and after Half-Hour Soaking Process.

Stress Level, kg/cm^2	Settlement, mm		
	Before Soaking	After Soaking	Change, %
1.11	-0.7	-0.72	+2.857
2.23	-0.85	-0.87	+2.353
4.47	-1.44	-1.47	+2.083

4. Analysis and discussion

Several reports have shown that there is a negative effect on the different gypseous soils, as mentioned in the literature review, such as, increasing in the deformation and decreasing in the shear strength. The present study was designed to estimate the effect of the time-based soaking process on the collapsibility of high gypsum (29%) sand soil in Al-Najaf city in Iraq. The soaking periods were half-hour, 1-week and 2-weeks within certain normal stresses of 1.11, 2.23, and 4.47 kg/cm^2 using Oedometer cell. The specimens were remoulded in the Oedometer cell with the density of 85% of the laboratory maximum density depending on standard Proctor test.

The current study found that with increasing the soaking period and the normal stress level there are increasing in percentage changes ((S_{AFTER}-S_{BEFORE})/S_{BEFORE}*100) in the settlement. In this study, soaking had a significant effect in the long period. A possible explanation for this might be that the softening of the gypsum materials is increased with increasing of the soaking period. This finding was also reported by Mohammed et al. 2018 [24] for low gypsum sand soil under different soaking periods before starting the loading.

Further analysis is made with reproducing of the data. Figure 9 provides the void ratio versus normal stress corresponding to the starting of the half-hour soaking. As stated above, there are no significant changes in soil behavior due to the specific soaking. While with increasing the soaking period up to one-week, the change in void ratio is more obvious and this change is increased with increasing the stress level of soaking, as shown in Figure 10.

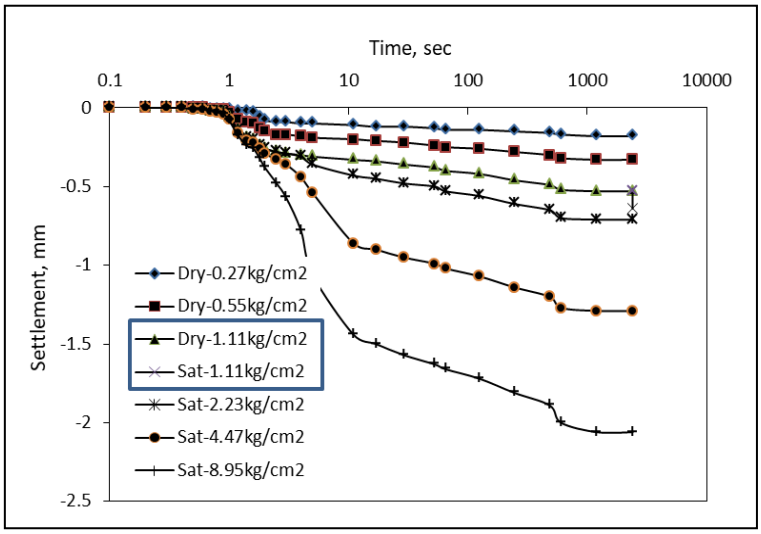


Figure 6. Settlement vs Time under Different Stress Levels with One-Week Soaking at 1.11kg/cm^2.

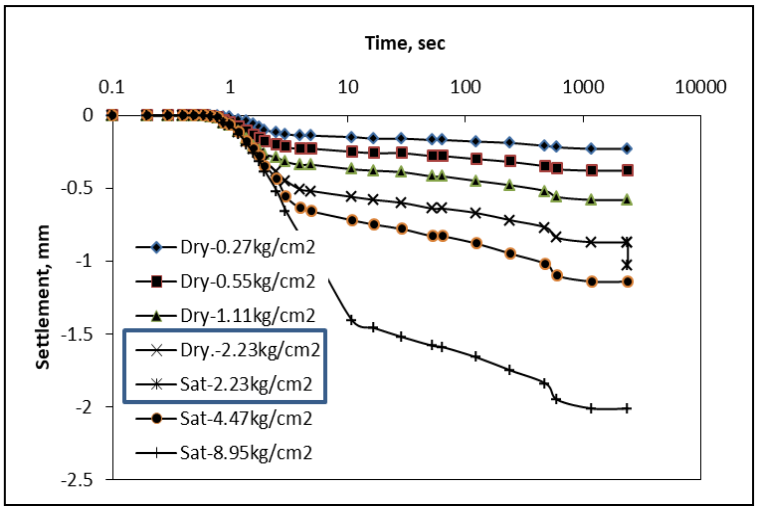


Figure 7. Settlement vs Time under Different Stress Levels with One-Week Soaking at 2.23kg/cm^2.

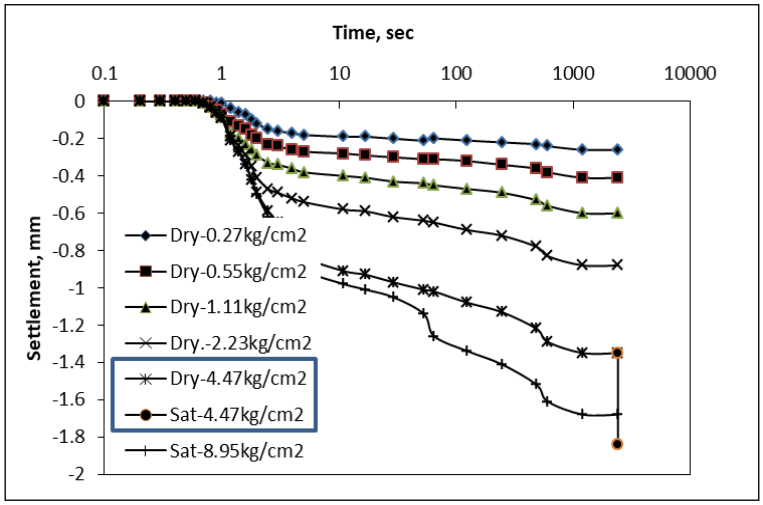
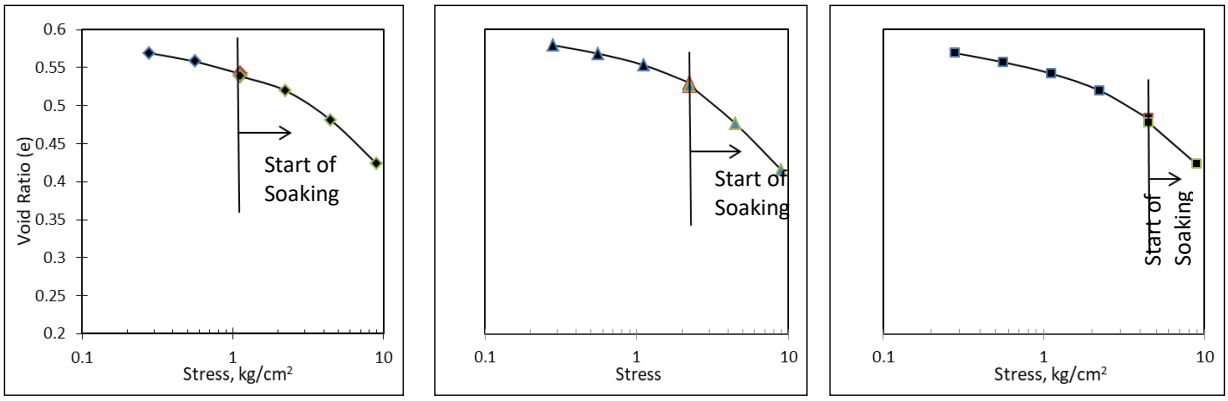


Figure 8. Settlement vs Time under Different Stress Levels with One-Week Soaking at 4.47kg/cm^2.

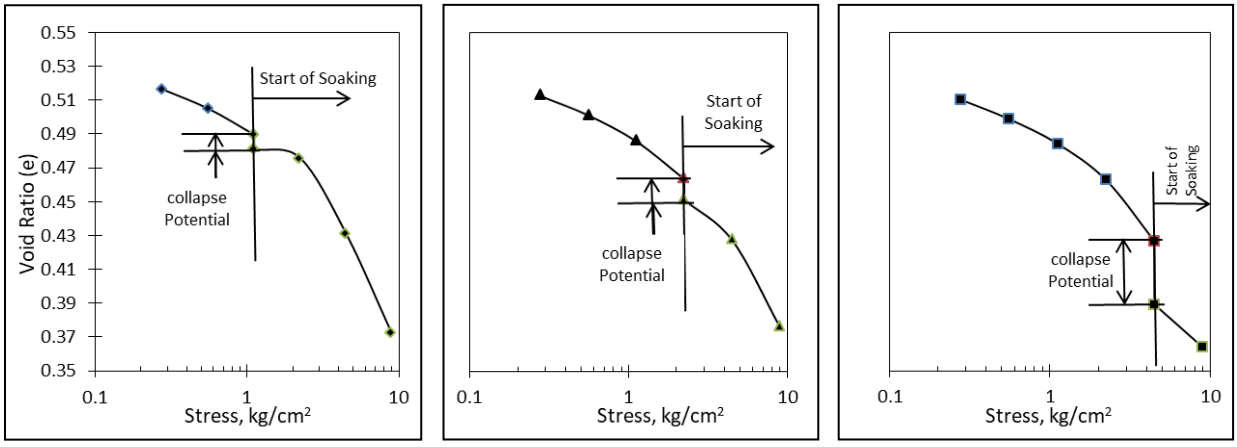
Table 3. Summary of the Specimen Settlement before and after One-Week Soaking Process.

Stress Level, kg/cm^2	Settlement, mm		
	Before Soaking	After Soaking	Change, %
1.11	-0.53	-0.64	20.755
2.23	-0.87	-1.03	18.391
4.47	-1.35	-1.84	36.296



(a) (b) (c)

Figure 9. Void Ratio vs Stress with Half-hour Soaking at (a) 1.11kg/cm^2, (b) 2.23kg/cm^2 and (c) 4.47kg/cm^2.



(a) (b) (c)

Figure 10. Void Ratio vs Stress with One-week Soaking at (a) 1.11kg/cm^2, (b) 2.23kg/cm^2 and (c) 4.47kg/cm^2.

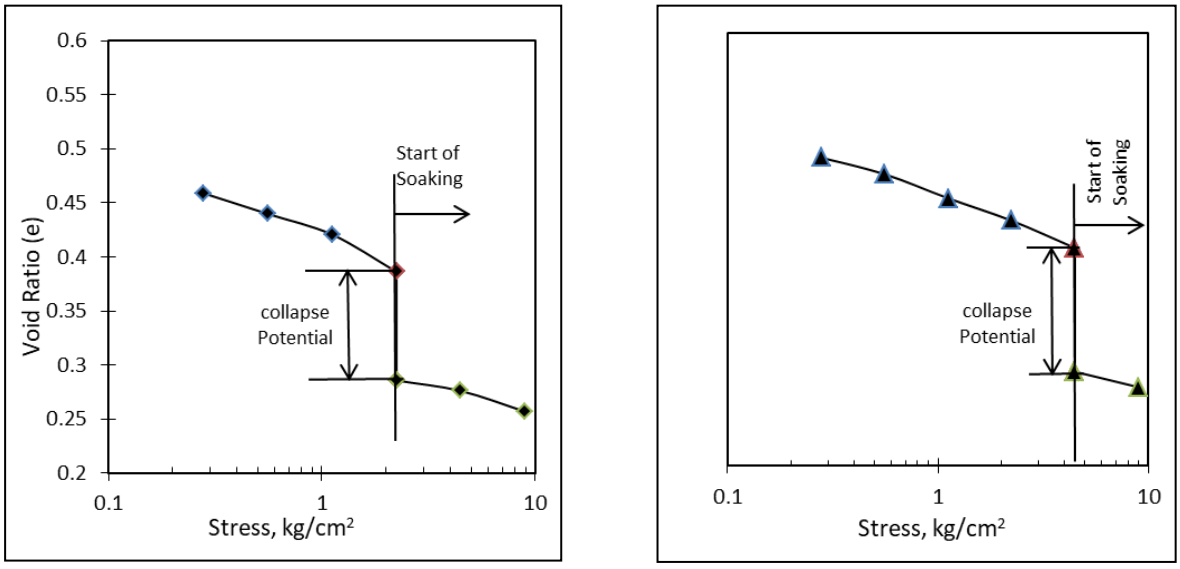
Additional tests were made to verify the recent results. Two-week of a soaking process is adopted for two stress levels (2.23, and 4.47 kg/cm2). Figure 11 presents the results of void ratio against stress for the two stress levels of soaking. The changes are larger and more effective.

Table 4 provides the collapsibility potential (CP) as was defined by Jennings and Knight, 1975, Eq. 1 [18]. The results of collapsibility potential can be categorized into three groups of soil collapse severity as defined by Jennings and Knight, 1975; no problem (CP>1), moderate trouble (1<CP<5)

and trouble (5<CP<10). The troubles are occurred in the condition of long term soaking process under high normal stress.

Overall, these results indicate that the soaking process and soaking periods are the main reason for the alteration of gypseous sand soil in Al-Najaf city. It can thus be suggested that take cautions in selection and analysis of soil properties of such soils.

Further work is required to establish the viability of the laboratory tests through in-situ tests under natural conditions of the soils.



(a) (b)

Figure 11. Void Ratio vs Stress with Two-Week Soaking at (a) 2.23kg/cm^2 and (b) 4.47kg/cm^2.

Table 4. Collapse Potential for the Different Stress Levels and Soaking Periods.

Stress Level, kg/cm^2	Collapse Potential, %		
	After Half-hour Soaking	After 1-Week Soaking	After 2-Weeks Soaking
1.11	-0.19*	-0.60*	-
2.23	-0.20*	-0.80*	-7.20***
4.47	-0.34*	-2.60**	-8.20***

* No Problem, ** Moderate Trouble, *** Trouble

5. Conclusions

In this investigation, the aim was to assess the gypseous sand soil in Al-Najaf city under different soaking periods and stress levels using Oedometer tests. These tests confirmed that with increasing of soaking periods and stress levels, there are increasing in collapse potential of such soils. The collapse potential was increased from <1% after half-hour soaking to about 8% after two-weeks of soaking. These findings have significant implications for the understanding of how gypsum softening affects soil behavior. An issue that was not addressed in this study was whether soil sensitivity is low.

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References

[1] Dadarya AK 2007 *Foundation Settlement in Buildings (Causes & Prevention)*Centre for Advanced Maintenance Technology Ministry of Railways Government of India Gwalior India.
[2] Smith G N and Smith Ian G N 1998 *Elements of Soil Mechanics* 7th ed Blackwell Science Ltd UK.
[3] Al-Almahmodi R 2018 *An Experimental Investigations on Saturation Collapse of AlNajaf Gypsum Sand* MSc Thesis Civil Eng Dep Ferdowsi University of Mashhad Iran.
[4] Al-Mufty A A 1997 *Effect of gypsum dissolution on the mechanical behavior of gypseous soils* PhD Thesis Civil Eng. Dep University of Baghdad Iraq.
[5] Al Saoudi Namir K S and Al Shakerchy Mohammed Sh M 2010 Water Infiltration Characteristics of Al Najaf City Soil *Proceeding of the 4th International Conference on Geotechnical Engineering and Soil Mechanics* November 2-3 2010 Tehran Iran.
[6] Al-Saoudi Namir K S, Al-Shakerchy Mohammed Sh M and Al-Janabi Salam A Abbas 2013 Water Infiltration Characteristics for Suggested Artificial Lake In Bahr Al-Najaf *Proceedings of 1st International Conference on Geotechnical and Transportation Engineering* ICGTE 2013 3 to 4 of April Baghdad Iraq.
[7] Al-Saoudi Namir K S, Al-Shakerchy Mohammed Sh M and Abdal Husain Mustafa M 2014 Infiltration Characteristics in Agriculture Area of Bahr al Najaf *Journal of Babylon University Engineering Sciences* 22(4) 971-978 Babylon Iraq.
[8] Al-Shakerchy Mohammed Sh M 2009 Effect of Water Head on the Infiltration Characteristics by Using the Laboratory Tests, *Al-Qadisiya Journal For Engineering Sciences* 2(4) 664-681 Iraq.
[9] Al-Khuzaie H M A 1985 *The effect of leaching on the engineering properties of Al-Jazirah soil (Doctoral dissertation* MSc Thesis Civil Engineering Department University of Mosul.
[10] Nashat I H 1990 *Engineering Characteristics of some Gypseous Soil in Iraq* PhD Thesis University of Baghdad Iraq.
[11] Salman A D 2011 Soaking Effects on the Shear Strength Parameters and Bearing Capacity of Soil *Engineering & Technology Journal* **29**(6)1107-1123University of Technology Baghdad Iraq.
[12] Mahmood Mohammed Sh 2017 Effect of Time-Based Soaking on Shear Strength Parameters of Sand Soils *Applied Research Journal* **3**(5) 142-149 Iran.
[13] Moula Baydaa H and Al- Saoudi Namir K 2010 Predication Collapse of Gypseous Soils Due to Wetting *Al-Taqani Journal* **23**(4) 157-164Foundation of technical education Iraq.
[14] Razouki S S and Al-Azawi M S 2003 Long–term soaking effect on strength and deformation characteristics of a gypsiferous subgrade soil *Engineering Journal of the University of Qatar* 16 49-60 Qatar.
[15] Abbas H O and Muarik S M 2012 Behavior of compacted gypsiferous sandy Soil during soaking and leaching process *Journal of Wassit for Science & Medicine* **5**(1) 165-176 Iraq.
[16] Fattah M Y, Hameedi M K and Aswad M F 2017 Determination of collapse potential of gypseous soil from field and laboratory tests *Diyala Journal of Engineering Sciences* **10**(2) 75-85 Iraq.
[17] Mahmood Mohammed Sh 2018 Prediction of Discrepancy Settlement Behaviour of Sand Soils *Applied Research Journal* **4**(2) 30-37 Iran.
[18] Ng Charles W W and Menzies Bruce2007*Advanced Unsaturated Soil Mechanics and Engineering* 1st ed Taylor & Francis Group ISBN 978-0-203-93972-7.
[19] Abdal Husain Mustafa M, Akhtarpour Ali and Mahmood Mohammed Sh 2018Wetting Challenges On the Gypsiferous Soils *Proceedings of 4th International Conference on Civil Engineering, Architecture and Urban Planning* Shiraz, Iran.
[20] Ahmad F, Said M A and Najah L 2012Effect of leaching and gypsum content on properties of gypseous soil *International J. of Scientific and Research Publications* ISSN: 2250-3153 **2**(9) 1-5.

[21] Al Shakerchy M Sh 2007 *Geotechnical Properties of Al Najaf City Soil with Emphasis on the Infiltration and Strength Characteristics* PhD Thesis Building and Construction Dep. University of Technology Baghdad Iraq.
[22] Al-Saoudi Namir K S and Al-Shakerchy Mohammed Sh 2010 Statistical Analysis of Some Geotechnical Properties of Najaf City *Proceedings of International Geotechnical Conference* 3 1173-1180, Moscow, Russia.
[23] Mahmood Mohammed Sh 2018 Effect of Soaking On the Compaction Characteristics of Al-Najaf Sand Soil *Kufa Journal of Engineering* **9**(2) 1-12 Iraq. DOI:10.30572/kje/2018/7108
[24] Mahmood Mohammed Sh, Aziz Laith J and Al-Gharrawi Asaad M B 2018 Load-Time-Settlement Behavior of Sand Soil Upon Soaking Process Using Oedometer Test *International Journal of Civil Engineering and Technology* (IJCIET) **9**(11) 860-869 India.