Investigation settlement for unsaturated soil AL-NAJAF upon matric suction and different loading using Oedometer

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Abstract. This research aims to conduct investigations on the settlement using an Oedometer matric suction device for unsaturated soil. The type of soil taken from the city of Najaf is as one model, a sandy gypsum soil, the percentage of gypsum content is 29% and the moisture content of the soil is 3%. The research includes experimenting by choosing three relative densities 95%, 85% and 75% with an amount of 150 KPA constant pore air pressure and three pore water pressure. 100 KPA, 130 KPA and 150 KPA where the matric suction values are 50 KPA, 20 KPA and 0 KPA respectively. Also, the soil is tested in the partially saturated state and fully saturated state under the influence of placing multiple loads 1kg, 2kg, 4kg, 8kg and 16 kg at a different matric suction (50 KPA, 20 KPA and 0 KPA) and relative densities. The settlement is measured by the LVDT device to measure the vertical displacement, where the data is recorded through a program installed on the calculator to measure the settlement data every second, where the results are then analyzed by excel program. The analysis of the experimental results achieves that the highest settlement ratio of 5.5% was achieved when loading (1kg) when applying matric (20 KPA) within 500 sec. The settlement increases with increasing time and stabilizes at the lowest interval of 76 sec., in the case initial of matric suction (50 KPA) at the relative density of 95% and 25 sec., in the case matric suction (0 KPA) at the relative density of 85%.

1. Introduction
The understanding of the behavior and mechanics of unsaturated soil needs to be improved urgently. For simplicity, that part dealing with saturated soils and that part dealing with unsaturated soils are often subdivided into the general field of classical soil mechanics. Although it can be seen that this arbitrary separation between saturated and unsaturated soils is needless, it can also be useful to use the information obtained from saturated soils as a guide and then to apply it as seen to the larger unsaturated environment [1,2]. Four steps [i.e. Interface for solid, water, air and air-water called contractile skin (Paddy, 1969)]. The behavior of unsaturated soil is more complex than that of soil that is saturated. [2,3]. The case of the soil that is unsaturated is more nuanced than that of soil that is saturated.[2]. Unsaturated soil mechanics may be described as "the application to engineering issues dealing with partially saturated soils of the laws of mechanics, hydraulics, and interfacial physics.[4]. The difference between pore air pressure (Ua) and pore water pressure is defined as matric suction (Uw). In the field of geotechnical engineering, pore air pressure can be regarded as equal to atmospheric pressure, so it can be ignored (Ua=0)[5]. Determining the distribution of the matric suction in the unsaturated zone This represents a significant step necessary for further geotechnical development. Applications on specific soil unsaturated behavior. For the determination of unsaturated soil shear strength, the permeability of
unsaturated soils, and the effective stress state in the unsaturated zone, matric suction \((U_a - U_W)\) is necessary.\[^{5,6,7,8}\]\footnote{\cite{5,6,7,8}}. Matric suction is a soil parameter that, both in terms of shear strength and permeability, influences the behavior of unsaturated soils. Gypseous soil is regarded as a difficult soil to work with because of its unpredictable behavior. When exposed to water, gypseous soils achieve high shear strength with low compressibility, but they suddenly collapse. Arid and semi-arid regions have more gypseous soil. Gypseous soil covers approximately 20-30% of Iraq's total area. Several structures in Iraq have been reported to have cracks and underexposing gypseous soil to water in various patterns. Changes in water content in gypseous soil cause the gypsum, which acts as a cementing agent, to dissolve within the soil mass, resulting in one or more of three processes: first, the gypsum-supported bonds between soil particles break down, followed by the collapse of the soil structure, which occurs almost instantly. Consolidation is the second process, while leaching occurs when water continues to flow through the soil mass. When the soil is loaded, the combination of these processes causes it to settle significantly.\[^9\]\footnote{\cite{9}}. Gypseous soils can be found throughout Iraq and other countries, in large areas and various regions. Percolation of water and gypsum dissolution are linked to many of the foundation failure issues that occur in these soils.

2. Previous studies
Several researchers have attempted to the properties of gypseous soils to reduce gypsum dissolution and the potential for these soils to collapse.\[^{10}\]\footnote{\cite{10}}. Many academics and scientists have been interested in the study of gypseous soils since the eighties of the last century. In general, in terms of engineering geology and geotechnics, recognizing problematic soils is critical.\[^{11}\]\footnote{\cite{11}}. The gypsum distributes in Iraq according to Barzanji, (1973).\[^{12}\]\footnote{\cite{12}}. Many previous studies looked into the impact of gypsum on various soil properties from various locations in Iraq.\[^{13,14,15,16}\]\footnote{\cite{13,14,15,16}}. Examine the impact of gypsum content on soil shear strength for various soil samples. Moula and Al-Saoudi (2010).\[^{17}\]\footnote{\cite{17}}. The recent paper investigates the effect of the soaking process within a half-hour on the settlement value of the sandy soils with 29% of gypsum in Al-Najaf city south-east of Iraq using Oedometer test. The settlement is assessed under different levels of normal stress.

3. Soil Used
The soil samples are taken from one of the northern districts (Al-Jama’a) in the province of Al-Najaf city in Iraq. A sieve analysis test is performed as shown in Figure 1 and according to the Unified Soil Classification System, the soil sample is Well graded Sand, SW with high gypsum content (29%). Table 1 summarizes (d) the properties of the soil sample. The soil is mainly sand and the maximum dry density and optimum moisture content are obtained from the standard Proctor test as seen in Figure 2.

| Test                          | Results |
|-------------------------------|---------|
| Fine Gravel, %                | 13      |
| Sand, %                       | 83      |
| Silt, %                       | 4       |
| Clay, %                       | 0       |
| soil classification(USCS)     | SW      |
| Specific Gravity of gypsum soil | 2.38   |
| Gypsum content, %             | 29      |
| Natural water content, %      | 3       |
| Maximum dry density, gm/cm³   | 1.82    |
| Optimum moisture content, %   | 15      |
| e maximum                     | 0.38    |
| e minimum                     | 0.29    |
4. Model preparation
The examination method includes finding the settlement of the unsaturated gypsum soil sample with 20 mm high and 50 mm in diameter. It is placed in the oedometer cell and stacked well as three layers. After which the cell is placed in the device of Oedometer as shown in Figure 3. The settlement values estimated under multiple loads (1kg, 2kg, 4kg, 8kg, 16kg), where it is the time required to obtain the final settlement is more than half an hour and the settlement is found under the influence of three cases of suction leaving the partially saturated state of the sandy gypsum soil where the suction is left in the initial state of 50 KPA and the second state of 20 KPA and the third case the soil is in the phase of total saturation where it is. The matrix suction value is 0kPa and settlement is found for three densities: 95%, 85%, 75%. The settlement is found by the LVDT device, where the oedometer is linked by a data logger to transfer the computational information to the laptop through the Excel program. The flow chart for each of the model tests is presented in Figure 4.
Figure 3. Device oedometer test.

Figure 4. Testing program.
5. Results and Discussion
The result of the consolidation test using a conventional Oedometer device is displayed as the relationship between time and settlement which is presented in Figure (5). The sample is exposed to three levels of matric suction through partially saturated soil, with initial matric suction values of 50 KPA and 20 KPA, and completely saturated soil, with a matric suction value of 0 KPA. For all three cases, a levelling level was determined for more than 30 minutes to find the best settlement final that the results indicate an immediate and rapid settlement, but increasingly with increasing loads. It is noted from Figure (5), the loading takes place in four (1kg, 2kg, 4kg, and 8kg) stages that a final settlement has been achieved for all cases, according to the attached table (3). At a final settlement value and according to each matric suction in the case of the relative density of 95%, it can be noted that the levelling increases with increasing time, as it starts in the case of suction matric 50 KPA and increases as well in the case of suction matric 20 KPA, but it becomes more in the saturated state (i.e matric suction 0 KPA). This is probably because the waterworks dissolve the gypsum granules coherent with the soil, which leads to increased levelling in the saturated state.

Figure 5. settlement versus time for different matric suction (50 KPA), (20 KPA), (0 KPA) at relative density 95%.

A maximum settling can be noted (0.08 mm) within 76 sec in the initial case of matric suction 50 KPA and becomes by 0.18 mm within a time of 216 sec in the case of matric suction 20 KPA. In the saturated
state explain (table 2), the fastest settlement was recorded by 0.74 mm within a time of 104 sec where the final stability of the fastest settling with the least time where was the (settlement rate) \((\Delta h_f / H_t)\) for each suction is left to the three levels 0.4%, 0.9%, 3.7%. The final stability ratio in the saturated state increases in the case of shedding the initial load 1kg for the fastest settlement and is less in the initial case of suction matric 50 KPA when shed 4kg load. It can be concluded that in the case of primary batter loaded the stability ratio is greater with total saturation, because this behaviour can be attributed to an increase in water activity at the same time and because the gypsum granules try to separate from the sand grains and try to dissolve upon contact with water.

Figure (6) illustrate(d)s the relationship between time and settlement of soil samples are exposed to three levels of matric suction (partially saturated soil, with initial matric suction values of 50 KPA and 20 KPA, and completely saturated soil, with a matric suction value of 0 KPA) as shown in figure 6. For all three cases, a levelling level was determined for more than 30 minutes to find the best value of the final settlement. The results indicate an immediate and rapid settlement, but increasingly with increasing loads as noted in Figure (5).

Figure 6. Settlement versus time for different matric suction (50 KPA), (20 KPA), (0 KPA) at relative density 85%.
The loading performed in four stages (1kg, 2kg, 4kg, and 8kg) that a final settlement has been achieved for all cases as shown in table (2). From this table, it can be noted that the final settlement values are according to each matric suction in the case of the relative density of 85% that the levelling increases with increasing time, as it starts in the case of suction matric 50 KPA and increases as well in the case of suction matric 20 KPA, but it becomes more in the saturated state in the case of matric suction 0 KPA. This is because the gypsum between the soil particles is dissolved by water, which leads to increased levelling in the saturated state.

The fastest settling was achieved by 0.29 mm within 923 sec in the initial case of matric suction 50 KPA and by 1.1 mm within a time of 500 sec in the case of matric suction 20 KPA and in the saturated state the fastest settlement was recorded by 0.23 mm within a time 25 sec where the final stability of the fastest settling with the least time ($\Delta hf / Ht$) for each suction is left to the three levels 1.45%, 5.5%, 1.15% where the final stability ratio in the unsaturated state of 20 KPA matrix suction increases significantly when the initial load is shed 1kg, and the reason is that the wetting process of the gypsum soil in the unsaturated state tries to press on the gypsum granules to dissolve and increase the stability ratio.

Table 2. Summary of final settlement with different Matric suction.

| Load (kg) | Matric suction (50KPA) | Matric suction (20KPA) | Matric suction (0KPA) |
|----------|------------------------|------------------------|------------------------|
|          | (settlement) (mm) (T)  | (settlement) (mm) (T)  | (settlement) (mm) (T)  |
| 1kg      | -0.63 1017 -0.67 471  | -0.74 104             |                        |
| 2kg      | -0.05 427 -0.06 570  | -0.07 1360            |                        |
| 4kg      | -0.08 76 -0.09 668  | -0.11 258             |                        |
| 8kg      | -0.14 994 -0.18 216  | -0.23 1944            |                        |

| Load (kg) | Matric suction (50KPA) | Matric suction (20KPA) | Matric suction (0KPA) |
|----------|------------------------|------------------------|------------------------|
| 1kg      | -1.05 1423 -1.1 500  | -1.13 842             |                        |
| 2kg      | -0.08 1035 -0.1 843  | -0.1 594              |                        |
| 4kg      | -0.1 1307 -0.16 661  | -0.23 25              |                        |
| 8kg      | -0.29 923 -0.33 551  | -0.4 554              |                        |

From figure 7, the increase of the voids affects the behaviour of the gypsum soil under the influence of the matric suction of the three stages, the partially saturated phase, the elementary matric suction (50 KPA), the phase (20 KPA), and the fully saturated phase. For the three stages, it can be seen that the percentage of voids increased with the rise of the settlement values, as it started to rise at the beginning of the settlement value of 0.63mm. This behaviour is due to the distribution of moisture across a mass of soil from the filter layer during the multiple moisturizing processes 95%, 85% have the same behaviour and their values converge equally in the test for the three matric suction states and continue to the saturated state matric suction (0 KPA) until the completion of the three tests. It is clear that soils
with densities of 95\% and 85\% have a large void ratio when compared with a settlement, the results show that a greater settlement is achieved in the saturated state of Matric suction (0 KPA).

Figure 7. Void ratio versus settlement.

6. Conclusions
  
  • The settlement increases with increasing time and stabilizes at the lowest interval of 76 sec in the case initial of matric suction (50 KPA) at the relative density of 95\% and 25 sec in the case saturation matric suction (0 KPA) at the relative density 85\%.
  
  • The highest settlement ratio of 5.5\% was achieved when loading the initial load (1kg) when applying matric (20 KPA) within 500 sec, which means that the settlement is faster due to the dissolution of the gypsum particles upon wetting at a relative density 85\%.
  
  • The deformations of the unsaturated highly gypseous soil under the foundations are continuing over time.
  
  • The void ratio increases with increasing settling values at the two relative densities 95\% and 85\%, the highest increase is reached at the saturated phase of matric suction (0 KPA) and the highest increase is at the density of 85\% due to increased soaking processes and dissolution of gypsum granules during humidification and in contact with water where particles are lost. Gypsum bonds with soil particles and settlement occurs.
  
  • These results have major implications for understanding how softening gypsum affects the behaviour of sandy soils
  
  • The relative pressure or the suction matric pressure comes from softening the gypsum in the loading stage and thus it takes more than 30 minutes to complete the final settlement process due to the lack of cohesion between the soil particles and the gypsum particles due to the increased soaking process.

7. References
  
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