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The Influence of Dry Density and Applied Loads on Expansive Soils

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Abstract

The present research studies the effect of changing dry density on expansive soil and the effect of applied load on expansive behavior of soils together with the comparison of the values of swelling pressure with free swelling.

The two types of effect have been studied on three samples of a mixture of bentonite and sand. After the identification of the physical characteristics of the sand and bentonite, the sand was used as a basic and natural material to decrease soil swelling.

The gained results proved that loads play an important role in reducing the ratio of swelling and it is necessity to obtain the required field density that lead to reducing swelling.

الخلاصــــــة

يدرس هذا البحث تأثير تغير الكثافة الجافة على انتفاخ التربة اضافة الى تأثير الاحمال المسلطة على سلوك الترب الانتفاخية ومقارنة قيم ضغط الانتفاخ مع قيم الانتفاخ الحر .

حيث درست التأثيرات المذكورة على ثلاث نماذج من خليط البنتونايت والرمل بعد التعرف على الخواص الفيزيائية لكل من الرمل والبنتونايت . واستخدم الرمل كمادة اساسية في تقليل انتفاخ التربة كونه مادة طبيعية متوفرة.

النتائج المستحصلة اثبتت ان للاحمال دور كبير في تقليل نسبة الانتفاخ ومن الضروري تحديد الكثافة الحقلية المسموحة للحصول على انتفاخ قليل.

1. Introduction

Expansive soil is an essential phase of soil mechanics. Soil behavior under various conditions has been the target of many research work, conferences and symposiums all over the world.

Arid and semi-arid climatic regions face the problems of potential volume change of soil all around the world; Iraq is not an exception in this issue since it lies within the region where there is a great degree of change in the moisture content which, in its turn, results in potential expansiveness of the soil.

A mixture of bentonite and sand could be one of the proposed solutions of problems in geotechnical engineering in which heave and many other damages could be prevented.

The present search aims to study the effect of adding sand on an expansive soil (bentonite) behavior. It is going to limit itself to the consideration of the effect of the particle size and the amount of sand the physical properties of expansive soil.

Swelling pressure and swelling reduction of expansive soil are tackled through adding different percentages and different sizes of particles of sand. The study also tackles the consequent effect of the whole process on strength characteristics.

The importance of this study lies in the fact behind prompting the need for reducing free swell and swelling pressure.

2. Background

Expansive soils that occur above the water table undergoes volumetric changes with changes in moisture content. Increase in moisture content causes swelling of the soil. Heaving of foundations is one of the serious consequences for structures founded on expansive soil (Sivapullaiah et. al.) [1].

With respect to expansive soil, there are many overlapping factors to control its behavior. This behavior may be accompanied by great perils on the structures and as a result, complex damage and exorbitant cost is expected (Al-Dahlaggi) [2].

Mitchell [3] stated that the montmorillonite formation is favored by high magnesium in the weathering environment. However, such conditions are favorable in semi-arid region with relatively low rainfall or highly seasonal moderate rainfall. Particularly where evaporation exceeds precipitation.

The type of clay mineral plays an important role in the determination of heave in expansive soils. Of the three types of clay minerals (Illite, Kaolinite and Montmorillonite) the latter possesses the ability to swell the most. The swelling potential of the expansive clay minerals is also dependent upon the (i) crystal lattice structure (ii) the structure of clay mass and (iii) the action exchange capacity of the minerals (Gromko) [4].

Bentonite is a mixture of clayey minerals, in which smectite is the main mineral and proved to be the most important one for swelling. The structure of a typical smectite like montmorillonite composed of two structural units, the silica tetrahedron and the alumina octahedron. These units are interconnected and extend to form in layers but only about 10A thick. Several such layers are stacked one above the other, to form a crystal particle Karaborni et. al. [5].

Katti and Shanmughasundaram [6] found that the free swell without applying any load to a specimen depends mainly on moisture content and on dry density when a certain load is applied, while the swell pressure in constant volume method depends on dry density.

Lerot and Low [7], showed that the expansive soil need long time to completed swelling process. Time is also function of permeability, thickness of layer, initial moisture content and dry density.

To reduce the effect of free swell in bentonite, soil can be mixed with amount of fraction material such as sand. These materials, available and efficient admixture for this purpose.

Shreif et. al. [8], stated that soil has low swell when eight different percents of sand are mixed with bentonite soil by an increment of 5%and they found also that (95%) does not have plastic index.

Sivapullaiah et. al. [1], used different percents of bentonite with different materials such as (Sand, Kaolinite, Silt) and they found, mixture may reach 80%from swelling after (2000minutes) at the percent of bentonite (40, 50 and 60).

Al-Ashou et. al. [9], used various percents of river sand and amount of bentonite and they found that the 20%sand is the best portion to reduce both swelling potential and swelling pressure to less than (50%) of their original values. Therefore this percent is recommended to be used for construction purposes.

3. Experimental Work

3-1 Materials

3-1-1 Bentonite

Ca-base bentonite manufactured by Al-Faluja cement factory was used as the expansive soil. The mineralogical composition and chemical tests of the bentonite are illustrated in **Tables (1)** and **(2)**, respectively. (97%) of bentonite passing through sieve No.200 (0.075mm) and (83%) is finer than (0.002mm).

Table (1) Mineralogical composition of bentonite

Comp.	SiO2	Fe2O3	Al2O3	So3	CaO	MgO	Na2O	K2O	TiO2	L.O.I
%	57 Max.	5.5 Max.	13 Max	1.3	5.5 Max.	3.5	1.2	0.5	0.8	10-11

Table (2) Chemical properties of the bentonite

Comp.	P.H.	SO3	Gypsum	T.S.S	O.M.
	7.7	1.23%	2.64%	4.08%	0.7%

O.M.= Organic Matter

The bentonite is mixed with silica sand in percentages and different particle sizes to get testing specimens as illustrated in **Table (3)**. The Materials, testing equipment and experimental procedures are adequately discussed. For all tests, oven dried bentonite specimens are used.

Table (3) Properties of the bentonite/sand soil mixture

Sample	% of Bentonite	Sand		% Passing Sieve No.200	% Finer <0.002
		%	Retained on Sieve No.		
1	40	60	40	38.85	31.24
2	40	60	140	38.85	31.24
3	40	60	200	38.85	31.24

3-1-2 Sand

The commercial silica sand brought from Samara city has mineralogical composition, as shown in **Table (4)** and chemical properties as shown in **Table (5)**. The grain size distribution for the silica sand is shown in **Fig.(1)**, it has (Cc= 1.118, and Cu= 3.2).

Table (4) Mineralogical composition of silica sand

Comp.	SiO2	Fe2O3	Al2O3	CaO	MgO	Alkalies (Na2O+K2O)
%	98.6	0.08	0.5	0.3	0.3	0.2

Table (5) Chemical test of the silica sand

Comp.	P.H.	SO_3	Gypsum	T.S.S	O.M
%	0.8	1.33	2.86	3.02	1.3

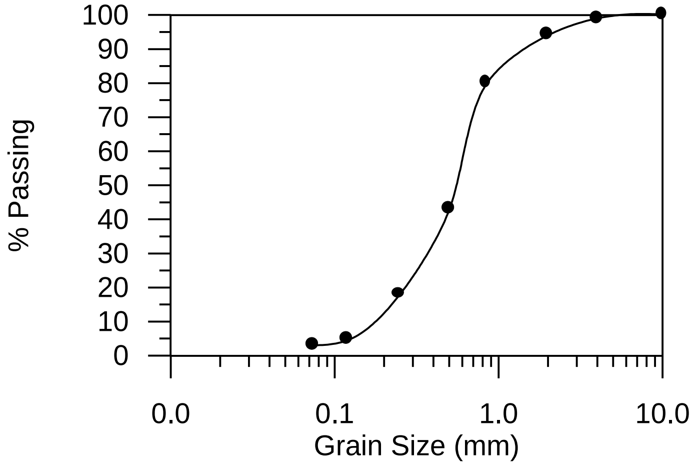

Figure (1) Grain size distribution for sand

The specific gravity is equal to (2.63) as determined according to *ASTM (D854-83-1988)*. Furthermore, shown in **Fig.(1)**. Tests for grain size distribution were carried out according to *ASTM (D421-85-1972 and D422-63-1972).*

3-2 Characteristics of Bentonite-Sand Mix.

In this study, bentonite is mixed with silica sand to obtain 3different sand/bentonite soil mixtures. Test results are analyzed to study the benefits of using silica sand in treating expansive bentonite clays.

3-2-1 The Specific Gravity

The Specific Gravity for all mixing ratios is shown in **Table (6)**, the specific gravity of soils is determined in accordance to *(BS 1377-1975, Test No.6)* using density bottle of 50ml capacity.

Table (6) Properties of bentonite/sand soil mixtures

Sample	Gs%	L.L %	P.L %	P.I %	O.M.C	γ_d max
1	2.630	59	22	37	17.25	17.8
2	2.639	72	31	41	15.5	16.6
3	2.652	80	31	49	21.1	15.5

Pure bentonite having P.I. = 76.5%

3-2-2 Atterberg Limits

3-2-2-1 Liquid Limit

Cone penetrometer apparatus was used for measuring liquid limit of the soil *(BS1377-1975, Test 2A)*. The liquid limit for all mixing ratios is shown in **Table (6)**.

3-2-2-2 Plastic Limit

The tests a carried out on all specimens according to *(BS 1477-1975, Test 3)*. The plastic limit for all mixing ratios is shown in **Table (6)**.

3-2-2-3 Compaction Test

The dry density-moisture content relationships for all bentonite/sand mixture were obtained using standard compaction test *(BS 1377-1975, Test 12)*. The value of O.M.C and γ_d (max) are given in **Table (6)**.

3-2-3 Mixing with Water

For all odometer specimens, the sand is mixed with bentonite without the addition for water. While for the CBR mold specimen, 10% of water is added and then mixed by hand and stored for (24 hr) to obtain specimen with uniform moisture distribution. Bentonite is oven dried at (105-110 c°) in accordance with *(BS 1377-1975, Test A).*

3-2-3-1 Swelling Test

Free swell and swelling pressure test were carried out using oedometer cells.

3-2-3-2 Soils Classification

According to the Unified Soil Classification System (**USCS**), the silica sand is classified as (SP) and the bentonite is classified as (CH).

4. Results

The swell percent is plotted against time in **Figs.(2)** to **(7)**. It can be seen that expansive soils take long period of time to complete their expansion. Al-Timimie [10] pronounced such behavior.

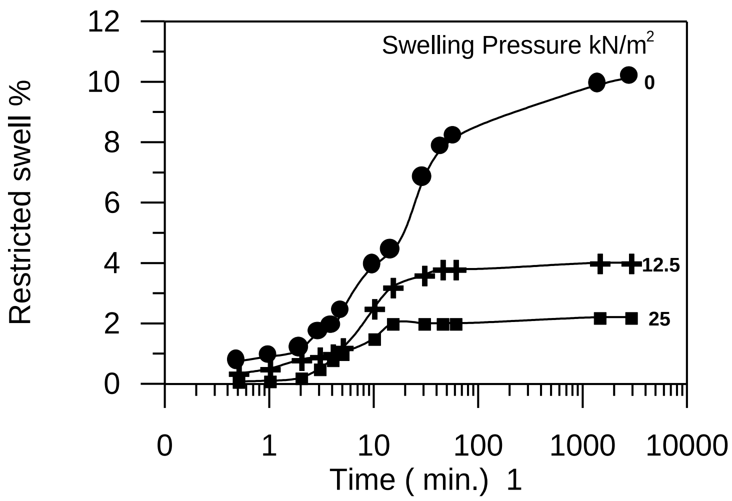

Figure (2) Restricted swell% vs. time (dry unit weight =15.5 kN/m³)

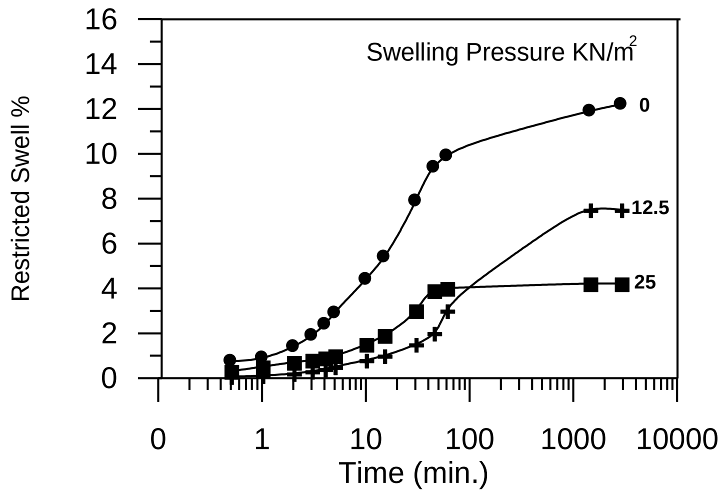

Figure (3) Restricted swell% vs. time (dry unit weight =16.6 kN/m^3)

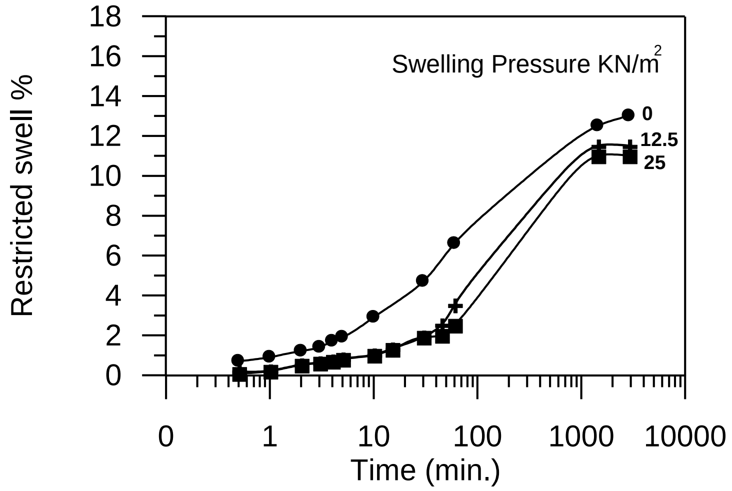

Figure (4) Restricted swell% vs. time (dry unit weight =17.8 kN/m^3)

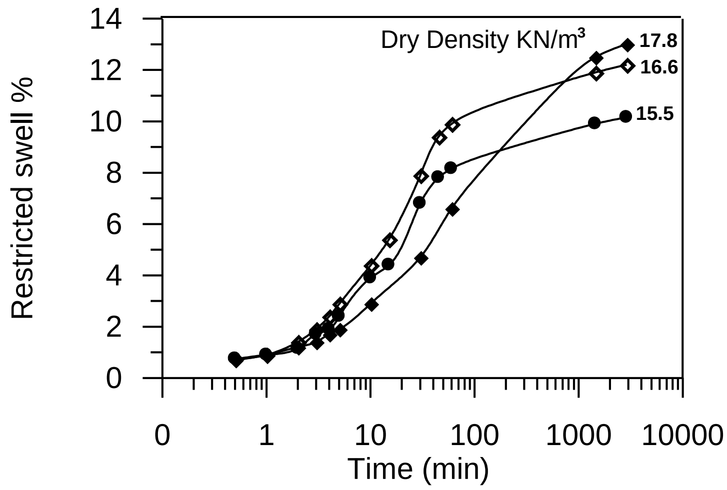

Figure (5) Restricted swell% vs. time (swelling pressure= 0 kN/m^2)

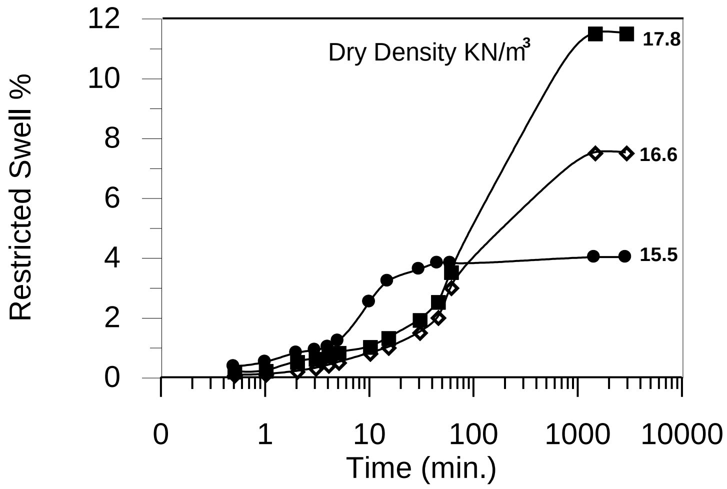

Figure (6) Restricted swell% vs. time (swelling pressure=12.5 kN/m^2)

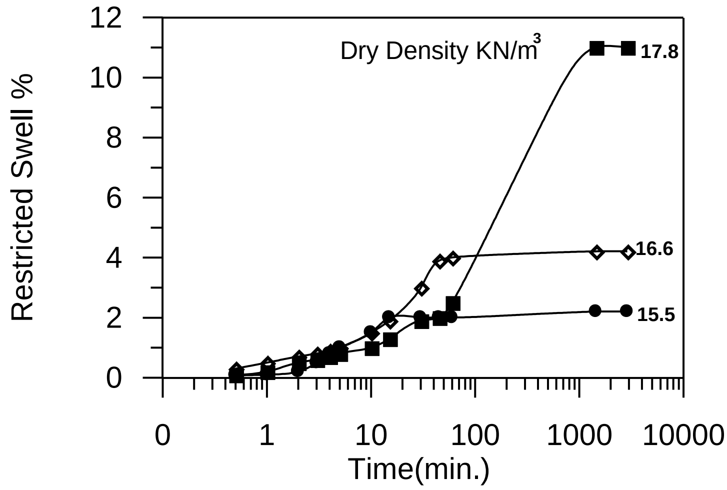

Figure (7) Restricted swell% vs. time (swelling pressure=25 kN/m^2)

4-1 Effect of Applied Loads

These figures show the effect of swelling pressure on the swelling of the sample since we notice the large decrease in swelling values due to loading (although the loading is very small) in comparison with the free swelling curve. Also it was notice convergence of the swelling values with the swelling pressure difference from (12.5 to 25 kN/m^2) that is caused by the movement of the sand particles and its position change in the sample, i.e. the swelling pressure in the two cases is applicable the sand frame and affect slightly on the spaces between the regular.

It was notice that the swelling in the first minutes very small in cause of the bentonite in the beginning more prevence from the water enter between its particles which leads to swelling lag.

It is noticed from **Fig.(3)** that the max. value of the sample swelling subjected to a pressure of 12.5 kN/m^2 equal 0.65 times the max. value of the free swelling for the same sample, and we notice that the max. value of the sample swelling subjected to a pressure of 25 kN/m^2 equal 0.35 times the max. value of the free swelling for the same sample.

Figure (4) shows that the max. value of the sample swelling subjected to a pressure if 12.5 kN/m^2, i.e. the pressure change from (12.5 to 25 kN/m^2) doesn't give an effect on the swelling value.

4-2 Effect of Dry Density

It is noticed for the **Figs.(5)** to **(7)** that the initial swelling for the samples of the density of (15.5 kN/m^3) after the minute 15 from the beginning of the swelling is larger than the samples swelling of the density (16.6 kN/m^3). Explanation that the samples of the higher density is more prevent to water enter between its (17.8 kN/m^3 and 16.6 kN/m^3) in the reason of its high density which leads to swelling lag in the beginning of the swelling stage about the sample of the lower density.

Figure (8) shows the decrease of the max. value of sample swelling subjected to a pressure of 25 kN/m^2 the max. value of the sample swelling subjected to a pressure of 12.5 kN/m^2 when the sample density is 15.5 kN/m^3. **Figure (9)** shows the change of the max. value of the swelling with the change of swelling pressure is a linear change. **Figure (10)** shows the pressure change from (12.5 to 25 kN/m^2) doesn't give an effect on the max. swelling value.

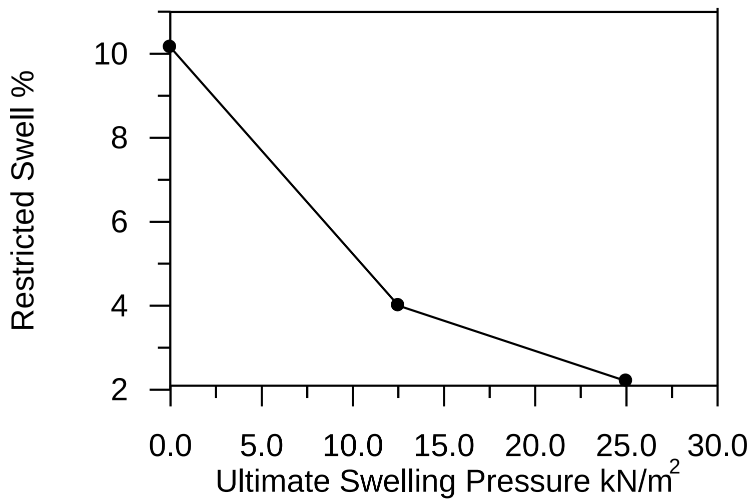

Figure (8) Restricted swell% vs. ultimate swelling pressure (dry unit weight =15.5 kN/m^3)

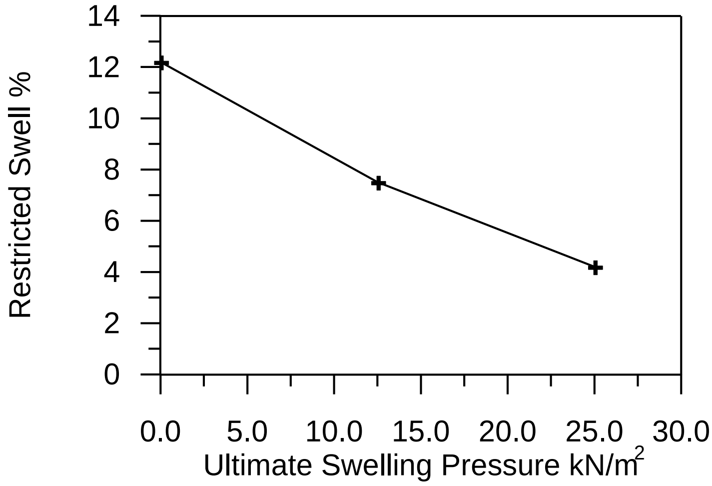

Figure (9) Restricted swell% vs. ultimate swelling pressure (dry unit weight =16.6 kn/m^3)

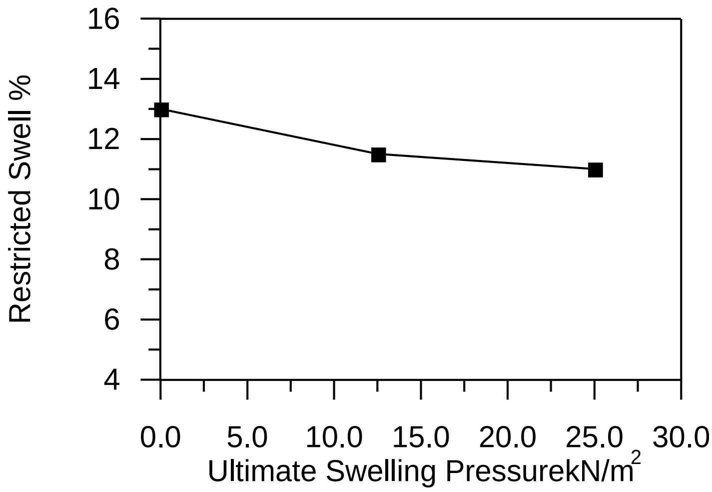

Figure (10) Restricted swell% vs. ultimate swelling pressure (dry unit weight =17.8 kn/m^3)

5. Conclusions

1. Both of the free and confined swelling of the samples subjected to an initial pressure increase with the increase of the density which means the necessity of field density specification which leads to unacceptable swelling or applying initial capacities specify the swelling.
2. The effect of swelling pressure on the swelling of the sample shows large decrease in swelling values due to loading (although the loading is very small) in comparison with the free swelling curve. Convergence of the swelling values with the swelling pressure difference from (12.5 to 25 kN/m2) that is caused by the movement of the sand particles and its position change in the sample is noticed. i.e. the swelling pressure in the two cases is applicable the sand frame and affect slightly on the spaces between the regular.

3. In a density the swelling decreases with the increase of the pressure, the previous experiments ensure the role of this initial capacities even if they are small in avoiding large ratios of the swelling.
4. The required time to reach to swelling fixity increases with the increase of density.

6. References

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