TREATMENT OF EXPANSIVE SOIL WITH CHEMICAL ADDITIVES

El Sharif M. Abdulaziz [1], Yahya K. Taha [2], Mamdouh A. Kenawi [3]and Ahmed O. Kamel* [4]

[1, 2] Civil Engineering Department, Faculty of Engineering, Assiut University, Assiut, Egypt
[3, 4] Civil Engineering Department, Faculty of Engineering, Sohag University, Sohag, Egypt

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ABSTRACT

Expansive soil is found in many regions in Egypt, especially in the new desert cities including New Sohag City(town in upper Egypt). In this study, The soil samples were taken from the place of the Faculty of Veterinary Medicine at New Sohag University from a depth of 5 meters and it's used in the experimental program. The physical and mechanical properties of the natural soil were obtained. Then the soil was treated with chemical additives (Addicrete P and Addicrete BV) 0.5%, 1% and 2% by dry weight of soil. After treatment of soil the properties of the samples were investigated. The natural soil properties were used as control points for comparison purposes.
The main results show that with increase of Addicrete P the plastic limit increases and liquid limit decreases, hence decreases plasticity index and it is revealed that a change of expansive soil texture takes place when Addicrete P are mixed with expansive soil. While Addicrete BV does not effect on the Atterberg limits or the soil texture of the soil. As the amount of "Addicrete P and Addicrete BV" is increased, there are an apparent reduction in optimum moisture content ,unconfined compressive strength, free swell, swelling potential and swelling pressure, and a corresponding increase in maximum dry density.
The paper contains many important test results and these results were analyzed to establish optimum dosage levels for each of the treated additives. Based on the results obtained, it can be concluded that the expansive soil can be successfully improved by Addicrete P and Addicrete BV.

Keywords: Expansive soil, Swelling soil, Soil Stabilization, Addicrete P, Addicrete BV, clay minerals, swelling potential, swelling pressure.

1. Introduction

Expansive soils denote clayey soils that not only possess the tendency to swell or increase in volume but also to shrink or decrease in volume when the prevailing moisture condition is allowed to change. Such change of moisture content of these soils can emanate from rains, floods, or leakage of sewer lines.

The response of expansive soils in the form of swelling and shrinkage due to changes in water content is frequently expressed superficially as heaving and settlement of lightly loaded geotechnical structures such as pavements, railways, roadways, channel and foundations or reservoir linings. Expansive materials that exhibit swelling problems include bentonitic mudstones, marls and silty mudstones, argillaceous lime- stones and altered conglomerates. Consequently, expansive soils cause distress and damage to structures founded on them "Amer[1]".

The climate in Egypt is arid, with high evaporation rates, so that there is always a moisture deficiency in soils and rocks. Supply of water from any source is liable to cause ground heave in any soils or rocks possessing swelling potential. Danger of expansive soils seem to be overlooked during the design and construction of some projects. Problems

* Corresponding author.
Email: engaaa780@yahoo.com

associated with expansive soils in Egypt are predominantly related to the presence of montmorillonite clay minerals in soils. As a result, some of structures in New Sohag City were subjected to distress and damage and in worst cases some building were demolished.

Extensive studies have been carried out on the stabilization of expansive soils using various additives such as lime, cement, fly ash, industrial waste products and Polypropylene Fiber [2–40]. However, the literature indicates minimal studies on the stabilization of expansive soils in Egypt. Therefore, this study was carried out to add new additives available commercially.

Lime is widely used in civil engineering applications. "Mohamed[2], Basma[3], Sherwood[4], Bell[5], Zhang[6], Amer[7], Arvind[8], Ilknur[9], AlMukhtar[10], Ramesh[11], Jagadish[12], Muzahim[13], Maria[14]" found that when lime is added to clay soils in the presence of water, a number of reactions occur leading to the improvement of soil properties. These reactions include cation exchange, flocculation and carbonation. The cation exchange takes place between the cations associated with the surfaces of the clay particles and calcium cation of the lime. The effect of cation exchange and attraction causes clay particles to become close to each other, forming floc; this process is called flocculation. Flocculation is primarily responsible for the modification of engineering properties of clay soils when treated with lime. Adding of lime significantly reduces the swelling potential, liquid limit, plasticity index and maximum dry density of the soil, and increases its optimum water content.

Cement stabilization is similar to that of lime and produces similar results. Cement stabilization develops from the cementitious links between the calcium silicate and aluminate hydration products and the soil particles. Add cement to clay soil reduces the liquid limit, plasticity index and swelling potential, also it causes increasing the shrinkage limit and shear strength "Sherwood[4], Amer[7], Croft[15], Amer[16]".

Fly ash produced in the combustion of coals exhibits self-cementing characteristics and can be used in a wide range of stabilization applications. Fly ash treatment can effectively reduce the swell potential of highly plastic clays and prevent the swell beneath the smaller foundation pressures. Laboratory test results on these soils indicate that fly ash is effective in improving the texture and plasticity of the fly ash treated soils by reducing the amount of clay size particles, plasticity index and the swell potential "Zhang[6], Amer[7], Arvind[8], Amer[16], Cokca[17], Zalihe[18], Ezekwesili[19], Vinay[20], Mallikarjuna[21], Mir[22]".

Fiber inclusions cause significant modification and improvement in the engineering behavior of soils. A number of research studies on fiber-reinforced soils have recently been carried out through triaxial tests, unconfined compression tests, CBR tests, direct shear tests, and tensile and flexural strength tests. One of the primary advantages of randomly distributed fibers is the absence of potential planes of weakness that can develop parallel to oriented reinforcement. (Andersland[23] ; Ranjan [23]; Mirzababaei[24]; Abd El Megeed[25]).

2. Experimental Program

2. 1. Materials

2. 1. 1. Natural soil

Swelling soil was obtained from Faculty of Veterinary Medicine at New Sohag City at a depth of 5 meters. Natural soil was greenish grey, very hard, laminated silty clay with traces of fine sand and calcareous matters. The ground water table was not being found. A test pit was excavated to obtain disturbed samples. Soil samples were transported to the Soil Mechanics Laboratory at Sohag University for preparation and testing. The physical and mechanical properties of the untreated soil are shown in Table 1. The geotechnical tests were performed in accordance with (Egyptian Code of Soil Mechanics and Foundation Design and Construction, 2009) [26]. Based on Casagrande plasticity chart, the soil was classified as a high plasticity inorganic clay (CVH). X ray diffraction analysis of clay minerals showed the presence of montmorillonite (73.7%), illite (5.3%) and kaolinite (21%). Properties of soil showed a plasticity index (39.7%) and an activity of 0.945. According to the Van der Merwe [14] classification system, the soil was classified as a high swelling soil.

2. 1. 2. Chemical additives

Where the clayey expansive soil is the basic component of the Cement and striking similarity in the properties. Therefore, this study was carried out to treated of expansive soils using additives (Addicrete P and Addicrete BV). Properties of Additives are given in Table 2.

2. 2. Laboratory tests

The soil was placed in an oven at 105 C0 for 24 hrs. The dry soil was pulverized to minus 40 sieve size. Then the soil was mixed with the additives at percentages 0.5%, 1% and 2% of unit weight of dry soil. Influence of additives on the geotechnical characteristics of expansive soil was investigated by conducting Atterberg Limits, standard Proctor compaction tests, unconfined compression tests, and swelling tests. The details of the tests performed are given in the following sections and the results of these tests are given in Table 3.

2. 2. 1. Atterberg limit tests

In the laboratory, Casagrande's apparatus has been used to determine liquid limit. The recorded values have been plotted on a semi-log scale and approximated as straight line. The water content corresponding to number of 25 has been considered to be the liquid limit (L.L) for the specific soil category under consideration. The plastic limit has been determined for each soil category. The plastic limit (P.L.) has been calculated as the average of three values of water contents for each soil category. For each soil category the plasticity index has been determined as the difference between the liquid limit and plastic limit. This index together with its liquid limit has been plotted on the A-line chart for each soil category [26].

2. 2. 2. Compaction test

The test was used to determine the optimum moisture content of the soil corresponding to a maximum dry unit weight condition. For each soil category, five soil samples with different water contents have been prepared and compacted according to the standard compaction test.

Table 1.
Properties of Natural Soil.

Properties	Values	Properties	Values
Natural water content (%)	3.4	pH	8.9
Field dry unit weight (t/m3)	2.05	"L.L%"	70.7
Specific gravity	2.69	"P.L%"	31
Passing No. 200 sieve (%)	90	"P.I%"	39.7
Clay content (≤ 2 μm) (%)	42	"O.M.C %"	16
Clay activity	0.945	"γd_{max}" (t/m^3)	1.522
Unified Soil Classification	CVH	UCS (kg/cm2)	6.035
Montmorillonite (%)	73.7	"F.S%"	185
Illite (%)	5.3	Swelling Potential (%)	40
Kaolinite (%)	21	Swelling Pressure (kg/cm2)	3.95

Table 2.
Characteristics of Additives.

Properties	ADDICRETE P	ADDICRETE BV
Field Of Use	Lime Replacer, Mortar Plasticizer	Water reducing and plasticizer concrete admixture
Advantages	• Entrains a controlled amount of microscopic air bubbles which act as frictionless aggregate in the mortar and reduces the amount of water required to give a specific consistency. • Permits saving in cement content and minimize the risk of cracking and crazing of plastering. • Improves moisture retention and bond properties of the mortar and minimizes the risk of separation of plastering from wall surfaces. • Produces mortars highly resistant to disruption caused	• Improves workability, with easier and quicker placing and compaction. • Provides a higher strength without increase of cement content or reduction of workability. • It improves the quality, the density and appearance of concrete, It improves durability and surface finishes. • It produces higher cohesion. Risk of segregation and bleeding are minimized Without reduction in the water content, it increases the slump and significantly improves concrete-flow characteristics.

Properties	ADDICRETE P	ADDICRETE BV
Field Of Use	Lime Replacer, Mortar Plasticizer	Water reducing and plasticizer concrete admixture
	by ground moisture capillary action. • Eliminates use of lime, saving storage space and plastering failures due to unsound lime.	• Easier low pumping pressures, which prevent clogging and reduce friction in the pipeline. • It increases durability and resistance of concrete to attack by aggressive agents.
Appearance	Light brown Liquid	Brown liquid.
Density	1.01 ± 0.01 kg/lit.	1.18±0.01 kg/lit.

2. 2. 3. Unconfined compressive test

Unconfined compression test was carried out on soil specimens. The natural and treated soil were compacted at optimum moisture content and maximum dry density at standard compression test. From molds, specimens of 38.1 mm diameter and 76.2 mm long were extracted and stored in desiccators at room temperature for curing. Samples were tested after 3 days of curing. The unconfined compressive strength was determined at a loading rate of 1.00 mm/min[26].

2. 2. 4. Swelling tests

2. 2. 4. 1. Free swelling test

According to the free swell method, an initial volume(Vi) of 10 cm3 of dry soil passing sieve No.40 has been poured into a 100 cm3 graduate cylinder filled with water. The volume of the swelled soil (Vf) after 24 hours has been recorded from the graduation of the cylinder. The percentage of free swelling (F.S.) has been calculated as following:

F.S. =(Vf-Vi)/Vi ………………………………………………….. [26]

2. 2. 4. 2. Pre-swelled swelling test

The standard oedometer was used to measure swelling potential and swelling pressure. Swelling potential has been used to describe the ability of a soil to swell in terms of volume change, and it is defined as the ratio of increase in height to the original height due to an increase in moisture content. Swelling pressure is designated as the pressure required to return sample to its original volume[26].

3. Results and analysis

Results of the standard compaction Proctor tests, Atterberg limits and swelling tests with the natural and with additives states of the clay samples are shown in Table 3.

Table 3.
Properties of natural and treated soil.

Characteristics	**Natural**	**0.5% P**	**1.0% P**	**2.0% P**	**0.5% BV**	**1.0% BV**	**2.0% BV**
"L.L%"	70.7	64	60.7	60.5	70.5	70	70
"P.L%"	31	31.5	32.5	33.5	35.7	34.5	34.5
"P.I%"	39.7	32.5	28.2	27	34.8	35.5	35.5
Unified Soil Classification	VHC	CH-MH	MH	MH	MVH	MVH	MVH
"γd_{max}" (t/m^3)	1.522	1.529	1.540	1.544	1.577	1.621	1.629
"O.M.C %"	16.0	14.0	13.2	12.4	15.2	14.4	13.2
"UCS" (kg/cm2)	6.035	5.048	3.651	2.872	4.149	3.050	2.703
"F.S%"	185	150	100	90	165	120	110
Swelling Potential%	40.0	36.4	21.2	18.6	35.1	18.6	18.2
Swelling Pressure (kg/cm^2)	3.95	3.71	3.55	3.55	3.55	3.39	3.31

3. 1. Atterberg limits

The soil texture, liquid limit, plastic limit and plasticity index of the untreated and treated samples with Addicrete P and Addicrete BV are shown in Figs. 4, 5 ,6 and 7. The results of the Atterberg limits tests on the soil samples in natural state and when mixed with varying percentages of Addicrete P show that there is a decrease in both liquid limit and plasticity index and an increase in plastic limit with increasing Addicrete P content. But for Addicrete BV, there is approximately unchanged in liquid limit, plastic limit or plasticity index.

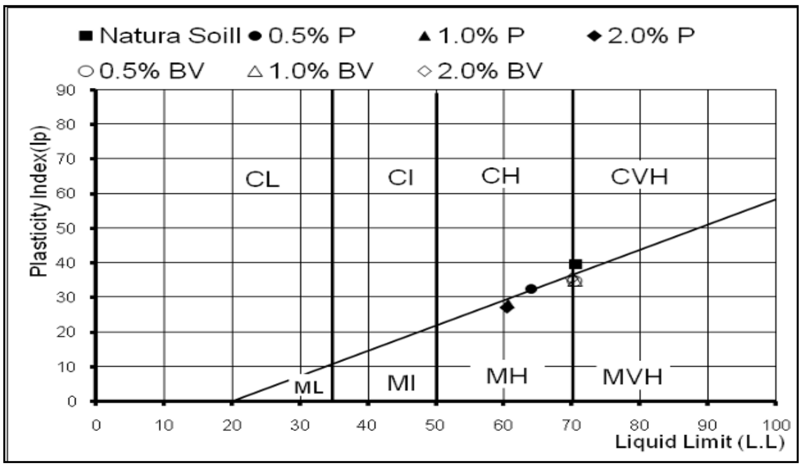

Fig. 4. Effect of additives on soil texture.

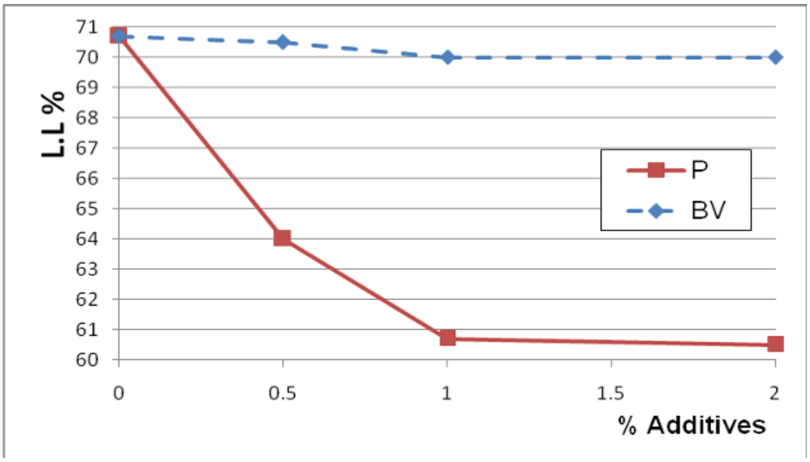

Fig. 5. Effect of additives on liquid limit.

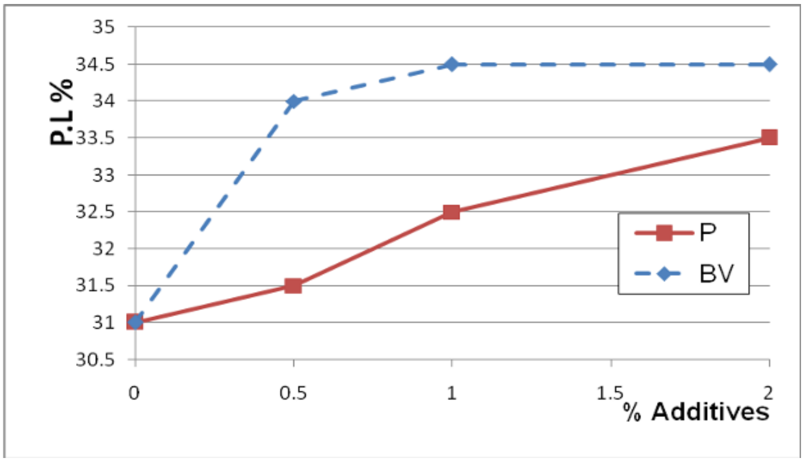

Fig. 6. Effect of additives on plastic limit.

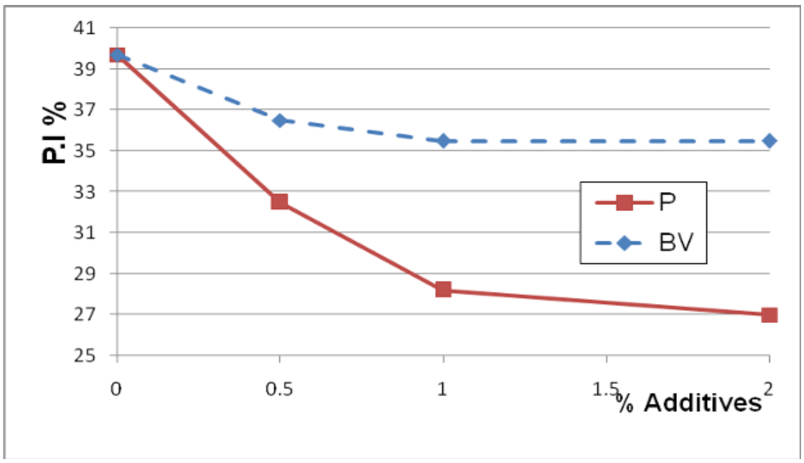

Fig. 7. Effect of additives on plasticity index.

3. 2. Compaction characteristics

Figs. 8 and Figs. 9 show the relation between maximum dry density and optimum moisture content. From the figures, It is observed that the compaction curve is shifted upward and toward the left with increasing additives. The maximum dry density and optimum moisture content values with different Addicrete P and Addicrete BV contents are illustrated graphically in Figs. 10 and 11. The addition of Addicrete P and Addicrete BV caused an increase in γd max and a decrease in OMC. The rate of increase in density of soil treated with Addicrete BV is greater than Addicrete P. However, the rate of decrease in optimum moisture content of soil treated with Addicrete P is greater than Addicrete BV. Also it's found that the rate of increase in density and decrease in optimum moisture content has reduced with increase percentage of additives.

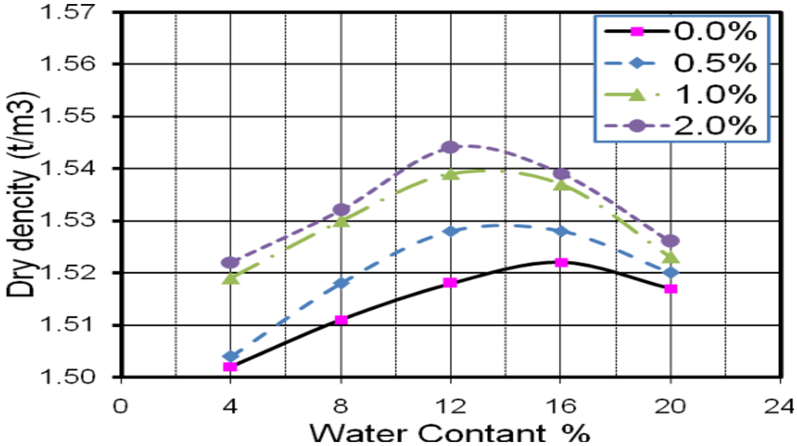

Fig. 8. Effect of Addicrete P on the compaction.

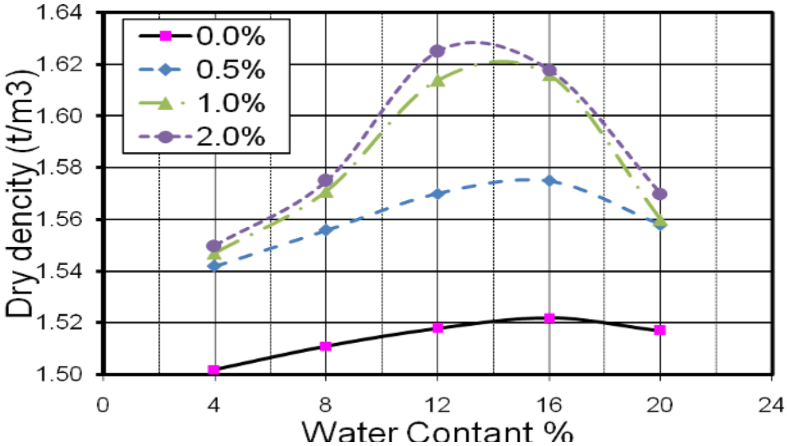

Fig. 9. Effect of Addicrete BVon the compaction.

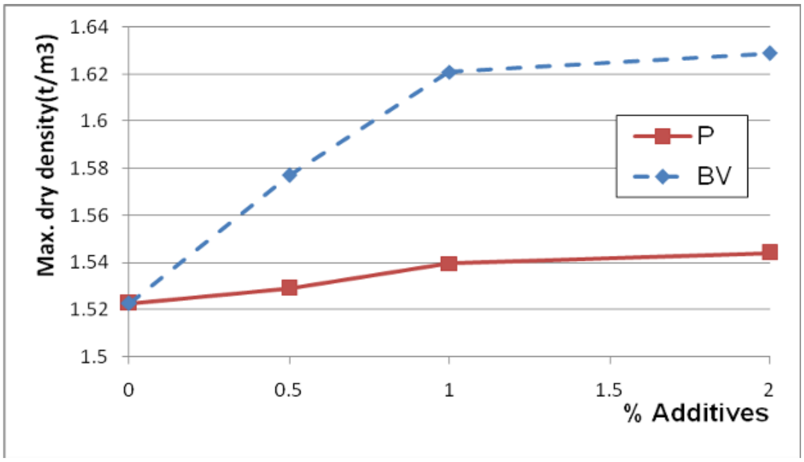

Fig. 10. Effect of additives on max dry density.

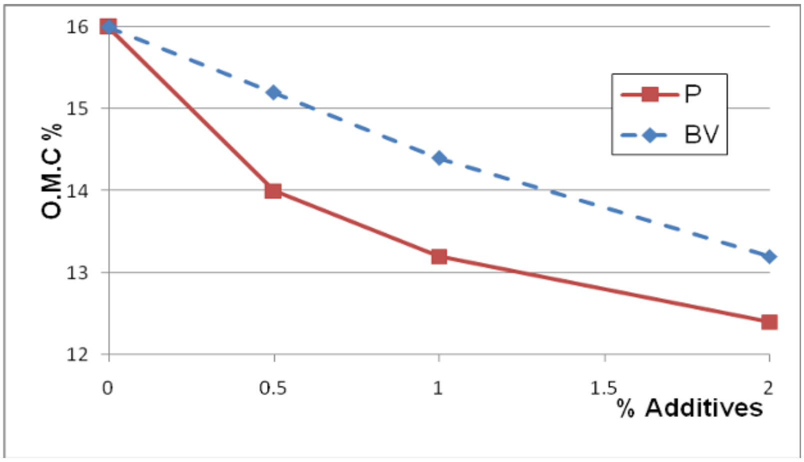

Fig. 11. Effect of additives on optimum water content.

3. 3. Unconfined compressive strength (UCS)

The relation between unconfined compressive strength and the percentages of additives are illustrated in Fig. 12. From the figure, It can be seen that the unconfined compressive strength of treated soil decrease with increase additives percentage. The rate of reduction in unconfined compressive strength is great up to 1.0% additive then this reduction is decrease. Also it's found that the reduction of cohesion with using Addicrete BV is greater than the reduction of cohesion with using Addicrete P.

3. 4. Swelling characteristics

3. 4. 1. Free swelling

The free swell values for the expansive soil decrease as mixed with additives. The rate of reduction in free swelling is great up to 1.0% additive then approximately the additive hasn't effect. Also it's found that the rate of reduction of free swelling due to using of Addicrete P is greater than using of Addicrete BV (as shown in Fig.13).

3. 4. 2. Swelling potential and swelling pressure

The swelling potential and swelling pressure values for the expansive soil decrease as mixed with additives. The rate of reduction in swelling potential and swelling pressure is great up to 0.5% additive then the rate of reduction is decrease. Also it's found that the reduction of cohesion due to using of Addicrete BV is greater than using of Addicrete P (as shown in Fig.14, 15).

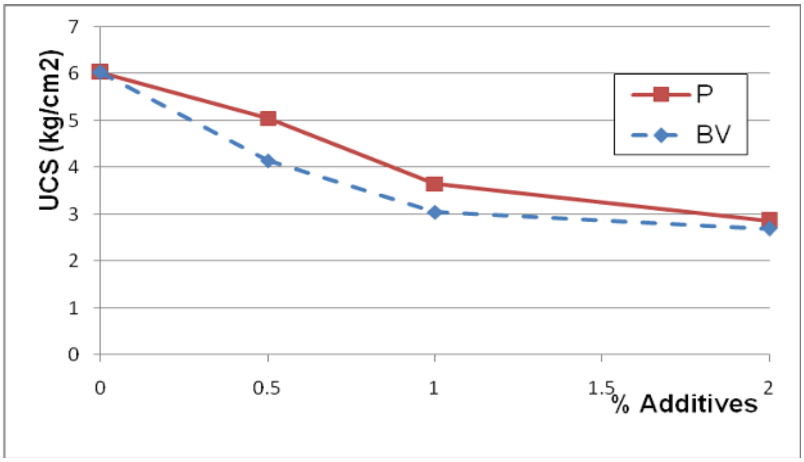

Fig. 12. Effect of additives on unc. comp. strength.

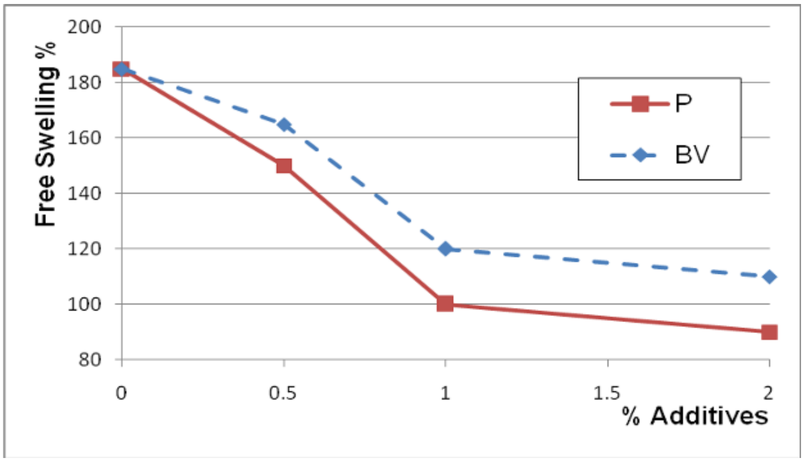

Fig. 13. Effect of additives on free swelling.

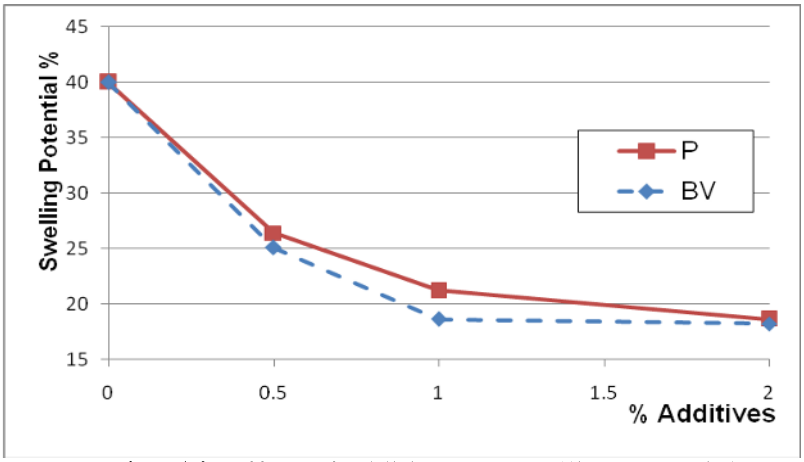

Fig. 14. Effect of additives on swelling potential

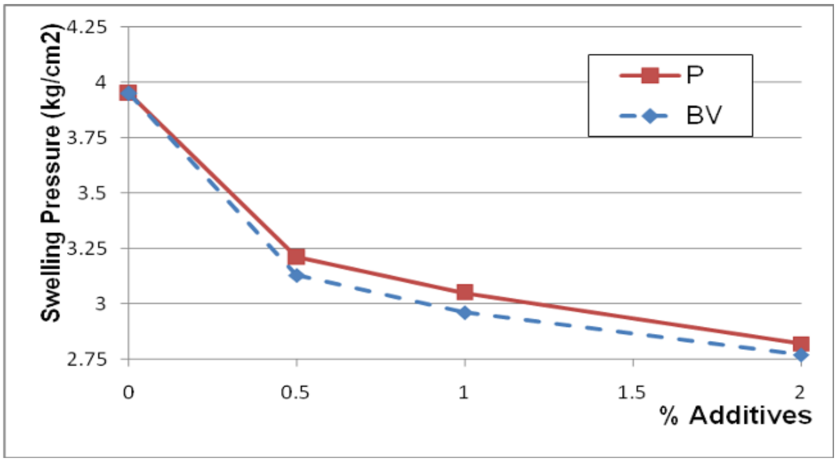

Fig. 15. Effect of additives on swelling pressure.

4. Conclusions

Based on the test results and the above analysis, It can be concluded that:

1. The liquid limit and plasticity index of expansive soil decrease, and the plastic limit of expansive soil increases with increase rate of Addicrete P. However, there is approximately no change in liquid limit, plastic limit and plasticity index when adding Addicrete BV.
2. An increase in $\gamma_{d\ max}$ and a decrease in O.M.C. can be happened on expansive soil with adding of Addicrete P and Addicrete BV. Note that adding Addicrete BV is more effective to increase the density of soil than adding Addicrete P. On the other hand, adding Addicrete P is more effective in decreasing optimum moisture content of soil than adding Addicrete BV.

3. The rate of unconfined compressive strength of soil decreases with increasing in additives percentage up to 1% additive, then this reduction is decreases.
4. Swelling values (free swelling, swelling potential and swelling pressure) of the expansive soil decrease when the soil is treated with additives. The rate of decrease is great up to 0.5% additives, then the reduction approximately be constant.
5. From the results of the present study, Addicrete P and Addicrete BV can be used to be a good stabilizers of expansive clay soil.

5. Notation

pH = power of hydrogen, L.L.= liquid limit, P.L.= plastic limit, P.I.= plasticity index, γd max = maximum dry density, O.M.C.=optimum moisture content, UCS=unconfined compressive strength, C=cohesion, F.S.=free swelling.

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معالجة التربة الانتفاخية بإضافات كيميائية

الملخص العربى

التربة الانتفاخية توجد في مناطق عديدة بمصر وخاصة في المدن الجديدة ومنها مدينة سوهاج الجديدة. ولهذه الدراسة، تم الحصول علي كميات من التربة الانتفاخية من أسفل اساسات كلية الطب البيطري بجامعة سوهاج الجديد على عمق 5 أمتار وتم نقلها إلي معمل ميكانيكا التربة والأساسات بكلية الهندسة جامعة سوهاج وحفظت بطريقة فنية لحين استخدامها في البرنامج العملي. تم إجراء الاختبارات المعملية وذلك لتعيين الخواص الفيزيائية والميكانيكية للتربة الانتفاخية بحالتها الطبيعية وكذلك للتربة بعد إضافة بعض المواد الكيميائية وهي أديكريت بي وأديكريت بي في عند نسب 0.5٪ و 1.0٪ و 2.0٪ من وزن التربة الجاف.

ومن أهم النتائج التي تم الحصول عليها من هذا البحث كالأتي:

1- يحدث زيادة أقصي كثافة جافة للتربة الانتفاخية ونقص في محتوي الرطوبة الأمثل لها مع زيادة نسبة إضافة "أديكريت بي" و"أديكريت بي في".

2- يحدث نقص في كلا من حد السيولة و مجال اللدونة وزيادة في حد اللدونة عند إضافة "أديكريت بي" للتربة بينما لا يحدث تغيير يذكر في تلك الخواص عند إضافة "اديكريت بي في".

3- يحدث نقص في نسبة الانتفاخ الحر و نسبة الانتفاخ وضغط الانتفاخ عند إضافة كلا من "أديكريت بي" و"اديكريت بي في".

4- يقل قيمة الضغط العير محاط للتربة مع زيادة نسبة المواد المضافة سواء أديكريت بي أو أديكريت بي في.

5- نستنتج من النتائج انه يمكن استخدام تلك المواد الكيمائية المقللة للنفاذيه و الانكماش سواء "أديكريت بي" أو "أديكريت بي في" في تحسين خواص التربة الانتفاخية بحيث تعطي نتاج مرضية .