Reduction of Swelling Potential of an Expansive Soil Treated By a Synthetic Plaster

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Abstract: This study presents an experimental investigation of the expansive soil behaviour before and after treatment. To represent the behaviour of expansive soil, a mixture between natural soil and bentonite of 1:1 was adopted. A synthetic plaster was used to improve the geotechnical properties of the tested soil. It is normally used as an adhesive for pasting tiles. A series of tests were conducted for original soil and soil-additive mixtures to detect the effect and efficiency of synthetic plaster on the geotechnical properties of the soil. Different contents of (0, 2.5, 5.0, 7.5, 10.0) % by dry unit weight of soil were used. Compaction, Atterberge limits and swelling potential tests were conducted for untreated and treated soil. The results show that considerable decrease in plasticity index for treated soil compared with the original soil. The maximum dry density increased with increasing the additive contents up to 5.0 % and then decreased. In contrast, the optimum moisture content experienced decreased up to additive content of 5.0 % and then increased. A significant reduction in swelling potential from 170 % to reach 68 % for treated soil by 10% additive. Moreover, the swelling pressure shows a reduction from 143 kPa for untreated soil to a value of 84 kPa for the same previous soil mixture.

Keywords: Expansive soil, Swelling potential, Swelling pressure, Synthetic plaster, Soil improvement

1. Introduction

Some structures face several problems when become in direct contact with clay soils. These problems in clay soils developed as a result of volume changes and susceptibility of strength to moisture content. Moreover, the ability to swell is a prominent phenomenon in clayey soils more than in other soils. High swell potential soils are called ‘expansive soils’. When they absorb water, they increase in volume and swell. But when dry, their volume is reduced and shrink [1].

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Generally, many reasons are there behind volume change in clayey soils. One is because of specific behaviour and a well-known phenomenon, termed consolidation which results from the expulsion of pore water from the voids upon static surcharge. During drying, volume change also happens due to the shrinking of clayey soils [2-5].

In another state, the volume of clayey soils increases due to swelling, "the tendency for volume to increase because of the moisture". As moisture penetrates into the clay, the spaces between clay mineral sheets are filled by water molecules which push them apart, this is the reason behind the pressure of swelling [6].

The phenomenon of volume change in the clayey soils causes swelling or shrinkage which are often large enough to make several defects to highway pavements and small buildings (i.e. light weight buildings). These defects take place as a result of heave in the soil beneath the structures (when swelled), or, on the other hand, a shrinkage in the volume of soil which induced decreasing in the bearing capacity and settlement of structures. Fears began with changing moisture content due to seasonal variation or occasional accidents such as leakage from drains or water supply pipes. Any of these reasons of moisture change induced swelling or shrinkage of clayey soil. Lifting or heaving of structures is prospected due to swelling pressure. On the other hand, differential settlement is foreseeable due to shrinkage. The structural damage would be more serious in the case of unevenly volume change beneath the foundation (i.e. some difference in swelling or shrinkage between the center of a foundation and its edges) [7,8]. So, the reduction of volume change of expansive soil is one of the important measures for geotechnical engineers. This problem could be treated by using different techniques such as calcium-based additives, stone columns, sand columns and geofiber.. etc. [9-12]. The calcium-based additives have some disadvantages. The disadvantages during the process of production involve high energy consumption and relatively high CO_2 emission which has negative environmental impact. Hence, it is needed to minimize the use of such materials. This work involves an examination of the ability of synthetic Plaster as an additive for the improvement of expansive soils. This material (synthetic Plaster) involves partially replacement of Portland cement by polymer and very fine quartz.

2. Materials

2.1. Soil Used

In order to represent the behaviour of expansive soil, a mixture of bentonite and natural soil of 1:1 was used. As result of the XRD test for the bentonite shown in

Figure (1), the bentonite is classified as sodium bentonite [13] The physical properties of the tested soil are given in Table (1).

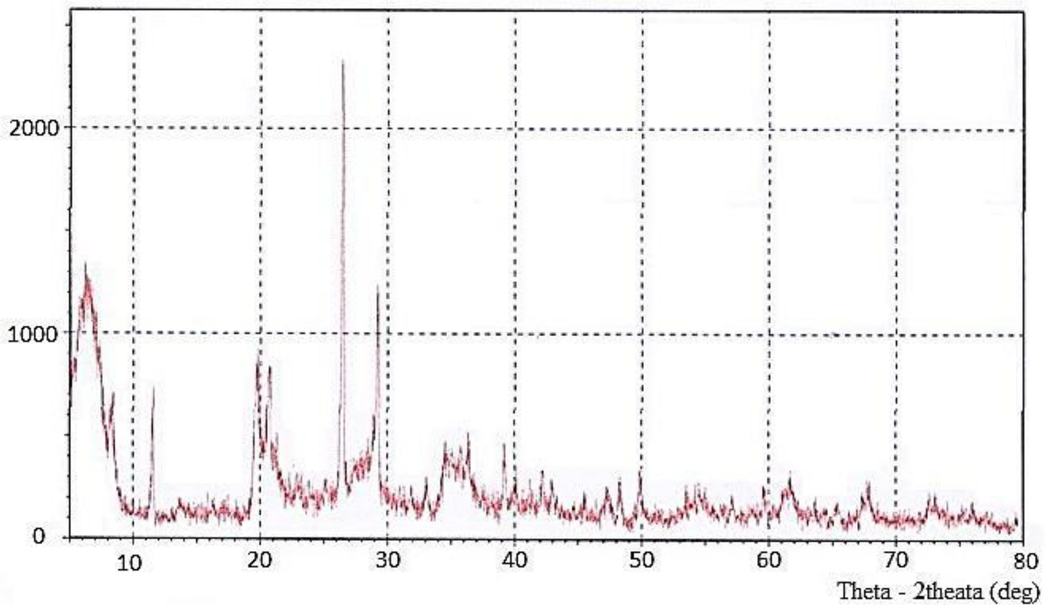

Figure 1: XRD test for Bentonite

Table 1: Physical properties of tested soil

Property	Value
Liquid Limit (L.L) %	103
Plasticity Index (P.I) %	54
Specific Gravity (Gs)	2.74
Activity	0.76
% gravel	0
% sand	11
% silt	18
% clay	71
Unified Soil Classification System USCS	CH
Optimum Water Content (OWC) %	23
Maximum Dry Density (MDD) (gm/cm^3)	1.43

2.2. Synthetic Plaster

A synthetic plaster was used as an additive for soil treatment. It is white in colour and consists of very fine powder. According to the manufacturer label, the main composition is Portland cement, quartz, and polymer. Figure 2 shows the plaster used.

Figure 2: Synthetic plaster

3. Specimens Preparation and Tests Program

The methodology of current research involves the preparation of five different specimens. These specimens are a soil-plaster mixture with plaster content of (0, 2.5, 5.0, 7.5, and 10.0) % by dry weight of soil. Optimum water content (OWC) and maximum dry density (MDD) for original soil were used to prepare the samples for the swelling test. A mellowing time of 24 hours at room conditions was adopted for all samples in this study. Sealed plastic bags were used for keeping the soil-plaster mixtures over the mentioned mellowing period to reduce water losses due to evaporation.

Liquid limit (L.L) and plastic limit (P.L) tests were performed according to ASTM D 4318. Initially, (L.L, P.L, P.I) are calculated to the original soil sample and then compare with soil-plaster mixtures. A Standard Proctor compaction test was carried out for all soil samples. ASTM D 698 - Standard Test Methods were adopted for this test.

The free swelling test was conducted for untreated and treated soil samples. The odometer device was employed for this test according to the ASTM D4546 specification. Untreated and treated soil is prepared at the OWC calculated by the proctor test (OWC untreated soil =23%) and curing time for all treated samples. The samples are submitted to full saturation and recording the dial gauge reading at 24hr during the saturation process. When the dial gauge reading is constant, this means the volumetric change is stable during the process of saturation. After that, the swelling potential is calculated. Then the same sample is loaded and read every 24 hours. The load that makes the sample return to origin is the swelling pressure.

4. Results and Discussion

4.1. Results of Compaction Tests

The maximum dry density MDD of treated soil experienced growth compared with untreated soil. This growth can be observed for soil-plaster mixtures of 2.5, 5.0, and 7.5%. While the soil-10.0% plaster mixture possesses MDD less than that of the original soil, this change may be related to the flocculation and agglomeration of soil particles when adding the plaster. The curve shows the reduction in MDD as shown in Figure (4).

Regarding the optimum water content OWC, it is clear that the OWC decreased for 2.5 and 5% mixtures compared with untreated soil. Whereas, it increased dramatically for 7.5 and 10% mixtures as presented in Figure (5). This deviation in the behavior of 7.5% and 10.0% mixtures may be related to the same reason mentioned above (flocculation and agglomeration of soil). Where the particles of soil-plaster mixtures of 7.5% and 10.0% became coarser than that of 2.5% and 5.0% plaster. The flocculation- agglomeration of soil particles can be shown in the Figure (6).

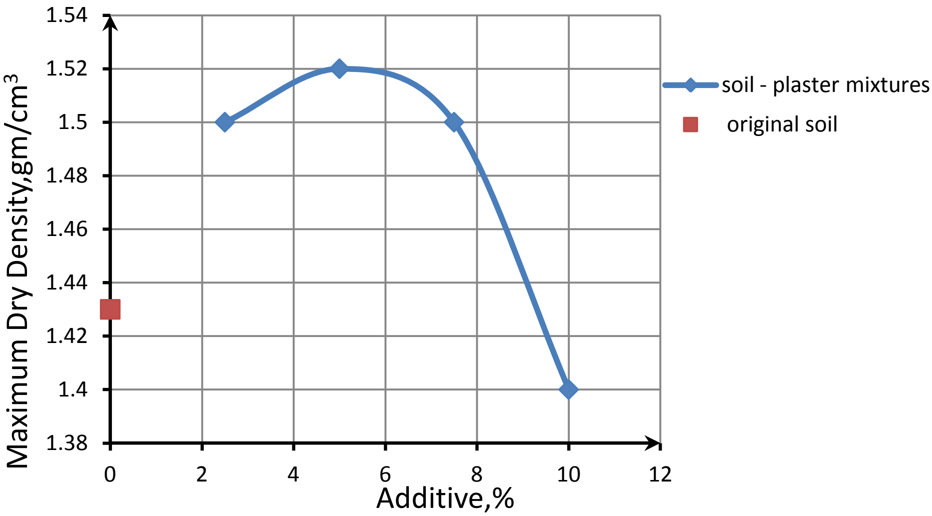

Figure 4: Variation of MDD with percent of the additive

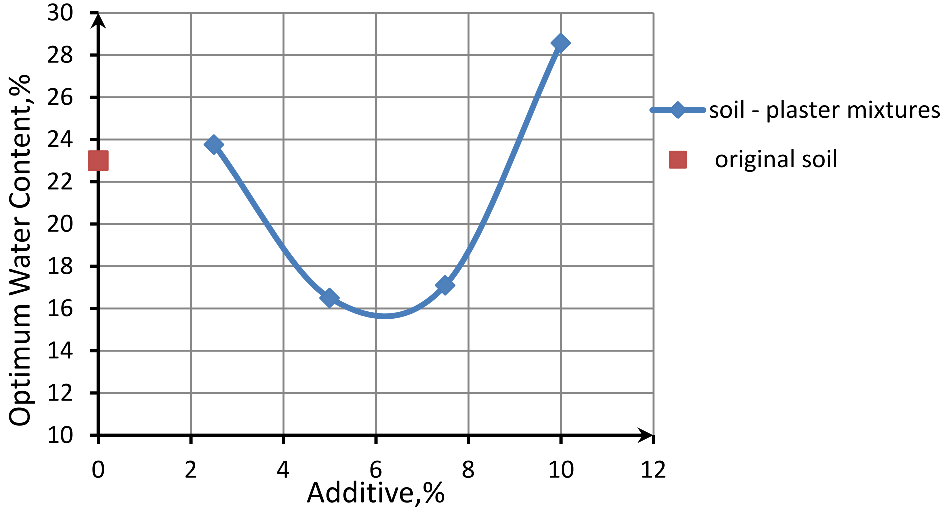

Figure 5: Variation of OMC with percent of additive

Figure 6: Agglomeration process

4.2. Results of Atterberg Limits

Figure (7) shows the results of L.L, P.L& P.I. It can be noticed that L.L decreased significantly with increasing plaster dosages. The value of L.L is 103 % for untreated soil which decreased gradually to reach a value of about 79% in the case of 10.0 % stabilizer. On the other hand, P.L increased progressively with plaster contents to change from 49% for the virgin soil to reach 59% for the mixture of 10.0% plaster. A considerable decline in PI can be seen with increasing the percentage of additives. Where, the value of PI of (54%) in the case of original soil decreased to 46%, 41%, 33% and 21% for soil- plaster mixtures of 2.5%, 5.0%, 7.5% and 10.0%, respectively. These results of P.I reduction indicate that the behaviour of soil changed from very high swelling to medium or low swelling soil based on the classification stated by Williams and Donalson [14].

4.3. Results of Swelling Potential

As per the results shown in Figure (8), the swelling potential of the original soil is (170%). The swelling potential experienced a considerable reduction in the case of treated soil. Where it decreased with increasing the percentages of additive. The swelling potential is lowered to around 105, 90, 79, and 65% for plaster content of 2.5%, 5.0%, 7.5% and 10.0%, respectively.

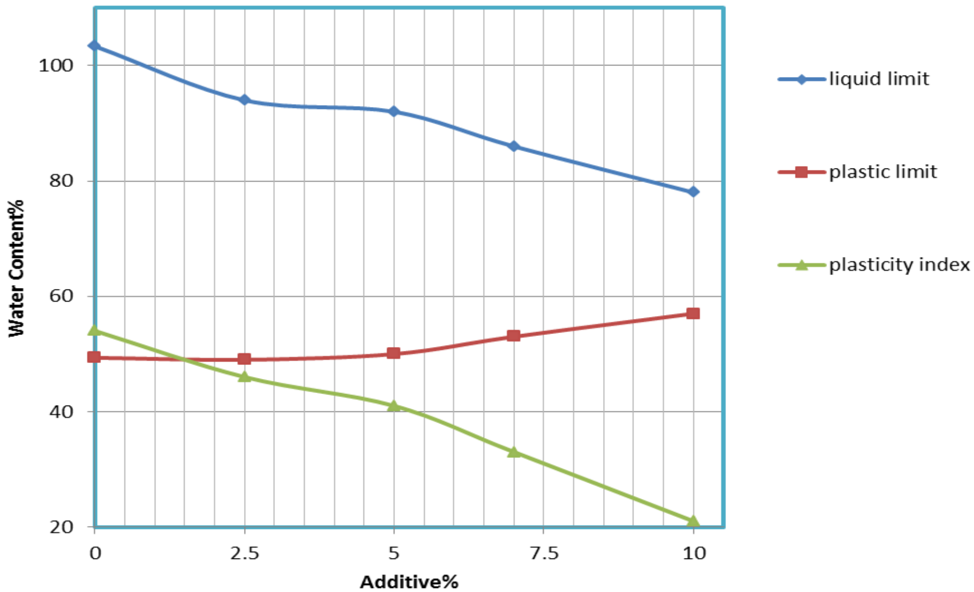

Figure 7: Results of Atterberg limits (P.I, L.L, and P.L)

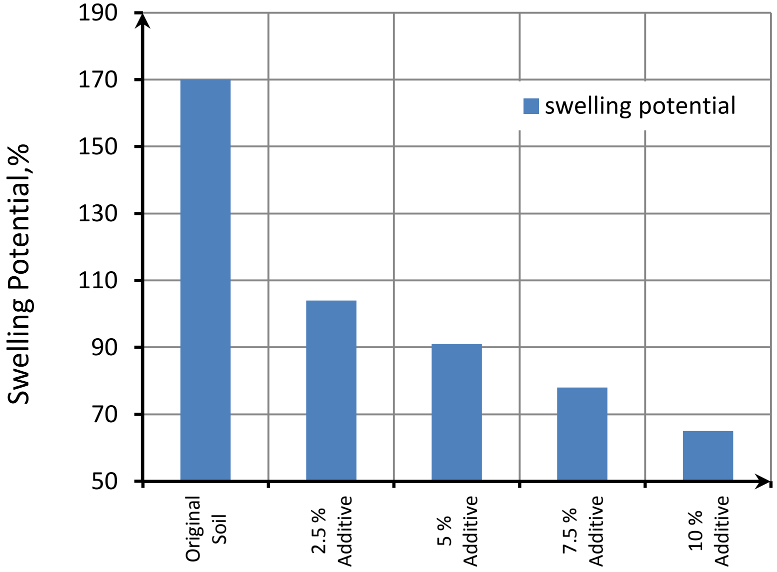

Figure 8: Swelling potential of treated and untreated soil

4.4. Results of Swelling Pressure

Generally, the swelling pressure shows a significant reduction for the treated soil compared with virgin soil as shown in figure 9. The results exhibited that the swelling pressure of virgin soil was more than 140 kPa. Whilst, values of (131, 102, 93, and 84) are the swelling pressure of soil-plaster mixtures of (2.5, 5, 7.5, and 10%) respectively.

5. Conclusions

Based on the obtained results, the following conclusions can be stated:

1. The maximum dry density increased with increasing the content of plaster up to 5% and then decreased. In contrast, the optimum water content decreased for soil-plaster mixtures of plaster content by up to 5% and then increased. Compared with the original soil, the OWC decreased for soil-plaster mixtures by (2.5-7.5) %. But, it increases for the mixture by 10% exceeding the OWC of the original soil.
2. Regarding the Atterberg limits, the plasticity index shows a significant reduction for treated soil compared with the original soil. It reduced from 54% for original soil for around 46%, 41%, 33%, and 21% for mixtures of 2.5%, 5%, 7.5%, and 10% of plaster respectively.

3. The results of swell potential test presented an important reduction in swelling potential. It reduced from 170% for original soil for around 104%, 91%, 78%, and 65% for mixtures of 2.5%, 5%, 7.5%, and 10% of plaster respectively.
4. A considerable reduction in swelling pressure can be seen for treated soil compared to the original soil. Where the pressure was reduced by a percentage of 70%. It reduced from 143kPa for original soil to around 131 kPa, 102 kPa, 93 kPa, and 84 kPa for mixtures of 2.5%, 5%, 7.5%, and 10% of plaster respectively.
5. The stabilizer used in this study shows high efficiency in improvement the engineering behaviour of expansive soil where the swelling pressure and swelling potential experienced a considerable reduction.

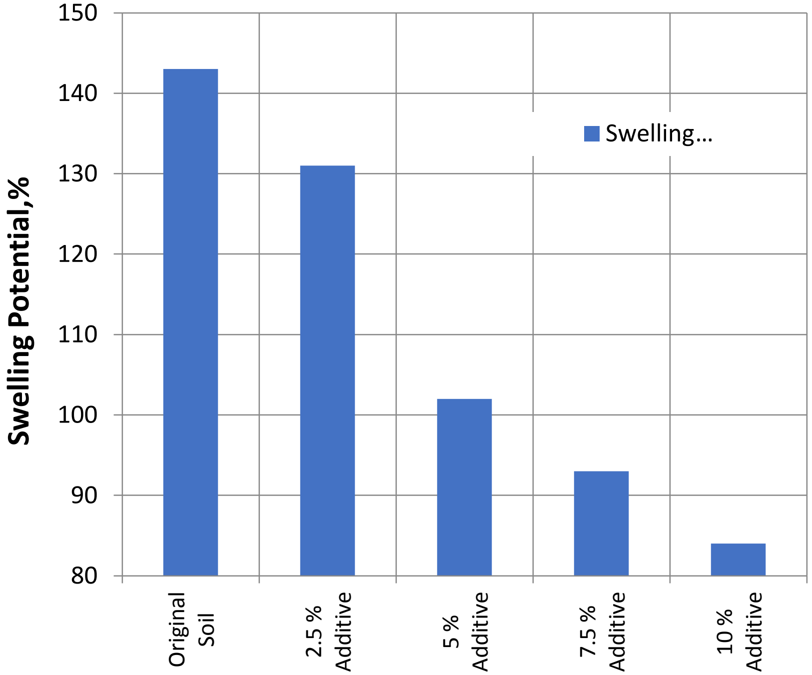

Figure 9: Swelling pressure of treated and untreated soil

6. References

[1] A. Dhowian, A. W., Erol, A. O. and Youssef, "Evaluation of Expansive Soils and Foundation Methodology in the Kingdom of Saudi Arabia Ed," 1990.

[2] C. M. Haberfield and I. W. Johnston, "Relationship between fracture toughness and tensile strength for geomaterials," 1989.

[3] J. Kodikara and S. Chakrabarti, "Modeling of moisture loss in cementitiously stabilized pavement materials," *Int. J. Geomech.*, vol. 5, no. 4, pp. 295–303, 2005.

[4] L. B. Hu, H. Péron, T. Hueckel, and L. Laloui, "Drying Shrinkage of Deformable Porous Media: Mechanisms Induced by the Fluid Removal," vol. 40901, no. October, pp. 1–10, 2007, doi: 10.1061/40901(220)17.

[5] C. Tang, B. Shi, C. Liu, L.-Z. Zhao, and B. Wang, "Influencing factors of geometrical structure of surface shrinkage cracks in clayey soils," *Eng. Geol.*, vol. 101, pp. 204–217, 2008.

[6] B. M. Das, *Geotechnical Engineering Handbook*. J. Ross Pub., 2010. [Online]. Available: https://books.google.iq/books?id=4HZMuJ4BBN4C

[7] and J. E. C. Samuels, S.G., "Long Term Heave of a Building on Clay Due to Tree Removal," *Proc. Conf. Settl. Struct.*, pp. 212–220, 1974, [Online]. Available: https://www.geplus.co.uk/download?ac=1423914

[8] J. D. Nelson and D. J. Miller, *Expansive soils: problems and practices in foundation and pavement engineering*. John Wiley & Sons Inc., 1992.

[9] A. E. M. K. Mohamed, "Improvement of swelling clay properties using hay fibers," *Constr. Build. Mater.*, vol. 38, no. 0, pp. 242–247, 2013, doi: http://dx.doi.org/10.1016/j.conbuildmat.2012.08.031.

[10] G. Stoltz, O. Cuisinier, and F. Masrouri, "Multi-scale analysis of the swelling and shrinkage of a lime-treated expansive clayey soil," *Appl. Clay Sci.*, vol. 61, pp. 44–51, 2012, doi: 10.1016/j.clay.2012.04.001.

[11] B. V. S. Viswanadham, B. R. Phanikumar, and R. V Mukherjee, "Swelling behaviour of a geofiber-reinforced expansive soil," *Geotext. Geomembranes*, vol. 27, no. 1, pp. 73–76, 2009, doi: http://dx.doi.org/10.1016/j.geotexmem.2008.06.002.

[12] Aparna, P. K. Jain, and R. Kumar, "Study of swelling behaviour

of black cotton soil improved with sand column," *Int. J. Adv. Eng. Technol.*, vol. 7, no. 3, pp. 905–910, 2014.

[13] C. Ureña, J. M. Azañón, F. Corpas, F. Nieto, C. León, and L. Pérez, "Magnesium hydroxide, seawater and olive mill wastewater to reduce swelling potential and plasticity of bentonite soil," *Constr. Build. Mater.*, vol. 45, no. 0, pp. 289–297, 2013, doi: http://dx.doi.org/10.1016/j.conbuildmat.2013.03.053.

[14] A. Williams and G. W. Donaldson, "Building on Expansive Soils in South Africa: 1973-1980," 1980.

الحد من جهد الانتفاخ للترب الانتفاخية المعالجة باللاصق الصناعي

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المستخلص: يقدم هذا البحث دراسة مختبريه حول سلوك التربة الانتفاخية قبل وبعد المعالجة. ولتمثيل سلوك التربة المنتفخة، تم تحضير التربة في المختبر بخلط التربة الطبيعية مع البنتونايت بنسبة 1:1 . البرنامج المختبري بدا بتصنيف التربة المحضرة بواسطة عدة فحوصات منها التحليل المنخلي والتحليل باستخدام المكثاف للإيجاد نسبة الحصى والرمل والغرين والطين بالإضافة الى حدود اتربرك (حد اللدونة وحد السيولة ومؤشر اللدونة). تم اعتماد فحص بروكتر القياسي لإيجاد الكثافة الجافة المختبرية والمحتوى الرطوبي الامثل للتربة الاصلية (بدون مضاف). استخدم جهاز هبوط الانضمام للإيجاد جهد الانتفاخ وضغط الانتفاخ للرتبة الاصلية. تم استخدام البلاستر الاصطناعي لتحسين الخصائص الهندسية للتربة المستخدمة في الدراسة .وهو يستخدم عادة كمادة لاصقة للبلاط .تم استخدام نسب مختلفة من المادة المضافة تراوحت بين 0، 2.5، 5.0، 7.5 ، 10.0 % من الوزن الجاف للتربة. تم اعادة الفحوصات أنفة الذكر للتربة بعد خلطها مع المضاف لكل نسبة من النسب المضافة. وقد لوحظ نقصان واضح بمؤشر اللدونة للتربة ويزدان النقصان بشكل متناسب مع نسبة المضاف وهذه النتيجة مؤشر واضح على التحسن بسلوك التربة من الناحية الانتفاخية . من جانب اخر فان التربة شهدت تزايدا تدريجيا بالكثافة الجافة العظمى مع نسبة المضاف لحد ما مقداره 5.0% بعدها تتناقص هذا الكثافة مع الزيادة بمحتوى المضاف. اما الرطوبة المثلى فعلى العكس من الكثافة فانها تتناقص مع زيادة محتوى المضاف لحد نسبة 5% وتزداد لاحقا مع زيادته. اظهرت النتائج انخفاض ا كبير ا في سلوك انتفاخ التربة المعالجة حيث ان جهد الانتفاخ انخفض بمقدار من 170% للتربة الغير معالجة ليصل الى 68% للتربة المعالجة بمحتوى مضاف مقداره 10% وكذلك ضغط الانتفاخ انخفض من 143 كيلوباسكال الى حوالي 84 كيلوباسكال لنفس نسبة المضافة انفة الذكر.

الكلمات المفتاحية: التربة الانتفاخية، جهد الانتفاخ ،ضغط الانتفاخ، اللاصق الصناعي، تحسين التربة

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