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Influence of Feldspar Addition on the Geotechnical Properties of Expansive Soil in Rahhaliya, Iraq

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ABSTRACT

The swelling soil's extension makes it necessary to build some structures on it, and most of the soils exist in unsaturated states. The expansive soil used in this study was obtained from Al-Rahhalyia city in Al-Anbar government, and this is pure clay (natural soil) that has a liquid limit (L.L.) of 69.8% and plasticity index (P.I.) of 21.47%. Feldspar-Soil (MFS) mixture includes several intensities (0, 5, 10, 15, and 20) %. The results of tests displayed significant improvement in the geotechnical properties of expansive soil, where the (L.L.) and (P.I.) decreased (7% to 15.6%) and (23.9 % to 39.3%) with increased (MFS) from 5% to 20%, respectively. Also, the free and pressure swelling of the soil is decreased by 9% and 21.6%, with increased (MFS) at 20%. Moreover, the Effect of (MFS) on an unconfined compression test was clear. Probable that soon, the civil engineering community have to produce structures in harmony with the idea of sustainable development through the use of high-performance resources with low environmental effects that are produced at a reasonable cost.

1. INTRODUCTION

All engineering facilities depend primarily for their stability and durability on the resistance of the soil to the loads imposed by these facilities [1]. Water is often an additional factor that affects soil, especially clay soil. Therefore, the properties of this soil must be improved [2]. The clay minerals such as montmorillonite, illite, and kaolin are considered the main constituents, which contain water in their crystalline structure. The clay minerals can adsorb certain anions and cations and retain them around the outside surface of plate particles clay in an exchangeable state. In Iraq, the expansive soil is the extent in the middle and west-north parts, destroying buildings, for example, schools, houses, and pavement [3].

A modified plasticity index (P.I.) is taken into account in the soil sample, not just the clay fraction, in the classification of swelling soils, provides a good indication of the actual value of plasticity of a soil used in engineering projects and removes discrepancies of sizes particles, this classification formed by the National House-Building Council [4], as shown in Table 1.

Table 1. Classification of shrink-swell clay soil

P.I. %	Volume Change Potential
>40%	High
20%-40%	Medium
20%-10%	Low

The expansive soil experiences a large change in volume when this soil adsorbs water or dries, and the volume change causes damage to the structures constructed on such soil [5, 6]. Many factors affect the features and the magnitude of expansion, such as the applied load, soil composition, dry density, and water content [7]. Also, feldspar has significant reactivation for the stabilization of soil just like the altered feldspar-chlorite and its ability in the gouges at hydrothermal conditions [8]. Thus, the swelling soil's extension makes it necessary to build some structures on it, and most of the soils exist in unsaturated states.

2. BACKGROUND LITERATURE

Sodium is essential to several materials silicate, such as rock, sodalite, micas, and feldspars of salts. Sodium salts are highly soluble in water [9]. The effect of salt components (NaCl, $CaCl_2$, … ,etc.) on L.L. was estimated for clayey soil and concluded that L.L. reduced with increasing the salt component [10]. The reduction in liquid limit and the plastic index was explained by increasing salt concentration in treatment water due to changes in water molecules [11].

Another study showed that increasing NaCl focus is interpreted as being due to a reduction in thickness of the double layer of swelling minerals between quasi-crystals; the double layer crystal surface is compacted with increasing NaCl concentrations so that the swelling can be decreased [12].

Another laboratory observations study showed that feldspar minerals can boost the expected injection-induced frictional strength and stability if subjected to seismicity that faults if devoid of chlorite alteration [13]. Furthermore, the result showed that in the plasticity test, the addition of feldspar to 30% in the swelling soil did not indicate a decrease in the potential of swelling; the potential for swelling became zero (0%) only if was additional feldspar to 55% by weight of the swelling soil [14]. At the same level, the cohesion value improved by increasing fly ash to 15%, then decreased. The influence of curing time on cohesion increased until 14 days, while cohesion was reduced at several contents of additional fly ash at the initial time. The improved internal friction angle with added fly ash in all samples is dependent on the curing time of the mix [15].

Moreover, adding waste glass powder (WGP) greatly decreased the swelling properties during the tested soil and improved the engineering characteristics. A maximum decline in swelling was displayed at a 20% addition of (WGP). Also, the liquid limit was reduced, but the Maximum Dry Unit Weight (MDD) and specific gravity increased by adding the optimal waste glass powder content [16]. Also, the soil's moisture content, plasticity, and swelling potential were reduced [17]. However, the unconfined compression test improved for the sample, the heave value decreased, and the increased pullout force of the screw pile fixed in the soil increased for total dissolve salt. NaCl acts as a bond between soil particles without adding materials or chemical solutions [18].

In summary, previous studies have spotlighted the important impact and the effect of feldspar on the characteristics of soil. The magnitude of this impact differs by several factors and situations. This study aims to inspect the physical and chemical influences tests for the feldspar metal on the expansive soil using Rahhaliya City as a case study.

3. MATERIAL PROPERTIES

The swelling soil in this state was taken from Al-Rahhalyia city in Al-Anbar Governorate. Al-Rahhalyia city is located south of Al-Ramadi city and west of Al-Razzaza lake. Figure 1 shows the Iraq country map and the study area.

Al-Rahaliyah City is positioned in Anbar Governorate in the Republic of Iraq. It is surrounded from four directions: in the north by the Euphrates River and the south by the vast Anbar desert, the Baghdad Governorate is surrounded at the east, and the west is found in the border areas with Syria and Jordan. It is characterized by its diverse terrain, where wide plains and high mountains combine. The height of the mountains in this region ranges from 500 to 1,000 meters above sea level, and small hills and plateaus give the area an amazing aesthetic view. Regarding the geographical location, Al-Rahaliya city is located between 33-34 degrees north latitude and between 42-43 degrees east longitude. A topographical description of this area helps to understand the geographical and geotechnical features. The understanding develops scientific research and investigation in the region. In the future, it will contribute to development and exploitation sustainably and effectively.

In this study 10g of soil passing through sieve number 4 was put in a glass tube 100mm^3 and added water to the tube. After 24 hours, the free swelling is recorded and compared with kerosene swelling. Figure 2 shows the swelling of soil.

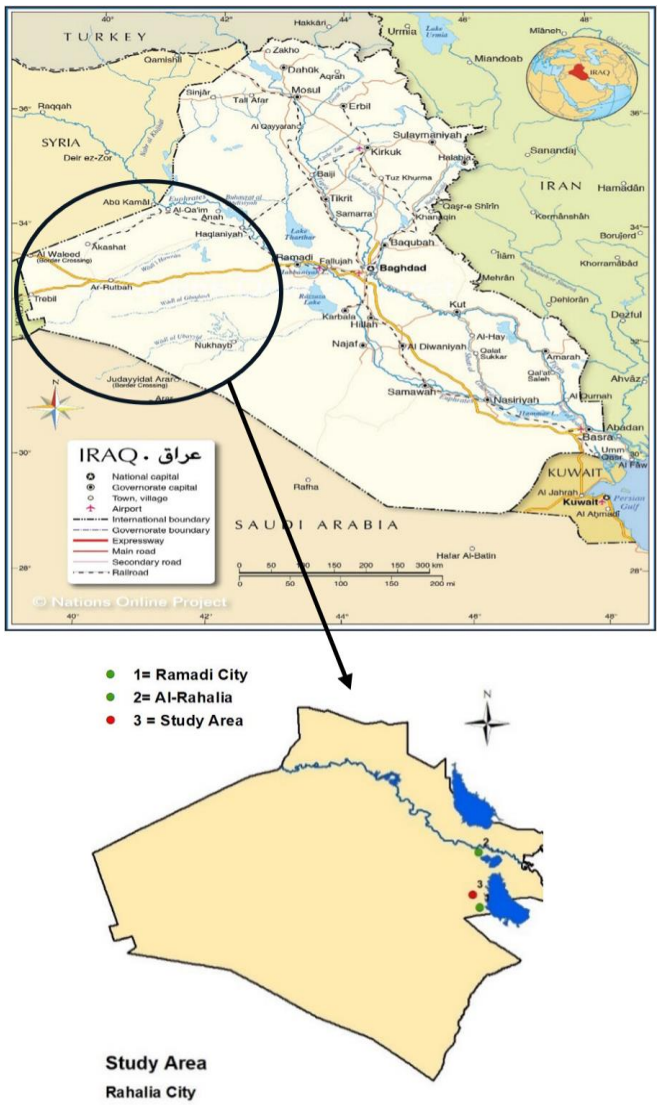

Figure 1. The study area map details

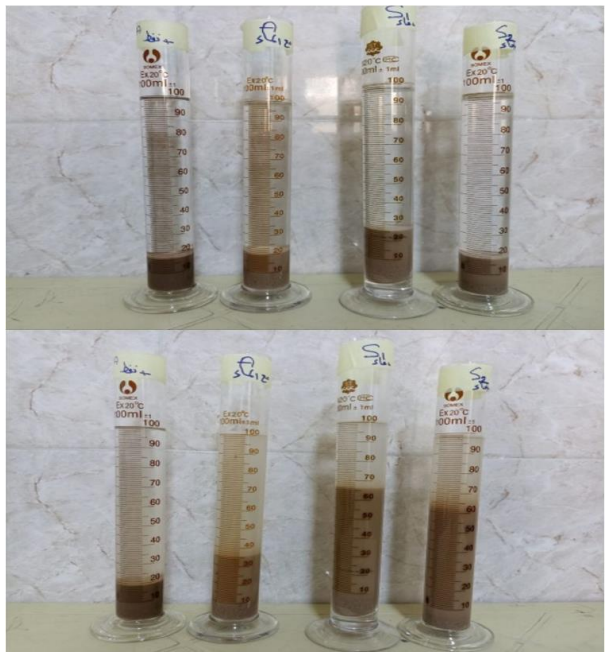

Figure 2. The swelling test of soil

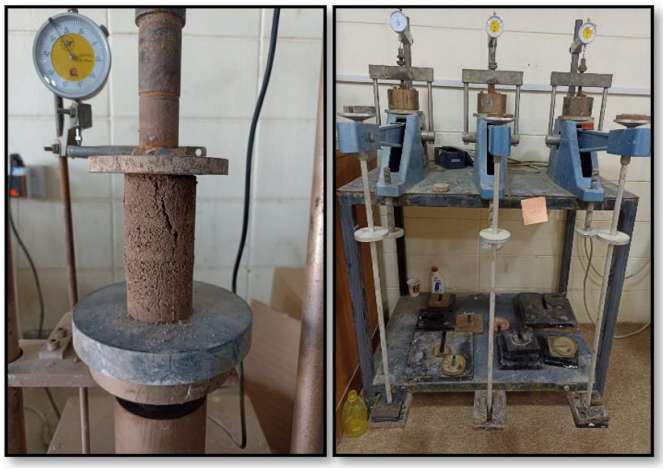

Figure 3. The pressure and uncofining swelling test of soil

Also, pressure and the unconfined swell test were carried out in this study. The soil sample was prepared according to the constant volume of soil at an approximate water content of 22% and dry density of 1.36g/cm^3. Figure 3 shows the shape of the test device to carry the pressure and unconfined swelling test.

3.1 The physical properties and chemical tests of soil

In this part, the physical and chemical characteristics are presented. The swelling soil samples were obtained from a depth of (0.5 to 1.5) meters under the natural ground surface. First, the physical properties of expansive soil measured in the study are the grain size distribution, standard proctor compaction test, specific gravity, and Atterberg's limits. The results of physical checks for soil samples are presented in Table 2 [19].

The chemical analyses were shown in order to adopt the percentages of Organic matter, gypsum, total soluble salts, sulfate (SO3), and pH for the swelling soil. The results of chemical tests on the expansive soil samples according to British Standard (BS-1377 part 2) are given in Table 3 [20].

Furthermore, the particle-size distribution curve is shown in Figure 4.

Table 2. The properties of swelling soil

Property	Value	Specification
Optimum moisture content (%)	22.0	ASTM D-1557
Maximum dry density (g/cm^3)	1.36	ASTM D-1557
Specific gravity	2.675	ASTM D-854
Void ratio	1.012	ASTM D-1557
L.L (%)	69.8	ASTM D-4318
P.L (%)	48.3	ASTM D-4318
P.I (%)	21.7	ASTM D-4318

Table 3. Summary of chemical test results conducted on soil used in the study

Property	Value
Sulfate content (SO_3)	4.43
Total soluble salts content, %	10.12
Organic matters content, %	1.4
Gypsum content, %	2.53
Chlorides, %	0.23
pH value	8.7

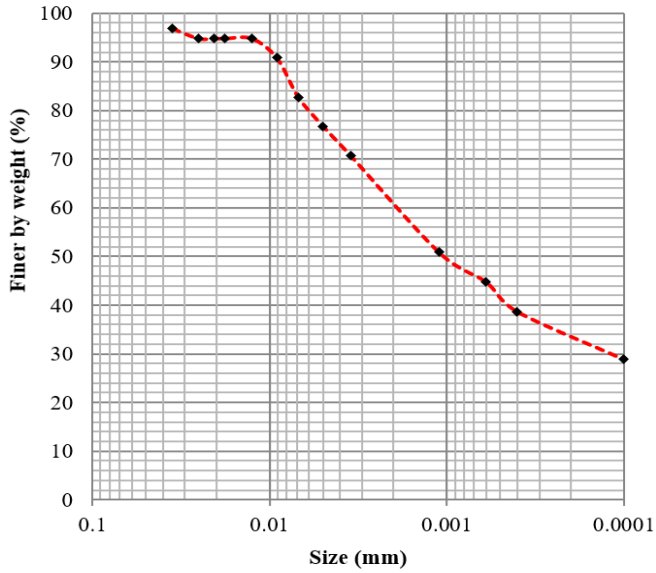

Figure 4. Grain size distribution for swelling soil

3.2 Feldspar

Feldspar was prepared in the state company for the class and refractions factory in Al-Ramadi city by crushing coarse raw material and sieving using sieve # 100. Feldspar has uniform particles with a diameter of 0.10mm fine feldspar. The specifications of the feldspar data are represented in Table 4.

Table 4. Properties of feldspar

Property	Value
SiO%	89
Fe_2O_3	1.95
Al_2O_3	3.8
K_2O	1.4
CaO	0.95
MgO	0.95
SO_3	0.8
Na_2O	1.15

4. RESULTS AND DISCUSSION

This part concentrates on feldspar's effect on the behavior of expansive soil. The percentages were 5%, 10%, 15%, and 20% of the fine feldspar added to clay soil. Then, these four Feldspar-Soil (MFS) mixtures were consistently mixed to reach the Atterberg Limit, free swelling, presser swelling, specific gravity, and unconfined tests.

4.1 Effect on Atterberg's limits

Atterberg limits were tested with various feldspar content, and the results are demonstrated in Figure 5. Increasing feldspar content reduces liquidity and Plastic limits, thereby decreasing the Plasticity Index.

The Atterberg limits decreased by 7% to 15.6% for liquid limit and 23.9% to 39.3% for plastic index soil treated by (MFS) of intensity 5% to 20%, respectively. The concentration of metals, silicate, and salts in feldspar increases due to decreasing the distance between the clay particles. The formation of feldspar decreases the available surface for contact with water, negatively reflecting Atterberg's limits.

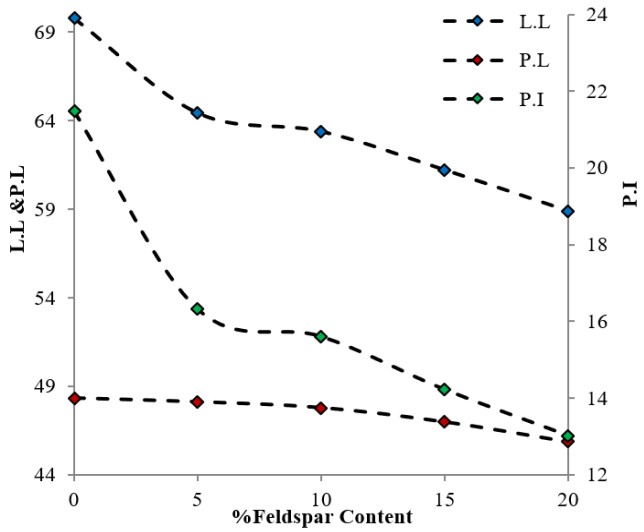

Figure 5. Relationship between consistency limits and (MFS)

4.2 Effect on free and pressure swelling test

In this part, 10g of soil passing through sieve number 4 (0.45mm) was placed in a glass tube (scale volume 100mm3) and was mixed with 100mm^3 of water to be added to the sample tube. Then, after 24 hours, the free swelling is recorded following the Bureau of Indian Standards (BIS), as shown in Figure 6 [21].

As shown in Figure 7, it is clear that the effects of increasing the feldspar would have a really huge impact on the free swelling. In fact, free swelling decreased by 28.7 to 9.9% for soil treated by (MFS) of intensity 5% to 20%, respectively.

The soil samples were prepared according to the constant volume of expansive soil at an approximate water content of 22% and dry density of 1.36g/cm^3 with used water. The swelling pressure decreased with increased feldspar intensity, as shown in Figure 4. The reduction in swelling pressure was from 2% to 21.6% for the soil samples treated with (MFS) of intensity 5% to 20%, respectively, which may be attributed to the increasing bonds between soil particles and seeping of salts and minerals in the voids of soil treated with feldspar.

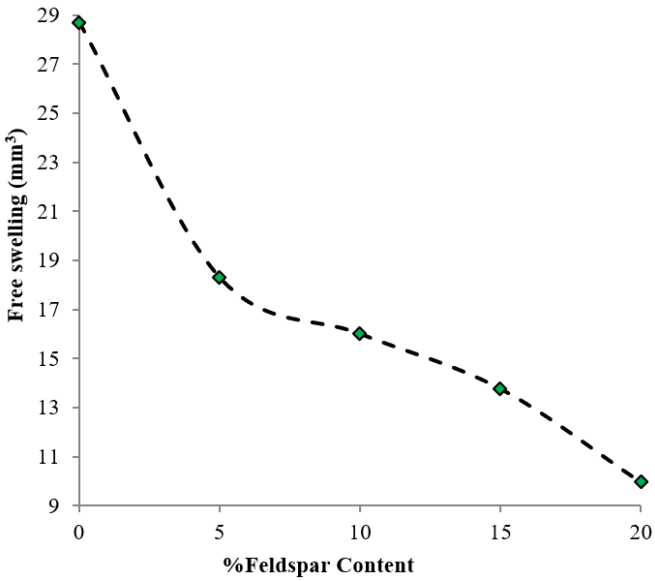

Figure 6. Relationship between free swelling and (MFS)

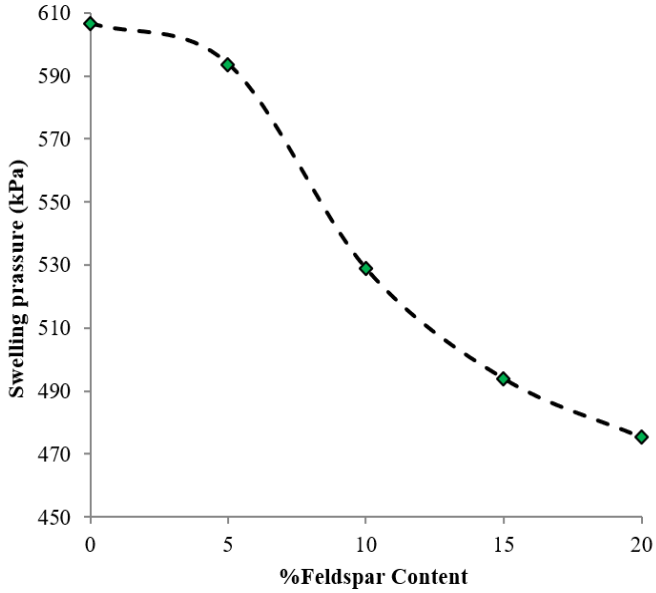

Figure 7. Relationship of pressure swelling and (MFS)

4.3 Effect on unconfined compressive strength test

The soil samples were prepared at water contents (22%); the unconfined compressive strength (qu) increased with increasing the (MFS) content from 73.6kPa to 152.5kPa when the (MFS) content increased from 0% to 20%. Figure 8 illustrates the effects of (MFS) on the result of unconfined compressive strength tests. From the results, it can be concluded that increasing the cohesion between soil particles can increase the concentration of the salts and minerals, which provides an interbond between the soil particles.

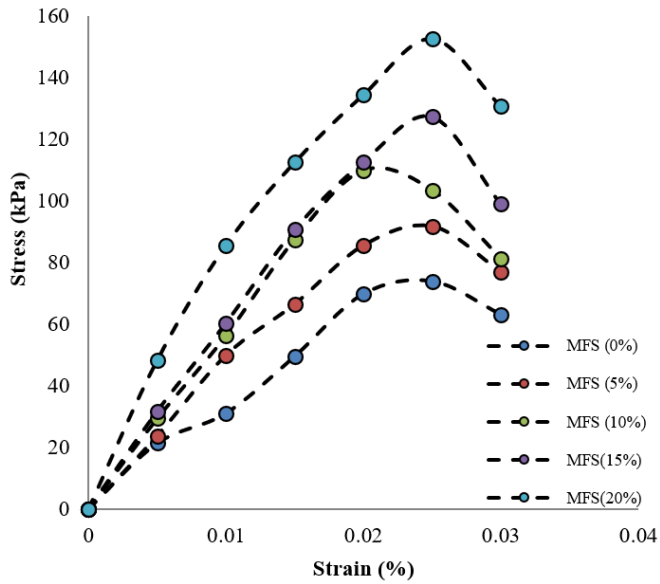

Figure 8. Relationship between unconfined compressive strength and (MFS)

4.4 Effect on specific gravity and organic content

The difference in specific gravity in mixing feldspar powder is presented in Figure 9. It is clear that the specific gravity of swelling soil improved from a value of 2.675 to a maximum of 2.897. This high specific gravity cases the least particle size, and the system's total weight increased with increasing (MFS).

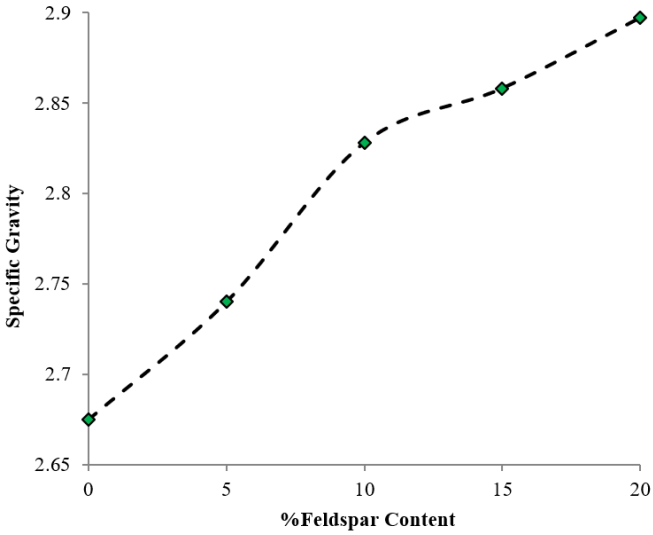

Figure 9. Relationship of specific gravity and (MFS)

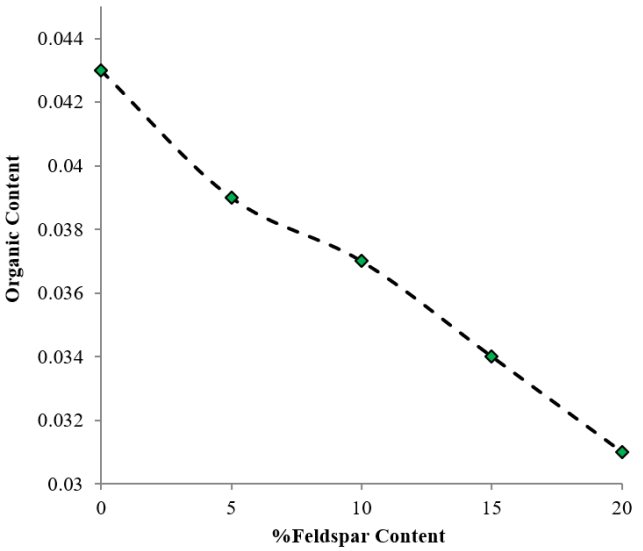

Figure 10. Relationship between organic content and (MFS)

The organic content test showed that the (MFS) would decrease the amount of organic content, which improved expansive soil. This process of expansive soil is fully illustrated in Figure 10.

5. CONCLUSIONS

Influence of (MFS) on some geotechnical properties of swelling soil. The soil treatment with feldspar increases the attractive force between soil particles, increasing their bonds and forming the bridge (as cementation) between the flat plate in the soil's pores. The main outcomes of this study can be listed below:

1) The treatment of swelling soil by (MFS) causes a significant reduction in its plasticity test.

2) The treatment of swelling soil by (MFS) causes a reduction in the swelling pressure and free swelling.

3) The unconfined compressive strength of swelling soil increased with increasing the intensity of (MFS).

Further investigations can be considered for some future work to address several impacts that my change the behaviour of the soil.

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