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IMPROVEMENT OF EXPANSIVE SOIL BY USING FIBER GLASS _SILICA FUME MIXTURE

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ABSTRACT

A fiber glass -silica fume and silica fume (SF) mix (F-SF) have been employed in this study in order to enhance and relate their effects on the expansive soil. Bentonite (B) was added with natural soil in a lab at a ratio of 50% by soil dry weight to create the soil used in this study. The (SF) was added alone at (8,9,10,11,12, and 13) % and 1 % of Fiber glass (F) was added to the (clay soil - SF) mixture. For both treated and untreated soil, odometer, shear box, and swelling tests were used to examine the behavior of the soil after the addition of (SF) and (F-SF) mixture. From the outcome of the experimental tests, we noticed that (SF) reducing both comparison index (Cc), reloading index (Cr), and swelling percentage (SW)%. Also, it is influenced on shear strength parameters by decreasing cohesion (c) and increasing internal angle friction (φ). As well as adding 1 % (F) to the (clay soil - SF) mixture modify the prepared soil by reducing (Cc), (Cr), (SW) % and increasing (c, φ). Based on all of the above results, we concluded that adding (SF) and (F-SF) mix. can enhance the engineering characteristics of swelling soil.

KEYWORDS

Expansive Soil, Silica Fume, Fiber glass, Soil Enhancement, Bentonite.

1. INTRODUCTION

The fundamental problems of foundation due to expansive soil, often known as shrink-swell soil (Abhishek et al., 2024). These soils will change in volume based on the quantity of moisture in the surrounding soil (Rashed and Abdulwahab, 2022). When these soils are utilized under a foundation, high moisture levels can cause structures to lift, while desiccation results in shrinkage, which leads to structural failure. Therefore, issues with foundations can frequently be resolved if the moisture content of these soils can be stabilized. To address this problem, various stabilizer types are employed (Rezaei, 2014) .

Soil stabilization indicates an increase in the soil's strength and durability (Utkarsh and Jain, 2024). The strength and durability of soil can be increased mechanically or, in other cases, by water proofing the soil's constituent parts with cement, lime, bitumen, or other chemicals (Al-Kalili et al., 2022). Occasionally, waste products or unconventional stabilizers like fly ash and rice husk ash are also used for stabilization. Stabilized soil is soil that has been treated with any of the aforementioned mixes (Fattah et al., 2015a).

In addition, the extensive application of "silica-alumina" or "silica" based materials for soil stabilization offers a low expensive compared with traditional materials like lime and cement. Because of the pozzolanic reactions these materials exhibit, gel compounds are produced, which strengthen the soils (Al-Kalili et al., 2022).

Numerous researchers investigated how well silica fume stabilized expanding soil, (SF) can be utilized individually (Mohammed et al., 2023, Goodarzi et al., 2015, Bharadwaj and Trivedi, 2016, Kalkan and Akbulut, 2004, Gupta and Sharma, 2014, Kalkan, 2009a, Kalkan, 2009b, Negi et al., 2013) or blended with additional substances (Kalkan, 2013, Mohamed, 2015, Karkush et al., 2018, Fattah et al., 2015a, Fattah et al., 2015b, Fattah et al., 2014, Rezaei, 2014).

The authors of (Hejazi et al., 2012) provided an overview of studies done on commonly used synthetic fibers to reinforced soil based on the literature they have read. We can see from the summary that several synthetic fibers were the subject of investigation. According to these earlier studies, the strength characteristics of fiber-reinforced soils with randomly distributed fibers depend on the amount of fiber present and the friction between the fiber and the soil's surface as well as the soil's and the fiber's strength qualities.

Due to their cost-competitiveness with other materials, fiber materials are a key subject of many research studies on geotechnical design and application. Since these fiber materials can be recycled from waste plastic and rubber components, the fiber stabilization of soils approach may be minimized (Kalkan, 2013).

Studies have been done on the impact of glass wool, silica fume, and cement additives on the compressibility and swelling properties of swelling soil. By combining three ratios of each additive (2, 4, and 6%) of the soil mass the soil samples were enhanced. The samples of stabilized soil were dried out for one day. According to test results, the swelling impact diminished as the percentage of additives was increased within a certain range. Additionally, the best material additive to improve the properties of swelling soil is polypropylene fiber additives, which reduce the void ratio to 40% at 2% of that material additive (Ahmed et al., 2016).

It was investigated whether soil enhancement could be accomplished by randomly introducing 70 mm-long polyester fibers to (SC) soil. Direct shear tests were used to measure the soil's improvement, for studied soil, It will be demonstrated that, When (c and φ) increases in comparison to soil without fibers the optimum amount of fibers is 1.0% (Nguyen et al., 2015)

It was investigated whether clayey soil reinforced with commercially available 20 mm glass fiber with varying fiber contents (0.25 to 1%) could be used as a paving material for roads. According to laboratory test results, fiber content increased the UCS, CBR, and shear strength values of clayey soil substantially, reaching an optimal value of 0.75% fiber content (Patel, 2022).

The purpose of this study is to examine the effects of using (SF) and (F-SF) mix to improve the geotechnical properties of swelling soil (Cc, Cr, c, φ, SW).

2. MATERIAL AND METHODS

2.1. Type of Soil

To produce the swelling soil in the laboratory, 50 % bentonite was mixed with original soil. Many experiments were performed on original (natural soil without B) and swelling soil (natural soil with 50% B) (Atterberg Limits, Specific Gravity, Sieve analysis, hydrometer test, Compaction test).

The physical and chemical characteristics of the soil used as shown in Table 1. From this Table we noticed that the physical properties of the original soil have been changed when 50 % B was added and the prepared soil in accordance with (USCS) become (CH). Fig. 1, 2 display the practical size distribution and compaction results for swelling soil.

Table 1. Physical and Chemical Characteristics of Soil.

Particulars	Original Soil	Swelling Soil
Liquid Limit, L.L %	25	67.5
Plastic Limit, P.L %	18.98	29.30
Plasticity Index, P.I %	6	38.2

Particulars	Original Soil	Swelling Soil
Specific Gravity, Gs	2.67	2.80
Gravel %	0	0
Sand %	38	35
Silt %	28	17
Clay %	34	48
Maximum Dry Density, (kN/m³)	19.4	14,68
Optimum Water content, (O.W.C) %	13.30	19.5
Soil Classification (USCS)	CL - ML	CH
Gypsum %	0.80	
TDS %	1.30	
SO3 %	0.41	
PH	8.73	
Ca CO4 %	30.7	

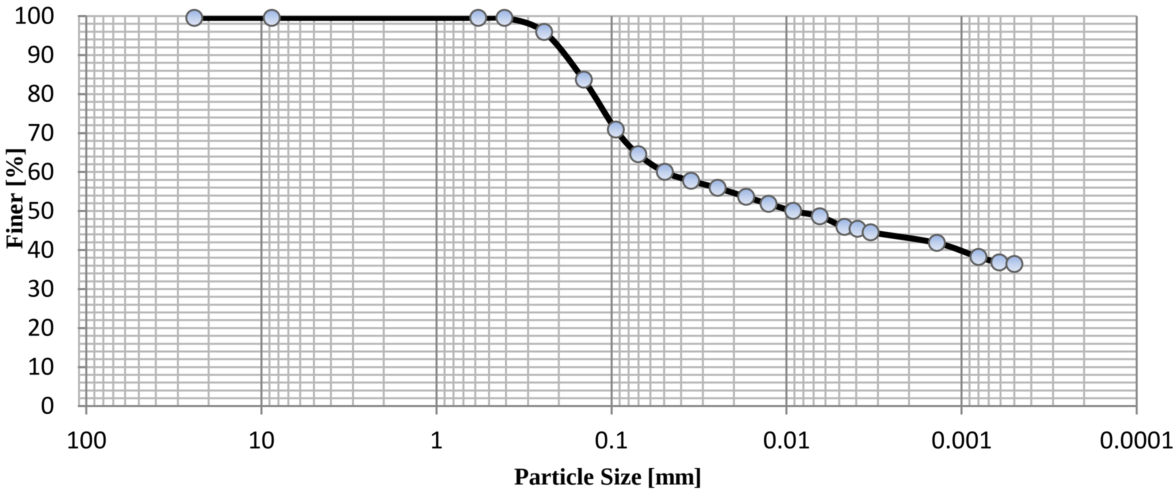

Fig. 1. Graine Size Curve of Expansive Soil.

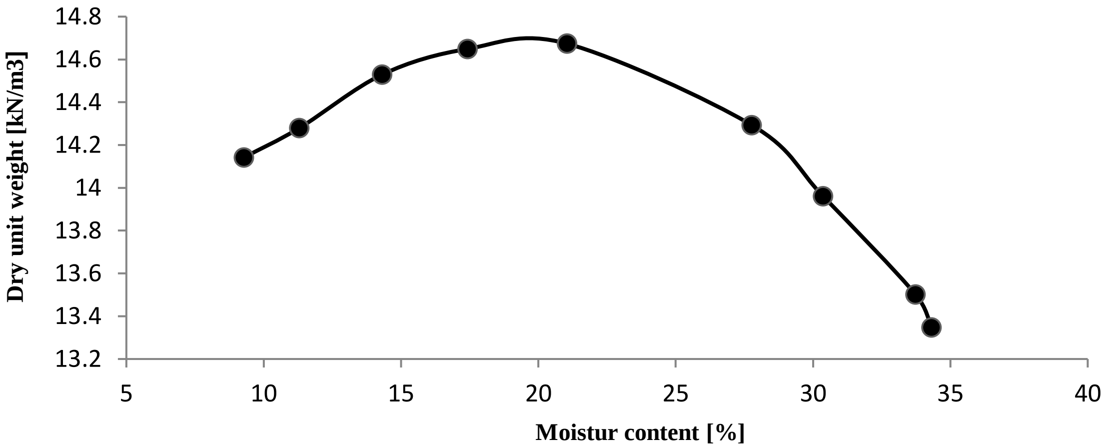

Fig.2. Compaction Characteristics of Expansive Soil.

2.2. Bentonite (B)

Bentonite is a group of clay minerals that are extremely hygroscopic and are created when volcanic ash weathers (Israr et al., 2014). It is a montmorillonite clay with a calcium or sodium base (Al-Ani, 2003). Iranian sodium bentonite was employed in this investigation from a variety of commercially accessible forms. where 50 % bentonite added to the natural soil to prepared expansive soil. The physical and chemical characteristics of the bentonite used shown in Table 2.

Table 2. Physical and Chemical Characteristics of Bentonite.

Particulars	%
L.L.	127
P.L.	77
P.I.	50
Na_2O	1.22
Al_2O_3	15.84
K_2O	0.56
SO_3	0.46
MgO	3.88
TiO_2	0.88
CaO	5.74
SiO_2	57.65
Fe_2O_3	5.32
L.O.I	8.45

2.3. Silica Fume (SF)

SF, an incredibly fine solid particle created during the silicon metal manufacturing process, has historically been considered a waste product. It is the end product of silicon metal or ferrosilicon alloy production. In spite of the fact that (SF) is a waste product from industry It has become the most valuable by-product pozzolanic material because of its high pozzolanic activity (Kalkan, 2013). The chemical composition of the (SF) used is presented in Table 3.

Table 3. Chemical Composition of (SF).

Composition	%
SiO2	98
Al2O3	.02
Fe2O3	.03
CaO	.21
MgO	.04
K2O	.09
Na2O	Nil

2.4. Fiber glass (F)

Fiber Glass of 10 mm length was used in this study. Because of its greater stiffness, strength, high surface area to weight ratio, dimensional stability, and ready biodegradability, glass fiber may be more beneficial for long-term soil remediation (Patel, 2022). Table 4 show some properties of fiber glass used in this study.

Table 4. property of fiber glass used.

Property	Value
Specific Gravity	1.99
Tensile Strength (MPa)	1770
Color	whitish
Density (gm/cm3)	2.55

2.5. Preparation of Mixture

To eliminate moisture, the natural soil was dried out for 24 hours at 105 degrees Celsius. To make expansive soil, it was initially blended with 50% bentonite and manually mixed with the required quantity of (SF) (8 - 13) % from its total dry weight. Then room temperature water was added in a light stream (at O.W.C) and the mixture was manually mixed until the water was evenly distributed. At the same way 1% (F) was added to the (clay soil - SF) mixture. It was decided not to go for a fiber level above 1% since, homogenous mixing of fiber was difficult due to lumps of soil and fiber forming (Nguyen et al., 2015).

3. RESULTS AND DISCUSSION

3.1. Impact of (SF) and (F - SF) Mix. on Compressibility characterizes

To investigated the effects of (SF) and (F - SF) Mix on compressibility, Prepared expansive soil that had been both treated and untreated was used for the odometer test. Tables 5,6 and Figs. 3,4 summarized this effect, it is clear that when (SF) % increased then (Cc) and (Cr) decrease. This behaviour could be explained by the low plastic content addition and the interaction of clay minerals with (SF) particles. Additionally, the reaction of activated silica with hydroxide and calcium results in the formation of calcium silicate gels. This chemical reaction has reduced the concentration of clay minerals in the composite samples. (Kalkan and Akbulut, 2004, Attom and Al-Sharif, 1998). Also, we noticed that adding 1% (F) to the (clay soil - SF) mix. modify the compressibility characterizes Cc and Cr. It is possible that adding (F) increased the samples' stiffness, which in turn decreased their compressibility (Abdi et al., 2008).

Table 5. Impact of (SF) and (F - SF) Mix. on Cc.

SF %	Cc at 0% F	% Reduction	Cc at 1% F	% Reduction
0	0.56		0.56	
8	0.52	7.142	0.47	16.07
9	0.46	17.85	0.45	19.64
10	0.41	26.78	0.4	28.57
11	0.34	39.28	0.31	44.64
12	0.25	55.35	0.21	62.5
13	0.19	66.07	0.17	69.64

Table 6. Impact of (SF) and (F - SF) Mix. on Cr.

SF %	Cr at 0% F	% Reduction	Cr at 1% F	% Reduction
0	0.146		0.146	
8	0.14	4.10	0.137	6.16
9	0.137	6.16	0.135	7.53
10	0.134	8.21	0.131	10.27
11	0.13	10.95	0.124	15.05
12	0.127	13.01	0.121	17.12
13	0.104	28.76	0.102	30.14

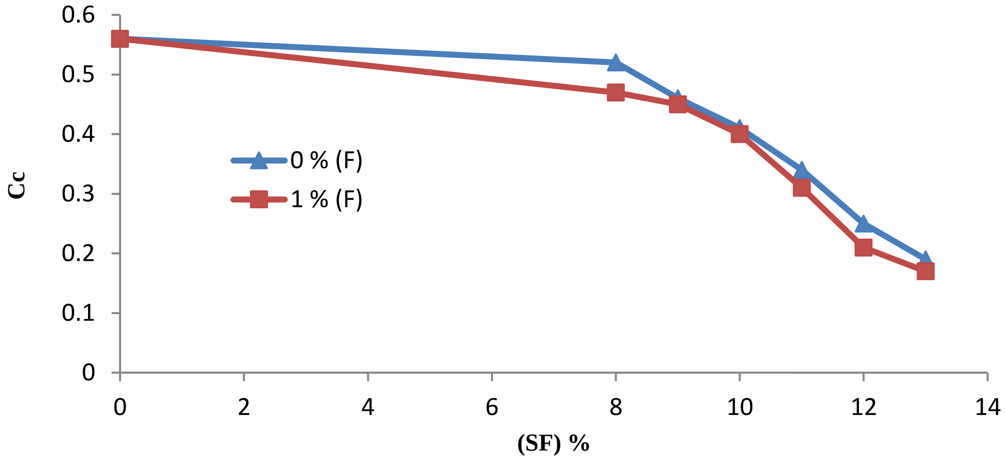

Fig. 3. Impact of (SF) and (F - SF) Mix. on Cc

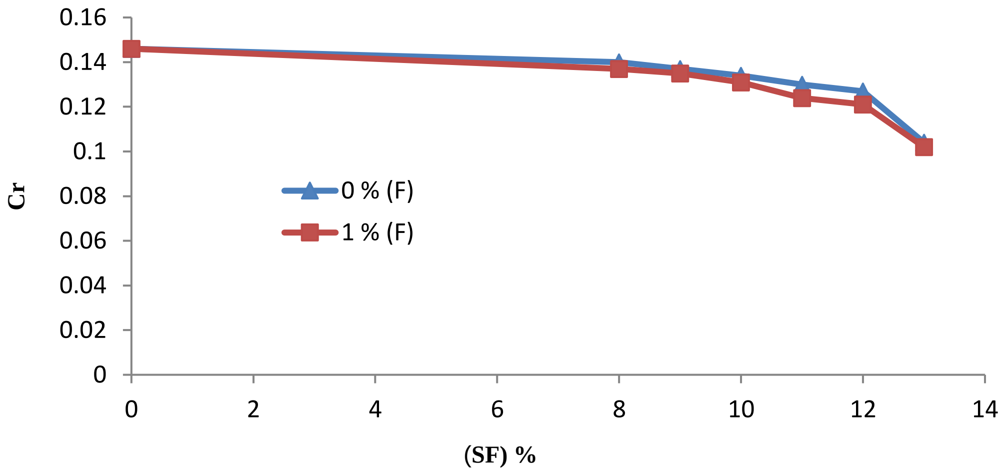

Fig. 4. Impact of (SF) and (F - SF) Mix. on Cr.

3.2. Impact of (SF) and (F - SF) Mix. on Shear Strength Parameters

The effect of the (SF) and (F - SF) Mixture on (c, φ) was investigated using a shear box test on prepared expansive soil that had been treated and untreated. The outcomes of these tests are displayed in Tables 7 and 8 and Figs. 5 and 6. We note that when (SF) % increased, (c) decreased and (φ) increased. This action is the outcome of internal friction of (SF) particles and chemical interaction between soil and (SF). As well as the effect of adding 1% (F) to the (clay soil - SF) mix. enhanced (c and φ) compared to use (SF) alone. Also we noticed that (c) slightly changed while (φ) increased compared to the untreated soil. This behavior may be attributed to the friction and bind strength between fibers and soil particles (Nguyen et al., 2015).

Table 7. Impact of (SF) and (F - SF) Mix. on cohesion.

SF%	C[kPa]	C[kPa] at 1% F
0	26	26
8	22	24
9	19	25
10	18	26
11	17	26
12	15	26
13	15	27

Table 8. Impact of (SF) and (F - SF) Mix. on Angle of Shearing resistance.

SF%	φ	% Improvement	φ at 1% F	% Improvement
0	9.46		9.46	
8	11.3	19.45	16.69	76.43
9	12.72	34.46	17.57	85.73
10	14.47	52.95	19.17	102.64
11	15.44	63.21	19.29	103.9
12	15.47	63.53	19.3	104.02
13	16.85	78.11	21.8	130.44

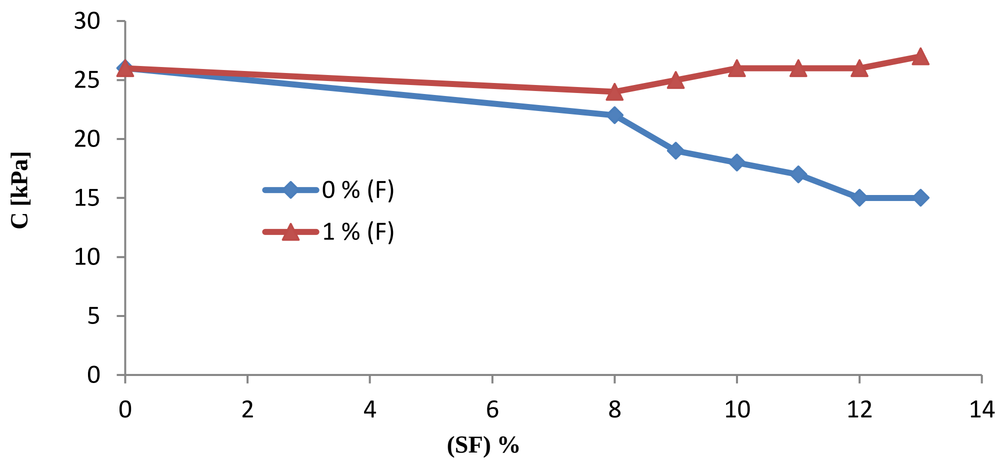

Fig. 5. Impact of (SF) and (F - SF) Mix on cohesion.

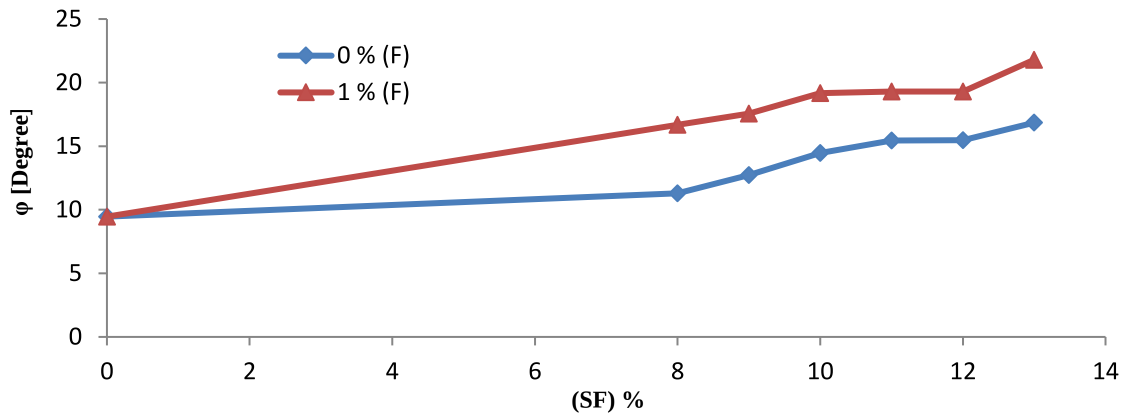

Fig. 6. Impact of (SF) and (F - SF) Mix. on Angle of Shearing resistance.

3.3. Impact of (SF) and (F - SF) Mix. on Swelling

To perform the effect of (SF) and (F - SF) Mix on soil swelling, a swelling test was performed using a consolidation cell on prepared expansive soil that had been treated and untreated. Table 9 and Fig. 7 depict the effect of (SF) addition on (SW)%. This shows that by increasing the (SF) %, the (SW)% is reduced. This is the outcome of (SF) particles interacting with the minerals in the soil. Also, the influence of adding 1 % (F) to the (clay soil - SF) mix. reducing (SW) %.The cohesion at the (soil / fiber) interfaces is the cause for this behavior (Abdi et al., 2008).

Table 9. Impact of (SF) and (F - SF) Mix. on (SW) %.

SF%	SW%	%Reduction	SW% at 1% F	%Reduction
0	10.32		10.32	
8	8.12	21.31	7.84	24.03
9	7.8	24.41	6.65	35.56
10	7.55	26.84	6.49	37.11
11	7.29	29.36	6.34	38.57
12	7	32.17	4.73	54.17
13	6.72	34.88	4.63	55.14

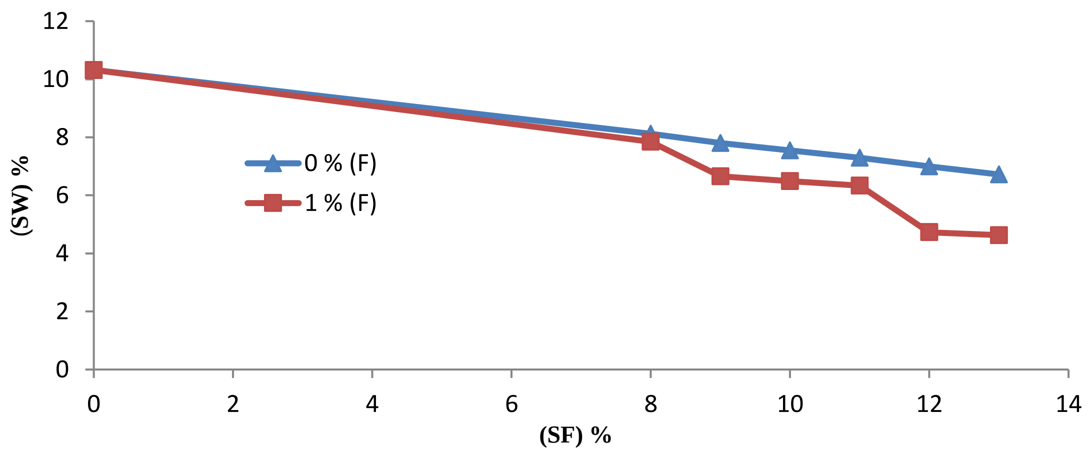

Fig. 7. Impact of (SF) and (F - SF) Mix. on (SW) %.

4. CONCLUSIONS

Based on the above results, the following was concluded:

1. The compressibility characterized (Cc) and (Cr) of the improved soil reduced with increasing (SF) % and the maximum value of reduction are 66.07 % and 28.76 % at 13 % (SF). As well as the addition of 1% (F) to the (clay - SF) mix. enhanced the compressibility index by reducing (Cc and Cr) and the maximum value of reduction are 69.64 % and 30.14 % at 13 % (SF) with 1 % (F).
2. The addition of (SF) to the clay soil decrease (c) and increase (φ) and the maximum value of increasing is 78.11% at 13 % (SF). Also blend 1% (F) with the (clay - SF) mix. Slightly effect on (c) but increasing (φ) and the maximum value of increasing is 130.44 % at 13 % (SF) with 1 % (F).
3. With an increase in (SF)%, (SW) % of the stabilized soil by (SF) decreased and the maximum value of reduction is 34.88 % at 13 % (SF). Furthermore when 1% (F) insert to the (clay - SF) mix. the (SW)% reduced and the maximum value of reduction is 55.14 % at 13 % (SF) with 1 % (F).
4. Based on our research, we have determined that the geotechnical characteristics of swelling soil can be modified by adding (SF) and (F - SF) Mix.

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