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Swelling Properties of Improved Expansive Soil by Rice Husk Ash (RHA) and Silica Fume (SF)

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ABSTRACT

Utilization of waste materials in agriculture products reduces the technical and environmental problems of plants wastes. Although rice husk ash (RHA) is a valuable admixture for concrete and soils, only about 5% of the total available RHA is used for improvement their properties. However, the utilization rate of it is steadily increasing every year. Newly developed admixture allow decreasing of swelling properties of expansive soil by incorporating of rice husk ash as waste material and silica fume (SF) which denote RHA-SF. This study presents an experimental study on expansive soil mixed with additives in different ratios. The work involves three types of mixes the first consists of four different percentages of RHA without SF, the second uses four different percentages of SF without RHA, the last mixes consists of sixteen different percentages of mixed RHA and SF.
Keywords: swelling soil, rice husk ash, Silica fume, swelling pressure

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INTRODUCTION

Expansion of clays is worldwide stability problem that causes extensive damage. Ground improvement methods such as stabilization by chemical additives, pre wetting, squeezing control, over loading and water content prevention are general applied methods for the solution of swelling problems [15]. Many investigators have been used natural and fabricated additives materials to improve geotechnical properties of expansive soil. Additive of lime, cement, rice husk ash or silica fume alone improve the geotechnical properties of expansive soil ([3], [7]-[9], [11]-[14]). Mixtures of lime-RHA or RHA-cement used for stabilization the geotechnical properties of swelling soil ([2], [16]-[21]).

Rice husk ash (RHA) is produced from burning the rice husk [16]. In addition to having pozzolanic properties, also has some self-cementing properties in the presence of water [2]. The stabilization, especially with RHA, is a common applied method among the others due its effective and economic usage. Many investigators examined the expansive soil stabilization with fly ashes ([2], [16]-[21]). The findings from the previous studies show that when RHA is added to expansive soils in the presence of water, reactions including cation exchange, flocculation and pozzolanic reaction take place [16]. It is stated that, flocculation is primarily responsible for the modification of the engineering properties of clay soils when treated with RHA [17]. The studies reported in the literature showed that the addition of rice husk ash increased the optimum moisture content, shrinkage limit and unconfined compressive strength, and reduced the swelling potential, liquid limit, plasticity index and maximum dry density of the soil ([2], [7], [9], [14], [16], [17]). For stabilizing the swelling soil, adding RHA with cement, lime or salt gives better result than that obtained by adding RHA alone ([2], [14], [16], [18]-[21]). It was found that The economic percentages of additives to minimize the values of swelling pressure and swelling potential are ranged between 5% to 7.5% RHA with salt or lime or cement by ratio of 5% of each of them but The best results on increasing unconfined compressive strength of swelling soil were obtained by using mixtures of RHA (ratio > 7.5%) with lime ratio ranged between 2.5% to 7.5% ([16], [17]).

Silica fume (SF) is a by-product of silicon material of industrial applications. It has become the most valuable by-product among the pozzolanic material due to its very active and pozzolanic property ([10], [13]). Silica fume also known as micro-silica, is a by-product of the reduction of high purity quartz with coal in electric furnaces in the production of silicon and ferrosilicon alloys. SF is also collected as a by-product in the production of other silicon alloys such as ferrochromium, ferromanganese, Ferro magnesium, and calcium silicon. Before the mid-1970s, SF was discharged into the atmosphere. After environmental concerns necessitated the collection and landfilling of silica fume, it became economically justified to use silica fume in various applications such increasing compressive strength of concrete, improving bond strength, and abrasion resistance, reducing permeability, and therefore helps in protecting reinforcing steel from corrosion of concrete ([1], [10]). Silica fume consists of very fine vitreous particles with a surface area on the order of 20,000m^2/kg. Because of its extreme fineness and high silica content, Silica Fume is a highly effective pozzolanic material ([1], [2], [10]-[13]). SF is available in two conditions: dry and wet. Dry silica can be provided as produced or densified with or without dry admixtures and can be stored in silos and hoppers. Silica Fume slurry with low or high dosages of chemical admixtures are available. Slurried products are stored in tanks with capacities ranging from a few thousand to 400,000 gallons.

Now days, swelling properties of expansive soil were improved by using silica fume. Reference [11] states that the liquid limit and plasticity index values decreased with increasing silica fume contents. However, the plastic limit increased with increases in the silica fume contents. By addition of silica fume to expansive soil, the maximum dry unit weight values decreased and the optimum water contents increased under the same compaction effort ([11]-[13]). The swelling pressure and swelling potential values steadily decreased with increasing silica fume content and the low values were finally reached in the stabilized samples with 25% and 30% silica fume contents [11].

All the previous researchers have found varied success in improving the engineering properties of expansive soil by using different additives.

This paper presents the performance of the treatment of the expansive clays incorporating of rice husk ash as waste material and silica fume (SF) which denote RHA-SF. The main objective of this study is to determine the suitable percentage of RHA with SF that calm down the swelling potential of expansive soil.

MATERIAL AND METHODS

In this research three types of materials were used which are expansive soil (the improved soil), rice husk ash, and silica fume as stabilizer materials.

A. Expansive Soil

In this study high swelling soil were selected for stabilization. It was extracted from location beside Toshka project near to Aswan, Mewat. The samples were taken from open pits at a depth 6.0 m from natural ground level. The soil was placed in plastic bags and transported to the soil mechanics laboratory in Delta Barrage. It is classified as high plasticity soil (CH) according to Unified Soil Classification System. Properties of the soil were summarized in Table 1 whereas chemical analysis is shown in Table 2.

B. Rice Husk Ash

Rice husk is local material and abundant in delta of Mewat. Rice husk used in this study was obtained from the rice product factory in Minia El-Basal, El-Mahala El-Koubra, Garbia governorate, Mewat. Rice husk ash was obtained by open burning of rice husk. As rice husks burn by themselves only a small amount of fuel is needed to start the fire. The used rice husk ash was passing through sieve No. 200 B. S. and then it was put in an oven at 500^{o}c for 24 hours. The chemical analysis of rice husk ash is shown in Table 3.

TABLE 1: PROPERTIES OF UNTREATED SOIL

Property	value	Property	value
Colour	yellow	Swelling Pressure	450 kN/m^2
Specific Gravity	2.65	Swelling Potential	25.4%
Liquid Limit	95.30%	Maximum Dry Unit Weight	16.4 kN/m^3
Plastic Limit	35.70%	Optimum Moisture Content	20.05%
Shrinkage Limit	11.20%	Sand	2.12%
Plasticity Index	59.60%	Silt	29.34%
Activity	1.05	Clay	68.54%

TABLE 2: CHEMICAL ANALYSIS OF UNTREATED SOIL

Constituent	Value	Constituent	Value
pH	8.21	$[Na]^+$	570.00 PPM
T.D.S	*2115 PPM*	$[K]^+$	8.60 PPM
$[SO_3]^-$	*360.00 PPM*	$[Ca]^{++}$	17.00 PPM
$[CO_3]^{-2}$	*11.50 PPM*	$[Cl]^-$	790.00 PPM
$[HCO_3]^-$	*146.40 PPM*	$[Mg]^{++}$	7.20 PPM

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TABLE 3: CHEMICAL ANALYSIS OF RHA

Constituent	Value	Constituent	Value
SiO_2	*75.06%*	Na_2O	0.47%
Al_2O_3	*9.23%*	K_2O	1.24%
Fe_2O_3	*4.64%*	SO_3	0.37%
CaO	*0.11%*	MgO	1.62%

C. Silica Fume

Silica fume used in this experimental study was supplied by the Ferrosilicon Alloys Company (Edfo - Komombo), Aswan, Mewat. Silica fume, a very fine solid material generated during silicon metal production, has historically been considered a waste product. It is a by-product of production of silicon metal or ferrosilicon alloys. Although the silica fume is a waste industrial material, it has become one of the most valuable by-product pozzolanic materials due to its very active and high pozzolanic property. Chemical properties of SF are presented in Table 4.

TABLE 4: CHEMICAL ANALYSIS OF SF

Constituent	Value	Constituent	Value
SiO_2	*91.31%*	Na_2O	0.26%
Al_2O_3	*0.78%*	K_2O	0.41%
Fe_2O_3	*0.98%*	SO_3	0.13%
CaO	*0.35%*	MgO	1.74%

EXPERIMENTAL PROGRAM

In this investigation, 24 samples are tested to investigate the swelling properties of expansive soil with different percentages of rice husk ash; silica fume and the combination of rice husk ash and silica fume respectively. The work involves three types of mixes; the first category consists of 4 different percentages of RHA without SF, the second uses 4 different percentages of SF without RHA, the last mixes consists of 16 different percentages of mixed RHA and SF. The percentages of different additives for each category are illustrated in Table 5.

TABLE 5: EXPERIMENTAL PROGRAM

Cat. [1]	Cat. [2]	Cat. [3]			
2.5% RHA	5.0% SF	2.5% RHA + 5.0% SF	5.0% RHA + 5.0% SF	7.5% RHA + 5.0% SF	10.0% RHA + 5.0% SF
5.0% RHA	10.0% SF	2.5% RHA + 10.0% SF	5.0% RHA + 10.0% SF	7.5% RHA + 10.0% SF	10.0% RHA + 10.0% SF
7.5% RHA	20.0% SF	2.5% RHA + 20.0% SF	5.0% RHA + 20.0% SF	7.5% RHA + 20.0% SF	10.0% RHA + 20.0% SF
10.0% RHA	30.0% SF	2.5% RHA + 30.0% SF	5.0% RHA + 30.0% SF	7.5% RHA + 30.0% SF	10.0% RHA + 30.0% SF

D. Preparing Samples for the Tests

The expansive soil was dried in an oven at approximately 105 °C before a grinding process. Test samples were mixed from pulverized, air-dry soil and de-ionized water. Treated specimens were prepared as follow:

1. The required amounts of expansive soil, rice husk ash, and silica fume according to recommended percentages were measured by a total dry weight of sample.
2. The amounts of the soil and the stabilizer product were weighed in accordance with the total weight of the composite samples and mixed together in the dry state.
3. Using the standard Proctor compaction test [6], the optimum moisture content (OMC) for compaction was determined for the untreated and treated soil.
4. The materials were blended together in dry conditions then the mixtures of dry soil and different additives were mixed with the required amount of water for optimum water content.
5. All mixing was done manually, and proper care was taken to prepare homogeneous mixtures at each stage of mixing.
6. The mixtures of swelling soil–stabilizers were compacted at optimum water content to obtain the improved expansive soil samples.
7. The samples were extruded from the compaction mold, and sealed in a plastic bag.
8. The sample was trimmed to an appropriate size for swelling tests for natural swelling soil and stabilized soil. Metal molds of 70 mm in diameter and 20 mm high were used to prepare samples accordance with ASTM [6].

E. Compaction Test

To determine the optimum water contents of natural and stabilized clayey soil samples and to prepare the samples for swelling tests, Standard Proctor tests were carried out in accordance with ASTM [6]. The compaction curves were plotted and the values of optimum water content and maximum dry unit weight were determined from the compaction curves. The natural swelling soil and the stabilized soil compacted at the optimum water content to prepare samples for swelling pressure, and swelling potential tests.

F. Swelling Pressure Test

This test is intended to measure the axial stress necessary to constrain radially confined soil specimen at constant thickness when immersed in water within in the cell. Swelling pressure tests were performed in the standard one dimensional oedometer apparatus in accordance with ASTM [5]. The swelling pressure of each sample was directly measured from the surcharge, which loads the sample. The sample was confined in the consolidation ring of 70 mm diameter and 20 mm high, and water was allowed to flow into the sample. The samples were submerged in water. The deflection of the dial gauge was set to zero. As a result, when the samples showed no further tendency to swell, the maximum surcharge load at that point was used for the calculation of the swelling pressure. The swelling pressure can be expressed by dividing the maximum surcharge by the sample area.

G. Swelling Potential Test

Swelling potential has been used to describe the ability of a soil to swell, in terms of volume change. To measure the potential expansiveness of the untreated and treated soils, potential swelling tests were conducted in accordance with ASTM [5]. Swelling potential tests were carried out in a similar way as swelling pressure tests. However, the sample was allowed to swell under a small load. The compacted and cured soil specimens were trimmed into 70mm diameter oedometer rings with a thickness of 20 mm. After applying a vertical seating pressure of about 0.7 kPa, the soil was inundated with water, which could seep into the sample through top and bottom porous stones. The dial gauge readings were recorded periodically until there were no further changes in swelling. The swelling percentage can be expressed by dividing the expansive thickness by the initial thickness.

RESULTS AND DISCUSSION

H. Effects of Additive on the Compaction Parameters

The addition of rice husk ash and silica fume affected the compaction parameters of swelling soil–additives mixtures. The effect of different additives on compaction parameters are shown in Figs.1&2. From these figures, It was observed that by increasing SF and RHA content in soil, the optimum water content values increased and the maximum dry unit weight values decreased but the effect of SF is more than of RHA. The maximum effect was when using RHA-SF additives.

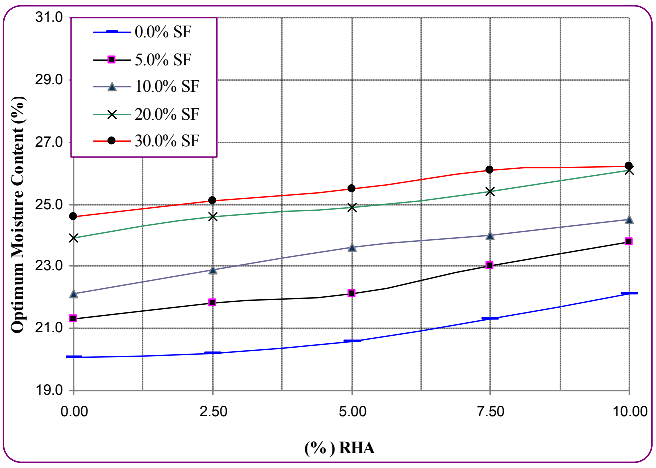

Fig. 1 Effects of RHA-SF additives on the optimum moisture content

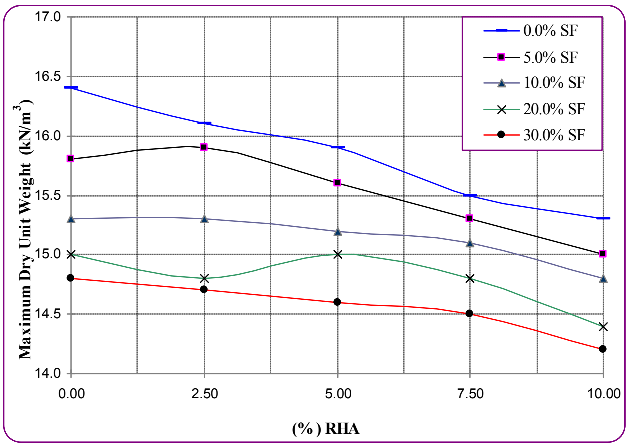

Fig. 2 Effects of RHA-SF additives on the maximum dry unit weight

Principally, increase in dry unit weight is an indicator of improvement. But unfortunately, both SF and RHA, instead, reduces the maximum dry unit weight. The increase in the optimum water content is due to the change in surface area of composite samples. The different additives changed the particle size distribution and surface area of the stabilized fine-grained soil samples ([12]-[14], [16]). In the same way, the decrease in the maximum dry unit weights is due to the low specific gravity of rice husk ash and silica fume, which filled the voids of the composite samples [14]. Due to the using RHA-SF additives, maximum dry unit weight of the soil decreases by 1.83 % to 13.41 % whereas, The increase in optimum moisture content varies from 0.75 % to 30.67 %.

I. Effects of Additive on the Swelling Properties

The effects of rice husk ash and silica fume content on the swelling pressure and swelling potential values of stabilized expansive soil samples are presented in Figs. 4 and 5. By increasing silica fume and rice husk ash content in the soil, the swelling pressure and swelling potential values steadily decreased. The swelling pressure of the improved soil decreased to 200 kN/m^2 from 450 kN/m^2 when it was stabilized with rice husk ash alone. it decreases to a value of 120 kN/m^2 when using silica fume alone. The swelling pressure of rice husk ash-stabilized soil found to decrease with increasing in RHA content. The same trend was obtained when using SF but with more effect. By using RHA-SF additives to the expansive soil The swelling pressure decreased to the least value of 80 kN/m^2 when using 10% rice husk ash and 30% silica fume but economically by using 7.5% rice husk ash and 20% silica fume swelling pressure decreased to 90 kN/m^2. it is clear that by adding silica fume to stabilized soil by rice husk ash the soil almost became a non-swelling material. Due to the using RHA-SF additives, the decrease in swelling pressure varies from 15.56 % to 82.22 %.

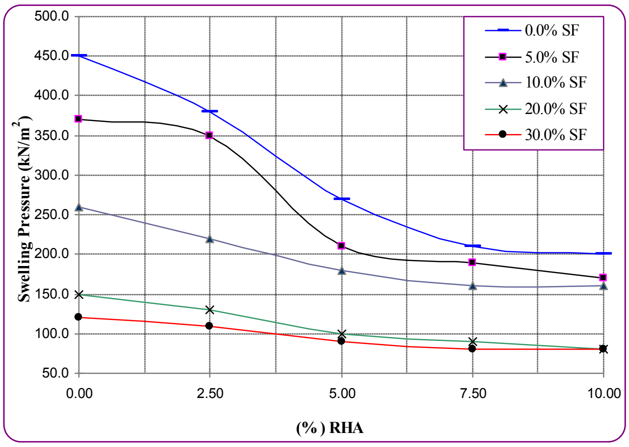

Fig. 3 Effects of RHA-SF additives on swelling pressure

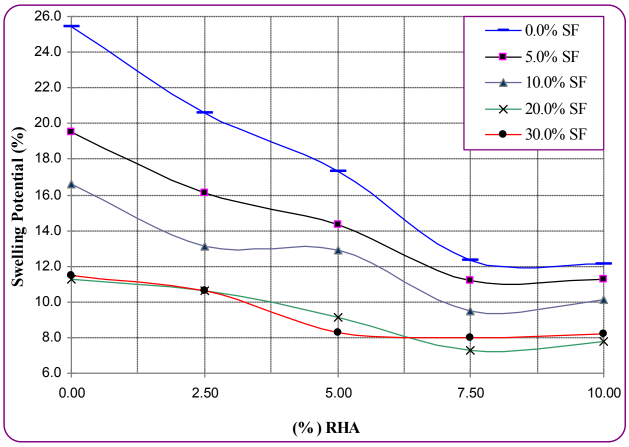

Fig. 4 Effects of RHA-SF additives on swelling potential

The results of swelling potential tests on expansive soil treated with different percentage of rice husk ash show that with increase in percentage of rice husk ash, the swelling potential of soil goes on decreasing gradually. The swelling potential decreases from 25.40% to 12.10% when rice husk ash is increased from 0.0 to 10.0%. Similarly with the addition of silica fume alone, the swelling potential values of stabilized sample containing 30% silica fume decreased from an initial value of 25.40% for the natural soil to 11.50%. With the addition of different percentage of silica fume to expansive soil-RHA mix, the swelling potential value further goes on significantly decreasing.

From Fig. 4 it is observed that the reduction in swelling potential varies from 18.90% to 71.26% at different percentage of RHA-SF as compared to the untreated soil. The economical values were reached at 7.5% rice husk ash with 20% silica fume contents. At these percentages of rice husk ash and silica fume, swelling potential decreases from 25.40% to 7.30%.

Although the swelling pressure and swelling potential values of all stabilized samples decreased with increasing rice husk ash or silica fume content, it was observed that the swelling pressure and swelling potential values decreased rapidly as the rice husk ash contents increased from 0 to 7.5% or silica fume contents increased from 0 to 20% and after these percentages, only slightly or no reduction in swelling pressure and swelling potential as the rice husk ash ratio increased to 10% or the silica fume content increased to 30%.

The reduction in the swelling pressure values of the improved soils is due to the addition of low-plastic materials (rice husk ash) and the interaction between the soil and silica fume particles ([9] & [20]). With addition of silica fume, the active silica reacts with calcium and forms calcium silicate hydrate (C–S–H) gel [11]. It was found that the samples of the stabilized swelling soil material became stronger and more brittle [12] than the natural expansive soil samples due to this basic reaction of silica fume–calcium in the swelling soil. Consequently, the swelling potential of treated expansive soil decreased.

CONCLUSIONS

Based on the results of different tests conducted on untreated and treated samples of expansive soil by rice husk ash and silica fume, the following conclusions may be drawn:

The moisture density relationship of swelling soil-rice husk ash mixtures significantly affected due to addition of silica fume. With the addition of silica fume alone, the maximum dry unit weight values decreased and the optimum water contents increased under the same compaction effort. Whereas using rice husk ash only shows the same trend but less noticeably.

By adding RHA-SF additives to expansive soil, maximum dry unit weight of the soil decreases from 16.40 kN/m^3 to 14.20kN/m^3 whereas, The optimum moisture content increased from 20.05 % to 26.20 %, when using 10% rice husk ash and 30% silica fume

The results from the RHA-SF (rice husk ash - silica fume) blend confirmed that the blend would diminish swell behavior of expansive soil.

The swelling pressure and swelling potential values steadily decreased with increasing rice husk ash content or silica fume content and the low values were finally reached in the stabilized samples when using RHA-SF additives.

The swelling pressure goes on decreasing with addition of rice husk ash or silica fume or both. The reduction in swelling pressure varies from 15.56% to 82.22% compared to untreated soil.

With the addition of different percentage of silica fume to expansive soil-RHA mix, the swelling potential value further goes on significantly decreasing and by using different percentage of RHA-SF, the decrease in swelling potential varies from 18.90% to 71.26%.

In general, 7.5% of rice husk ash and 20% silica fume shows optimum amount to reduce swelling properties of expansive soil

All of these factors can be summarized to say that by blending rice husk ash with silica fume together, you may enhance the swelling properties of expansive soil. This is advantageous for work construction in the civil engineering field. This utilizing is an alternative to reduce construction cost, particularly in the rural area of developing countries.

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