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Impact of Silica on Geotechnical Properties of Clayey Soil Present in Edfu- Aswan, Egypt.

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***Abstract*—It may be necessary to improve the engineering properties of clayey soils to make them suitable for construction by using some kind of stabilization methods. Treatment with lime, cement or waste materials such as silica fume (SF) has traditionally been used for the stabilization of clayey soils. The soil chosen in this research was extracted from a site in Edfu- Aswan, Egypt. Investigating the effect of properties of cohesive soils when mixed with SF is the main objective of this study. Silica fume is a mineral made up of ultra-fine solid, amorphous silicon dioxide glass spheres (SiO2) from the metallurgical industries company (E.JS.C) in Edfu. A series of laboratory experiments for samples prepared with different percentages were implemented of SF 0%, 2%, 4%, 6%,8%, and 10%. The results show that the blend will increase the maximum dry density of clayey soils. Their Plasticity Index and the liquid limit would increase, the permeability of clayey soil decreases, the unconfined compression strength will increase.**

All of these results can be summarized to say that the engineering properties of cohesive soils can be improved by combining Silica Fume and clayey soils together.

***Keywords*—Waste Material, Soil Stabilization, Cohesive Soils, Silica Fume, Lime.**

I. INTRODUCTION

Finding the subgrade to be clay uncovers a difficult civil engineering problem. The high content of clay in clay soils increases the tendency to swell their moisture content allowance. This moisture may result from rains, floods, sewer lines leaking, or surface evaporation reduction when a building or pavement covers an area. Quite often, these clay soils are responsible for the cracking and breaking of pavements, highway embankments, roads, railways, foundations, and channel or reservoir lines. The improvement of both strength and durability of the soil is implied for soil stabilization in its broadest sense. Adding deficient particle sizes may improve the soil as it gives a more satisfactory grading. Soil is using cement, bitumen, lime or special additives to bind or waterproof the particles of soil and so increase its durability and strength by a process known as mechanical stabilization.

Stabilization also applies waste materials or nontraditional stabilizers like Fly ash and Silica Fume. Stabilized soil is when the soil has been mixed with any of the mixtures mentioned above. Using Silica Fume as a stabilizer is a focus of this study.

Silica Fume is a highly effective pozzolanic material containing silicon dioxide, SiO_2, reacts with clay minerals (aluminium oxide, $Al2O_3$) and produces Aluminium silicate hydrate (A-S-H). Aluminium silicate is a type of fibrous material and considered cemented material made of aluminium oxide and silicon dioxide,) but the effect of add of silica fume has a little effect up to 5% because there is no reaction between aluminium oxide and silicon dioxide.

Silica fume (SF), also referred to as micro silica, is defined as a by-product of the reduction in silicon and ferrosilicon alloy production of high purity quartz with coal in electric furnaces. It is also collected as a by-product of other silicon alloys such as ferromagnesium, ferrochromium, silicon calcium, and ferromanganese. It becomes economically justified to use Silica fume in various applications; after the collection and landfilling of (SF) was necessitated by environmental concerns. SF consists of very fine vitreous particles with a surface area of approximately 20,000 m^2/kg (215,280 ft^2/lb) when measured using nitrogen absorption techniques, with particles about 100 times smaller than the average cement particle. (SF) It is a pozzolanic material that is extremely efficient because of its high silica content and extreme finesse. To improve properties Concrete uses Silica Fume. It has been found that SF bonds strength and resistance to abrasion, reduces permeability and improves compressive strength and thus helps protect steel from corrosion.

SF comes in two conditions: wet and dry. Dry silica can be supplied with or without dry admixtures as densified or produced and can be stored in hopper and silos. (SF) is available with high or low dosages of chemical admixtures. Slurred products are stored in tanks ranging from a few thousand gallons to 400,000 gallons (1,510 m3) [5, 6].

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II. Experimental Work

The impact of the use of (SF) was studied on the physical and mechanical properties of silty clay (soil A) and (soil B) clayey silt soil was studied. The tests were performed by mixed cohesive soil with a different amount of the (SF) (0, 2%, 4%, 6%, 8%, and 10%) by weight of the dry soil. The properties of soils include classification, Atterberg limits, compaction characteristics, shear strength parameters, and consolidation behavior.

A. Test Soils

The soils tested in this investigation were extracted from an open pit in Edfu- Aswan, Egypt. There was disturbance to the soil samples. The physical characterization of silty clay and clayey silt is shown in Table 1. Table 3 shows the chemical element of the tested materials. The distribution of the natural grain size of the tested soils is shown in fig (1). soil (A) is classified According to the ASSHTO soil classification system as A-7-6, and soil (B) classified as A-6.

B. Stabilizer Product

The materials used in this study for the stabilizer were (SF). (SF) products were brought from Ferrosilicon Alloys Company (Edfu), Aswan, Egypt. SF minerals' composition is presented in table 2. The laboratory test was done in Soil Mechanics and Foundations Laboratory, Assiut University.

TABLE I
SHOWS THE CLAYEY SOIL PROPERTIES

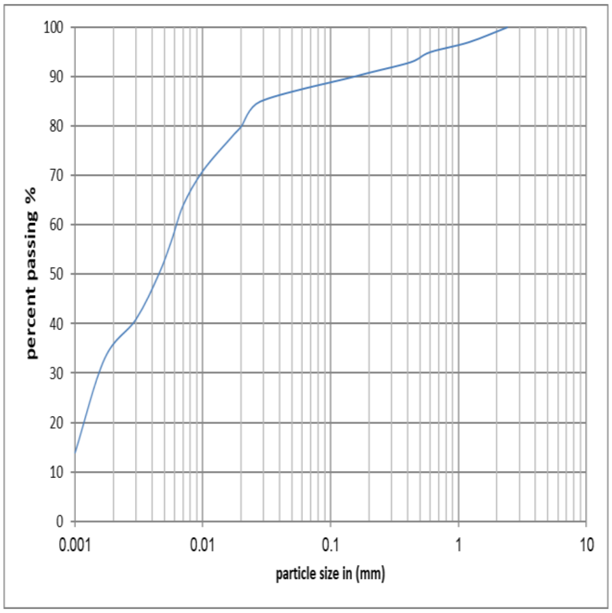
Physical Properties	Soil(A)	Soil(B)
γ d max	1.62 gm/cm^3	1.73 gm/cm^3
O.M.C	21%	21.17%
L.L	52.7%	34.5%
P.L	25.7%	24.6%
P.I	27%	9.9%
S.L	13.1%	20.53
Clay content	14%	20%
Silt content	77%	51%
Sand	9%	29%

TABLE II
CHEMICAL COMPOSITION OF SILICA FUME MINERALS

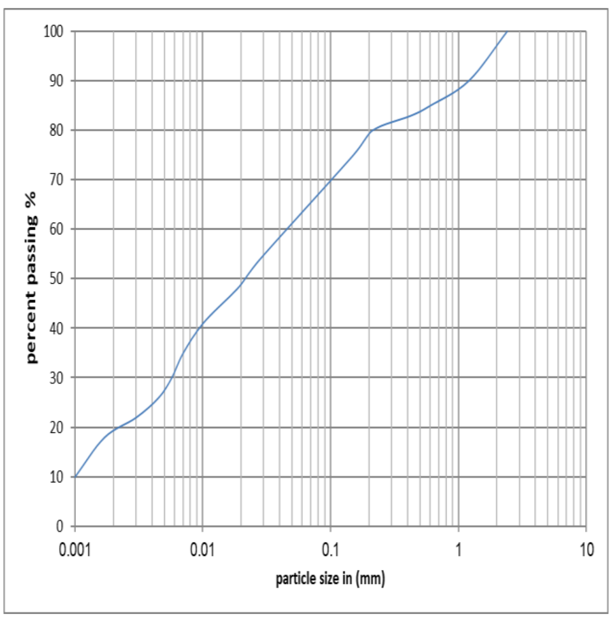
Chemical Compound	Mineral	Composition (%)
Silicon dioxide	SiO2	92.4
Aluminum oxide	Al2O3	0.47
Iron(III) oxide	Fe2O3	0.92
Calcium oxide	CaO	0.26
Magnesium oxide	MgO	0.60
Sulfur trioxide	SO3	0.1
Sodium oxide	Na2O	0.64
Potassium oxide	K2O	1.15
Water	H2O	0.27
Loss on ignition	L.OI	1.43
Carbon	C	0.78
	PH	7.10
	Residual coarse particle	0.76

TABLE III
CHEMICAL ANALYSIS OF CLAYEY SOIL SAMPLE

No	Molecular Formula	Soil (A)	Soil (B)
1	Si o_2	34.21%	33.04%
3	So_3	4.22%	7%
4	Al_2 o_3	19.98%	22.86%
5	Fe_2 o_3	7.98%	9.83%
6	Ca co_3	6.38%	8.5%
7	Mg co_3	9.62%	8.80%
8	Mg o	6.56%	2.9%
9	Cao	10.65%	7%



sample (A)



Sample (B)

Figure 1: The Grain size distribution of tested soil.

C. Laboratory Experiments

The physical and mechanical properties of the studied soil samples were determined accordance with the Egyptian code of soil mechanics and foundation design, part 2 [laboratory tests]. Those experiments shall measure the soil's engineering properties as follows:

- Unconfined compression strength
- Compaction Characterization
- Grain Size Distribution
- Physical Properties
  - Specific Gravities
  - Consistency Limits
- Consolidation Test

III. Analysis Of Results

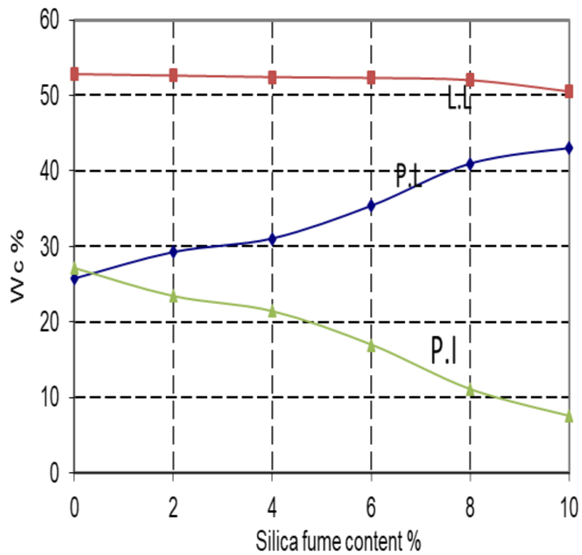
A. Consistency Limits

Different percentages of SF are mixed with soil samples as 0, 2 %, 4%, 6%, 8% and 10% of the weight of the dry soil weight for each soil sample, the physical properties (LL, PL, and PI) are determined and the effect is described as the follows:

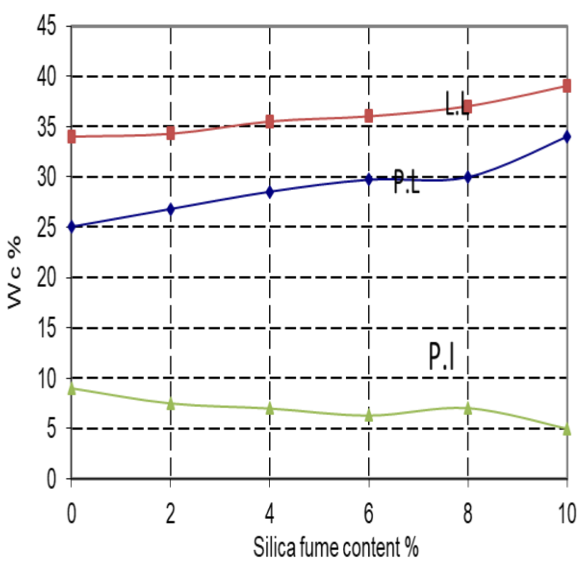
From fig. (2) Which shows the ratio of water content to the percentage of SF, it's clear that the LL increases with increasing the percentage of SF in soil samples, the PI values decrease with increasing the percentage of SF and the (PL) values slightly increase with increasing the amount of SF in soil samples.

B. Compaction Characterization

To determine the moisture-unit weight for all untreated test soils, a modified proctor compaction effort was used [8]. In figure 3, the influence of SF on OMC and γd max of soil is presented. The increase in the characterization of compaction due to the (SF) working as a filler material fills the voids in the soil and decreases it the γd max values increase with increasing the percentage of SF.

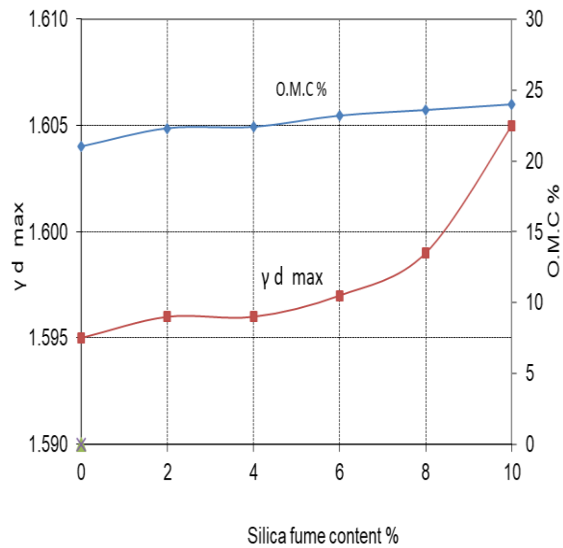


Soil (A)

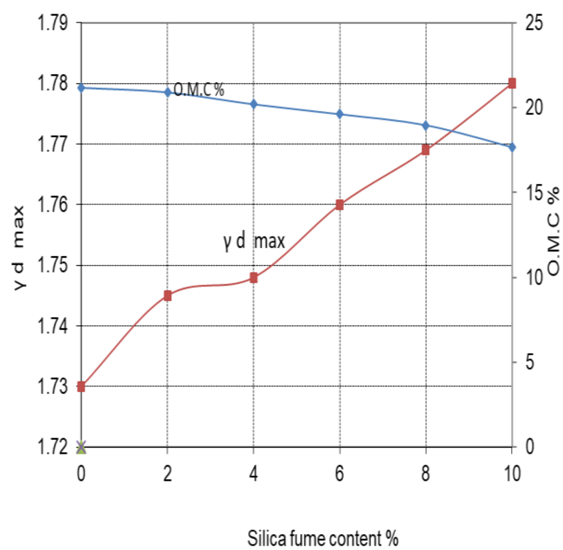


Soil (B)

Figure 2: SF content impact on consistency limits.



Soil (A)



Soil (B)

Figure 3: SF content impact on the compaction characterization.

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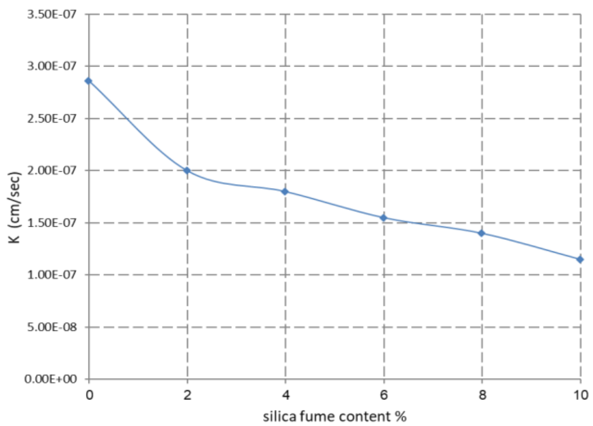
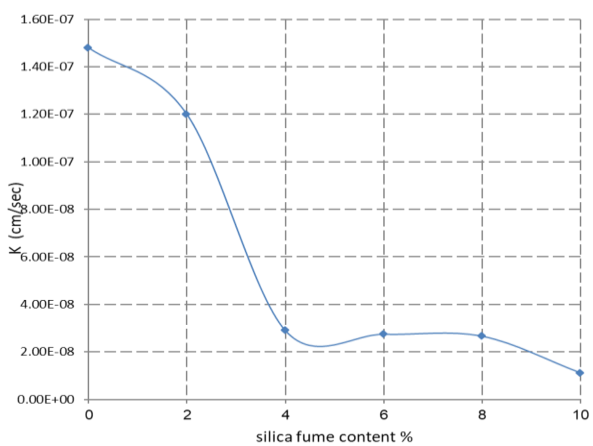
C. The permeability of collapsible soil

Figure (8a) shows a tendency to decrease the value (k) from 2.86 * 10-^{7} to 1.15 * 10-^{7} for soil (A) and to decrease from 1.48 * 10-^{7} to 1.13 * 10-^{8} for soil (B).



Soil (A)



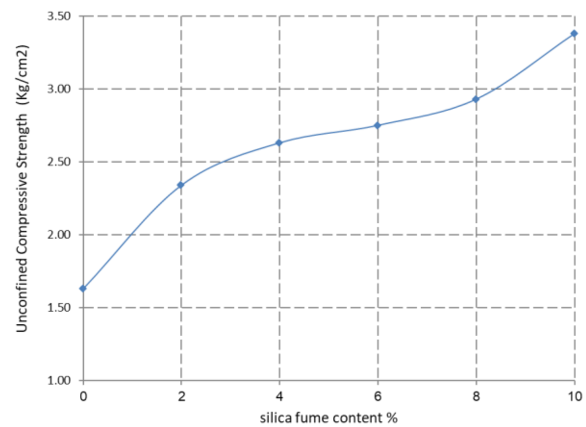
Soil (B)

Figure 8: SF content impact on the permeability of the compacted sample.

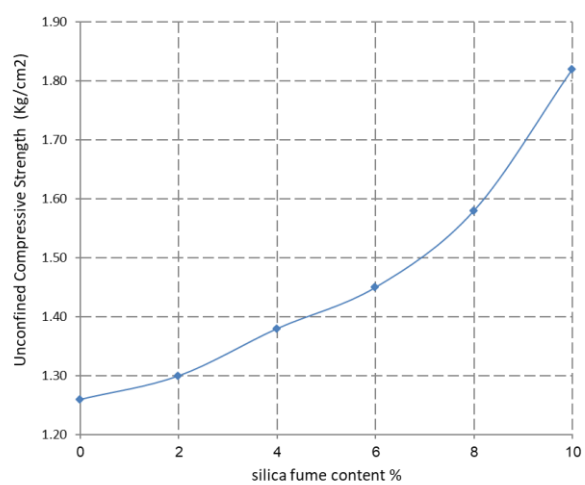
D. Unconfined compression strength

Results of the Unconfined compression strength test of samples with Mixed by different quantities of the (SF) (0, 2%, 4%, 6%, 8%, and 10%) are shown in fig (4). The (qu) unconfined compression strength of stabilized samples increases significantly with an increase in silica fume content from 0 percent to 10 percent (an improvement from 1.63 to 3.38 kg/cm^{2}.

However, after that, the unconfined compression strength is slightly affected by additional silica fume content. The increase in (qu)is due to silica fume particle internal friction and the chemical reaction between silica fume and soil. An increase in the amount of silica fume in soil has made the stabilized soil samples more porous than the natural soil samples, which is ductile compared to all the stabilized samples.



Soil (A)

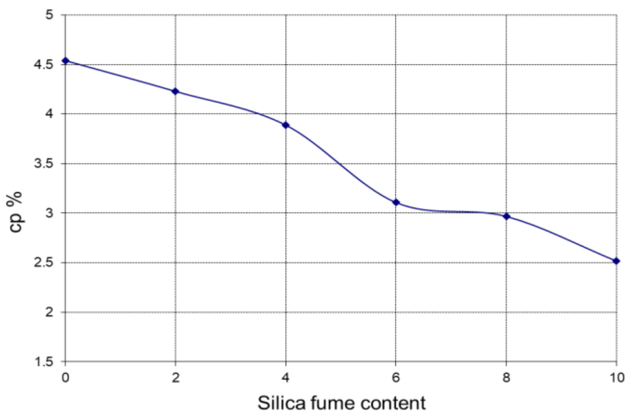


Soil (B)

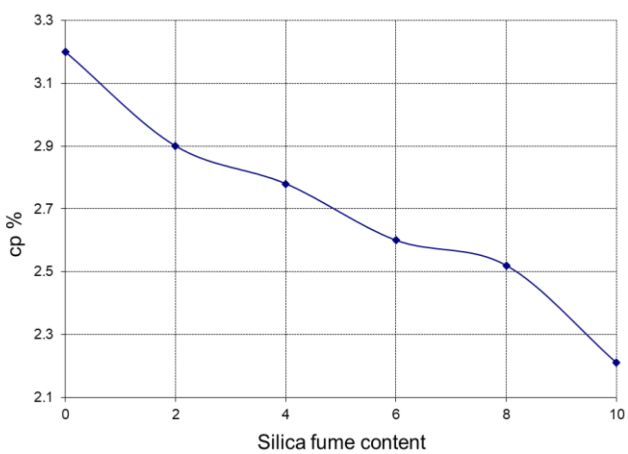
Figure 4: Influence of SF content on the unconfined compression strength.

E. Collapsible potential

The collapsible potential (CP) of the undisturbed sample is 4.54% for soil (A) and 3.2% for soil (B). The Oedometer test results for compacted soils mixed with SF are shown in figure 5, Fig (5a) reveals a downward trend the value of CP from 4.54% to 2.52% for samples compacted at O.M.C soil (A). for soil (B) the CP value from 3.2% to 2.21% for samples compacted at O.M.C.



Soil (A)



Soil (B)

Figure 9: Influence of SF content on the collapsible potential of the compacted sample.

IV. CONCLUSIONS

The following general conclusions can be drawn on the basis of the analysis and discussion of the test results of the present study on the effect of silica fume on cohesive soil properties:

1. The increase in the (SF) amount led to an increase in liquid limit and decrees plasticity index values although it led to an increase in the plastic limit.
2. Increasing the amount of (SF) causes a slight increase in maximum dry density.
3. The collapsible potential decreases with increasing the silica fume solution injection.
4. It was found that adding silica fume in the range of 0-10% has improved the engineering properties of soil, such as Compaction Characterization because the silica fume is filler material that fills the voids in the soil and decreases it.
5. The unconfined compression strength of stabilized samples significantly increases from 0 percent to 10 percent (increase from 1.63 to 3.38 kg / cm^2) with increasing silica fume content. The increase in the (qu) is due to silica fume particle internal friction and the chemical reaction between silica fume and soil. An increase in the amount of silica fume in soil has made the stabilized soil samples more porous than the natural soil samples, which is ductile compared to all the stabilized samples.
6. The other properties such as collapsible potential, consistency limits and unconfined compression strength show improvements when mixed with the SF blend in the range of 0-10percent. (SF) is a highly effective pozzolanic material (silicon dioxide, SiO_2) that reacts with clay minerals of the soil such as aluminum oxide, $Al2O_3$ and produces aluminum-silicate hydrated cement (cemented material) with soil particles.

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