Effect of Silica Fume on Engineering Properties of Black Cotton Soil

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ABSTRACT:

Due to rapid growth of urbanization and industrialization, minimization of industrial waste is serious problem in present days. To encounter this ennovative and nontraditional research on waste utilization is gaining importances now a days. Soil improvement using the waste material like Slags,Rice husk ash,Silica fume etc.,in geotechnical engineering has been recommanded from environmental point of view. The main objective of this study is to evaluate the feasibility of using Silica fume as soil stabilization material. In this paper the effect of Silica fume on engineering characteristics of expansive clay like Black Cotton Soil has been presented. A series of laboratory experiment has been conducted on black cotton soil blended with Silica fume content from 5% to 20% by weight of dry soil. The experimental results showed a significant increase in California bearing ratio and Unconfined compressive strength.The Differential free swell of the clay is reduced from 50% to 7% with increase in Silica fume content from 0% to 20% respectively.The Proctor compaction results showed a small decrease in Maximum dry density and increase in Optimum moisture content. From this investigation it can be concluded that the Silica fume as a potential to improve the characteristics of black cotton soil.

KEYWORDS: *Silica Fume. Black cotton soil. Soil Stabilization. Enaineerina Properties.*

I. INTRODUCTION:

Black cotton soil (BC Soil) represents a well known category of problematic from civil engineering point of view. They exibit large volumetric changes shrinkage and swelling behaviour if the moisture content changed.Due to this nature this type of soil is susceptible to damage to the structures and pavements founded on it.In india expansive soils cover about $0.8X10^6$ km² area approximately 20% of surface area[1].Structure founded in areas with soft or weak soil have need for improvement of soil properties by using additives.Soil stabilization techniques are used to improve shear strength,CBR, reducing expansive characteristics, etc.Silica fume also referred as micro-silica is a product resulting reduction of high purity quartz with coal in an electric arc furnace in the manufacture of silicon or ferro-silicon alloy.Silica fume rises as an oxidized vapour. It cools,condenses and is collected. It is fine grey coloured powder sometime similar to Portland cement or some flyashes.Condensed silica fume is essentially silicon-dioxide (more than 90%) in non crystalline form. Since it is an air borne material line flyash it has spherical shape.It is extremely fine with a particle size less than 0.1 micron and specific surface area of about 20,000m²/kg.Silica fume is used as an artificial pozzolanic admixure in concrete. As far as the production of silica fume is concerned nearerly 100,000 tons of micro silica is produced each year world wide[2].Iron also has a large amount of micro silica production. Steel Authority of India has provided necessary facilities to produced more than 3000 tons of Silica fume annually[3].

Many waste materials are used to modify the characteristics of soft soils. Traditionally the soils are stabilized by lime ,cement, etc.In recent year the uses of waste materials like flyash,plastic, rice- husk ash,slag,etc. for soil stabilization is gaining importance.In this study attempts are made to find the influences of silica fume on engineering characteristics of black cotton soil.

II. LITERATURE REVIEW:

The engineering properties of clayey subgrade soils may need to be improved to make them suitable for construction using some sort of stabilization methods. Stabilization of pavement subgrade soils has traditionally relied on treatment with lime,cement, or waste materials such as flyash,slags,Silica Fume,etc.Many researchers

are looking for alternative materials for soil stabilization, fly ash is an effective agent for chemical and mechanical stabilization of soil.[4-6]

Saranjeet Rajesh Soni et. al. concluded that solid waste disposal is an economical and effective way to achieve improvement in engineering performance of black cotton soils. The stability of soil using fly ash and rice husk powder can be increased .[7] Abd.El-Aziz M.et al.(2004), examined the effect of lime-silica fume stabilizers on engineering properties of clayey subgrades. They summerised that the plasticity index and swell potential decreases and CBR value increases significantly. There is improvement in shear strength parameter also. [8] .Azzawi et al.(2012) studied effect of silica fume addition on behaviour of silty clayey soils, they investigated that there is significant important on swelling pressure and compressive strength of composite samples with silica fume.The permeability of soil increased with increase in silica fume content. It is observed that the addition of silica fume decreases the development of cracks on the surface of compacted clay samples reducing the cracks width by 75%.[9]Venu Gopal N., studied the soil properties with silica fume as stabilizer and comparing the same with other materials. The laboratory investigations indicate that soil samples possessing low strength can be treated with varying silica fume of 5% to 20% by weight of dry soil. The treated soil samples showed significant improvement in the strength characteristics.[10]

Biswas et al.(2012) studied the utilization of rice husk with lime in subgrade soil for a rural road;they concluded that a very little amount of lime (3%) added to the clayey soil with RHA, improve the CBR value and compaction characteristics to a great extent.[11]The effect of marble dust with RHA on expansive soil has been studied by Sabat and Nanda (2011) it has been reported that the CBR and UCS values increase substantially due to addition of these two materials with natural expansive soil.[12] Kalkan and Addulut (2004) examined the suitability of silica fume for the construction of hydraulic barrier in landfill. The concluded that clay mixed with silica fume in different proportions, has higher binding strength.,low swelling pressure, and high compressive and shear strength.[13] M.Karimi and A.Ghorbani (2011) studied effect of lime and microsilica admixtures on silty sand soils, in presence of sulphates.Results showed that the addition of microsilica to the silty sand soil increases the CBR strength and decreases swelling, therefore microsilica waste material can be successively used to enhance the strength of silty soil.[2]

III. MATERIALS AND METHODOLOGY:

In soil, Silica fume is mixed on percentage basis i.e. 0%, 5%, 10%,15% and 20% by weight of dry soil.The following Tests were conducted on BC soil and Silica Fume mixes ;as per relevant IS Code.

- Compaction Test
- California Bearing Ratio
- Unconfined Compressive Strength
- Differential Free Swell

SILICA FUME

The stabilizer materials used in this study was Silica Fume . Silica Fume used in this study brought from Shisher Export House, Raipur,(C.G.). The composition of SF is presented in table-1.

CHEMICAL PROPERTIES

Table-1,Chemical composition of silica fume

S.No.	Parameters	Test Value
I	Chemical Test	
1.	Silica as SiO2, % by mass	89.9
2.	Total Sulphur Content as SO3, % by mass	0.58
3.	Lime as CaO, % by mass	7.85
4.	Magnesia as MgO, % by mass	4.03
5.	Alumina as Al2O3, % by mass	Nil
6.	Iron Oxide as Fe2O3, % by mass	Nil
II	Physical Test	
1.	Density , g/cc	2.07
2.	Particle Size Distribution (%)	59

Black Cotton Soil

The black cotton soil has been used as a base material in this study.It has been replaced partially by silica fume by weight of dry soil.The clayey soil involved in this research was collected from Railway Station Nursery Area, Adhartal, Jabalpur (M.P.). The soil sample was disturbed. The soil is classified as clay of high plasticity (Gs = 2.71 with 95% fines) with expansive behavior. The engineering characterictics of clay sample are presented in Table-2.

Table-2,Engineering Properties of black cotton soil

Sr.No.	Particulars	Test results
1	Soil Classification	CH
2	Specific Gravity	2.71
3	Liquid Limit , (%)	53
4	Plastic Limit , (%)	27.52
5	Plasticity Index , (%)	25.48
6	Shrinkage Limit , (%)	7.55
7	Grain Size Distribution: Sand (%) Silt + Clay (%)	 5 95
8	Compaction Characteristics Optimum Moisture Content (%) Maximum Dry Density (kN/m³)	 17 1.58
9	California Bearing Ratio	1.63
10	Swelling Characteristics Differential Free Swell (%)	 50
11	Unconfined Compressive Strength (kN/m²)	qu=125.1

The grain size distribution curve of BC soil is shown in figure 1

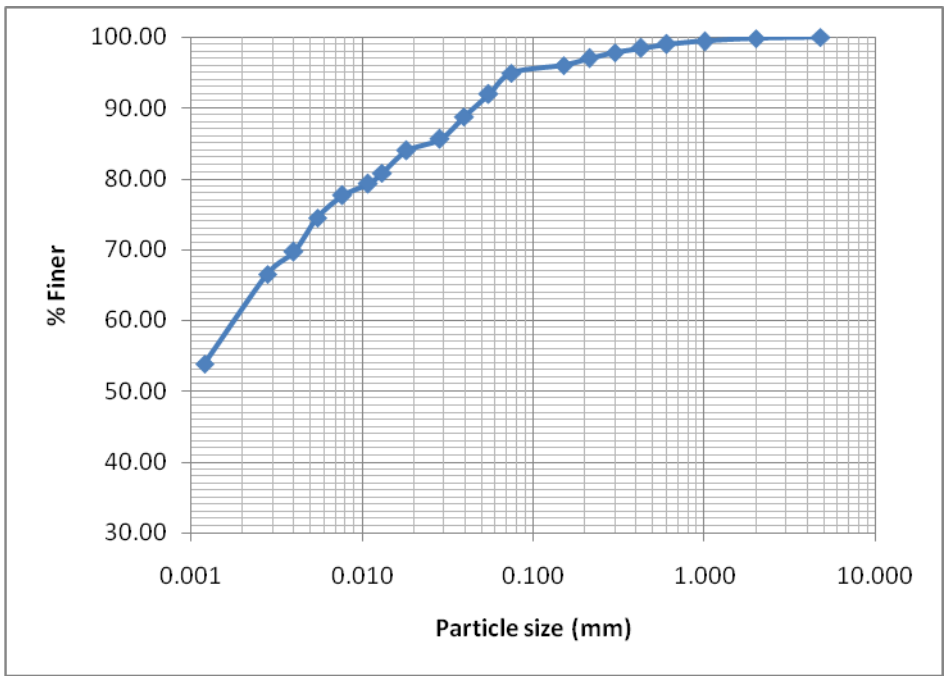

Figure-1, Grain Size Distribution of BC soil

IV. RESULTS OF VARIOUS TESTS

The results of various tests are summarized in table -3

Table-3, Results of various tests

Sr.No.	Particulars	Observation & Results				
		CS0	CS5	CS10	CS15	CS20
I	Compaction Characteristics Optimum Moisture Content (%) Maximum Dry Density (kN/m³)	 17 1.58	 18 1.55	 23 1.53	 27 1.51	 28 1.50
II	California Bearing Ratio	1.63	2.37	2.51	2.60	2.81
III	Swelling Characteristics Differential Free Swell (%)	 50	 25	 15	 11	 7
IV	Unconfined Compressive Strength (kN/m²)	qu=125.1	qu=127.6	qu=136.0	qu=155.6	qu=163.6

Where, CS0 = Clay + 0% Silica Fume
CS5 = Clay + 5% Silica Fume
CS10 = Clay + 10% Silica Fume
CS15 = Clay + 15% Silica Fume
CS20 = Clay + 20% Silica Fume

Result and Discussions:

The test results obtained from the experimental work are briefly discussed below.

The compaction tests have been carried out on virgin soil and soil-silica fume mixtures. The proctor tests were conducted as per IS 2720 (Part-VIII). The variation of optimum moisture content (OMC) and maximum dry density (MDD) are shown in figure 2. Both the OMC and MDD decrease with increase in silica fume content.However this decrease is not much as compare to the initial values. Soaked CBR tests were performed to evaluate the strength properties of the soil and mix.The CBR values increase from 1.63% to 2.81% as the silica fume content increases from 0% to 20%. The variation of CBR values with increase in silica fume content is shown in figure 3. The swelling behaviour of the soil is also checked to a great extent. The differential free swell (DFS) values are decrease from 50% to 7%. The variation is shown in figure 4. There is significant improvement in Unconfined compressive strength of the black cotton soil. The Unconfined compressive strength increases from 125.1 kN/m² to 163.6 kN/m² with the increase in silica fume content 0% to 20%. The variation is shown in figure 5.

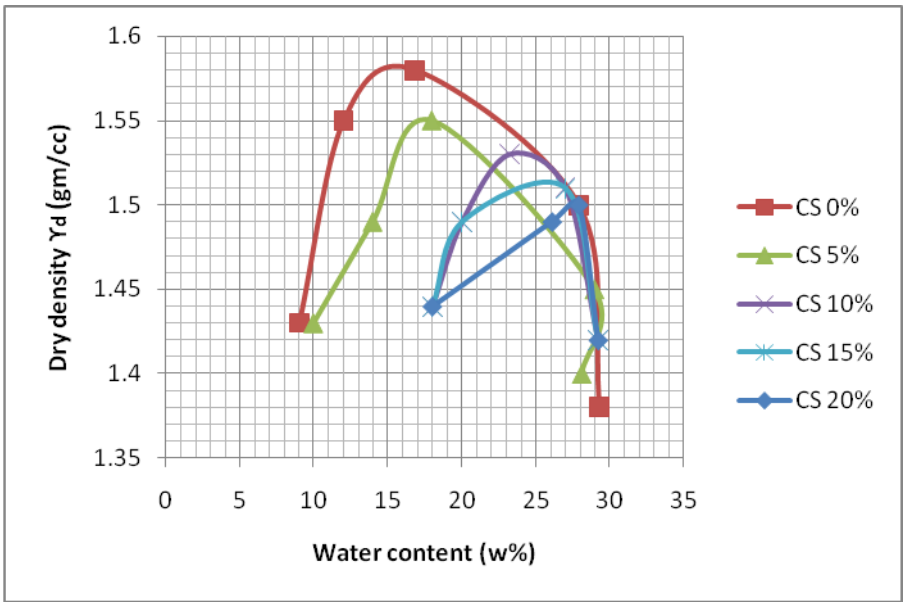

Figure 2 :Effect of Silica Fume on Compaction Characteristics of Soil.

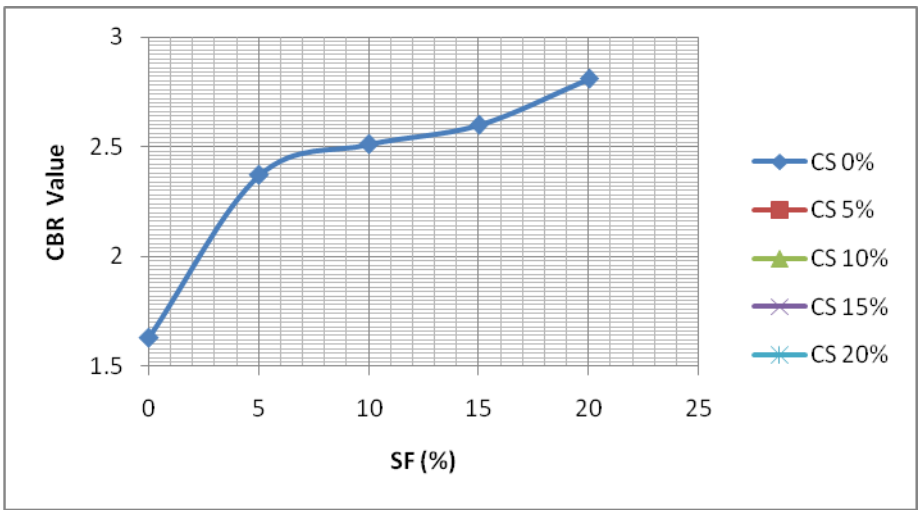

Figure 3: Effect of Silica Fume Content on California Bearing Ratio.

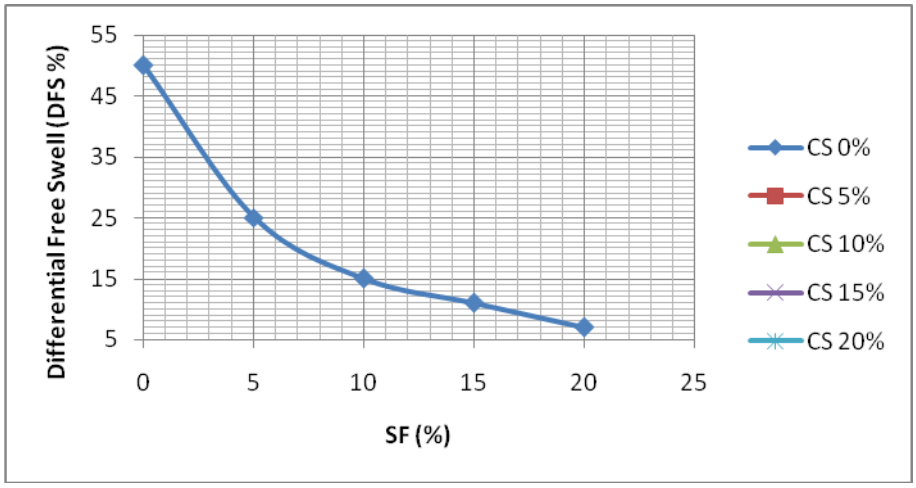

Figure 4: Variation of Differential Free Swell(DFS) with silica fume content.

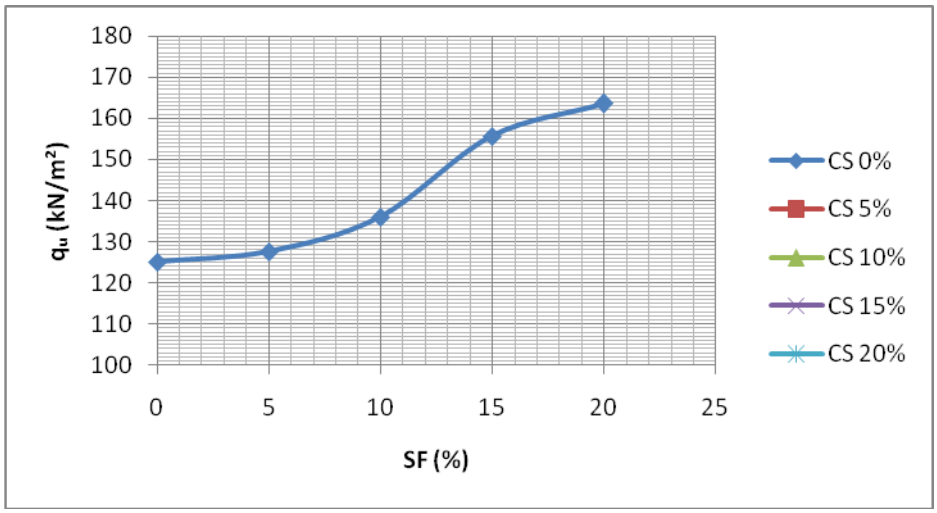

Figure 5: Variation of Unconfined Compressive Strength (qu) with silica fume content

V. CONCLUSIONS:

From the above laboratory investigations the following conclusions can be drawn :

[1] The BC soil-Micro Silica change the proctor compaction parameters.The addition of silica fume to the black cotton soil increase the optimum moisture content and decreases the maximum dry density with the increase in silica fume content.

[2] The addition of silica fume to the black cotton soil improve the soaked CBR considerably.The addition of 20% silica fume to the black cotton soil increases the CBR strength by 72% approximately.

[3] There is a significant decrease in the swelling characterristics of the soil. The degree of expansiveness reduceses from "High to Low".

[4] The addition of silica fume also increases the Unconfined compressive strength.The UCS of stabilized samples significantly increases from 125.1 kN/m² to 163.6 kN/m² i.e. approximately 31% increase.

[5] From the laboratory investigation it can be concluded that the industrial wastes like silica fume has the potential to modify the engineering characteristics of expansive clay like black cotton soil.

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