

Effect of Silica Fume on Index Properties of Black Cotton Soil

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Abstract— The aim of this research is to investigate the effect of Silica Fume addition on the behavior of black cotton soil which has inadequate natural stability. The Index properties of clayey soils may need to be improved to make them suitable for construction using some sort of stabilization methods. Stabilization of black cotton soils has traditionally relied on treatment with lime, cement, or waste materials such as Silica Fume (SF), Rice Husk Ash, Steel Slag, etc. The main objective of this study is to investigate the effect of the index properties of clayey soils when blended with SF. A series of laboratory experiments have been conducted on samples with 0%, 5%, 10%, 15% and 20% of Silica Fume by weight of dry soil. The test results showed a significant change in consistency limits of samples containing Silica fume. The Liquid limit would increase by 54% to 57% and Plastic limit would decrease by 27.07% to 26.29% with increasing Silica fume contents from 5% to 20%. Their Plasticity Index would increase from 26.93% to 30.71% and shrinkage limit would increase from 7.55% to 12.70%, respectively, when subjected to a SF blend of 5% to 20%. Also the Differential Free Swell decreased from 25% to 7% showing appreciable decrease in swelling behaviour. The investigation showed that the Silica fume is a valuable material to modify the index properties of black cotton soil to make them suitable for different construction activities.

Keywords— Silica Fume, Black cotton soil, Soil Stabilization, Index Properties.

1 INTRODUCTION

DISPOSAL of waste material produced from different industries is a great problem now a days. These material cause environmental pollution in the nearby locality. In recent year, application of industrial wastes in soil stabilization have been investigated by many researchers.

Traditionally soil, stone aggregates, sand, bitumen, cement etc are used for road constructions naturally materials are gradually declining. Keeping this in mind people are looking alternative materials for road construction. Industrial waste like blast furnace slags, fly ash, silica fume etc are considered as alternative materials for soil stabilization. Waste materials or non traditional stabilizers, such as Silica Fume and Fly Ash, are also sometimes applied for stabilization. This study focuses on using Silica Fume as a stabilizer material for BC soils. Silica fume is a very fine non-Crystalline silica produced in electric arc furnaces as a by-product of the production of elemental silicon or alloys containing silicon. It is usually a grey colored powder, somewhat similar to Portland cement or some fly ashes. SF is also collected as a byproduct in the production of other silicon alloys such as ferrochromium, ferromanganese, ferromagnesium, 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.

The main objective of the proposed study is to investigate the effect of Silica fume on the characteristics of soft clay like BC soil. The characteristics like Index properties of BC soil containing different percentages of Silica Fume have been investigated.

2 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. [1-3]

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. [4]

Abd.El-Aziz M. et al. (2004), examined the effect of lime-silica fume stabilizers on engineering properties of clayey subgrades. They summarised that the plasticity index and swell potential decreases and CBR value increases significantly. There is improvement in shear strength parameter also. [5] 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%. [6]

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. [7]

3 MATERIALS AND METHODOLOGY

A series of laboratory tests were conducted on BC Soil mixed with Silica fume in various percentages 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. The tests are :-

- Grain size distribution
- Liquid limit
- Plastic limit
- Plasticity index
- Shrinkage limit
- Specific Gravity
- Differential free swell (DFS)

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 SiO ₂ , % by mass	89.9
2.	Total Sulphur Content as SO ₃ , % by mass	0.58
3.	Lime as CaO, % by mass	7.85
4.	Magnesia as MgO, % by mass	4.03
5.	Alumina as Al ₂ O ₃ , % by mass	Nil
6.	Iron Oxide as Fe ₂ O ₃ , % by mass	Nil
II		
Physical Test		
1.	Density, g/cc	2.07
2.	Particle Size Distribution (%)	59

BLACK COTTON SOIL

The clayey soil involved in this research was brought 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 physical characterization of clay sample is presented in Table-2.

Table-2, Physical and Index 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	Differential free swell (%)	50

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

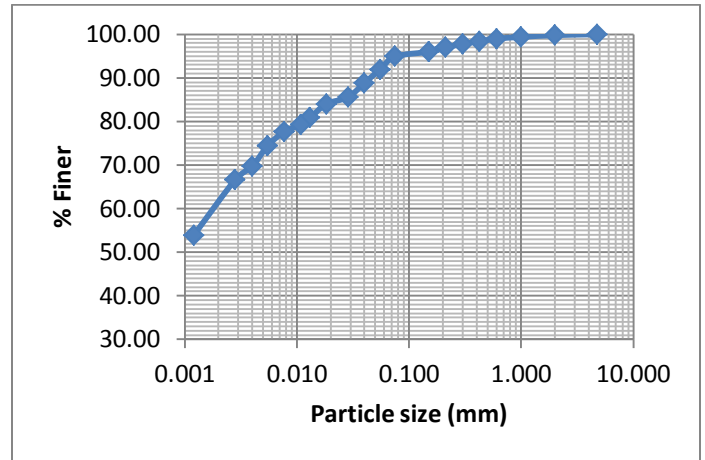


Figure-1, Grain Size Distribution of BC soil

4 TEST RESULTS

Various tests were conducted on black cotton soil mixed with silica fume in different proportion as per the relevant IS code of practice. The test results obtained from various laboratory investigations are summarized in table-3.

Table-3 Summary of results

Sr. No.	Particulars of tests	Results				
		CS0	CS5	CS10	CS15	CS20
1	Soil Classification	CH				
2	Specific Gravity	2.71	2.66	2.64	2.63	2.61
1	Liquid Limit (%)	53	54	55	56	57
2	Plastic Limit (%)	27.52	27.07	27.29	26.27	26.29
3	Plasticity Index (%)	25.48	26.93	27.71	29.73	30.71
4	Shrinkage Limit (%)	7.55	8.85	9.11	9.40	12.70
III	Differential free swell (%)	50	25	15	11	7

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.

5 RESULTS AND DISCUSSIONS

The variation of liquid limit, plasticity index, shrinkage limit, specific gravity and differential free swell are shown in figure 2 to figure 6. The Liquid limit increased from 53% to 57% as a silica fume content is increased from 0% to 20%. Similarly the plasticity index of BC soil increases from 25.50% to 30.70% with the increase of silica fume content in the black cotton soil. The shrinkage limit increases from 7.55% to 12.7% and differential free swell from 50% to 7% this indicates that the swelling behavior of the soil is completely checked.

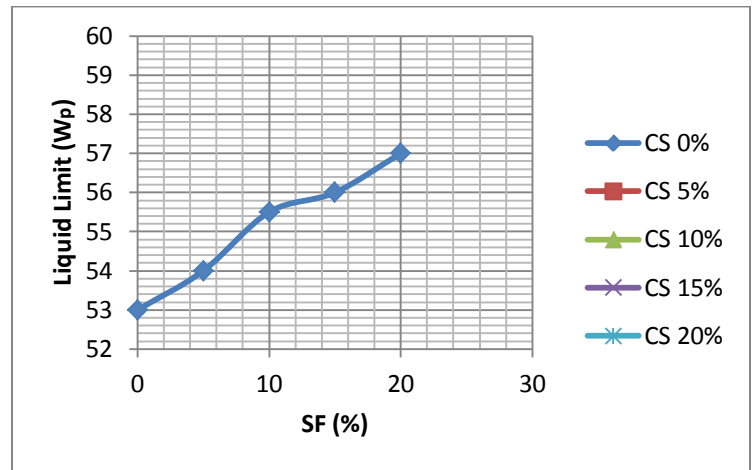


Figure-2, Variation of Liquid limit for clay-silica fume mixtures.

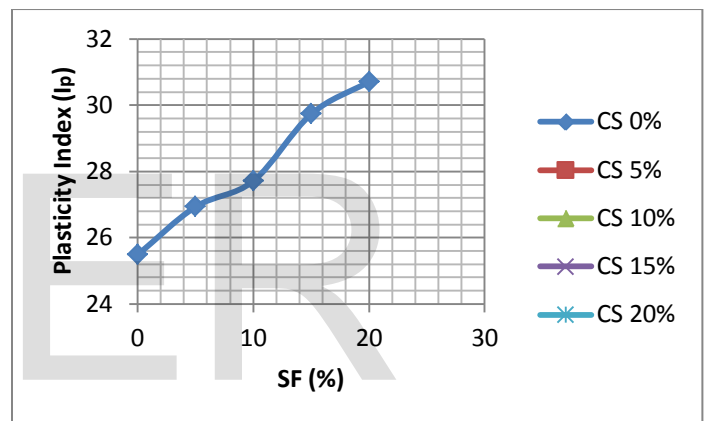


Figure-3 Variation of Plasticity Index values with increase in silica fume content.

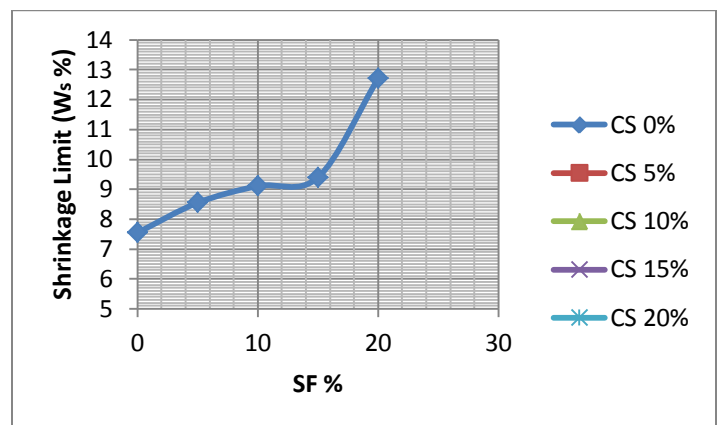


Figure 4 Variation of Shrinkage limits for clay-silica fume mixtures.

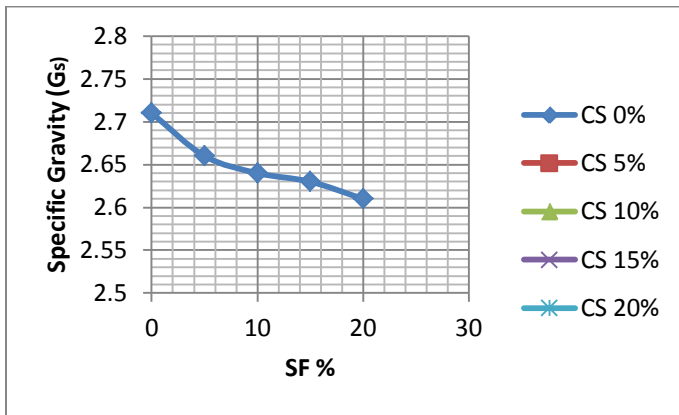


Figure 5 Variation of specific gravity for clay –silica fume mixtures.

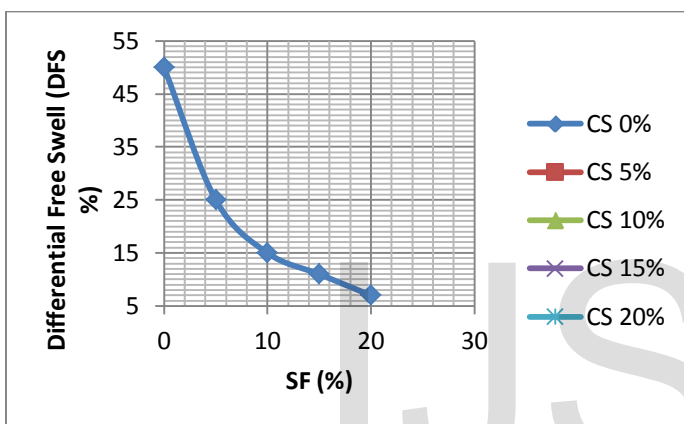


Figure 6 Variation of differential free swell for clay –silica fume mixtures.

6 CONCLUSIONS

The waste materials such as Silica Fume (SF) can also be used as nontraditional stabilizer for black cotton soils. This paper examines the effect of adding Silica Fume (SF) on the index properties of BC soils. From the series of laboratory experiments have been conducted on varieties of samples containing: 0%, 5%, 10%, 15% and 20% for Silica Fume, it was found that the index properties of soil have been improved by adding different percentage of Silica Fume. The swelling properties of BC Soil have also improved.

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