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Effect of Silica Fume on Expansive Soil Properties

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Abstract: ***In this research paper we study the effect of adding silica fume to black cotton soil in order to improve its engineering properties. Silica fume has been added in different percentages 0%, 2.5%, 5%, 10% by weight of soil. The results of test show that the addition of silica fume reduces the liquid limit, plasticity index, specific gravity, optimum moisture content, free swell % and increases plastic limit, unconfined compression strength with increasing California bearing ratio.***
Keywords: Expansive Soil, Silica Fume (SF), California Bearing Ratio (CBR), Atterberg's Limit.

I. INTRODUCTION

Soil is one of the most commonly available materials for civil engineering projects. Structures founded on the soil which is expansive in nature creates greatest hazard. Clay minerals like montmorillonite, kaolinite, illite etc contain this expansiveness of soil in considerable amount. Due to the clay minerals, the soil shrinks on drying and swelling soil expand on wetting. These soils are commonly unsaturated. These expansive soils create problems for the structures, mainly lightweight structures and the structures most commonly damaged are small buildings, roadways, pipelines and irrigation canals. The moisture in the soil shows variations due to climatic changes, change in the water table, watering of gardens, presence of trees and shrubs, and drainage pipes. Soil stabilization is the technique introduced many years ago with main purpose to render the soil capable of meeting the requirements of the specific engineering projects. In addition, when the soils at site are poor or when they have undesirable property making them unsuitable for use in a geotechnical projects, they may have to be stabilized. Stabilization of embankment and pavement subgrade soil has traditionally relied on treatment with lime, cement, and special additives such as pozzolanic materials. Pozzolanic materials such as fly ash, silica fume, and rice husk ash, which are regarded as wastes maybe used for soil improvement. Main purpose of stabilization is to improve the performance of the soil, increase durability and strength and reduce compressibility of the soil.

II. MATERIALS AND PROPERTIES

In this study, silica fume is used for stabilizing and considering its effects on the black cotton soil.

1) Black Cotton Soil: The soil for this research was collected from Maharajpura Area, Gwalior (M.P.). Black cotton soil is used as a base material in this study. It has been partially replaced by the mix of silica fume and lime by weight of dry soil. The soil sample collected was disturbed. The soil classified as clay of expansive behavior with high plasticity having Gs = 2.69 with 90% fines. The properties of the soil collected from the site tabulated such as:

Table1. Properties of Black Cotton Soil

S.N.	Particulars	Test Results
1.	Grain Size Distribution Sand (%) Silt + Clay (%)	 10% 90%
2.	Liquid Limit (%)	64
3.	Plastic Limit (%)	33
4.	Plasticity Index (%)	31
5.	Specific Gravity	2.69
6.	Optimum Moisture Content (%)	19
7.	Maximum Dry Density (KN/m^3)	15.572
8.	Differential Free Swell (%)	45.32
9.	Unconfined Compressive Strength (KN/m^2)	130

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2) Micro Silica Fume: Micro silica fume is a by-product which is produced during the reduction of high-purity quartz with coal in electric arc furnaces in the production of silicon and ferrosilicon alloys. The silica fume used in this study was 'Elkem Micro Silica' Grade 920 is a dry silica fume powder. The composition of silica fume is presented in table:

Table2- Chemical and physical properties of silica fume

Property	SiO_2	H_2O	Loss of ignition	Retained on 45 micron sieve	Pozzolanic Activity Index, 7 days	Bulk density
Specified Value (ASTM C1240-14)	Maximum 85%	Maximum 3%	Maximum 6%	Maximum 10%	Minimum 105% of control	500-700 Kg/m^3
Analysis	87.64	0.28	1.20	0.25	124	625

III. TESTING METHODOLOGY

Laboratory tests were carried out on black cotton soil mixed with silica fume at various percentages i.e. 0%, 2.5%, 5%, 10% by weight of dry soil. The following tests were conducted on black cotton soil with silica fume as per relevant IS Code. The conducted tests are :-

A. Grain size distribution (IS 2720 Part IV)
B. Liquid limit (IS 2720 Part V)
C. Plastic limit (IS 2720 Part V)
D. Plasticity index (IS 2720 Part V)
E. Specific gravity (IS 2720 Part III)
F. Standard proctor test (IS 2720 Part VIII)
G. Differential free swell (DFS) (IS 2720 Part XI)
H. California bearing ratio (C.B.R.) test (IS 2720 Part XVI)
I. Unconfined compressive strength (UCS) test (IS 2720 Part X-1991)

IV. RESULTS AND DECLARATION

The test results obtained from various laboratory investigations are summarized in table

S.N.	Particulars of tests	Soil + SF 0%	Soil + SF 2.5%	Soil + SF 5%	Soil + SF 10%
1.	Soil Classification	CH			
2.	Liquid Limit (%)	64	59	55	52
3.	Plastic Limit (%)	33	34	36	39
4.	Plasticity Index (%)	31	25	19	13
5.	Specific Gravity	2.69	2.64	2.61	2.56
6.	Optimum Moisture Content (%)	19	18	16	14
7.	Maximum Dry Density (kN/m^3)	15.572	15.8	16.42	16.0
8.	Differential Free Swell (%)	45.32	32.3	28.3	15.7
9.	Unconfined Compressive Strength (kN/m^2)	130	145	180	210

Table for California Bearing Ratio (CBR):

S.N.	Penetration	Soil + SF 0%	Soil + SF 2.5%	Soil + SF 5%	Soil + SF 10%
1.	2.5 mm	2.32	2.82	3.43	3.51
2.	5 mm	1.92	2.25	2.74	2.87

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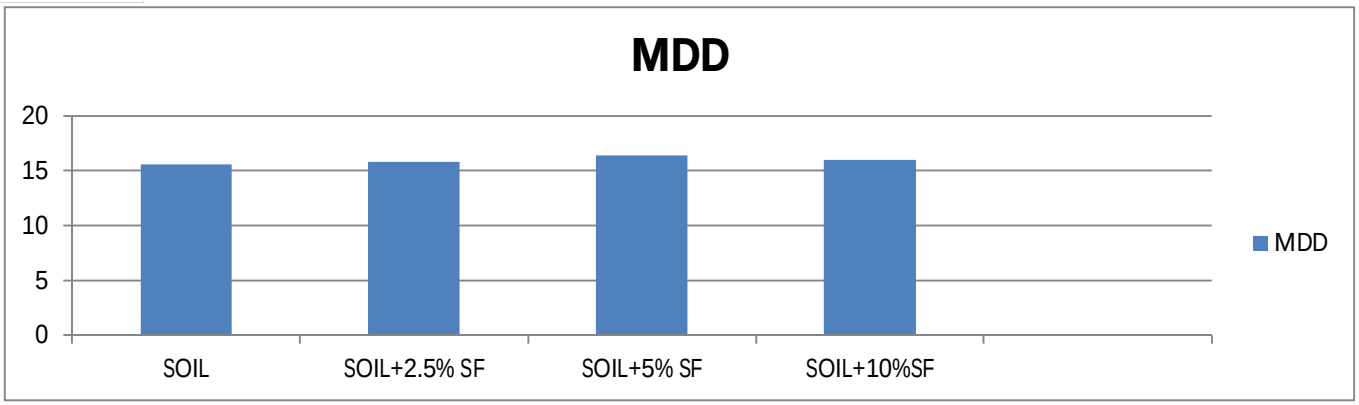


Fig .1. Chart showing the variation in MDD for mix proportion of soil and silica fume

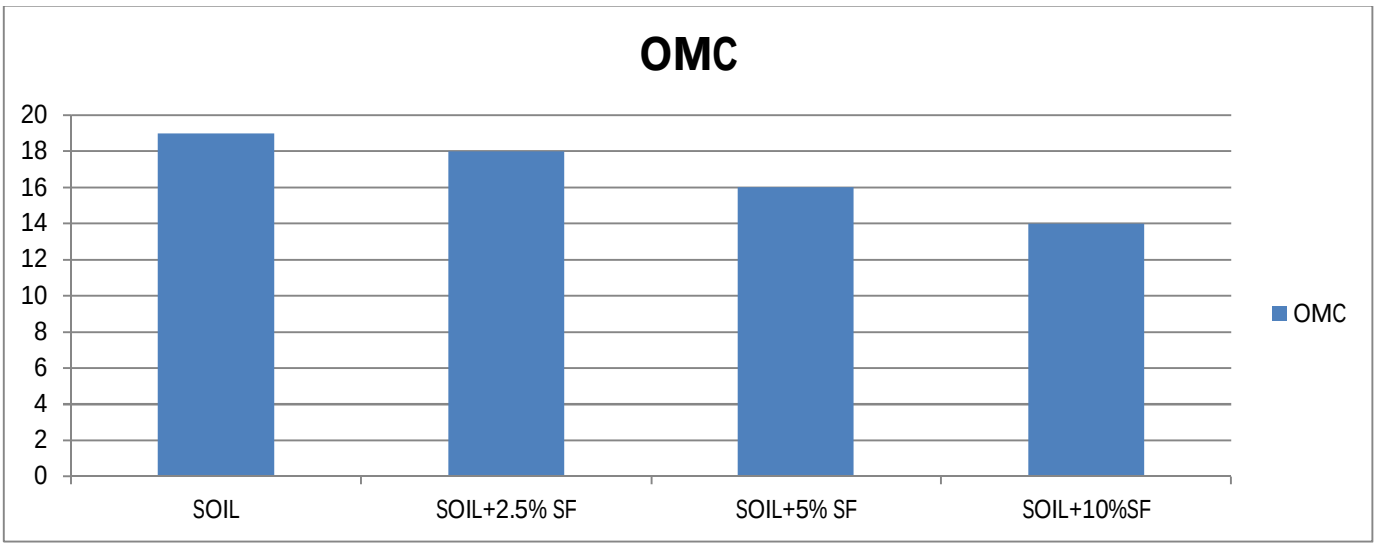


Fig .2. Chart showing the variation in MDD for mix proportion of soil and silica fume

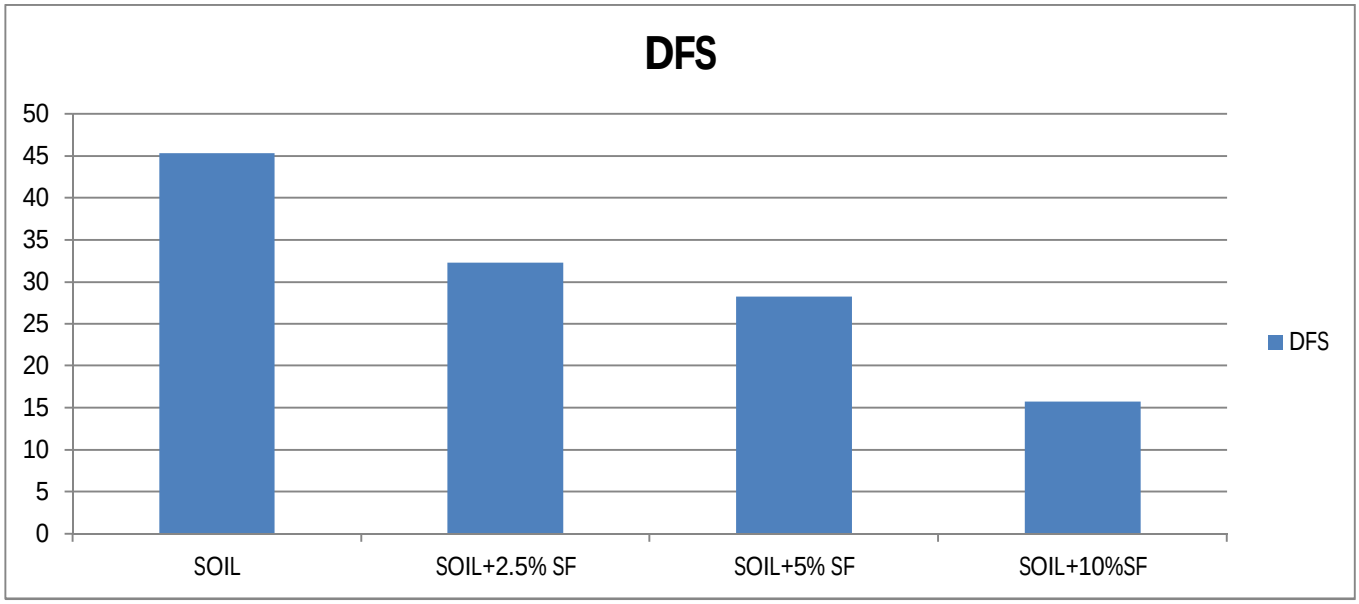


Fig .3. Chart showing the variation in DFS for mix proportion of soil and silica fume

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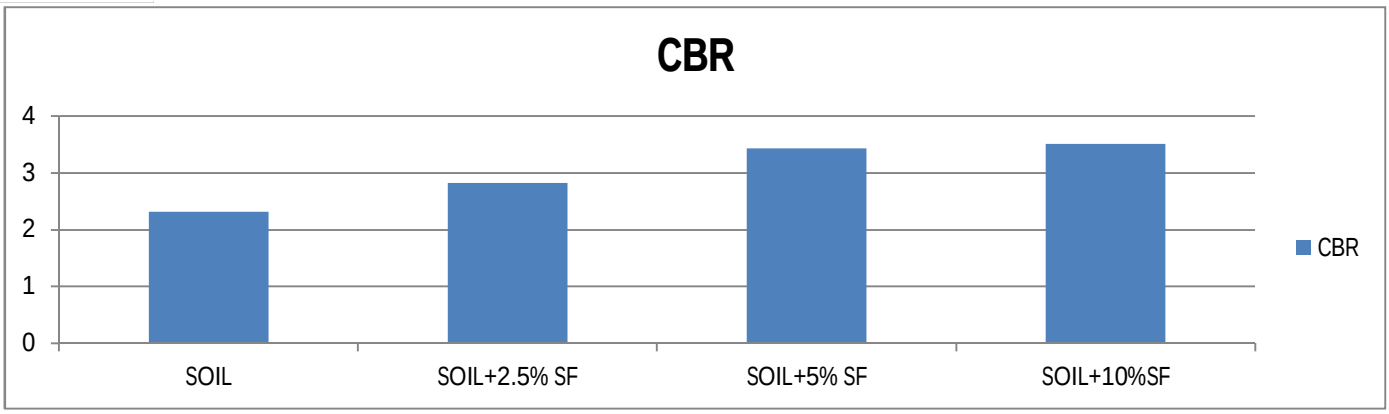


Fig. 4. Chart showing the variation in DFS for mix proportion of soil and silica fume

V. CONCLUSION

In this study a series of tests has been performed on expansive clayey soil mixed with different percents of silica fume to investigate the characteristics of soil. It is found that the index properties and swelling properties have been improved by adding different percentage of silica fume. Tests concluded that liquid limit decreased from 64% to 55%, plastic limit decreased from 33% to 36%, OMC decreased from 19% to 16% at 5% replacement of silica fume with soil. A slight increase is noted in maximum dry density and high amount of decrement in DFS is observed. CBR value is increased from 2.32 to 3.43. Thus black cotton soil stabilized with micro silica fume can be used for the constructions of embankments and pavements in rural roads.

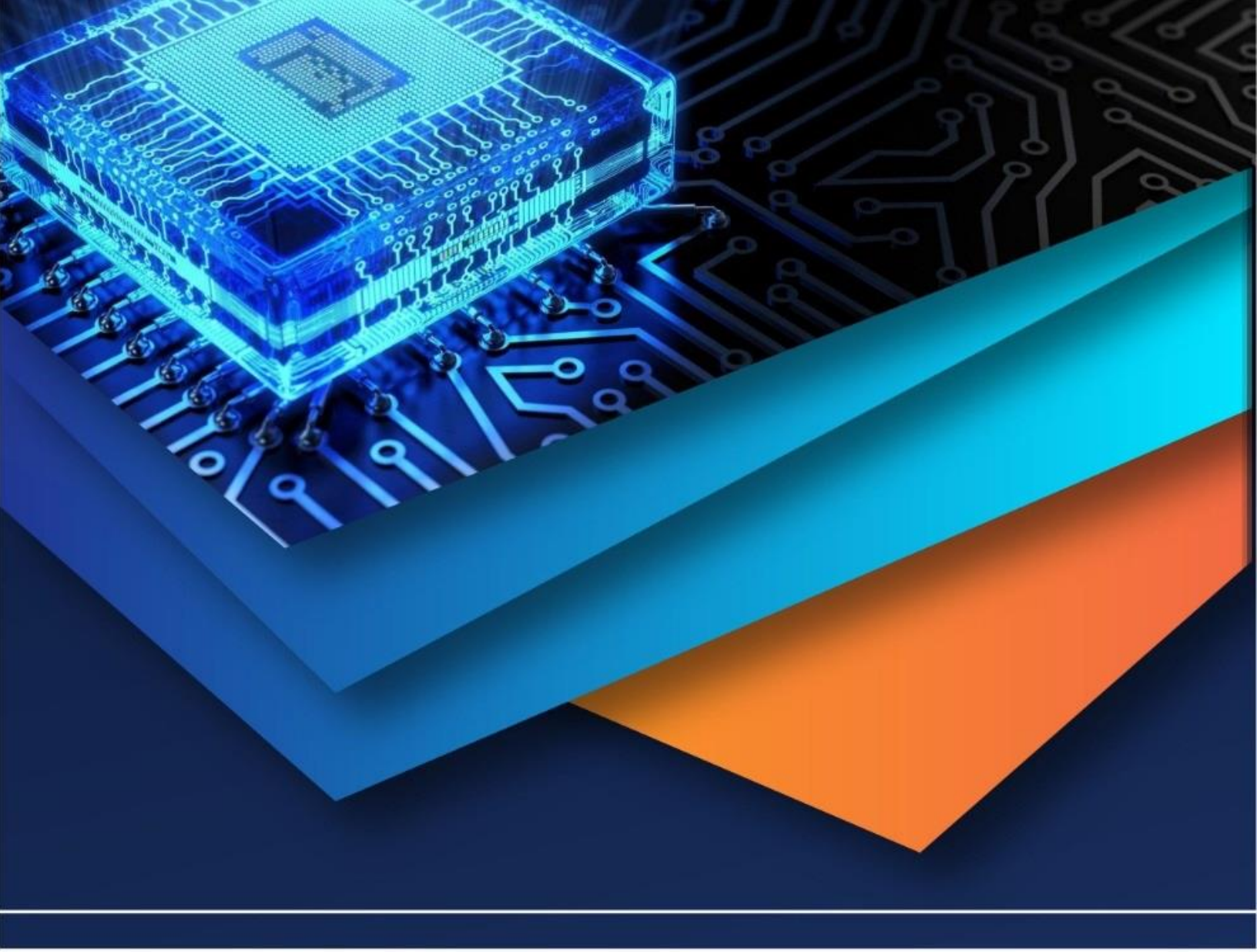
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