Comparison of Soil stability using Silica fume and Basalt fiber on Black cotton soil

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Abstract - *It is essential to choose soil stabilization if good soil is not accessible at the construction location. The technique of stabilizing soil aims to maintain or enhance the functionality of the soil as a building material. This study has been undertaken to investigate the comparison of soil stability by using Silica Fume and Basalt Fiber on black cotton soil which has inadequate natural stability. The index properties of clayey soils might need to be improved to make them suitable for construction using any kind of stabilization methods. Stabilization of black cotton soils has been traditionally relied on treatment with lime, cement or waste materials such as silica fume, rice husk, steel slag etc. The main objective of this study is to investigate the effect of index properties of clayey soils when blended with silica fume and basalt fiber. A series of laboratory experiments have been conducted on samples with 0%, 5%, 10%, 15% and 20% of Silica fume and 0.05%, 0.1%, 0.15% and 0.2% of Basalt fiber by weight of dry soil. The test results showed a significant change in consistency limits of samples containing Silica fume and basalt fiber. 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. The addition of basalt fiber gives a very good compressive strength to the BC soil as compared to silica fume.*

Key Words: Soil Stabilization, Black cotton soil (Expansive soil), Silica fume, Basalt fiber

1.INTRODUCTION

The rapid growth of urbanization worldwide, is prompting a vast infrastructure development in the recent decades which necessitates the building activities in almost all types of soil regardless of its strength. Hence the ground improvement techniques like soil stabilization have become mandatory before the construction activities. But many a times when engineers come face to face with the challenge of carrying out the construction on soil with less physical strength creating a need to have a proper knowledge about their properties and factors which affects their behavior. Hence the process of enhancing the soil strength qualities to achieve a strong foundation for construction is a very much required job and has to be carried out carefully taking in the essential properties of each soil, its nature, surrounding conditions and behavior upon the addition of chemicals or compaction etc. This technique of enhancing the soil condition have been prevalent since time and been used in the field of agriculture to obtain the soil with desired properties. Over the years the same technique became prevailing in construction sector owing to the any advantages it poses. Mechanical stabilization and chemical stabilization are the two broad categories into which all kinds of soil stabilization may be categorized. A soil's grading is altered during mechanical stabilization by mixing it with other types of soil of various grades. When a soil is stabilized mechanically, its grading is altered by combining it with other soil types of various grades. By doing so, a compacted soil mass can be achieved Contrarily, chemical stabilization refers to the alteration of soil characteristics by the addition of chemically active substances. Understanding the material qualities involved in the mixing of soils and the results after mixing are crucial for soil stabilization.

1.1 Black Cotton Soil

Indians refer to expansive soil by the term "black cotton soil" (BC soil). Expansive soils are those that undergo volume changes when in contact with water. It expands when it rains. shrinks during the summer due to water intake. season. The features of expansive soils are due to the presence of clay minerals that are swelling. The salient features or the characteristics of expansive soil include the free swell index, swelling pressure and potential, which are directly related to the stability and strength of the foundation above such soil. Characteristic swell and shrinkage of BC soil produces concerns like foundational cracks. Thus, it is essential to enhance these soils' characteristics to prevent damage to the structure.

1.2 Silica Fume

Amorphous Silica is a kind of silicon dioxide. It is a by-product of the manufacturing of silicon and ferrosilicon alloys and is made up of spherical particles with an average particle diameter of 150 nm. Its primary use is as a pozzolanic component in high performance concrete. This silica fume can also be used to stabilize soils and improve their qualities. The average size of the spherical particles in silica fume, which are smaller than 1 µm in diameter, is about 0.15 µm. This reduces it to a size that is around 100 times smaller than the typical cement particle. The bulk density of silica fume ranges from 130 to 600 kg/m³, depending on the silo's degree of densification. The Specific gravity is in the range of 2.2 to 2.3.

1.3 Basalt Fiber

Basalt is an igneous rock, which means it started off in a molten condition, and is a hard, dense volcanic rock that can be found in most nations worldwide. Basalt has long been used in casting methods to create tiles and slabs for use in architecture. Basalt fiber comprises of minerals such as plagioclase, pyroxene and olivine. It is similar to fiber glass, having better physiochemical properties than fiberglass, but being significantly cheaper than carbon fiber. It is used as fireproof textile in aerospace and automotive industries and can also be used as a composite to produce products such as camera tripods. Recently, these fibres are used in concrete for hardening purpose but it is rare to be used in soil improvement.

2. METHODOLOGY

Present study is to know geotechnical properties of soil and improve its properties by adding admixtures like silica fume and basalt fiber in different proportions. The soil sample was collected from 1.5m deep in ground from Navalgund taluk in Karnataka. The soil is investigated for different index properties and engineering properties in the laboratory.

- Specific gravity test
- Atterberg's limit test
- Compaction test
- Unconfined Compression test

1. Specific Gravity Test (IS 2720-3 (1980)):

   Specific gravity G is defined as the ratio of total weight of sample to the weight of equal volume of water.

Table -1: Specific Gravity of BC soil sample

Sample number	1	2
Weight of empty bottle, (W1) in gms.	32	33
Weight of bottle + dry soil (W2) in gms	58.8	58.4
Weight of bottle + dry soil + water (W3) in gms	97.1	96.3
Weight of bottle + water (W4) in gms	80.2	80.3
Specific gravity	2.71	2.70
Average Specific gravity	2.7	

2. Atterberg's limit test:

- Liquid limit test (LL) (IS 2720-5 (1985))

Table -2: Specific Gravity of BC soil sample

Moisture Content %	57	55	54	52	48	40	35
No. of blows	8	14	17	21	29	33	42

From the above results, Liquid limit of soil sample = 50.3 %

- Plastic limit test (PL) (IS 2720-5 (1985))

The plastic limit is defined as the water content corresponding to the arbitrary limit at which the soil passes from plastic state to semisolid state of consistency. It is minimum water content at which the change in the shape of the soil is accomplished by visible cracks when work beyond this limit, soil crumbles.

Plastic limit of soil sample = 34.76%

- Plasticity index (PI)

The difference between liquid limit and plastic limit is known as plasticity index.
Plasticity index = 50.3 – 34.76 = 15.54 %
Soil is medium plastic in nature.

3. Compaction test (IS 2720-7 (1980))

Table -3: Light Compaction of BC soil sample

Water content %	Bulk density kN/m³	Dry density kN/m³
8.65	16.82	15.49
11.54	17.95	16.09
17.8	19.33	16.41
21	19.20	16.09
24.5	19.10	15.40
26.34	18.51	14.65

From the above table,
Optimum moisture content (OMC) = 17.8 %
Maximum Dry density (MDD) = 16.41 kN/m³

4. Unconfined Compression test (IS 2720-10 (1991))

Table -4: Unconfined Compression test of BC soil sample

Time (s)	DGR Δh (cm)	PGR	$E = \Delta h/l$	$A_h = A_0/(1-E)$	q_U	UCS = q_U / A_h
30	0.04	32	0.01	10.81	8.21	0.76
60	0.15	45	0.02	10.97	11.41	1.04
90	0.25	56	0.03	11.12	14.23	1.28

Unconfined compression strength of soil sample = 125.1 kN/m²

Properties of Black Cotton soil sample:

Table -5: Properties of BC soil sample

Serial No.	Properties	Result
1	Specific gravity	2.7
2	Liquid limit	50.3 %
3	Plastic limit	34.76 %
4	Plasticity index	15.54 %
5	Optimum moisture content	17.8 %
6	Maximum dry density	16.41 kN/m³
7	Unconfined Compressive strength	125.1 kN/m²

TEST ON BC SOIL SAMPLE USING SILICA FUME:

- Atterberg's limit test:

Table -6: Atterberg's limit of soil sample with varying percentage of silica fume

Serial No.	Percentage of Silica fume	Liquid limit (%)	Plastic limit (%)	Plasticity Index (%)
1	5	53	27.1	25.9
2	10	54	27.3	26.7
3	15	53	27.83	27.17
4	20	53	27.14	25.86

- Compaction test:

Table -7: OMC & MDD of soil sample with varying percentage of silica fume

Serial No.	Percentage of Silica fume	Optimum moisture content (%)	Maximum dry density (kN/m³)
1	5	18.5	16.29
2	10	23.6	15.89
3	15	25.2	15.2
4	20	24.6	15.4

- Unconfined Compression test:

Table -8: Unconfined Compression strength (UCS) of soil sample with varying percentage of silica fume

Serial No.	Percentage of Silica fume	Unconfined compression strength (kN/m²)
1	5	126.7
2	10	134
3	15	152.5
4	20	144.8

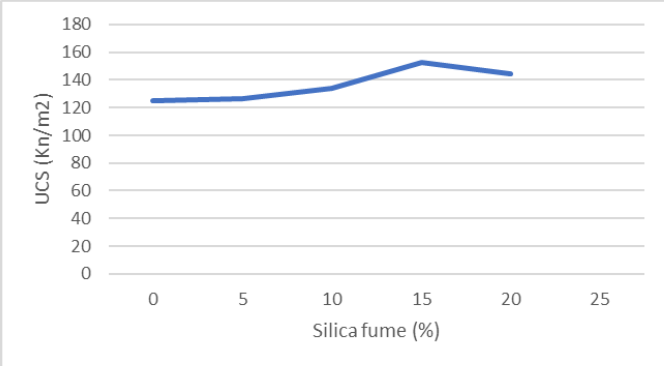

Chart -1: Variation in UCS of BC soil due to varying silica fume content

TEST ON BC SOIL SAMPLE USING BASALT FIBER:

- Atterberg's limit test:

Table -9: Atterberg's limit of soil sample with varying percentage of basalt fiber

Serial No.	Percentage of Basalt fiber	Liquid limit (%)	Plastic limit (%)	Plasticity Index (%)
1	0.05	49.84	27.83	22.46
2	0.1	51.75	28.24	23.51
3	0.15	53	28.93	24.07
4	0.2	52.38	28.66	23.72

- Compaction test:

Table -10: OMC & MDD of soil sample with varying percentage of basalt fiber

Serial No.	Percentage of Basalt fiber	Optimum moisture content (%)	Maximum dry density (kN/m³)
1	0.05	16.4	13.2
2	0.1	15.48	13.9
3	0.15	14.76	14.9
4	0.2	14.46	14.57

- Unconfined Compression test:

Table -11: Unconfined Compression strength (UCS) of soil sample with varying percentage of basalt fiber

Serial No.	Percentage of Basalt fiber	Unconfined compression strength (kN/m²)
1	0.05	263.4
2	0.1	312.7
3	0.15	358.9
4	0.2	330.7

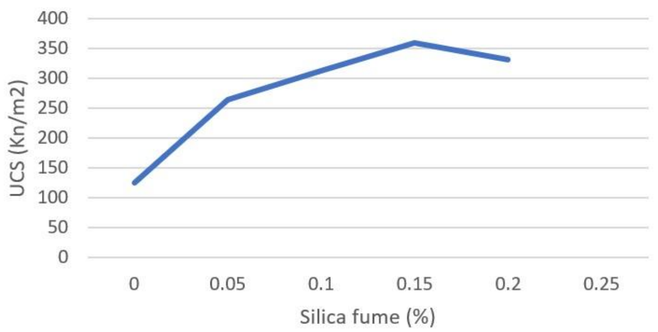

Chart -2: Variation in UCS of BC soil due to varying basalt fiber content

3. CONCLUSIONS

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

- There is increase in the liquid limit, plastic limit and plasticity index of black cotton soil on addition of silica fume as well as basalt fibre on increasing their percentage in the soil.

- The addition of basalt fibre to black cotton soil increase the maximum dry density of soil and decreases the optimum moisture content of the soil.

- The addition of silica fume and basalt fibre also increases the unconfined compressive strength. The UCS of stabilized samples with silica fume significantly increases from 125.1 kN/m² to 152.5 kN/m², whereas the stabilized sample with basalt fibre drastically increases from 125.1 kN/m² to 358.9 kN/m² which is more than two times the strength of virgin soil.

- The optimum moisture content of the stabilized soil increases on adding silica fume and decreases on adding the basalt fibre, whereas the maximum dry density of stabilized soil decreases on adding silica fume and increases on adding basalt fibre.

- On increasing the dosage of silica fume in BC soil by 20% there is decrease in the strength of the soil, this indicates that 15% SF is the optimum dosage of SF that gives higher strength of soil.

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- On increasing the dosage of basalt fibre in BC soil by 0.2% there is decrease in the strength of the soil, this indicates that 0.15% BF is the optimum dosage of BF that gives higher strength of soil.

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