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Black Cotton Soil Stabilization Using Waste Glass Powder and Sawdust Ash

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Abstract: This project investigates the use of waste glass powder (WGP) and sawdust ash (SDA) as stabilizing agents for black cotton soil, known for its expansive nature and low bearing capacity. The study explores how these materials can improve the soil's engineering properties, such as reducing plasticity, increasing shear strength, compaction characteristics, and California Bearing Ratio (CBR). Laboratory tests, including Atterberg's limits, compaction, CBR, and unconfined compression tests, were conducted with varying proportions of WGP and SDA. The results show that these stabilizing agents significantly improve the soil's performance, making it more suitable for construction while contributing to sustainability by utilizing waste materials.
Keywords***: soil stabilization, waste glass powder, sawdust ash, Atterberg's limits, UCC, CBR, MDD, OPM***

I. INTRODUCTION

This paper explores an innovative approach for black cotton soil stabilization using waste glass powder and sawdust ash. The objective is to investigate the effectiveness of waste glass powder and sawdust ash as a stabilizing agent to improve the engineering properties of black cotton soil. The study begins with an overview of the challenges connected with black cotton soil, highlighting its susceptibility to volume changes and low bearing capacity. It then introduces waste glass powder and sawdust ash as a potential stabilizer, focusing their properties. The experimental phase involved a series of laboratory tests, including Atterberg limits, compaction tests and California bearing ratio test. Black cotton soil samples have been treated with varying percentages of mixture of waste glass powder and sawdust ash. The results have been compared with untreated soil to assess improvements plasticity compaction characteristics and shear strength. Black cotton soil also known as expansive clay soil common in many parts of the world, poses significant challenges for construction due to its high shrink-swell capacity. Stabilizing this soil is crucial for improving its engineering properties. Traditional methods of soil stabilization involve the addition of lime, cement, or chemical agents to improve soil properties. In this project we proposed an innovative approach to stabilize black cotton soil using waste glass powder and sawdust ash. Waste glass powder derived from crushed glass and sawdust ash is a byproduct of burning wood sawdust, are both considered as environmentally friendly materials, and recent research has suggested their potential as sustainable and cost-effective stabilizing agents. This project aimed to explore the possibility of using waste glass and sawdust ash to stabilize black cotton soil. we have investigated how the introduction of waste glass powder and sawdust ash into the soil can affect its engineering properties. On the successful completion, it becomes evident that this approach could be offered an eco-friendly and cost-effective solution for the challenges possessed by black cotton soil in construction.

II. SPECIFIC OBJECTIVES

1) To determine the index and geotechnical properties of black cotton soil.
2) To study and compare compaction properties, Unconfined compressive strength and California bearing ratio values of black cotton soil with different percentages of waste glass powder and sawdust ash.
3) To recommend the use of glass and wood ash for practical approaches and hence disposal problems.

III. MATERIALS AND METHODS

The materials required for the study are black cotton soil, waste glass powder and sawdust ash. Laboratory tests such as specific gravity test, hydrometer analysis, Atterberg's limit test, UCC strength test, heavy compaction test, and CBR test were conducted to determine the basic properties of collected soil sample. The sawdust ash and waste glass powder will be added to the soil in various proportion. Then the tests have been conducted such as standard proctor test, unconfined compressive strength, Atterberg's limits test and California Bearing Ratio test.

A. Black cotton soil

Black cotton soil, abundant in clay minerals, exhibits high shrinkage and swelling tendencies. Covering approximately 22% of India's landmass. It is prevalent in states such as Gujarat, Maharashtra, Karnataka, Madhya Pradesh, and some parts of Tamil Nadu and Kerala, primarily found on the Deccan Plateau. The soil sample is collected from Eruthampathy, Chittur taluk, in Palakkad district, Kerala.

B. Sawdust ash

Sawdust ash, rich in potassium and calcium, can act as a pozzolanic material, which reacts with soil and moisture to form cementitious compounds. This reaction can improve the soil's load bearing capacity and reduce its expansiveness. The sawdust sample is collected from Chemmaniyod in Malappuram district, Kerala and it is burned to form ash.

C. Waste glass powder

Waste glass powder can enhance the mechanical properties of black cotton soil. Its fine particles can fill voids in the soil matrix, reducing plasticity and improving compaction. Additionally, the silica content in waste glass powder can contribute to soil strength and stability. Here we used waste glass powder of 90 microns and the sample of is collected from Thrissur district, Kerala.

D. Mix proportion

Mix proportion adopted for this study is given in Table 1. Six set of soil samples was treated with various percentage of SDA and WGP.

TABLE 1
MIX PROPORTION

SAMPLE	SDA %	WGP %
A	9	5
B	9	10
C	9	15
D	12	5
E	12	10
F	12	15

The mix proportion table presents six different soil samples (A to F) treated with varying percentages of sawdust ash (SDA) and waste glass powder (WGP). The SDA percentage varies between 9% and 12%, while the WGP percentage ranges from 5% to 15%. These combinations aim to analyze their effects on the mechanical and structural properties of black cotton soil.

E. Preliminary tests

Following tests are conducted on black cotton soil for finding the basic properties of black cotton soil. They are: -

Atterberg's limit (LL, PL, SL): The Atterberg Limit Test determines the critical water content values of a soil, which help classify its consistency and engineering behavior. It includes Liquid Limit (LL): Water content at which soil transitions from liquid to plastic state. Plastic Limit (PL): Water content at which soil transitions from plastic to semi-solid state. Shrinkage Limit (SL): Water content at which soil stops shrinking.

Compaction characteristics (MDD & OMC): Determine the optimal moisture content and maximum dry density of a soil to achieve stable and efficient compaction.

CBR value: Determine the bearing capacity of a soil or subgrade material to support pavement or foundation loads.

UCC value: Determine the compressive strength of a soil.

Specific gravity: Determine the specific gravity (G) of a soil, which is the ratio of the soil's density to the density of water.

Grain size distribution: Determine the proportion of different grain sizes in a soil sample, which affects its engineering properties.

Swelling test: Measure the potential of a soil to swell when exposed to water, which affects its engineering properties.

F. Experimental study on black cotton soil mixed with waste glass powder and sawdust ash

Sawdust ash was added to the soil in varying proportions (9% and 12%), along with waste glass powder (5%, 10%, and 15%). Subsequently, tests such as the Standard Proctor Test, Unconfined Compressive Strength Test, Atterberg's Limits Test, and California Bearing Ratio (CBR) Test were conducted.

IV. RESULTS AND DISCUSSION

A. The Basic Properties

Basic properties of untreated sample of black cotton soil are given in Table 2.

TABLE 2
BASIC PROPERTIES OF SOIL

SI No	PROPERTY	VALUE
1	Liquid limit	64%
2	Shrinkage limit	13.28%
3	Plastic limit	30%
4	Plasticity index	34%
5	Optimum moisture content	23.08%
6	Maximum dry density	1.21 g/cc
7	California bearing ratio	2.23%
8	UCC strength	170.65 kpa
9	Specific gravity	2.72

B. Properties of Soil Treated with SDA and WGP

Atterberg's limit test, unconfined compressive strength test, heavy compaction and California Bearing Ratio test were conducted to determine the change in properties of soil treated with various percentages of SDA and WGP.

1) Variation of Atterberg Limit Values with Varying Percentage of SDA and WGP.

The liquid limit, plastic limit, shrinkage limit, and plasticity index of untreated black cotton soil and treated black cotton soil is given in Table 3. The variation in LL, PL, SL and PI of samples treated with SDA and WGP are presented in Fig 1, Fig 2, Fig 3 and Fig 4.

TABLE 3
ATTERBERG'S LIMIT OF SOIL

SAMPLE	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX(%)	SHRINKAGE LIMIT (%)
BCS	64	30	34	13.28
A	51.5	23	28.5	14.45
B	52	26.17	25.9	16.42
C	60	34.8	25.2	17.68
D	48	22.17	25.83	16.15
E	40	16.45	23.55	16.89
F	56.5	28.5	28	19.38

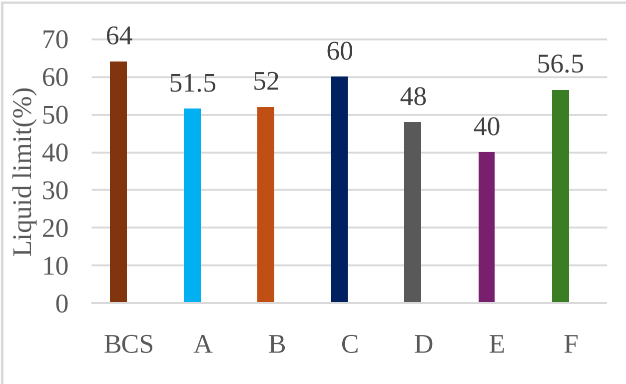

Fig.1 Variation of liquid limit

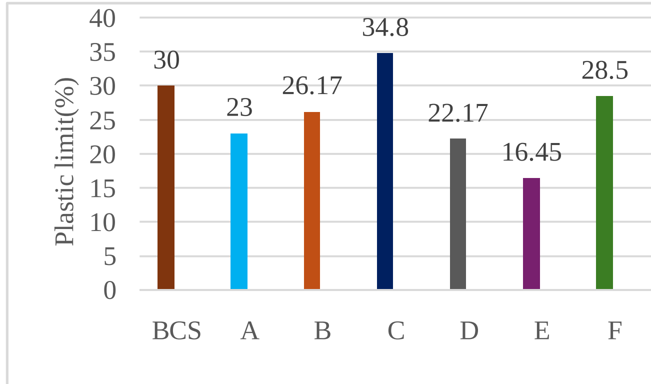

Fig.2 Variation of plastic limit

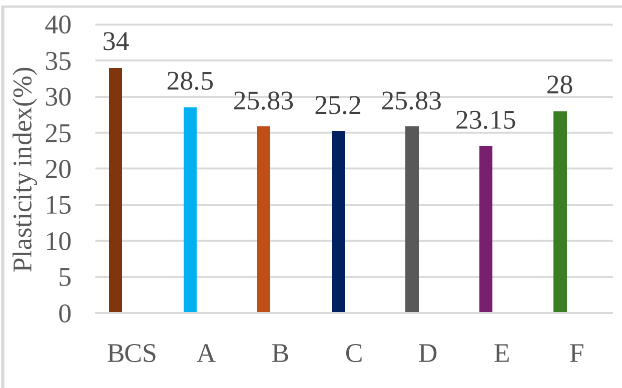

Fig.3 Variation of plasticity index

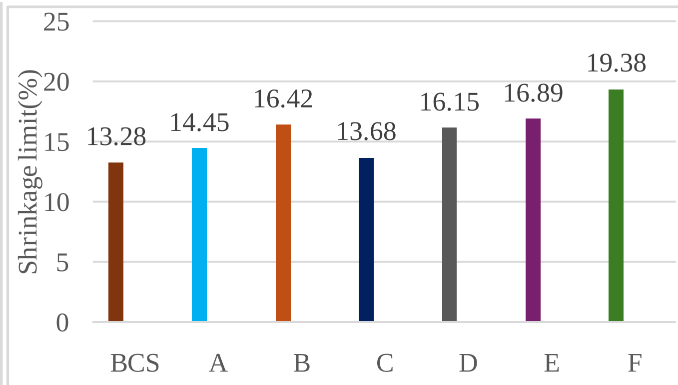

Fig.4 Variation of shrinkage limit

Liquid limit of untreated soil was 64% and it decreased by the addition of waste glass powder and sawdust ash. The sample E, the liquid limit obtained is 40%, shown a better reduction in liquid limit, and there by indicating the water affinity of soil is minimum in sample E hence adds to the improvement of stability and workability. Plasticity index gradually decreased to 23.15% from 34% for sample E that is when 12% SDA and 10% WGP was added. Sample E will less prone to cracking when dry and expanding when wet, as PI is minimum for Sample E. The soil exhibits moderate plasticity.The plastic limit is obtained as 16.45% for sample E, which shows better reduction in plastic limit and the soil became easier to handle and compact. Shrinkage limit of untreated black cotton soil is 13.28% which shows the soil is highly susceptible to volume changes due to moisture variations. Here the highest shrinkage limit recorded is 19.38% which is obtained for sample F, this combination significantly improved soil resistance to shrinkage.

2) Variation of UCC strength with varying percentages of SDA and WGP.

The unconfined compressive strength of untreated and treated black cotton soil is given in Table 4. The variation UCC strength with various percentages of SDA and WGP is shown in Fig.5 and Fig.6.

TABLE 4
UCC STRENGTH OF SOIL

SAMPLE	UCC STRENGTH (kpa)
BCS	170.65
A	196.25
B	188.84
C	213.26
D	206.01
E	234.64
F	251.71

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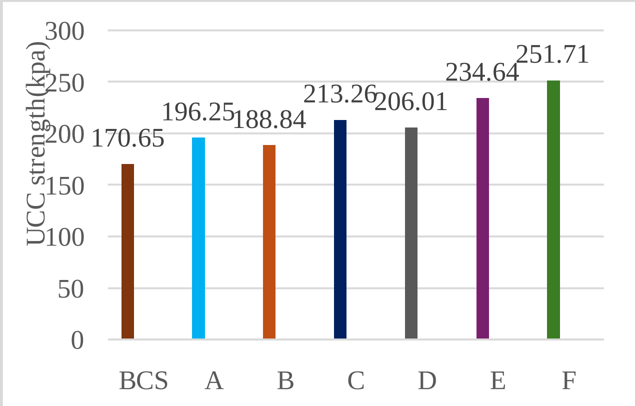

Fig.5 Variation of UCC strength

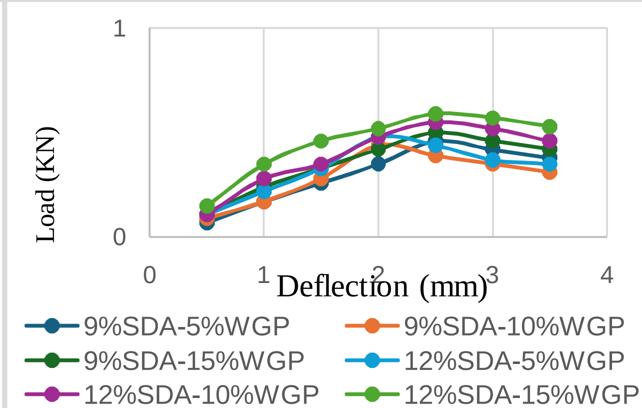

Fig.6 Load VS Deflection

The UCC strength of natural black cotton soil is 170.65 kpa, which is relatively low, making it weak and unsuitable for heavy construction without stabilization. The highest UCC strength is observed as 251.71 kpa, proving that sample F, that is 12% SDA and 15% WGP provide the best stabilization, significantly improving soil strength and it is suitable for moderate-load construction applications.

3) Variation of OMC, MDD and CBR value with varying percentages of SDA and WGP.

The optimum moisture content, maximum dry density and California bearing ratio value of treated and untreated black cotton soil is given in Table 5. The variation of OMC and MDD is shown in Fig 7 and Fig 8. Variation of CBR value is shown in Fig 9.

TABLE 5

OMC, MDD AND CBR VALUE OF SOIL

SAMPLE	OMC (%)	MDD (g/cc)	CBR (%)
BCS	23.08	1.21	2.23
A	19.6	1.51	4.46
B	18.9	1.52	6.76
C	14.6	1.29	6.84
D	19.8	1.29	6.92
E	16.3	1.28	7.8
F	17.71	1.27	8.59

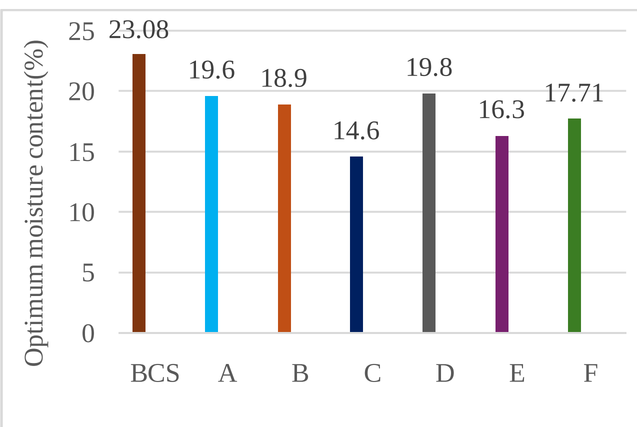

Fig.7 variation of OMC

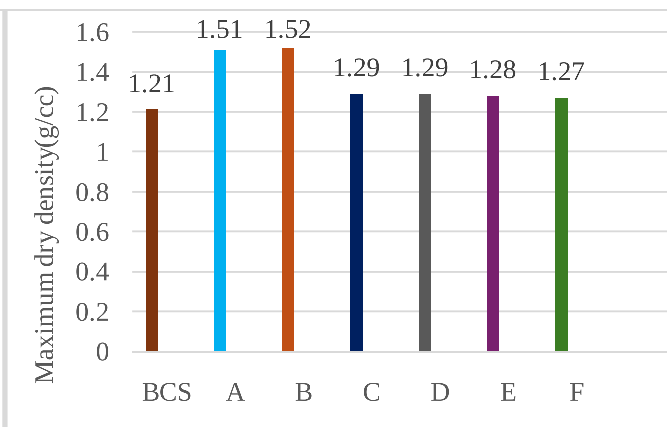

Fig.8 Variation of MDD

The MDD of natural black cotton soil is 1.21 g/cc, which shows the soil is loose and less compactable structure and the OMC is 23.08, which is quite high and the soil has natural tendency to retain water.

The most effective stabilization occurs at 9% SDA and 10% WGP that is sample B, where MDD is highest and OMC is significantly reduced, making soil more suitable for construction and require less moisture for compaction.

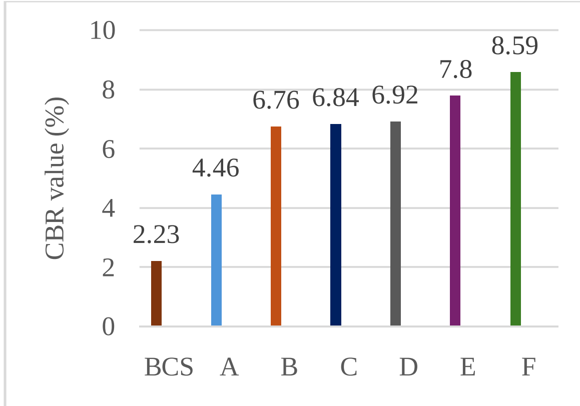

Fig.9 Variation of CBR

The CBR value of untreated BCS is 2.23% which shows the soil has low load-bearing capacity.It can observe that the CBR value of BCS with addition of SDA-WGP mixture is increased. The highest CBR value of 8.59% is achieved when soil is treated with sample F, that is 12% SDA and 15% WGP and the soil became more resistant to penetration and better able to support loads. The CBR value for subgrade in road construction in India as per IRC 37-2012 is in the range of 3-15%, the CBR value obtained for sample F is within the limit, hence it can be used as subgrade soil.

V. CONCLUSIONS

This project explored using sawdust ash and waste glass powder as soil stabilizers for black cotton soil, addressing its challenges like volume changes and low bearing capacity. We have carried out preliminary tests such as Atterberg's limit, compaction tests, CBR, UCC, grain size distribution, specific gravity and swelling index test on black cotton soil.The test results revealed that the black cotton soil exhibits inadequate engineering properties, necessitating stabilization to enhance its performance.We have conducted Atterberg's limit tests,UCS test, compaction test and CBR value test on black cotton soil stabilized with various percentages of waste glass powder and sawdust ash.From the results of those tests we can conclude that the mixture of 12% SDA and 15% WGP is the best suitable combination for black cotton soil stabilization which shows better increment in the strength and bearing capacity of soil. In conclusion, the stabilization of black cotton soil using waste glass powder and sawdust ash offers a promising, sustainable solution to improve soil properties for construction purposes.The addition of these materials enhances the soil's strength and improves its load-bearing capacity, making it more suitable for engineering applications. Moreover, utilizing waste products like glass powder and sawdust ash not only addresses the environmental concerns associated with disposal but also contributes to resource conservation.

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