AN EXPERIMENTAL STUDY ON IMPROVEMENT OF EXPANSIVE SOIL TREATED WITH BAGASSE ASH AND SODIUM SILICATE

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Abstract -. Expansive soils are considered problematic due to their tendency to swell upon water absorption and shrink upon drying. This cyclic volume change often leads to severe structural damage and significant financial losses. The present study investigates the potential of industrial by-products and chemical stabilizers in improving the engineering properties of expansive soil. Bagasse Ash (BA), an agro-industrial by-product, and Sodium Silicate (SS), a chemical stabilizer, were used as additives. Bagasse Ash was incorporated at varying proportions of 4%, 8%, 12%, and 16% by the dry weight of soil, while Sodium Silicate was added at a fixed dosage. Laboratory investigations, including Differential Free Swell, Modified Proctor, Atterberg Limits, California Bearing Ratio (CBR), and Triaxial tests, were conducted to evaluate the effects of stabilization. The results revealed that the combined addition of Bagasse Ash and Sodium Silicate considerably reduced the liquid limit and plasticity index while increasing the maximum dry density. A significant improvement in CBR values was also observed. The mix containing 88% expansive soil and 12% Bagasse Ash was identified as the optimum combination. Furthermore, the addition of 3% Sodium Silicate to this mix yielded the highest CBR value, indicating enhanced strength and reduced swelling potential of the soil.

***Key Words*: Expansive Soil(ES), Bagasse Ash(BA), Sodium silicate(SS), Soil Stabilization, CBR.**

1. INTRODUCTION

Expansive soil is a type of clayey soil that undergoes significant volumetric changes with variations in its moisture content. This behavior is primarily attributed to the presence of clay minerals such as Montmorillonite, Smectite, and Bentonite. The swelling and shrinkage of expansive soils pose serious challenges in various civil engineering applications. These soils are generally characterized by high water content, high compressibility, and low bearing capacity, making them unsuitable for direct use in foundation or pavement construction. The heaving action of expansive soils can result in slope instability, pavement upheaval, driveway displacement, and even the cracking or collapse of structural walls. To mitigate these issues, stabilization techniques are commonly employed, using materials such as lime, cement, or other chemical and industrial binders to improve the engineering properties of the soil.

1.1BAGASSE ASH

Sugar Cane Bagasse Ash (SCBA) is a voluminous by-product in the sugar mills when the juice is extracted from the cane.it is however generally used as a fuel to fire furnaces in the same sugar mill that field about ashes containing high amount of un-burnt matter, silicon, aluminum, iron and calcium oxides but the ashes obtained directly from the not reactive because of these are burnt under controlled conditions and at very high temperatures. The ash there becomes an industrial waste and poses disposal problems.

1.2SODIUM SILICATE

Sodium silicate, also known as water glass or liquid glass, is a compound that consists of sodium oxide (Na_2O) and silica ($SiO2$) in various proportions. It is commonly represented by the formula $Na2SiO3$. Sodium silicate is a versatile material used in various industrial applications due to its adhesive, binding, and sealant properties. In the present study, Sodium Silicate with the chemical name of Sodium Silicate (Meta) Non-hydrate (i. e $Na_2SiO_3.9H_2O$) from one of non-traditional Loba Chemie Pvt. Ltd, which is stabilizers has been used.

2. OBJECTIVE OF THIS PRESENT STUDY

- To study the properties of Expansive Soil.
- To access the influence of varying dosage of Bagasse Ash (4%, 8%, 12% and 16% by dry weight of soil) on strength characteristics.
- To find out the optimum dosage of Bagasse Ash to achieve maximum strength.
- To access the effect of varying dosage of Sodium Silicate(1%, 2% 3% and 4% by dry weight of soil) on the strength properties.

- To find out the optimum dosage of Bagasse Ash with addition of Sodium Silicate to achieve maximum strength of soil.

3. LITERATURE REVIEW

Chitta Ranga et al. used agricultural waste such as Sugarcane bagasse ash. rice husk ash and groundnut shell ash are used to stabilize the weak sub grade soil. t he sub grade soil is treated with above three wastes separately at 0%, 3%. 6%, 90/0, 12% and 15% and CBR test carried out for each percent. The results of these tests showed improvement in CBR value with the increase in percentage of waste up to a certain optimum content.

Kiran et al. (2013) mixed different percentages (4%, 8% and 12%) of Bagasse Ash and observed that blend of Bagasse Ash with different percentage of cement for black cotton soil imparted significant changes in values of MDD, CBR and UCS. The MDD values got increased from 1.516 g/cc to 1.65 g/cc for addition of 8% Bagasse Ash with 8% cement, CBR values got increment from 2.12 to 5.3 for addition of% Bagasse Ash with 8% cement and UCS values got changed to 174.91 KN/m^2 from 84.92 KN/m^2 for addition of 8% Bagasse Ash with 8% cement.

Sabat (2012) had investigated the effects of bagasse ash and lime sludge on OMC, MDD, UCS, CBR and Ps of an expansive soil areas. The best stabilization effects were Obtained when the optimum percentage of Bagasse Ash was 8% and Lime sludge was 16%. The effects of compaction delay and moulding water content on CBR of the soil stabilized at the optimum proportion Were also studied.At the optimum proportion the stabilizer is cost effective and the molding water content and compaction delay affected the CBR value of the stabilized soil significantly.

Al-Azzo (2009) had studied the stabilizing effect of crushed line stone on engineering properties of expansive clayey. Different percentages of crushed limestone dusts added were 2,4,6,8 and 10%. It was found that there was reduction in the plasticity of the clay and significant decrease in expansion.

Mohankumar S R, P.G Rakareddy (2018) Has studied the effects of stabilization of expansive soil using Magnesium Chloride and the results obtained shows that with increase in the concentration from 0.5N to 4N of MgCl, decreased the liquid limit by 28.97% and plasticity index by 64.52%, leading to significant reduction in the free swell index. This, in turn, increased the maximum dry density from 1.32g/cc to 1.42g/cc and decreased the optimum moisture content from 34% to 28%. The unconfined compressive strength of soil has been increased from 24 kPa to 603.5 kPa with increase in concentration from 0.5N to 4N of MgCl2 for 28 days of curing.

Abood et al. (2007) Has studied the effect of adding three chloride compounds (NaCl, MgCl2, CaCl2) on the properties of silty clay soil. The findings showed that the addition of each one of the chloride compounds decreased the liquid limit and plastic limit and plasticity index for the soil. The dry density increased and the optimum moisture content decreased with the increased in salt percentage. The compressive strength of the soil increased with the addition of chloride compounds. This could help improving soil strength and other soil properties.

Abdul Shukoor (2017) studied that the stabilization of expansive soil can be achieved by treating it with Rice Husk Ash (RHA) and further enhancing it with Tandur Stone Slurry Powder, which improves soil strength and increases the California Bearing Ratio (CBR) value.

Monica Malhotra, Sanjeev Naval (2013) studied that the Stabilization of expansive soil can be effectively achieved by mixing low-cost materials like lime and fly ash. This method reduces swelling potential and increases optimum moisture content, improving the soil's properties and mitigating issues related to shrinkage and settlement.

4. METHODOLOGY

The experimental program was carried out in several stages to evaluate the performance of marine clay stabilized with Bagasse Ash and Sodium silicate The overall procedure included soil collection, material preparation, proportioning of mixes, laboratory testing, and analysis of results.

4.1 Soil Collection

Expansive Soil required for the study was collected from rameswaram,, East Godavari district, Andhra Pradesh. at a depth of about 2 m below ground level to avoid surface contamination. The soil samples were carefully excavated, transported to the laboratory, and air-dried under shade to preserve their natural properties.

4.2 Materials

- **Expansive Soil:** The collected soil sample was used as the base material for the stabilization study. Preliminary tests were conducted to determine its index and engineering properties, which served as the foundation for further stabilization analysis.
- **Bagasse Ash:** This ash, a by-product of sugar and power plants, is rich in amorphous silica and has pozzolanic properties.
- **Sodium Silicate:** Sodium silicate, also known as water glass or liquid glass, is a compound that consists of sodium oxide (Na_2O) and silica (SiO2) in various proportions. Sodium silicate is a versatile material used in various industrial

applications due to its adhesive, binding, and sealant properties.

4.3 Mix Proportions

The stabilization process involved preparing soil samples with different proportions of Bagasse Ash and Sodium Silicate, mix ratios were considered, with 4%, 8%, 12%,and 16% for Bagasse Ash and 1%, 2%, 3%, and 4% for Sodium Silicate (by dry weight of soil) added to Expansive soil. For each percentage, two sets of samples were prepared: one with only Bagasse Ash and another with combined with Sodium Silicate . This allowed a comparison between mechanical stabilization and combined mechanical–chemical stabilization.

Table -1: Mix Proportions for testing Soil

S.NO	Stabilizing Agent	Mix proportions
1	Bagasse Ash	4,8,12,16,
2	Sodium Silicate	1,2,3,4,

4.4 Laboratory Testing

To assess the influence of Bagasse Ash and Sodium Silicate on the properties of Expansive soil, a series of laboratory tests were carried out in accordance with relevant IS codes. The tests conducted are as follows:

- **Specific Gravity Test (IS: 2720 Part 3 – 1980)** This test determines the specific gravity of soil solids, which helps in identifying the type and classification of soil. It is an essential property used in calculating various soil parameters such as void ratio, degree of saturation, and unit weight relationships.

- **Differential Free Swell (DFS) Test (IS 2720 – Part 40):** The free swell behavior of the untreated and treated Expansive Soil was studied to evaluate the reduction in expansiveness after stabilization. The DFS value was obtained by immersing oven-dried soil samples in kerosene and distilled water separately, and calculating the difference in swell percentage. This testing is provided to reflect the potential of the soil to swell under different conditions.

- **Atterberg Limits Test (IS 2720 – Part 5):** This test was conducted to determine the liquid limit, plastic limit, and plasticity index of both untreated and stabilized soil samples. The Atterberg Limits test helps to identify the critical water contents of fine-grained soils, particularly clays and silts, which define their consistency states and plastic behavior.

Modified Proctor Compaction Test (IS 2720 – Part 7): Compaction tests were carried out to determine the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) for each mix proportion. These tests were used to evaluate the effect of Bagasse Ash and Sodium Silicate on the densification characteristics and moisture requirements of the soil.

- **California Bearing Ratio (CBR) Test (IS 2720 – Part 16):** Both soaked and unsoaked California Bearing Ratio (CBR) tests were conducted to evaluate the load-bearing capacity of the stabilized soil. The results provided valuable insight into the improvement in strength characteristics and the potential suitability of the stabilized expansive soil for use as a foundation or subgrade material in pavement construction.

- **Triaxial Compression Test (IS: 2720 Part 11 – 1993)**

The triaxial compression test was conducted to determine the shear strength parameters of the soil, namely cohesion (c) and the angle of internal friction (ϕ), under varying drainage and loading conditions. This test provides a realistic simulation of in-situ stress conditions by subjecting the soil specimen to both confining and axial pressures. It aids in understanding the stress–strain behavior of soil under controlled conditions and is widely used for the analysis and design of slopes, foundations, and embankments.

Table -2: Properties of Expansive Soil

S.NO	NAME OF THE EXPERIMENT	VALUE
1	**Particle size distribution**	
	Sand (%)	6
	Silt (%)	25.5
	Clay (%)	68.49
2	**Atterberg's Limit**	
	Liquid Limit (%)	67
	Plastic Limit (%)	28.3
	Plastic Index (%)	38.6
3	**Modified Compaction Results**	
	Optimum Moisture Content (%)	28.06
	Maximum Dry Density (g/cc)	1.51
4	Differential Free Swell (%)	95
5	Specific gravity	2.51
6	IS Classification	CH
7	CBR(%)	1.34
8	Cohesion (KN/m^2)	95.41
9	Angle of Internal friction (^{0})	2.4

5. RESULTS AND DISCUSSION

5.1 Differential free swell

Table -3: Results of Free swell index test

S.NO	MIX PROPORTION	DFS
1	88% ES with 12% BA + 0	65

	%SS	
2	88% ES with 12% BA + 1%SS	58
3	88% ES with 12% BA + 2%SS	52
4	88% ES with 12% BA + 3% SS	46
5	88% ES with 12% BA+ 4%SS	41

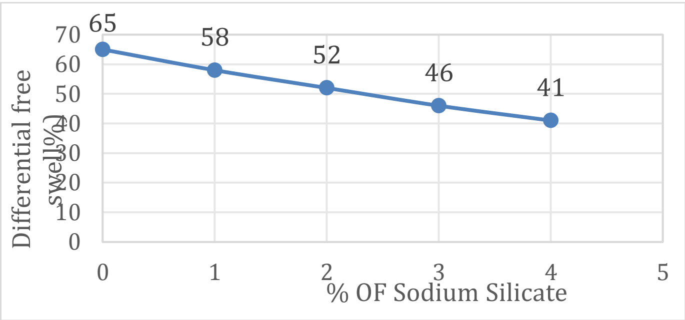

Fig -1: Variation in DFS of Expansive soil and Bagasse Ash treated with percentage of Sodium Silicate.

5.2 Atterberg's Limit Test

Table -4: Results of Atterberg's limit test

S.NO	MIX PROPORTION	LL (%)	PL (%)	Ip (%)
1	88% ES with 12% BA + 0 %SS	60.9	37.19	23.71
2	88% ES with 12% BA + 1%SS	59.02	40.2	18.82
3	88% ES with 12% BA + 2%SS	58.18	41.77	16.41
4	**82% ES with 18% BA + 3% SS**	**57.1**	**43.17**	**13.93**
5	82% ES with 18% BA + 2%SS	55.27	45.2	10.07

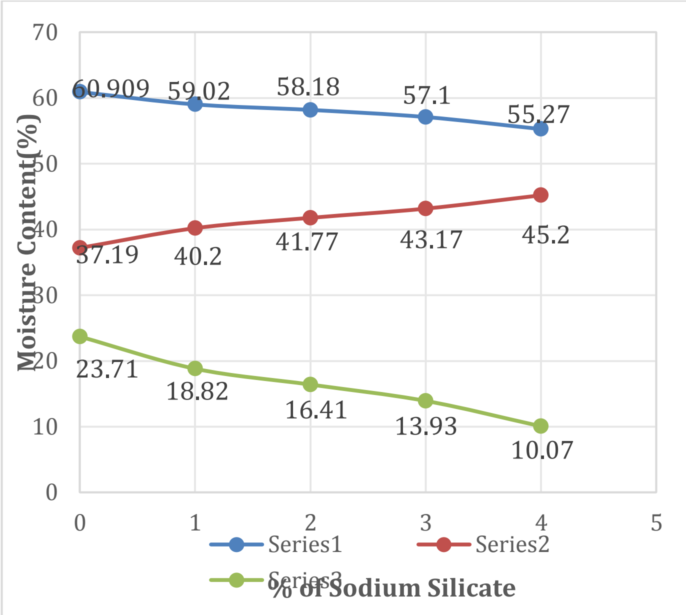

Fig -2: Variation in LL, PL & PI of Expansive Soil and Bagasse Ash treated with percentage of Bagasse Ash.

5.3 Modified Proctor Compaction Test

Table -5: Results of Modified Proctor Compaction Test

S.NO	MATERIAL PROPORTION	OMC	MDD
1	88% ES with12 % BA + 0% SS	21.69	1.69
2	88% ES with12 % BA + 1% SS	20.46	1.72
3	88% ES with 12% BA+ 2% SS	18.44	1.75
4	**88% ES with 12% BA + 3% SS**	**17.23**	**1.8**
5	88% ES with 12% BA+ 4% SS	15.92	1.78

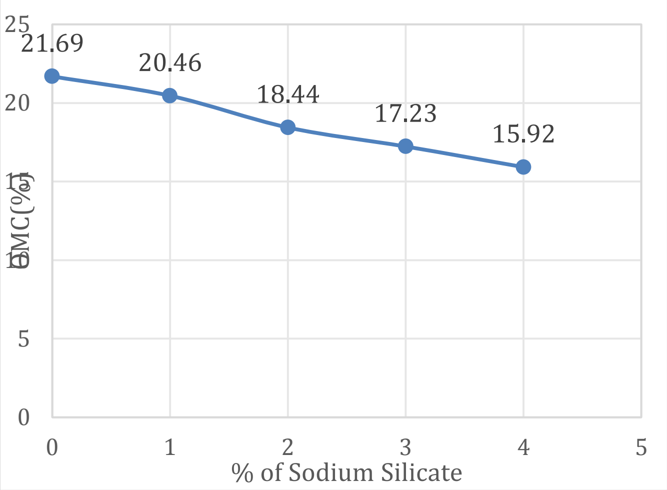

Fig -3: Variation in OMC of Expansive Soil and Bagasse Ash treated with percentage of Sodium Silicate.

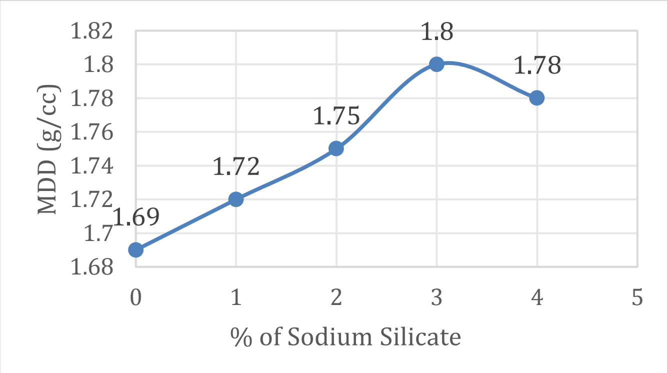

Fig -4: Variation in MDD of Expansive Soil and Bagasse Ash treated with percentage of Sodium Silicate.

5.4 California Bearing Ratio (CBR) Test

Table -6: Results of CBR test

S.NO	MATERIAL PROPORTION	CBR SOAKED (%)
1	88% ES with 12% BA + 0 %SS	4.33
2	88% ES with 12% BA+ 1 %SS	5.46
3	88% ES with 12% BA + 2%SS	5.93
4	**88% ES with 12% BA + 3% SS**	**7.72**
5	82% ES with 18% BA + 2 %SS	6.03

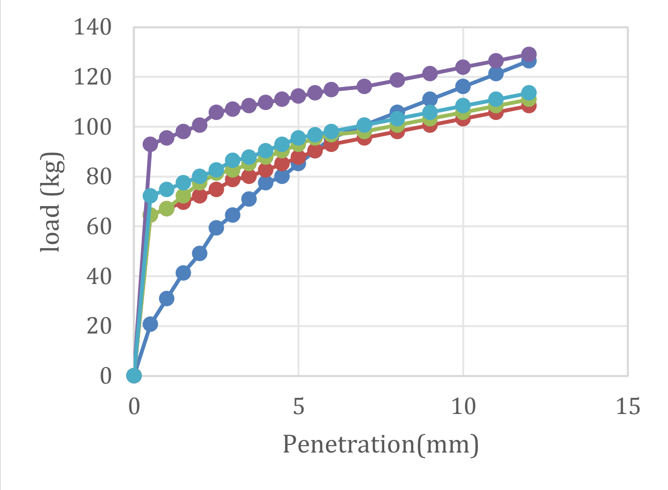

Fig -5: Variation in Compaction curves of Expansive Soil and Bagasse Ash treated with percentage of Sodium Silicate.

5.5 Triaxial test

Table -7: results of Triaxial test

S.NO	MATERIAL PROPORTION	C(Kg/m²)	Φ(⁰)
1	88% ES with12 % BA + 0% SS	77.5	4.8
2	88% ES with12 % BA + 1% SS	72.19	5.2
3	88% ES with 12% BA + 2% SS	68.58	5.9
4	**88% ES with 12% BA+3% SS**	63.14	6.4
5	88% ES with 18% BA + 4% SS	61.26	6.1

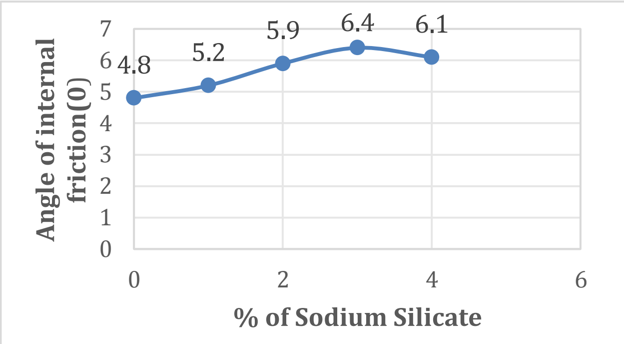

Fig -6: Variation in Angle of Internal Friction of Expansive Soil and Bagasse Ash treated with percentage of Sodium Silicate.

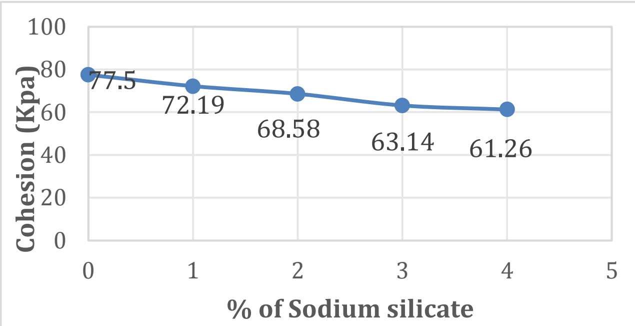

Fig -7: Variation in Cohesion of Expansive Soil and Bagasse Ash treated with percentage of Sodium Silicate.

6. CONCLUSIONS

The following conclusions were based on the laboratory studies carried out of Bagasse Ash and Sodium Silicate. found through the laboratory on this study. From the laboratory investigations the Optimum percentage research is 12% and 3% respectively.

Table -7: Optimum Percentages of BA and SS, observed the laboratory investigations

S.NO	Additives	Optimum percentage addition
1	Bagasse Ash	12%
2	Sodium Silicate.	3%

- It is noticed from the laboratory test results that the Differential Free Swell Index of Expansive soil has been reduced from 90% to 65% on the addition of 12% BA and it has been further reduced from 65% to 46% with and addition of 3% Sodium Silicate.when compared with untreated Expansive soil.
- It is observed from the laboratory test results that the Liquid limit of Expansive Soil has been decreased from 70.2%% to 60.9% on the addition of 12% BA and it has been further decreased from 60.9% to 57.1% with an addition of 3% Zycobond.
- It is observed from the laboratory test results that the Plastic limit has been increased from 31.26% to 37.19% in addition to 12% and BA it has been further increased from 37.19% to 43.17% with an addition of 3% Sodium silicate.
- It is noticed that the Plasticity Index has been decreased from 38.93% to 23.71% in addition to 12% BA and it has been further decreased from 23.71% to 13.93% with addition of 3% Sodium silicate.
- It is observed from the laboratory tests that the OMC of the Expansive soil has been decreased from 27.49% to 21.69% on the addition of 12% BA and it has been further decreased from 21.69% to 17.23% with addition of 3%Sodium silicate.
- It is observed from the laboratory tests that the MDD of the Expansive Soil has been increased from 1.46/cc to 1.69 g/cc on the addition of 12% BA and it has been further increased from 169g/cc to 1.8g/cc with addition of 3%Sodium silicate.
- It is observed that the CBR of the Expansive soil has been increased from 1.48% to 4.33% on the addition of 12% BA and it has been further increased from 4.33% to 7.72% with addition of 3%Sodium silicate.
- It is observed that the Cohesion of the soil has been decreased from 97.2 to 77.5^0 on the addition of 10% FS and it has been further decreased from 77.5^0 to 63.14^0 with addition of 3%Sodium silicate.
- It is observed that the Angle of Internal Friction of the Expansive soil has been increased from $2.1^{\mathbf{0}}$ to $4.8^{\mathbf{0}}$ on addition of 12% BA and it has been further increased from $4.8^{\mathbf{0}}$ to $6.4^{\mathbf{0}}$ with addition of 3%Sodium silicate.

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