Journal of Gateway to sustainable Research
February 2026, Vol. 1, Issue No. 1, pp: 6-10

An Experimental Study On Stabilization Of Expansive Soil By Using Lime And Sugarcane Bagasse Ash

P. Dastagiri*, K Mohan Teja Reddy, S Mahemoodh

Department of Civil Engineering, Chaitanya Bharathi Institute of Technology, Proddatur, Andhra Pradesh 516360, India.

*Corresponding Author E-mail: tdasthagiri1999@gmail.com

Abstract: The large sizable soils pose a significant problem in the civil engineering undertakings as it has a huge volume change as it varies in moisture content. The movements can make pavements, foundations of buildings and buried infrastructures crack and damage. The feasibility of using lime and sugarcane bagasse ash (SBA) to improve the geotechnical behavior of the retrieved expansive soil in the Chapadu village in Kadapa District, Andhra Pradesh is evaluated in the current study. The proportions of lime added were 3, 6, 9 and 12 percent and SBA was added 3, 6, and 9 percent. Extensive laboratory testing was performed which consisted of grain size distribution, specific gravity, Atterberg limits, free swell index, Standard Proctor compaction, California Bearing Ratio (CBR), and Unconfined Compressive Strength (UCS) tests. The results indicate that the joint action of lime and SBA decreases swelling potential and improves the parameters of strength. The fire produced the best outcomes using a blend of 6% lime and 6 percent SBA. The results indicate that SBA, a by-product of agriculture can be a good inexpensive and greener stabilizing material in combination with lime.

Keywords: Expansive soil, Lime stabilization, Sugarcane bagasse ash, CBR, UCS, Sustainable soil improvement.

1. Introduction: These are what are commonly known as expansive soils also known as shrink-swell soils that experience large volumes of changes as a result of changes in moisture levels. These soils contain high amounts of clay minerals like montmorillonite and present a great danger to the infrastructure because they cause cracking, settlement and heaving. Conventional stabilization process commonly depends on the employment of cement or lime, but there has been a rising focus on sustainability, which has paved the way to the utilization of industrial and agricultural by-products. Sugarcane bagasse ash (SBA) is a by-product of sugar industries, which contains a high amount of silica and has a pozzolanic nature. In combination with lime, it increases the strength of soils by cementitious reactions. The current paper presents the assessment of the interaction between lime and SBA in the stabilization of expansive soil.

Research on the use of multiple stabilizers on expansive soils has been carried out in the past. In the investigation of lime and SBA stabilization, Yadav et al. [1] used both laboratory work and field experiments and found out that the durability was enhanced under environmental exposure. In another study, Sant et al. [2] were able to compare the performance of lime, SBA and fly ash and concluded that lime SBA mixtures were effective in lowering swelling and plasticity.

Adnan et al. [3] showed that fly ash and rice husk ash do decrease plasticity index, enhance CBR and UCS values. Adnan et al. [4] noted the gains of strength with the help of silica fume and tannery sludge. Hadas [5] recorded that 10% SBA in compressive strength was raised 65 percent as a result of pozzolanic reactions. Moreover, Gidday et al. [6], Dang et al. [7], and Melese et al. [8] verified the enhancement of compaction and strength parameters with the help of lime and SBA. The lime-SBA proportions were optimised statistically by Azhar et al. [9] and the economic viability of it was shown in the research of Kennedy et al. [10] and Vaishnava et al. [11]. All these studies point to the fact that lime and SBA have technical and environmental advantages in stabilization of expansive soils.

3. Materials And Methods

3.1 Materials

Expansive Soil: Collected from Chapadu village, Kadapa District.

Lime: Calcium oxide (CaO) content = 74.23%.

Sugarcane Bagasse Ash (SBA): Silica content = 66.23%.

3.2 Experimental Program

The following tests were conducted:

- Grain size analysi
- Specific gravity
- Atterberg limits
- Free swell index
- Standard Proctor test
- CBR test
- UCS test

Lime was added at 3%, 6%, 9%, and 12%.

SBA was added at 3%, 6%, and 9%.

Optimum combined proportion tested: 6% Lime + 6% SBA

4. Results And Discussion:

4.1 Untreated Soil: The fundamental nature of the natural soil is that it is evidently expansive as shown by its characteristic properties. Liquid limit at 48 percent and plastic limit at 20 percent give a comparatively high plasticity index thus justifying its vulnerability to change in volume. The indexes of free swell which would be 57.63 percent also indicate that the soil is classified as highly expansive soils. The CBR value of 1.09% is very low indicating bad load-bearing capacity and therefore soil is not suitable in its natural state to be used as a subgrade. In the same way, the value of UCS of 21.9 kN/m 2 means that the shear strength is low. These findings explain why stabilization is necessary before one can use the soil to construct their buildings.

Table 1: Properties of Untreated Soil

Property	Value
Specific Gravity	2.23
Liquid Limit	48%
Plastic Limit	20%
Free Swell Index	57.63%
OMC	15.79%
MDD	1.47 g/cc
CBR	1.09%
UCS	21.9 kN/m^2

4.2 Grain Size Analysis: The grain size distribution curve gives a continuous gradation of particles of different sizes in the sieve sizes. The resultant values of D 0, D 3 0 and D 6 0 show a moderate consistency in the particle size distribution. The uniformity coefficient (Cu) and coefficient of curvature (Cc) calculated are confirmative of the fact that the soil is well graded. The soil is however well graded, and it has clayy properties because the percentage of the soil going through the 75 micron sieve is high. This is the reason why plasticities and swellings were high in the tests that followed.

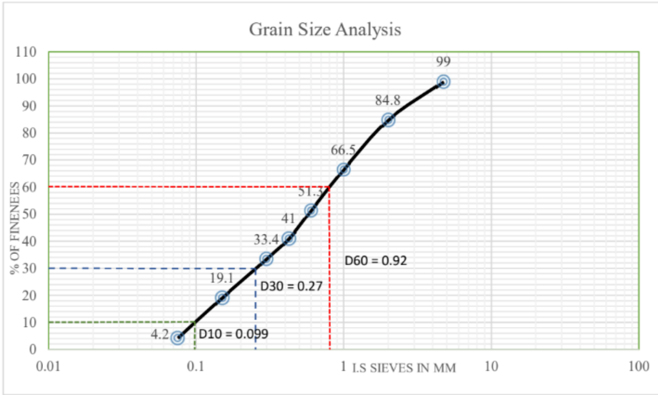

Figure 1: Grain Size Distribution Curve

$D_{10} = 0.099$ mm

$D_{30} = 0.27$ mm

$D_{60} = 0.92$ mm

$Cu = D_{60}/D_{10}$

$Cc = (D_{30})^2 \ / \ (D_{60} \times D_{10})$

The soil is well graded.

4.3 Effect on Specific Gravity: Change in specific gravity with addition of lime and SBA shows the changes in composition of soil. This effect of the lime addition to the specific gravity is owed to the fact that lime has a relatively higher density than the natural soil. On the other hand, the decrease is as a result of the low specific gravity of bagasse ash with increased content of SBA. This trend shows that SBA brings in a lightening effect on composite mixture that can affect compaction properties. The slow decrease in specific gravity with high replacement percentages is also indicative of more development of flocculated soil structure.

Table 2: Effect on Specific Gravity

Mix	Specific Gravity
Soil	2.23
+3% Lime	2.58
+6% Lime	2.52
+9% Lime	2.45
+12% Lime	2.33
+3% Lime	2.33
+6% Lime	2.13

+9% Lime	1.88

4.4 Effect on Liquid Limit: Liquid limit graph proves a significant decrease in plasticity at the optimum stabilizer content. To begin with, the momentary flocculation of liquids and redistribution of moisture could explain why liquid limit increases slightly with a decrease in lime content in the sample. Nevertheless, above 6% of lime and with addition of SBA, the liquid limit reduces because of pozzolanic reactions which weaken the activity of the clay. The reduction in the liquid limit indicates enhancement of the soil workability and the swelling capacity. The minimal increment with lime and SBA addition at very high percentages (12% lime or 9% SBA) indicates that the stabilizer content does not proportionally affect the result of compaction but rather promotes surface area and hydration needs.

Mix	Specific Gravity
Soil	48
+3% Lime	55
+6% Lime	48
+9% Lime	43.5
+12% Lime	45.5
+6% SBA	41

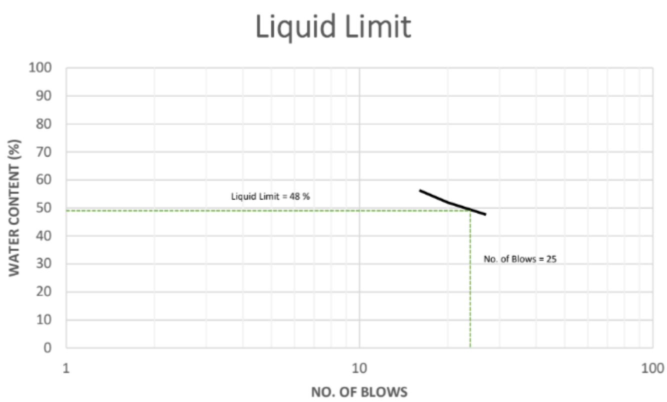

Figure 2: Liquid Limit Variation

4.5 Compaction Characteristics: Both the lime and SBA additions at very high percentages (12% lime or 9% SBA) indicate gradual increment in the OMC, which could have been due to surface area and hydration demands. The initial increase in MDD is attributed to a greater rearrangement of particles but a minor decrease is observed in higher percentages of stabilizers by density of SBA and the development of flocculated structure. The findings have shown that 6% lime and 6% SBA are a good balance in terms of the density without unreasonable increase in moisture demand.

Mix	OMC (%)	MDD (g/cc)
Soil	15.79	1.47
Soil + 3 % Lime	16.00	1.45
Soil + 6 % Lime	15.38	1.50
Soil + 9 % Lime	15.21	1.51
Soil + 12 % Lime	11.32	1.49
Soil + 3 % SBA	15.15	1.47
Soil + 6 % SBA	11.42	1.40
Soil + 9 % SBA	15.90	1.38

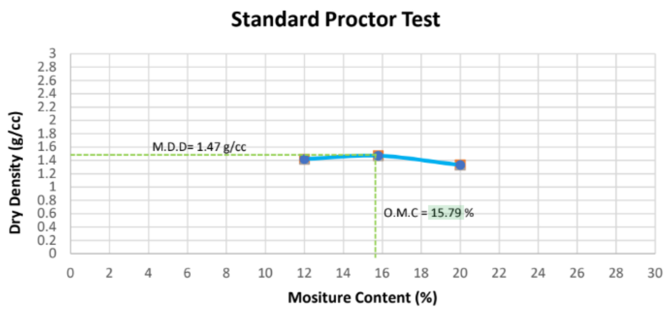

Figure 3: Compaction Curve

MDD increased slightly with lime up to optimum content.

4.6 CBR Results: The CBR graph clearly shows that there was a significant increase in the load-bearing capacity with stabilization. The cementitious compounds that have formed mainly contribute to the rising of the CBR value which includes calcium silicate hydrate (C-S-H). Lime triggers the process by raising the pH of soil and SBA provides reactive silica. Optimal pozzolanic interaction has been recorded as the highest improvement of 6% lime + 6% SSA. Above this percentage the increase is also only slight and indicates that excess stabilizer can not greatly add to strength. The enhanced CBR confirms the fact that stabilized soil can be successfully utilized as subgrade material in pavements.

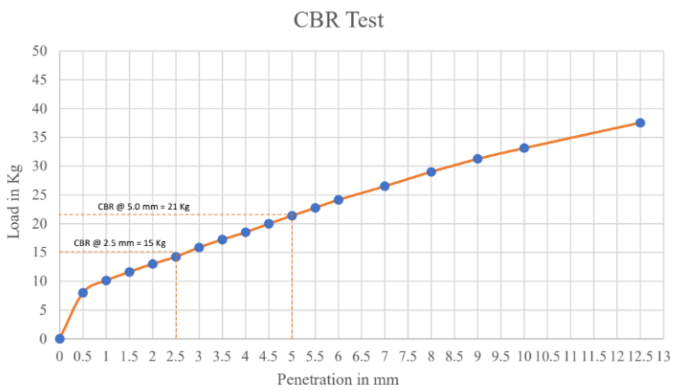

Figure 4. Graphical Representation for CBR

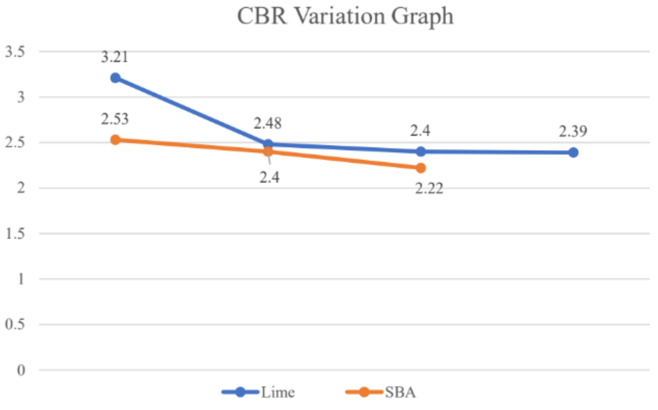

Figure 5. Graphical Representation of CBR Values for different Proportioning

4.7 UCS Results: The UCS variation graph shows that the compressive strength is constantly increasing with the addition of stabilizers. This gain in strength is explained by the enhanced bonding of soil particles because of the hydration reaction and pozzolanic reaction. The cementitious gel formation makes the cement less porous and more cohesive. The maximum UCS of the 6% lime + 6% SBA, shows the maximisation of lime and reactive silica in SBA. The percentage of gain in strength levels off at higher percentages and this indicates, that the extra stabilizer does not add proportionately to more bonding. This proves the existence of an optimum stabilizer content.

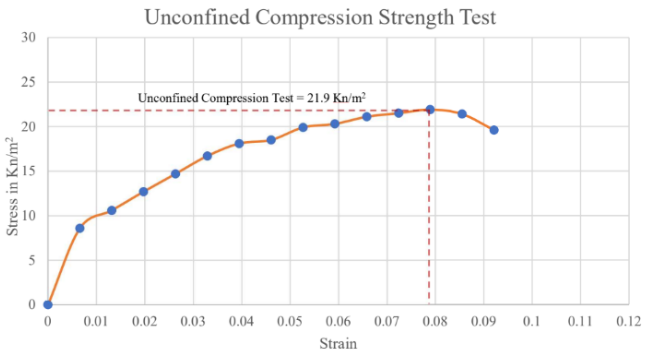

Figure 5. Graphical Representation for UCS

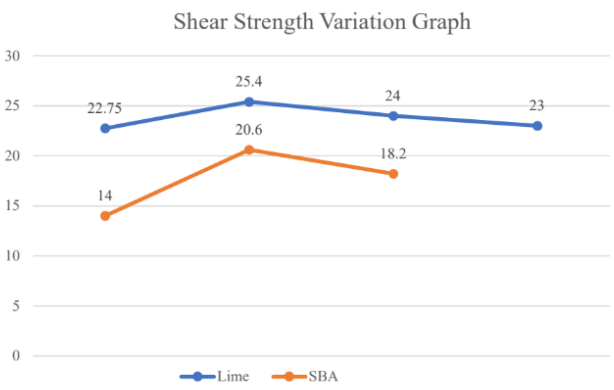

Figure 6. Graphical Representation of Shear Strength Values for different Proportioning

6. Conclusions: The investigation revealed that the expansive soil that is found in Chapadu village is characterized with a high propensity to be swollen and low bearing capacity of the soil when it is in bare form that limits its application at the construction activities. The geotechnical performance improvements were observed to be the product of lime and sugarcane bagasse ash stabilization. The treatment reduced plasticity and free swell index and increased compaction behavior, California Bearing Ratio (CBR) and unconfined compressive strength. This enhancement could be attributed to the chemical reactions such as the cation exchange, flocculation-aggregating, and the pozzolanic reactions, which spur the formation of stable cementitious products within the soil structure. When the different proportions were taken into account, the blend with 6 percent of lime, 6 percent of sugarcane bagasse ash produced the best overall performance since it had a high strength enhancement and low swell characteristics. It has been shown that sugarcane bagasse ash which is a by-product in the agricultural industry alongside lime is a viable, green and inexpensive method of stabilizing the expansive soils in geotechnical and pavement construction projects.

References:

1. Mechanics, S. (2017). Foundation by BC Punmia, Ashok Kumar Jain and Arun Kumar Jain.

2. Sant, H., Jain, S., & Meena, R. (2016). Stabilization of black cotton soil with bagasse ash. International Journal of Engineering Research & Technology, 4(23), 1-3.

3. Adnan, M., Kumar, S., Garg, N., Gupta, K. K., & Das, S. K. (2023). Soil stabilization using waste "Bagasse ash and lime": A review. Materials Today: Proceedings.

4. Adnan, M., Kumar, S., Garg, N., Gupta, K. K., & Das, S. K. (2023). Soil stabilization using waste "Bagasse ash and lime": A review. Materials Today: Proceedings.

5. Hadas, E., Mingelgrin, U., & Fine, P. (2021). Economic cost–benefit analysis for the agricultural use of sewage sludge treated with lime and fly ash. International Journal of Coal Science & Technology, 8(5), 1099-1107.

6. Gidday, B. G., Malefia, T. L., & Gidday, B. G. (2023). Simulating the Effect of Bagasse Ash Blended With Lime in Stabilizing Weak Subgrade Soil for Flexible Pavement:(Case Study Arbaminch Town, Ethiopia).

7. Dang, L. C., & Khabbaz, H. (2018). Assessment of the geotechnical and microstructural characteristics of lime stabilised expansive soil with bagasse ash. GeoEdmonton 2018.

8. Melese, B. E. T. E. L. H. E. M. (2018). Review on soil stabilization using bagasse ash with lime and molasses with cement. Addis Ababa Science and Technology University, Addis Ababa.

9. Azhar, M. B., Mujtaba, H., Farooq, K., Shah, M. M., & Masoud, Z. (2025). Bridging experimental work and environmental application: LCA-driven scalability of bagasse ash for eco-friendly stabilization of swelling clay subgrade. Ain Shams Engineering Journal, 16(10), 103623.

10. Kennedy, C., Amgbara, T. O., & Wokoma, T. T. T. (2018). Comparative evaluation of effectiveness of cement/lime and Costus afer bagasse fiber stabilization of expansive soil. Global Scientific Journals, 6(5), 97-110.

11. Vaishnava, R. Geotechnical Behaviour of Soils Modified with Bagasse Ash and Lime.