WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Potentials of SANBASE Soil Stabilizer for Rural Roads Application

Suleiman Mannir [a], Nura Usman [a], Gidado Garba Lawal [a]

[a] *Department of Civil Engineering, Hassan Usman Katsina Polytechnic, Katsina, Nigeria.*

A B S T R A C T

Soil stabilization is a critical aspect of geotechnical engineering, aimed at enhancing the physical and mechanical properties of soil to meet engineering requirements. In this research, a locally produced chemical soil stabilizer called SANBASE seal was used to improve soil engineering characteristics with a view to investigates its potentials for use in rural untarred roads. By evaluating the performance improvements of this novel stabilizer, this research aims to contribute to the advancement of infrastructure development and the optimization of soil stabilization practices in sub-saharan Africa. The test conducted on unmodified and 0.2%, 0.4%, 0.6% and 0.8% SANBASE modified soil were compaction test, Atterberg limit test, California bearing ratio test and unconfined compressive strength test. From the results, SANBASE soil stabilizer decreases both soil's Optimum moisture content and maximum dry density with increase in SANBASE stabilizer. Liquid limits of SANBASE modified soil decreased from 18.5% to 14.2% at 0.4% modification, it further decreased to 14.2% at 0.8% modification. This shows that, liquid limit of modified soil decreases with the increase of SANBASE percentages. California bearing ratio of SANBASE modified soil increased from 25% at 0% to 47% at 0.4 SANBASE modification and decreased to 22% at 0.8% modification. The unconfined compressive strength of modified soil was improved from 111kN/m2 at 0% to 167 kN/m2 and decreased to 122 kN/m2 at 0.8% modification. From the findings of this research, 0.4% SANBASE seal could be used as soil stabilizer for the improvement of soil strength.

Keywords: Stabilization, soil improvement, California bearing ratio, unconfined compressive strength, Atterberg limits

1. Introduction

Soil stabilization is the process of improving the engineering properties of soil to enhance its strength, durability, and stability (Archibong, 2020). This process is essential for construction and civil engineering projects to ensure that the soil can support structures like buildings, roads, and bridges. Soil stabilization is a crucial step in many construction projects, providing the necessary support and durability to ensure the longevity and safety of structures (Puppala, 2021). By choosing the appropriate method based on soil type and project requirements, engineers can effectively address challenges posed by weak or unstable soils.

Engineers used mechanical means to stabilize soils such as compaction by increasing the soil density using roller and compactors (Zhang et al., 2022). They also used soil replacement by removing poor soil replacing it with suitable materials (Fentaw et al., 2021). Mechanical stabilization is also conducted by reinforcing un suitable soil with geotextiles, geogrids and geocells (Sinha et al., 2022). Soil stabilization could be conducted through biological means by introducing natural polymers such as Xanthan gum to increase soil cohesion (Moghal & Vydehi, 2021). Su et al. (2022) used Microbial Induced Calcite Precipitation (MICP) technique to stabilize soil, in which bacteria was used to precipitate calcite, which binds soil particles together.

Another soil stabilization technique is performed physically through thermal stabilization in which heat is applied to the soil to change its properties to create cohesion (Lahoori, et al., 2021). Presently, electrokinetic stabilization is being used for soil stabilization in which electrical current is applied in to the soil which induces chemical reactions that stabilize soil (Tang, et al., 2022).

Chemical stabilization is also widely used for soil remedy techniques, chemicals are used to develop a strong bonding between soil particles. In this technique, lime is being used to reduce plasticity, increase strength, and improve workability of soil (Okonkwo & Kennedy, 2023). Other chemicals such as calcium chloride, sodium silicate, and fly ash are used to enhance soil properties (Turan, et al., 2022). Cement stabilization is popular technique in soil stabilization as cement create a stronger, more cohesive soil materials (Liu et al., 2022). Another mode of stabilization is bituminous stabilization in which bitumen is used to bind soil particles together especially in road construction (Andavan & Kumar, 2020).

It's evident that soil stabilization could be expensive especially in sub-saharan Africa where soil stabilizers are predominantly imported, therefore there is a need for locally produced effective inexpensive soil stabilizers. In view of this, this research tends to investigate the potentials of locally produced soil stabilizer in improving soil engineering characteristics.

Nomenclature

Aradius of

Bposition of

Cfurther nomenclature continues down the page inside the text box

2. Materials and methods

2.1 Materials

2.1.1 Soil

The soil used for this study is laterite soil that was brought from Dukuma village in Ingawa local government Katsina state Nigeria. Table 1 presents the characteristics of the lateritic soil used in this research.

Table 1 - Characteristics of soil used in this research

S/No.	Soil characteristics	Value
1	Optimum moisture content	19%
2	Maximum Dry Density (MDD)	1780 Mg/m^3
3	Liquid Limit	42%
4	Plastic limit	26%
5	California Bearing Ratio (CBR)	25%
6	Unconfined Compressive strength (UCS)	564 kN/m^2

2.1.2. SANBASE seal Stabilizer

SANBASE seal is a locally produced chemical material obtained by mixing different local ingredient together which the local builders used as strength improving agent in laterite block for walling and plastering/rendering. SANBASE seal is rich in silicon (Si), Silicon Oxide (SiO2) and other elements and oxides in minutes quantities. Tables 2 and 3 show elements and oxides concentration presents in SANBASE seal soil stabilizer respectively.

Table 2 - Element Concentration of SANBASE Seal

S/No.	Soil characteristics	Value
1	Silicon (Si)	28.45
2	Magnesium (Mg)	1.35
3	Calcium (Ca)	0.87
4	Aluminium	0.60
5	Antimony (Sb)	0.45
6	Strontium (Sr)	0.31
7	Sulphur (S)	0.15
8	Cadmium (Cd)	0.12

Table 3 - Oxide Concentration of SANBASE Seal stabilizer

S/No.	Soil characteristics	Value
1	Silicon Oxide (SiO_2)	60.03
2	Magnesium Oxide (MgO)	1.27
3	Calcium Oxide (CaO)	1.22
4	Barium Oxide (BaO)	1.00

5	Stabium Oxide (SbO)	1.00
6	Sirconium Oxide (SrO)	0.40
7	Phosphorous Oxide (P_2O_5)	0.12
8	Titanium Oxide (TiO_2)	0.11

2.2 Methods

To investigate the efficiency of SANBASE for soil stabilization, the material was used to stabilize soil at percentages of 0.2%, 0.4%, 0.6%, and 0.8%. The tests conducted on the stabilized soil are: compaction, Atterberg limits, California bearing ratio (CBR) and unconfined compressive strength (UCS) test.

2.2.1 Compaction test

Soil compaction was conducted to determine the optimum moisture content and maximum dry density which are crucial for ensuring the stability and durability of construction projects (Ali et al., 2024). The test was conducted on unmodified and SANBASE modified soil samples. The test was conducted based on ASTM D1557-12.

2.2.2 Atterberg limits test

Atterberg limits are the basic measure of the critical water contents of fine-grained soils. They are used to characterize the properties of soil, particularly its consistency and plasticity (Moreno-Maroto et al., 2021). This test was conducted on unmodified and SANBASE modified soil samples. The Atterberg limits are essential for classifying fine-grained soils based on their plasticity and understanding their behavior under varying moisture conditions (O'Kelly, 2021). These tests help engineers determine the suitability of soils for construction purposes and predict how soils will respond to environmental changes. The test was conducted based on ASTM D4318-17.

2.2.3California bearing ratio (CBR)

The California Bearing Ratio (CBR) test is a penetration test used to evaluate the strength of roads and pavements materials (Khasawneh et al., 2024). The results of the CBR test are used with empirical curves to determine the thickness of materials needed for the pavement layers. The test was conducted on unmodified and SANBASE modified soil samples. The test was conducted based on ASTM D1883-16.

2.2.4 Unconfined compressive strength (UCS)

The Unconfined Compressive Strength (UCS) test is to determine the compressive strength of soils, it measures the maximum axial compressive stress that a cylindrical soil sample can withstand under unconfined conditions (Du et al., 2024). The test was conducted on unmodified and SANBASE modified soil samples. The test was conducted based on ASTM D2166-16.

3. Results and Discussions

3.1 Compaction test

Compaction test was conducted to determine the response of SANBASE stabilized soil to maximum dry density and optimum moisture content. The result of compaction test is resented in Figures 1 and 2 for optimum moisture content and maximum dry density respectively.

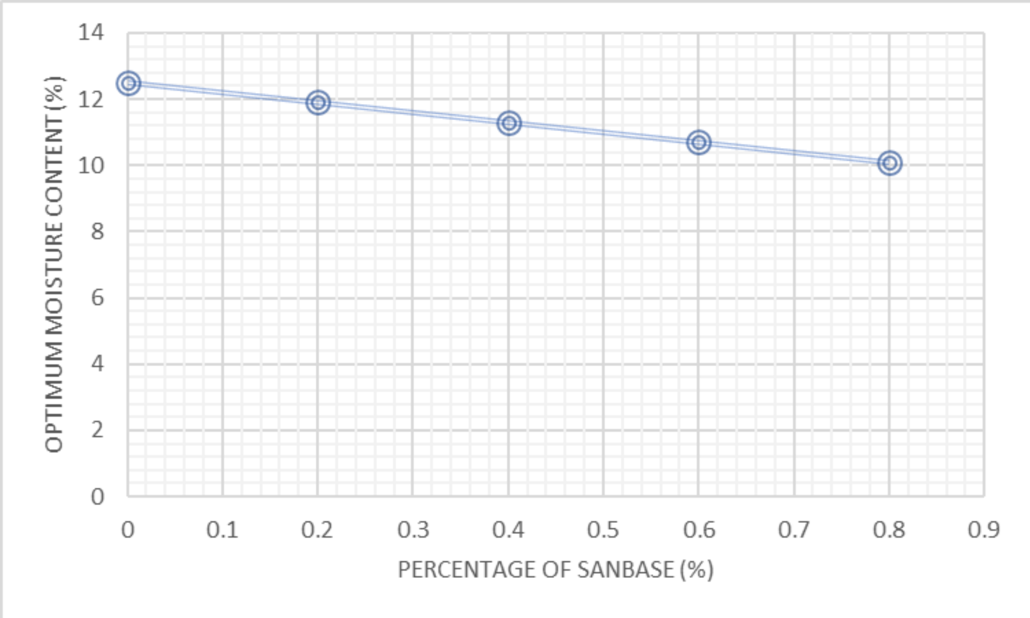

Fig. 1 - Optimum Moisture content of unmodified and SANBASE modified weak soil

From Figure 1, the optimum moisture content of the SANBASE modified weak soil have reduced by 4.8% at 0.2% dosage of SANBASE, it could be also noted that at 0.4% modification the optimum moisture has been reduced by 9.6% compared to unmodified weak soil. This is attributed to the ability of SANBASE to reduce the optimum moisture content through creating a cohesive compound that reduces soil plasticity and moisture holding capacity (Falah & Muteb, 2023).

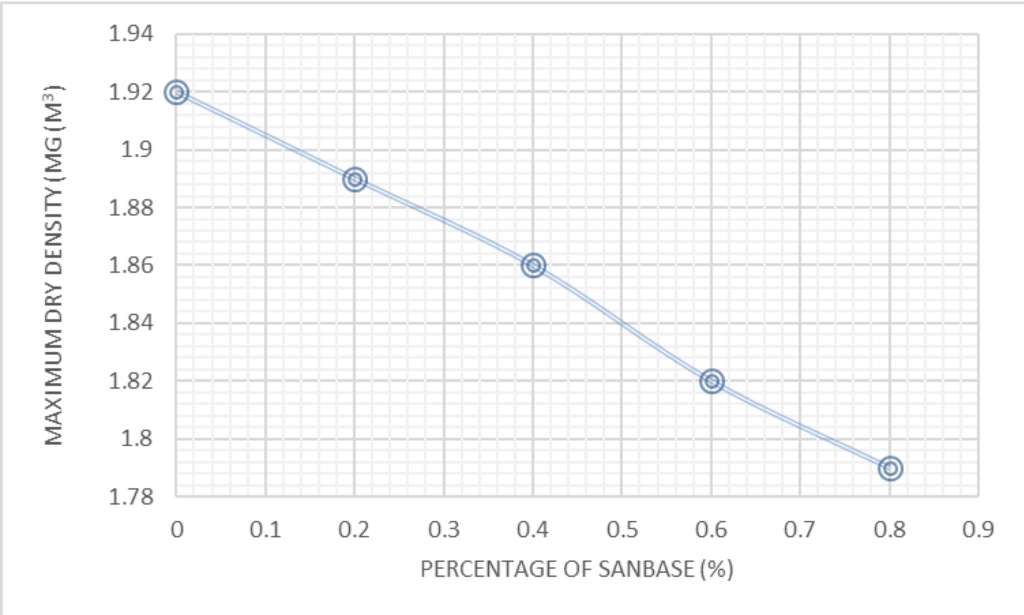

Fig. 2 - Maximum Dry Density of unmodified and SANBASE modified weak soil

Figure 2 is a plot of maximum dry density of unmodified and SANBASE modified weak soil. From the figure, the maximum dry density of SANBASE modified weak soil has the same trend with optimum moisture content. MDD decreases with the increase in SANBASE stabilizer from 0.2% to 0.8%. At 0.2% SANBASE stabilization, the MDD was decreased by 1.6%, it was further decreased by 3.1% at 0.4% stabilization. At 0.8% stabilization, the decrease in MDD was 6.8%. This reduction in MDD is attributed to the ability of SANBASE stabilizer to produce calcium silicate that formed a rigid structure that increased the volume of soil matrix without increasing its mass thus reducing overall dry density (Jangde & Khan, 2023).

3.2 Atterberg limit test

Atterberg limits test was conducted on unmodified and SANBASE modified weak soil, the result is presented in Table 4.

Table 4 - Result of Atterberg limits test

Percentage of SANBASE	Liquid limit (%)	Plastic limit (%)
0	18.5	0
0.2	16.8	0
0.4	15.4	0
0.6	14.8	0
0.8	14.2	0

From table 4, the liquid limit of modified weak soil decreases with the increase of SANBASE stabilizer. The decrease in liquid limit is attributed to the ability of SANBASE to plasticize the soils at lower moisture contents.

3.3 California bearing ratio (CBR)

California bearing ratio test was conducted on unmodified and SANBASE modified weak soil. The result is presented in figure 3.

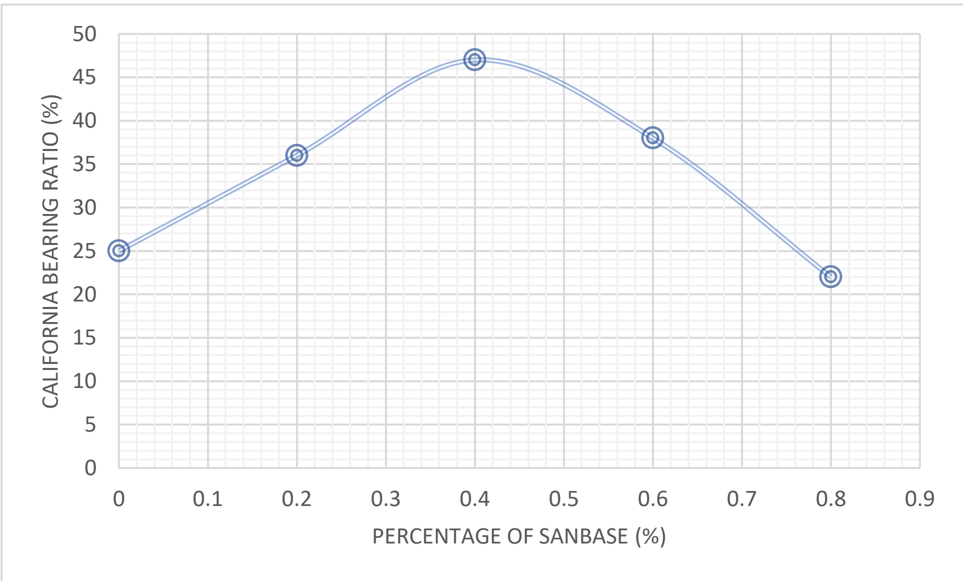

Fig. 3 - Improvement of soil's California bearing ratio with SANBASE stabilizer

From Figure 3, California bearing ratio of modified weak soil was improved with the percentage increase of SANBASE stabilizer from 0.2% to 0.4%, and then decreased at 0.6% and 0.8%. At 0.2% modification, the percentage improvement is 44% while at 0.4% SANBASE modification, the improvement is 88%. At 0.6% and 0.8% modification, the CBR value has decreased.

3.4 Unconfined compressive strength (UCS)

Unconfined compressive strength test was conducted on unmodified and SANBASE modified soil samples, the result is presented in figure 4.

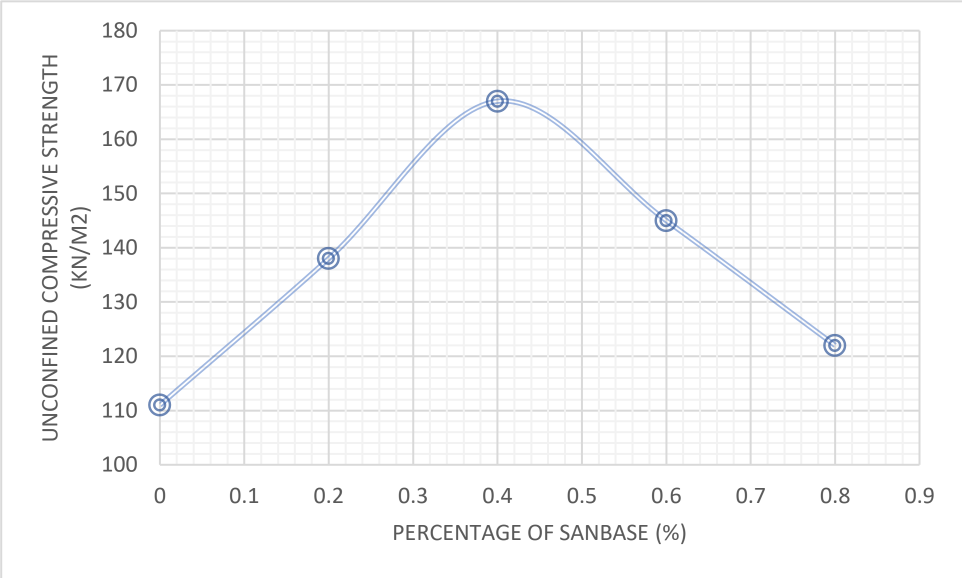

Fig. 4 - Improvement of soil's Unconfined compressive strength with SANBASE stabilizer

From figure 4, unconfined compressive strength of modified soil has increased by 50% at 0.4% modification. The improvement is due to confinement ability of SANBASE stabilization.

4. Conclusion

The aim of this paper was achieved through experimental works, and the following conclusions are drawn:

i. SANBASE soil stabilizer decreases both soil's Optimum moisture content and maximum dry density with increase in SANBASE stabilizer.

ii. Liquid limits of SANBASE modified soil decreased from 18.5% to 14.2% at 0.4% modification, it further decreased to 14.2% at 0.8% modification. This shows that, liquid limit of modified soil decreases with the increase of SANBASE percentages.

iii. California bearing ratio of SANBASE modified soil increased from 25% at 0% to 47% at 0.4 SANBASE modification and decreased to 22% at 0.8% modification.

iv.The unconfined compressive strength of modified soil was improved from 111kN/m2 at 0% to 167 kN/m2 and decreased to 122 kN/m2 at 0.8% modification.

Acknowledgements

The authors wish to recognize the efforts and sponsorship of this research by Tertiary Education Fund (TETFUND), and also the management of Hassan Usman Katsina Polytechnic for giving the enabling environment for this research to take place.

References

Ali, H. F. H., Omer, B., Mohammed, A. S., & Faraj, R. H. (2024). Predicting the maximum dry density and optimum moisture content from soil index properties using efficient soft computing techniques. *Neural Computing and Applications*, 1-31.

Andavan, S., & Kumar, B. M. (2020). Case study on soil stabilization by using bitumen emulsions–A review. *Materials Today: Proceedings*, *22*, 1200-1202.

Archibong, G. A., Sunday, E. U., Akudike, J. C., Okeke, O. C., & Amadi, C. (2020). A review of the principles and mesthods of soil stabilization. International Journal of Advanced Academic Research| Sciences, 6(3), 2488-9849.

Du, S., Ma, J., Ma, L., & Zhao, Y. (2024). Unconfined compressive strength and failure behaviour of completely weathered granite from a fault zone. Journal of Mountain Science, 21(6), 2140-2158.

Falah, M. W., & Muteb, H. (2023). Applying different soil stabilization mechanisms: a review. Archives of Civil Engineering, 69(4).

Fentaw, M., Alemayehu, E., & Geremew, A. (2021). Experimental study of stabilization of expansive soil using the mixture of marble dust, rice husk ash and cement for sub-grade road construction: A case study of Woldia town. Journal of Civil Engineering, Science and Technology, 12(2), 141-159.

Jangde, H., & Khan, F. (2023). Experimental investigation on Interrelation between hydraulic conductivity and Compressive strength of soft soil using metakaolin as stabilizer. Iranian Journal of Science and Technology, Transactions of Civil Engineering, 1-13.

Khasawneh, M. A., Al-Akhrass, H. I., Rabab'ah, S. R., & Al-sugaier, A. O. (2024). Prediction of California bearing ratio using soil index properties by regression and machine-learning techniques. International Journal of Pavement Research and Technology, 17(2), 306-324.

Lahoori, M., Rosin-Paumier, S., & Masrouri, F. (2021). Effect of monotonic and cyclic temperature variations on the mechanical behavior of a compacted soil. Engineering Geology, 290, 106195.

Liu, L., Deng, T., Deng, Y., Zhan, L., Horpibulsuk, S., & Wang, Q. (2022). Stabilization nature and unified strength characterization for cement-based stabilized soils. Construction and Building Materials, 336, 127544.

Moghal, A. A. B., & Vydehi, K. V. (2021). State-of-the-art review on efficacy of xanthan gum and guar gum inclusion on the engineering behavior of soils. Innovative Infrastructure Solutions, 6, 1-14.

Moreno-Maroto, J. M., Alonso-Azcárate, J., & O'Kelly, B. C. (2021). Review and critical examination of fine-grained soil classification systems based on plasticity. Applied Clay Science, 200, 105955.

O'Kelly, B. C. (2021). Review of recent developments and understanding of Atterberg limits determinations. Geotechnics, 1(1), 59-75.

Okonkwo, U. N., & Kennedy, C. (2023). The Effectiveness of Cement and Lime as Stabilizers for Subgrade Soils with High Plasticity and Swelling Potential. Saudi J. Civ. Eng, 7, 40-60.

Puppala, A. J. (2021). Performance evaluation of infrastructure on problematic expansive soils: Characterization challenges, innovative stabilization designs, and monitoring methods. Journal of Geotechnical and Geoenvironmental Engineering, 147(8), 04021053.

Sinha, P., Anusha Raj, K., Kumar, S., & Singh, D. (2022). Mechanical behavior of geotextile and geogrids on soil stabilization: a review. Recent Advances in Mechanical Engineering: Select Proceedings of CAMSE 2021, 299-308.

Su, F., Yang, Y., Qi, Y., & Zhang, H. (2022). Combining microbially induced calcite precipitation (MICP) with zeolite: A new technique to reduce ammonia emission and enhance soil treatment ability of MICP technology. Journal of Environmental Chemical Engineering, 10(3), 107770.

Tang, Y., Wang, N., Xu, F., Teng, D., & Cui, X. (2022). Electrokinetic stabilization of marine clayey soil using magnesium chloride solution: A green soil stabilizer. Marine Georesources & Geotechnology, 40(2), 248-254.

Turan, C., Javadi, A. A., Vinai, R., & Russo, G. (2022). Effects of fly ash inclusion and alkali activation on physical, mechanical, and chemical properties of clay. Materials, 15(13), 4628.

Zhang, Q., An, Z., Huangfu, Z., & Li, Q. (2022). A review on roller compaction quality control and assurance methods for earthwork in five application scenarios. Materials, 15(7), 2610.