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ijirset@gmail.com



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# Experimental Investigation using Silane Based Compounds in Stabilization of Black Cotton Soil

Ankith B <sup>1a</sup>, Chirag Chand <sup>1b</sup>, Dhanush S R <sup>1c</sup>, Darshan S <sup>1d</sup>, Sridhar H N <sup>2</sup>

UG Final Year Students, Department of Civil Engineering, Dayananda Sagar College of Engineering,  
Bangalore, India<sup>1-</sup>

Assistant Professor, Department of Civil Engineering, Dayananda Sagar College of Engineering, Bangalore, India<sup>2-</sup>

**ABSTRACT:** Soil stabilization through chemical methods involves the application of various agents to enhance the engineering properties of soil, mitigating challenges such as poor load-bearing capacity, high plasticity, or susceptibility to erosion. This abstract explores the effectiveness of chemical stabilizers such as silane in transforming soil into a durable and structurally sound construction material. The study evaluates the impact of these chemicals on soil properties, such as compressive strength, cohesion, and permeability, through laboratory testing and field assessments. The findings contribute valuable insights into sustainable and cost-effective practices for soil stabilization, essential for infrastructure development and environmental conservation.

**KEYWORDS:** load-bearing capacity, engineering properties, compressive strength, permeability.

## I. INTRODUCTION

Soil Stabilization is the biological, chemical, or mechanical modification of soil engineering properties. In civil engineering, soil stabilization is a technique to refine and improve the engineering properties of soils. These properties include mechanical strength, permeability, compressibility, durability and plasticity. Physical or mechanical improvement is common but some schools of thought prefer to use the term ‘stabilization’ in reference to chemical improvements in the soil properties by adding chemical admixtures.

For any construction project, whether it's a building, a road or an airfield, the base soil acts as the foundation. Additionally, soil is one of the crucial construction raw materials. As such, the soil should possess properties that create a strong foundation. Soil stabilization, a fundamental aspect of geotechnical engineering, plays a pivotal role in enhancing the mechanical properties of soil to meet the demands of construction and infrastructure development. The practice of soil stabilization dates back centuries, where ancient civilizations utilized rudimentary methods to fortify natural soils for various structures. These early techniques often involved the incorporation of locally available materials, such as gravel or lime, to improve soil stability.

The advent of systematic soil stabilization methods gained momentum during the late 19th and early 20th centuries. Engineers began experimenting with various admixtures to modify soil behavior, addressing challenges related to poor load-bearing capacity, expansive clay soils, and erosion susceptibility. Lime emerged as one of the earliest chemical stabilizers employed to modify soil properties. Its ability to react with soil particles, altering their structure and promoting cohesion, marked a significant milestone in soil stabilization practices.

As engineering knowledge progressed, the mid-20th century witnessed a surge in the exploration of diverse admixtures for soil stabilization. Cement, another influential stabilizer, gained prominence for its ability to form durable and stable structures. The introduction of polymers and synthetic additives further diversified the range of available stabilizing agents, offering solutions tailored to specific soil types and project requirements.

In recent decades, the field of soil stabilization has seen a paradigm shift towards environmentally friendly and sustainable practices. This has led to the exploration of innovative techniques, including the use of silanes, which exhibit unique bonding properties. Silanes, as soil stabilizers, have shown promise in addressing contemporary challenges associated with construction on problematic soils, such as expansive clays or loose sands.

This ongoing evolution in soil stabilization practices underscores the importance of continually refining and expanding the toolkit of available admixtures. The exploration of new materials and methods reflects a commitment to developing efficient, cost-effective, and environmentally conscious approaches to address the diverse geotechnical challenges encountered in construction and infrastructure projects.

## II. MATERIALS AND METHODOLOGY

### 2.1 Soil: *Black cotton Soil*

The black cotton soil selected for this experiment is sourced from a representative site (regions of Hubli-Dhrawad) known for its expansive clay characteristics. This soil is typically rich in montmorillonite clay minerals, contributing to its expansive nature. Its high plasticity index and shrink-swell behavior make it an ideal candidate for studying the impact of silane-based compounds on soil stabilization. Key properties of the black cotton soil under investigation include its Atterberg limits, which determine the soil's plastic and liquid limits, as well as its natural moisture content. These parameters provide insights into the soil's inherent characteristics and responsiveness to external stabilization methods. Additionally, the grain size distribution of the soil is analyzed to understand its particle composition and potential for compaction.



### 2.2 Experimental Admixture: Liquid Silane ( $\text{SiH}_4$ )

Silanes are a group of chemical compounds containing silicon (Si) atoms and various organic functional groups. The general formula for silanes is  $\text{SiH}_4$ , representing a single silicon atom bonded to four hydrogen atoms. In the context of soil stabilization, specific silane compounds are employed to interact with the soil particles, forming bonds that alter the soil's structure and enhance its strength, cohesion, and resistance to erosion. The detailed chemical structure of silane-based compounds used in soil stabilization may vary, depending on the specific organic groups attached to the silicon atom. Examples of organic functional groups include alkoxysilanes, chlorosilanes, and aminosilanes.

**TERRANOBOND** is a nanotechnology based water-soluble Organosilane compound designed to address and prevent capillary water movement in soil. Its nano-sized molecules react with the smallest particles of substrates, forming stable water-repellent alkyl siloxane bonds. TERRANOBOND's versatility allows it to be mixed with water, forming a hydrophobic solution that can be sprayed on the soil surface or mixed directly with soil. When exposed to heat, the treated soil becomes hydrophobic, repelling water from the surface. The Organosilane penetrants in chemically react and bond with the soil, providing a molecular-level hydrophobic surface that protects against weathering and natural



abrasion. Notably, TERRANOBOND's non-leachable nature ensures a permanent binding to soil particles, and its nanotechnology base allows for molecular-level waterproofing of various materials, including cementitious silicate-containing materials, lime, and bitumen emulsions. Overall, TERRANOBOND appears to be a promising solution for waterproofing and stabilizing soil, offering permanent and versatile benefits through its nanotechnology-based formulation,

Table 1 Properties of soil

Property	Value
Specific gravity	2.38
<i>Grain size distribution</i>	
Sand	4 %
Silt	70 %
Clay	26 %
<i>Atterberg Limit</i>	
Liquid limit	56.07 %
Plastic limit	21.1 %
Plasticity index	35%
IS classification	CL
<i>Compaction characteristics</i>	
Maximum dry density	1.88 g/cm <sup>3</sup>
Optimum moisture content	22 %

### III. LITERATURE REVIEW

- Effect of liquid silane-based anti-stripping additives on rheological properties of asphalt binder and hot mix asphalt moisture sensitivity by Peyman Mirzababaei, Fereidoon Moghadas Nejad & Koorosh Nader:**

This paper suggests that the liquid nano-materials Zycosoil and Zycotherm, especially at 0.5% concentration, are more effective in reducing moisture damage potential in asphalt binders compared to full replacements with Portland cement and hydrated lime. The study emphasizes the importance of proper additives in enhancing the performance of asphalt mixtures. Rheological evaluation indicates slight variations in modified binders compared to the base binder, with lower temperature susceptibility noted. However, the discussion remains open regarding the exact impact of these liquid additives on the temperature susceptibility of bitumen in civil engineering applications.

- Properties and performance of silane: blended cement systems by M. A. Kargol, U. Müller & A. Gardei :** This paper highlights the importance of studying the performance of water repellents on blended cement pastes, given the shift away from dominant use of Portland cement in European markets due to sustainability concerns. The research emphasizes the need for understanding interactions between water repellent agents and various blended cement compositions (CEM II–CEM V). Silane-based products were applied to cement substrates containing limestone, fly ash, slag, and trass, and their functionality was evaluated through laboratory measurements, including hydrophobicity, water absorption, color changes, and penetration depth. The study suggests that the effectiveness of water repellents can be influenced by the specific composition of blended cements, especially when incorporating slag and trass. The findings contribute to advancing knowledge in the field of civil engineering, aiding in the selection and application of water repellents for diverse cement formulations.
- Feasibility of Using Nanosilanes in a New Hybrid Stabilised Soil Solution in Rural and Low-Volume Roads by José Luis Díaz-López, Manuel Cabrera, José Ramón Marcobal, Francisco Agrela, and Julia Rosales :** This study suggests that incorporating nanosilica in soil stabilization processes can have positive effects on the mechanical behavior and structural capacity of rural and low-volume roads. The addition of

nanosilica slightly increases maximum dry density and reduces optimum water content, leading to potential resource savings and environmental benefits. The hybrid stabilisation solution, particularly with nanomaterial N1, enhances the bearing capacity, measured by the CBR index and unconfined compressive strength. The proposed solution also demonstrates a reduction in section thickness and increased bearing capacity, making it a promising alternative for road construction. However, the study acknowledges the need for verification in different climatic conditions, emphasizing effectiveness in Southern Spain but suggesting caution in regions with high humidity and large temperature variations. Overall, the use of nanomaterials within specific percentage ranges appears beneficial for soil stabilization, with room for further investigation into performance during rainy periods.

4. **Stabilization of black cotton soil subgrade using sawdust ash and lime by C.C. Ikeagwuani, I.N. Obeta, J.C. Agunwamba:** This study suggests that black cotton soil can be effectively stabilized for use as subgrade material using a combination of sawdust ash (SDA) and lime. The key findings highlight the achievement of adequate strength with a relatively low combination of 4% lime and 16% SDA. This contrasts with other lime stabilization cases that often require higher quantities of lime, resulting in increased construction costs. The utilization of sawdust, an inexpensive by-product, not only proves economically viable but also contributes to minimizing environmental pollution, especially when compared to open-air burning practices by sawmills operators.

The method proposed in the study, while acknowledging room for improvement, offers a more environmentally friendly alternative for stabilizing expansive clays. The large-scale production of ash, using higher quality furnaces and complying with environmental regulations, is mentioned as a feasible approach. The achieved California Bearing Ratio (CBR) value of 20.64% meets the criteria set by Nigerian General Specification for Roads and Bridges (1997) and TRL (1993), suggesting the suitability of the stabilized black cotton soil for subgrade use in road construction.

5. **STABILIZATION OF BLACK COTTON SOIL WITH SAND AND CEMENT AS A SUBGRADE PAVEMENT by V. Ramesh Babu, K. Niveditha:** The experimental investigation on black cotton soils, incorporating varying percentages of sand and cement for stabilization, reveals several trends in the mechanical properties. The addition of sand and cement exhibits a nuanced impact on specific gravity, with a general increase observed as fly ash content rises, though careful consideration is needed for potential decreases. Plastic limit decreases with higher proportions of sand and cement, and while the liquid limit decreases, the relationship is not directly linked to the initial plastic limit of the soils. Proctor density experiences a decrease in optimal moisture content (OMC) and an increase in maximum dry density (MDD) at around 30% addition of sand and cement. Unconfined compressive strength shows a gradual increase at 20%, followed by a decrease at 30%, while shear strength decreases at 20% and increases at 30%. California Bearing Ratio (CBR) decreases at 20% and increases at 30%. These findings highlight the complex interplay between sand, cement, and black cotton soils, providing insights into the optimal mix proportions for soil stabilization in construction applications.
6. **Stabilization of Black Cotton Soil using different Stabilizers by H S Jayatheertha, Vinay Kumar K S, P Girish, Vinayak A Hosur:** The study demonstrates that the addition of 5% lime and 30% demolished concrete effectively improves the geotechnical properties of black cotton soil. The combination leads to a substantial decrease in both liquid limit (from 55.7% to 43.33%) and plastic limit (from 26.11% to 18.56%). Similarly, incorporating 5% lime and 30% bagasse ash results in a significant reduction in liquid limit (to 47.98%) and plastic limit (to 20.16%). The addition of 5% lime and 30% demolished waste not only increases maximum dry density (from 1.429g/cc to 1.776g/cc) but also decreases optimal moisture content (from 27.2% to 18.25%). The improvements extend to mechanical properties, with unconfined compressive strength increasing from 1.618 kg/cm<sup>2</sup> to 1.9422 kg/cm<sup>2</sup> and CBR values showing substantial enhancements under both soaked and unsoaked conditions. The study suggests that while bagasse ash contributes to improved CBR values, demolished waste concrete is more effective in enhancing the index properties of black cotton soil, emphasizing the potential of these materials in geotechnical applications.

7. **Chemical Stabilization of Black Cotton Soil by Patil Atul Ajit, Choudhary Vinod Ruparam, Sarkar Samrat Ashok:** The study demonstrates the influence of Terrasil at various dosages (0.9%, 1.1%, and 1.3%) on the geotechnical properties of Black Cotton soil in Ravet, Pune, Maharashtra. The results indicate several key findings: firstly, the maximum dry density of the Black Cotton soil decreases with an increase in Terrasil content, suggesting potential reactions between coal minerals and chemicals leading to the formation of new products. Secondly, the optimum moisture content increases with Terrasil addition, showing a rise from 23.07% to 28% at a dosage of 1.3%. Thirdly, the Free Swell Index (FSI) of the treated soil significantly decreases compared to the parent soil, indicating a reduction in swelling capacity due to the film of adsorbed water around soil particles being reduced. Overall, the study concludes that Terrasil serves as an effective stabilizing agent for Black Cotton soil, providing substantial and durable benefits by altering swelling behavior and enhancing compressive strength. These findings highlight Terrasil's potential as a worthy stabilizer for improving the geotechnical properties of Black Cotton soil in the specified region.
8. **Stabilization of Black Cotton Soil using Waste Material Quarry Dust by Milan J. Kotadiya , Ayushi D. Panchal , Dhruti R. Patel , Nevil N. Naik, Kalpana P. Patel:** The experiments on black cotton soil mixed with quarry dust reveal several significant conclusions. The soil initially exhibits high swelling properties with a shrinkage limit of 20.18% and a swell index of 90%. However, the addition of quarry dust in different proportions results in notable improvements. At 10% quarry dust + 90% black cotton soil, the liquid limit (LL) decreases from 54.8% to 38.74%, plastic limit (PL) slightly decreases from 26.54% to 26.38%, and plasticity index (PI) decreases significantly from 28.27% to 12.35%. Moreover, the maximum dry density increases to 1.66 gm/cc, and moisture content decreases slightly. The California Bearing Ratio (CBR) value improves from 11.53% to 15.28% with the addition of up to 10% quarry dust, indicating enhanced strength. The unconfined compressive strength (UCS) also increases from 0.67 kg/cm<sup>2</sup> to 0.74 kg/cm<sup>2</sup>. Overall, the study suggests that the addition of quarry dust has a positive impact on the geotechnical properties of black cotton soil, leading to improved strength and reduced swelling tendencies, making it a promising method for soil stabilization.
9. **Stabilization of Black Cotton Soil by Using Plastic Granules as a Subgrade Material by Veeresh A Salimath, S.R.Kulkarni:** The study on the stabilization of black cotton soil using plastic granules presents several notable conclusions. Firstly, the black cotton soil is categorized as well-graded soil and, based on liquid limit and plastic limit, is classified as clay with high compressibility. The addition of plastic granules leads to a substantial increase in Maximum Dry Density (MDD) up to 6% by weight, beyond which it decreases, reaching 2.01g/cc at 6% plastic granules. Optimum Moisture Content (OMC) experiences a substantial decrease with the addition of plastic granules, reaching 6.38% at 6% by weight. Free Swell also significantly decreases with a 6% addition of plastic granules, registering at 40%. The California Bearing Ratio (CBR) improves from 1.31% in the original black cotton soil to 1.97% after stabilization with 6% plastic granules. The soaked CBR value sees a remarkable 50.40% increase after stabilization. These findings collectively suggest that the addition of plastic granules is effective in enhancing the geotechnical properties of black cotton soil, improving density, reducing moisture content, decreasing swell potential, and significantly increasing CBR values, showcasing its potential as a stabilizing agent for subgrade material.
10. **Stabilization of black cotton soil using plastic waste by G. Swetha; B. Veeraswamy; B. Nikhil; B. Varunkumar; P. Tharun:** The study on the stabilization of black cotton soil using plastic waste addresses the challenge of using expansive and moisture-sensitive black cotton soil in construction. Black cotton soil is known for its unsuitability due to inherent instability, particularly in moist conditions. The research employs plastic waste obtained from SYS INVESTMENTS PVT. LTD BOLLARAM to stabilize the soil and enhance its strength. The motivation for using plastic waste lies in its abundance, considering the significant plastic waste generation reported by the Central Pollution Control Board in India. Tests, including Standard Proctor Test and California Bearing Ratio (CBR), are conducted on the soil with polypropylene at various percentages (1%, 1.5%, 2%, and 2.5%). The untreated soil serves as a reference for comparison. Overall, the study suggests that incorporating plastic waste in different percentages effectively stabilizes black cotton soil, potentially offering a sustainable solution for utilizing plastic waste in construction and improving the geotechnical properties of problematic soils.

#### IV. TESTS

**4.1** Laboratory tests have been conducted to natural black cotton soil to determine following properties

1. Specific gravity
2. Atterberg Limits (Liquid limit, Plastic limit)
3. Plasticity Index
4. Maximum dry density
5. Optimum moisture content

**4.2** Laboratory procedures to evaluate the effectiveness of liquid silane as admixture at different concentrations:

1. Liquid Limit
2. Plasticity Index
3. Shrinkage Limit
4. Maximum Dry Density, MDD
5. Optimum Moisture Content
6. Unconfined Compressive Strength

#### V. CONCLUSION

The experiments on black cotton soil mixed with (TERRANOBOND) liquid silane reveal several significant conclusions. The soil initially exhibits high swelling properties with a Shrinkage limit of 8-15 % and a Liquid limit of 50-60%. However, the addition of liquid silane in different proportions results in notable improvements such as reducing moisture, behaving as a water repellent additive, increases maximum dry density and reduces optimum water content, leading to potential resource savings and environmental benefits, permeability becomes almost nil, and the TERRANOBOND organosilane proves its compatibility with most types of soil.

#### VI. FURTHER RESEARCH

Future research endeavors could focus on several key areas to explore the efficacy and feasibility of using liquid silane (TERRANOBOND) for stabilizing black cotton soil:

**Optimization of Mix Proportions:** Investigate the optimal mix proportions of liquid silane (TERRANOBOND) and black cotton soil to achieve desired engineering properties, including improved strength, reduced plasticity, and enhanced durability. This would involve conducting laboratory experiments and geotechnical tests to assess the influence of varying silane contents on soil stabilization performance.

**Effect of Curing Conditions:** Evaluate the influence of curing conditions, such as curing time and moisture content, on the effectiveness of liquid silane (TERRANOBOND) stabilization. Long-term curing studies can provide insights into the durability and long-term performance of stabilized black cotton soil under different environmental conditions.

**Mechanisms of Stabilization:** Explore the mechanisms underlying the stabilization of black cotton soil with liquid silane (TERRANOBOND), including chemical reactions, mineralogical changes, and microstructural modifications.

**Environmental Impact Assessment:** Evaluate the environmental implications of using liquid silane (TERRANOBOND) for soil stabilization, including its effects on soil fertility, groundwater quality, and ecosystem health. Life cycle assessment (LCA) and environmental impact assessment (EIA) methodologies can help quantify the environmental benefits and trade-offs associated with liquid silane (TERRANOBOND) utilization compared to traditional stabilization methods.

By addressing these research gaps and challenges, further investigation into the application of liquid silane (TERRANOBOND) for stabilizing black cotton soil can contribute to sustainable soil management practices, enhance infrastructure resilience, and support eco-friendly solutions for geotechnical engineering projects.



## REFERENCES

1. Mirzababaei, P., Moghadas Nejad, F., & Nader, K. (2018). Effect of liquid silane-based anti-stripping additives on rheological properties of asphalt binder and hot mix asphalt moisture sensitivity. ORCID Icon. <https://www.tandfonline.com/doi/ref/10.1080/14680629.2018.1507920?scroll=top>
2. Kargol, M. A., Müller, U., & Gardei, A. (Year). Properties and performance of silane: blended cement systems.
3. Díaz-López, J. L., Cabrera, M., Marcobal, J. R., Agrela, F., & Rosales, J. (2019). Feasibility of Using Nanosilanes in a New Hybrid Stabilised Soil Solution in Rural and Low-Volume Roads.
4. Ikeagwuani, C. C., Obeta, I. N., & Agunwamba, J. C. (Year 2019). Stabilization of black cotton soil subgrade using sawdust ash and lime. ScienceDirect, Volume59(Issue1). <https://www.sciencedirect.com/science/article/pii/S0038080618302087>
5. Babu, V. R., & Niveditha, K. (2007). Stabilization of Black Cotton Soil with Sand and Cement as a Subgrade Pavement. , Irjet
6. Jayatheertha, H. S., Kumar, V. K. S., Girish, P., & Hosur, V. A. (Year). Stabilization of Black Cotton Soil using different Stabilizers. Journal Name, Volume06(Issue11).
7. Ajit, P. A., Ruparam, C. V., & Ashok, S. S. (Year). Chemical Stabilization of Black Cotton Soil. ijarset, Volume02(Issue06).
8. Kotadiya, M. J., Panchal, A. D., Patel, D. R., Naik, N. N., & Patel, K. P. (Year). Stabilization of Black Cotton Soil using Waste Material Quarry Dust. irjet, Volume08(Issue06). <https://www.ijert.org/stabilization-of-black-cotton-soil-using-waste-material-quarry-dust>
9. Salimath, V. A., & Kulkarni, S. R. (2021). Stabilization of Black Cotton Soil by Using Plastic Granules as a Subgrade Material. irjet, Volume08(Issue12),
10. Swetha, G., Veeraswamy, B., Nikhil, B., Varunkumar, B., & Tharun, P. (Year). Stabilization of black cotton soil using plastic waste.





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