Review Paper on Stabilization of Black Cotton Soil Using Binary Blends

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Abstract — Black cotton (BC) soils are highly expansive clays that present serious challenges for geotechnical engineering due to large seasonal volume changes, low bearing capacity, and problematic shear strength characteristics. This review synthesizes laboratory and field investigations into the stabilization of BC soils using binary blends — combinations of two stabilizing materials (e.g., lime + fly ash, lime + GGBS, cement + fly ash, fly ash + bio-waste ash). The paper summarizes stabilization mechanisms, dominant material pairs, laboratory behaviour (index properties, compaction, Atterberg limits, unconfined compressive strength, CBR, swelling potential), durability considerations, environmental and economic aspects, and identifies gaps and priorities for future research.

Keywords: Black Cotton Soil, Ground Granulated Blast Furnace Slag (GGBFS), Pozzolanic Material, Silica Fume (SF), Metakaolin (MK), Rice Husk Ash (RHA)

I. Introduction

Black cotton soils (highly plastic, montmorillonitic clays) are widespread in semi-arid and tropical regions. Traditional single-agent stabilizers (lime, Portland cement, fly ash) are effective but may have limitations: cost, greenhouse-gas footprint, variable performance in sulfate-rich soils, or insufficient long-term durability. Binary blends — purposely combining two stabilizers — can create synergistic effects: improved pozzolanic reactivity, optimized particle packing, supplemental hydraulic reactions, and utilization of industrial by-products. This review examines the current state of knowledge for binary-blend stabilization of BC soils, consolidating typical material choices, performance trends, mechanisms, and research gaps.

A. Engineering problems posed by black cotton soil

- High plasticity index and liquid limit leading to large shrink–swell cycles.
- Low natural strength and bearing capacity; high compressibility under load.
- Potential for differential settlements and cracking in pavements and foundations.
- Sensitivity to moisture variation and prolonged wetting.

II. Literature review

On or below the surface of the earth you may find civil engineering projects such as buildings, bridges, highways, tunnels, dams, and towers. It is necessary to assess the soil's compatibility and properties in order to guarantee stability. In order to properly design and construct the foundations of the proposed site, the researcher is required to conduct a geotechnical analysis of the subsoil in the studied area and supply relevant input data. According to research, building structures may be better designed and built to reduce the likelihood of post-construction problems, structural collapse, and adverse environmental effects. When planning an architectural or building strategy, it is important to understand both the above- and below-ground components. Rather than overdesigning the building and increasing its costs, it is better to invest in underground space when the structures are very stunning and the load and area of impact are large. Evaluating the complexities is vital in complex undertakings like building bridges, dams, and other structures. Buildings placed on land that is prone to subsidence are certain to fail. Therefore, design considerations necessitate data on the degree of soil compaction. Soil strength, pliability, and compressibility are always going to have an impact on building design. There is a risk of design errors due to a lack of understanding of soil structures. The technical features of soil, not its aesthetic qualities or superficial similarities, are what should be considered when determining the soil's appropriateness for a certain purpose. The kind of soil determines how much weight the ground can support. Relative bearing capacity is often low in soils with fine particles. To better understand how soil behaves, engineers rely on crucial elements like the plasticity index and liquid limit. When it comes to stability issues like foundations, slope stability, earth pressure calculations, bearing capacity, embankments, and dams, shear strength is a crucial property that shows how the soil's geotechnical structures interact with one another. Mechanical compaction is one method that is commonly used to improve soil quality. It is crucial to have knowledge of soil compaction characteristics (MDD and OMC) for building dams, roads, railroads, landfill liners, and storage facility backfill [5]. Flexible paved roads are the most common type of highways in India. The building of flexible pavements can be accomplished in several ways. One effective method for dynamic design is the California Bearing Ratio (CBR) test. For soil investigations including pavement growth, the load test is a useful tool. The CBR value determined by this test is an essential part of several approaches for flexible pavement design. New building designs must be based on samples that have been integrated with water for four days prior to testing, and have been developed at the optimal moisture content (OMC) in accordance with Proctor Compaction [7]. There may be a connection between the evolutionary history of soil types and their unique properties. The mineralogy, micromorphology, chemistry, plasticity, and stress management behavior of clay in the past are all affected by the density and development of granular soil. When pollutants react with soil, they drastically change the soil's properties. Environmental parameters, pollutant concentration, particle size, particle aggregation, ion exchange capacity, and other factors determine the rate of soil characteristic changes, among others. The contact effect is proportional to the particle size. Consequently, geotechnical foundation failures are worsened in an industrial setting when soil contamination is present. Before choosing a chemical stabilizer, geotechnical engineers must determine how well it will work with the soil matrix. Soils would not have minerals with waterproof qualities if they were not open-ended. Changes to the soil occur throughout time as a result of the continuous extraction and depletion of biomass, solar energy, and freshwater. These changes are probably most noticeable while the soil aggregates are being formed, especially when it comes to the mineralogy and composition of the clay portion of the soil.

In order to prevent foundation instability, shear failure, and structural fragmentation improvement, the geotechnical engineer had to select a solid soil type. Analysis and decision-making are perpetually difficult tasks for geotechnical engineers. Stabilization by chemical modification is a typical strategy for improving the characteristics of expansive soil and might fix all of these difficulties. Soil strength and deformation qualities are improved, and the likelihood of soil swelling and shrinking is reduced, by this treatment. When working with soil, a variety of chemicals are employed. The pozzolanic qualities of the stabilizer are the main determinants of its soil strengthening ability. A higher concentration of pozzolons in the soil results in a stronger final product. To make BC soil have these characteristics, several substances are added to it, including cement, GGBFS, FA, SF, MK, and RHA.

Using one or two layers of horizontally placed geo-synthetic reinforcements (Glasgrid, Tenax 3D grid, and Tenax multimat) at different depths from the subgrade soil's highest surface, Meenakshi Singh (2019) conducted experimental study to assess the subgrade soil's performance. According to the findings, the optimal spacing for the Tenax 3D grid reinforcement, with H representing the soil specimen's height, is between 0.3H and 0.36H. Placing Glas grid and Tenax MultiMate reinforcements between 0.41H and 0.62H yields the most reinforcing impact.

In their 2019 publication, Ayush Mittal and Shalinee Shukla detail a laboratory investigation on the impact of polyester biaxial geo-grid on the behavior of strength in subgrade soils that are not very good. Scientific research has demonstrated that weak subgrade soil is strengthened by surface friction and the interlocking of soil particles with geo-grid fibers. Wet CBR and UCS forecasts were made using several linear regression models.

In order to conduct the CBR test on the soil sample that did not contain geotextile, Raut, Aniket, S. et al. (2016) additionally used woven geotextile at different depths, such as 3 cm, 6 cm, and 9 cm of the sample height from top. The geotextile positioned 6 cm deep in the middle of the sample had a higher CBR value.

Using woven polyester geotextile, Srivastava, Rishi, et al. (2016) tested CBR on black cotton soil by inserting specimens at varying depths. The CBR value that performed the best was discovered at a depth of 0.4H from the specimen's top.

One and two-layer granular soils of different grades were examined by Rudramurthy and Vikram (2016), with and without geotextiles. Results show that granular soil supplemented with geotextile has a higher bearing ratio.

The behavior of geotextile reinforced clay under unconsolidated undrained triaxial compression was investigated by Kuo-Hsin-Yang et al. (2016) using a coarse material sandwich approach. conducted a battery of UU triaxial tests using varying thicknesses of sand layers and coating pressures. The results demonstrate that the shear strength increases with increasing geotextile layer thickness.

Researchers Olaniyan and Akolade found that geo-grids significantly improve CBR values, which indicates that weak soils are significantly reinforced (2014). According to the study, placing the geo-grid at different depths greatly increases the sub-grade's strength. The subgrade's performance improves dramatically when the soil is not damp after soil reinforcement.

Field testing is the primary method that Ahmet Demir (2011) plans to use to demonstrate the possible advantages of geo-grid reinforced soil footings. Reinforced soil footings (RSF) subgrade modulus and bearing capacity are significantly affected by the usage of geo-grid and granular fill, according to the test results. According to Pardeep Singh and K.S. Gill (2012), a single layer of geo-grid has the potential to boost a soil's CBR by 50-100%. Both the soil type and the geo-grid's location determine the degree to which the soil is improved.

Embankments and earth dams are stabilized using geo-synthetics, according to Raju, N. Ramakrishna (2010). When working with soft soil, reinforced embankments or infills need less material, land, and time to construct.

The CBR is higher when the Non-Woven geotextile sheet (Fibertex F-32) is placed in the center of the sample height with granular soil, rather than at the top or bottom, according to Naeini, S.A. and Mirzakhanlari, M. (2008).

Sivapragasam.C and Vanitha.S. (2010) paved roads in the Virudhunagar area of Tamil Nadu using synthetic non-woven geotextiles. They were laid on top of the samples in both single and double layers at varying soil depths. The study's authors discovered that various soil levels—3 cm, 6 cm, and 9 cm—received a single layer of synthetic non-woven geotextiles. The same holds true for the numerous layers at3,6, and 9 centimeters. According to the CBR UCC test, the soil's carrying capacity has increased. The results showed that samples with a single layer of geotextile placed in the center (mid-depth) fared better than samples with geotextile at various depths.

Chowdary, A.K. et al. (2011) carried out a battery of compressive bearing resistance (CBR) tests on expansive soils for unreinforced reinforced cases with varying layers of geogrid and jute geotextile. The soil's CBR value was dramatically raised when Singh, H.P., and Bagra, M. (2013) utilized Jute geotextile sheets in triaxial test samples of soil in various combinations, including 1, 2, 3, and 4 layers. From the top of the specimen, different numbers of reinforcement layers were added at embedment ratios (z/d) of 0.25, 0.50, 1.0, and 1.50, respectively, according to the results. The geotextile sheets used were Jute.

In 2014, Dilip Kumar Talukdar investigated how various soil conditions relate to the California bearing ratio. Following the collection of sixteen samples, the following were computed: particle size, consistency constraints, compaction characteristic, and CBR value. The relationship between CBR and plasticity index, the impact of maximum dry density, and the appropriate moisture content are used to visually examine soil properties. Check the CBR value that was calculated mathematically against the one that was achieved in the lab.

In their laboratory studies, Hossain, Md. Akhtar, et al. (2015) examined the behavior of granular soil reinforced with jute bre at weight percentages of 0.5, 1.0, 1.5, and 2.0, as well as a combination of jute bre and geotextile. The most effective way to reinforce the granular soil using geotextile and jute fiber was determined by reviewing the test data.

In 2015, M. Deivanai and colleagues investigated how natural bre affected the subgrade of the soil. Coir, jute, bamboo, and sisal were the four different natural fibers that were tested in this study. The percentages of each fiber were determined using wet and unsoaked California bearing ratio tests. For Proctor compaction, UCS testing, and CBR testing, locally available soil reinforced with these natural bres was utilized to strengthen the subgrade for pavement design. The wet and unsoaked materials, both reinforced and unreinforced, were subjected to a battery of CBR tests in the lab after being compressed to the ideal moisture content and maximum dry density.

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III. Conclusion

Binary blends are a promising route to improve the engineering behavior of black cotton soils while lowering environmental impact and cost. The synergy between chemical activation (lime/cement) and reactive industrial by-products (fly ash, GGBS, agricultural ashes) yields improved strength, reduced swell, and enhanced bearing capacity. However, site-specific studies and long-term field validations are essential to translate lab-scale success into reliable engineering practice.

References

[1] Durga Prasad.S, Prasad. D S V, Prasada Raju. G V R (2019) “Stabilization of black cotton soil using ground granulated blast furnace slag and plastic fibers" International Journal of Recent Technology and Engineering. Vol. 7, Issue 6, pp.633-638.

[2] Vasu (2019) "Improvement of geotechnical properties of black cotton soil by ggbs and metakaolin" International Journal of Scientific Research and Reviews. Vol. 8, Issue 2, pp.4923-4933.

[3] Kawther Y, AL-Soudany (2018) "Improvement of expansive soil by using silica fume" Kufa Journal of Engineering. Vol. 9, Issue 1, pp.222-239.

[4] Ramya. V, Sowmiya.S, Karthickeyan. S (2018) "Stabilization of black cotton soil using bamboo slag and silica fume" International Journal of Innovative Research in Science, Engineering and Technology. Vol. 7, Issue 5, pp.114 119.

[5] Jeeva. P (2018) "An experimental study on high performance concrete by partial replaced cement by using metakaolin and industrial waste" International Research Journal of Engineering and Technology (IRJET). Vol. 5, Issue 5, pp.3845 – 3849.

[6] Prakash. N, Gokulnath. S, Ramkumar .M, Vasudevan. R, Sakthiganesh.M (2018) "Stabilization of expansive soil using metakaolin and granite powder" International Journal of Civil and Structural Engineering Research. Vol. 6, Issue 1, pp.13-17.

[7] Vaidya M. R, Shinde H.H (2018) "Comparative study of moorum and stabilized black cotton soil by 15% addition of fa and rha" International Journal of Innovative Research in Science, Engineering and Technology. Vol. 7, Issue 11, pp.11099 – 11106.

[8] Vishal Ghutke, Pranita Bhandari, Vikash Agrawal (2018) "Stabilization of soil by using rice husk ash" The International Journal of Engineering and Science. Vol. Issue, pp.92-95.

[9] Hassnen M. Jafer, William Atherton, Monower Sadique, Felicite Ruddock, Edward Loffill (2018) "Development of a new ternary blended cementitious binder produced from waste materials for use in soft soil stabilization" Journal of Cleaner Production. pp.516-528.

[10] Malathy J, Ganesh Kumar S, Pranav Satish, Arunachalam S (2018) "Experimental investigation in developing a ternary blended cementitious binder produced from waste materials for pavements on soft soils" International Journal of Civil Engineering and Technology. Vol. 9, Issue 5, pp.274–283.

[11] Sravanthi, Shaik Khasim Peera (2017) "Black cotton soil stabilization with ground granulated blast furnace slag and RBI grade-81" International Journal of Innovative Research in Science, Engineering and Technology. Vol. 6, Issue 7, pp.12906-12913.

[12] Venkata Rao. E, Rama Krishna.M (2017) "Improvement of black cotton soil using ggbs and polypropylene fibers" International Journal of Engineering Research. Vol. 5, Issue 2, pp.336-344.

