A Review On The Use Of Secondary Materials As An Alternative For Stabilizing Expansive Soils

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ABSTRACT:
This paper examines the impact of various admixtures aimed at enhancing strength and minimizing deformation characteristics of black cotton soil, based on research conducted by multiple scholars. The stabilization of black cotton soil is focused on ensuring the creation of stable and long-lasting engineering structures. This process becomes essential when the materials designated for foundation and pavement construction do not fulfill the standards required in civil engineering practices. Black cotton soil from the north-eastern region of Nigeria, as well as from various global locations, is predominantly categorized as A-7-6 soils by the American Association of State Highway and Transportation Officials (AASHTO); classified as CH high plasticity clay soils by the Unified Soil Classification System (UCSC); and identified as high swell potential black cotton soil by the Nigerian Building and Road Research Institute (NBRRI). The experiments conducted include Atterberg's Limits, Specific Gravity, Sieve/hydrometer Analysis, Free Swell, Compaction, Triaxial, Shear Box, Unconfined Compressive Strength (UCS), and California Bearing Ratio (CBR) tests. Soil properties such as maximum dry density (MDD), optimum moisture content (OMC), CBR values, shear strength, cohesion, and angle of internal friction were significantly enhanced by admixtures including lime, cement, E-waste, reclaimed asphalt pavement, and steel mill ore. In contrast, admixtures like groundnut ash, bagasse ash, and plantain peel powder showed inadequate improvement when utilized independently. Therefore, it can be concluded that black cotton soil, when stabilized with admixtures such as lime, cement, reclaimed asphalt pavement, E-waste, and steel mill ore, is suitable for use in foundation and pavement construction. This study ultimately recommends the combined use of weaker admixtures with certain cementitious materials to achieve a robust and durable foundation.

Keywords:*Stabilization, Black Cotton Soil, Admixtures*

1. INTRODUCTION

Soil stabilization is a very important engineering activity; this is mainly aimed at improving the mechanical and physical properties of soils to fulfill the requirements of construction, especially in foundation and pavement design. Black cotton soil has been a huge challenge among problematic soils for its high plasticity and expansive nature, low bearing capacity, and undependable capacity to undergo volumetric change with alteration in moisture content. Hence, BCS is unfit to be directly used in any civil engineering work without some form of treatment or stabilization.

They are popularly spread all over the tropical and subtropical regions of the world, including some African countries, India, and Australia [1]. They are mostly found in the northeastern part of Nigeria and have so far been classified by the American Association of State Highway and Transportation Officials (AASHTO) as A-7-6 soils, placed under CH soils by the Unified Soil Classification system, while the Nigerian Building and Road Research Institute considers them as soils with a high swell potential [2]. While these classifications reflect all of the poor engineering performance of the soils with respect to the wetting-drying cycles, the physical result of swelling, shrinkage, cracking, and failure of structures is the engineer's concern. To treat these soils for mitigation purposes, numerous works have been carried out that involved chemical and mechanical stabilization methods to improve the engineering characteristics of BCS. The primary purpose of stabilization is to enhance strength parameters such as unconfined compressive strength (UCS), California Bearing Ratio (CBR), shear strength, cohesion, and angle of internal friction and to reduce unfavourable characteristics such as free swell index, plasticity index, and volume change tendencies [3].

Various admixtures and chemicals have been utilized for soil stabilization across the world, ranging from traditional materials such as lime and cement to those manufactured from industrial wastes and by-products like fly ash, rice husk ash, groundnut shell ash, bagasse ash, plantain peel powder, reclaimed asphalt pavement (RAP), E-waste, and steel mill ore [4–10]. While some of these additives have shown promise for improving the engineering behaviour of expansive soils, some have shown less to negligible effect at modifying soil properties when applied alone [11]. Lime, for example, has widely been used for stabilizing black cotton soils, as lime reacts pozzolanically with clay minerals, resulting in reduced plasticity and strength gain [12]. Cement, however, is fast strength gaining and durable but is considered too expensive for stabilization purposes on a very large scale [13]. Recently, industrial by-products, such as E-waste and steel mill ore, have earned consideration as environmentally friendly alternatives that further the technical efficiency of soil performance [14–15].

Nevertheless, certain agricultural-based admixtures such as groundnut ash, bagasse ash, and plantain peel powder improve strength characteristics marginally and need improvement via blending with cementitious materials before the desired results can be achieved [16–17]. This brings to focus the exploration of mixing weak and strong stabilizers for cost-effective and sustainable stone improvement practices. The increasing demand for sustainable infrastructure development must open up possibilities for the use of alternative and eco-friendly raw materials for soil stabilization processes. Such an approach would help lessen dependency on traditional materials and aid in waste management and conservation of resources. Hence, this aim of this study is intended towards determining the effectiveness of secondary raw materials as an alternate means of stabilizing black cotton soil for the promotion of durable and eco-regulated construction.

The paper highlights an overview of experimental investigations carried out on black cotton soils stabilized with various admixtures, the emphasis being on their effects on important geotechnical properties. The mechanisms of the laboratory tests employed include Atterberg limits, sieve/hydrometer analysis, compaction, shear box, triaxial, unconfined compressive strength, and California Bearing Ratio tests. Depending upon the results, recommendations pertaining to the amenability of admixtures and their combinations for efficient and sustainable stabilization of black cotton soils are made herein.

2.LITERATURE REVIEW

2.1Stabilization of Black Cotton Soil Using Chemical Admixtures

2.1.1Stabilization of Black Cotton Soil Using Lime as Stabilizer

Singh [35] found that the geotechnical properties of black cotton soil can be stabilized by varying amounts of lime. It was observed that the liquid limit increased by nearly 12.1% with the addition of 4% lime. Conversely, a reduction of approximately 17.1% was noted with the addition of 6% lime. The maximum dry density (M.D.D.) decreased by 2.4% and 5.6% at 4% and 6% lime content, respectively. The California Bearing Ratio (C.B.R.) of black cotton soil mixed with 4% and 6% lime at a penetration of 2.5 mm showed a consistent enhancement. At a penetration of 5.0 mm, the C.B.R. value also exhibited a steady increase. This indicates that lime can effectively stabilize deficient soil. Hegde [16] established that the application of lime to black cotton soil initiates a pozzolanic reaction, resulting in enhanced stability. The hydrated lime interacts with clay particles, converting them into a robust and durable cement matrix. The fundamental parameters of the soil were assessed using black cotton soil with low to medium swelling potential. Parameters such as plastic limit, liquid limit, maximum dry density (MDD), optimum moisture content (OMC), free swelling, swelling pressure, and California bearing ratio were evaluated. The introduction of lime to swelling soil promptly diminishes its swelling potential upon contact with water. As the lime concentration in the soil increases, the plasticity decreases while the stiffness of the soil enhances. The optimal lime percentage identified in the study for improving strength properties ranged from 3.5% to 4.5%. Amruta [7] discovered that incorporating 6% lime into black cotton soil significantly diminishes its flexibility, shrinkage, and swelling characteristics. When saturated, the compressive strength increases to approximately 15.22 kg/cm2. The C.B.R. values rise from 3.3% for untreated soil to about 62.8% for treated soil. The modified black cotton soil can be reliably utilized as sub-grade, sub-base, or base material, allowing for a reduction in the thickness of a road's upper layer made from expansive materials like hard stone.

2.1.2Stabilization of Black Cotton Soil Using Lime and Other Material as Stabilizers

Ikeagwuani [18] conducted an investigation that suggests black cotton soil can be effectively stabilized for use as subgrade material. A sufficient strength was achieved with a combination of 16%

SDA and 4% lime content. The importance of these results lies in the fact that, unlike other instances of lime stabilization where higher lime proportions are necessary for optimal stabilization of expansive clays, favorable outcomes were attained with only 4% lime and 16% SDA. The CBR value recorded was 20.64%, which complies with the Nigerian General Specification for Roads and Bridges (1997). Annafi [7] explored the effect of mixing time on the strength properties of lime and iron ore tailings when applied to black cotton soil as a subgrade material. The soil was treated with varying percentages of lime (0, 2, 4, 6, 8, and 10%) and iron ore tailings (0, 2, 4, 6, 8, and 10%). Tests including Atterberg limits, compaction, unconfined compressive strength (UCS), and California bearing ratio (CBR) were conducted to assess the impact. Statistical analysis was performed using MINI-TAB software. The findings indicated a reduction in the liquid limit of the mixtures as the lime and iron ore tailings content increased. Following the mixing process, the liquid limit of all treated black cotton soil samples increased within an hour. Conversely, the plastic limit (PL) of the soil decreased as the content of additives rose. Between 0 - 2 hours post-mixing, both the Unconfined Compressive Strength and California Bearing Ratio values increased with higher additive content. The highest values for all evaluated lime contents were noted at the 8% lime and 8% iron ore tailings treatment. S. Srikanth [33] demonstrated that lime stabilization enhances the strength characteristics of black cotton soil, enabling its use as a subbase material. The maximum dry density and optimum moisture content improved with a mixture of 20% brick powder and lime additive, reaching 80%. The soaked CBR value of lime and brick powder-stabilized black cotton soil increased by approximately 135%, rendering it suitable for use.

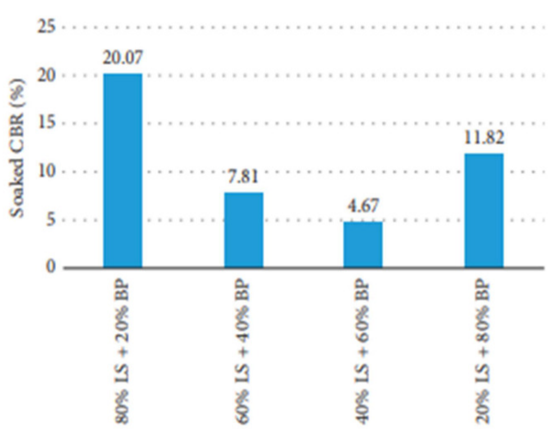

Figure 1. Various mix proportion of lime-stabilized black cotton soil and brick powder.

2.1.3Stabilization of Black Cotton Soil Using Cement and Other Materials

Ibrahim [17] conducted an analysis on twenty (20) disturbed soil samples of ordinary Portland cement stabilized black cotton soil. The additives were introduced in increasing percentages of 2, 4, 6, and 8, while waste glass was incorporated at rising percentages of 5, 10, 15, and 20, all at optimum moisture content. Statistical regression was utilized to correlate the soaked California Bearing Ratio values with various measured soil characteristics. The independent variables included maximum dry density (MDD), waste glass (WG), cement content (Cm), liquid limit (LL), and plastic limit (PL). It was noted that the variables for both prediction models and compaction of the CBR were quite close to the actual findings.

Sajja [34] employed cement, lime, and rice husk to stabilize black cotton soil, establishing that at the optimum dosage, the free swell index of black cotton soil improved by 85%, the plastic limit increased by 12.35%, and the liquid limit rose by 56.35%. The plasticity index for black cotton soil was enhanced by 44.50%. The soil was classified as CH (Inorganic Clays of high plasticity) according to AASHTO, with the optimum moisture content (OMC) and maximum dry density (MDD) values determined to be 28.5% and 1.51 g/cc, respectively.

Paul [30] examined the stabilization of black cotton soil (BCS) through the application of iron ore tailings (IOT) and cement, focusing on their response to different compaction efforts. The British Standard light compaction was performed for varying percentages of iron ore tailings and cement (ranging from 0 to 10%), resulting in optimum moisture content values of 21.2, 20.8, 20.5, 20, 20.3, and 20.2 percent. A similar trend was observed with increased cement concentrations and compactive efforts. Utilizing software for regression modelling, the analysis indicated that the independent variables significantly influence the dependent variables. The contributions of cement and IOT to the enhancements were assessed through ANOVA (analysis of variance). Consequently, for applications in soil rehabilitation or geotechnical engineering, black cotton soil treated with a blend of 4 percent cement and 10 percent IOT, compacted using British Standard Heavy energy, yields the optimal strength.

Prathap [32] examines the impact of cement kiln dust (CKD) on black cotton soil. CKD, a byproduct of the cement industry, was utilized as a stabilizing agent for black cotton soil (BC soil) in this research. The study involved characterizing black cotton soil in terms of Atterberg's limits, specific gravity, pH, compaction properties, and unconfined compressive strength by mixing it with CKD at different percentages. The results indicate that both the liquid and plastic limits increase with a higher percentage of CKD. For BC soil mixed with 12 percent CKD, it was observed that the unconfined compressive strength (UCS) improves as the curing duration extends. Given that CKD is an industrial waste, it can effectively stabilize BC soils and enhance their engineering properties. An increase in CKD percentage correlates with rising liquid and plastic limits. However, when the CKD content exceeds 12 percent, the plasticity index begins to decline. The pH of BC soil mixed with CKD showed a slight increase when CKD levels were between 4% and 8%, after which the pH decreased and stabilized beyond the 12 percent CKD threshold. The maximum dry density of BC soil with 12 percent CKD significantly increased, accompanied by a decrease in optimal moisture content (OMC), which is favourable. The highest UCS value was recorded in BC soil containing 12 percent CKD. It was also noted that for BC soil with 12 percent CKD, UCS rises with longer curing periods. Consequently, it was concluded that 12 percent CKD yields the most favourable outcomes in terms of reducing plasticity and enhancing strength in BC soil mixed with CKD.

Anigilaje [6] In the course of examining the compactive efforts, a mixture of up to 10% cement kiln dust was incorporated with Black cotton soil, employing British Standard heavy (BSH), West African Standard (WAS), and British Standard light (BSL). The laboratory testing results on soil specimens indicated an overall enhancement in the soil's qualities following the addition of cement kiln dust. The optimal addition was determined to be 10% cement kiln dust. It was noted that for the different compactive energies, the unconfined compressive strength (UCS) values recorded were 357.07, 382.49, and 528.82 kN/m2 for British Standard Light, West African Standard, and British Standard Heavy, respectively, with the California Bearing Ratio (CBR) values being 7, 10, and 19 percent. Upon examination of the samples using an electron microscope, a reduction in particle sizes was observed as the curing period progressed. The findings suggest that cement kiln dust can effectively stabilize black cotton soil.

2.1.4Stabilization of Black Cotton Soil Using Sodium Silicate

Ola [26] collected samples of black cotton soils from various locations in North-Eastern Nigeria. It was determined that the soil from this area contains significant proportions of clay and silt. The flexible pavements are at risk of swell-shrink potential, which leads to cracks and eventual failure of the pavements in the region. In the study, acrylic copolymer was employed to stabilize the collected soil, and it was found to be effective in enhancing the geotechnical characteristics by reducing the plasticity, swelling, and shrinkage properties of the soil. The conclusion drawn was that acrylic copolymer can be widely utilized to stabilize unsuitable soils for engineering constructions.

Pramod [31] investigated the combination of lime and Envirobase sodium silicate to assess their effects on the geotechnical properties of black cotton soil. Laboratory experiments, including compaction and California bearing ratio tests, were conducted to evaluate the soil properties. The incorporation of Envirobase into the black cotton soil significantly improved the California bearing ratio, while the addition of sodium silicate with lime resulted in a decrease in the soil's plasticity index. Furthermore, the combination of sodium silicate with lime, along with the soil, reduced the liquid limit. When 1 percent of Envirobase is added to the liquid limit, it remains stable, but decreases as the proportion of Envirobase increases. Given that sodium silicate combined with lime is cost-effective and readily accessible, it can serve as a local stabilizer in small-scale construction projects. For Envirobase to be applicable, the construction project must be substantial, and Envirobase is recognized as one of the most effective soil stabilizers for highway and airfield development.

2.2Stabilization of Black Cotton Soil Using Organic Chemical Admixtures

2.2.1Stabilization of Black Cotton Soil Using Plantain Peel Powder

Oluwafemi [27] investigated the impact of plantain peel powder (PPP) on black cotton soil. Due to the influence of montmorillonite, which possesses a significant lattice structure, black cotton soil (BCS) is regarded as expansive and highly susceptible to volumetric changes in moisture. In this research, plantain peel powder (PPP) was utilized to stabilize the black cotton soil sourced from Yola, Adamawa State, Nigeria. The stabilization of the black cotton soil was conducted at varying proportions of 0, 2, 4, 6, 8, and 10 percent. A series of laboratory tests, including gradation test, natural moisture content, linear shrinkage, specific gravity, plastic limit, and liquid limit, were performed to determine the engineering characteristics of the BCS when treated with PPP. The percentage of soil passing through sieve 200 exceeded 35%. The analysis of the effects of plantain peel powder on the engineering properties indicated that with the addition of 0 to 10 percent of plantain peel powder, the liquid limit percentages ranged from 48 to 32, the plastic index varied from 28 to 13, and the linear shrinkage percentage fluctuated between 14 and 7.5. This suggests that plantain peel powder effectively reduces the clay content and enhances the engineering properties. It was found that the incorporation of plantain peel powder into BCS significantly improves the engineering characteristics of the sampled BCS. Consequently, plantain peel powder (PPP) is deemed suitable for stabilizing roadwork materials when combined with stronger admixtures.

2.2.2Stabilization of Black Cotton Soil Using Polyvinyl Acetate

Oluyemi [9] collected soil samples from six distinct locations throughout the country, and their geotechnical properties were evaluated in both their natural and stabilized forms. The tensile characteristics of the soil samples showed considerable enhancement when mixed with polyvinyl acetate. According to the CBR data, all samples were upgraded from unsuitable base materials to suitable ones. By stabilizing with this substance, some of the country's commonly available but inappropriate soil resources could be utilized for road construction, thereby contributing to the development of adequate road networks in the regions.

Oyekan [11] conducted a study that demonstrates the effect of polyvinyl waste on the engineering properties of black cotton clay soil. To assess the soil stabilization potential, the soil was mixed with the admixture at 5, 10, 15, 20, and 30% concentrations. As the content of ground polyvinyl waste increased, both the soaked and unsoaked California bearing ratio (CBR) improved. At a 30% admixture level, the unconfined compressive strength increased by nearly 60%. The CBR of the soaked samples rose by approximately 20%, while the CBR of the unsoaked samples increased by nearly 50%. The results indicate that the use of ground polyvinyl waste to enhance black cotton soils has a substantial impact.

2.2.3Stabilization of Black Cotton Soil Using Groundnut Shell Ash

Oriola [29] identified the maximum soaking CBR values of 4% at SP and 4% at WA for 6 percent (GSA) and 0 percent (GSA), respectively. These values did not meet the specified requirements for the CBR of base or sub-base materials. The durability of the specimen, evaluated by its resistance to strength loss, failed to achieve the necessary 80% resistance to strength loss for samples cured for 7 days and soaked for 4 days. Consequently, groundnut shell ash is not suitable for stabilizing black cotton soil. Records of the unconfined compressive strength of specimens cured for 7, 14, and 28 days indicate that groundnut shell ash shows an increase in strength with extended curing periods.

Ijimdiyaa [38] determined that groundnut ash treated soil does not meet the requirements set by the Nigerian Building and Road Research Institute (NBRRI) for base course material. An optimum CBR of 6% was observed at 8% groundnut shell ash. This value does not satisfy the specified requirements for subgrade materials. The unconfined compressive strength recorded was 1034.25 kN/m2 at 7 days, which is also below the standards established by TRRL (1977). Therefore, it is recommended that groundnut shell ash should not be utilized as a standalone stabilizer.

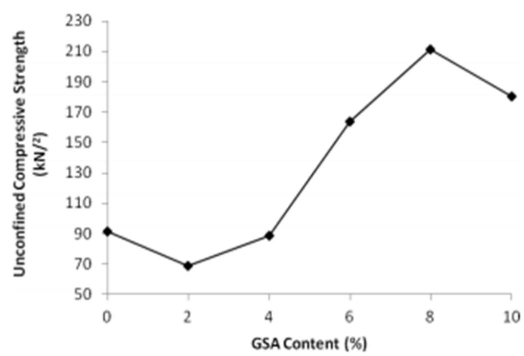

Figure 2. Variation of UCS with GSA content.

2.2.4Stabilization of Black Cotton Soil Using Bagasse Ash

Jayatheertha [14] conducted a study demonstrating that Bagasse ash waste is utilized to enhance engineering properties, such as the CBR value of soil. In contrast, demolished waste concrete proves to be more effective than bagasse ash in improving index properties, including the liquid limit and plastic limit of black cotton soil. The CBR value increased from 1.28% to 12.34% under soaked conditions, while for unsoaked conditions, the CBR value rose from 2.38% to 16.23%.

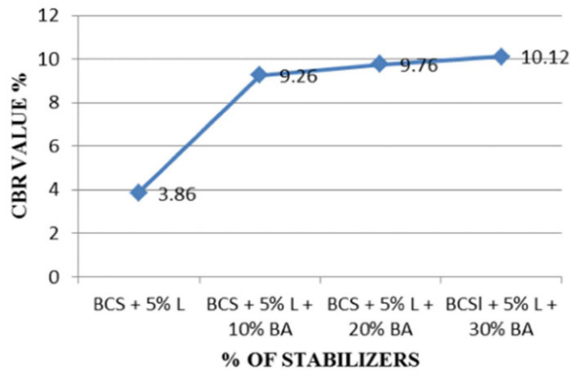

Figure 3. Variation in CBR with lime and bagasse ash in unsoaked condition.

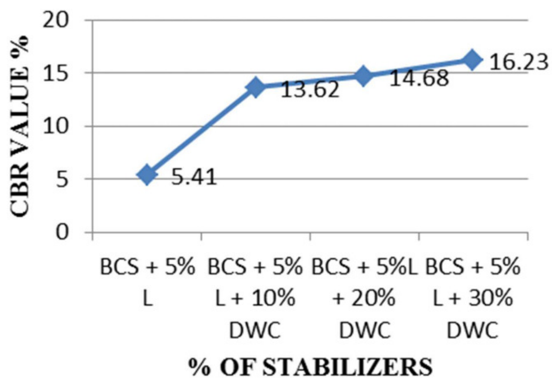

Figure 4. Variation in CBR with lime and demolished waste concrete in unsoaked condition.

Amit [4] conducted laboratory trials on black cotton soil utilizing Bagasse Ash as a partial replacement (3.2 percent, 6.4 percent, 9.6 percent, and 12.8 percent). This study indicates that a 6 percent substitution of Bagasse Ash enhances the properties of black cotton soil without the use of any chemicals or cementing agents. The Plasticity Index of the soil treated with Bagasse Ash was observed to decrease from 24.00 percent to 17.40 percent. The density of black cotton soils significantly increased from 1.57 to 1.78 g/cc following the addition of 6% Bagasse Ash. However, the Optimum Moisture Content (OMC) decreased from 17.20% to 15.00%. Density decreases with the addition of more Bagasse Ash, while OMC increases. At a concentration of 6% Bagasse Ash, the Unconfined Compressive Strength (UCS) values improved from 93 kN/m2 to 429 kN/m2. UCS values tend to decline with the addition of more Bagasse Ash. In comparison to other dosages, the increase in the California Bearing Ratio (CBR) at a dosage of 6% exhibited a more pronounced effect. An increase in the California Bearing Ratio suggests a reduction in settling. Due to the incorporation of 6% waste Bagasse Ash, CBR values significantly rose from 1.16% to 6.8%. CBR values begin to decrease as additional Bagasse Ash is introduced.

2.2.5Stabilization of Black Cotton Soil Using Bagasse Ash and Other Additives

Kiran et al. [22] performed a laboratory experiment using varying amounts of bagasse ash at percentages of 4, 8, and 12, along with different additive mix proportions. Furthermore, a study was carried out on the application of bagasse ash waste to enhance the stabilization of pavement materials for construction. In the case of black cotton soil, the mix ratio of bagasse ash combined with various percentages of lime led to improved values of California Bearing Ratio (CBR) and Unconfined Compression Strength. However, it was noted that as the lime content in the mixture increased, the density values decreased. Subsequently, an increase in CBR was recorded in the blend, rising from 2.12 to approximately 4.57 with the addition of 4% bagasse ash and 4% lime content. Similarly, the unconfined compression strength increased from 84.92 kN/m² to 153.05 kN/m² with the incorporation of 4% bagasse ash and 2% lime. The combination of 2% to 4% lime and 4% to 8% bagasse resulted in significantly higher strength.

2.2.6Stabilization of Black Cotton Soil Using Reclaimed Asphalt Pavement

Mustapha [25] investigated the impact of Reclaimed Asphalt Pavement (RAP) on stabilizing Black Cotton Soil (BCS) sourced from Numan in Nigeria's northeastern region, as well as BCS from a deteriorated road surface along the Minna-Bida road in Niger state. The BCS was substituted with RAP at varying proportions of 0%, 10%, 20%, 30%, and 100% by weight of the soil. The BCS was predominantly composed of quartz, microcline, albite, and kaolinite, while the RAP contained significant amounts of quartz, albite, orthoclase, phlogopite, and actinolite. The maximum dry density (MDD) of the mixtures increased from 1890kg/m3 with no RAP content to a peak of 2036kg/m3 at 30% RAP, before declining to 1925kg/m3 at 100% RAP. Scanning Electron Microscopy revealed fewer cracks in the mixtures with 20% and 30% RAP, instead showing an interlocking of particles of varying sizes in a compact arrangement. The Unconfined Compressive Strength (UCS) increased by 58.6%, rising from 392kN/m2 at 0% RAP content to 947kN/m2 at 30% RAP content. Subsequently, at 100% RAP content, the strength decreased to 17.5kN/m2. The modulus of elasticity saw an increase of 75.5%, from 10.4 MPa at 0% RAP to 42.5 MPa at 30% RAP, before dropping to 2.9MPa at 100% RAP content. The swelling potential of the mixtures varied from medium at 0% RAP content to low at 30% RAP level.

2.3Stabilization of Black Cotton Soil Using Non-chemical Admixtures

2.3.1Stabilization of Black Cotton Soil Using E-waste

KPrabin [23] emphasizes the use of strong trash (E-waste) for soil stabilization. The study's findings indicate that commercial wastes can effectively serve as alternative materials in soil stabilization. It was also demonstrated that each type of company waste possesses distinct properties, which modify the soil's index and engineering characteristics. Consequently, stabilized soil is utilized as an eco-friendly material in construction due to these enhancements.

Onkar [28] conducted an experiment to assess the effects of E-waste at different dosages on black cotton soil. The soil was mixed with varying concentrations of E-waste, specifically 2%, 5%, and 8%. To evaluate the performance of E-waste stabilized soil, physical and strength performance tests were conducted, including Atterberg's limit, specific gravity, compaction test, unconfined compressive test, California bearing ratio (CBR), and direct shear test. These assessments aimed to measure the improvements in the soil's strength properties. The results indicated that the unconfined compressive strength of the specimen increased to 2.63 kN/m2 at an optimal dosage of 5%. Additionally, the angle of friction (Φ) increased following the direct shear test, with the friction angle rising in correlation with the percentage of E-waste. Since bearing capacity is affected by C, it was also noted that the bearing capacity had improved. As E-waste filled the voids in the soil, the maximum dry density (MDD) increased by 2%, while the optimum moisture content (OMC) decreased by 5%, leading to denser soil. However, for an E-waste dosage of 8%, MDD gradually decreased. This indicates that a 5% dosage of E-waste is optimal.

2.3.2Stabilization of Black Cotton Soil Using Ionic Soil Stabilizer 2500

Hashim [15] evaluated the effects of the "Ionic Soil Stabilizer 2500" on black cotton soil in North-East Nigeria, with samples collected along the Dikwa–GamboruNgala route. The black cotton soil was found to be deficient, as over 60% of the soil passed through a sieve with a diameter of 0.0075mm, as determined by particle distribution tests. The primary components of the Ionic Soil Stabilizer include organic bi-sulphate acid and Sulphur. Laboratory investigations involved mixing doses of the Ionic Soil Stabilizer at 0, 1, 2, and 3mls with 6kg of black cotton soil. The pH test results indicated that the acidity of the samples increased with higher doses of the Ionic Soil Stabilizer, due to the presence of acids. There was a notable reduction in plasticity, accompanied by an increase in electrical conductivity. A California Bearing Ratio test was conducted using the British light compaction method in accordance with energy levels. Consequently, the CBR values showed a slight increase, yet they remained below the standards required for soil-cement stabilization in pavement foundation materials. The results from the experiment with the Ionic Soil Stabilizer did not yield satisfactory outcomes, preventing any definitive conclusions regarding its effectiveness in enhancing the characteristics of black cotton soil to meet road base specifications.

2.3.3Stabilization of Black Cotton Soil Using Steel Mill Scale

Ogundalu [2] assessed the stabilizing capabilities of Black cotton soil when treated with steel mill scale. Tropical Black Cotton clay soils were combined with Steel Mill Scale at varying percentages of 0%, 5%, 10%, 15%, 20%, and 30% based on the dry weight of the soil. The addition of steel mill scale enhanced the soil's Maximum Dry Density (MDD) by approximately 19% and reduced the Optimum Moisture Content (OMC) by about 28%. The Soaked California Bearing Ratio (CBR) improved as the Steel Mill Scale content increased, while the Un-Soaked CBR decreased with higher Steel Mill Scale content. Specifically, steel mill scale raised the unsoaked CBR by roughly 19% but decreased the soaked CBR by around 75%. The incorporation of Steel Mill Scale mitigated the risk of swelling by approximately 60%. At a Steel Mill Scale content of 5%, the unconfined compressive strength of black cotton soils was enhanced by nearly 53%. These results indicate that the application of Steel Mill Scale for the reinforcement of Black cotton soils holds significant potential.

3.CONCLUSION

Numerous studies have indicated that Black cotton soil can be effectively stabilized to enhance its engineering properties, rather than simply ignoring the soil type due to its undesirable expansive characteristics when subjected to fluctuations in moisture conditions.

Stabilizers such as lime, cement, E-waste, reclaimed asphalt pavement, and steel mill ore have demonstrated significant improvements when utilized for soil stabilization. Conversely, stabilizers like groundnut ash, bagasse ash, and plantain peel powder have shown inadequate enhancement when applied independently. It is advisable to complement these weaker stabilizers with more cementitious materials to achieve a robust and durable soil suitable for use as foundation or sub-grade material.

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