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An Experimental Investigation for evaluating Fly Ash, GGBS and RHA's Impacts on Black Cotton Soil Stability

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Abstract

In order to stabilize Black Cotton Soil (BCS), this study focuses on maximizing the combination of ambient-cured geo-polymers such as using sustainable materials including GGBS, fly ash and RHA. Emphasizing environmental sustainability and value-effectiveness, the research explores the effect of these materials at the engineering properties of BCS, particularly specializing in unconfined compressive strength, plasticity index, and limits. Advanced analytical techniques are employed to assess the physical, chemical, and microstructural characteristics of the stabilization method. The efficacy of those geopolymers is evaluated through a sequence of soil tests, including the unconfined compressive strength across numerous curing periods. This study also delves into the usage of alternative materials like agricultural wastes and industrial by-products to enhance soil stabilization techniques, supplying a greener and more cost effective approach to construction and geotechnical engineering.

Keywords: Black cotton soil, stabilization, RHA, FA, GGBS, UCS.

Introduction

Soil stabilization refers to the process of enhancing the structural and geotechnical properties of soil, which includes its mechanical strength, permeability, compressibility, lifespan, and plasticity. Over the span of a century, significant advancements have been made in soil stabilizing technologies and additives. Numerous researchers have examined the current state of technology and the challenges associated with stabilizing techniques. improving the engineering traits of soil by using soil stabilization is important, specially when using constructing foundations, roads and dams. Improving the property of the soil's capacity for carrying, strength at shear, and other important characteristics for construction is important because of bad quality of soil often presents issue for engineers. Several stabilizing compounds, which includes conventional and environment friendly substitutes, have been the concern to scientific investigations [1]. It is important to use both with and without calcium primarily based changes while amending soil parameters to fulfil engineering requirements. The improved attention on green building methods is drawing attention towards these eco-friendly substitutes. The two fundamental methods of stabilizing soil are mechanical and chemical, as illustrated in Fig. 1 [2]. While chemical stabilization affects the physico-synthetic traits of clay particles to stop infiltration and exfiltration of water, the method of mechanical stabilization modulates the gradation of soil in order to improve its performance. By strengthening the soil's shear strength, load-bearing ability, and other important traits, every method enables making the material perfect for construction. Various stabilizing methods are utilized for the construction industry in order to improve the lifespan and durability of roads constructed on a low- or medium-grade soil. When paired with geotechnical solutions, these methods can ensure the complete functioning and life span of the advanced infrastructure [3]. The use of additives like lime, cement, grouting materials, and chemicals which is a form of stabilization in construction which is aiming to improve the traits of soil as a whole and ensure that the projects under construction may be finished successfully. Stabilization is important in the engineering of construction in order to maximize engineering features and prolong the life of infrastructure. A crucial aspect of construction engineering is the optimization of engineering aspects and an extension of infrastructural lifetime. Novel stabilizing materials as well as methods are the focus of the research in an effort to advance robust and eco-friendly construction systems. By blending different kinds of soil the mechanical integrity of the soil may also include features. When it comes to creating and maintaining roads, cost management is crucial features. When it comes to create and maintain roads, cost management is crucial.

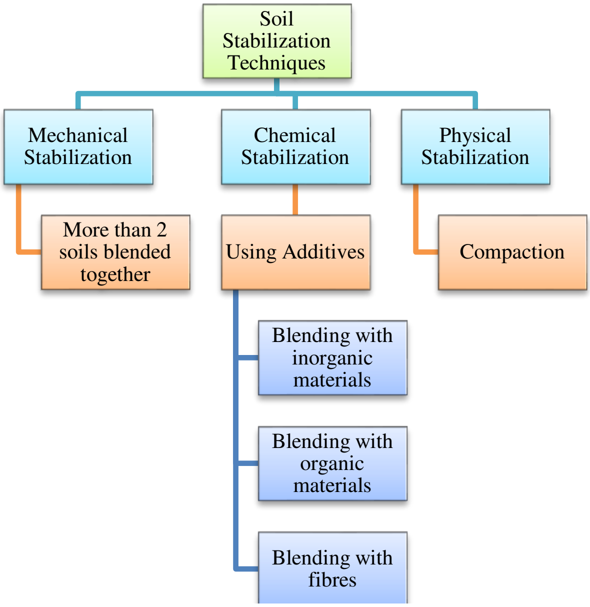


Figure 1 Methods for Enhancing Soil Stability

The study, which was conducted in Sejzi, Iran, examined at the way usual PC (Portland cement) and RHA, which is also known as Rice Husk Ash could help stabilize the soil in order to improve the geotechnical properties of clay-based sand. X-ray fluorescence, or XRF, trials have been utilized for examining the oxidizing components that constitute RHA, cement, and soil [4]. By improving the UCS and CBR values to 25.44 and 18.2 respectively, results suggest the concrete and RHA are efficient for the stabilization of soil. Alum sludge (also known as AS) is an efficient alternative for stabilizing the soil which provides an affordable and ecologically sound method to successfully get rid of waste. The soil has become stabilized as a consequence of the significant rises in CBR and UCS values. The study demonstrated that alum sludge may be implemented for protecting soil at various dry levels concentration [5] as well as construct roads through studying the correlation between CBR and soil parameters using Artificial Neural Networks. Research to create a combination of substances of soil and other inclusions, such FA or lime, is influenced for the effective performance of every structure that concerns the soil's carrying capacity in order to maximize the advantage of the characteristics of materials made or accessible through industrial activities. The optimal parameters were moisture content, MDD values, plasticity index, and 8% alum sludge. This highlights the significance of considering a variety of parameters at different stages of the stabilizing process. Stabilization techniques are crucial for engineering applications, especially when working with delicate soil. Using stabilizers for the soil represents one of these techniques. By strengthening and preserving the soil, stabilizers like these offer affordable options for constructing roads and other infrastructure. These methods additionally encourage environment friendly methods to soil management. The study examines the benefits potential of the geo-polymerization technique for stabilizing the soil and addresses current studies and efforts improvement. One feasible solution for the stability of soil for the long run is geo-polymerization, which emphasizes on the need for ongoing development. Through the utilization of geo-polymerization techniques alum sludge and waste from agriculture, stabilizing the soil components the characteristics of the soil and addresses the issues associated with building and infrastructure. Through complete examination and testing, those methods improve settling operations so that you can optimize engineering results and conserve the surroundings [6].

2.Enhancing Soil Stability: Using Fly Ash, RHA and GGBS

A study [7] found that gypsum soil may become lesser of a problem for the environment by utilizing RHA or Rice Husk Ash, GGBS and oxide from nano- magnesium (M) as soil stabilization agents. This would mitigate the adverse consequences of cement bacillus. In comparison to soil samples treated with calcium oxide-stabilized binding materials, those treated with 20% M-RHA, M-GGBS, or M-GGBS-RHA led to a reduction in the swelling concern. The samples of soil with such substances showed a range of strengths after 90 days, from 2.7 to 12.8 MPa, suggesting higher efficiency than chemicals stabilization using calcium oxide commonly known as lime. Scanning Electron Microscopy (SEM) and energy Disperse X- Ray (EDX) analysis favoured the research observations indicating zero production of ettringite (cement bacillus) took place in soil stabilizing using M-RHA, M-GGBS, or M-GGBS-RHA [8]. In projects to construct roads, the utilization of soil-based additives was conducted like limestone, GGBS, asphalt, dust from cement kiln and cement has increased lifespan and reduced costs. Promising outcomes have been obtained by a study on the way it impacts GGBS and RHA on the geotechnical characteristics of black cotton soil. According to California Bearing Ratio (CBR) tests, the most effective combination for road surfaces and foundations was a mixture of 10% RHA and 8% GGBS. This combination yielded the highest taking CBR value. A study using modern analytical techniques discovered that RHA (Rice Husk Ash RHA), a by-product by the rice milling industry, offers both health and risk to the environment. The research examined [9] cement made from geo-polymer using multiple parts and evaluated the chemical, mechanical, and micro-structural characteristics of RHA by means of highly sophisticated analytical methods like XRF, XRD, PSA , FITM and FESEM. Observations showed that though Rice Husk Ash lessened workability and strength of compression, a mix with 10% RHA had an exceptional compressible strength of 25 MPa, which made it suitable for use in construction. The study underlines the ways

in which RHA can be used to develop suitable for the environment geo-polymerized binders that will promote sustainable building methods.
In [10], an examination is conducted to assess the physical, chemical, and microstructural attributes of rice husk ash, a by-product originating from the rice milling industry. This work employs advanced analytical techniques, along with XRF, XRD, PSA, FTIR, and FESEM, to examine the structure of geopolymer concrete this is relying on fly ash blast furnace slag at varying stages of incorporation of rice husk ash. The study of RHA in geo-polymer concrete decreases functionality and compressive strength, consistent with the findings provided here. Although, the 10% RHA geopolymer concrete established a compressive power of 25 MPa, increasing the usage of RHA inside the geo-polymerization process for greater environmentally pleasant binder synthesis. The study performed in [11] examines the effects of incorporating kenaf fiber and rice husk ash (RHA) on soil characteristics, including density, shear ability, UCS, and CBR. The ash from rice husks (0 to 12.5%) with a 2.5% growth and kenaf fiber (0 to1%) with a 0.25% growth comprised the substances utilized to stabilize clay soil. After conducting general proctor compression tests, 10% become located to be the ideal percentage of RHA. Adding kenaf fiber to soil mixtures resulted in an increase in the coefficient of permeability as well as an increase in UCS, shear strength, and CBR. It is thought that 0.75 percent kenaf fiber is equivalent for soil stabilization. The use of costly soils for aquaculture, agricultural production, and agriculture—but not for roads—is the subject of [12]. Lime was added to the soil in different amounts to stabilize it; 10% proved to be the ideal amount. Rice husk ash was applied in different amounts during the second phase; it was discovered that 5%, 15%, and 25% was the ideal amount. In comparison to natural soils, the addition of lime and rice husk ash improved the moisture content, MDD, and plasticity index while simultaneously flattening the moisture-density curves. According to the study, these types of soils require advanced planning techniques in addition to appropriate construction standards. The purpose of [13] is to assess the possibility of a binder that stabilizes expansive soils by mixing fly ash and GGBS. Experiments in the lab indicated that the behaviour of the soil swelling decreased as the binder content increased. The final percent swell could be predicted since the percent swell-time correlation fit the hyperbolic curves. The binder's ability to reduce swelling was enhanced by adding 1% lime. In soil/binder mixes without lime, there is a direct correlation among the modified free swell index (MFSI) and the percent oedometer swell; in the addition of lime, there is not. The properties of the soil/binder mixes' compressibility decreased slightly as the binder content increased, but they decreased dramatically when lime was present. With fewer chemical additions, the study's binder is a cost-effective and efficient way to stabilize expansive soils. According to the study in [14], the RHA, a product of waste

of the agricultural sector, could be used as a substitute of fly ash for high strength, highly ductile engineered cement-based composites (ECC). The ECC mixes' compressive strength improved from 82 MPa to 108 MPa with the incorporation of RHA, which also facilitated pozzolanic reaction and sped up the procedure of hydration. RHA addition also resulted in enhanced tensile characteristics, with the possible exception of a 50% substitution ratio that showed the maximum strength. RHA was added to ECC, which increased pseudo strain-hardening PSH indices and suppleness by decreasing fracture tip toughness and theoretical complementary energy [15].

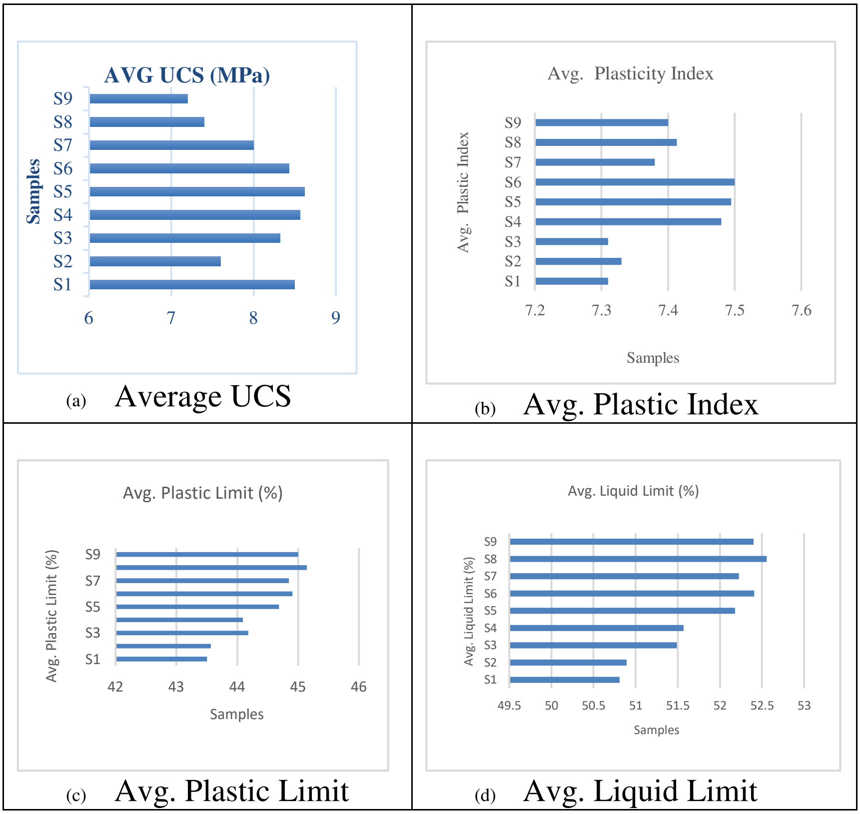
3. Material and methods

In order to improve the soil qualities of black cotton, the study investigates the use of geopolymer stabilization as an environmentally responsible substitute for conventional binders. It creates a thorough testing program that specifies the components, composition, methods of preparation, and processes for creating samples in order to assess the effectiveness of soils treated with geopolymer. The dark colour and high clay content of black cotton soil, which is abundant in nutrients and found in tropical and subtropical areas, make it perfect for growing cotton. As a byproduct of the blast furnace process used to make iron, ground granulated blast furnace slag (GGBS) is used as an additional cementitious material in construction projects. Due to its pozzolanic and latent hydraulic qualities, it's far a useful Portland cement alternative. One useful soil stabilizer is fly ash, which additionally has the capacity to lessen settling and growth soil particle cohesiveness. Additionally, it lessens cohesive soils' flexibility, which lessens swelling and shrinking. In an effort to create cement-like compounds, rice husk ash (RHA), an environmentally benign soil enhancer, desires a hydraulic binder, which include lime. Burning rice husks to reduce waste and produce RHA offers environmental advantages and a sustainable approach for managing waste. By utilising these by-products, we will minimize waste and promote sustainable agriculture.

The motive of the study turned into evaluate fly ash, GGBS, and RHA's efficacy in stabilizing black cotton soil. After samples had been collected and prepared, the quality compositions for stabilization were determined by usage of a Taguchi design of Experiments. The set up compositions have been used to prepare the soil samples, and unique calculations have been made to assure even dispersion. Following preparation, the plastic limit, liquid limit, plastic index, and unconfined compressive electricity of the soil specimens had been assessed. For every composition mixture, many duplicates were made, and statistical analysis become carried out to get beneficial results. In order to determine the effectiveness of various compositions, the information was examined and interpreted, with particular interest paid to the combination that produced the maximum unconfined compressive power and the most favoured plastic properties. The observe also taken into consideration the curing period, with assessments conducted at 7 days, 14 days, and 21 days to study strength improvement over time.

4. Result and Discussion

This segment appears at a study that used geopolymer techniques to stabilize soil. It examines through the effects of incorporating additives which includes fly ash, GGBS, and RHA into black cotton soil, with an emphasis at the soil's structural properties. The unconfined compressive electricity, plastic and liquid limits, and plastic index of the soil had been investigated throughout a variety of curing durations. The findings display that black cotton soil's fundamental qualities may be substantially more advantageous by means of soil stabilization the usage of geopolymers. The sample preparation involves measuring the sample's diameter (d= 7.29 cm) and length (L0 = 14.seventy eight cm), which might be important for calculating parameters. The soil is stabilized the use of those substances, which can be usually used to beautify soil engineering attributes, inclusive of strength, swelling reduction, and stability. The specific quantities of every supplement are ascertained by considering the attributes and features of the soil. In order to determine how efficiently the stabilization worked, the soil must be mixed with the binding additives, compacted then tested. The impact of the additions on the stabilizing properties of black cotton soil can be examined using the data gathered. Nine different soil stabilization samples were created using fly ash, GGBS, and RHA. These samples were tested using the Unconfined Compressive Strength (UCS) test, revealing the peak strength each blend achieved. The results are documented in graphical format, indicating the maximum strength values corresponding to their specific mixture ratios.



(a) Average UCS (b) Avg. Plastic Index

(c) Avg. Plastic Limit (d) Avg. Liquid Limit

Figure 2 (a) Average UCS; (b) Average Plasticity Index; (c) Average Plastic Limit; (d) Average Liquid Limit

According to the figure, Sample S5, which consists of 20% Fly Ash (FA), 20% (GGBS), and 30% Rice Husk Ash (RHA), achieves the greatest average Unconfined Compressive Strength (UCS) value. 2 (a). With varying curing periods, geopolymer-treated Black Cotton Soil (BCS) showed significant strength improvements, with an optimal value of 8.620 MPa. It measured 7.31% for plastic, and 50.81% for liquid. Plastic limits were found to be 45.14%, providing insight into plastic and moisture retention properties. For stabilizing BCS, composition S5 with 20% fly ash, 20% GGBFS, and 30% RHA exhibited the highest UCS and desirable plastic properties.

4. Conclusion

Fly ash, crushed GGBS, silicate of sodium, and rice husk or RHA for short, were added to an ambient-cured geo-polymer combination for enhancing the stability of Black Cotton Soil (BCS). It was found that in order to solve the issues brought on by contamination of soil, erosion, and inadequate drainage, soil stabilizing techniques are required. BCS's usage of geo-polymers significantly enhanced its engineering qualities. With different curing times, there was a significant rise in the UCS), with an ideal value of 8.620 MPa being reached. There was 45.14% of plastic limit and a plastic index of

7.31%. Composition S5, consists of 20% GGBS, 30% RHA and 20% fly ash is recognized to possess the highest UCS and most favorable plastic properties for BCS stabilization. The findings highlight how fly ash, GGBFS, and RHA can be used in geo-polymer stabilization techniques to improve the sustainability of building approaches.

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