Advancements In Effective Black Cotton Soil Stabilization: A Review

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Abstract*: Soil stabilization has become the main concern to develop promising structures by strengthening the characteristics of weak soil. This can be achieved by incorporating many stabilization techniques like sand cushions, CNS layer method, columns, vibrations, and chemical methods. This review is based on a study of different soil stabilizing procedures and their effectiveness in altering and intensifying the features like Optimum Moisture Content (OMC), California Bearing Ratio (CBR), Maximum Dry Density (MDD), Unconfined Compressive Strength (UCS) and shrinkage behavior, etc., of feeble soil as it covers the greatest land area in India.

Keywords: **Black cotton soil, Engineering properties, Soil stabilization**

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I. INTRODUCTION

Various kinds of soils are present in India. In which black cotton soil (BCS) or expansive soil is one of the main forms of soil, which has covered the greatest land area of about 300000km^2. They are found in the region of Deccan Plateau and Malwa Plateau. These soils are very important to develop huge structures like bridges, high rise buildings, dams, airfield pavements etc.

These black cotton soils are popularly called expansive soils because they show problematic behaviour of swelling and shrinkage, when they are dried which is highly undesirable for construction purposes. As a result, it throws an adverse effect on strength and mechanical properties. So to overcome these problems, black cotton soil needs to be stabilized, and then it becomes suitable for use in the construction of buildings and other important structures. There are several techniques such as sand cushions in which the thin layer of soil is replaced by a cushion bed, vibration method, sand columns method in which sand columns are used to replace the soil (dry soil), stone columns (same as sand columns), CNS layer techniques in which the upper layer of expansive soil that is black cotton soil is replaced with CNS (cohesive non-swelling soil) and by adding chemicals like fly ash, lime, cement, and bitumen. So after stabilization of BCS, some of the basic soil properties were improved and altered to attain an effective result of BCS.

In this study, it reveals how the percentage values of various above mentioned properties of BCS is varied and obtained by changing certain parameters like materials, and material composition. And it throws some light on the cause of the addition of some particular stabilizers and the optimum content values for the best and appropriate suitability of BCS in some construction applications. This BCS can also be implemented for the construction of pavements after achieving high strength by stabilization.

II. LITERATURE REVIEW

Babu et al., [1] worked on "Use of Coir Fibers for Improving the Engineering Properties of Expansive Soils" and found that, a massive a part of middle India and a part of Southern part of India are protected with expansive soils. This type of soil has excessive swelling and shrinkage traits and energy of shear strength is extraordinarily low; henceforth, there may be a need for development of those features. Coir fiber is herbal recyclable fabric plentifully to be had in a few components of coastal place and southern part of India. This review reveals the outcomes of complete experimental inquiries and the use of tri-axial shear checks and consolidation checks to measure the development of energy, swelling and compressibility traits of expansive soil strengthened with coir fibers in an arbitrary manner. This helps using aggregate of expansive soil and coir fibers for bearable improvement purposes.

Osinubi et al., [2] worked on "Black cotton soil stabilization using sugarcane bagasse ash and lime" and found that, lab research was carried to study the impact of Sugarcane Bagasse Ash (SBA) additives at the engineering houses of lime handled expansive soil. Bagasse ash is received from boiling the fiber residue by extracting sugar juice from sugarcane. The effects disclosed that the moisture density dating tracks a fashion of growing ideal OMC with reduced MDD. The CBR values received were declined than less than 100% CBR criterion for raw base path materials. The top CBR price received changed into 31% at 8% of lime and 4% of SBA. This price encounters the endorsed standards for subgrade materials. The UCS for about 7 days was decreased to the value of 1034.25 kN/m^2. Based on the idea of the soaked CBR and sturdiness values, it's far endorsed that expansive soil may be stabilized for avenue creation the usage with 8% of lime and 4% of SBA combination of additives at fashionable compaction.

Ramesh et al., [3] studied on "Efficiency of sodium carbonate and calcium carbonate in stabilization of BCS" and found that the structures constructed on black cotton soil experiences damage, which is a common issue. There are several methods like sand cushions, sand columns, vibration techniques, CNS layer techniques, stone columns, and by adding chemicals, etc. In which chemical stabilizing method is costly compared to other methods of stabilizing process but it offers a controlled setting and curing time. This study showed that the calcium carbonate was more effective over sodium carbonate in strengthening, stabilizing, and enhancing the features of an expansive soil.

Ramlakhan et al., [4] worked on "Effect of lime and fly ash on Engineering Properties of Black Cotton soil" and found that the features of expansive soil like liquid limit, compaction, plastic limit, and CBR (California bearing ratio) will be upgraded by adding 3% to 12% of lime and 10% to 40% of fly ash as admixtures and stabilizers. The engineering soil behaviors such as atterberg's limit, optimum moisture content (OMC) and California bearing ratio (CBR) were found to be increasing with an increment in the content of lime but MDD was reduced for the same rise in lime percentages. And for an increased amount of fly ash features such as atterberg's limit, and maximum dry density (MDD) were decremented whereas OMC was incremented. The main motto of this research is to determine the optimum values of lime and fly ash which is suitable and to enhance the properties especially the CBR value of the expansive soil that has been used as a subgrade material in highway constructions.

Bairagi et al., [5] experimented on "Effect of Jute Fibers on Engineering characteristics of Black Cotton Soil" and found that black cotton soil experiences brutal damages because of its swell-shrinkage activities due to variability in water content so it is named as expansive soil for the same in which it is dangerous to structures like runways, highways, railroads and other important structures. This expansive soil is hazardous to be implemented without any proper or well-engineered approach. There are some means to stabilize a soil out of which jute geotextile is one novel technique. Here the study throws light on the efficacy of jute based fibers in monitoring the swelling behaviour of expansive soil in the presence as well as in the absence of the reinforced jute based fibers. And result showed that the samples with 0%, 1%, 2% to 5% of reinforced jute fibers by weight of black cotton soil were used and after performing tests like shrinkage limit, optimum moisture content, California bearing ratio, maximum dry density, and unconfined compressive strength found a notable increase in shrinkage limit from 8.66% to 14.68%, California bearing ratio varied from 1.8% to 4.1% and the value of unconfined compressive strength incremented from 1.09 kg/cm^2 to 1.35 kg/cm^2 and also a remarkable fall in expansive behavior of black cotton soil.

Mishra et al., [6] investigated "Effect of Granite Dust on Index Properties of Lime Stabilized Black Cotton Soil", and showed that the black cotton soil stabilized with 5% lime had been tested with varying percentages like 0%, 10%, 20%, and 30% of granite dust by weight of expansive soil to improve the geo-technical properties such as differential free swell, plastic limit and liquid limit as per Indian standard code provisions. The results

revealed a prominent fall in the swelling behavior in an expansive soil. The value of liquid limit was decreased from 37% to 28% and the plasticity index decreased from 17.45% to 4.80% for the above-mentioned values of lime and granite dust.

Jayasree et al., [7] studied on "Shrinkage Characteristics of Expansive Soil Treated with Coir Waste" and found that, usual natural coir fiber waste is amassing appreciably produced in all international locations the world. This work gives research idea related with shrinkage traits of waste of coir blend with an expansive soil through various coir pith varying from 0% to 3% and brief coir fiber from 0% to 1%. The effects confirmed that the inclusion of coir pith and brief coir fiber efficiently monitors the shrinkage traits of the soil. Shrinkage indices through BS and Ranganatham and Satyanarayana determined the greater practical value than that received through the opposite methods. It showed that, volumetric shrinkage limit test can be easily studied using 3-D shrinkage strain test than shrinkage limit test.

Lekha et al., [8] worked on "Electrolyte Lignin and Fly Ash influencing Stabilizing of Black Cotton Soil" and showed that, sub-grade layer is the most significant for of layer in the pavements. The main property of the subgrade is to withstand the loads transmitted from the pavement structures by avoiding the deformations under adverse conditions. This work is based on the evaluation of fly ash, ELS (electrolyte lignin stabilizer) and the blend of fly ash and ELS with expansive soil for the stabilization purpose. The fundamental soil properties were studied using CBR and UCS etc. Another test called, dynamic repeated load test was performed in order to analyze the property of tiredness of the soil. The tests such as, freeze-thaw and wet-dry cycle tests were conducted to analyze the durability of the soil. The studies showed that, the dry density, CBR, UCS and consistency limits were observed with the curing durations of 1 day, 7 days and 28 days. And also, the weight loss for 12 cycles was found to be of about 14% which in turn revealed the stabilized soil was having high durability. Soil treated with fly ash and electrolyte lignin stabilizer offered improved results as compared to the soil treated with ELS alone. Further, the swelling behavior was also decreased with curing period of 28 days. Finally, it was concluded that, the combination of fly ash and ELS offers enhanced subgrade strength.

Pai and Patel [9] conducted an experiment on "Effect of GGBS and lime on the strength characteristics of black cotton soil" and the study focuses on stabilizing BCS with GGBS and in combination with lime and GGBS. Fundamental soil tests were carried to govern the power of the treated soil. To conduct the test, one sample was considered with GGBS with dosages of about 3% to 12% varying with 3% and another mixture of GGBS (2 parts) and also lime (1 part) with the same dosages were considered. The stabilized soil was improved with an increment in curing time and content of binder. But there was a reduction in the strength of the stabilized soil due to soaking. The overall result concluded that a partial mixture of GGBS with lime had minor improvement in elastic modulus and UCS but, there was a tremendous improvement of more than 50% in CBR value. The combination of lime and GGBS mixture found to be effective content of binder than the GGBS mix for the enhancement in expansive soil properties.

Peter et al., [10] investigated on "Laboratory Analysis In The Development Of Subgrade Properties Of BCS Stabilized With Coir Fiber Waste" and showed that soft soils shape complicated for pavements because of its small bearing capability and electricity. Pavement masses approaching at the smooth sub-grade soil can also be a reason for an adverse pumping moves while it may be positioned in regions with excessive water desk which reasons each production and in-carrier overall performance troubles. Excavation and alternative of soil will become very high priced specifically while soils need to be hauled to big distance. Treatments use the numerous components which can enhance the homes of smooth soils. A current fashion in stabilization is to make use of regionally to be had business wastes to enhance the homes of smooth soils. Here, the approach has twin gain of growing the electricity of soil and an answer to the complicated discarding of such wastes. Coir wastes (coir fiber and coir pith) are extra unwanted materials of coir production enterprise acquired by coconut husk. This work offers a research at the conduct of smooth soil treated with various probabilities of coir pith (0% to 3%) and coir fiber (0% to 1%) through wearing out Static Triaxial take a look at, Standard Proctor and CBR tests. The consequences confirmed that treatment with coir waste had a big impact at the compaction as well as the elastic modulus and CBR values of the soil.

Naveena et al., [11] carried work on "Prediction of Strength Development in Black Cotton Soil Stabilized with Chemical Additives" and revealed that nowadays chemical admixtures are added to problematic soil to increase strength and serviceability. For expansive soils with high swelling and compressibility, admixtures like lime and cement are extensively used. This work includes sodium silicate, residue of calcium carbide, lime, and sodium silicate + lime are used as stabilizers. Impact of these industrial bi-products on compaction and Atterberg's limits are focused considering the strength development of expansive soil. The study resulted in a reduction of the 1/3rd of plasticity index. Generally, the compaction behavior of expansive soil is dependent on soil pore fluid interaction. To attain durability, the soil was mixed with an optimum content of lime and sodium silicate was steady. Based on Abrams' law, the strength forecast equations for various curing durations and combinations of W/c ratio and chemical additives content are projected as well as checked.

Pusadkar et al., [13] experimented on "Effect of Nano-Copper on Performance of Black Cotton Soil" and showed that soil stabilization by adding materials like cement, admixtures, and stabilizers is important to treat pathetic soil where black cotton soil is one. This study focused on adding nano-copper as a stabilizer to achieve geotechnical properties such as compaction, liquid limit, CBR value, UCS, and swelling behavior. Addition of nano-copper of about 1%, 1.5%, and 2.5% to the weight of expansive soil. To achieve the required strength, optimum values of nano-copper was obtained at 1.5%.

Silmi et al., [14] studied on "Enhancing the engineering properties of expansive soil using bagasse ash" and found the stabilization of BCS at laboratory level. The main aim of the work is to enhance the features of black cotton soil using bagasse ash. The bagasse ash with 0%, 5%, 10%, 15% and 20% of composition was used to stabilize the BCS. The consequence of addition bagasse ash on the soil was examined by subjecting to tests such as strength test and physical tests such as standard proctor test, plasticity index and percentage swelling tests. The characterization methods like XRF (x-ray fluorescence) and XRD (x-ray diffractometer) were utilized to analyze the structural features and chemical conformation of bagasse ash. The results revealed that, the variation in the result bare soil and ash added soil. Further, the plasticity index was decremented from the value of 53.18% to 47.70%. Whereas, value of MDD (maximum dry density) was decreased from 5.48% to 3.29%. So it was showed that, the soil properties were enhanced after the addition of bagasse ash.

Muthukumar et al., [15] studied on "Swelling and Shrinkage Behaviour of Expansive Soil Blended with Lime and Fibers" and showed that, BCS are taken into consideration to be notably tricky due to their volumetric changes. They exhibit both shrinkage and swelling behaviors. Due of this twin swell-cut back feature, expansive soil is mysterious in civil structures. Various qualifying strategies are followed to encounter the issues developed by the BCS, either by transforming the soil features or by implementing different treating methods. Swell assessments have been achieved through various the content of fiber material and with content of lime with expansive soils. Tests have been additionally carried out through mixing lime and fibers together with BCS. In a comparable way, shrinkage assessments have been additionally achieved for the diverse proportions. The take a look at end result display that swelling has a tendency to lower barely with a growth with inside the fiber content material. while shrinkage has a tendency to lower effectively on addition of fibers. Swelling and shrinkage has a tendency to be lowered greatly with growing content of lime material. The highest quality material of fiber turned into located to be 2%. Hence, the BCS specimens combined with 2% of fibers and with various content of lime material turned into tested. The mixing 2% of fibers and 15% of lime together in BCS is taken into consideration to be extra powerful in regulating the shrinking and swelling features.

Patil [16] worked on "Effect of Steel Slag on CBR Value of Black Cotton Soil" and showed that the expansive soil is very much useful for cultivation but again in the case of construction it is quite difficult because of its varying water content. Where steel slag is one of the industrial wastes and can be used for black cotton soil stabilization. This study evaluates the cause of the addition of steel slag as a stabilizer in various percentages to check its appropriateness to be used as a material for the road construction, buildings, and embankments. This study mainly concentrated on two phases, in the first phase by performing the CBR test on unstabilized soil was carried. Where in the second phase, steel slag with varying percentages as 5%, 10%, and 15% were added and the study showed the gradual rise in properties with a suitable rise in steel slag content.

Cheng and Huang [17] investigated on "Mineral Additives Influence on the Feature of BCS to Implement in Highway Subgrade Soils" and showed that expansive soil (BCS) is well-known for its high shrinkage and swelling behavior as they form an important soil group in the place called Kenya and is deviated due to its high shrink/swell potential when uncovered to water. Many trials were performed on expansive soil treated in combination with lime (0% to 9%) and volcanic ash (0% to 25%) to understand the geotechnical and mineralogical behaviors of BCS. To study the soil movement and wetness change in expansive soils, a trial road of BCS was stabilized with lime and volcanic ash is used instead of BCS. The same trial was performed with lime and volcanic ash separately and the results disclosed that CBR (California bearing ratio) and UCS (unconfined compressive strength) were high in a combination of both stabilizers (lime and volcanic ash) when compared to individual stabilization. And optimum content of lime and volcanic ash were found to be 3% and 15%. The increase in factors like pH and electrical conductivity in treated soil is very important to aid chemical reactions among black cotton soil and stabilizers to develop new cementitious agents that were characterized through XRD (X-Ray Diffraction) and TEM (Transmission Electron Microscope). Black cotton soil forms the main and vast form of soil available in Kenya also allows a cost-effective approach for research.

Srivastava et al., [18] studied on "Strength and Stiffness behaviour of the Black Cotton Soil Reinforced with Tire Chips under Ring Footing" and found that swelling and shrinking features of black cotton soil are hazardous to civil structures and causes settlement, cracking in various parts of the structures because of its varying water content. Various techniques that are popular such as adding admixtures and reinforcements are adopted to develop structures on black cotton soil. Here to realize the strength and stiffness behavior of soil mixed with tire

chip beneath the ring footing, several tests were performed by using soil mixed with tire chips. To understand the capacity of load-carrying, black cotton soil parameters such as the effect of tire content (5% to 20%) and the depth of footing (0.5D to 1.5D) were investigated. Such that 'D' is the diameter of the ring. The result showed that the highest performance achieved at the depth of 0.5D with 10% of tire content.

R. Gobinath et al., [21] focussed on "Studies on strength characteristics of black cotton soil by using novel SiO_2 combination as a stabilizing agent" and revealed that, the quick development in the population and indstrialization influences in the huge quantity of wastes with greater silica composition. This work focusses on the accumulation silica wastes and to implement those silica wastes as an admixtiure for the black cotton soil stabilization. The characterizations such as SEM (scanning electron microscope) and EDX (energy dispersive x-ray analysis) were employed to evaluate the chemical configuration of silica, magnesium and aluminium proportion in the waste. These EDAX and SEM results revealed that, the composition of silica, magnesium and aluminium forms the cementitious complex. This complex mixture offered greater binding capacity, hydraulic behavior and strength properties by adding 20% to the weight percentage of soil. Properties like North Dakota and CBR (California bearing ratio) of the soils were evaluated after adding stabilizers. The results exhibited that, the properties of graded soil were enhanced and also showed the advancement in properties of the soil.

III. CASE STUDY

This study focusses on the strength of an expansive soil and how it was enhanced by stabilized using discrete glass fiber and further implication for pavement applications. The glass fiber of about 0.25% and 1.0% varied weight percentages were considered. The tests such as, California bearing ratio (CBR), indirect tensile strength (ITS) and unconfined compressive strength (UCS) were conducted.

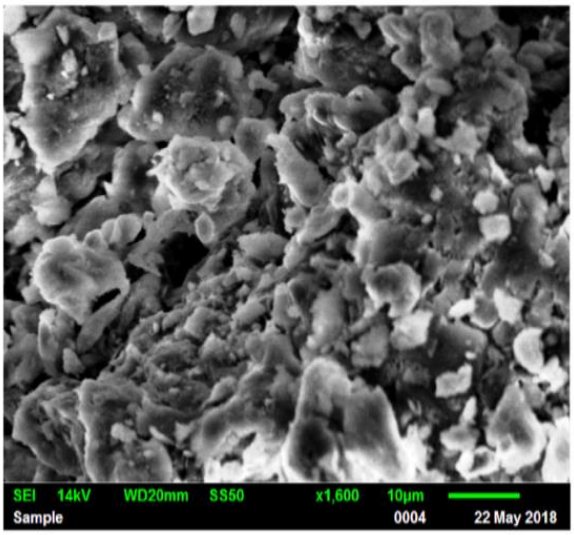

Figure 1: SEM image of natural expansive soil

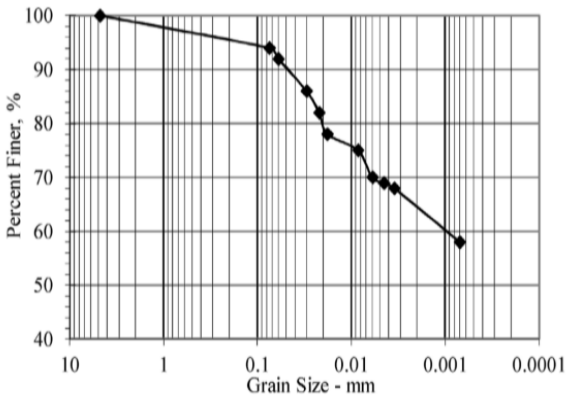

Figure 2: Grain size analysis curve

Figure 3: Glass fiber for reinforcement

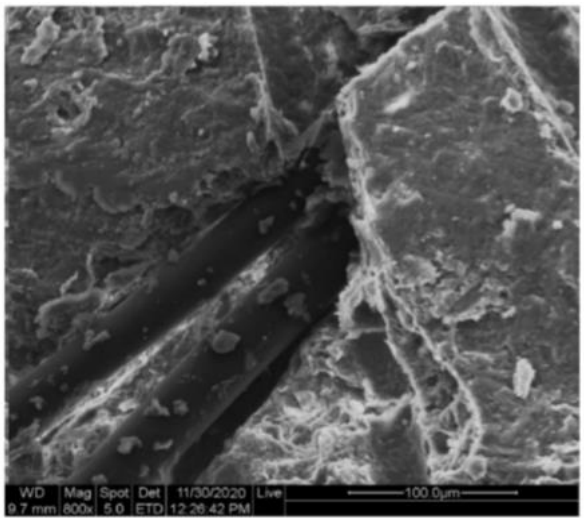

Figure 4: SEM image of reinforced soil

Figure 5: UCS test images

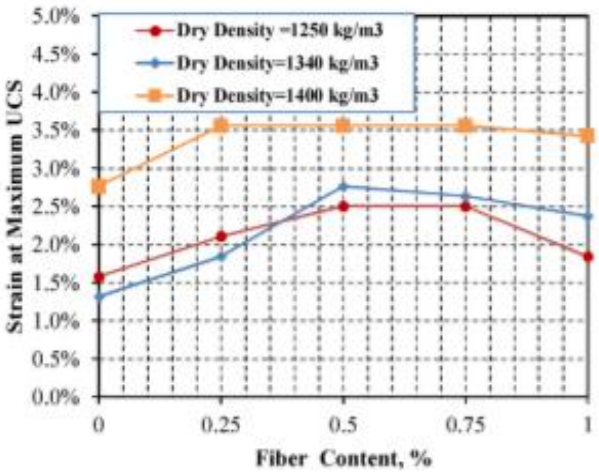

Figure 6: UCS result of glass fiber stabilized soil

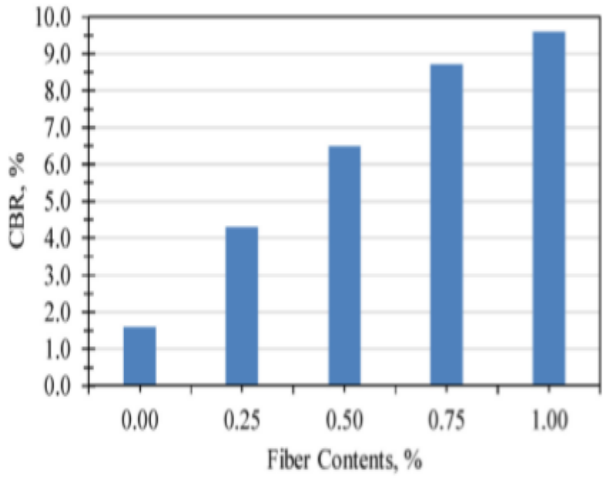

Figure 7: CBR result of glass fiber stabilized soil

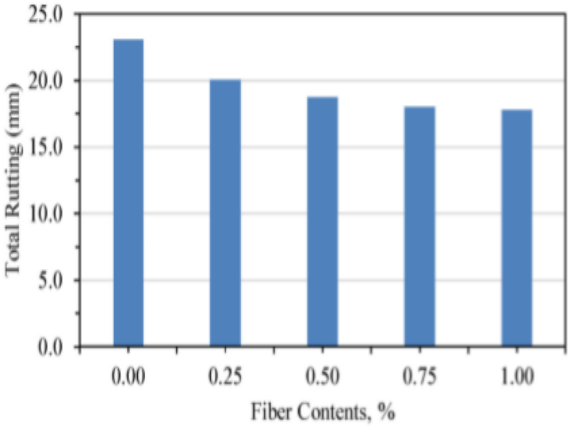

Figure 8: MEPDG analysis

Further, the performance and design of the reinforced soil was examined using MEPDG (mechanistic-empirical pavement design guide). However, this MEPDG also showed that, the glass fiber is a most suited and a promising reinforcement material for pavement construction. The required lower value of pavement thickness can be attained with addition of glass fiber. The results revealed that, there was a decrement in the value of free swell along with the increment in the values of ITS, UCS and CBR.

IV. RECENT INNOVATIONS

Urbanization has influenced the deterioration of land quality. The black cotton soils (BCS) are a type of tricky soils available in India for about 23%, even though with its high fertility behavior, they are not useful for construction of buildings and roads. This BCS are associated with problems of swelling and shrinking action due to the variation in moisture content. Because of great swelling and shrinking actions, they experience dryness and surface cracks. In order to implement this BCS effectively, appropriate land improvement methods are

required. One of the great methods is to stabilize the black cotton soil by using additives such as cement, lime, GGBS, fly ash, coir fiber, sugarcane bagasse ash etc. In the recent works, an attempt had made to use the combination of lime and GGBS as admixtures. The varied percentages of lime with 2%, 4% and 6% were used with 5% and 10% of GGBS. Tests such as California bearing ratio (CBR), unconfined compressive strength (UCS), atterberg's limit test and standard proctor test were performed. Finally, the results indicated that, there was an increment in the soil values after UCS and CBR tests.

Further, the material composition of cement and terrazyme can be used widely for the stabilization of expansive soil or black cotton soil. In the recent work, the cement-kiln dust (CKD) was implemented for the stabilization and its effect after stabilization was analyzed. The cement kiln dust of about 10%, 15% and 20% compositions was used along with 2.5% of terrazyme composition. The study revealed the promising work and results.

V. CONCLUSION

Black cotton soil or expansive soil is one of the main forms of soil found widely in some parts of India. But due to its swelling and shrinkage behaviors, they are stabilized and their properties are improved and used in construction applications. After stabilization, it was found that properties like CBR, UCS increased to 4.1% and 14.68% respectively and also by using lime as a chemical stabilizer, which in turn reduced the expansive nature of BCS. Some results disclosed that not only lime but also some materials such as nano copper, calcium carbonate, and the combination of lime and ground-granulated blast furnace (GGBS), nano copper, combination of lime and GGBS, cement, glass fibers and terrazyme plays an effective role in decreasing the shrinkage and swelling activity of BCS. The increase in factors like pH and electrical conductivity in treated soil is very important to aid the chemical reactions among black cotton soil and stabilizers to develop new cementitious agents and implement them in the construction of pavements.

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