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Strength Behaviour Of Fly Ash Stabilized Black Cotton Soil Reinforced With Waste Plastic Strips

C. Rasool Basha, Mutturu Anuradha, S Mahemoodh

Department of Civil Engineering, Chaitanya Bharathi Institute of Technology, Proddatur, Andhra Pradesh 516360, India.

*Corresponding Author E-mail: crasool1994@gmail.com

Abstract: Expansive black cotton soil exhibits significant volume fluctuations in response to changes in moisture content, which results in excessive swelling and shrinking. These characteristics often result in general structural instability, pavement degradation, and foundation settlement. To improve its engineering performance, the right stabilization approaches are required. This study examines the combined effects of Class F fly ash (FA) and waste plastic strips (WPS) on the strength characteristics of black cotton soil. Fly ash was spread in various ratios of 0%, 5%, 10%, 15%, and 20% by dry weight of soil, while waste plastic strips were added at 1%, 2%, and 3%. Numerous laboratory tests, including as sieve analysis, Atterberg limits, specific gravity, free swell index, Standard Proctor compaction test, Unconfined Compressive Strength (UCS), and California Bearing Ratio (CBR) tests, were carried out to evaluate the altered soil properties. According to the experimental results, strength measurements have improved and swelling potential has been decreased. Out of all the combinations evaluated, the mixture containing 15% fly ash and 1% plastic strips fared the best in terms of UCS and CBR values. The study's findings offer a workable and sustainable way to stabilize expansive soils while promoting the beneficial use of industrial byproducts and plastic waste.

Keywords:

1. Introduction: Construction of roadways, pavement and foundation on soft and expansive soil can be problematic because these types of soil typically have no shear strength and high compressibility to avoid such problem the soil is stabilized chemically using various types of admixtures or the soil is stabilized mechanically by mixing various types of material in the soil such as rice husk, fly ash, coir fiber. Adding these constituent materials ultimately includes the various properties of soil such as CBR value, Liquidity Index, Shear strength, unconfined compressive strength and bearing capacity, so that the soil can be used for various construction purposes.

The use of waste materials and industrial byproducts to enhance the engineering qualities of expansive soils has been studied by a number of researchers. A brief summary of noteworthy contributions that are pertinent to the current investigation is provided in the section that follows. The impact of plastic waste fibers on the geotechnical behavior of clayey soil was investigated by Hassan et al. [1]. Polyethylene terephthalate and polypropylene fibers were made from waste bottles and plastic bags and applied in the following amounts by dry weight of soil: 1% to 4%. The study found a negative relationship between the fiber content, optimal moisture content, and maximum dry density. After reaching 1% fiber content, the unconfined compressive strength remained nearly constant. The authors explained that the increase in strength was due to the increase of frictional interaction between the soil particles and fibers. Mallikarjana et al. [2] assessed the applications of waste plastic strip in black cotton soil. Plastic of discarded chairs was used as a proportion of 2, 4, 6 and 8. The value of California Bearing Ratio rose with plastic content to 4, and then it declined. The research found 4% optimum plastic content to increase bearing capacity and that plastic waste could be used successfully to increase the performance of subgrade. The study by Tarun Kumar et al. [3] was on the impact of low-density polyethylene strips on clayey soil. The results showed that the CBR value increased to an optimum before falling, and the maximum dry density decreased as the plastic content increased. The ideal strip length was determined to be 2 cm, demonstrating the significant influence of fiber geometry and content on the behavior of soil reinforcement. The stabilization of expansive soil with alkali-activated Class F fly ash was investigated by Partha Sarathi et al. [4]. The ratios of fly ash used were 20, 30, and 40. The lowest activator-to-ash ratio, which varied from 0.3 to 0.6, produced the highest unconfined compressive strength. The importance of the curing time and activator concentration in achieving strength development has been emphasized by the research. Cadersa et al. [5] studied the concept of using bottom ash as a stabilizing measure in subgrade soil. The percentages of bottom ash were added to 15 percent, 30 percent and 40 percent. These findings indicated optimal CBR at 30 percent bottom ash composition, as well as a large decrease in swelling potential. The authors came to a conclusion that bottom ash is effective in increasing mechanical stability of subgrade soils. Tastan et al. [6] examined the stabilization of organic soil by fly ash and cement. They were fly-ash contents of 10, 20 and 30 per cent. The compressive strength that is not confined increased according to the soil type and fly ash properties. The paper has noted that soil organic matter also plays a role in determining the effectiveness of stabilization. Singhai et al. [7] investigated the fly ash and rice husk ash as stabilizers on black cotton soil. The proportions of fly ash were up to 25% and the test was conducted after 28 days of curing. The findings showed that there were decreases in liquid limit, index of plasticity and index of free swell which showed enhanced engineering behavior. As presented by Shiva Prashanth et al. (2019), the authors assessed a mixture of fly ash and coir fibers in clayey soil. The experiment found a linear relationship between liquid limit and fly ash content and data gives maximum improvement of strength at 20% fly ash and 1% fiber reinforcement. Brooks et al. [8] indicated that addition of fly ash up to a level of 25% had a great effect on enhancing unconfined compressive strength and swell potential of expansive soil. The research advised fly ash of 15% to be used in the reduction of swelling and 25% in enhancing strength. Gullu et al. [9] researched on the basis of stabilization of low plasticity clay with bottom ash, lime and superplasticizer. The disintegration resistance and strength of the mixture were enhanced by stabilizers, which acted as a combination during loading. Ghais et al. [10] experimented with fly ash stabilization of additions of between 5 and 20 percent. It was found in the study that plasticity was reduced by 50% at 20 percent fly ash and there was enhancement of bearing capacity at 15 percent addition making it suitable to use in pavement construction.

2. Materials And Methodology:

2.1 Materials used:

Black Cotton Soil: Expansive soils, particularly certain types of clay, are regarded as highly challenging materials in geotechnical engineering. These soils undergo significant volume changes when exposed to variations in moisture content. As they absorb water, they tend to swell, and upon drying, they shrink. This repeated expansion and contraction can lead to cracking, settlement, and structural distress in foundations, pavements, and other civil engineering works. For the experimental purpose, the soil samples was taken from korrapadu, upparapalli, jammalamadugu, and potladhurthi villages in surrounding of Kadapa district. The soil was left to dry for a period of five days and wassubsequently broken down into small, fine pieces. Following this, the soil was passed through an IS 4.5 mm sieve to obtain a consistent texture. Only the soil that passed through the sieve was used for the remaining experiments. And over all 4 places of soils get one place of soil will comes under week section that soil will be upparapalli soil so we need to stabilize the upparapalli.

Figure 1. Collection of Black Cotton Soil

Fly Ash: A byproduct of burning coal, usually in electric power plants, is fly ash. When fly ash is added to soil, it first causes flocculation and agglomeration of clay particles by ion exchange at the soil particle surface, much like Portland cement does. Improved workability and an instant decrease in the soil's propensity to swell, shrink, and become plastic are the results of this reaction. The experiment was conducted using fly ash of class F.

Waste Plastic Strips: Plastic is a significant invention that has greatly impacted various aspects of life, including the scientific field. However, with the increasing use of plastic, it has become a major environmental pollutant due to its "use and throw" mechanism. In the current scenario, it is essential for everyone to think about limiting the use of plastic to prevent severe consequences for both humans and the environment soon. Since plastic is non-degradable, there is a growing need to recycle or reuse it to reduce its wastage. In this study, polyethylene terephthalate (PET) (water bottles) was used. Plastic fibers were prepared by cutting waste bottles into 3cm length and 1.5cm width. They were used in varying percentage of 1% 2% and 3% percentage. The use of plastic in soil stabilization can make the soil more resistant to water, reducing the likelihood of erosion and improving its ability to retain moisture, use of plastic in soil stabilization is often less expensive than other methods such as chemical stabilization, which can require expensive materials and equipment.

3. Results and Discussions:

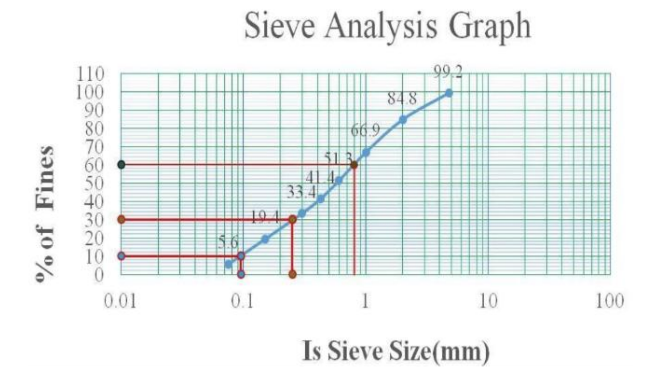

Figure 2: Sieve Analysis of the soil

By observing below graph results with increase in (%) of FA, Liquid Limit decreases considerably. From the above results L.L of Black Cotton Soil is 53.125%. By adding different (%) of FA, L.L of soil is less than 53.125% and the sufficient. Liquid limit is at 15% FA=34.85 When compare to y remaining (%) of FA. Therefore, by this we can conclude that with addition of FA we can decrease Liquid Limit of the soil.

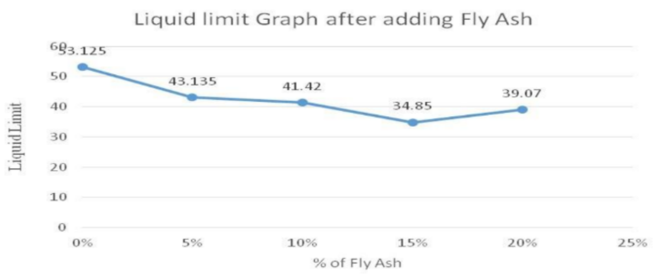

Figure 3: Liquid Limit of the soil

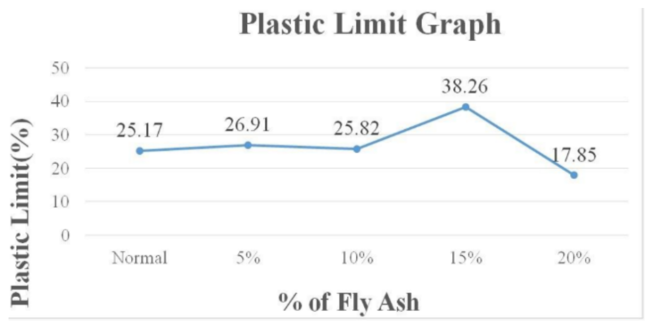

Figure 4: Plastic Limit of the soil

Based upon above test results of plastic limit, it is observed that by Adding % Fly Ash by 5%, the plastic limit of soil shows a decreasing trend. At 15% FA, Plastic limit of soil is 38.26%. By increasing in % of FA by 5%, the values of P.L decreased from 25.17% to 17.85%.

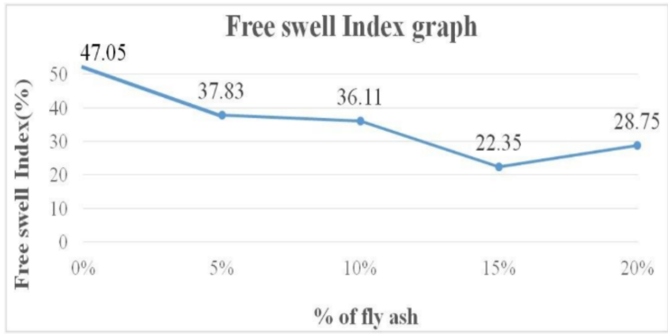

Figure 5: Free Swell Index of the soil

The Free Swell Index (FSI) generally decreases as the proportion of fly ash increases in the soil mixture. A higher dosage of fly ash or similar admixtures tends to limit the swelling potential, thereby reducing overall expansion behavior. In addition, FSI is influenced by several parameters that govern soil volume change, including the type and proportion of clay minerals present, soil density, applied loading conditions, structural arrangement of particles, and the prevailing moisture content.

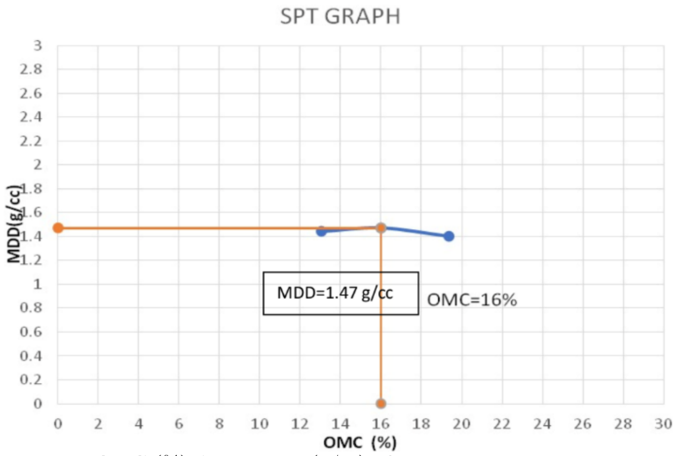

Figure 6: OMC (%) AND MDD (g/cc) of the soil

The table displays the maximum dry density (MDD) and optimum moisture content (OMC) of the soil sample at various ratios. Maximum dry density (MDD) and optimum moisture content (OMC) values increased as the percentage of additives increased. The highest values for ideal OMC and MDD, 17.04 percent and 1.59 g/cm3, respectively, are found in the soil sample that contains 15% fly ash and 1% plastic waste.

Figure 7: UCC of the soil

The UCC values for the soil sample with different proportions are presented in the table above. Initially, the UCC value for BC soil was 38.06 kn/m^2. However, with the introduction of additives, the UCC value for the soil gradually increased. The ideal UCC value was achieved by adding 15% fly ash and 1% plastic waste resulting in a UCC value of 49.47kn/m^2.

4. Conclusion: The report discusses the variations in different soil engineering qualities that resulted from studies on Black Cotton soil mixes with fly ash and plastic garbage. At 2.4, the maximum specific gravity was achieved. When evaluating the qualitative behavior of soil, specific gravity is an important metric. We can deduce that when specific gravity is large, it strengthens the layer of pavement and roads. The maximum dry density and optimum moisture content of the clay also increases when Fly ash and plastic waste are added. The clay soil will have an ideal moisture content of 16% and an ideal dry density of 1.47g/cc, much like regular BC soil. In comparison to the other percentages, the clay soil achieves optimal moisture content and maximum dry density of 17.04 percent and 1.59 g/c, respectively, when 15 percent fly ash and 1 percent plastic trash are added. When fly ash and plastic trash are added to the California Bearing Ratio (CBR). At 15% fly ash and 1% plastic waste, the values increase; after that, they begin to fall. At this ratio, the CBR value begins to rise until it reaches its peak at 5% fly ash and 1% plastic trash, respectively, after which it begins to decline. The UCC value, calculated as a percentage, is 49.47kn/m^2. The following findings are drawn from the experimental investigation of soil stabilization utilizing fly ash and plastic debris. In order to stabilize the soil, different percentages of fly ash and plastic waste were added in this study. The findings were compared to those of a typical soil sample. According to the research, adding 15% fly ash and 1% waste plastic strips to the soil boosts its strength in the CBR Test and the UCC Test. Similarly, adding 5% fly ash and 1% waste plastic strips increases the soil's strength.

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