The Effective Study of Black Cotton Soil Using Flyash and Geopolymer

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Abstract: ***Nearly 51.8 million hectares of land area in India are covered with Expansive soil (mainly Black Cotton soil). The property of these expansive soils, in general, is that they are very hard when in dry state, but they lose all of their strength when in wet state. In light of this property of expansive soils, these soils pose problems worldwide that serve as challenge to overcome for the Geotechnical engineers. One of the most important aspects for construction purposes is soil stabilization, which is used widely in foundation and road pavement constructions; this is because such a stabilization regime improves engineering properties of the soil. In the present study soil is considered namely Black cotton soil have been stabilized using geopolymers (Alkaline activators, sodium silicate:sodium hydroxide in 2:1ratio). The alkaline solution , sodium silicate: sodium hydroxide in 2:1 ratio was used in different concentrations.In this study deal with the obtaining the unconfined compressive strength values and California bearing ratio by fixing 25% Flyash and % varying of Alkaline material (2%, 4%, 6%, 8% and 10%).***

Keywords: Expansive soil, Flyash, Geopolymer, Unconfined Compressive strength (UCS) and California Bearing Ratio(CBR)

1. Introduction

Geotechnical engineering, especially the treatment and usage of soil (or earth) in construction, is a venerable technical field, dating to the beginning of human civilization. Soil stabilization in a wide-ranging sense includes various methods used for modify the properties of soil to improve its engineering performance. By stabilization the major properties of soil, i.e., volume stability, strength, compressibility, permeability, durability and dust control is improved, which makes the soil suitable for use.

There are different methods of stabilization, which include physical, chemical and polymer methods of stabilization. Physical methods involve physical processes to improve soil properties. This includes compaction methods and drainage. Compaction processes lead to increase in water resistance capacity of soil. Drainage is less common due to generally poor connection between method effectiveness and cost. But, compaction is very common method. Although, it makes soil more resistant to water, this resistance will be reducing over time. Chemical soil stabilization uses chemicals and emulsions as compaction aids, water repellents and binders. The most effective chemical soil stabilization is one which results in non-water-soluble and hard soil matrix. Polymer methods of stabilization have a number of significant advantages over physical and chemical methods. These polymers are cheaper and are more effective and drastically less dangerous for the environment as compared to many chemical solutions.

In the present study, expansive soils are considered for effectiveness of Geopolymer stabilization. As an alternative to such traditional soil treatment and improvement techniques, biological approaches are now being actively investigated in the field of geotechnical engineering, including microbe injection and by product precipitation.

2. Objective

The objective of this research is to evaluate the strength behavior of soil with Geopolymers, (Alkaline material, sodium silicate: sodium hydroxide in 2:1ratio) and to determine the effect of the Geopolymer stabilizers on engineering properties of expansive soils.

In this study dealt with the obtaining the unconfined compressive strength values and California bearing ratio by fixing 25% Flyash and % varying of Alkaline material (2%, 4%, 6%, 8% and 10%).

3. Literature Review

Satyanarayana*et al.* (2004) studied the combined effect of addition of fly ash and lime on engineering properties of expansive soil and found that the optimum proportions of soil: fly ash: lime should be70:30:4 for construction of roads and embankments.

Phani Kumar and Sharma (2004) observed that plasticity, hydraulic conductivity andswelling properties of the expansive soil fly ash blends decreased and the dry unit weight and strength increased with increase in fly ash content. The resistance to penetration of the blends increased significantly with an increase in fly ash content fora given water content. They presented a statistical model to predict the undrained shear strength of the treated soil.

Buhler and Cerato (2007) studied the stabilization of expansive soils using lime and Class C flyash**.** The reduction in linear shrinkage was better with lime stabilization as compared to same percentage of Class C fly ash.

Wagh (2006) used fly ash, rock flour and lime separately and also in combination, indifferent proportion to stabilize black cotton soil from Nagpur Plateau, India. Addition of either rockflour or fly ash or both together to black cotton soil improved the CBR to some extent and angle of shearing resistance increased with reduced cohesion. However, in addition to rockflour and fly ash when lime was mixed to black cotton soil, CBR value increased considerably with increase in both cohesion and frictional resistance.

Attomet al. (2007) investigated the effect of shredded waste tire on the shear strength,swelling and compressibility properties of the clayey soil from northern part of Jordan. The shredded tires passing US sieve number 4 were added with the soil at 2%, 4%, 6%and 8% by dry weight of soil. The test results showed that increasing the amount of shredded waste tires increased the shear strength and decreased the plasticity index, maximum dry density, permeability, swelling pressure, swell potential and the compression index of the clayey soil.

4. Materials

Following are the materials which are used in the present study:

4.1 Expansive Soil

The soil sample was locally collected from Ramarajupalli village, near Fathima Institute of Medical Science kadapa district. Maximum area of the village was covered by black cotton soil .Soil was taken by removing the top layer containing organic matter. The sample was extracted by 50 cm deep. The soil lumps were broken into small pieces and screened through 4.75 mm size sieve to make it free from roots, pebbles, gravel etc. The following table shows the various soil properties obtained:

Table 1: Properties of Expansive Soil

S.No	*Properties*	*Expansive Soil*
1	Specific Gravity	2.32
2	Free Swell Index	90%
3	Liquid Limit	65.32%
4	Plastic Limit	35.45%
5	Plasticity Index	29.86%
6	Standard proctor compaction	OMC:26.25%
		MDD:1.30(gm/cc)
7	Unconfind Compression Strength	1.122(kg/cm2)
8	California Bearing Ratio	Unsoaked:3.45
		Soaked:2.38

4.2 Fly ash

The fly ash is light weight coal combustion by product, which result from the combustion of ground or powdered bituminous coal, sub-bituminous coal or lignite coal. Fly ash is generally separated from the exhaust gases by electrostatic precipitator before the flue gases reach the chimneys of coal-fired power plants. Generally this is together with bottom ash removed from the bottom of the furnace is jointly known as coal ash. The fly ash is highly heterogeneous material where particles of similar size may have different chemistry and mineralogy. There is variation of fly ash properties from different sources, from same source but with time and with collection point (Das and Yudhbir, 2005). Fly ash contains some un-burnt carbon and its main constituents are silica, aluminium oxide and ferrous oxide. In dry disposal system, the fly ash collected at the bottom of the mechanical dust collectors and ESPs. From the dry storage silos also fly ashes are collected in closed wagons or moisture 50 proof bags or metallic bins, if the quality of the fly ash is good. The dry fly ash so collected is then transported to the required locations where it is subjected to further processing before its use in many non-geotechnical applications such as cement industry, brick manufacturing and the like. In the present study fly ashes were collected from the captive power plant of National Aluminium Company Ltd, Angul, Odisha. After procuring, the fly ash samples were screened through 2 mm IS sieve, to separate out the vegetative and foreign material. To get a clear homogeneity, the samples are mixed thoroughly and heated in an oven maintained at 105-110 0 C for 24 hours and then is stored in an air tight container, for subsequent use.

4.3 Sodium silicate

Sodium silicate, usually known as "water glass" or “liquid glass”, is well-known due to wide commercial and industrial application. It is mostly composed of oxygen-silicon polymer backbone lodging water in molecular matrix pores.

Sodium silicate products are manufactured as solids or thick liquids, depending on proposed use. For instance, water glass functions as a sealant in metal components.

Finally, even though, sodium silicate manufacture is a mature industry, there is current research for new applications given its heat conductive properties. Sodium silicate is a versatile, inorganic chemical made by combining various ratios of sand and soda ash (sodium carbonate) at high temperature. This process yields a variety of products with unique chemistry that are used in many industrial and consumer application.

Figure 1: Sodium Silicate

4.4 Sodium hydroxide

Sodium hydroxide, also known as lye and caustic soda, is an inorganic compound with formula NaOH. It is a white solid ionic compound consisting sodium cations Na+ and hydroxide anions OH−. Sodium hydroxide is a highly caustic base and alkali, that decomposes proteins at ordinary ambient temperatures and may cause severe chemical burns. It is highly soluble in water and readily abso+6rbs moisture and carbon dioxide from the air. It forms a series of hydrates NaOH. *n*H2O. The monohydrate NaOH.

H_2O cystallizes from water solutions between 12.3 and 61.8 °C. The commercially available "sodium hydroxide" is often this monohydrate, and published data may refer to it instead of the anhydrous compound.

Sodium hydroxide is used in many industries in the manufacture of pulp and paper, textiles, drinking water, soaps and detergents and as a drain cleaner. Worldwide production in 2004 was approximately 60 million tonnes, while demand was 51 million tonnes.

Figure 2: Sodium Hydroxide

5. Sample Mixing

For the sample preparation, two different mixing methods can be adopted: dry mixing in which the Geopolymer was directly mixed with the soil before adding water and wet mixing in which Geopolymer was mixed with water to form hydro- solution before mixing in the soil. Dry mixing method was used. Soil sample mixed with various percentage of Geiopolymer (2%,4%,6%,8%, and 10%).

6. Methodology

In this study the properties of black cotton soil such as index and engineering properties were analyzed. From the index and engineering properties of the soil was found to be having very low strength and expansive in nature. In order to improve the properties of soils, We chosen the Soil stabilization with Fly ash and Alkaline material.

In the present study soil is considered namely Black cotton soil have been stabilized using geopolymers (Alkaline activators, sodium silicate:sodium hydroxide in 2:1ratio). The alkali solution , sodium silicate:sodium hydroxide in 2:1 ratio was used in different concentrations.

In the present study, the alkaline was prepared by taking sodium silicate and sodium hydroxide keeping in view, the ratio of sodium silicate to sodium hydroxide in their dry mass as 2.The prepared alkaline material(S) was added in varying percentages (2%, 4%, 6%, 8% and 10%) with 25% Flyash by dry weight of total solids to black cotton soil.

The Alkaline material taken in (2%,4%,6%,8%,10%) with Flyash 25% by dry weight of total solids was also added with Black Cotton soil. Then, Atterbergs limits, optimum moisture content (OMC), maximum dry density(MDD), unconfined compression test(UCS) and California bearing ratio test(CBR) of different samples were experimentally investigated and compared with Black Cotton soil.

California bearing ratio test(CBR) was conducted on two soil samples such as unsoaked, soaked conditions. Soaked soil sample is tested after curing of 4days.

The process of improvement in properties of black cotton soil split into two stages. The First stage of this study deals with, the Flyash was added in varying percentages (5%, 10%, 15%, 20%, 25%, 30%, 35% and 40%) by dry weight of total solids to black cotton soil. Then Optimum moisture content (OMC), Maximum dry densty(MDD), Unconfined compressive strength(UCS) and California bearing ratio test(CBR) of different samples were experimentally investigated and compared with only Black Cotton Soil samples. The Maximum dry density (MDD) for maximum Black Cotton Soil added with Flyash is 25%.

The second stage of this study deals with, by fixing 25% Flyash and % varying of Alkaline material (2%, 4%, 6%, 8% and 10%) by dry weight of total solids to black cotton soil . Then Optimum moisture content(OMC), Maximum dry densty(MDD), Unconfined compressive strength(UCS) and California bearing ratio test(CBR) of different samples were experimentally investigated and compared with only Black Cotton Soil samples.

7. Results & Discussion

Results of experimental tests show that the strength values of the Geopolymer treated soils mainly depend on four factors: (1) type of soil, (2) dehydration (e.g., moisture content), (3) Geopolymer and (4) mixing method.

7.1 Effect of Geopolymer on UCS of Soil:

The UCS value increased with increasing Alkaline material such as 2% 4% 6% 8% and 10%.

Table 2: Unconfined compression test for Black Cotton Soil +25% Flyash +Varying % Alkaline material.

S. No	Properties	Unconfined Compressive Strength (kg/cm2)	Shear Strength (kg/cm2)
1	B.c soil + 25% Fly ash + 2% Alkaline material	1.254	0.627
2	B.c soil + 25% Fly ash + 2% Alkaline material	1.268	0.634
3	B.c soil + 25% Fly ash + 2% Alkaline material	1.294	0.647
4	B.c soil + 25% Fly ash + 2% Alkaline material	1.316	0.658
5	B.c soil + 25% Fly ash + 2% Alkaline material	1.340	0.670
6	B.c soil + 25% Fly ash + 2% Alkaline material	1.356	0.678

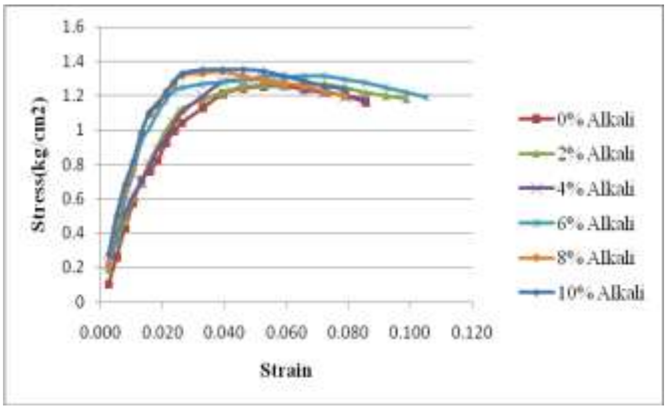

Figure 3: Stress Strain Behaviour of Black Cotton Soil +25% Flyash +Varying % of Alkaline material.

Unconfined Compressive Strength (UCS) of the soil, 25% Flyash and Alkaline material with varying content of Alkaline material is observed. The graph shows the variation of UCS with changing Alkaline material. it was observed that UCS value was increased with increasing alkaline material.

7.2 Effect of Geopolymer on CBR of Soil:

The CBR value increased with increasing Alkaline material such as 2% 4% 6% 8% and 10%. California bearing ratio test(CBR) was conducted on two soil samples such as unsoaked, soaked conditions. Soaked soil sample is tested after curing of 4days.

Table 3: Unsoaked & Soaked CBR Values for BC Soil + 25% of Lime + Varying Percentages of Alkaline material

S.No	Properties	CBR (soaked)(%)	CBR (unsoaked) (%)
1	B.c soil + 25% Fly ash	9.12	6.94
2	B.c soil + 25% Fly ash + 2% Alkaline material	10.34	7.66
3	B.c soil + 25% Fly ash + 4% Alkaline material	11.28	8.65
4	B.c soil + 25% Fly ash + 6% Alkaline material	11.89	9.41
5	B.c soil + 25% Fly ash + 8% Alkaline material	12.57	9.92
6	B.c soil + 25% Fly ash + 10% Alkaline material	13.11	10.76

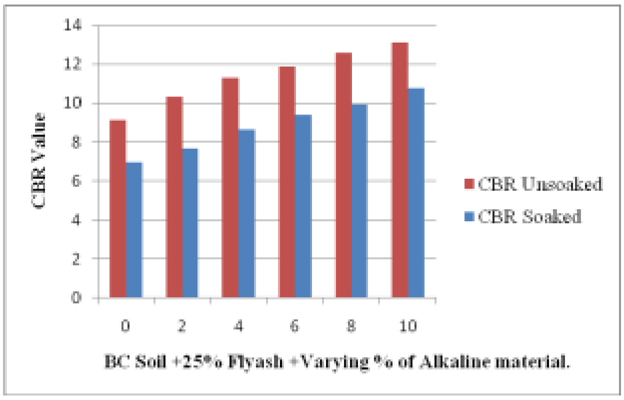

Figure 4: Variation of CBR Soaked & Unsoaked Values for BC Soil + 4% Flyash + % Varying % of Alkaline material.

Both un-soaked and soaked California Bearing Ratio (CBR) tests are conducted with 25% Flyash and varying content of Alkaline material in the black cotton soil. From the graphical comparison of these values against the varying Alkaline material, it can be observed that the CBR values in un-soaked and soaked was increased with increasing alkaline material.

8. Conclusion

Based on the results obtained and comparisons made in the present study, the following conclusions can be drawn:

1) Thus, fly ash as an additive decreases the swelling, and increases the strength of the black cotton soil.
2) Standard compaction test for the soil-fly ash mixture varied with the changing fly ash content. it was observed that optimum moisture content and Maximum Dry Density (MDD) was initially decreased with the addition of fly ash. Then, optimum moisture content increment with increasing fly ash content in the soil-fly ash mixture. Then Maximum Dry Density (MDD) decrease with increasing fly ash content in the soil-fly ash mixture. Maximum Dry Density (MDD) was found to change with varying content of flyash, Then highest value observed being at fly ash content of 25% by weight.
3) Standard compaction test for the soil, 25% fly ash and alkaline material mixture varied with the changing alkaline material. it was observed that optimum moisture content was decreased with the addition of alkaline material and Maximum Dry Density (MDD) was increased with increasing alkaline material.
4) Unconfined Compressive Strength (UCS) of the soil is observed. The graph shows between the stress-strain behaviour of Black Cotton soil. The maximum value of UCS was obtained with soil is 1.122kg/cm2.
5) The Unconfined Compressive Strength (UCS) of the soil with variation of fly ash content showed similar trend as that of the MDD values, except the fact that the peak value was observed for a fly ash content of 25% by weight.
6) The change in Unconfined Compressive Strength (UCS) of the soil, 25% Flyash and Alkaline material with varying content of Alkaline material is observed. The graph shows the variation of UCS with changing Alkaline material. it was observed that UCS value was increased with increasing alkaline material.
7) California bearing ratio value is observed. The graph shows between the load verses settlement of Black Cotton Soil. The maximum Unsoaked and soaked CBR values are obtained with soil is 3.45and 2.38 respectively .
8) In un-soaked and soaked California Bearing Ratio (CBR) tests of soil conducted with varying fly ash content, Then the CBR values increased gradually with the increase in fly ash content till its valuation was 25% by weight of the total mixture respectively. The values decreased thereafter.
9) In un-soaked and soaked California Bearing Ratio (CBR) tests of soil conducted with 25% fly ash content and varing % of alkaline material, Then the CBR values increased gradually with the increase alkaline material by weight of the total mixture respectively.

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