Enhancing Index and Strength Properties of Black Cotton Soil using Combination of Geopolymer and Flyash

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Abstract. A Combination of admixtures - fly ash and Geopolymer are used for stabilization of black cotton soil. Black cotton (BC) soils are mainly clayey soils having montmorillonite as their clay mineral. The moisture changes in BC soils will affect compressibility and strength characteristics, which are greatly enhanced with the addition of combination of Flyash (FA) and Geopolymer (GP). The evaluation study includes analysis of soil properties some of index properties like specific gravity, liquid limit, shrinkage limit and Uniaxial compression values. Different percentages of combination of admixtures (percentage by dry weight) are added to natural BC soil and further experiments are performed from these soil mix ratios (MR). The results show that the utilization of combination of admixtures decreases liquid limit by enormously and increases unconfined compressive strength i.e. the strength of the soil.

1. Introduction

Expansive soil is one of the most desolation types of soil damaging highways, buildings, and other infrastructural facilities. Various attempts are being done to stabilize the soil and reduce the blows due to it [10]. Several factors affects every year have driven to surge in the many people in recent years immigrate to metropolitan cities. Obviously cities are massively occupied and have necessitated civil engineers to tackle problems of construction in localities with black cotton soils [2]To tackle this a novel method has been introduced several years ago is soil stabilization which is a technique/framework designed with the main aim to deliver the soil capable of meeting the requirement of specific engineering outcomes of projects. The approach of stabilizing soil is often used to improve many geotechnical properties of soils by prior knowledge of using chemical stabilizers such as lime, cement or industrial by products such as fly ash and a chemical Geopolymer etc are involved in improving expansive soils. Many of researcher’s results showed that methods perform with sufficient reliability when used in real time problems.

Therefore in this study an attempt has been made to understand effect of combination of GP and FA in different percentages in improving black cotton soil. Various index properties and UCS has been studied.
2. Literature Review

Gandhi K. S. (2012) performed research on soil of Surat region on to advancing expansive soil strength, by using byproduct of sugar cane industry i.e bagasse ash added in different percentages which improves the stability of expansive soil and reducing the swelling potential of the soil[12]. Akshaya Kumar S (2012) had conducted work on the effects of combination of two industrial byproducts such as bagasse ash and lime sludge on various engineering properties like compaction characteristics, unconfined compressive strength (UCS), California bearing ratio in soaked condition (CBR) and expansive soil swelling pressure of an have been discussed. Effects of moulding water content and compaction delay on soaked CBR of bagasse ash, lime sludge stabilized expansive soil [11]. P.Dilip Kumar Rao & Srinivas Ganta (2016) the effectiveness of geopolymer is studied in terms of unconfined compressive strength (UCS), differential free swelling (DFS), swelling pressure (SP), durability and dispersion tests. The swelling pressure got reduced by 97.14% finally with addition of 40% fly ash and 15% bentonite. From UCS and durability test it is observed that bentonite added with 40% fly ash and 10% solution gave better results. The effectiveness of biopolymer is studied based on UCS tests on dispersive soil and pond ash at their moisture content. Partha Sarathi Parhi et.al (2019) Different combination of sodium hydroxide and sodium silicate were used in terms of Na2/SiO2 ratio. The activator to ash ratios (liquid to solid mass ratio) was also varied with different percentage of class F fly ash percentage. The various percentages fly ash (20, 30 and 40%) relatively to the total solids of the expansive soil are used. The activator to ash ratios (liquid to solid mass ratio) was kept between 1 and 2.5. The effectiveness of this binder is discussed in terms of unconfined compressive strength [10].

3. Materials and Methodology:

3.1 Black Cotton soil: For conducting various tests the soil procurement was done from a village ‘Hebsur’ near Hubli, Karnataka state. The soil was excavated up to 1.5 feet deep and after confirming uniform soil stratum sample was collected. The basic soil properties were listed below in table 1.

| No | Properties                        | Experimental Values |
|----|-----------------------------------|---------------------|
| 1. | Grain Specific gravity (Gs)       | 2.45                |
| 2. | Particle size distribution        |                     |
|    | Gravel Size (%)                  | 2                   |
|    | Sand Size (%)                    | 10.64               |
|    | Silt and Clay Size (%)           | 87.96               |
| 3. | Consistency Limits               |                     |
|    | Liquid limit (LL) (%)            | 84.00               |
|    | Shrinkage limit (SL) (%)         | 13.16               |
| 4. | Compaction Properties            |                     |
|    | Moulding water Content (%)       | 21                  |
|    | Highest dry density (g/cc)       | 1.48                |
| 5. | Uniaxial Compressive Strength (N/mm²) | 0.056              |
3.2 Fly Ash: Fly ash is an industrial waste obtained from thermal power plants due to incinerating of pulverized coal which is also a material of pozzalonic characteristics. FA was brought from the industrial area PENYA Bangalore Karnataka. The various property of the Fly ash has been mentioned below as given by the supplier is shown in table 2.

| Property of Flyash | Values |
|--------------------|--------|
| Specific gravity   | 2.21   |
| Blaine fineness (cm²/g) | 2351 |
| Percent retained on 45 μm sieve | 32 |
| Percent retained on 90 μm sieve | 14.4 |

3.3 Geopolymer: Geopolymer is a blend of Sodium hydroxide and Sodium silicate. The combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate is used as common alkaline activator used in geo-polymerization process. The sodium silicate activator dissolves rapidly and begins to bond with another byproduct from thermal industry FA particles.

3.4 Preparation of test specimen & Testing Programme: BC soil sample is taken, dried and stabilizing agents are added in 2%, 4% and 6% to the soil by its dry weight and various tests will be performed according to IS 2720:1980.

Figure 1: Materials for testing and specimen preparation, Testing
Following testing program was used in the study.

Table No: 3 Testing Program used in the study

| Sl. No | Mix Proportion       | Number of tests performed |
|-------|----------------------|---------------------------|
|       |                      | Specific Gravity (G) | Liquid limit (WL) | Shrinkage Limit (Ws) | Uniaxial Compressive strength |
| 1     | Natural BC soil+ 2%(FA+GP) MR-1 | 1 | 2 | 2 | 2 |
| 2     | Natural BC soil+ 4%(FA+GP) MR-2 | 1 | 2 | 2 | 2 |
| 3     | Natural BC soil+ 6%(FA+GP) MR-3 | 1 | 2 | 2 | 2 |

4. Results and Discussions

4.1 Specific Gravity Test: IS 2720 Part 2 procedure is used to perform Specific gravity test. Test results are summarized in table 4.

Table No: 4 Specific gravity test results

| Mix Proportion | Results obtained |
|----------------|------------------|
| Natural BC Soil | 2.45             |
| MR-1           | 2.51             |
| MR-2           | 2.58             |
| MR-3           | 2.72             |

From the above results its observed increase in admixture proportion has increased in specific gravity values of BC soil that may be due to pozzalonic reaction between GP and FA with the soil.

4.2 Liquid Limit test: Using Casagrande apparatus liquid limit variation is observed with various percentages of combination FA and GP. Following results were observed and shown in table 4.

Table No: 5 Liquid Limit test results

| Mix Proportion | Results obtained |
|----------------|------------------|
| Natural BC Soil | 84%              |
| MR-1           | 70%              |
| MR-2           | 65%              |
| MR-3           | 53%              |

It’s observed from above results that additions of mixture of GP & FA are very much effective in reducing liquid limit of soil. Results show that increase in percentages of admixtures is decreasing Liquid limit of BC soil which is very effective in controlling compressibility characteristics of expansive soils.

4.3 Shrinkage Limit test: Shrinkage soil specimens were prepared by adding different percentages of admixtures to natural soil, according to standard procedure afterword’s Mercury displacement tests are done.
Table No: 6 Shrinkage Limit test results

| Mix Proportion | Results obtained |
|----------------|------------------|
| Natural BC Soil| 13.16            |
| MR-1           | 13.05            |
| MR-2           | 12.78            |
| MR-3           | 12.07            |

From the above results shown in table 6 it’s been observed that a combination of mixture of admixtures is moderately reduces shrinkage limit values of natural soil.

4.4 Unconfined Compression test: Shear strength is an important property of soil which shows its load bearing capacity. Specimens were prepared by adding the optimum water content and maximum dry density obtained from the test in a compaction and then specimens were obtained by sampling tube using specimen extractor or alternatively remoulded specimens were prepared by pressing soil in split mould the adding optimum water content obtained from compaction test on natural BC soil. Following were test results obtained from UCS test which was conducted using strain controlled instrument using strain at rate of 1.25 mm/min till specimen shows failure sign essentially by breakage.

Table 7 Uniaxial Compressive strength test results

| Mix Proportion | Results obtained in N/mm² |
|----------------|---------------------------|
| Natural BC Soil| 0.056                     |
| MR-1           | 0.040                     |
| MR-2           | 0.095                     |
| MR-3           | 0.083                     |

It’s observed from above results shown in table 7 that additions of mixture of GP & FA are very much effective in improving unconfined compressive strength of soil. Results show that increase in percentages of admixtures is increase compressive strength of BC soil till 4% of FA+GP, which is very effective in shear strength characteristics of expansive soils.

5. UCS and Liquid limit test graphs
The Unconfined compressive strength (UCS) tests conducted with different percentages of combination of admixtures are shown in figure 2. The variation of liquid limit for different percentages of combination of admixtures is shown in figure 3.

Figure 2: Comparison of UCS results for varying combination of flyash and geopolymer blended with BC soil
6. Concluding Remarks
Following conclusions can be drawn from this experimental study:

- A combination of FA+GP admixtures under current study was effective stabilizers in improving properties of BC soils. It’s observed from results of various tests from the study.
- Uniaxial compressive strength values were enormously increased and 4% of FA+GP combination found to be more effective in improving BC soils. The 4% of FA+GP combination has resulted in increase in 69% compressive strength compare to its natural strength.
- BC soil liquid limit values were greatly decreased with increase in different percentages of FA+GP combination which is very important in reducing volume changes in the soil.

References:
[1] Ajay Goyal, Hattori Kunio, Ogata Hidehiko, Mandula, 2007, Report submitted to Tottori university “Properties and Reactivity of Sugarcane Bagasse Ash” Department of Environmental Engineering, United Graduate School of Agricultural Sciences, Tottori University
[2] Akshaya Kumar Sabat, 2012, Electronic journal of Geotechnical Engineering, “Utilization of Bagasse Ash and Lime Sludge for Construction of Flexible Pavements in Expansive Soil Areas” pp 1037-1046
[3] Anma.O, Ogunnyi S.A, Oladeji, Department of Civil Engineering, 2011, American Journal of Scientific and Industrial Research “Geotechnical properties of lateritic soil stabilized with sugarcane straw ash” pp 323 – 331.
[4] J. Osinubi, M. A. Oyelakin A. O. Eberemu1, 2011, Nigerian National Engineering Conference “Improvement of Black Cotton Soil with Ordinary Portland cement - Locust Bean Waste Ash Blend”
[5] Ken C. Onyelowe, 2012, Material Science “Cement Stabilized Akwuete Lateritic Soil and the Use of Bagasse Ash as Admixture” Vol-1 issue-2, pp 1025-1031
[6] Mohammed Abdullah Mu’azu, 2007, Leonardo Journal of Sciences “Evaluation of Plasticity and Particle Size Distribution Characteristics of Bagasse Ash on Cement Treated Lateritic Soil” pp 137-152.
[7] Mohammed Abdullah, 2007, Leonardo Electronic Journal of Practices and Technologies “Influence of Compactive Effort on Bagasse Ash with Cement Treated Lateritic Soil” pp 79-92
[8] Mtallib M.O.A, Bankole G.M, 2011, Electronic journal of geotechnical engineering The Improvement of the Index Properties and Compaction Characteristics of Lime Stabilized Tropical Lateritic Clays with Rice Husk Ash (RHA) Admixtures. Vol.16 pp 986 – 996.
[9] IS: 2720 -1980, “Geotechnical engineering laboratory testing compendium.” Bureau of Indian Standards, New Delhi.
[10] Parhi P.S., Garanayak L., Mahamaya M., Das S.K., 2018, “Stabilization of an Expansive Soil Using Alkali Activated Fly Ash Based Geopolymer”. In: Hoyos L., McCartney J. (eds) Advances in Characterization and Analysis of Expansive Soils and Rocks. GeoMEast 2017. Sustainable Civil Infrastructures, Springer, Cham.

[11] P. Dilip Kumar Rao & Srinivas Ganta, 2016, AJREAS, “Soil stabilization using geopolymer and biopolymer” Vol. 1, Issue 10, ISSN-2455-6300, pp 280-289.

[12] K. S. Gandhi, 2012, “Expansive Soil Stabilization Using Bagasse Ash” IJERT, Vol. 1 Issue 5, July – 2012, pp. 1-3.