Utilisation of Recycled Glass Powder for the Stabilization of Black Cotton soil by Alkali Activation

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Abstract. Black Cotton Soil forms a major soil group in India. It covers 20% of the total area of India. Due to its high swelling and shrinkage characteristics, Black cotton soil has been challenging for construction activities. To overcome the problems caused by black cotton soil, the soil needs to be stabilized. Stabilization increases the strength of soil and controls the swell and shrinks potential of soil thus improving the load bearing capacity of soil. Lime and Cement are commonly used additives in soil stabilization. The production of commonly used additives like lime and cement contributes to a higher carbon footprint. Recycled glass powder is a construction and demolition waste. Recycled glass powder is rich in Silica and Alumina, thereby on addition of an alkali; it forms a geopolymer that enhances the strength of the soil. In this study Recycled glass powder is added in the proportions of 0%, 3%, 6%, 9%, 12%, 15% and 18 % along with Sodium Hydroxide and Sodium Silicate in the ratio of 1:2.5 to the Black cotton soil to facilitate the geopolymerization reaction. The effect of Recycled glass powder based geopolymer on the strength of Black cotton soil for the curing period of 3 and 7 days is investigated. The Unconfined compressive strength of Black cotton soil increases with the increase in proportion of geopolymer up to an optimum value of 9%. With the increase in curing time the strength of Stabilized Black cotton soil increases. A Recycled glass powder based geopolymer can be used as an effective soil stabilizer.

1. Introduction

Expansive soils such as Black cotton soils are clays having high compressibility. Black cotton soils are a part of the major soil group in India. They cover about 20% of the total area of India. Black cotton soils are characterized by their high shrinkage property and swelling property. [1] Black cotton soil contains a relatively high percentage of clay, in the form of montmorillonite. During monsoons, the soil imbibes water and swells up and its capacity to bear water is reduced. While in summers, the soil shrinks
due to the evaporation of water. [6] Black cotton soil is considered to have a potential natural hazard, which when not stabilized can cause damage to the structures built over the soil. [3]

Soil stabilization is the process of treating the soil in order to alter and improve the behaviour of the soil. [6] Soil stabilization can be achieved by the incorporation of additives or by the mechanical blending of various soil types. Stabilization increases the shear strength capacity of the soil and it controls the shrinkage and swelling properties of the soil, thereby improving load bearing capacity of the soil. [2, 5, 6, 7]

Geopolymerization is the reaction between a source of alumino-silicate and an alkaline solution to produce a complex geopolymer. [9, 10] Stabilization of soils by geopolymerization has a lower environmental impact than stabilization by conventional methods. [8, 9] It is an alternate approach to stabilization of expansive soil. The Most common method to form a geopolymer is by direct mixing of aluminosilicate with the alkaline solution.

In the present study, The Black cotton soil is stabilized by mixing Recycled Glass powder with a combination of Sodium hydroxide (NaOH) and sodium silicate (Na$_2$SiO$_3$) to facilitate geopolymerization reaction. The effect of the Recycled glass powder based geopolymer on the strength of the black cotton soil is investigated upon curing for a period of 3 and 7 days. The feasibility of the Recycled Glass powder based geopolymer as an effective soil stabilizer is evaluated.

2. Materials and Methodology

2.1. Black Cotton Soil (BCS)

About 40kgs of Black Cotton Soil (BCS) which was used in the present investigation was collected by making an open excavation from a depth of 1 meter from the natural ground from Charantimath Gardens, Dharwad (Karnataka). The extracted BCS was oven dried for a period of 24 hours. The characteristics of the Black cotton soil are as shown in Table 1.

| Characteristics of the Black Cotton Soil |
|----------------------------------------|
| Specific Gravity                        | 2.53 |
| Free Swell Index                       | 50%  |
| Liquid Limit                           | 74.40% |
| Plastic Limit                          | 34.97% |
| Plasticity Index                       | 39.43% |
| Optimum Moisture Content               | 18%  |
| Maximum Dry Density                    | 1.34 kN/m$^3$ |
| Unconfined Compressive Strength        | 73.263 kN/m$^2$ |

2.2. Recycled Glass Powder (RGP)

Recycled Glass powder is a source that is rich in silica and alumina thereby it facilitates the Geopolymerization reaction. [4] The Recycled Glass powder that was used in the present investigation was collected from a seller in Madurai, India.
2.3. The Alkaline solution
A combination of Sodium silicate (Na$_2$SiO$_3$) and sodium hydroxide (NaOH) in the ratio 1:2.5 was used in the present study. [1]

2.4. Methodology
Recycled Glass powder in the proportion of 3%, 9%, 12%, 15% and 18% was added by weight to the soil and mixed thoroughly to obtain a homogenous mixture, the alkaline solution of Sodium hydroxide and Sodium silicate was added to this mixture to initiate the geopolymerization reaction. The prepared stabilized samples were air cured at room temperature for the period of 3 and 7 days. Unconfined Compression strength test was conducted on the cured samples.

3. Results

3.1. The Effect of Recycled Glass powder based geopolymer on the strength of Black Cotton Soil.

The Raw BCS is treated by varying percentages of Glass powder. The raw BCS is stabilized with 3%, 6%, 9%, 12%, 15%, and 18% Glass Powder. The UCS of all the samples is determined. From Fig 2, it is observed that for the stabilized soil samples cured for the period of 3 days and 7 days, the compressive strength increased with the increase in the addition of Glass Powder to BCS up to 9% GP and decreased further on. Therefore the optimum values of compressive strength for both 3 days and 7 days cured samples as seen from Fig 2 are 410.31(kN/m$^2$) and 530.18(kN/m$^2$) respectively. The optimum value of Glass Powder to be added to the BCS to get maximum strength is 9% GP.

| Soil Sample  | 3 Day Strength (kN/m$^2$) | 7 Days Strength (kN/m$^2$) |
|--------------|--------------------------|----------------------------|
| Raw BCS      | 73.263                   |                            |
| BCS + 3% GP  | 247.67                   | 268.7                      |
| BCS + 6% GP  | 332.62                   | 408.29                     |
| BCS + 9% GP  | 410.31                   | 530.18                     |
| BCS + 12% GP | 360.63                   | 516.56                     |
| BCS + 15% GP | 340.76                   | 417.67                     |
| BCS + 18% GP | 308.31                   | 370.88                     |
3.2. The Effect of Curing Time on the Strength of Black Cotton Soil.

The stabilized soil samples are Air cured for 3 and 7 days at room temperature, and the unconfined compressive strength of the samples after curing are determined. From Fig 3, it is observed that the stabilized samples cured for a period of 7 days exhibited higher compressive strength than the samples that are cured for a period of 3 days. With an increase in curing time the unconfined compressive strength of the samples increases. Curing time has a significant effect in strengthening the soil.

4. Conclusion

Being a problematic soil, Construction over the black cotton soil is quite challenging. The soil once stabilized will overcome its problems. The conclusions drawn based on the present investigations are as follows.
1. The Unconfined compressive strength of the treated soil samples is found to be increasing with increase in geopolymer dosage; Increase in Recycled glass powder up to an optimum value of 9% increased the UCS of the specimens.
2. Increase in curing time of stabilized specimens increases the UCS value of soil. Stabilized samples that were cured for 7 days exhibited a higher UCS values than samples that were cured for 3 days.
3. The Recycled Glass powder based geopolymer is effective in increasing the strength of the soil and hence can be used as a soil stabilizer.

5. References

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