An Experimental Investigation of Properties of Black Cotton Soil treated with Copper Slag and Groundnut Shell Powder

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Abstract: Expansive soils have large volume changes due to the variation of water content. Therefore expansive soils are also known as problematic soils due to its expansive nature. The black cotton soil has very low bearing capacity, high plasticity, high compressibility, low permeability and high swelling and shrinkage properties due to the presence of montmorillonite mineral. Due to these properties, black cotton soils are problematic soils. Therefore it is necessary to improve its properties by using soil stabilization method. This study aims at conducting stabilization of black cotton soil of Bharuch region in Gujarat state by using combination of two soil stabilizing agents; copper slag and groundnut shell powder. In this research, copper slag is added 5% and 10% and Groundnut shell powder is added 2% and 4% respectively. The research gives comparison between the soil properties of non-treated and treated black cotton soil. Various laboratory tests are carried out such as specific gravity, liquid limit, plastic limit, shrinkage limit, free swell index, standard proctor compaction test, unconfined compressive strength test for both the cases by taking IS:2720 as reference. These laboratory tests results can be helpful to engineers to carry out soil stabilization on field during construction.

Keywords: Black cotton soil, Copper Slag, Groundnut Shell Powder

1 Introduction

Black cotton soil is a one type of expansive soil and is a one of the major deposits of India. Black cotton soil is found in Gujarat, Maharashtra, Uttar Pradesh, Madhya Pradesh, Andhra Pradesh, Tamilnadu and Karnataka. Black cotton soil is produced geologically by the decomposition of volcanic rock and is very rich loamy earth of great productiveness and abnormal power of retaining moisture. Black cotton soil is a one type of clayey soil because of presence of montmorillonite mineral in this soil which expands when it comes in contact with water and it shrinks when the water is evaporated. Therefore black cotton soil expands during monsoon and shrinks during

summer season due to intake of water respectively. Black cotton soil has large volume changes due to the variation of water content. The soil indicates high shrink-swell characteristics with surface cracks, opening during the dry seasons which are more than 50mm or more wide and several mm deep. These cracks close during the wet season and an uneven soil surface is produced by irregular swelling and heaving [4]. The colour of this soil varies from deep black to light black due to presence of iron and aluminum compounds. The soil has low bearing capacity, low permeability, high plasticity and high swelling and shrinkage properties. In south Gujarat black cotton is found in Bharuch, Valsad, Vadodara, Surat, and Junagadh as deep black cotton soil. The heavy loaded structures are most susceptible to damages as a result of volume changes. Because of the swelling and shrinkage characteristics of soil, therefore treatment of the soil or special design needs to be adopted. To improve properties and increase the strength of soil, soil stabilization method is used. The main aim of soil stabilization is to improving the load bearing capacity, shear strength, foundation by using materials and chemicals or by using proportions and the addition of suitable admixture like stabilizers. The copper slag and groundnut shell powder are two soil stabilizer agents which are used to improve strength of soil. Waste & industrial by-products of copper utilize in the soil stabilization of civil constructions. Copper slag can be used as a building material, formed into blocks. Copper slag is widely used as an abrasive media to remove rust, old coating and other impurities in dry abrasive blasting due to its high hardness (6-7 Mohs), high density (2.83.8 g/cm3) and low free silica content [13]. Groundnut contains about 25% Protein and 45 to 50 % oil. Groundnut shells contain high cellulose (37%), hemi cellulose (18.7%), Lignin (28%) and carbohydrates (2.5%) content, which increase the efficiency of fermentation and provide better yield [5]. Lignin prevents the absorption of water which used as coatings, agricultural chemicals, micronutrients, natural binders, adhesives, resins [11]. In this research, to used copper slag (CS) and groundnut shell powder (GSP) to improve the engineering performance of Black Cotton soil which may be an economical solution of soil stabilization.

Copper slag and steel slag are used as stabilizing agents in the stabilization of black cotton soil. The specific objectives of this study to determine the index and engineering properties of the soil samples and determined the optimum % of copper slag and steel-slag content required. All tests were carried out in accordance with the procedures outlined in BS 1498 (1970) for the natural and treated soils, respectively [10].

The UCS of the treated black cotton soil with groundnut shell ash did not improved properties of soil [4]. Alkaline treated groundnut shell powder has been shown to improve the mechanical properties of GSP-recycled polyethylene composites, with a treated GSP of 20% weight fraction recycled polyethylene composite having the highest mechanical properties. This treated sample also has a lower rate of water absorption and this shows that composites produced with alkaline treated GSP and smaller particles are better materials for their intended applications [14].

1.1 Objectives of the study

- To study the combined effects of copper slag and groundnut shell powder on properties of black cotton soil.
- To improve the engineering properties of black cotton soil.
- To reduce the plasticity of the black cotton soil.
- To determine the unconfined compressive strength of BC soil mixed with different percentages of copper slag and groundnut shell powder.

2 Materials and Methods

2.1 Materials

Black Cotton Soil. : Black cotton soil is a one type of clayey soil because of presence of montmorillonite mineral in this soil which expands when it comes in contact with water and shrinks when the water is evaporated. The black cotton soil was collected at a depth of 2 m from Rahadpor village near Nandelav Part in Bharuch city. The Bharuch city located in South Gujarat area of India which having top layer of black cotton soil. Around 20 kg of black cotton soil was used. The properties of Non-treated Black Cotton Soil are as given below:

Table 1. Properties of Non-Treated Black Cotton Soil

Properties	**Black Cotton Soil**
Colour	Grayish Black
Water Content (%)	8.45
Specific Gravity	2.36
Liquid Limit (%)	60.33
Plastic Limit (%)	23.91
Plasticity Index (%)	36.42
Shrinkage Limit (%)	3.60
Soil Classification	CH
Free Swell Index (%)	62.33
Compaction Test: Standard Proctor Test: Maximum Dry Density (g/cc)	1.529
Optimum Moisture Content (%)	23.9
Unconfined Compressive Strength (Kg/cm^2)	2.51

Copper slag. : Copper slag is a by-product of copper release by smelting. During smelting, impurities become slag which floats on molten metal. Copper slag was col-

lected from Nice Treading Company, Harni, Vadodara. 15 kg copper slag is used to conduct experiments.

Fig. 1. Copper Slag

Copper slag is used passed through 600 microns IS sieve. The proportion of copper slag mixed with black cotton soil is in the range of 5% and 10%.

Table 2. Chemical composition of copper slags determined by X-ray fluorescence [9]

wt.%	**Min**	**Max**
Al_2O_3	0.01	18.9
CaO	0.15	21.9
FeO total	0.67	62.0
K_2O	0.01	4.83
MgO	0.09	6.45
MnO	0.03	6.55
Na_2O	0.01	4.31
SiO_2	9.82	70.7
TiO_2	0.1	11.8

Groundnut shell Powder. : The groundnut shell powder is produced by the best grade ground nut shell. It contains high level of nutrients like Ca, Mg, K, P, Na, S and the micro-nutrients Mn, Cu, Zn, Mo, B, Cl, and Fe. [7]. The chemical compositions of groundnut shell powder are contains Organic matter (92%), Ash content (3.8%), Crude protein (5.4%), Crude fat (0.1%), Lignin (36.1%), Hemicellulose (5.6%) Cellulose (44.8%) [12]. Groundnut shell powder was collected from KD Oil Mill, Jambuva, Vadodara. 10 kg groundnut shell powder is used to conduct experiments.

Fig. 2. Groundnut Shell Powder

Groundnut shell powder is used passed through 600 microns IS sieve. The proportion of groundnut shell powder mixed with black cotton soil is in the range of 2% and 4%.

2.2 Methods

Various Laboratory tests are performed such as specific gravity, atterberg's limits, free swell index, standard proctor compaction test and unconfined compressive strength with IS 2720 references. These tests are performed with non-treated soil and compared with treated soil with different percentage of proportions as below:

Table 3. List of various proportions

Soil (% by weight)	Copper Slag (% by weight)	Groundnut shell Powder (% by weight)
100	0	0
93	5	2
86	10	4

Specific Gravity. : To perform specific gravity, 10g of oven dried soil samples are taken and transfer it carefully to the density bottle. Take the weight of empty weight of density bottle (M_1), weight of dry soil with density bottle (M_2), weight of density bottle with dry soil and water (M_3) and weight of density bottle with water (M_4). For 93% BC soil (9.3 g), 2% groundnut shell powder (0.2 g), 5% copper slag (0.5 g),test were performed as per IS 2720-3(1980). The specific gravity is calculated as below:

$$G = \frac{M_2 - M_1}{(M_4 - M_1) - (M_3 - M_2)}$$

Atterberg's Limits. : To perform Liquid Limit & Plastic Limit**,** 300 g sample required for conducting the experiment for each proportions. For 93% of soil by weight (279 g), 2% groundnut shell powder (6 g), 5% copper slag (15 g) and for 86% of soil by weight (258 g), 4% of groundnut shell powder (12 g) and 10% copper slag (30 g) were taken which are passed through 425 microns IS sieve and mixed as per IS 2720-5(1985). Shrinkage Limit test was performed as guidelines require in IS 2720-6(1972).

Free Swell Index. : To perform this test, 20 g of oven dried soil specimens passing through 425 microns IS sieve and 10 g of soil specimen should be poured two glass cylinders of 100ml capacity. One cylinder shall be filled with kerosene and the other with distilled water up to 100ml mark. After 24 hours to take the reading and determine the volume of soil in both cylinder. For this paper 93% BC soil (18.6 g), 2% groundnut shell powder (0.4 g), 5% copper slag (1 g) and 86% BC soil (17.2 g), 4% groundnut shell powder (0.8 g), 10% copper slag (2 g) proportions were used to make a soil specimens and test were performed as per IS 2720-40(1977).

Standard Proctor Compaction Test.: Tests were performed as per IS 2720-7(1980) for standard proctor test. The sample is mixed thoroughly with soil, copper slag and groundnut shell powder. Water content is added from 10%, 13%, 16%, 19%, 22%, 25% and 28% by weight of the sample. Then mix is placed in the mould and compacted in three layers and each layer was compacted using 2.6 kg rammer under a free fall of 310cm.This Process is continuing till the weight of soil decreases with increment of water added and a graph is plotted between dry density and moisture content.

Unconfined Compressive Strength Test.: The aim of this test is to determine a compressive strength of soils as per IS 2720-10(1991) specifications. The soil specimen is prepared with adding optimum water content and weight of soil required based on maximum dry density.

3 Observations And Results

3.1 Properties of treated black cotton soil & compared with properties of non-treated black cotton soil:

Specific Gravity:

Table 4. Specific Gravity

Proportions	Specific Gravity
100% BC soil, 0% GSP, 0% Copper Slag	2.36
93% BC soil, 2% GSP, 5% Copper Slag	2.09
86% BC soil, 4% GSP, 10% Copper Slag	2.01

Free swell Index:

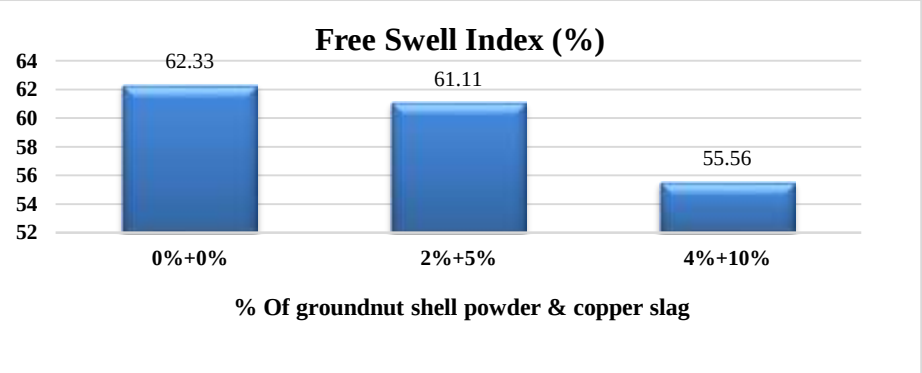

Fig. 3. Graph of Free Swell Index

Atterberg's Limit:

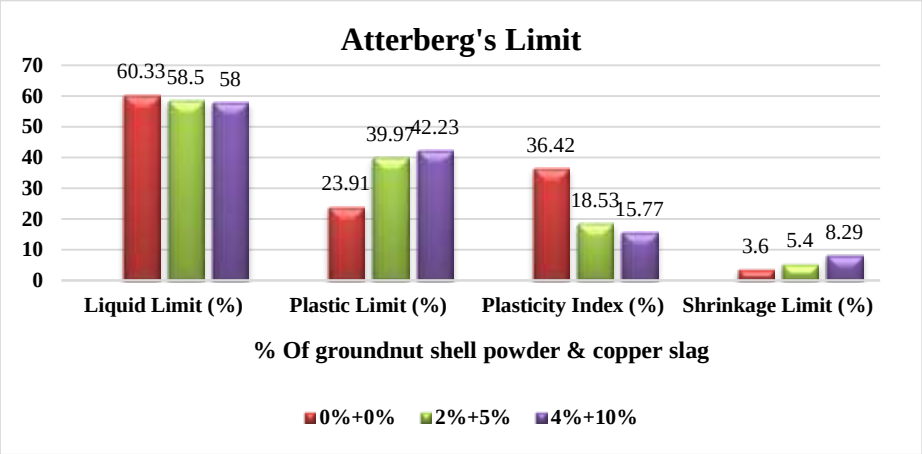

Fig. 4. Graph of Atterberg's Limit

Standard Proctor Compaction Test:

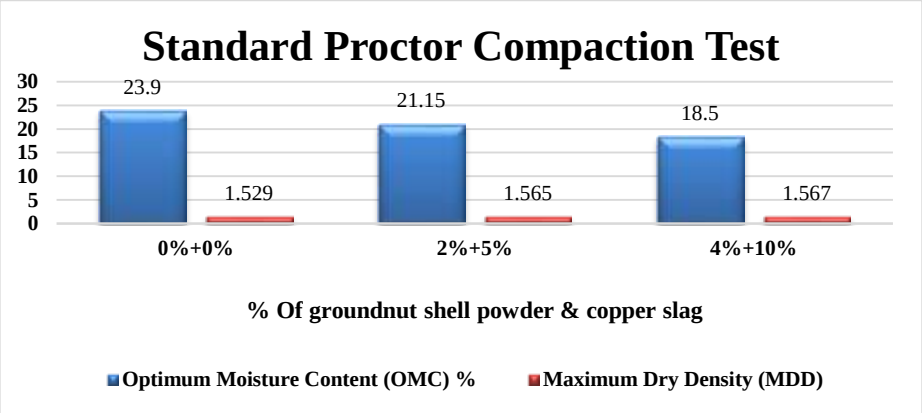

Fig. 5. Graph of Standard Proctor Compaction Test

Unconfined Compressive Strength Test:

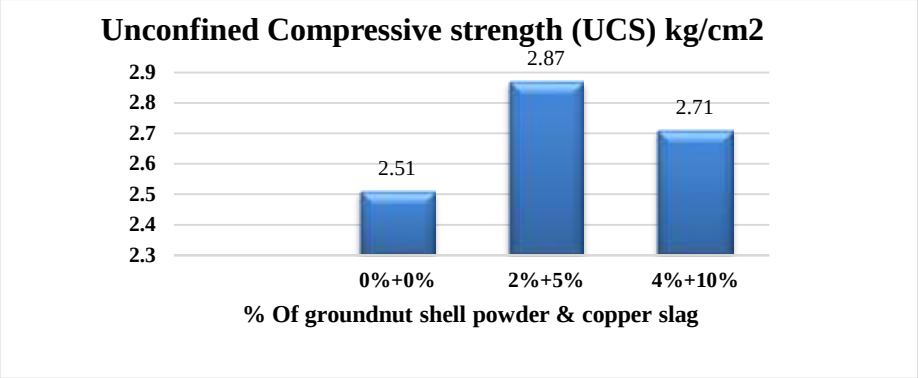

Fig. 6. Graph of unconfined compressive strength

4 Discussion

- The black cotton soil changes behaviour due to combination of groundnut shell powder and copper slag. The combination of groundnut shell powder and copper slag with black cotton soil gives low plasticity from black cotton soil inorganic clay of High plasticity. The plasticity of black cotton soil decreases with increasing in percentage of groundnut shell powder and copper slag.
- The behaviour of montmorillonite mineral may changes due to breaking of water bond and removal of interlayer cations between clay particles, while it combines with minerals present in copper slag and groundnut shell powder under hydration process.

- Lignin presents in groundnut shell powder which may give strength to bond particles of treated soil by act as a coating, natural binder or adhesive to the soil.

5 Conclusions

Based upon the results of experimental investigations and objectives of this research, following conclusions were obtained.

- The combined effect of copper slag and groundnut shell powder is to improve the engineering properties of black cotton soil.
- The plasticity of black cotton soil is decreases from 36.42 % to 15.77% with increasing in percentage of copper slag and groundnut shell powder.
- The swelling index of black cotton soil is decreases from 62.33% to 55.56% with increasing in percentage of copper slag and groundnut shell powder.
- The shrinkage Limit is varies from 3.60% to 8.29% with increase in percentage of groundnut shell powder and copper slag.
- The maximum dry density and optimum moisture content of non-treated black cotton soil is 1.529 g/cc and 23.9% determined but when 86% BC soil+4% GSP+10% copper slag is added in black cotton soil, the maximum dry density and optimum moisture content are increased up to 1.567 g/cc and 18.5% respectively. Use of groundnut shell powder and copper slag could be an economical and feasible solution to stabilize the black cotton soil due its economical cost.
- The unconfined compressive strength of black cotton soil is 2.87 kg/cm^2 at optimum percentage of 93%BC soil+2%GSP+5%copper slag.

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