

Load Settlement Behaviour of Model Footing Tests on Black Cotton Soil Reinforced with Untreated and Treated Jute Fibers with Optimum Dosage of Copper Slag

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ABSTRACT: Utilization of waste materials in transportation has been vogue all over the world for quite some time. Copper slag is one of the waste material being extensively used in civil engineering construction and natural fiber jute which is abundantly and locally available is used as reinforcing material for black cotton soil. The present study discusses the results of a series of load settlement behavior of model footing tests on black cotton soil reinforced with untreated and treated jute fibers with optimum dosage of copper slag. The optimum dosage of copper slag is obtained by compaction test, from results it is concluded that optimum dosage was 50% replacement of copper slag with black cotton soil. An attempt has been made for alkali treatment of jute fibers to avoid degradation and to act as water repellent, a series of unconfined compressive strength test was carried out to determine optimum percentage of untreated and treated jute fibers. Six series of different combinations of load settlements tests are observed with two different sizes of model footings.

KEYWORDS: Black cotton soil, Copper slag, Jute fiber, Load settlement behavior.

I. INTRODUCTION

One of the most fundamental and important problems in the field of civil engineering is prediction of bearing capacity and settlement of building foundations and other structures. The load transmitted to the soil causes the settlement of the soil. As different type footings are used in variety of fields, nature of load transmitted also varies. By limiting the total settlement, differential settlements, the structures are ensured to be safe. The settlement of footing due to the load transmitted to soil must be within 50mm for structural safety purpose. A settlement depends upon various factors such as bearing capacity, type of soil, particle size, area and shape of the footings and so on. Out of this, extensive experimental and theoretical studies on square or equivalent shaped footings are carried out. Two different sizes of footings may show different settlements on the same soil with same loading condition.

Black cotton soil is one the most problematic soil in civil engineering compared to other soils, although we are using this as construction material from past decades. Being poor in mechanical properties, black cotton soil undergo alternative swelling and shrinkage upon wetting and drying due to seasonal moisture fluctuations. In India about one-fifth of the land area in and around the Deccan plateau is covered with these soils, design of problem free and economical foundation was the biggest dispute to geotechnical engineers.

Natural fibers are classified based on their origins, from plants. Generally, plants or vegetable fibers are used to reinforce soil. All the natural fibers undergo biodegradation by aerobic bacteria and fungi. Among all the natural fibers, jute is the second most important vegetable fiber after cotton. Jute fibers are extracted from the fibrous bark of jute plants growing to about 3m high and stem diameter varies from 20 to 30mm. Aggarwal and Sharma (2010) Studied the

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performance of jute fibers in the improvement of pavement characteristics. They used different lengths(5mm – 20mm) of jute fibers in different percentages of 0.2% to 1% to reinforce soil. The maximum value of California bearing ratio was observed with 1cm long and 0.8% fibers , by using coated jute fibers the California bearing ratio increased upto 2.5 times compared to plain California bearing ratio value. Shivakumar babu and vasudevan (2008) discussed on strength and stiffness characteristics of coir fiber reinforced in tropical soil, they prepared number of specimens in which soil reinforced with coir fibers of different percentages, the specimen was kept under triaxial test apparatus for determining the strength stiffness of soil. The results obtained are compared with unreinforced soil, based on these comparison the addition of coir fiber (1% to 2%) increases both strength and stiffness of soil. Gassan and Bledzki (1999) studied alkali treatment on the isometric jute yarn, and reported that there was an improvement in tensile strength and modulus by 120% and 150% respectively. They also treated jute yarn with 25% NaoH solution for 20 minutes, which showed 60% improvement in jute/epoxy composition properties reinforced with treated jute yarn compared to untreated fiber composite. Samal et al (1995) Jute fibers subjected to NaoH treatment solution of different concentration of 1%,8% for 48 hours and 2% for 1hour. These experimental results showed an remarkable improvement in fiber properties by 130% for 1% and8% concentration under 48hours treatment and 13% improvement for 2% concentration under 1hour respectively. Singh et.al (2011) studied the strength and stiffness response of soil reinforced with coir-fiber. Singh and Yachang (2012) used the Jute Geotextile sheets to improve the laboratory CBR value of fly ash. Based on the experimental results they found that stress-strain behaviour of soil is improved by inclusion of coir-fiber into the soil and Jute Geotextile sheets improves the California Bearing Ratio (CBR) value of fly ash significantly. They further concluded that the deviator stress at failure is increased up to 3.5 times over the plain soil. They also observed that stiffness modulus of reinforced soil increases considerably which can reduce the immediate settlement of soil significantly.

Copper slag is a byproduct obtained during the copper smelting and refining process. As refineries draw metal out of copper ore, they produce a large volume of non metallic dust, soot and rock; collectively these materials make up slag which can be used in number of civil engineering applications and other fields. At present situation around 33lakhs ton of slag is generated. The industries produce around 6 to 6.5Mt tons of slag at different sites, among these sterlite industries has huge production of copper slag which is used in civil engineering field. A 30% of copper slag is being used in filling, embankment and in other applications as per the ministry of environment and forest. Copper slag is expected to have good potential to produce high quality pozzolanas, because of combined percentage of alumina, iron oxide and silica which acts as natural pozzolana.

II. MATERIALS AND METHODS

A. Black cotton soil

Black cotton soil used in this present investigation was collected from hosadurga region, which is tropical black clay formed from weathering of Meta volcanic rocks. The soil was taken at depth of 1m below ground level. The geotechnical properties of soil are given in table1.

Table 1. Geotechnical properties of Black cotton soil

Sl.No	Properties	Values
1	Specific gravity	2.51
2	Liquid limit(%)	54
3	Plastic limit(%)	22.75
4	Plasticity index(%)	31.25
5	Shrinkage limit(%)	12.37
6	Silt and Clay content(%)	76
7	Sand (%)	24
8	Maximum dry density(KN/m ³)	13.09
9	Optimum moisture content(%)	22

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B. Copper slag

Copper slag is an industrial by product which is produced during smelting and refining of copper. Copper slag used in this work was brought from sterlite industries Ltd, Tutcorin Tamilnadu. The physical and chemical properties of the slag are presented in table 2 and 3.



Fig 1. Copper slag

Table 2. Physical properties of copper slag

Property	Value
Color	Black
Appearance	Black glassy granule
Gravel size (%)	1.00
Sand size (%)	98.9
Clay and silt sizes (%)	0.05
Specific Gravity	3.5-3.8
Plasticity index (%)	Non Plastic
Swelling Index	Non-Swelling
Bulk density(gm/cc)	1.7-1.9
Hardness	6-7 MoH scale
Moisture (%)	Less than 1

Table 3. Chemical properties of copper slag

Property	(% wt)
Iron Oxide , Fe_2O_3	40-48
Silica, SiO_2	27-33
Sulphur	0.2-1.5
Calcium Oxide, CaO	1.0-3.5
Copper	0.6-0.9
Aluminium Oxide, Al_2O_3	4.0-6.0

C. Jute fibers

Jute fibers which are used as reinforcement in soil with optimum dosage of copper slag, which were procured from local market, were used in the present study

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Fig 3. Jute Fibers

D. Chemicals used

Chemicals used Sodium hydroxide and dilute acetic acid were used to modify the surface characteristics of jute fibers.

III. METHODOLOGY

Compaction test is carried out on various combination of copper slag with black cotton soil in order to determine the optimum dosage of copper slag, which can be used as stabilizing material for black cotton soil. The treatment of jute fibers is carried out by soaking in 5%NaOH solution for 4hrs and washed in dilute acetic acid. The effective percentage of treated and untreated jute fiber is determined by unconfined compressive strength test in which fibers of different percentage is mixed with black cotton soil alone and with combination of black cotton soil with copper slag which was obtained from compaction characteristics, which is further used for the preparation moulds for determination of load settlement behavior. Load settlement test were performed for black cotton soil mixed with optimum dosage of copper slag and jute fibers which are randomly distributed. Universal testing machine is used to perform load test. Load is applied on footing kept on top of the soil specimen, seating load is applied before actual load is applied and test has been conducted till settlement of 25mm is recorded.

IV. RESULTS AND DISCUSSION

A. Compaction characteristics

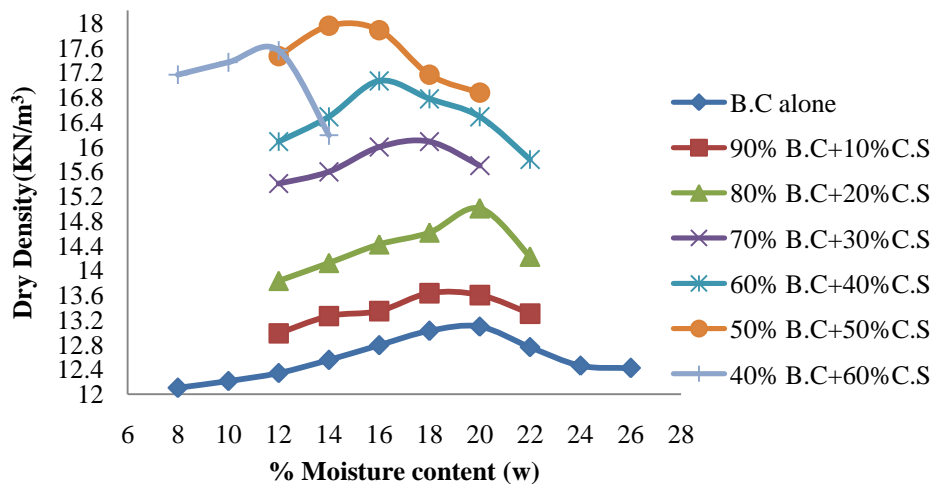


Fig 4. Combination of variation in Dry Density with Moisture content in B.C with various percentages of CS

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The graph is obtained by conducting series of compaction test on black cotton soil with various percentages of copper slag to determine optimum dosage of copper slag. The above graphs are plotted for different combinations of copper slag, as percentage of copper slag increases in black cotton soil the maximum dry density also increases and then decrease. It was observed that for combination of 50% black cotton soil with 50% copper slag, maximum dry density of 17.95KN/m^3 is obtained at optimum moisture content 14%.

B. Unconfined compressive strength

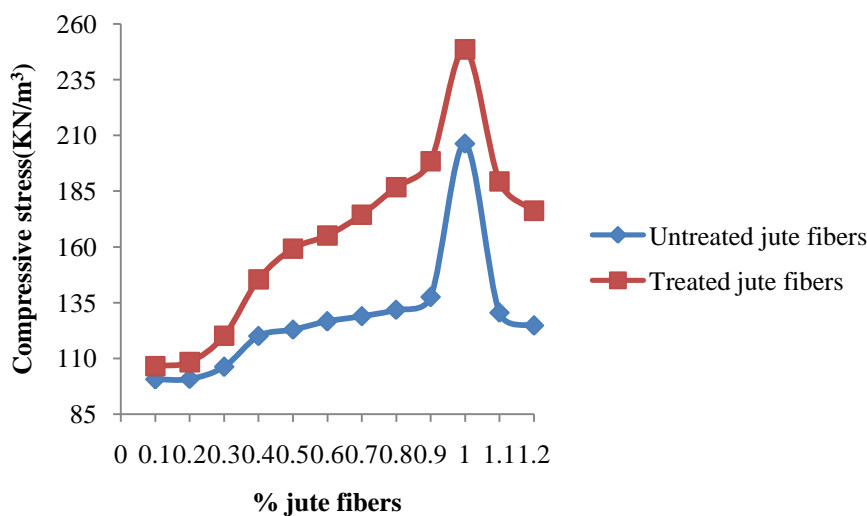


Fig 5. Shear characteristics for different % of UTJF and TJF with 50%B.C + 50% CS

The above graphs represent different percentages of untreated and treated jute fibers with black cotton soil and optimum dosage of copper slag. From fig 5 it is clearly shown that percentage of untreated jute fiber increases the stress value. It is observed that maximum stress value of 206.30KN/m^2 is observed at 1% UTJF, which is also taken as effective percentage of jute fiber. Similarly from fig the effective percentage of treated jute fibers is found to be 1% and corresponding stress value is 248.54KN/m^2 .

C. Load settlement behaviour

The fig 6 shows variation of load v/s settlement for all combinations of 30mm diameter footing. In case B.C soil alone the ultimate load was 1.8KN, where after reinforcing B.C soil with 1% untreated and treated jute fibers the ultimate load was increased from 2.8KN and 3.0KN due to proper bonding between soil and fibers. Another combination is B.C soil was mixed with Opt dosage of copper slag and ultimate load was 3.2KN, which acts as good stabilizing material with B.C soil. But for combinations of B.C soil reinforced with 1% untreated and treated jute fibers with Opt dosage of copper slag load was found to be 4.2KN and 4.5KN respectively for 25mm settlements.

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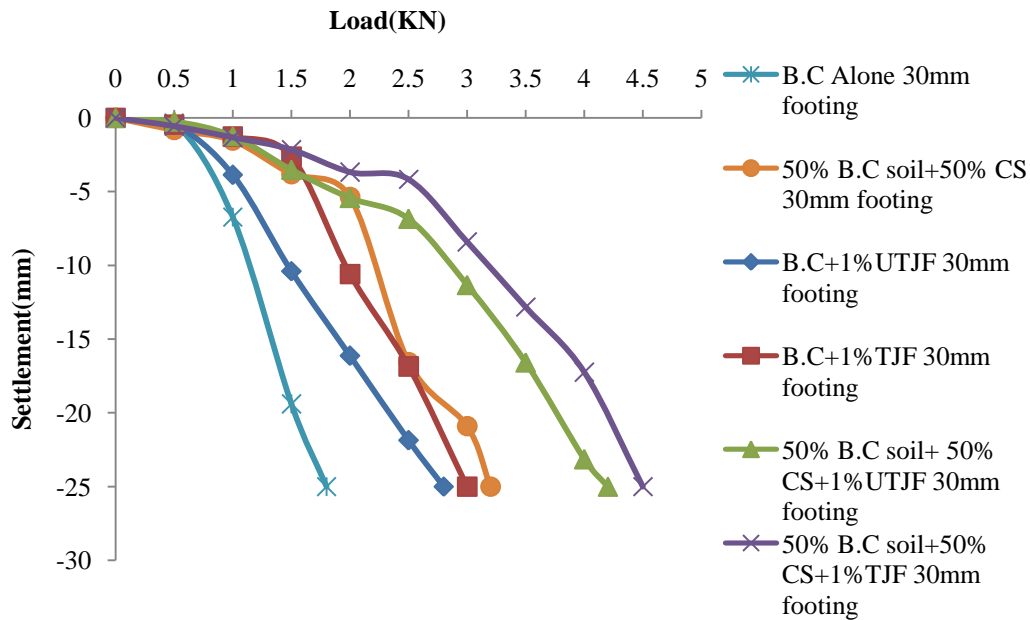


Fig 6. Comparison of load v/s settlement for all combination for 30mm footing

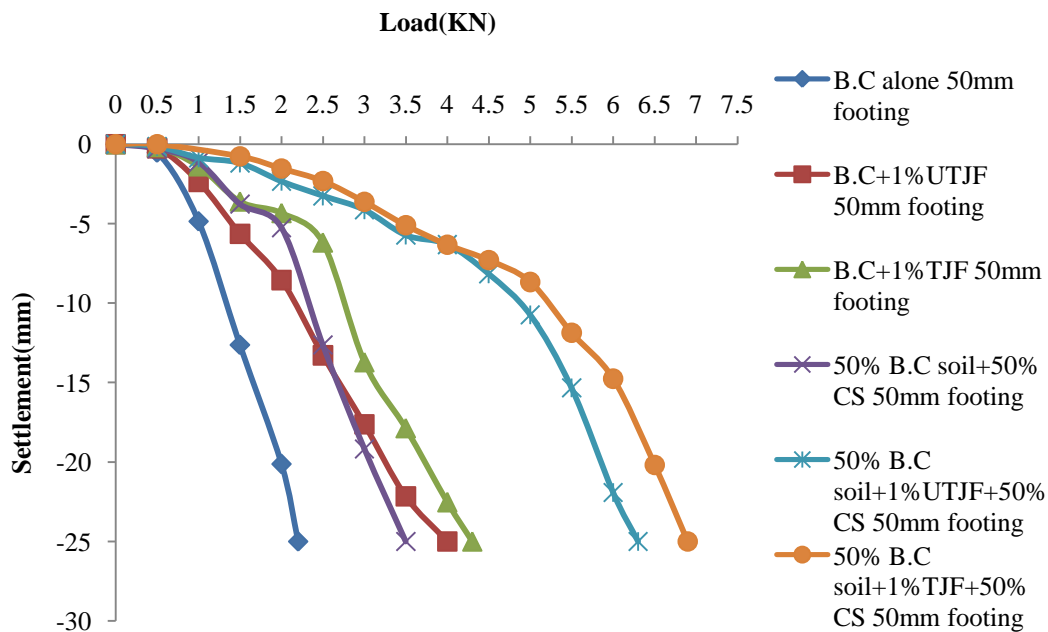


Fig 7. Comparison of load v/s settlements for all combinations for 50mm footing

The fig 7 represents the variations of load deformation for all combinations of 50mm diameter footing. For 50mm footing the ultimate load of B.C soil was 2.2KN, after reinforcing B.C soil with 1% untreated and treated jute fibers load was increased from 4.0KN and 4.3KN. After stabilizing with Opt dosage of copper slag the load was 3.5KN. The

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combinations of B.C soil reinforced with 1% untreated and treated jute fibers with Opt dosage of copper slag for 50mm diameter footing load was found to be 6.3KN and 6.9 KN for 25mm settlements.

V. CONCLUSION

In this present study, a series of load settlement tests have been carried out on different sizes of model footings supported on waste copper slag and unreinforced soil. The results have been used and understand capability of reinforcing soil with and without copper slag which in turn increases bearing capacity and compared with unreinforced soil. Based on above results following conclusions were drawn

- The density of B.C soil with 50% copper slag has increased from 13.63 KN/m³ to 17.55KN/m³. High value of maximum dry density was found to be 17.95KN/m³ with optimum moisture content of 14%.
- The UCC strength of alkali treated jute fiber and untreated jute fiber are found to be 248.54 KN/m² and 206.30KN/m² respectively thus proving the effectiveness of surface treatment.
- The ultimate load of B.C soil reinforced with untreated and treated jute fibers for 30mm diameter footing was 2.8 KN and 3.0 KN and for 50mm diameter footing was 4.0 KN and 4.3 KN respectively for 25mm settlement.
- The ultimate load for combination B.C soil + Opt dosage of CS + 1% UTJF for 30mm and 50mm was 4.2 KN and 6.3 KN respectively for 25mm settlement.
- The ultimate load carrying capacity for B.C soil + Opt dosage of CS + 1% TJF for 30mm and 50mm diameter footing was 4.5 KN and 6.9 KN respectively for 25mm settlement.
- The combination of 50% B.C soil with 50% CS was found to be most satisfactory combination to get good stabilization.
- For both 30mm and 50mm footings the ultimate load for B.C soil + Opt dosage of CS + 1% TJF is found to be the best combination.
- Copper slag is a byproduct obtained during the process of copper smelting and refining is proved to be economically, technically feasible to use as good stabilizing material
- The results indicate that addition of copper slag to B.C soil shows a vast improvement in strength, thereby reducing overall settlement.

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