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Effect of Nano-Copper on Performance of Black Cotton Soil

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ABSTRACT
Soil stabilization has become useful solution to treat the weak soil to achieve the required engineering properties. Soil stabilization by adding materials such as cement, lime, bitumen, etc. is the effective method for improving the geotechnical properties of soil which have been applied for many years now. This work is intended to study the effect of adding nano-copper on geotechnical properties of black cotton soil i.e. liquid limit, compaction characteristics, unconfined compression strength, CBR value and swelling pressure. Nano-copper was mixed with soil in three different percentages (i.e. 1, 1.5 and 2.5 % by weight of soil). The optimum nano-copper content found to be 1.5 % for attaining the maximum strength.
Keywords: CBR, Geotechnical properties, Nano-copper, Stabilization, Unconfined compressive strength

I. INTRODUCTION

The black cotton soil is one of the major soil deposit in India and its spread 300000 km^2. The black cotton soil extends over the states of Maharashtra, Madhya Pradesh, Karnataka, Andhra Pradesh, Tamilnadu and Uttar Pradesh. These soils are expansive in nature due to presence of montmorillonite and illite clay minerals. The soil surface is hard in nature in summer season but becomes slushy and loses its strength substantially during rainy season. The volume change up to a depth of 1.5 m generally occurs due to seasonal moisture changes. The highly loaded structures are most susceptible to damages as a result of volume changes. Because of the swelling and shrinkage characteristics of soil, special treatment of the soil or special design needs to be adopted.

To enhance the properties of the weak soil, many methods like soil stabilization, soil reinforcement, grouting, addition of admixtures etc. are being adopted. Addition of admixtures like lime, fly ash, bitumen based on type of soil improves the properties of soil to some extent. Use of industrial waste as additives is recently under study, but it arises a question of toxicity. So there is a need for finding a new innovative material.

One of the new innovative fields recently introduced to soil is Nanotechnology. Nanotechnology is the science that deals with the particles which are in nonmetric scale, play a crucial role in the behaviour of soil exhibiting different properties. This technology is already being used in various fields of civil engineering, but it is recently introduced to soil stabilization. Use of these nano particles (in order of 10^{-9}) in stabilization influences the shear strength, dry density, CBR value, permeability and bearing capacity of the soil and makes more reactive to soil because of its high specific surface area. In this investigation, an attempt has been made to investigate the influence of nano-copper powder in the improvement of black cotton soil.

II. LITERATURE REVIEW

Kumar [1] *et al*. (2007) carried out the experimental investigation to study the effects of polyester fibre inclusions and lime stabilization on the geotechnical properties of the fly-ash soil mixture. Test specimens were cured for 7, 14, 28 days and subjected to compaction test, unconfined compressive strength test, tensile strength test. It was concluded that expansive soil can be successfully stabilized by the combine action of lime, fibers and fly ash.

Sharma and sivapullaiah[2] (2012) carried out the experimental investigation to study the findings of laboratory tests carried out on local Indian expansive black cotton soil with GGBS mixed with the expansive soil in different proportions. The specimens compacted to their respective Proctor's optimum moisture content and dry density were cured for a period of 7, 14 and 28 days. It was observed that the strength improvement depends on the amount of GGBS used and the effect of curing period ws less pronounced. Ramteke [3] *et al.* (2014) carried out the experimental investigation to determine the optimum dose of the stabilizer, which improves the strength of soil (CBR less than or equal to 2% to more than 7%) which was suitable for pavement structure. The result shows that the use of sand and cement in combination, increases the

California Bearing Ratio values (CBR) i.e. the strength of soil to a great extent.

Mevada and Tewar[4] (2015) carried out the experimental investigation to analyse the effect of Foundry waste on expansive soil, for improvement in strength and swelling-shrinkage characteristics and increase its suitability for effective use in construction.

Bagewadi and Rakaraddi[5] (2015) carried out the experimental investigation to determine the effect of geopolymer on stabilization of a soft soil. The effect of geopolymer on strength characteristic of Black cotton soil had been studied for a curing period of 7, 15 and 28days. The compressive strength of black cotton soil increases with geopolymer dosage and curing. The density of black cotton soil also increases with the increase in geopolymer.

Majeed and Taha[6] (2011) carried out the experimental investigation on effect of addition of different nanomaterials including nano Cu, nano MgO, and nano clay (0.05% to 1%) on the geotechnical properties of Penang soft soil. Addition of each of the nanomaterials decreased the liquid limit, plastic limit, plasticity index, and linear shrinkage of the soil and increased in dry density, optimum moisture and compressive strength of the soil increased with nanomaterial addition.

Taha[7] *et al*. (2012) carried out the experimental investigation on influence of nanomaterial on the expansive and shrinkage soil behaviour. An experimental study was performed on four types of soils mixed with three types of nano-material (nano-clay, nanoalumina, and nano-copper) of different percentages results in swell strain and shrinkage strain reduced and also decreased in the development of desiccation cracks and hydraulic conductivity.

The work carried out by various author shows that the study on black cotton soil is lagging for different nanomaterials. The present study shows the performance of black cotton soil mixed with nano-copper.

III. MATERIALS

3.1 Soil

Soil used in experimental investigation was a locally available black cotton soil from Amravati, Maharashtra. Table 1 shows the index properties of soil. The soil was classified as CH and based on FSI value the soil had high swell characteristic. From Unconfined compression test, it was found that undrained cohesion of the untreated soil was found to be 151.15 kN/m^2 at optimum moisture content.

Table 1: Index properties of soil

Properties	Values
Liquid Limit %	49.80
Plastic Limit %	18.35
Plasticity Index %	31.36
Shrinkage Limit %	13.39
Free Swell Index %	60.00
Maximum Dry Density (kN/m^3)	15.30
Optimum Moisture Content %	28.50
Soil Classification	CH

3.2 Nano-copper

The nano-copper powder which was used in the experimental investigation for stabilizing the black cotton soil was procured from Ladhani Metal Corporation, Mumbai having size 325µ and is as shown in Fig. 1.

Fig. 1: Nano-copper powder

IV. METHODOLOGY

The series of experimental investigation were conducted on untreated and treated soil to evaluate the effects of different percentages of nano-copper powder on black cotton soil. The various geotechnical properties like liquid limit and plastic limit, compaction characteristics, unconfined compressive strength, CBR values and swelling pressure were determined.

For liquid and plastic limit the BC soil was pulverised and test was conducted as per IS 2720 (part V) 1985. The nano-copper powder in 1%, 1.5% and 2.5% were mixed with soil and water to form a paste and allowed it for drying, the dried sample was then again pulverised into powder, passed through 425µ sieve and tests were conducted.

The compaction characteristics were determined from standard proctor test. The oven dried soil was passed through 4.75mm sieve and mixed with various percentages of nano-copper powder. Then required amount of water (i.e. 10%) was added in the sample. This moist soil mass was kept in polythene bags at same moisture content for nearly 24 hours before moulding to give proper consistency to the soil mass for easy moulding.

For the unconfined compressive strength tests, the soil sample was mixed with 1%, 1.5% and 2.5 % of nano-copper powder. The mixture was prepared at OMC and filled in cylindrical mould in three equal layers and the number of blows required

per layer was 25. The sample was extracted from the mould with the sampling tube of size 38 mm diameter x 76 mm height specified in IS: 2720 (part x). Two specimens were tested for each combination of mixture. The samples were cured in airtight polythene bag in humidity chamber at room temperature for 7 and 28 days.

CBR tests were implemented for soaked and unsoaked conditions by mixing soil with 1%, 1.5% and 2.5 % of nano-copper powder. The mixture was prepared at OMC and compacted in same way as in case of UCS, only the blows required per layer was 56. The prepared samples were kept for curing for 7 days by applying polythene bags at top and make it airtight for unsoaked condition. For soaked condition after 7 days the polythene bags were removed and the soil samples were submerged into water for 4 days and then tests were carried out.

Swelling pressure test was carried out only on optimum percentage which was obtained from unconfined compressive strength test.

V. RESULTS AND DISCUSSIONS

In this study, various tests were conducted on stabilized soil and natural soil. The liquid limit, plastic lilmit and plasticity index of treated and untreated soil is presented in Table 2. It was observed that liquid limit and plasticity index of stabilized soil increases with increase in percentage of nano-copper powder upto 1.5% after that it was decreased. The plastic limit increases with increase in percentage of nano-copper.

Table 2: Atterberg limits

Tests	Untreated Soil	Soil Treated with Nano-Copper Powder (%)		
		1%	1.5%	2.5%
LL	49.80	53.15	58.00	55.00
PL	18.34	17.14	18.34	26.92
PI	31.36	36.01	39.66	28.07
Sl	13.39	9.52	11.00	9.96

The standard Proctor test was carried out for the compaction characteristics of untreated and treated soil. The maximum dry density and corresponding moisture content were obtained from compaction curves. The results for MDD and OMC of stabilized soil are tabulated in Table 3. The results show that as the percentage of nano-copper increases the OMC was decreased upto 1.5% and MDD increased for all % of nano-copper.

Table 3: MDD and OMC of soil

Tests	Untreated Soil	Soil Treated with Nano-Copper Powder (%)		
		1%	1.5%	2.5%
OMC (%)	28.50	27.20	22.70	23.35
MDD (kN/m^3)	15.30	15.45	15.92	15.20

The unconfined compressive strength test was conducted on untreated and treated sample and cured for 7 and 28 days. The strain vs unconfined compressive strength of stabilized soil is shown in Fig. 2. As the percentage of nano-copper powder increased the strength is maximum and after that it decreased. The maximum unconfined compressive strength of stabilized soil was observed to be 675.91 kN/m^2.

The unconfined compressive strength for different percentage of nano-copper was shown in Table 4. It was observed that the unconfined compressive strength of soil stabilized with nano-copper powder increases as the percentage of powder increases and duration of curing increases. The optimum % of nano-copper for maximum strength was found to be 1.5%.

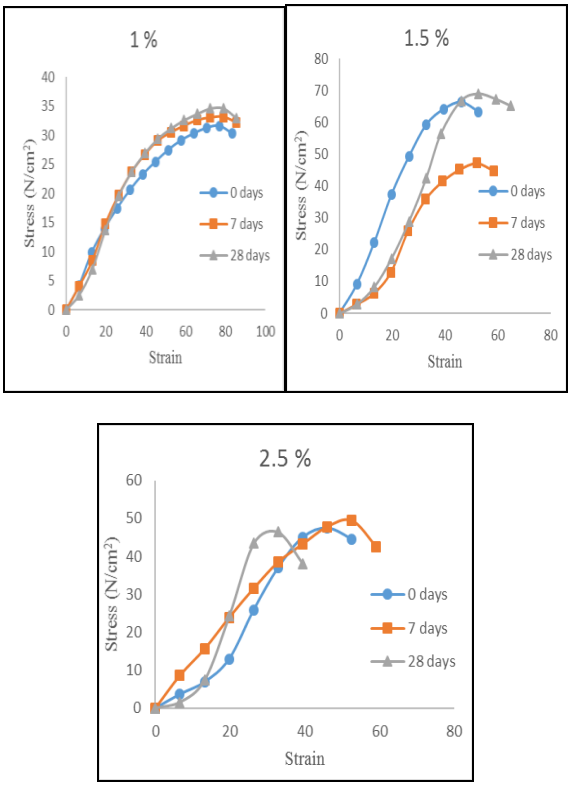


Fig. 2: Strain Vs unconfined compressive strength of stabilized soil

Table 4: Unconfined compressive strength

Days	UCS of Untreated Soil	UCS of Treated Soil (kN/m^2)		
		Nano-Copper Powder (%)		
		1%	1.5%	2.5%
0	151.15	338.00	420.80	481.96

7	-	327.85	656.50	485.37
28	-	328.87	669.78	481.47

The increase in UCS value due to addition of 1.5% nano-copper powder is 343.12% over untreated soil. The percentage increase in UCS value is shown in Fig. 3.

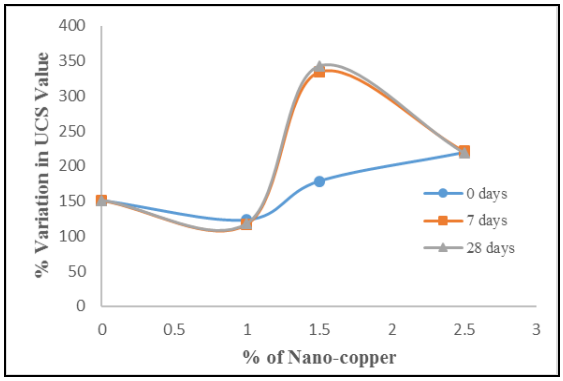
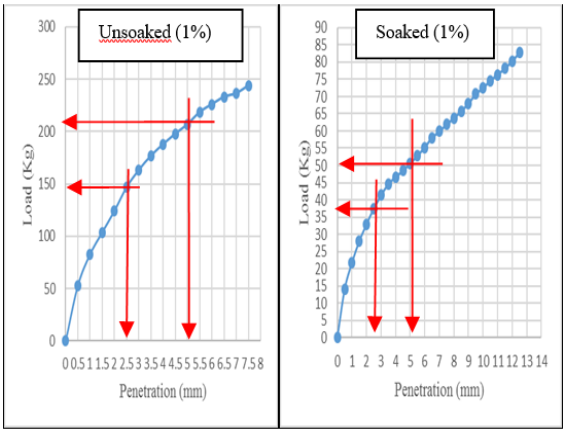


Fig. 3: Percentage variation in UCS Value

CBR was determined for untreated and treated soil in unsoaked and soaked condition by mixing different percentage of nano-copper powder with soil. The graph of CBR values stabilized with nano-copper powder is as shown in Fig. 4. The CBR values for unsoaked and soaked condition at different percentages are shown in Table 5. It shows that CBR increases in soak and unsoaked condition for treated soil with maximum at 1.5% nano-copper.



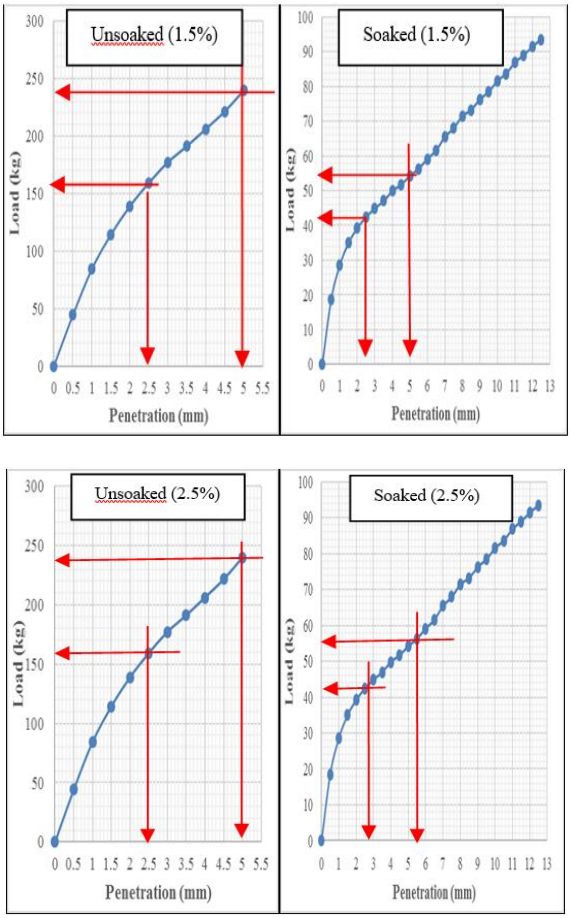


Fig. 4: CBR values for stabilized soil

Table 5: CBR values

Content	CBR for Untreated Soil	CBR of Treated Soil Nano-Copper Powder (%)		
		1%	1.5%	2.5%
Unsoaked	7.44	10.95	11.68	11.67
Soaked	1.45	2.63	3.14	3.06

The increase in CBR value for unsoaked condition due to addition of 1.5% nano-copper powder is 57% over untreated soil and for soaked condition, it is 116.55% over untreated soil. The percentage increase in UCS value for unsoaked and soaked condition is shown in Fig. 5.

Swelling pressure was determined for untreated and treated soil with 1.5% nano-copper powder. The swelling pressure for untreated and treated soil is as shown in Fig. 6. The addition of 1.5% nano-copper powder reduces swelling pressure by 22%.

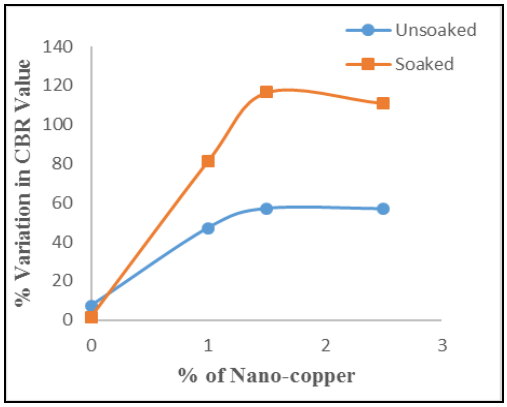


Fig. 5: Percentage variation in CBR value

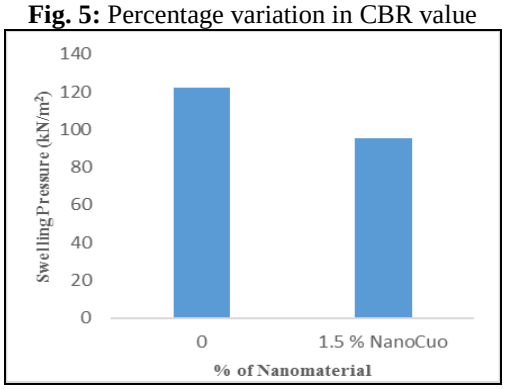


Fig. 6: Swelling pressure variation for untreated and treated soil

The increase in unconfined compressive strength, CBR value of soil and reduction in swelling pressure shows that nano-copper powder of 1.5% mixed with black cotton soil improves maximum strength characteristics of BC soil. Hence, the optimum % of nano- copper powder was found to be 1.5%.

VI. CONCLUSIONS

6.1 Introduction

Based upon the results of experimental investigations, following conclusions were obtained.

1. The liquid limit and plasticity index of black cotton soil was increases with addition of nano-copper powder upto 1.5%.
2. Optimum moisture content decreased and maximum dry density increased with increased in nano-copper powder percentage.
3. The unconfined compressive strength was increases 343.12% with increase in percentage of nano-copper powder and curing days.
4. The CBR value was increases 57% for unsoaked and 116.55% for soaked condition with increased in percentage of nano-copper.
5. The swelling pressure was reduced by 22% for optimum percentage of nano-copper.
6. The optimum % of nano-copper was found to be 1.5%.

6.2 Advantage

The materials required for treating the soil is in less quantity hence may be cost effective.

6.3 Applications

1. The present work may be useful for stabilization of soil for flexible pavement.
2. This work may be useful in preventing the damage of the structure constructed on weak soil.

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