International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 3.45 (SJIF-2015), e-ISSN: 2455-2584
Volume 3, Issue 06, June-2017

Effect of Nano-Silica on Performance of Black Cotton Soil

Dr. Sunil Pusadkar[1], Snehal Bakhade[2], Dr. Anant Dhatrak[3]

[1]*Head of Civil Engineering Department, Government College of Engineering Jalgaon, Maharashtra (India),*
[2]*P.G. Student, Government College of Engineering Amravati, Maharashtra (India),*
[3]*Associate Professor, Civil Engineering Department, Government College of Engineering Amravati, Maharashtra (India),*

Abstract— Black cotton soil exhibit high swelling and shrinking when exposed to changes in moisture content and hence have been found to be most troublesome from engineering considerations. Black cotton soil is one of the major soil deposits of India, so there is a need of enhancing its geotechnical properties and make it suitable for the construction purpose. There have been many methods available to controlling the expansive nature of the soils. The stabilization of soil by adding different binding materials such as enzymes, biopolymers, emulsions, cement, lime, bitumen, etc. is the conventional and effective method for improving the geotechnical properties of soil. Treating the black cotton soil with nano-silica powder is one of the techniques to improve the behaviour of black cotton soil. Hence, in the present work, the experimentation is carried out to study the effect of adding nano-silica on geotechnical properties of black cotton soil especially Atterberg limits, compaction characteristics, unconfined compressive strength, CBR value and swelling pressure. Nano-silica was mixed with soil in three different percentages (i.e. 0.3, 0.6 and 0.9 % by weight of soil). Based on obtained results, in order to reach the maximum increase in strength parameters, the optimum nano-silica content occurs at 0.6 %.

Keywords— Stabilization, Geotechnical properties, Nano-silica, CBR, Unconfined compressive strength

I. INTRODUCTION

Black cotton soil is one of the most problematic soil which is found in states of Maharashtra, Madhya Pradesh, Karnataka, Andhra Pradesh, Tamilnadu and Uttar Pradesh covering an area of about 3.0 lakh sq. km. Black cotton soils in India are highly problematic, as they swell on absorption of water and shrink on evaporation of water. The primary arises with regard to expansive soils is that deformations are significantly greater. The movement is usually in an unseen pattern and of such a magnitude to cause extensive damage to the structure resting on them. The structure founded on expansive soils are subjected to differential deflections which in turn causes distresses on expansive clays and produce hazardous damage to the structures. Because of the swelling and shrinkage characteristics of soil, special treatment of the soil or special design needs to be adopted. Extensive research is going on to find the solutions to black cotton soils.

Proper remedial measures are to be adopted to modify the soil or to reduce its detrimental effects if expansive soils are indentified in a project. Many stabilization techniques are in practice for improving the expansive soils such as removal and replacement, using additives such as lime, cement, calcium chloride, rice husk, fly ash etc., by using chemical admixture, etc. These are the conventional methods 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-silica powder in the improvement of black cotton soil.

II. LITERATURE REVIEW

Sridevi and Rao[1] (2005) carried out the experimental investigation on effect of lime stabilized flyash layer on CBR value of black cotton soil. In the experimental study the lime content in the flyash layer was varied from 0% to10% with an increment of 2%. California bearing ratio test were conducted on the prepared samples. The result revealed that providing lime stabilized flyash layer can improve CBR of black cotton soil.

Singhai and Singh[2] (2014) carried out the experimental investigation on soil which was treated with different proportion of FA (5%,10%,15%,20%,25%) and RHA (,10%,15%,20%,25%,30%) and Optimum moisture content, Maximum dry density and california bearing capacity is evaluated. Test were conducted on BC soil and Fly Ash, Rice husk ash mixtures prepared at optimum water content. The MDD, OMC values were decreased and CBR increased.

Rajoria and Kaur[3] (2015) carried out the detailed laboratory investigations on the soil sample stabilized with polymer stabilizer. The polymer stabilizer was used in conjunction with cement to improve its efficiency with the soil particle. The soil samples were treated with different doses of polymer stabilizer and cement. The proportion of cement in the soil specimen was varied from 2% to 8% by weight of soil sample and for each variation of cement in the soil sample; the proportion of renolith was varied from 0% to 8% by weight of cement. Polymer stabilizer was proved to be effective on poor soil as significant enhancement in the engineering properties and index properties of soil was observed.

Seyed[4] *et al.* (2013) carried out the experimental investigation on application of nanomaterial to stabilize a weak soil. Fifty CBR tests were conducted. The results proved a little effect of lime in the soil improvement. The effect of nano-silica on the stabilization of the soil-lime mixture was studied. The results showed that the CBR strength of the soil-lime mixture increased more rapidly with adding nano-material. The optimum mixture design was found to be 5% lime and 3% nano-silica.

Kirithika[5] *et al.* (2015) carried out the experimental investigation on influence of nanosized silica and lime particles on the behaviour of soil. Silica and lime are taken as additives to mix with soil. Silica is mixed with soil upto 15% (5%, 10% &15%) with the addition of lime from 2% to 10% (2%, 6% & 10%). The index properties, compaction test, UCC test were carried out in soil and Nano materials. The results indicated that the nano admixed soil yielded UCC strength of 589 kN/m^2 which is 1.2 times higher than non- nanoparticles.

Changizi and Haddad[6] (2015) carried out the experimental investigation on effect of nano-SiO_2 on the geotechnical properties of cohesive soil. Nano-SiO_2 was mixed with soil in three different percentages (i.e. 0.5, 0.7, and 1.0 % by weight of the parent soil). It was found that increase in nano-SiO_2 content resulted in increase in the angle of internal friction, the cohesion, the unconfined compression strength and maximum dry unit weight of the clayey soil.

Sadrjamali[7] *et al.* (2015) carried out the experimental investigation on clay with low plasticity property to increase soil shear strength parameters using different additives micro-silica, cement, lime (Cao). The presence of lime resulted in decreasing the strength and increasing the swelling. To achieve soil shear strength parameters, optimum value of nano-silica for stabilizing of soil- 5%, lime- 5% and gypsum admixture is 2% based on direct shear test.

Pashabavandpouri and Jahangiri[8] (2015) carried out the experimental investigation on effect of nano silica on swelling, compaction and strength properties of clayey soil stabilized with lime. The effects of adding nano-silica and lime with different percentages on clay were investigated. The result revealed that slight addition of nano-silica to clay mixed with lime results in a significant improvement in plastic properties, compaction, strength and swelling of the modified soil. The effects of curing time were also evaluated and results showed that adding nano-silica causes strength of soil mixed with lime to increase more rapidly in a shorter time.

Khalid[9] *et al.* (2015) carried out the experimental investigation on effect of nanoclay in soft soil stabilization. The unconfined compression strength test, consolidated drained test and atterberg limit test were performed. The result showed that the mixing of 3 % nanoclay with soft soil improved the soil strength and effectiveness of the shear strength.

III.MATERIALS

A. *Soil*

Soil used in experimental investigation was a locally available black cotton soil from Amravati, Maharashtra. TABLE I 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 I: 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

B. *Nano-copper*

The nano-silica powder which was used in the experimental investigation for stabilizing the black cotton soil was procured from Adinath Industries, Rajasthan having size 250μ and is as shown in Fig. 1.

Fig. 1: Nano-silica powder

IV. TESTING PROGRAM FOR BLACK COTTON SOIL

The series of experimental investigation were conducted on untreated and treated soil to evaluate the effects of different percentages of nano-silica 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.

A. Atterberg Limits

For liquid, plastic limit and shrinkage limit the BC soil was pulverised and test was conducted as per IS 2720 (part V) 1985. The nano-silica powder in 0.3%, 0.6% and 0.9% 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.

B. Standard Proctor Test

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-silica 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.

C. Unconfined Compressive Strength Test

For the unconfined compressive strength test the soil sample was mixed with 0.3%, 0.6% and 0.9 % of nano-silica 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.

D. California Bearing Ratio (CBR) Test

CBR tests were implemented for soaked and unsoaked conditions by mixing soil with 0.3%, 0.6% and 0.9 % 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.

E. Swelling Pressure Test

Swelling pressure is defined as the pressure which the expansive soil exerts, if the soil is not allowed to swell or the volume change of the soil is arrested. Swelling pressure test was carried out only on optimum percentage which was obtained from unconfined compressive strength test.

V. TESTING RESULTS FOR BLACK COTTON SOIL

In this study, various tests were conducted on stabilized soil and natural soil.

A. Atterberg Limits

The liquid limit, plastic lilmit and plasticity index of treated and untreated soil is presented in TABLE II. It was observed that liquid limit, plastic limit and plasticity index of stabilized soil increases with increase of percentage of nano-silica powder upto 0.6% after that it was decreased.

TABLE II: Atterberg Limits

Tests	Untreated Soil	Soil Treated with Nano-Silica Powder (%)		
		0.3%	0.6%	0.9%
LL	49.80	58.85	52.00	54.10
PL	18.34	50.00	25.00	18.34
PI	31.36	8.85	27.00	35.76
SL	13.39	15.76	17.15	10.15

B. Standard Proctor Test

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 III. The results show that as the percentage of nano-silica increases the OMC was decreased upto 0.6% and MDD increased.

TABLE III: MDD and OMC of Soil

Tests	Untreated Soil	Soil Treated with Nano-Silica Powder (%)		
		0.3%	0.6%	0.9%
MDD (kN/m^3)	15.3	15.13	15.58	14.52
OMC (%)	28.50	24.15	25.40.	26.00

C. Unconfined Compressive Strength Test

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-silica powder increased the strength is maximum and after that it decreased. The maximum unconfined compressive strength of stabilized soil was observed to be 716.03 kN/m^2.

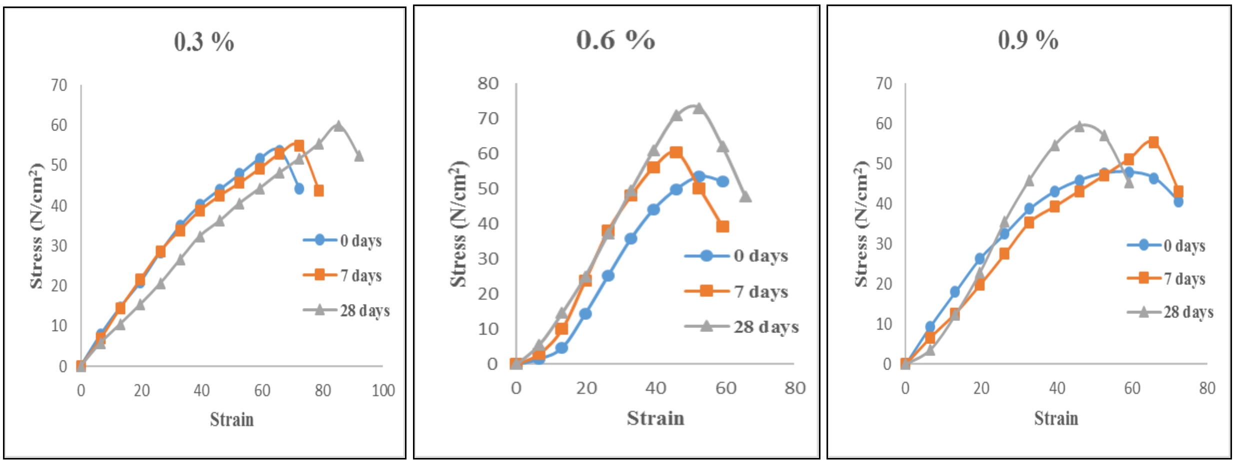

Fig. 2: Strain vs unconfined compressive strength of stabilized soil

The unconfined compressive strength for different percentage of nano-silica was shown in TABLE IV. It was observed that the unconfined compressive strength of soil stabilized with nano-silica powder increases as the percentage of powder increases. The optimum % of nano silica for maximum strength was found to be 0.6%.

TABLE IV: Unconfined Compressive Strength Test

Days	UCS of Untreated Soil (kN/m^2)	UCS (kN/m^2) Soil Treated with Nano-Silica Powder (%)		
		0.3%	0.6%	0.9%
0	151.15	526.06	525.35	470.49
7	-	538.96	591.87	542.14
28	-	587.36	716.03	565.94

The increase in UCS value due to addition of 0.6% nano-silica powder is 373.72% over untreated soil. The percentage increase in UCS value is shown in Fig. 3.

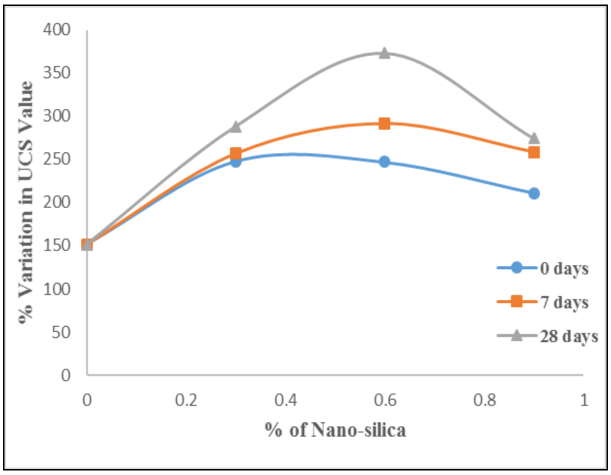

Fig. 3: Percentage variation in UCS value

D. California Bearing Ratio (CBR) Test

CBR was determined for untreated and treated soil in unsoaked and soaked condition by mixing different percentage of nano-silica powder with soil. The graph of CBR values stabilized with nano-silica powder is as shown in Fig. 4. The CBR values for unsoaked and soaked condition at different percentages is shown in TABLE V. It shows that CBR increases in soak and unsoaked condition for treated soil with maximum at 0.6% nano-silica.

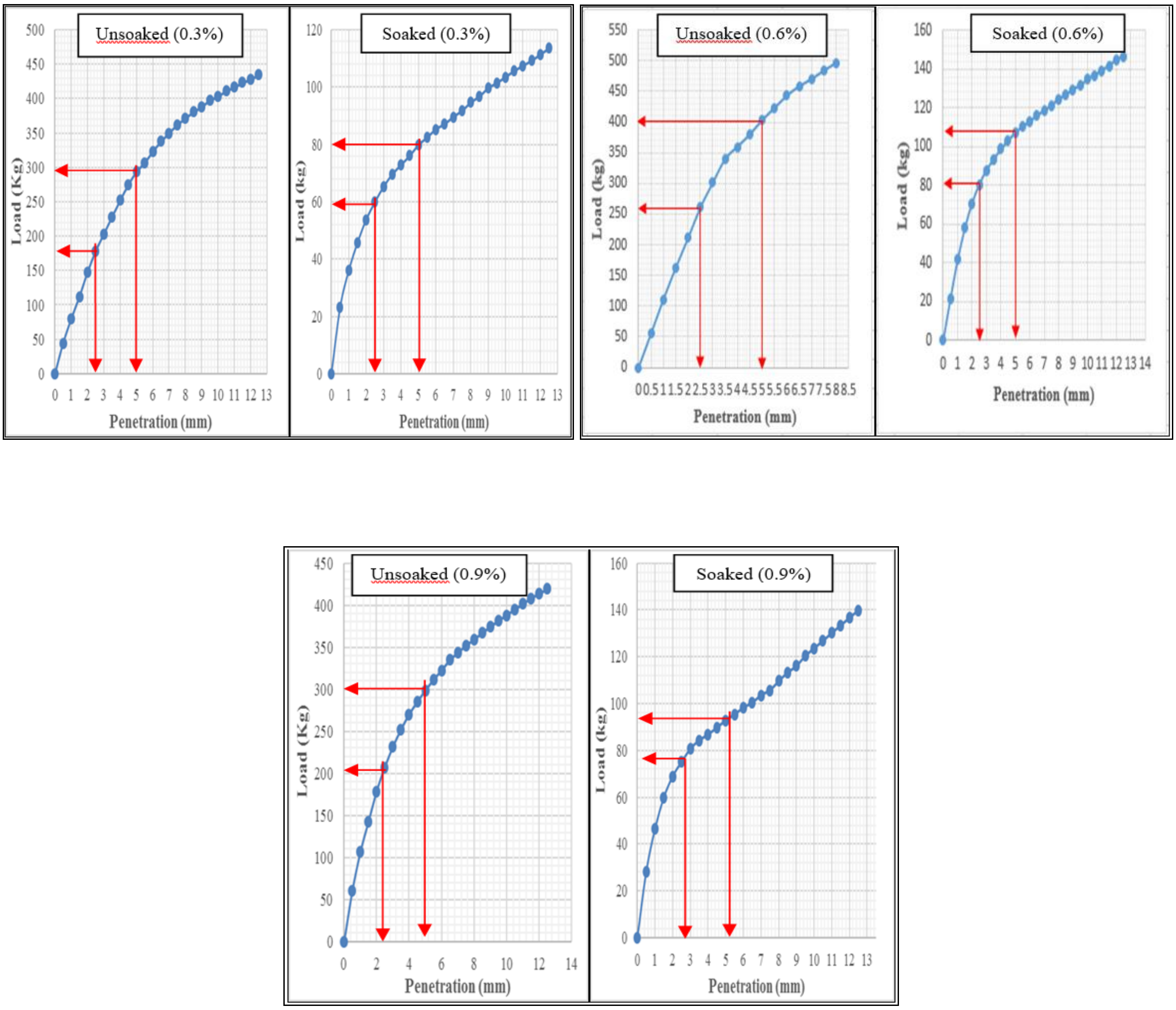

Fig. 4: CBR values for stabilized soil

TABLE V: CBR Values

Content	**CBR of Untreated Soil**	**CBR of Treated Soil**		
		Soil Treated with Nano-Silica Powder (%)		
		0.3%	**0.6%**	**0.9%**
Unsoaked	7.44	13.04	17.85	15.13
Soaked	1.45	4.38	5.84	5.47

The increase in CBR value for unsoaked condition due to addition of 0.6% nano-silica powder is 140% over untreated soil and for soaked condition, it is 303% over untreated soil. The percentage increase in UCS value for unsoaked and soaked condition is shown in Fig. 5.

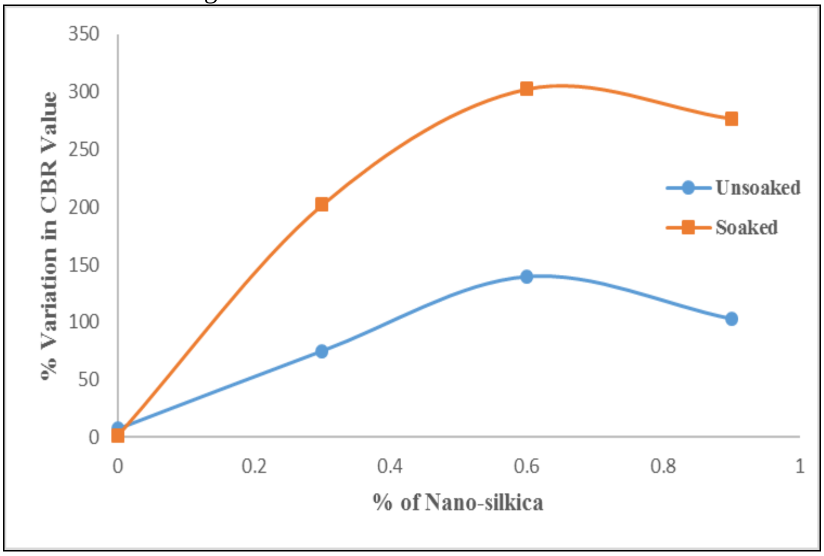

Fig. 5: Percentage variation in CBR value

E. Swelling Pressure

Swelling pressure was determined for untreated and treated soil with 0.6% nano-silica powder. The swelling pressure for untreated and treated soil is as shown in Fig. 6. The addition of 0.6% nano-silica powder reduces swelling pressure by 14%.

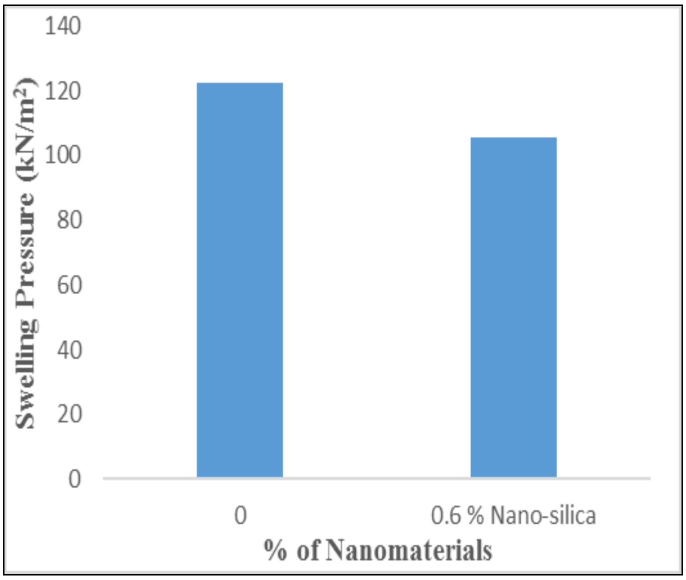

Fig. 6: Swelling pressure variation for untreated and treated soil

The increase in unconfined compressive strength, CBR value of soil and reduction in swelling pressure shows that nano-silica powder of 0.6% mixed with black cotton soil improves maximum strength characteristics of BC soil. Hence, the optimum percentage of nano- silica was found to be 0.6%.

VI. CONCLUSIONS

1. The liquid limit and plasticity index of black cotton soil was increases with addition of nano-silica powder upto 0.6%.
2. Optimum moisture content decreased with increased in nano-silica powder percentage.
3. The unconfined compressive strength was increases 373.72% with increase in percentage of nano-silica powder and curing days.
4. The CBR value was increases 140% for unsoaked and 303% for soaked condition with increased in percentage of nano-silica.
5. The swelling pressure was reduced by 14% for optimum percentage of nano-silica.
6. The optimum % of nano-silica was found to be 0.6%.

REFERENCES

[1] G Sridevi, M Rama Rao and J Padmini (2005), "Effect of Lime Stabilized Flyash Layer on CBR Values of Black Cotton Soil", *Proceedings of Indian Geotechnical Conference,* Ahemdabad, 305-308.

[2] Anil Kumar Singhai and Sudhanshu Shekhar Singh (2014), "Study of Strenth Charataristic of Black Cotton Stablizing with Fly Ash and Rice Husk Ash", *International Journal of Computational Engineering Research (IJCER)***,** Vol. 04, Issue 12, 22-27.

[3] Vijay Rajoria and Suneet Kaur (2015), "Effect of Polymer Stabilizer on the Geotechnical Properties of Black Cotton Soil", *50th Indian Geotechnical Conference*

[4] Seyedi Gelsefidi Seyed Alireza, Mirkazemi Seyed Mohammad and Baziar Mohammad Hasan (2013), "Application of Nanomaterial to Stabilize a Weak Soil", *Seventh International Conference on Case Histories in Geotechnical Engineering,* Missouri University of Science and Technology, Paper No. 6.10a.

[5] M. Kirithika, T. Prabu and V. K. Stalin (2015), "Influence of Nanosized Silica and Lime Particles on the Behaviour of Soil", *50th Indian Geotechnical Conference,* Pune, Maharashtra, India.

[6] Foad Changizi and Abdolhosein Haddad (2015), "Effect of Nano-SiO_2 on the Geotechnical Properties of Cohesive Soil", *Springer International Publishing Switzerland,* 9962-9969.

[7] Marjan Sadrjamali, Seyed Mojtaba Athar and Alireza Negahdar (2015), "Modifying Soil Shear Strength Parameters Using Additives in Laboratory Condition", *An International Research Journal of Environmental Science,* Special-Issue 1.17.

[8] Mohammad Ali, Pashabavandpouri and Sajad Jahangiri (2015), "Effect of Nano Silica on Swelling, Compaction and Strength Properties of Clayey Soil Stabilized with Llime", *Journal of Applied Environmental and Biological Sciences,* Volume5, Issue7, 538-548.

[9] Norazlan Khalid and Mazidah Mukri (2014), "Effect of Nanoclay in Soft Soil Stabilization", *Springer Science and Business Media Singapore,* 905-914.

.