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Strength and Micro-Structure Evolution of Soft Soils by using Nanosilica

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Abstract. A Comparative study on the Effect of Nano-silica (NS) on Physical, chemical, and Micro structural characteristics of soft soil were investigated. Nano-silica widely used in concrete and cement stabilized soft soil to enhance macro performance. Up to now, the improvement of soft soil using Nano-silica is not completely explored. In this study, a comparison has been done to determine the potential of Nano-silica to stabilize the soil Different experimental work has been performed, especially the standard proctor test, unconfined compressive strength (UCS)and California bearing ratio (CBR) of clay with highly compressible (CH) soil adding Nano-silica. The soil considered here accommodates varying percentages of Nano-silica (0.6%, 0.8%, 1%, 1.5% by weight of soil) and is added for investigation of the relative strength enhance of soil. The present study is to evaluate the Maximum Dry Density, Unconfined Compressive Strength, and California Bearing Ratio of soil using varying percentages of Nano-silica. The test outcomes explain that the shear strength, UCS, CBR value of soil increases by the addition of Nano-silica in soil. The result showed that the addition of Nano-silica with soft soil can accelerate hydration, improve the interfacial zone between soil particles and binder, due to pozzolanic nature and fine particle size. By using Scanning Electron Microscopy (SEM), the interaction at the interface between Nano-silica and soil matrix was analysed. And by Energy-dispersive X-Ray Spectroscopy technique (EDS) the elements and chemical characteristics of soil analysed.

Keywords: Nano-silica, UCS, EDS

1 Introduction

In civil engineering soil is one of the most frequently used materials. Nearly all structure usually rest on soil. Presence of weak or soft soil in the construction sites is a major issue for any type of construction. To strengthen the of the Weak soil properties, many methods like stabilization of soil, soil reinforcement, grouting, addition of admixtures etc. are adopted. Addition of admixtures like Lime, fly ash, Cement, 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 arise a question of toxicity.

So there is a need for finding a new innovative material. Improving the engineering properties soil by using additives, stability and strengthening of the soil increases.

One of the new innovative fields Nanotechnology is recently been introduced to Geotechnical Engineering. Nanotechnology is the science that deals with the particles which are less than 100 nm. The sizes of Nano particles have crucial part in behaviour of soil exhibiting different properties. To enhance strength of soft soil use of industrial by-products, waste materials and innovative material is being necessary A series of laboratory test carried out by Pham and Nguyen (2014) to study the fundamental geotechnical properties by adding Nanosilica with the clayey soil and obtained that Swelling of clay soil decreases by using of Nanosilica. Experimental test carried out by Mohammadi and Niazian (2013), use of nano-clay enhances the value of liquid limit and plastic limits of soil and also improve the shear strength parameters of additive mixed sample. Zhang et al. (2004) indicated that the use of Nanosilica as additive the Atterberg limits and strength capacity of clay increased and permeability decreases.

2 Experimental Work and Methodology

The different type of material used, preparation of sample and procedure of test has discussed. To analyze the Engineering characteristics of soil various test such as Grain size analysis, Atterberg's limit test, specific gravity test, compaction test, UCS test, CBR (soaked, unsoaked) test was conducted.

2.1 Material used

Soil: Soil sample used for research work was collected from a site at Krushna prasad block, puri, Odisha at a depth of 2ft below ground level. The soil was oven dried and lumps were crushed in to small segments and screen by 4.75 mm size sieve to separate pebbles, roots, gravel etc. The soil was categorized according to the IS classification system

Table 1. Geotechnical properties of soil

Properties	Value
1. Specific Gravity	2.40
2. Liquid Limit (%)	58.01
3. Plastic Limit (%)	24.74
4. Plasticity Index (%)	33.27
5. Classification of soil as per IS 1498	CH
6. Compaction properties	
MDD(g/cc)	1.58
OMC (%)	20.70
7. UCS (kN/m²)	80.54
8. CBR (%)	
Unsoaked	3.46
Soaked	1.81

Nano-silica

Nano-Silica used in this experimental study was supplied by the Astrra Chemicals, Chennai. The tests were conducted at percentage of Nano-silica contents of 0%, 0.6%, 0.8%, 1.0%, and 1.5%. Physical composition and Chemical Characteristics of Nano silica are illustrated in Table no. 2 and 3 respectively.

Table 2. Physical Composition of Nanosilica

Purity (%)	Avg. particle size (nm)	Specific surface area(m^2/g)	Specif-ic Gravity	Temped Density(g/l)	Sieve Residue	PH value
99	17	202	2.4	44	0.02	4.12

Table 3. Chemical properties of Nanosilica

Material	Content (%)
SIO_2	99.88
C	0.06
Cl	0.009
Al_2O_3	0.006
TiO_2	0.003
Fe_2O_3	0.001

2.2 Test method

Preparation of sample

First the soil was air dried and it was pulverized with the help of wooden hammer. Then it was sieved with 4.75mm I.S sieve. First the require content of Nano silica have been blended with clayey soil under dry condition. The different Percentage of Nano-silica are 0.6%, 0.8%, 1.0% and 1.5% of by the total soil weight taken for test and variation of OMC, MDD , UCS and CBR values was evaluated.

Specimen preparation for compaction test

The test was carried out by standard Compaction method as per IS2720 (Part VII)-1980 to determine the OMC and MDD. The compaction tests were done on the soil-Nano silica. Different percentage of Nanosilica was blended with weighted oven dry

soil. The appropriate amount of water was mixed with soil-Nanosilica mixture and also the wet specimen was compacted in proctor mould in 3 layers using 2.6kg of standard proctor rammer.

Specimen preparation for unconfined compression test

For UCS test, samples were prepared as per IS: 2720(Part 10)-1991 at OMC and MDD obtained from compaction test. The Cylindrical specimen used for the test having diameter 3.7mm and height 10.2mm. Mixture filled in mould with three equal lays of having each layer carried 25 numbers of blows. After Compaction the sample taken in extruder of cylindrical stainless tube from mould and placed in load frame machine. The force given should be produce rate of axial strain 0.5 to 2% per minute. Each test was carried out by at least three samples to minimize error and average values were used. The tests were done with soil, soil with Nanosilica.

Specimen preparation for California bearing ratio test

Samples for CBR test were prepared as per IS 2720 :(part 16)-1987.The mould used for the test have the diameter of 150mm and height 175 mm. The samples were compacted in 5 lays and each layer carried 55 numbers of blows by 4.5 kg weight rammer with free fall of 450 mm. For soaked CBR test, specimen kept submerged in water for 96 hours before testing. Tests were conducted at a rate of penetration of 1.25mm/min until 12.5 mm penetration. From the test results the Load- penetration curve were plotted and CBR value calculated. By using different percentage of Nano-silica with soil both soaked and unsoaked CBR test were conducted.

3 Results and Discussion

A Series of experimental work has been performed with combination of Nano-silica in natural soil. There are very limited literature on studies of use of nanosilica on strength of soil. Results of Experiments such as Atterberg's limits, Compaction Test, Unconfined Compressive Strength test, CBR Test (Both soaked and unsoaked) of admixture mixed soil is compared with values of untreated soil. The consequences of Nano-silica on various engineering properties were evaluated. The interaction at the interface between Nano silica and soil matrix is examined by using Scanning Electron Microscopy (SEM) . EDS test shows the chemical Composition of materials.

3.1 Compaction test

Effect of Nanosilica on compaction characteristics of soil: The Compaction test on soil treated with varying percentage of Nanosilica by conducting Standard Proctor Test Results graphs has been plotted which has been shown in fig. 1 . It is observed that Relative Proportion of Nanosilica have considerable effects on the OMC and MDD of compacted mix. Increase Nanosilica content from 0 to 1.5%, the MDD Value increases and then decrease at a certain point and OMC value decreases with high-

er percentages of Nano-silica. In addition of 1% of Nanosilica with soil the OMC value decreased to 16.1 and MDD value increased to 1.71g/cc.

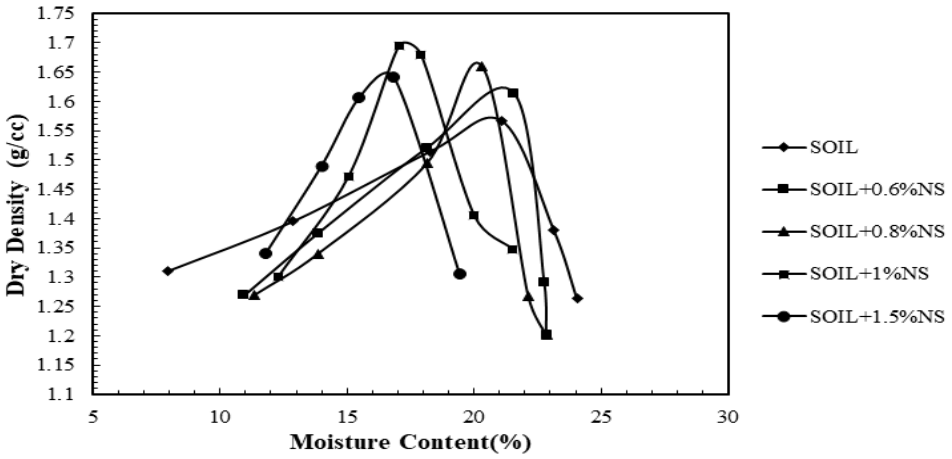


Fig. 1. Variation of compaction curve of soil using different proportion of NanoSilica

3.2 Unconfined compressive strength test

Effect of Nanosilica on UCS of soil

The UCS test was conducted for Nanosilica Mixed soil and the stress- strain results are representing in Fig 2. Result from the study shows that, by increase nanosilica percentage the UCS value increases. So the Optimum Nano-silica content is Found 1.5% and corresponding UCS value is 208.17 KN/m². The UCS of Optimum Nano silica of 1.5% stabilized soil increased by factor 2.58 when compared with that of natural soil.

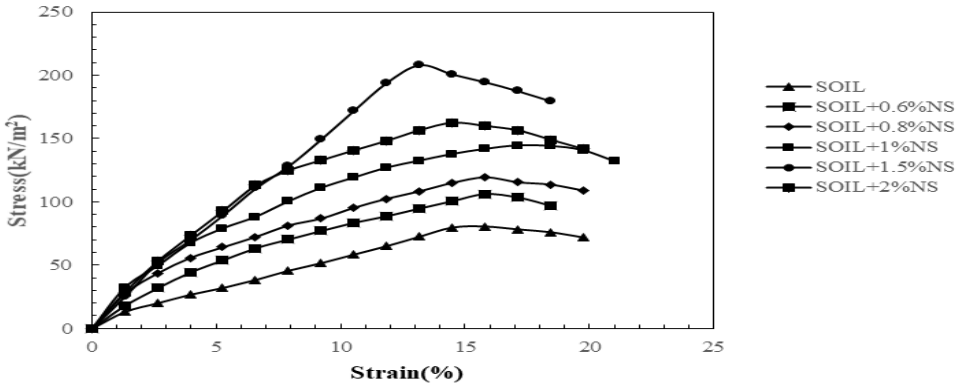


Fig. 2. Stress-strain curve of soil using different content of Nanosilica

3.2 California Bearing Ratio test (CBR)

Effect of Nano silica on CBR of soil

Soaked CBR test

CBR Value is important engineering parameter to evaluate a sub-base and sub-grade material for design of pavement . Results shows that addition of Nanosilica, increase the soaked CBR up to Nanosilica Content 1.0%, then the CBR value decreases. The soaked CBR value increases from 1.81% to 3.03%, when 1.0% Nanosilica mixed with soil. Thus Maximum percentage of Nanosilica for soaked CBR is 1.0%.The load penetration curve for soaked soil sample treated with different percentages of Nano-silica are given in fig 3 and 4.

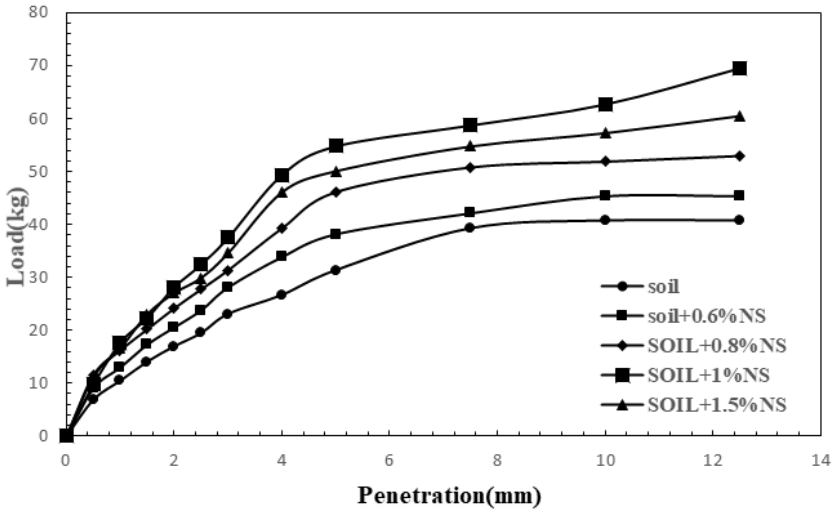


Fig. 3. Load-Penetration Curve for Nano-silica Reinforced Soil Obtained from Soaked CBR test

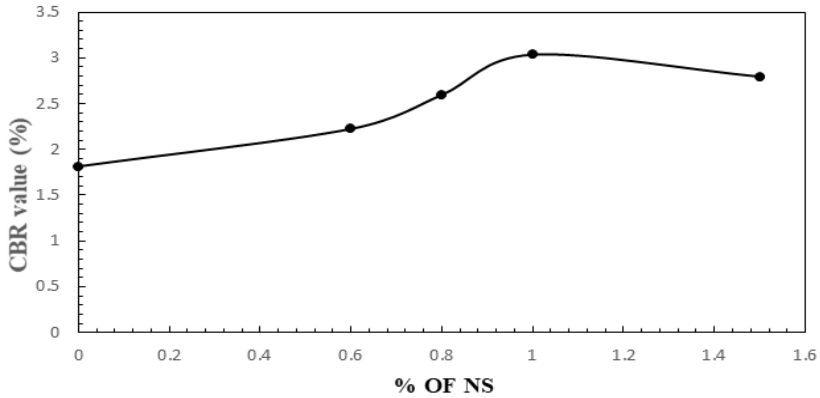


Fig. 4. Effect of Nanosilica on Soaked CBR of Soil

Unsoaked CBR test

The Unsoaked CBR value test results of soft soil treated with different percentage of Nano silica are given below in Fig 5, 6. In addition of different percentages of Nano-silica, increasing Nano-silica content significantly increased the Unsoaked CBR value when compared to virgin soil. The CBR value increases from 3.46% to 9.32%, when 1.0% Nano-silica was added.

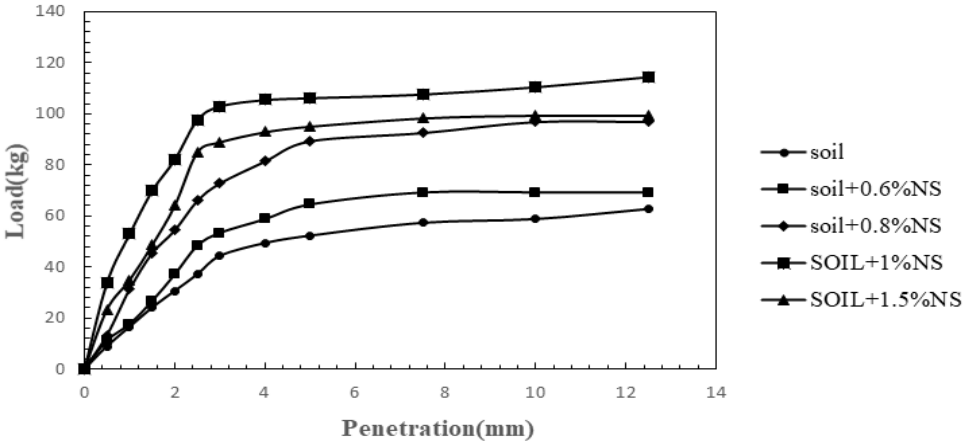


Fig. 5. Load-Penetration Curve for Nano-silica Reinforced Soil Obtained from Unsoaked CBR

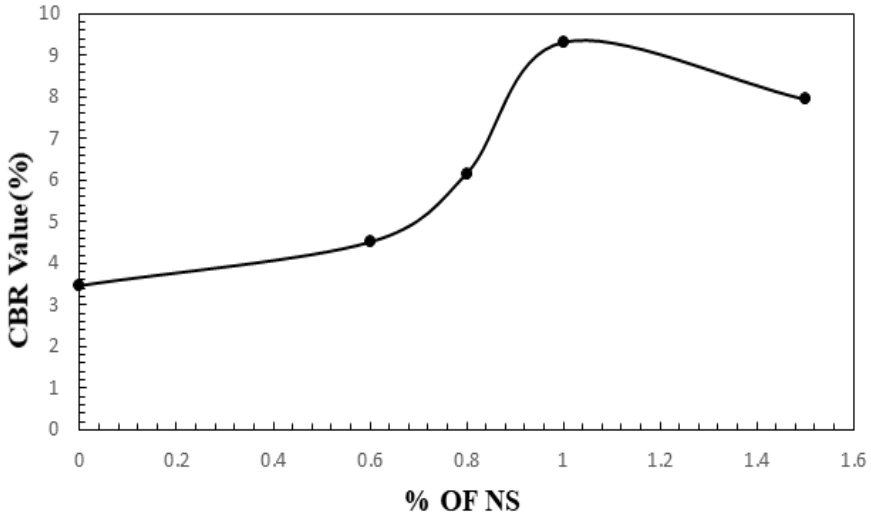
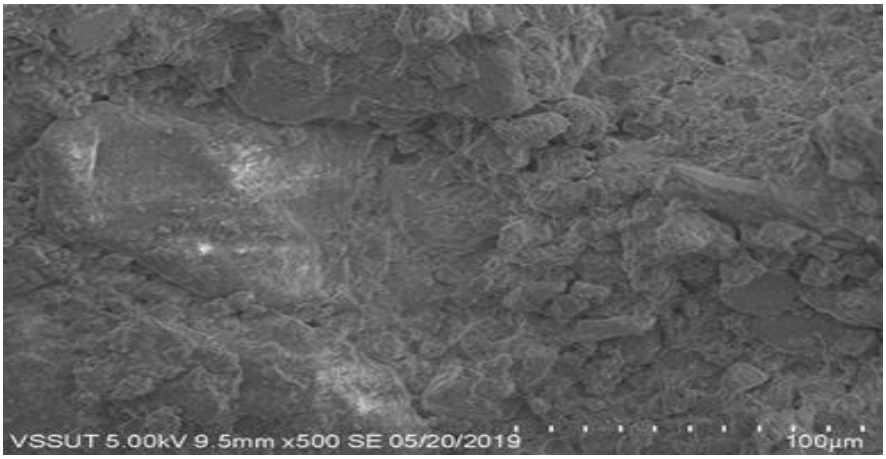


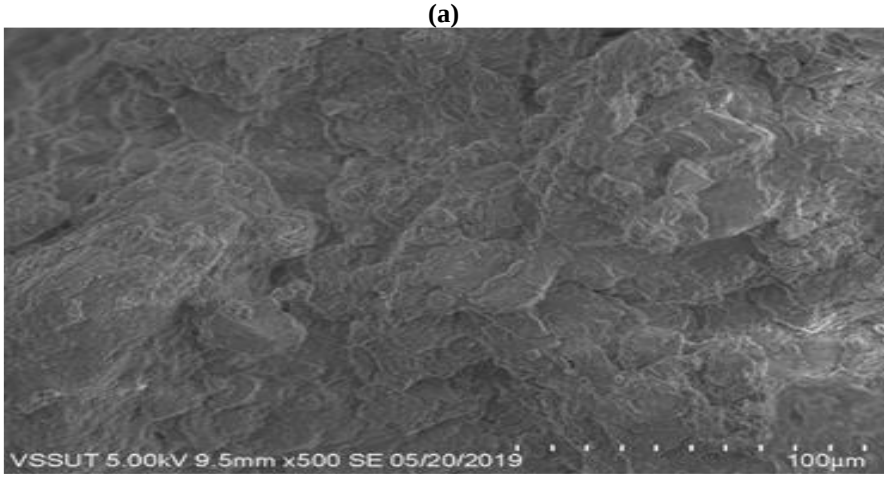
Fig.6. Effect of Nano silica on Unsoaked CBR of soil

3.3 Scanning Electron Microscope (SEM) test

In this samples were carried out for SEM test i.e. untreated natural soil, soil treated with 1% Nanosilica Which is shown in Fig 5.29 (a),(b) . Examining SEM image reveals the Individual particle's surface texture and morphology. According to the results adding Nano-silica to soil may help to improve the shearing resistance. When water is added with nano-soil composite viscous gel is occur because of mixing water with Nanosilica frictional strength between soil particles enhance due to presence of viscous gel. The nano-soil makes the soil particles distances lesser, produce denser soil matrix. It means increasing nano soil results improve effective interfacial contact area between soil contents and enhance the interfacial friction and bond strength.



(a)

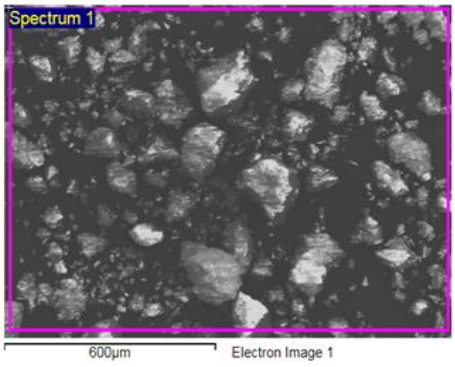


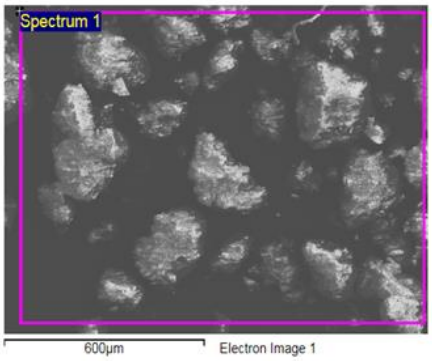
(b)

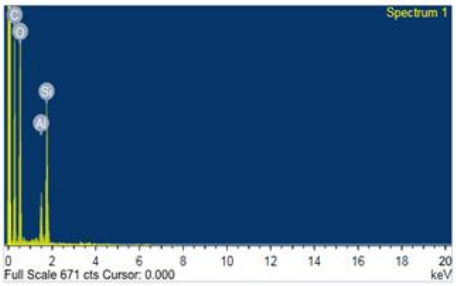
Fig. 7. SEM images of soil specimens (a) untreated soil (b) soil stabilized with Nanosilica

3.4 Energy-Dispersive X-RAY Spectroscopy (EDS)

Fig 8 (a), (b) shows the EDS of soil, soil + Nano-silica, samples. From EDS analysis it is observed that the component of soil nearly equal to the components of soil with Nano-silica mixture ,it means Nano-silica can not do any chemical reaction with soil EDS test is used for analysis of elements and chemical characterization of a sample. It depends on an interaction of few source of X-Ray excitation and sample. The Basic study of this analysis is to know each element has a unique atomic structure allowing unique set of peaks in its X-Ray emission spectrum.

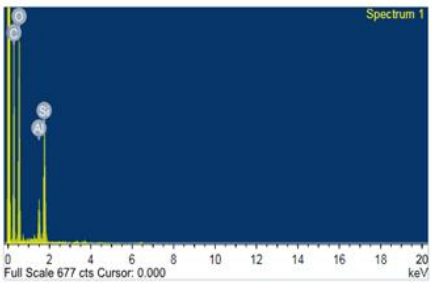






Elem...	Weight%	Atomic%
C K	43.43	51.81
O K	50.04	44.82
Al K	1.69	0.90
Si K	4.85	2.47
Totals	100.00	

Fig. 8 (a) EDS of soil sample



Elem...	Weight%	Atomic%
C K	45.61	53.89
O K	48.71	43.21
Al K	1.45	0.76
Si K	4.24	2.14
Totals	100.00	

Fig. 8(b) EDS of soil + Nano silica

4 Conclusions

Nowadays, Analysis on the application of Nanomaterials has become a large topic follow from economic advantage. To review the result of nano-material on engineering properties of soil, an experimental program was carried out by adding Nanosilica on the soft soil. The following Conclusions can be taken from the Experimental outcomes.

1. The MDD values of soft soil initially increased with addition of Nanosilica then decreased after optimum. The MDD value increases up to 1% of Nanosilica thereafter its value consistently decreased. In the other hand OMC has continuously decreased with by using nanosilica in soil.
2. The UCS values of soft soil with out curing increases up to 1.5% of Nanosilica and after that decreases.
3. Both the CBR soaked and unsoaked values increases with use of up to 1% nanosilica. Soaked CBR value gives better result for both subgrade and pavement construction.
4. Inclusion of nanosilica to the soil it showed formation of a very dense matrix SEM image in which pores were filled to a large extent and interlock between the particles increases which helps to improve the strength of soft soil.

In this paper, it is noticed that the method of soil stabilized with Nanosilica and is a considerably applied method of ground improvement, which increases the shear strength, UCS, and both soaked and unsoaked CBR of soil. Because of this, it increases the stability of structures, i.e. foundation and roadbed. This improvement technique can be considered as a practical method for improvement of mechanical behaviours of soil in civil engineering project.

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