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EVALUATION AND ANALYSIS OF SOIL STABILIZATION WITH NANO SILICA ANDCEMENT KILN DUST

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Abstract- Soil reinforcement is an effective and reliable technique which is widely used in geotechnical engineering practice for slope stability and strengthening, bearing capacity of road pavement, embankment, earthquake liquefaction and solving foundation capacities problems. There are many ways to reinforce soil in geotechnical engineering. One of them is using additives such as cement. Cement has been extensively used in soil stabilization and is usually used as a major addition material to improve the mechanical properties (strength and stiffness) of soil in the past decade. However, there are some issues associated with the use of cement.

The use of stabilizing technologies has significantly expanded in recent years specially when sites are frequently construction in poor land locations. This study suggests using nano-silica to improve clayey soil's functionality. The motivation behind this research was to learn more regarding the properties of soil strengthen with Cement kiln Dust and Nano silica material. The use of these materials reduces pollution and human reliance on natural resources, resulting in a more sustainable construction approach. The consequences of Cement kiln Dust and Nano silica on soil strength prospects for clayey soil are investigated in this study. An experimental investigation was undertaken by treating clayey soil with Nano silica in four different concentration proportions of (0.3%, 0.6%,0.9%,0.12%). After that the Cement kiln dust was blended in various proportions with the soil and 0.9% NS mixed soil at the rate 5%, 10%, 15%, and 20%. The investigation of an influence of Nano silica and cement kiln dust on Atterberg limits, C.B.R., U.C.S., O.M.C., and M.D.D. was done. Adding Nano silica and cement kiln dust improved the U.C.S. and C.B.R. As per experimental results, the ideal value of C.B.R. and U.C.S. was at 0.9% Nano silica, 15% CKD and 84.1 % Soil.

Key words: Cement Kiln Dust, Nano Silica, CBR test, UCS test.

1. INTRODUCTION

Soil reinforcement is an effective and reliable technique which is widely used in geotechnical engineering practice for slope stability and strengthening, bearing capacity of road pavement, embankment, earthquake liquefaction and solving foundation capacities problems. There are many ways to reinforce soil in geotechnical engineering. One of them is using additives such as cement. Cement has been extensively used in soil stabilization and is usually used as a major addition material to improve the mechanical properties (strength stiffness) of soil in the past decade. However, there are some issues with the use of cement.

For example, curing time is inevitably required for cement treated soil and the use of cement will have a great impact on the ecology and surrounding environment. Moreover, the cement grouting often requires high pressure to inject cement slurry into the target soil. Therefore, the adjacent buildings may have higher risk of damage. The method of using fibers to reinforce clayey soil has attracted much attention from researchers in many applications due to the desirable properties and advantages of fibers, such as reliable strength, slow biodegradation rate, and low cost. In particular, the short synthetic fibers have attracted increasing attention in the study of soil modification over the past years owing to their high tensile resistance that could impart greater strength to the soil compared with natural fibers. However, reinforcing soil with synthetic fiber is still a relatively new technique and the mechanism of soil-fiber performance needs to be fully examined in each geotechnical project.

Nowadays, with the emergence of nanotechnology, the use of nano materials in soil improvement has received a lot of research interest, especially for cohesive soil such as clayey soil. It is believed that the use of nano materials can enhance the mechanical properties of soil through different mechanisms.

Therefore, soil is bonded to suppress the effect of such particle, which is responsible for the high percentage of expansiveness and cracks thus; it is dangerous for the construction. Therefore, it is important either to remove the existing soil and replace it with a non-expansive soil or to improve the important properties of the existing soil by stabilities prior to construction of a road on such subjugate.

This study, particularly aims at testing the viability of utilizing materials such as Cement kiln dust and Nano silica which are eco-friendly as well as economical, for soil stabilization.

LITERATURE REVIEW

Sadegh Ghavami(2021) The results demonstrated that the amount of 1% nano-silica and 15% silica fume by dry soil weight was an optimum addition content of employed activators for enhancing the CKD-treated soil's geotechnical properties, respectively. Furthermore, the sustainability evaluation revealed that CKD-treated soil was the most sustainability addition less than 2% and silica fume to the CKD-stabilized soil can lead to propose treated soil with considerably more sustainability than cement. It is essential to highlight that the sustainability of CKD- treated soils containing silica fume was considerably more than that of stabilized soils comprising nano-silica.

Barbhuiya et al (2020) The nano-silica has a positive effect on both the unconfined compressive strength and shear strength of soil. This paper also presents the influence of nano-silica on compaction parameters, atterberg limits and plasticity index, specific gravity, hydraulic conductivity, consolidation, california bearing ratio and elasticity modulus. Also, the microstructural determination is discussed in details. The incorporation of nano-additives reduces the plasticity, influences compaction parameters and consolidation, increases elasticity modulus and california bearing ratio but reduces specific gravity and hydraulic conductivity of soil.

Amir Kalhor et al. (2019) The results show that when the clayey soil is stabilized with nano-SiO2, the optimum moisture content, liquid limit (LL) and plastic limit (PL) increase, while the maximum dry unit weight and PI decrease. An increase of nano-SiO2 up to an optimal of 2% and curing time up to 42 days improves the unconfined compressive strength (UCS) by about 63%. In addition, the increase in nano-SiO2 leads to brittle behavior of the specimens. Moreover, the freeze-thaw cycle decreases the UCS of the specimens. However, a descending trend for strength is observed in nano-SiO2 stabilized specimens compared with untreated clay. After nine freeze-thaw cycles, the strength of untreated and treated soil with 2% nano-SiO2 decrease by about 64% and 42%, respectively. Also, with increasing the freeze-thaw cycles, stabilized specimen .

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K.C. Onyelowe (2018) used nano-structured kaolin material to stabilized soil (lateritic). Also, the effect on soil stabilization by adding additives in different percentage had been investigated. Todetermine the particle size of additive material tests such as UV–visspectrophotometric was performed. For experiment silty clay soil wasconsidered and the tests such as liquid limit (47%) and plastic limit(25.15%) were conducted. The additive material was added indifferent proportions ranges from 3% to 15% with an interval of 3%. **Diksha Sharma (2017)** had focused to examine the effects of twodistinct nano-materials such as MgO and Al2O3. The nanomaterialswas added in expansive soil in various dosages such as 0.5%, 1.0%,1.5% and 2.0%. The results also showed that the swelling potentialwas decreased using the above mentioned nanomaterials.

Abhay et al. (2017) Soil blended with nano-silica content at 5–20% by weight of dry soil. The experimental results showed an increase in optimum moisture content with the increase in nano-silica content. It was found that unconfined compressive strength also showed an increase in the addition of stabilizing material. From the investigation, it can be concluded that nano-silica particles have a potential to improve the engineering properties of the clayey soil along with its proper utilization from the environmental point of view.

Majdi et al.,(2016) Nano-SiO2 powder mixed with soil has a great specific surface area and its water absorption increases. On the other hand, the increase and combination of nano-SiO2 with soil reduces the maximum specific gravity of specimens due to very low specific weight of nano-SiO_2.

Anuj Tomar et al. (2016) Four different combinations of Nano-Silicaat different percentages 1%, 3%, 5% and 7% are used in integration with polypropylene fiber is used in different percentages such as,0.1%, 0.4%, 0.7%, 1%, and 1.3%. From these experiments, it has been analyzed that with the increase of PPF content in addition to Nano- Silica, the UCS increases and maximum value of UCS is obtained at 7% of Nano-Silica with 0.7% of PPF. The intermixing of PP fiber with the soil acts as a reinforcing material in binding the soil particles and the 'bridge effect' of fiber reinforcement in soil impedes thefurther development of tension cracks.

Changizi and Haddad (2015) added 0.1%, 0.3% and 0.5% polyester fibers and 0.5%, 0.7% and 1% nano-SiO2 to a clay soil classified as CL to discover the effect of soil stabilization effects. They found that the friction angle and cohesion of treated specimens stabilized with nano-SiO2 were enhanced by increasing the percentage of nanoparticles. They found that the internal friction angle and cohesion of specimens containing 1% nano-SiO2 and 0.3% polyester fibers increased by about 2.72 and 2.81 times, respectively..

Seyedi et al. (2013) studied the effect of nano-SiO2 additive on CL-lime mixture by performing CBR tests and found that the strength of soil containing 5% lime increased 2, 7.5 and 8 times by adding 1%, 3% and 5% nano-SiO2, respectively. Similarly, CBR strengthincreased with increasing the curing time.

2. MATERIAL AND METHODOLOGY

3.1 Soil

In this project we will use clayey soil as this soil is most problematic because of montmorillonite mineral which have high shrinkage and swelling properties.

Source of soil

The soil used in this study was obtained from jammu. As per IS classification of soil, the soil used is clayey. The soil properties are given in the table as under:

Table no. 3.1 Properties of soil used in the study

S. No.	Properties of soil	Value
1	Specific gravity	2.68
2	Liquid Limit (%)	44
3	Plastic Limit (%)	24.7
4	Plastic Index (%)	19.3
5	Maximum Dry Density (kN/m^3)	19.1
6	Optimum Moisture Content (%)	13.2
7	CBR (soaked) CBR (unsoaked)	10.30 10.55
8	Unconfined compressive strength 28 days(kN/m^3)	190

3.2 Nano Silica

In this study, amorphous nano-silica with a solid content of more than 99% will applied.

(i) Nano Silica

(ii) Nano silica with soil

Table 3.2: Physical properties of Nano-silica

Physical properties	Value
Diameter (nm)	20 – 30
Surface volume ratio (m2 /g)	193
Density (g/cm3)	1.7
Purity (%)	>99

Table 3.3: Chemical properties of nano-silica

Sr. No.	Compound	Value (%)
1	Silicon Oxide(SiO2)	99.88
2	Al_2O_3	0.05
3	Iron Oxide (Fe2O3)	0.01
4	Carbon content	0.06
5	Chloride content	0.09

3.3

3.4 Cement Kiln Dust

As an industrial by-product, the composition of cement kiln dust is a function of many variables. Its constituents include partially calcined and unreacted raw feed, clinker dust, and fuel ash, enriched with alkalisulphates, halides, and other volatiles. For the purpose of soil stabilization, CKD's may be segregated into two categories, pre- calciner kiln dust and long-wet or long-dry kiln dusts. Pre-calciner kiln dust is generally coarser, higher in free lime, and concentrated with alkali volatiles, while dust from the long kilns will contain more calcium carbonate with more limited amounts of free lime.

Table No. 3.4 Chemical composition of CKD

Constituent	% by weight
$CaCO_3$	55.5
SiO_2	13.6
CaO	8.1
K_2SO_4	5.9
$CaSO_4$	5.2
Al_2O_3	4.5
Fe_2O_3	2.1

RESULTS AND DISCUSSION

This chapter contains the results of various tests conducted on the soil in the laboratory. After determining the properties of virgin soil, the amount of NS was optimized by Standard proctor test . This quantity of NS that has been optimized was mixed with varying content of CKD. The soaked CBR values were obtained for soil- NS- CKD mix. Then compressive strength test was done by mixing different proportions of soil, NS and CKD for 7 days and 14 days curingperiod.

4.1 Atterberg's limits result;

DESIGNATION (S:NS:CKD)	Liquid limit	Plastic limit	Plasticity Index
100:0:0	44	24.7	19.3
99.7:0.3:0	44.2	24.5	19.7
99.4:0.6:0	44.3	24.4	19.9
99.1:0.9:0	44.6	24.3	20.3
99.88:0.12:0	44.1	26	18.1
94.1:0.9:5	43.9	27.7	16.2
89.1:0.9:10	43.8	27	16.8
84.1:0.9:15	42.8	25.2	17.6
79.1:0.9:20	42.6	24.9	17.7

4.2 STANDARD PROCTOR TEST

Table 4.2.1 MDD and OMC values of Soil and NS

SOIL:NS:CKD (%)	MDD (kN/m^3)	OMC (%)
100:0:0	19.1	13.2
99.7:0.3:0	18.5	13.5
99.4:0.6:0	18.8	14
99.1:0.9:0	19.3	14.4
99.88:0.12:0	18.6	15.4

4.2.1 Graphs representing the MDD and OMC value of Soil:NS

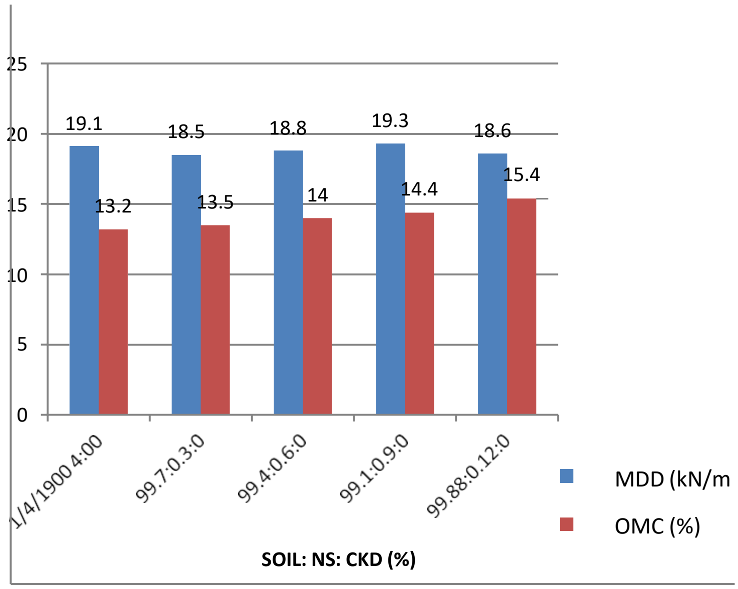
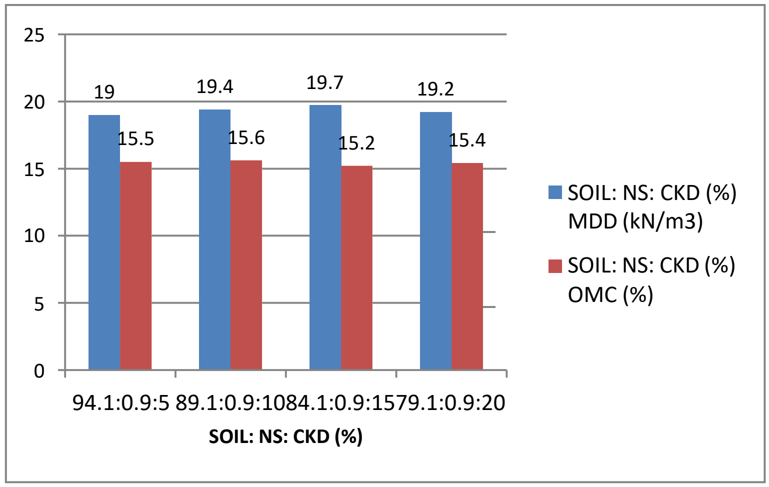


Table 4.2.2 MDD and OMC Values of Soil, NS and CKD

SOIL: NS: CKD (%)	MDD (kN/m^3)	OMC (%)
94.1:0.9:5	19	15.5
89.1:0.9:10	19.4	15.6
84.1:0.9:15	19.7	15.2
79.1:0.9:20	19.2	15.4

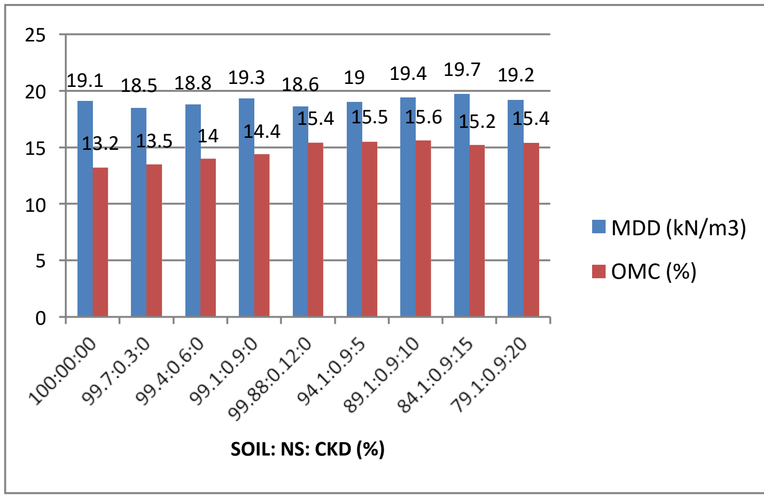


4.2.2 Graphs representing the MDD and OMC value of variousmixes together

4.2.3. Table representing the MDD and OMC value of various mixes together

SOIL: NS: CKD (%)	MDD (kN/m^3)	OMC (%)
100:0:0	19.1	13.2
99.7:0.3:0	18.5	13.5
99.4:0.6:0	18.8	14
99.1:0.9:0	19.3	14.4
99.88:0.12:0	18.6	15.4
94.1:0.9:5	19	15.5
89.1:0.9:10	19.4	15.6
84.1:0.9:15	19.7	15.2
79.1:0.9:20	19.2	15.4

4.2.3 Graphs representing the MDD and OMC value of variousmixes together



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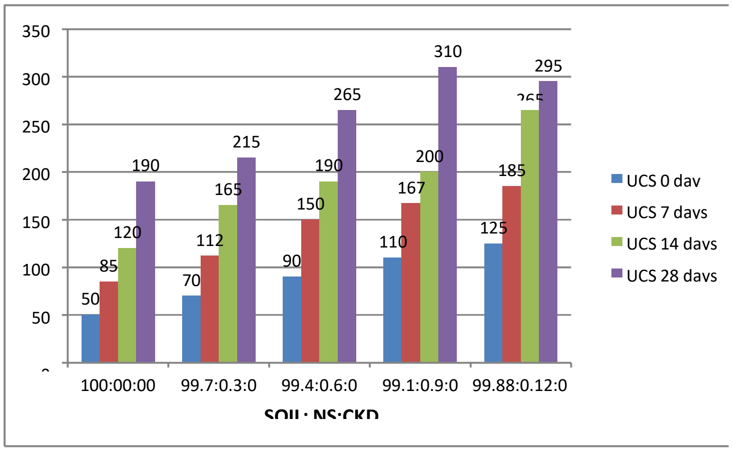
4.3 Unconfined Compressive Strength

4.3.1 UCS OF CLAYEY SOIL AND NS

SOIL: NS	UCS (kPa)	UCS (kPa)	UCS (kPa)	UCS (kPa)
	0 day	7 days	14 day	28 days
100:0:0	50	85	120	190
99.7:0.3:0	70	112	165	215
99.4:0.6:0	90	150	190	265
99.1:0.9:0	110	167	200	310
99.88:0.12:0	125	185	265	295

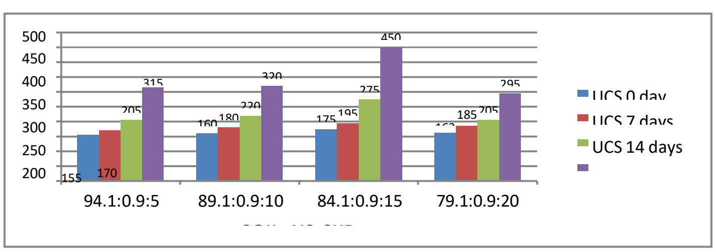
4.3.1 UCS Graph of SOIL and NS



4.3.2 UCS OF CLAYEY SOIL AND NS AND CKD

SOIL: NS : CKD	UCS (kPa)	UCS (kPa)	UCS (kPa)	UCS (kPa)
	0 day	7 days	14 days	28 days
94.1:0.9:5	155	170	205	315
89.1:0.9:10	160	180	220	320
84.1:0.9:15	175	195	275	450
79.1:0.9:20	162	185	205	295

4.3.2 UCS Graph SOIL and NS and CKD

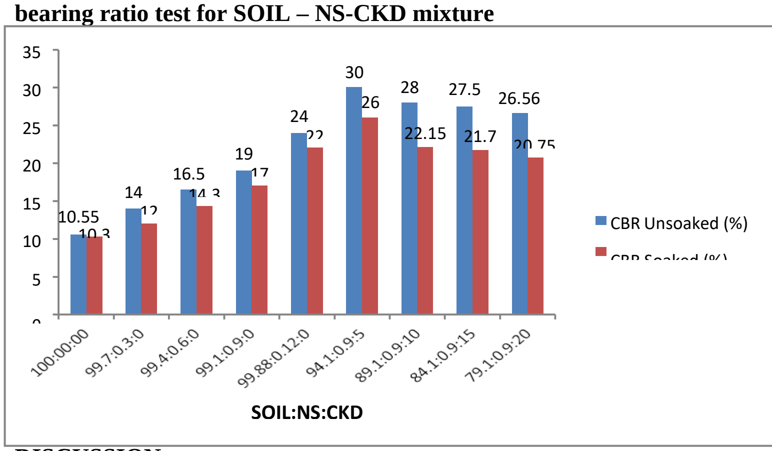


4.4 California Bearing Ratio

TABLE. 4.4.1 CALIFORNIA BEARING RATIO (UNSOAKEDand SOAKED) TESTS RESULTS FOR SOIL-NS-CKD MIXES

Mix Type	CBR Unsoaked(%)	CBR Soaked (%)
100:0:0	10.55	10.30
99.7:0.3:0	14	12
99.4:0.6:0	16.50	14.30
99.1:0.9:0	19	17
99.88:0.12:0	24	22
94.1:0.9:5	30	26
89.1:0.9:10	28	22.15
84.1:0.9:15	27.50	21.70
79.1:0.9:20	26.56	20.75

4.4.1 Graphs representing the curves that are obtained from California bearing ratio test for SOIL – NS-CKD mixture



DISCUSSION

Standard proctor test

The apparatus used for the standard proctor test comprised of a cylindrical mould having an internal diameter of 100 mm, height 127.5 mm and volume 1000 mm; the removable collar of 60 mm height and a removable base. The rammer used was 2.6 kg weight with a drop of 310 mm .

About 2.5 kg of oven dried soil sample passing through 4.75 mm sieve was taken and was mixed with about 10% of water by weight in a container. The mould was cleaned. Oiling of the mould was done. The collar was attached on the mould and mould was filled with soil in such a way that after compacting it with 25 evenly distributed blows of rammer, it is 1/3 rd of its previous height. Scratching of top of first layer was done with knife before placing and compacting the second layer. The second and third layers were compacted in a similar manner. The collar was removed from the mould and a straight edge was used to trim off the excess soil. The sample alongwith mould was weighed. This procedure was repeated 5 to 7 times after making a 2 %increase in water content to the previous value till there was a decrease in the weight of compacted soil in the mould. The dry density and water content was then calculated for each set and then from the graph, and MDD and OMC was determined.

The procedure was repeated for determining the OMC and MDD of soil - NS – CKD mix at different mix proportions

California bearing ratio

The California bearing ratio represents the bearing capacity of the soil at how much load how much penetration happens in the soil surface. The load and area of the surface leads to calculate the stress value. With the penetration we get the deformed values, with the help of which we achieve to the strain value. With the value of stress and strain we achieve to the value of modulus of elasticity. The modulus of elasticity shows the ductility of the soil which indicates earlier the soil is going to be failing under the load with the help of which we can prevent our structure to get fail. The increment in the CBR value is shown in the optimum mix (84.1:0.9:15) sample under dry condition is from 10.55% to 30%.

Unconfined compressive strength

The unconfined compressive strength is the parameter which shows the ability to bear the compressive load by the soil. In this test various samples has been done and kept for 3 days, 7 days and 28 days for curing for testing. The motive of keep it under curing to make the pozzolanic action to take place. The results show that with an increase in curing days there is vast increase in the strength of the samples. The increase in the strength after curing period is varying from 60 kN/mm^{2}to 640 kN/mm^2. The results also shows that with an increase in the curing period the strain value also goes on increasing but at greater strength, which shows that sample at 28 days resist much amount of load and save our structure from sudden collapse.

CONCLUSIONS

The conclusions drawn from the experimental investigation are as under:

- When percentage NS increases in soil there is increase in O.M.C. and decrease in M.D.D for some values.
- With the increase in quantity of CKD the value of O.M.C. And MDD increases.
- The optimum value of NS to be used for further work was 0.9%.
- The best ratio obtained was 84.1% soil: 0.9% NS: 15%CKD.
- UnSoaked CBR value increases from 10.55% for virgin soilto 30% for the best ratio of the mix.
- Unconfined compressive strength of soil- NS mixtures increase with increase in CKD up to 15 % by weight.

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