USE OF NANO SILICA AND COIR FIBER TO STRENGTHEN THE ENGINEERING PROPERTIES OF CLAYEY SOIL

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Abstract - One of the problematic soils is expansive soil, which has a strong tendency to shrink when dried and to inflate when its moisture level changes. In India, expansive soils made up of clays are referred to as black cotton soils. The alternating swell-shrink tendency of expansive soils results in foundation structures, including buildings and earth retaining wall pavements, to become distressed. For geotechnical engineers, comprehending the behavior of expansive soil and implementing the proper control measures has been a challenging challenge. A lot of study is being done to develop solutions for soils that produce black cotton. This review study uses the soil index and engineering features to examine the behavior of clayey soil stabilized with different proportions of Nano silica and Coir Fiber. Coir is a naturally occurring, biodegradable material that is widely accessible in several coastal and southern regions of India. Nano silica is a type of filler material that increases ductility without compromising strength. With less swelling potential, the generated nano silica functioned as a hydraulic binder. In expansive soils, coir fiber and nano silica are combined for the goal of sustainable development. As part of this comparison study, laboratory tests including Atterberg's limit, Compaction test, CBR test, and UCS test were performed for both modified and unmodified clayey soil. In this work, expansive soil was stabilized using Nano silica and Coir Fiber. Coir Fiber was fixed at 3.5%, after that Nano silica was changed to 2%, 4%, and 6%.

Key Words**:** Compaction test, CBR, UCS, Coir Fiber, Nano Silica

INTRODUCTION

In India, expansive soil covers nearly about 20% of the land and includes approximately the entire Deccan Plateau. They are mostly black and reddish brown in colour and are generally found with layer thickness between 0.5 m to 10 m below the surface. Because the expansive soil is prone to volume changes when it came in contact with the water by rain or water table capillary action, it will get expand and may cause lifting of the structures built over it. So, these soils are not suitable for construction works until they are properly stabilized which can increase the low bearing capacity of expansive soils.

In India, nearly 46% of total land is covered by Alluvial soil which is the most important soil type of or country. Other soils such as Black cotton soil, desert soil, laterite soil and marine soil are also the important soil groups of India. The Alluvial soil and the black cotton soil mainly consists of clay which is very fine soil and it’s the main constituent of expansive soils and due to the cohesive nature of clay, these soils absorb large amounts of water and show swelling characteristics which create problems such as bulging of soil, low bearing strength of soil, and can cause cracks in the foundation.

2. Literature Review

Datta et al. (2023)

Terrasil and coir fiber were utilized in this investigation in quantities of 0.5%, 0.5%, 1.0%, 1.5%, and 2.0%, respectively. According to analyses or test results, clay subgrade soil that has been stabilized with 0.5% Terrasil and 1.5% coir fiber displays specific strength and CBR value augmentation values. The number of layers required for the subgrade is reduced as a result of the treated soil's normally higher CBR estimated value, which is 90% more than the untreated soil.

Samin et al. (2021)

In this study, PE and PP have been used in the form of fibres. The effect of the stabilisation was evaluated through carrying out standard laboratory tests. These tests have been conducted on natural and stabilised soils with four fibre contents (1%, 2%, 3%, and 4%) of the soil weight. The tests included the standard compaction test, unconfined compressive strength (UCS) test, California Bearing Ratio (CBR) test, and resilient modulus (Mr) tests. In all these tests, the fibre content was added in two lengths, which were 1.0 cm and 2.0 cm. Laboratory test results revealed that the plastic pieces decrease maximum dry density (MDD) and optimum moisture

content (OMC) of the stabilised soils, which are required for the construction of embankments of lightweight materials. In addition, there was a significant improvement in the UCS of soils by 76.4 and 96.6% for both lengths of PE fibres and 57.4% and 73.0% for both lengths of PP fibres, respectively. Results of the CBR tests demonstrated that the inclusion of plastic fibres in clayey soils improves the strength and deformation behaviour of the soil especially with 4% fibre content for both lengths 1.0 cm and 2.0 cm, respectively, to a figure of 185 to 150% for PE and PP, respectively. Furthermore, the results of the Mr tests demonstrated that the mechanical properties improved to an extent. For an increase in fibre content, the resilient modulus increased by about 120% at 4% fibre content for PE. However, for PP, improvement in resilient modulus declined at 3% fibre content. Therefore, for soil stabilisation with fibre material, optimum fibre content shall be sought.

Tripathi et al. (2020)

In this study, soil engineering qualities are improved by using stabilizers such as Recron 3-S fiber, Terrasil, and silica fume. Our primary focus has been on increasing the soil's CBR because doing so contributes to reducing the pavement's thickness and has positive economic benefits.

Singh et al. (2019)

The main motive of this research is to investigate the optimal combination of Nano-Silica and Polypropylene fiber with clay soil. The engineering properties such as liquid limit, plastic limit, maximum dry density and unconfined compressive Strength (UCS) are analyzed with virgin soil, the soil with Nano-Silica and combination of soil with Nano-Silica and polypropylene fiber. The Durability test is performed to understand the durability of stabilized soil by analyzing wetting–drying cycles Also, Scanning Electron Microscopy (SEM) test is carried out and images are obtained to understand micro-structural modification towards mixture of Nano-SiO_2 and PPF. Four different combinations of Nano-Silica at 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 the further development of tension cracks.

Sharma et al. (2019)

In the present study, therefore we have investigated the influence of waste polypropylene fibers on the resilient modulus of clay soil. Under this investigation, several cyclic CBR tests were performed on soil specimens by reinforcing the clay soil with polypropylene fibers which were added in different percentages i.e. 0.3%, 0.4%, 0.5%, 0.6% by weight of soil. The outcomes show that the experimented technique is very effective to improve the resilient modulus of clay soil. It is found that for the best results, optimum percentage of waste polypropylene fibers to be added is 0.4 % by weight of soil. Finally, it has been concluded that reinforcing the clay soil with polypropylene fibers provides positive influence on resilient modulus of the soil.

Suresh et al. (2018)

This review paper presents an investigation of behavior of clayey soil stabilized with varying percentages (0.5-10%) of coir fiber and Nano silica, by carrying out the index and engineering properties of soils. Coir is a natural biodegradable material abundantly available in some parts of south and coastal regions of India. Nano silica is small filler size materials increase ductility with no decrease of strength. The induced of the nano silica acted as a hydraulic binder with lesser swelling potential. The combination of coir fiber and Nano silica are used in expansive soils for sustainable development purpose.

3. Materials

3.1 SOIL

Source of soil

With high clay content, the soil is alluvial in character. Roughly 120 kg of earth had been gathered in total. Prior to beginning the tests, all of the soil is sieved using a 4.75 mm sieve. In order to remove any remaining moisture from the soil, it is oven dried for a full day before using. Prior to testing with different amounts of Coir Fibre and Nano silica, virgin soil is first examined for its characteristics and strength value without any admixtures. The various properties of untreated soil that is used are:

Table no. 1 Properties of soil used in the study

S.No.	Properties	Result
1.	Liquid limit (%)	35
2.	Plastic limit (%)	22
3.	Plasticity Index (%)	13
4.	Specific Gravity	2.57
5.	Maximum Dry Density (KN/m^3)	17.91
6.	Optimum Moisture Content (%)	14.76
7.	Soil Classification	CI (Intermediate Compressive Clay)
8.	CBR (%) (soaked)	2.32
9.	CBR (%) (Unsoaked)	4.2
9.	UCS ($kN/m^{2)}$	271

3.2 Nano Silica

Source of Nano Silica

Nano Silica used in this research work was collected from Ludhiana.

The properties of Nano Silica are listed in Table 2 and Table 3

Table 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: 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 Coir Fiber

These fibers are environmentally friendly and biodegradable. Among all natural fibers, it possesses the highest tearing strength and maintains this quality when wet. Coconut fiber was chosen as the study's reinforcement material as a result. The 30 mm strip of coir utilized for the investigation was cut.

Table 4:- Properties of Coir Fiber

S.No	Property	Value
1.	Density (g=cm^3)	1.2
2.	Modulus (GPa)	4-6
3.	Tensile Strength (MPa)	175
4.	Elongation of Failure (%)	30
5.	Water Absorption (%)	130-180

4. EXPERIMENTAL RESULTS

4.1 STANDARD PROCTOR TEST

Table no. 5: Results of OMC and MDD for mix proportions of Nano silica and Coir Fiber

SOIL:NS:CF	**MDD (kN/m³)**	**OMC (%)**
100:0:0	17.91	14.76
94.5:02:3.5	17.43	15.10

92.5:04:3.5	16.96	15.65
90.0:06:3.5	16.35	16.27

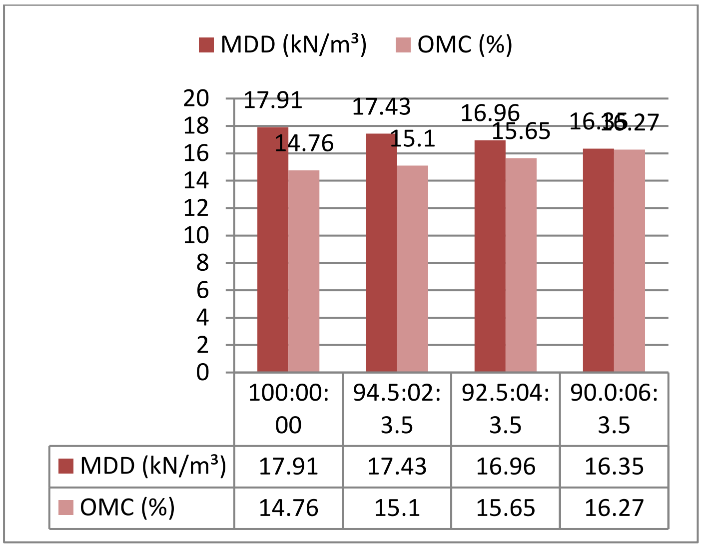

Fig:-1 Differences b/w MDD and OMC of Nano Silica and Coir Fiber in various ratios

Table 6: Results of UCS of Nano silica and Coir Fiber

Clayey Soil :NS: CF	**Curing Period (Days)**	**UCS (kN/m^2)**
100:00:00	7	271
94.5:02:3.5	7	340
92.5:04:3.5	7	435
90.0:06:3.5	7	530

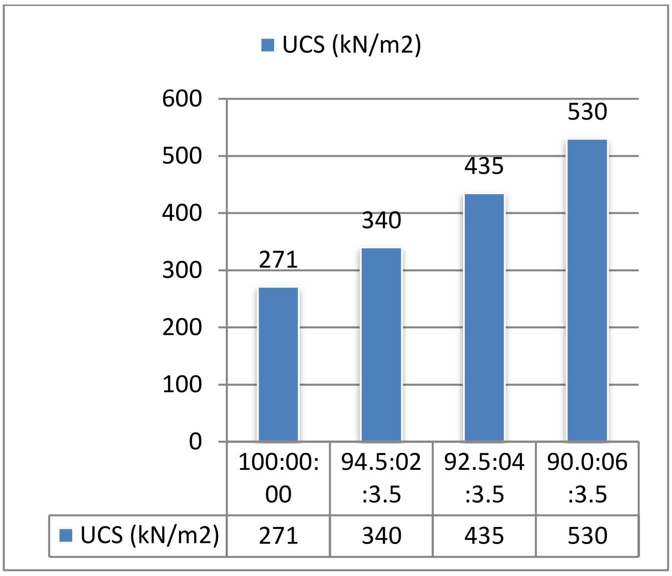

Fig:-2 various ratios of Nano silica and Coir Fiber are shown in the UCS graph.

Table 5: Results of CBR for Nano silica and Coir Fiber

Mix Proportions (CS:NS:CF)	**CBR (%) (Soaked)**	**CBR (%) (Unsoaked)**
100:00:00	2.32	4.2
94.5:02:3.5	3.7	6.29
92.5:04:3.5	4.9	7.84
90.0:06:3.5	6.2	9.90

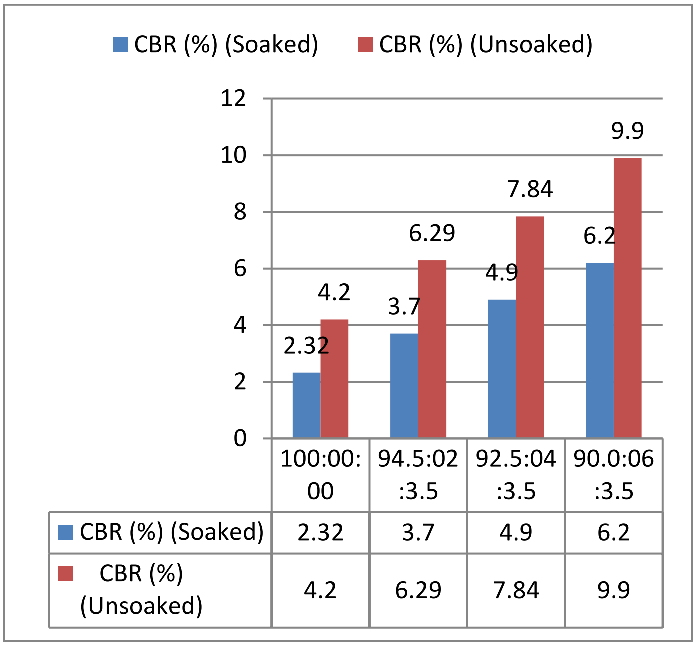

Fig:-3 CBR Graph of Nano silica and Coir Fiber with various ratios

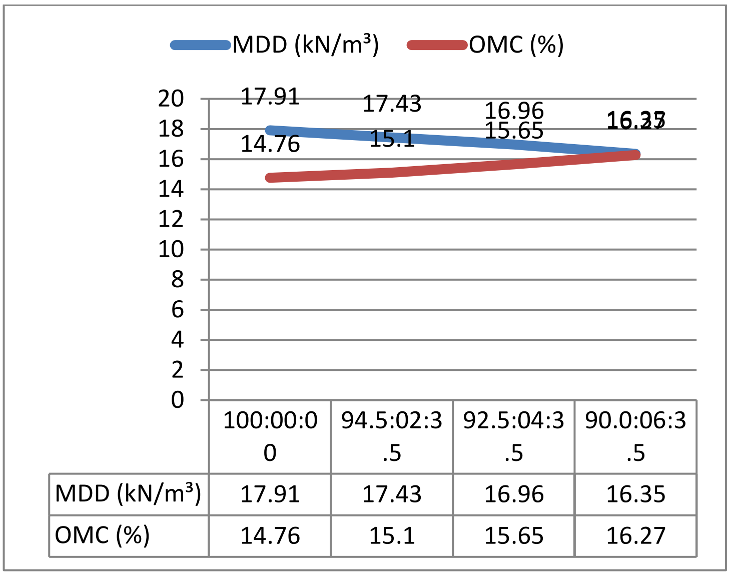

Fig:-10 Variations b/w MDD and OMC values of Nano Silica and Coir Fibre Mix with Soil

5 DISCUSSIONS

5.1 STANDARD PROCTOR TEST:

- There is a decrease of MDD from 17.91 to 16.35% and increase of OMC from 14.76 to 16.27% when the percentages of Nano Silica vary from 2% to 4% and Coir Fibre is fixed from 3.5%.

- There is a decrease in MDD of modified soil with increase in percentage of Nano Silica, due to the lower specific gravity of Nano Silica as compared to the unmodified soil and OMC of modified soil is increase as the percentages of Nano Silica increases, due to the increase in cohesive property of soil.

5.2 CBR TEST:

- The CBR value of untreated soil is 2.32 and it increases to 2.19 times with addition of 7% Nano Silica when observed in soaked conditions.
- The CBR value of untreated soil is 2.32 and it increase to 2.67 times when Nano Silica 6% and Coir Fibre 3.5% is added to untreated soil. This enhancement in CBR may be because of the gradual formation of hydration compounds in the soil due to the reaction between the stabilizers and the essentials particle present in the soil.

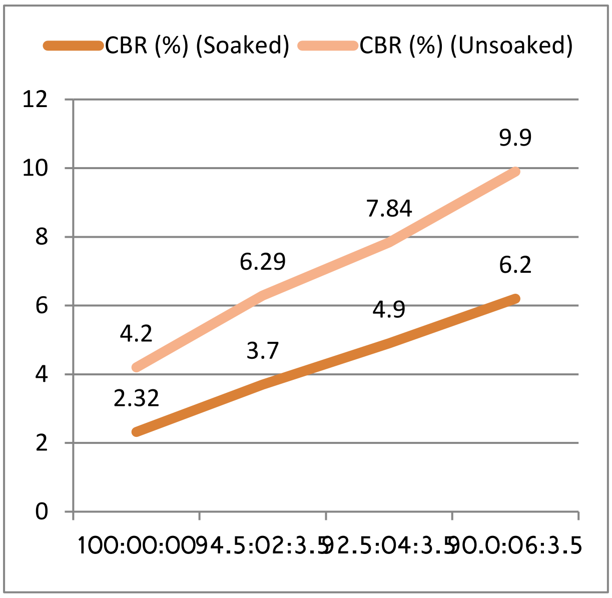

Fig:-11 Variations b/w CBR Values of Nano Silica and Coir Fiber Mix with Soil

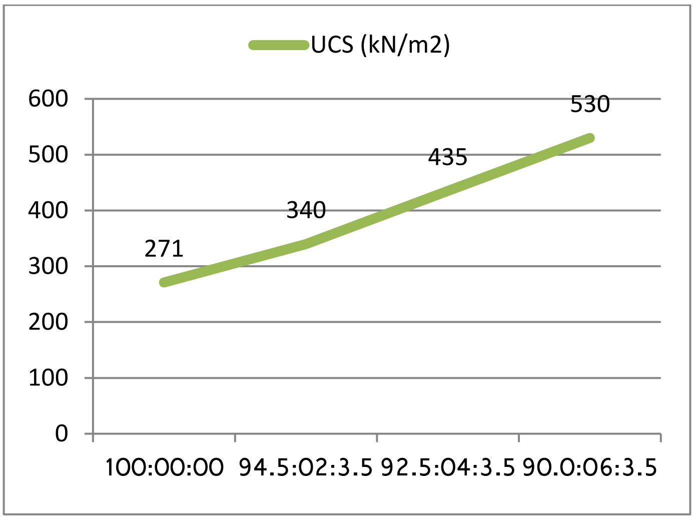

Fig:-12 Variations b/w UCS Values of Nano Silica and Coir Fibre Mix with Soil

5.3 UCS TEST:

- The UCS values of untreated soil also improve considerably with expansion of Nano Silica 6% and Coir Fibre 3.5%. The value increases from 271kN/m² to 530kN/m² with addition of Nano Silica and Coir Fibre.
- The reason behind of this when Nano Silica and Coir Fibre comes in contact with water, Because Nano-silica wraps the outer surface of the fibre and hence form better bond between the soil particles and the fibre surface which results in improving soil characteristics.

CHAPTER 5

CONCLUSIONS

Following conclusions can be inferred on the basis of the experiments performed:

In present time, there has been an investigation into the use of recycled fibre. It is a hot issue due to environmental benefits and cost efficiency. Past studies had shown that the addition of waste chemicals can improve the strength properties of soft clay. This study investigates the effects of recycled Nano Silica and Coir Fibre on the mechanical properties of clay based on the results a number of series of tests like – LL, PL, PI, Compaction, CBR, and UCS. The following conclusions can be drawn;

I. Based on the test results achieved from UCS after the curing periods of 7 days, the optimum mixing stabilizing agent for clay soil is 6% of Nano-silica and at 3.5% of Coir Fibre.

II. Because nano-silica wraps the outer surface of the fiber and hence form better bond between the soil particles and the fibre surface which results in improving soil characteristics.

III. The C.B.R value increases with increase of Nano Silica along with increasing quantity of Coir Fibre. It increased 1.95 times from the untreated soil.

IV. Thus the optimum ratio of mixture of 86.5% soil/ 6% NS/ 3.5% Coir Fibre is suggested for usage as soil stabilization process.

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