ROLE OF NANO SILICA AND POLYPROPYLENE FIBER IN AMENDING THE EARLY STRENGTH DEVELOPMENT OF A EXPANSIVE SOIL

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Abstract- Recently, the use of plastic products,such as. polyethylene (PE) bottles and polypropylene (PP), has. been significantly increased, which may lead to many environmental issues. Therefore, it is important to find methods to manage these waste materials without causing any ecological hazards. One of these methods is to use plastic wastes as soil stabiliser materials. In this study, Polypropylene Fiber (PP) has 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 (0.5%, 0.8%, 1.1%, and 1.4 %.) of the soil weight. The tests included the standard compaction test, unconfined compressive strength (UCS) test, California Bearing Ratio (CBR) test. 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. Four different combinations of Nano-Silica at different percentages 2%, 4%, 6% and 8% are used in integration with Polypropylene Fiber is used in different percentages such as, 0.5%, 0.8%, 1.1%, and 1.4%. From these experiments, it has been analyzed that with the increase of Polypropylene Fiber 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 Polypropylene Fiber.

Keywords: Polypropylene fiber ,NanoSilica,CBRtest,UCStest.

INTRODUCTION

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Expansive soil

Expansive soils are the soils which have high shrinkage and swelling characteristics and lower strength when it came in contact with water. These soils are very sensitive to variations in water content and show excessive volume changes and has high compressibility. This highly plastic soil may create cracks and damage the construction work done above these type of soils.

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

The term soil stabilization means the improvement of the properties of soil such as stability or bearing strength with the use of controlled compaction, proportioning and the addition of suitable admixture or stabilizers. Soil stabilization deals with both the physical and chemical methods to make the soil stabilized to serve its purpose as the ground bed for the construction work. Stabilization of weak soil involves the use of various industrial waste material such as fly ash, pond ash, rice husk ash, blast furnace slag, cement kiln dust, marble dust, nylon fibre etc. All these industrial wastes needs to be thrown out in land fills or any other type of dumping site which make them costly to dump. So, these industrial wastes should be utilized in some processes so that the waste can be used for some useful purposes. One of the common and feasible ways to utilize these waste products is to go for construction of roads, highways and embankments. If these materials can be used in required proportion for the construction purpose, the environmental problems and valuable land acquisition caused by these industrial wastes can be greatly reduced. Stabilization is the method used in this project to increase the inherent strength of expansive soil. The present project work aims at evaluating the effectiveness of Nano silica and Polypropylene fibre in reinforcing and stabilzing the expansive soil as the cement kiln dust help in the process of chemical stabilization and the nylon fibre acts as a reinforcing agent.

General

To construct building using weak/soft soil is very risky because it is sensitive to differential settlements because of its weak shear strength. For improvement in certain properties such as carrier capacity, shearing soil capacity and permeability characteristics, a number of methods such as prefabricated vertical drains and soil stabilizations are followed by engineers. The chemical stabilization is the most commonly used strength improvement method for soil stabilization . The main intend of soil stabilization is to enhance the strength of the soil and to lessen its settlement. The utilization of recycled/ waste materials comprises of different benefits economically as well as environmentally . This also helps in minimising the construction cost of engineering projects. Thus, a lot of studies have been carried out to investigate the utilization of recycled materials as a novel stabilizer in the projects of soil stabilization. Nano technology revolves around to create a variety of collections of nano-materials. It basically covers nano-particles with nano objects. The particles of about 100 nm or less than are known as nanomaterials whereas nano objects is doubled lower than the same size . The nanotechnology was first come into existence in 1959 in a lecture provided by Feynman which was entitled as ‘ ‘ There is a lot of space underneath” . It is important although at that time the term ’ nanotechnology’ was not there yet. Years later, this technology made rapid and imperative progress in science. Due to its great features such as low cost, green environmental approach, it finds applications in different engineering fields such as biosynthesized nano-particles , agriculture, biomedical and engineering sector.

LITERATUREREVIEW

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, 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.

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-SiO2 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.

Al.-Jaberi et al. (2017)

In their study, they improved the properties of poor subgrade soil using Cement Kiln Dust.

They investigate the effects of CKD on the properties of the poor subgrade soils using CBR testing method with different doses of CKD (5%, 10%, 15%, 20%, 25%, and 30%bythedry weight of the selected soil) in combination with different curing periods (1 day,3 days, 7 days, 14 days, and 28 days). They concluded that the optimum amount of CKD to be used is 20% and the optimum curing period for this came to be 14 days.

Keerthi et al. (2017)

The stabilization of clayey soil is done using CKD. In which the CKD proportions is varied from 0 to 50% by weight of soil. In their study, it is found that the Unconfined Compressive Strength of soil is increased when CKD is added 50% as compared to 0% CKD. They also concluded that the optimum quantity of CKD for light applications is varied between 12-30% however for heavy applications, CKD content of upto 50% can be used.

Rokade et al. (2017)
Addition of nylon fibre along with fly ash to measure the change in the strength parameters of black cotton soil. The CBR of the soil was determined by conducting three series of tests. Tests were carried out on the BC soil mixed with varying percentage of fly ash, from 10% to 40% out of which 20% came out to be cptimum. Then, nylon fibre with aspect ratios (length/ diameter) 20, 40, 60 and 80 and fiber contents were varied from 0.25% to 1.5% with 0.25% interval, out of which 0.75% of fibre content is considered as optimum on the basis of MDD and maximum CBR value.

Ajit kumar et al. (2016) The study is an experimental investigation on the use of HDPE (High Density Polyethylene) mixed with a CL-ML soil. The HDPE sheets were cut into 5mm wide strips and then into three aspect ratios as 1, 2 and 3. Such strips were then randomly mixed in the soil in different proportions (0.5%, 1.0%, 1.5% and 2%) by dry weight of soil. The paper reports results obtained on dry density and CBR behaviour of the soil. A decrease in the dry density of soil with increasing aspect ratio as well as percentage of HDPE content was obtained. On the other hand, CBR value is found to increase with increase in aspect ratio, the maximum CBR value obtained at 1.5% HDPE content. Increasing HDPE to 2%, resulted in reduction of CBR. In view of HDPE, being relatively less expensive as compared to other reinforcing materials; the results find application in designing base material for highway construction and reducing compressibility of soil. Also, it will certainly lead to safe disposal of the waste in eco-friendly manner.

Strength increased withi ncreasing the curing time.

1. MATERIALANDMETHODOLOGY

3.1 Soil

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

Sourceofsoil

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 asunder:

Tableno.3.1 Propertiesofsoilusedinthestudy

S. No.	Properties of soil	Value
1	Specificgravity	2.68
2	LiquidLimit(%)	44
3	PlasticLimit(%)	24.7
4	PlasticIndex(%)	19.3
5	MaximumDryDensity(kN/m^3)	19.1
6	OptimumMoistureContent(%)	13.2
7	CBR(soaked) CBR(unsoaked)	10.30 10.55
8	Unconfinedcompressivestrength 28days(kN/m^3)	190

3.2 **NanoSilica**

Inthisstudy,amorphousnano-silicawithasolidcontentofmorethan99%will applied.

(i) Nano Silica

(ii) Nano silica with soil

Table3.2:PhysicalpropertiesofNano-silica

Physicalproperties	Value
Diameter(nm)	20– 30
Surfacevolumeratio (m2/g)	193
Density(g/cm3)	1.7
Purity(%)	>99

Table3.3:Chemical properties of nano-silica

Sr.No.	Compound	Value(%)
1	SiliconOxide(SiO2)	99.88
2	Al2O3	0.05
3	IronOxide(Fe2O3)	0.01
4	Carboncontent	0.06
5	Chloridecontent	0.09

Polypropylene Fiber

Source of Polypropylene fiber

The Polypropylene fiber used in this study was obtained from Jindaram Exports, Sirsa. Polypropylene fiber is a natural fibre having greater tensile strength and can be used as an effective reinforcing material in soil stabilization. The properties and composition of Polypropylene fiber are discussed in table no. 3.4

S. No	Property	Value
1	Colour	White
2	Specific Gravity (Kg/$m^3 m^3$)	910
3	Water Absorption (%)	110
4	Length of fibre (mm)	12
5	Diameter of propylene fibre (mm)	0.034
6	Tensile Strength(MPa)	350
7	Modulus of elasticity (GPa)	3500
8	Unit weight	0.91g/cm^3

RESULTS AND DISCUSSION

This chapter includes the complete details and information on all the different tests that were performed in this project. All the details about how the different materials of the project work are utilized and processed. The details about the soil, and all the mix proportions of soil with different materials. The results which include standard proctor test results, CBR test results, UCS test results and Atterbergs limits are shown in this chapter.

MIX RATIOS USED

Different proportions of different materials were used in the project work. Nano silica was 2%, 4%, 6% & 8% and Polypropylene Fiber used was 0.5%, 0.8%, 1.1% & 1.4%.
Now, S=Soil, NS= Nano Silica, PPF= Polypropylene Fiber

Table no. 4.1: Various Mix proportions of Soil, Nano Silica and Polypropylene Fiber

Sr. No.	Designation (S:NS:PPF)
1	100:0:0
2	98:02:00
3	96:04:00
4	94:06:00
5	92:08:00
6	99.5:00:0.5
7	99.2:00:0.8
8	98.9:00:1.1
9	98.6:00:1.4
10	94.6:05:0.4
11	92.3:07:0.7
12	92.0:09:1.0

STANDARD PROCTOR TEST

4.5.1 Untreated Soil and Nano Silica Mix

Table 4.2: Results of OMC and MDD for Untreated soil and NS mix

SOIL:NS	MDD (kN/m^3)	OMC (%)
100:0	18.23	15.2
98:02	17.6	17.2
96:04	17.1	17.9
94:06	16.6	18.4
92:08	16.2	19.1

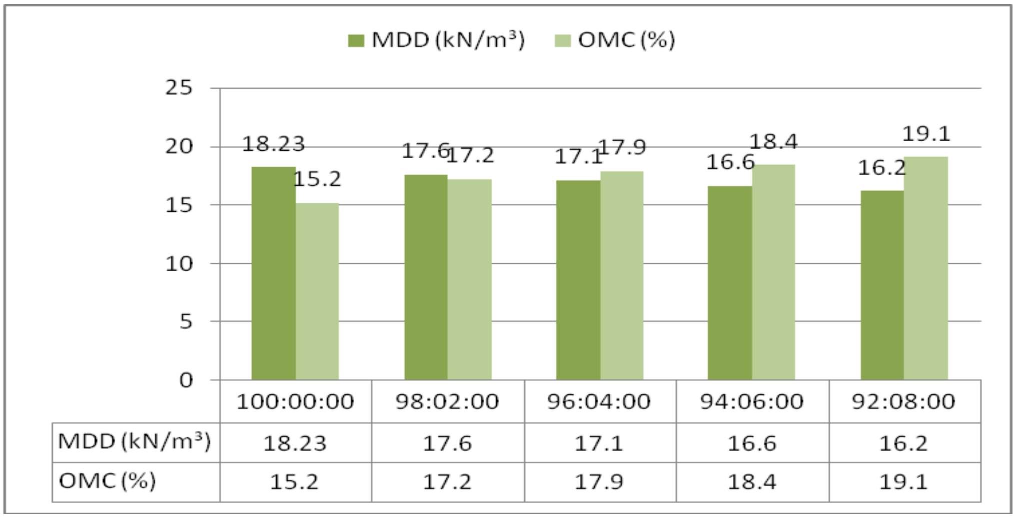


Fig:-1 Variations b/w MDD and OMC of Nano Silica & soil with different proportions

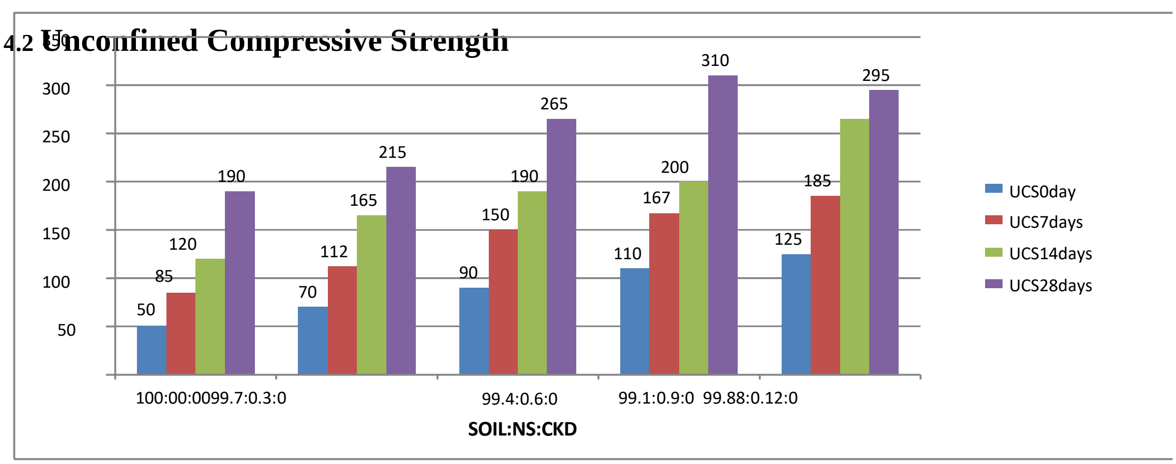
4.1.1 :NS

CLAYEY SOIL AND POLYPROPYLENE FIBER MIXES

Table no. 4.3: Results of OMC and MDD for mix proportions of Soil and Polypropylene Fiber

SOIL:PPF	**MDD (kN/m³)**	**OMC (%)**
100:0:0	18.23	15.2
99.5:0.5	18.6	14.8
99.2:0.8	19.1	14.3
98.9:1.1	19.5	13.9
98.6:1.4	20.1	13.6

4.2 Unconfined Compressive Strength



4.5.3 CLAYEY SOIL-NANO SILICA AND POLYPROPYLENE FIBER MIXES

Table no. 4.4: Results of OMC and MDD for mix proportions of Soil, Nano Silica and Polypropylene Fiber

SOIL:NS:PPF	MDD (kN/m³)	OMC (%)
100:0:0	18.23	15.2
94.6:05:0.4	17.50	15.90
92.3:07:0.7	17.10	16.80
92.0:09:1.0	17.70	16.20

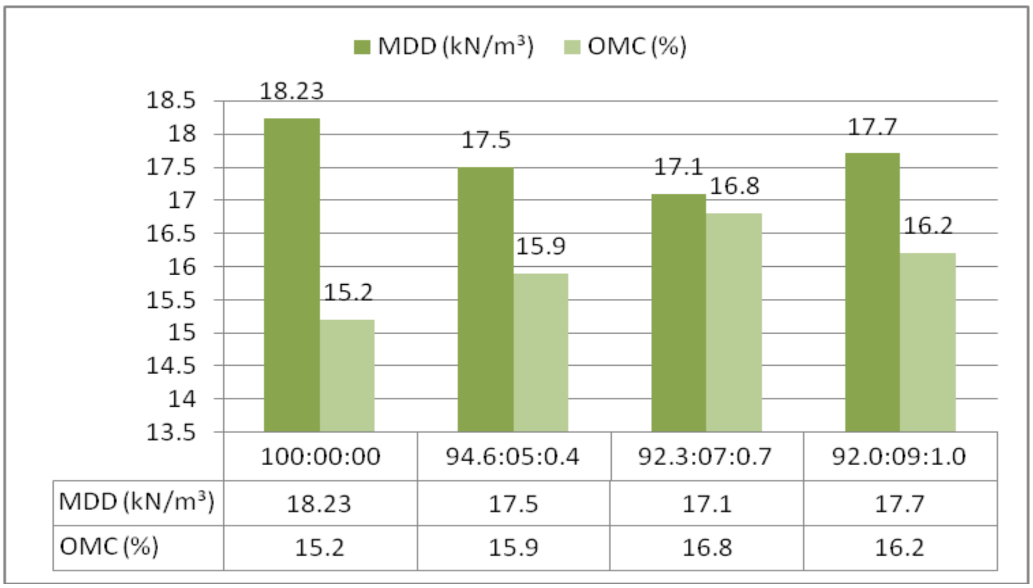


Fig:-3 Variations b/w MDD and OMC of Nano Silica, Polypropylene Fiber & soil with different proportions

4 UNCONFINED COMPRESSION STRENGTH TEST

Table 4.5: Results of UCS Test of untreated soil

Clayey Soil	Curing Period (Days)	UCS (kN/m²)
100 : 00	7	265

Results of UCS of Nano Silica

Clayey Soil : NS	Curing Period (Days)	UCS (kN/m^2)
100:00	7	265
98:02	7	310
96:04	7	425
94:06	7	513
92:08	7	630

UCS Values of Clayey soil And Nano Silica

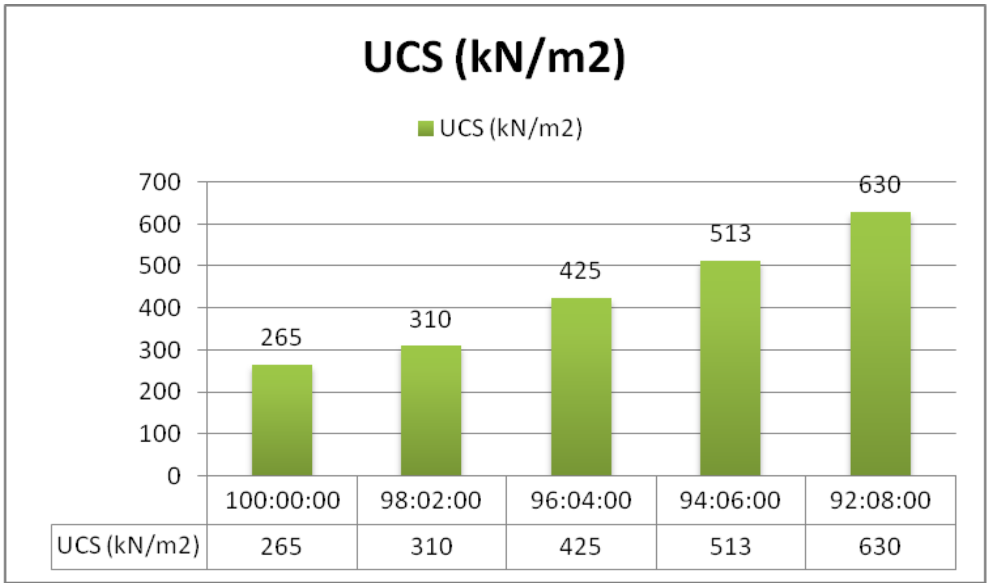
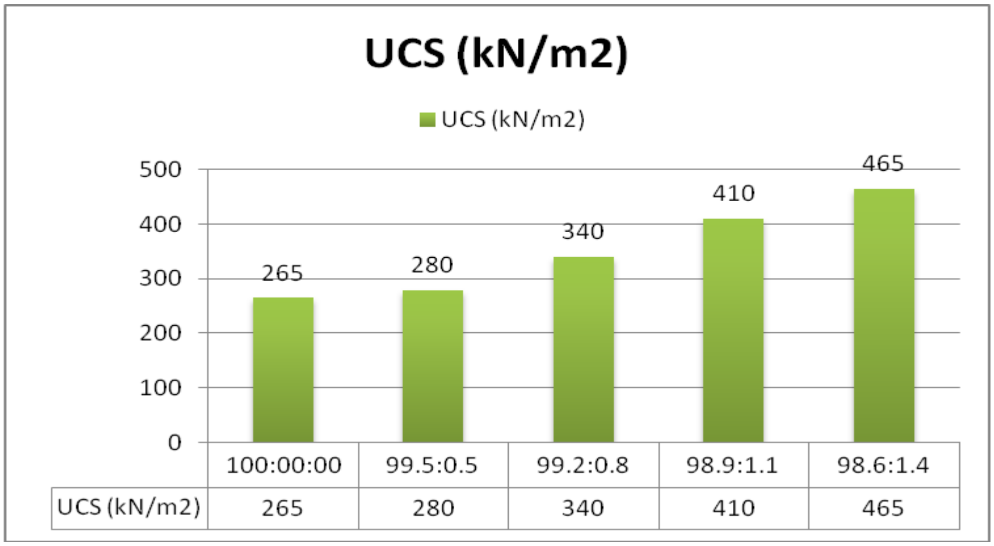


Table 4.7: Results of UCS of Polypropylene Fiber

Clayey Soil : PPF	Curing Period (Days)	UCS (kN/m^2)
100:00	7	265
99.5:0.5	7	280
99.2:0.8	7	340
98.9:1.1	7	410
98.6:1.4	7	465

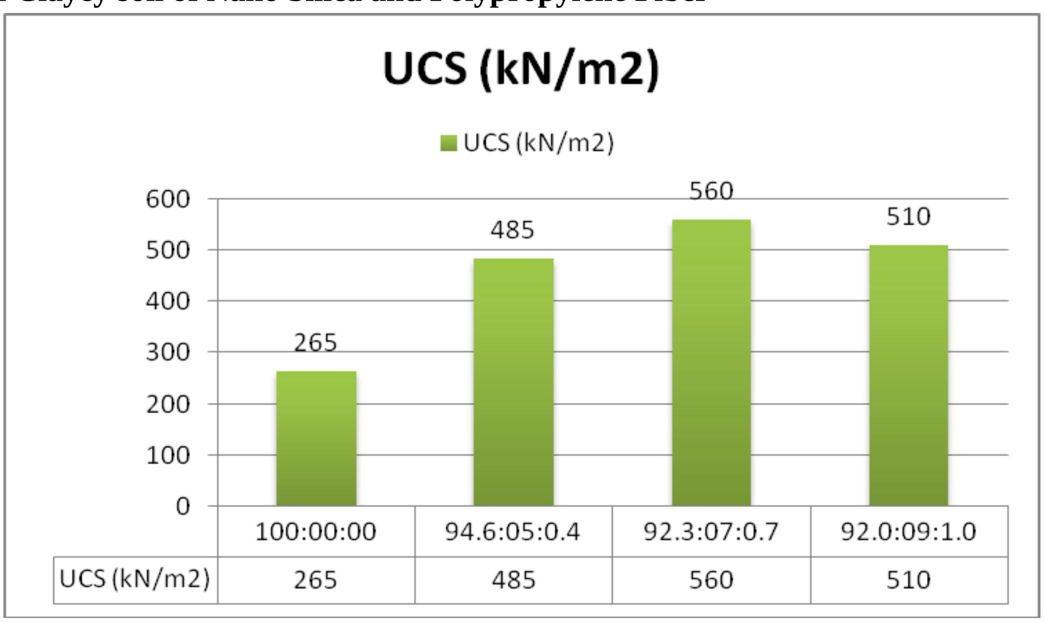
UCS Value of Clayey soil And Polypropylene Fiber



: Results of UCS of Nano Silica and Polypropylene Fiber Mix with Soil

Clayey Soil :NS: PPF	Curing Period (Days)	UCS (kN/m^2)
100:00:00	7	265
94.6:05:0.4	7	485
92.3:07:0.7	7	560
92.0:09:1.0	7	510

UCS Value of Clayey soil of Nano Silica and Polypropylene Fiber



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4.7 CALIFORNIA BEARING RATIO TEST

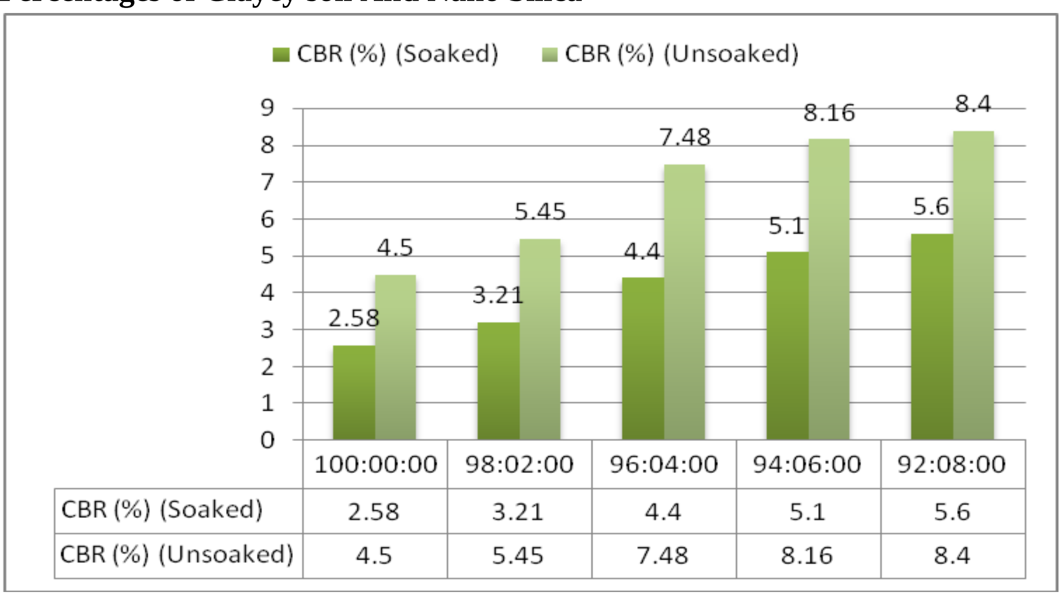
Table 4.9: Results of CBR value for untreated soil sample.

Clayey soil	CBR (%) (Soaked)	CBR (%) (Unsoaked)
100:00:00	2.58	4.5

Results of CBR of Nano Silica

Mix Proportions (CS:NS)	CBR (%) (Soaked)	CBR (%) (Unsoaked)
100:00	2.58	4.50
98:02	3.21	5.45
96:04	4.40	7.48
94:06	5.10	8.16
92:08	5.60	8.40

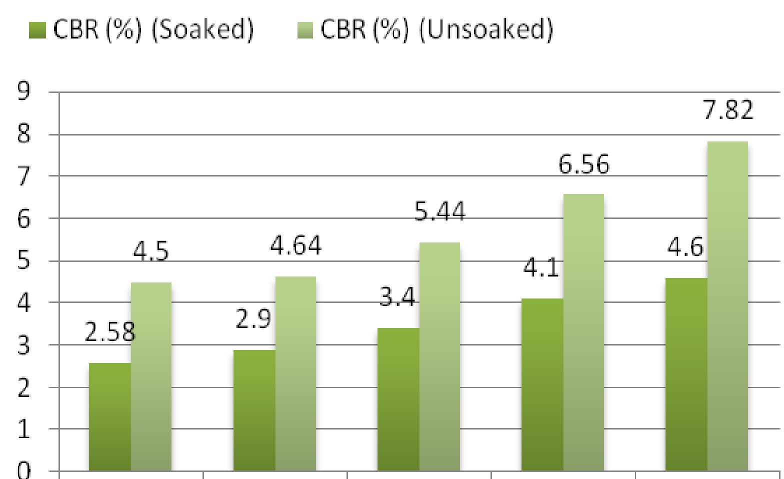
CBR Percentages of Clayey soil And Nano Silica



Results of Soil and Polypropylene Fiber

Mix Proportions (CS:PPF)	CBR (%) (Soaked)	CBR (%) (Unsoaked)
100:00	2.58	4.5
99.5:0.5	2.90	4.64
99.2:0.8	3.40	5.44
98.9:1.1	4.10	6.56
98.6:1.4	4.60	7.82

CBR Percentages of Clayey soil And Polypropylene Fiber

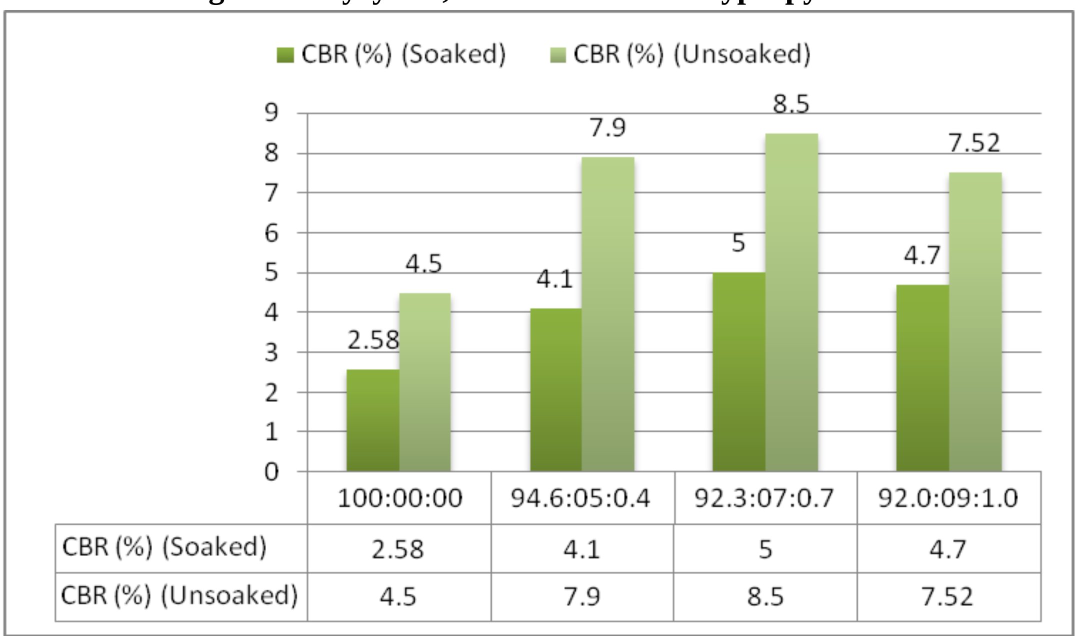


	100:00:00	99.5:0.5	99.2:0.8	98.9:1.1	98.6:1.4
CBR (%) (Soaked)	2.58	2.9	3.4	4.1	4.6
CBR (%) (Unsoaked)	4.5	4.64	5.44	6.56	7.82

Results of CBR of Nano Silica and Polypropylene Fiber Mix with Soil

Mix Proportions (CS:NS:PPF)	CBR (%) (Soaked)	CBR (%) (Unsoaked)
100:00:00	2.58	4.5
94.6:05:0.4	4.10	7.90
92.3:07:0.7	5.00	8.50
92.0:09:1.0	4.70	7.52

Fig:-9 CBR Percentages of Clayey soil, Nano silica and Polypropylene Fiber



About 2.5 kg of oven dried soil sample passing through 4.75 mm sievewas taken and was mixed with about 10% ofwater by weight in acontainer. The mould was cleaned. Oiling of the mould was done. Thecollarwasattachedonthemouldandmouldwasfilledwithsoilinsuchawaythataftercompactingitwith25evenlydistributedblows oframmer, it is 1/3 rd of its previous height. Scratching of top of first layerwas done with knife before placing and compacting the second layer.The second and third layers were compacted in asimilar manner. Thecollar was removed from the mould and a straight edge was used to trimoff the excess soil. The sample alongwith mould was weighed. Thisprocedure was repeated 5 to 7 times after making a 2 %increase in watercontent to the previous value till there wasa decrease in the weight ofcompacted soil in the mould.Thedry density and water content wasthen 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

Californiabearingratio

The California bearing ratio represents the bearing capacity of the soil athow much load how much penetration happens in the soil surface. Theload and area of the surface leads to calculate the stress value. With thepenetration we get the deformed values,with the help of which weachievetothestrainvalue.Withthevalueofstressandstrainweachieve to the value of modulus of elasticity. Themodulus of elasticityshows the ductility of the soil which indicates earlier the soil is going tobe failing under the load with the help of which we can prevent ourstructure to get fail. The increment in the CBR value is shown in theoptimum mix(84.1:0.9:15) sample under dry conditionis from 10.55%to30%.

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 varioussamples has been done and keptfor 3 days, 7 days and 28 days forcuring fortesting.The motive ofkeepitundercuringto make thepozzolanic action to take place.The results show that withan increasein curing days there is vast increase in the strength of the samples. Theincrease in the strength after curing period is varying from 60 kN/mm^{2}to640 kN/mm^2. The results also shows that with an increase in the curingperiod the strain value also goes on increasing but at greater strength,which shows that sample at 28 days resist much amount ofload andsaveour structure fromsuddencollapse.

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 fiber. 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 Polypropylene Fiber 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;
Based on the test results achieved from UCS after the curing periods of 7 days, the optimum mixing stabilizing agent for clay soil is 7% of Nano-silica and at 0.7% of PPF.
Because nano-silica wraps the outer surface of the fiber and hence form better bond between the soil particles and the fiber surface which results in improving soil characteristics.
Surface cracks in the form of narrow and Nano-cracks on the compressed soil surface are visibly observed. The minimization of cracks in the soil shows that the Nano silica and PPF material acts as

bridge between the particles of soil and hence results in increasing soil strength. As a result, the PPF material strengthens the spreading soil site and maintains it during load transfer condition.
The C.B.R value increases with increase of Nano Silica along with increasing quantity of Polypropylene Fiber. It increased 1.93 times from the untreated soil.

Thus the optimum ratio of mixture of 92.3% soil/ 7% NS/ 0.7% PPF is suggested for usage as soil stabilization process.

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