ROLE OF NANO SILICA AND EGG SHELL POWDER IN AMENDING THE EARLY STRENGTH DEVELOPMENT OF CLALEY SOIL

SATYAM MAHAJAN[1], Anoop Sharma[2]

[1]PG student, Dept. of Civil Engineering, Sri Sai College of Engineering and technology, Badhani,Pathankot,Punjab
[2] Assistant Professor, Dept. of Civil Engineering, Sri Sai College of Engineering and technology, Badhani,Pathankot, Punjab

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Abstract - Clayey soils are one of the problematic soil which is widespread in the country and has a low bearing capacity due to the presence of the montmorillonite material. This study investigates some of the mechanical properties of soft clay soil after adding the environmental waste material like egg shells. This study uses eggshell powder (ESP), Nano silica which can be used as a stabilizer for soft clay while preserving natural limestone from consumption. ESP can be used as a replacement for limestone due to some similarities in chemical composition between it and limestone components. 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 ESP and Nano silica (NS) material. The index and engineering properties were carried out to access the behaviour of soil with the addition of eggshell powder. The ESP has the ability to controls the plasticity index of the soil. The standard proctor test was conducted to get the maximum dry density values and OMC. The UCS test was conducted for optimum dosages ESP and NS. The tests were also conducted for samples which were cured for 7 days. The strength value increased considerably on addition of ESP and NS. 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 ESP was blended in various proportions with the soil and 0.9% NS mixed soil at the rate 4%, 8%, 12%, and 16%. The investigation of an influence of Nano silica and ESP on Atterberg limits, C.B.R., U.C.S., O.M.C., and M.D.D. was done

Key Words: Egg Shell Powder, Nano silica, CBR test, UCS test

1. INTRODUCTION

Clayey soils are one of the problematic soil which is widespread in the country and has a low bearing capacity due to the presence of the montmorillonite material. There are many ways to reinforce soil in geotechnical engineering. High plasticity clayey soils are seen as problematic soils due to their low bearing capacity, high plasticity, high swelling and shrinkage properties. Nowadays, extensive research is carried out on natural materials especially low-cost, easy-tofind, and environmentally friendly for the improvement of such soils. 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.

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. Chemically stabilized soil studies have revealed that the efficiency of stabilization is primarily depends on the natural environment of the soil. Because of its poor qualities, this sort of soil is classified as problematic. Expansive soils such as clay soil does not satisfy the standards for structural applications at this stage because its load applied from the building's apex will be transmitted to the soil layer 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.

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

This study investigates some of the mechanical properties of soft clay soil after adding the environmental waste material like egg shells. This study uses eggshell powder (ESP), Nano silica which can be used as a stabilizer for soft clay while preserving natural limestone from consumption. ESP can be used as a replacement for limestone due to some similarities in chemical composition between it and limestone components. 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 ESP and Nano silica (NS) material.

LITERATURE REVIEW

Sreerema Prasad .S (2022): The study concluded that the addition of waste additives enhance the engineering properties of clayey soil. Both ESP and CFF are waste products which may cause severe environmental problems. The utilization of these products as soil stabilizers makes economical and become a best solution for sustainable environmental protection

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 ESP-treated soil's geotechnical properties, respectively. Furthermore, the sustainability evaluation revealed that ESP-treated soil was the most sustainable mixture. Given the sustainability effects, nano-silica addition less than 2% and silica fume to the ESP-stabilized soil can lead to propose treated soil with considerably more sustainability than cement. It is essential to highlight that the sustainability of ESP-treated soils containing silica fume was considerably more than that of stabilized soils comprising nano-silica.

Aneesh P.C,et.al (2020) It is an experimental study focused on stabilization of cochin clay with Egg Shell Powder(ESP) and Shredded LPDE. 3 various proportions of ESP (2%, 5%, 8%) plastic wastes (0.25%, 0.5%, 0.75%, 1%) were added to obtain optimum percentage of each additive. The collected sample comes under silt clay (53.3%) and from the plasticity index, according to Unified soil classification system (USCS) our clay sample is grouped under CH

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.

Alzaidy.M.N.J (2019) In this paper, the effect of the combination of Egg Shell Powder and Plastic Waste Strips in some engineering properties of clayey soil represented by compaction characteristics, unconfined compressive strength, swelling potential, California bearing ratio test and finally shear strength parameters have been studied. The aim of this paper is to investigate the influence of plastic wastes, eggshell powder contents and the curing duration in the strength behavior of clayey soil. An increase in ESP content causes to an increase in unconfined compressive strength. A significant net positive change has been noticed in the engineering characteristics of the clayey soil after adding both of ESP and PWS. These beneficial changes depend on ESP, PWS contents and the curing duration.

Amir Kalhor et al. (2019) The results show that when the clayey soil is stabilized with nanoSiO_2, 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-SiO_2 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-SiO_2 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-SiO_2 stabilized specimens compared with untreated clay. After nine freezethaw cycles, the strength of untreated and treated soil with 2% nano-SiO_2 decrease by about 64% and 42%, respectively. Also, with increasing the freeze-thaw cycles, stabilized specimens exhibit more ductility.

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. To determine the particle size of additive material tests such as UV–vis spectrophotometric was performed. For experiment silty clay soil was considered and the tests such as liquid limit (47%) and plastic limit (25.15%) were conducted. The additive material was added in different proportions ranges from 3% to 15% with an interval of 3%.

Diksha Sharma (2017) had focused to examine the effects of two distinct nano-materials such as MgO and Al_2O_3. The nanomaterials was 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 potential was 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-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.

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 strength increased with increasing the curing time .

2. Materials and Methods

Section 2.1 EGG Shell Powder and Nano Silica as stabilizer.

Egg Shell Powder

Eggshells, preferably the chicken eggshell perceived a waste material. It used as a replacement for soil stabilizer like lime since they have the same chemical composition. The eggshell powder was sieved using IS Sieve No.200 (75µ), and the powder passing through the sieve was used. The eggshell primarily contains lime, calcium and protein. It has been in use as a source of lime in agriculture, which confirms that lime is present in considerable amount in eggshell. Most good quality eggshells from commercial layers contain approximately 2.2 grams of calcium in the form of calcium carbonate

Nano Silica

Among the nano-materials, nano-silica is the most widely used by the researchers. Nano-silica improves the soil strength and stiffness due to its high pozzolanic activity, tiny size, void-filling effect and high specific surface area (SSA).

(i) Nano Silica (ii) Nano silica with soil

Section 2.2 - METHODS

The present project can serve as an effective method to uticlize industrial wastes Egg Shell Powder and Nano Silica Powder in the construction of low cost rural roads and stabilize the subgrade of pavements where the soil is expansive in nature. These various tests needs to be carried out on samples selected for study:

- To study the plastic limit, liquid limit and specific gravity of untreated soil.
- To study the compaction characteristics of untreated soil and treated soil with ESP and NS.
- To study the California bearing ratio of untreated soil and treated soil with different proportions of ESP and NS.
- To study the unconfined compressive strength of untreated soil and treated soil with different proportions of ESP and NS.

Table -1: Properties of Soil Used

S.No.	Properties	Result
1.	Liquid limit (%)	44
2.	Plastic limit (%)	24.7
3.	Plasticity Index (%)	19.3
4.	Specific Gravity	2.68
5.	Maximum Dry Density (KN/m³)	19.1
6.	Optimum Moisture Content (%)	13.2
7.	Soil Classification	CI
8.	CBR Soaked CBR Unsoaked	10.30 10.55
9.	UCS (kN/m$^{2)}$	190

Table -2: Physical composition of Egg Shell Powder

S.No	Compound	Value (%)
1	CaCO3	47.49
2	SiO2	0.11
3	Mg0	-Nil
4	K2S04	5.9
5	CaS04	5.2
6	Al203	Nil
7	Fe203	traces

TABLE- 3 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 4 Chemical Composition of Nano Silica.

S.No	Compound	Value (%)
1	Chloride content	0.09
2	SiO2	99.88
3	Carbon content	0.06
4	Al203	0.05
5	Fe203	0.01

Results and Discussion

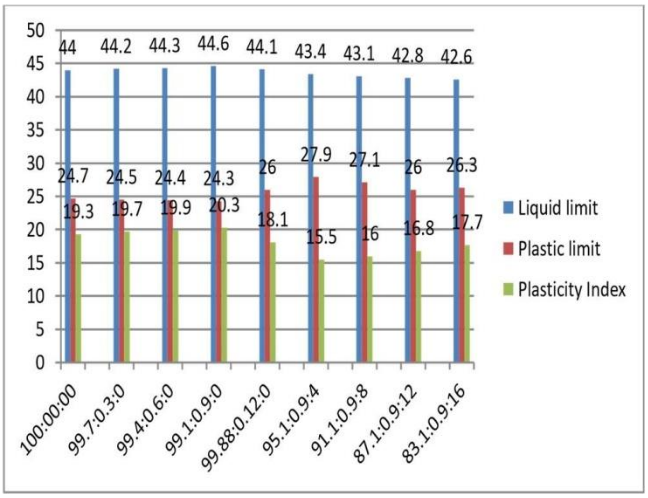
This chapter contains the results of various tests conducted on the soil in the laboratory. After determining the properties of virgin soil, the amount of NS was optimized by STANDARD PROCTOR test . This quantity of NS that has been optimized was mixed with varying content of ESP. The soaked CBR values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

EXPERIMENTAL RESULTS

Atterberg's limits result;

DESIGNATION (S:NS:ESP)	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
95.1:0.9:4	43.4	27.9	15.5
91.1:0.9:8	43.1	27.1	16
87.1:0.9:12	42.8	26	16.8
83.1:0.9:16	42.6	26.3	16.3

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 07 | July - 2023 SJIF Rating: 8.176 ISSN: 2582-3930



4.1.1 Graphs representing the Liquid limit, Plastic limit and Plasticity index value of various mixes.

STANDARD PROCTOR TEST

SOIL:NS:ESP	MDD (kN/mt)	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

Table no. 4.2.1: Results of MDD and OMC value of soil, NS

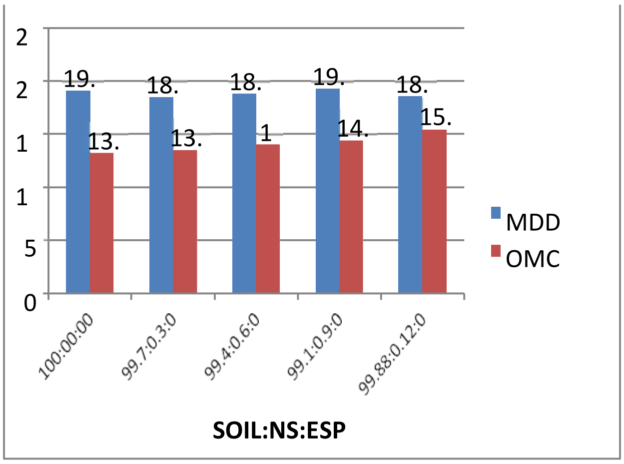


Fig:-4.2.2 Graph representing the MDD and OMC value of Soil: NS

TABLE NO.4.2.2 :- MDD AND OMC VALUE OF SOIL ,NS AND ESP

SOIL:NS:ESP	MDD (kN/mt)	OMC (%)
95.1:0.9:4	19.1	15.3
91.1.0.9:8	19.5	15.7
87.1:0.9:12	19.8	15.4
83.1:0.9:16	19.3	15.2

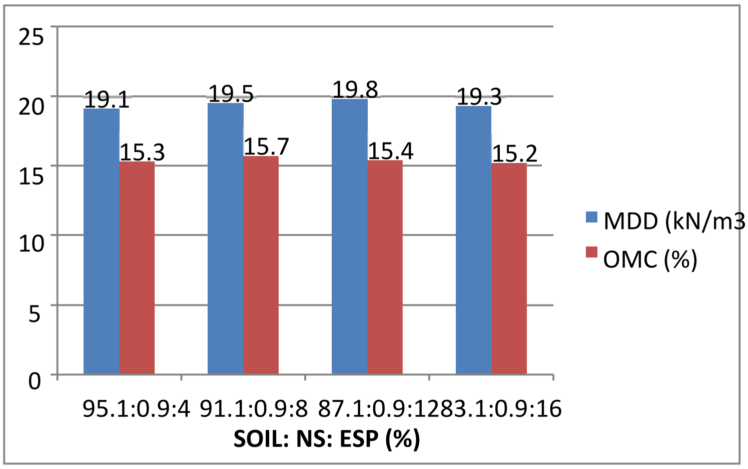


Fig.4.2.2: Graphs representing the MDD and OMC value of various mixes together.

TABLE NO4.2.3. : REPRESENTING MDD AND OMC VALUE OF MIXED TOGETHER.

DESIGNATION (S:NS:ESP)	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
95.1:0.9:4	43.4	27.9	15.5
91.1:0.9:8	43.1	27.1	16
87.1:0.9:12	42.8	26	16.8
83.1:0.9:16	42.6	26.3	16.3

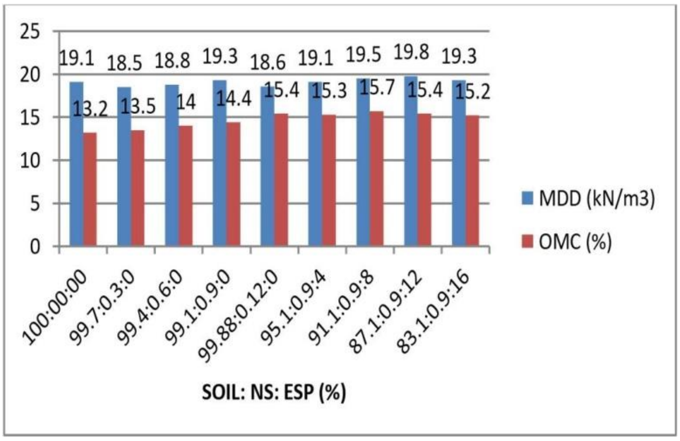


FIG 1.2: Graphs representing the MDD and OMC value of various mixes together

UnConfined Compressive Strength

UCS OF CLAYEY SOIL AND NS.

SOIL: NS	UCS (kPa)	UCS (kPa)	UCS (kPa)	UCS (kPa)
	0 day	**7 days**	**14 days**	**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

FIG.4.3.1. UCS GRAPH OF SOIL AND NS

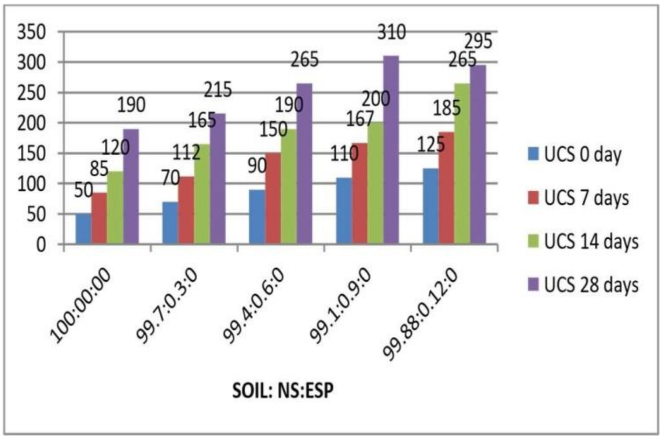
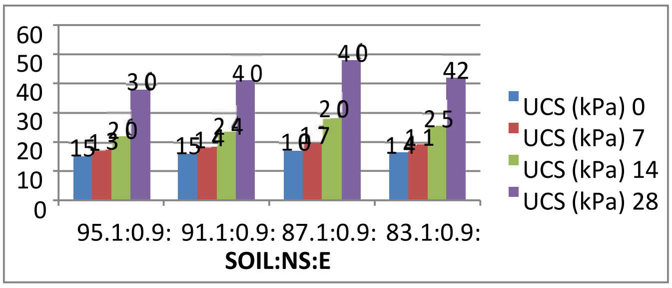


TABLE NO.4.3.2: UCS OF CLAYEY SOIL AND NS AND ESP.

SOIL: NS : ESP	UCS (kPa)	UCS (kPa)	UCS (kPa)	UCS (kPa)
	0 day	**7 days**	**14 days**	**28 days**
95.1:0.9:4	150	173	220	380
91.1:0.9:8	158	184	234	410
87.1:0.9:12	170	197	280	480
83.1:0.9:16	164	191	255	420

FIG.4.3.2:-UCS GRAPH SOIL AND NS AND ESP



: CALIFORNIA BEARING RATIO TEST

Mix Type	CBR Unsoaked (%)	CBR Soaked (%)
100:00:00	10.55	10.3
99.7:0.3:0	14	12
99.4:0.6:0	16.5	14.3
99.1:0.9:0	19	17
99.88:0.12:0	17	15
95.1:0.9:4	19.3	16.4
91.1:0.9:8	22.25	19.32
87.1:0.9:12	29.75	23.3
83.1:0.9:16	26.5	20.75

TABLE NO.4.4.1 CBR(SOAKED AND UNSOAKED) TESTS RESULTS FOR SOIL NS ESP MIXES.

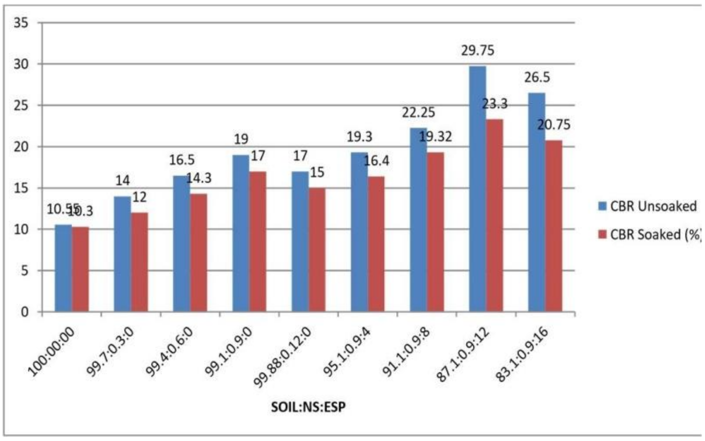


FIG.4.4.1: GRAPHS REPRESENTING THE CURVE THAT ARE OBTAINED FROM CBR TEST FROM SOIL NS ESP MIXTURE.

DISCUSSIONS

STANDARD PROCTOR TEST:

The MDD of stabilized soil decreases with increase in NS. The MDD and OMC for clay soil are 19.1 kN/m^3 and 13.2% respectively. The MDD and OMC for the optimum mix are 19.8kn/m^3 and 15.4%, respectively. The optimum mix is determined from the consistency's limit tests. The OMC increases from 13.2% to 15.4% and the MDD after varying different values reaches to maximum value of 19.8 to kn/m^3 from virgin soil to stabilized clay soil. The increase in OMC (from 13.2% to 15.4%) is observed at 87.1:0.9:12 (Clay: NS:ESP).

CBR TEST:

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 (87.1:0.9:12) sample under dry condition is from 10.55% to 29.75%.

UCS TEST:

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 190 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

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

- 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 ESP 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 87.1% soil: 0.9% NS: 12% ESP.
- Un Soaked CBR value increases from 10.55% for virgin soil to 29.75% for the best ratio of the mix.
- Unconfined compressive strength of soil- NS mixtures increase with increase in ESP up to 15 % by weight.

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