Study on Strength Improvement of Tropical Residual Soils Blended With Flyash, Lime And Nano Calcium Silicate

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Abstract- *As the construction industry evolves the issue of sustainability and the use of environmentally friendly methods of construction has become one of the major concerns. Stabilization of soil refers to improvement of soil behaviour against loads by reduction indeformation and disposition. Stabilization of soil is generallyascertained by mechanical, chemical and physical methods.Use of Nano materials is anemerging trend, the cause being the increase in the surface area compared to the volume, whichensures greater interaction between the parent soil and other stabilizer used along the nanomaterial. Hence use of Nano materials in stabilization of soil helps in filling the voids of the soilmass ensuring improvement in the strength of the soil, Nano particles blend with the cementitious material in the mix and reinforce its performance by filling the voids between the particles. The current study evaluates the strength characteristics of tropical soil treated with nano calciumsilicate(NCS)(synthesized with a proprietary method of the authors) and in combination with two different materials such as lime and fly ash added with dosages of NCS, lime and fly ash in the ratio with soil. Stabilization of residual soil using fly ash, lime and nano calcium silicate has been studied. The present Investigation includes the evaluation of properties of the soil such as compaction, shear strength, CBR.*

Keywords- clayey soil, fly ash, lime, nano calcium Silicate (NCS) standard Proctor compaction test, California bearing ratio.

I. INTRODUCTION

High quality soil as materials for geotechnical engineering construction are rare in many parts of the world, and most often than not, engineers are forced to seek alternatives to reach the stipulated requirements. In addition, the gradual increase in population as well as rapid development in the construction industry in recent years have make it more urgent than ever to gain the sufficient knowledge and information needed to improve existing soil for geotechnical engineering purposes. Soil stabilization is the process of improving the physical and engineering properties of soil to obtain some predetermined targets. It operates in various ways such as mechanical, biological, physical, chemical and electrical. Nowadays, among the different methods of soil improvement, using chemical additives for soil stabilization in order to increase soil strength parameters and loading capacity is catching more attention. Engineers in construction industry particularly in the geotechnical sector use chemically soil stabilization techniques in many ways such as road construction, slope stabilization and erosion control, foundation and embankment treatment, and improving the coastal line for construction.

This popularity is due to their low cost and convenience, particularly in the geotechnical projects that require a high volume of soil. Each type of chemical additives has different mechanism and influence on soil properties. For instance, there have been noticeable important dissimilarities between tropical soils from the more ordinary soils of moderate climates. Rock weathering in these areas is very rigorous that can be described by fast disintegration of feldspars as well as ferromagnesian raw materials, the displacement of bases including Na2O, K2O, and MgO and silica, and the absorption of aluminum and iron oxides (Eisazadeh et al., 2011). This procedure which includes leakage of silica and decomposition of iron and aluminum oxides is called laterization (Gidigasu, 1972).

This soil category is affluent in aluminum, iron, and kaolinite clays (Townsend, 1985). This soil group usually exists at hillside and offers brilliant borrow areas for wide adoption in many different construction operations. The optimum utilization is determined by the quantity of issues encountered in construction connected to their workability, field compaction, and strength. The stabilization of soils with additives is a chemical method that can be used to improve soils with poor engineering properties. However, sometimes it is necessary to add some additives to the soil in order to improve certain properties of the soil to be used for specific purpose of the project. The soil stabilizers are categorized as traditional and non-traditional. Traditional additives include cement, lime, fly ash, and bituminous materials, while non-traditional additives consist of various combinations such as enzymes, liquid polymers, resins, acids, silicates, ions, and lignin derivatives (Tingle et al., 2007; Hafez et al., 2008).

The non-traditional additives can be produced using different kinds of chemical agent that give different reactions while added to soil. Nevertheless, published reports on such additives are still scarce compared to traditional additives, either in terms of their geotechnical performance or basic stabilization mechanisms. Moreover, their exact chemical components are mostly kept confidential by their respective owners. In recent years studies have been done by some researchers on the mixtures of different types of soil and calcium-based powder type of non-traditional stabilizers. The results of their assessment indicated that these additives has potential to improve soil parameters, in particular the soil strength (Peethamparan et al., 2008; Obuzor et al., 2012; Manso et al., 2013; Agapitus, 2013). Non-calcium-based liquid soil stabilizers are actively marketed by a number of companies. In addition to being cheaper to transport than traditional bulk stabilizer materials, these products are a potentially attractive alternative for soil treatment. The exact chemical composition of these stabilizers has not been released due to their commercially registered brand. These are mostly sold as concentrated liquids, which are diluted with water at site. Some are directly applied to the soil before compaction while other is pressure injected into deeper layers. It should be noted that the result of previous study indicated that the non-traditional liquid additives can help to increase soil strength with curing time (Zhu and Liu, 2008; Fon, 2010; Liu et al., 2011; Ahmad et al., 2013).

Proper knowledge on soil additive reactions is an essential part of this technique. In this research the mechanisms responsible for improving the soil properties of using domestic traditional and non-traditional additives has been studied.

II. LITERATUREREVIEW

2.1 PREVIOUS RESEARCH PAPERS AND CONCLUSIONS

Soil stabilization is a procedure where we improve engineering properties of soil with the use of natural or synthesized admixtures. In the past many researchers have carried out their research work for improving the strength of soil using different types of admixture at different percentages. A brief review of previous studies on residual soil is presented in this section and past efforts most closely related to the needs of present work.

ERDAL COKCA (2001):

Effect of Fly ash on expansive soil was studied by Erdal Cokca, Fly ash consists of often hollow spheres of silicon, aluminum and iron oxides and unoxidized carbon. There are two major classes of fly ash, class C and class F. The former is produced from burning anthracite or bituminous coal and the latter is produced from burning lignite and sub bituminous coal. Both the classes of fly ash are puzzolans, which are defined as siliceous and aluminous materials. Thus Fly ash can provide an array of divalent and trivalent cations under ionized conditions that can promote flocculation of dispersed clay particles. Thus expansive soils can be potentially stabilized effectively by cation exchange using fly ash. He carried out investigations using Soma Flyash and Tuncbilek fly ash and added it to expansive soil at 0-25%. Specimens with flyash were cured for 7days and 28 days after which they were subjected to Oedometer free swell tests. And his experimental findings confirmed that the plasticity index, activity and swelling potential of the samples decreased with increasing percent stabilizer and curing time and the optimum content of flyash in decreasing the swell potential was found to be 20%. The changes in the physical properties and swelling potential is a result of additional silt size particles to some extent and due to chemical reactions that cause immediate flocculation of clay particles and the time dependent puzzolanic and self hardening properties of flyash and he concluded that both high –calcium and low calcium class C fly ashes can be recommended as effective stabilizing agents for improvement for improvement of expansive soils.

PHANIKUMAR AND SHARMA (2004):

A similar study was carried out by Phanikumar and Sharma and the effect of fly ash on engineering properties of expansive soil through an experimental programme. The effect on parameters like free swell index (FSI), swell potential, swelling pressure, plasticity, compaction, strength and hydraulic conductivity of expansive soil was studied. The ash blended expansive soil with flyash contents of 0, 5, 10,15 and 20% on a dry weight basis and they inferred that increase in fly ash content reduces plasticity characteristics and the FSI was reduced by about 50% by the addition of 20% fly ash. The hydraulic conductivity of expansive soils mixed with fly ash decreases with an increase in flyash content, due to the increase in maximum dry unit weight with an increase in fly ash content. When the flyash content increases there is a decrease in the optimum moisture content and the maximum dry unit weight increases. The effect of fly ash is akin to the increased compactive effort. Hence the expansive soil is rendered more stable. The undrained shear strength of the expansive soil blended with flyash increases with the increase in the ash content.

PRAMOD K in 2014

done a project on stabilization of black cotton soil using fly ash and geopolymer and conclusions are based on various laboratory tests carried out on Black Cotton Soil stabilized with Fly ash and Geopolymer. Through experiments by addition of stabilizing agents like Fly ash and Geopolymer in quantities like 2%, 4% and 6% has showed the increase in specific gravity of the soil to 2.51, 2.58, and 2.72 respectively. The liquid limit of the soil should be less for construction purpose. Liquid limit was reduced to 70%, 65% and 53% respectively. The shrinkage limit of the Black cotton soil of this project was 13.16% further by addition of stabilizing agents like Fly ash and geopolymer in percentages like 2%, 4% and 6% the shrinkage limit of the soil was reduced to 13.05%, 12.78 and 12.07 respectively. The Black Cotton soil was subjected to compaction test by Jodhpur mini compacting mould where the Maximum Dry Density (MDD) and Optimum Moisture Content obtained is 1.48 g/cc and 21%. The soil for construction purpose should have good load bearing characteristics. This load baring capacities was determined by Unconfined Compression Strength test. The soil of this project had strength of 0.056 N/mm2. By addition of stabilizing agents like Fly ash and Geopolymer in percentages like 2%, 4% and 6% the results obtained are 0.04 N/mm2, 0.095 N/mm2 and 0.083 N/mm2 respectively. Compressive strength was increasing up to addition of stabilizing agent till 4% on further addition there will be decrease in the soil strength. Finally it can be concluded that the stabilizing agents like Fly ash and geopolymer will help in increasing the engineering properties of the Black Cotton soil like specific gravity, liquid limit, shrinkage limit, compaction characteristics and unconfined compressive strength.

VAIBHAV R. DHAWALE published a paper in October 2016 on black cotton soil stabilization by using fly ash, lime and nylon fiber and gave some conclusions by carrying some laboratory investigations:

The moisture –density relationship of soil-fly ash mixtures significantly affected due to addition of fibers. The MDD is increases and OMC decreases in fly ash and soil mixtures. Whereas the soil has shown reverse trend but less noticeably. With Fly ash percentage increased with soil BC soil optimum moisture content decreased from 21% to12. The MDD of BC soil increases with the addition of lime with corresponding increase in OMC. The adhesion between the water and soil particles increases with the increase in lime content up to 2%. With the further addition of lime beyond 2% .MDD reduces and OMC increases. The relative benefit in CBR values due to fibers increases only up-to 1.00 % by dry weight and length up to 12mm for all soil-fly ash specimens. By addition of fly ash alone the CBR of the mixture is increased nearly 2.7 times where as by addition of fiber only CBR is increased by 1.6 times only. Effect of fiber on fly ash Soil mixture is limit because of the high plasticity of the Clay soil while lime alone works well to establish clay soil, a combination of lime and fly ash is beneficial for lower plasticity, higher silt content. The peak unconfined compressive strength, stiffness and ductility of clayey soil increase with increasing fibre content. The post peak softening drop in compressive resistance is found to be decrease with increase in fibre content. But, clayey soil containing nylon fibres shows poor result than Clayey soil containing palmyra fibres. The bearing resistance of specimens is found to increase with the fibre content. However, the rate of increase of strength with fibre content is not uniform. At low strain levels the bearing resistance is found to remain almost constant with fibre.

CH.MAHESH and **Dr A.S.RAO** Effect of Nylon Fibers & Rice Husk on Engineering Properties of Soils

Optimum moisture content and maximum dry density decreases with increase in the lime content.CBR value decreases with increase in the quantity of rice husk. CBR value is high at 5% rice husk. CBR value is high at 20% lime when compared to 5%, 10%, 40% of lime mixed with soil. CBR value is high at 10% lime + 1.5% fiber when compared to the remaining proportions. CBR value for (soil +10% lime) and (soil + 40% lime) is same. CBR gradually increases with increase in fibers up to 2% (soil + 5% lime). CBR value increases up to 1.5% addition of fibers in and decreases at 2% fiber in (soil + 10% lime). CBR value gradually decreases with increase of fiber content in (soil+ 20%lime). CBR value gradually increases with increase of fibers in 40% lime with soil.

From the observations, the strength at 20% lime is more. Hence 20% of lime may be used for strength purpose and for low traffic the rice husk may be used for economical purpose

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made an attempt to determine the utility of industrial wastes in Stabilization of medium plastic clays (CI). Fly ash (FA) and waste tire rubber (WTR) have been considered to investigate their potential in stabilizing the CI soils. Laboratory Experimentation is done to evaluate the optimum contents of fly ash and waste tire rubber Content to check the

California Bearing Ratio strength (CBR), Differential Free Swell % and Unconfined Compressive Strength (UCC) strength. The results indicated that the 25% addition of fly ash to the medium plastic clay soils (CI) resulted in a CBR value of 10% and a 7 Day UCC strength of 330 kN/Sqm. 6% addition of waste tire rubber content to CI soil resulted in a CBR value of 4.36% and a 7 day UCC value of 80kN/Sqm. The differential free swell % evaluated for the optimal mixes indicated that the stabilized mixes exhibited low expansiveness. Industrial wastes namely fly ash and waste tire rubber can be effectively used to stabilize clay subgrades to achieve high strength values thus resulting in decreased pavement thickness and low maintenance.

2.2 STABILIZATION

Using lime, flyash have been more attractive recently due to its promising results compared to other sources. Overview about the methods and the basis of application will be presented in this section. Soil stabilization is the process of improving engineering properties of the soil and thus making it more stable. Soil stabilization means the improvement of the stability or bearing power of the soil by the controlled compaction; proportioning and/or addition of suitable admixture or stabilizers. Soil stabilization is the alteration of soil to enhance their physical properties.

METHODS OF SOIL STABILIZATION

- Mechanical Stabilization.
- Soil Cement Stabilization.
- Soil Lime Stabilization.
- Soil Bitumen Stabilization.
- Thermal Stabilization.
- Chemical Stabilization.

III. METHODOLOGY

The methodology of this project is carried out by collection of tropical soil sample from proposed area and various tests on soil have been performed as per IS(2720) on raw soils and soil with proportion of lime, rice husk ash and nano calcium silicate. Based on test reports various discussions have been present as per the strength variations criteria.

The various physical properties of soil were assessed using methods below given in different parts of Indian standards (IS 2720). The specific gravity, grain size analysis, atterberg limits and shrinkage limits were derived as per the methods given in IS 2720: part 3(1980), IS 2720: part (1980), IS 2720: part 5(1980),IS 2720: part 6(1972) respectively. Compaction test as per IS 2720: part 7(1980) was performed to determine optimum moisture content and maximum dry density of the soil specimen.

In this chapter, a brief description of the materials adopted in this investigation and the methodology adopted during the course of study are briefly presented.

MATERIALS USED AND THEIR PROPERTIES

3.1 SOIL

The red soil was collected from maredumilli, India in an airtight container for seizing the escape of natural moisture content. Red colour of the soil indicates that the presence of iron oxide in it, the USCS (Unified soil classification system) indicated that the soil belongs to CL (Clay with low or medium plasticity).

3.2 FLY ASH

Fly ash is also typically use to stabilize the sub base or sub grade and should not be used for surfacing due to low resistance to abrasive action of traffic and machinery movements.

The source of the coal and the type of the coal burning process determine the fly ash properties, which further influences the performance of soil stabilization using fly ash. There are two class of fly ash; class „C‟ which is self-cementing and class „F‟ which is non-self-cementing. Class „C‟ is the result of the combustion of younger lignite or sub bituminous coal. In the presence of water, class „C‟ is fly ash will harden and gain strength over time. Class “F” fly ash is produced from burning harder, older anthracite and bituminous coal. This kind of fly ash contains less than 20%lime and thus glasey silica and alumina are the only pozzolans present in sufficient quantities soil stabilization using fly ash class ‟F‟ will be feasible only it additives such as Portland cement and quick lime, or hydrated cement added, when fly ash blended with water, result in the products that bind soil grains or increases the strength in the soil matrix.

The extent of leaching and harmfulness to humans of fly ash leachate is still not entirely known but is being investigated. Unlike soil stabilization using fly ash, environmentally, safe solutions are created by global road technology. For this project work the fly ash is collected from the NTPC Visakhapatnam, Andhra Pradesh.

TABLE 3.1 Chemical properties of Fly ash

Constituents	Percentage (%)
SiO2	55
Al2O3	20.3
Fe2O3	6.3
CaO	12
MgO	3.5
Alkali	1
SO3	1.5
Heavy Metals	Trace

3.3 LIME

The commercial Birla lime taken from market for the purpose of stabilizing soil, which imparts cementing property to the soil mix.

3.4 NANO CALCIUM SILICATE

Nano calcium silicate is a proprietary material, bright white crystalline powder synthesized by reaction of silica with ions of calcium. The major constituent, which forms the NCS, are the platelets like particles with thickness around 5-10 nm and dimensions across being 300 nm. The platelets join together into particles of size 1-5 µm with a “gypsum desert rose” like structure (Mohammed and Moghal 2016; Mohammed et al. 2017). The structure affords the soil the desired physical properties of a large pore volume and high accessible surface areas exceeding conventional materials with greater surface area.

IV. LABORATORY EXPERIMENTATION

The soil was initially air dried prior to the testing. The tests were conducted in the laboratory on the marine clay to find the properties of virgin marineclay.

- Grain size distribution
- Specific gravity
- Index properties –liquid limit, plastic limit
- Compaction tests
- Penetration tests-California bearing ratio test.
- Unconfined Compression Test-Tri axial

V. RESULTS AND DISCUSSIONS

5.1 INTRODUCTION

Details of the laboratory experimentation carried-out with different combinations of materials have been discussed in the previous chapter. In this chapter a detailed discussion on the results obtained from various laboratory tests done on residual Soil are presented.

5.2 GENERAL

In the laboratory, various experiments were conducted by replacing different percentages of lime, flyash and nano calcium silicate and to the red Soil. Liquid Limit, Plastic Limit and Compaction, CBR and UCS tests were conducted with a view to determine the optimum combination of lime, flyash and NCS and CBR and UCS are conducted for durability studies.

The influence of the above said materials on the Index, Compaction and Strength properties were discussed in following sections. In the laboratory, all the tests were conducted per IS codes of practice and the strength behaviour pertaining to unconfined compressive strength (UCS), Optimum moisture content (OMC), Maximum dry density (MDD) and Plasticity index (PI) of different combinations of soil and admixtures such as lime and NCS, fly ash and NCS have been performed.

5.3 SOIL+NCS – Mix Preparation Technique

The dry soil sample was spread on a non-porous surface layer by layer and the NCS was sprinkled on every layer and the soil mass was mixed manually for sufficient time to ensure proper distribution of NCS in the soil. This combination will be termed as Mix 1 henceforth in the paper.

5.4 SOIL+FLYASH+NCS-Mix Preparation Technique

Soil sample amended with fly ash, NCS was prepared by first mixing NCS with fly ash, Fly ash and NCS was taken in a porcelain dish and mixed thoroughly until NCS was distributed uniformly throughout the fly ash sample. NCS fly ash mixture was added to soil in the same way in which Mix 1 is prepared. The combination Soil fly ash and NCS will be expressed as Mix 2 henceforth in the paper.

5.5 SOIL+LIME+NCS - Mix Preparation Technique

The third combination taken up in the present study was soil, lime and NCS this combination will be expressed as Mix 3 henceforth in the paper. Preparation of Mix 3 was carried out in the same method as that of Mix 2.

5.6 EFFECT OF % LIME ON THE PROPERTIES OF SOIL

The individual influence of Lime on the Index, Compaction properties of marine soil are clearly presented in Figures 5.1and 5.2 respectively. The percentage of LIME was varied from 0%, to 8% with an increment of 2%. From the above graphs, it was observed that the treatment as individually with 6% LIME has moderately improved the marine soil. It can be inferred from the graphs, that there is a gradual improvement in the maximum dry density and optimum moisture content with an increment in % replacement of LIME up to 6%.

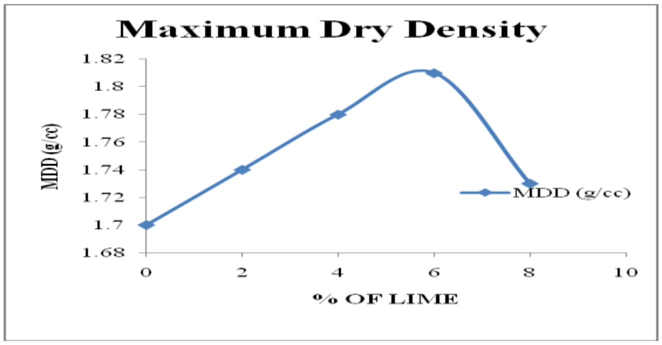

Fig 5.1 Plot showing the Variation in maximum dry density with % of lime

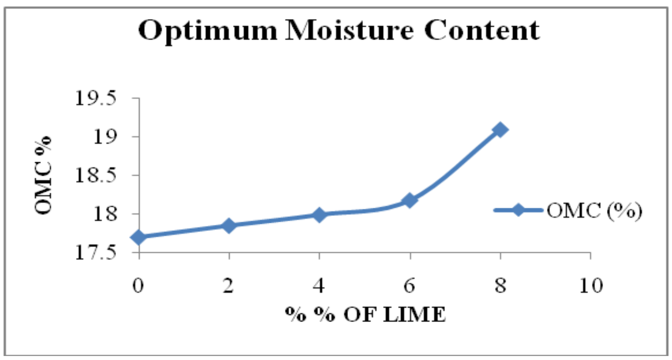

Fig 5.2 Plot showing the Variation in optimum moisture content with % of lime

5.7 EFFECT OF % FLYASH ON THE PROPERTIES OF WEAK SOIL

The individual influence of flyash on the Index, Compaction properties of marine soil are clearly presented in Figures 5.3 and 5.4 respectively. The percentage of flyash was varied from 0%, to 8% with an increment of 2%. From the above graphs, it was observed that the treatment as individually with 6% flyash has moderately improved the marine soil. It can be inferred from the graphs, that there is a gradual improvement in the maximum dry density and optimum moisture content with an increment in % replacement of flyash up to 6%.

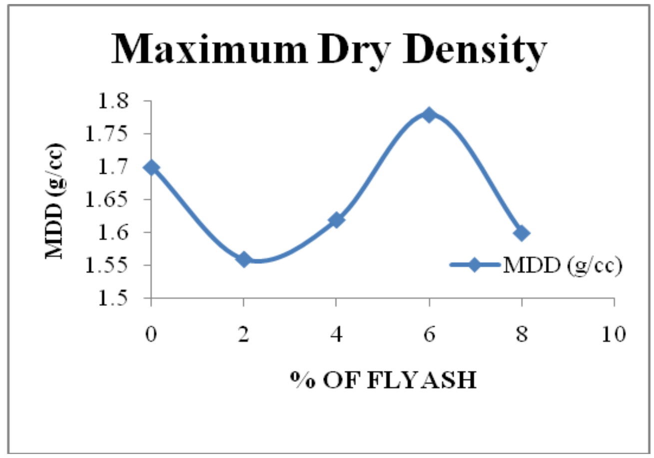

Fig 5.3 Plot showing the Variation in maximum dry density with % of flyash

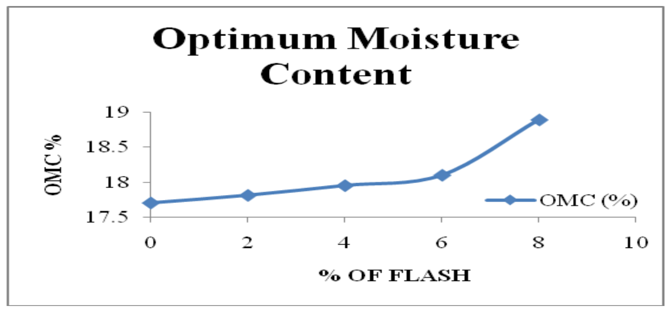

Fig 5.4 Plot showing the Variation in optimum moisture content with % of flyash

Present study appraises the strength characteristics of the soil with different dosages of the NCS, Fly ash and Lime. The combination chosen was 6% lime and 6% Fly ash separately with different dosages of NCS i.e. 0.04% to 0.40% with an increment of 0.04% by weight of the dry soil.

To understand the performance of stabilizers, UCS test, OMC and Atterberg Limit Values were found for the different dosages, which can be applied, for improvement in geotechnical properties of soils. Table 5.1 shows the summary of experiments conducted for the combinations of stabilizers with different dosage of NCS in soil. Study of the plastic characteristics of soil throw light on the strength behaviour of soil. Plasticity index (PI) is expressed as the difference between the LL and the PL. PI gives indication that to what extent the soil remains plastic (Bahmani et al. 2014). Increase in plastic limit and decrease in LL, which results in the reduction in PI (Eberemu et al. 2011) and also assures the improvement in soil strength. Reduction of the PI is one of the major indication of soil improvement in terms of strength (Amu et al. 2011). Increase in Plasticity index imperils the soil mass to shrink due to the wavering levels of moisture content. (Fauzi et al. 2013).

It can be observed in Table 4.2 that the value of PI decreases with the increase in the dosage of NCS in the soil along other stabilizers and simultaneously increase in the strength characteristics due to formation of CSH gel by the pozzolanic reaction of NCS. The gel formed is viscous in nature and has the capacity of holding water, finally making the soil plastic (Dash and Hussain 2012). Use of Nano material has its own role in the soil along Lime and with Fly ash. The results obtained show that the PI reduced from 10.85% to 9.3% for Mix 3 and from 9.42 to 7.78 for Mix 3, and 10.32 to 9.01% for Mix 1, the reduction is about 1.55%, 1.64% and 1.31% respectively with the dosage from 0.08% of NCS to 0.4% NCS. With increasing quantity of NCS (0.08% to 0.4%), the reduction in the plasticity index can be visualised as the development of hydrophobicity at molecular level in the soil mass due to Nano material (Ugwu et al. 2013). The dosage of lime was 6% in the combination with lime as an additive. 6% lime happens to be the most favourable quantity for lime stabilization of soil and further addition of lime seizes to affect the PI. Plasticity Index reduces with the addition of the lime due to the cat-ion exchange between the soil particles and leading to attraction between them. It is also suggested that the reduction in PI is on account of stepping down of the diffuse ion layer concentration caused due to pozzolanic reaction initiated by lime from the increase in interchangeable ions of calcium and salinity of pore water. Decrease in the PI promises fair increase in the compressive strength in the soil (Manso et al. 2013). Use of fly ash with NCS shows reduction in the PI in the present study. It is confirmed that the use of even rice husk ash, silica fume along fly ash as a stabilizer also cater to the reduction of PI in the soil, and these additives achieve the environmental gain (Harichane et al. 2011a).

5.8 EFFECT OF OPTIMUM MOISTURE CONTENT (OMC) ON SOIL MIXTURES.

Standard proctor test results portrayed that, a slight increase in percentage of water was required to reach the OMC with increase in dosage of NCS. Table 4.2 represents the variation of OMC with change in soil mixtures. It can be observed that with increase in NCS content the OMC also has increased although marginally and overall increase in OMC for Mix 1. is 7.74% and correspondingly the increase in OMC for Mix 2 and Mix 3 were 6.72% and 9.01% respectively with increase in NCS dosage from 0.08% to 0.4%.

This is attributed to the ion exchange process between the soil particles and formation of lumpy mass, which needs additional moisture, the soil, becomes crumbly for compaction requiring slightly higher moisture content for attaining maximum density due to the addition of Nano material. It can be seen that soil, lime and NCS combinations require a slightly greater amount of moisture when compared to the other two combinations, which is witnessed for red soil due to the presence of clay particles and aggregation of the soil, making it occupy greater volume in the soil mass and hence more moisture content.

5.9 EFFECT OF SOIL MIXTURES ON THE MAXIUMUM DRY DENSITY OF SOIL

The effect of the addition of lime and NCS shows decrease in the MDD values with increase in the NCS dosage as shown in the figure , the decrease in MDD followed with corresponding increase in OMC can be conceived as probable accumulation of particles leading the way to occupy greater areas influencing the soil grading. It can also be a reason that usually lime has lower specific gravity when compared to that of the tested soils because of which the soil assumes lower density depending on the amount of lime added (Harichane et al. 2011a).

Researchers also suggest that the effect on density is observed due to soil's specific gravity and particle size and even properties of the stabilizers used. Whereas the combination of fly ash and NCS also shows decrease in the MDD which might be due to increase in water absorption of the Fly ash.

5.10 EFFECT OF NCS ON THE SOIL WITH DIFFERENT DOSAGES ALONG WITH FLY ASH AND LIME

Effect of NCS on the soil with different dosages along with Fly ash and lime shows that the compressive strength increases with increase in the dosage of the NCS, however the dosage of a Nano material is preferred to be kept within 1%, since it absorbs more water (Changizi and Haddad 2016).

5.11 EFFECT OF SOIL MIXTURES ON THE UCS VALUES OF THE SOIL

Figure represents the UCS results for samples cured for three days. It can be observed that the increase in dosage of NCS increases the UCS value, which is an indication that the NCS causes a change in the behaviour of the soil mass by producing greater bonding between the soil particles. NCS also reduces the spacing between the soil particles, even the generation of viscous gel is proposed to be formed due to Nano material (Changizi and Haddad 2016).

The effect of Nano material is achieved by the polar and electrostatic interactions leading the behaviour between particles at nano range due to weak Vander Waals forces, and further aggregation of particles due to the forces developed, is controlled by the effect of Brownian diffusion, fluid motion and gravity (Sarma et al. 2015).

The Figure shows the variation of UCS value of the soil sample against the dosage of NCS cured for seven days, it can be observed in that the UCS value increases until the dosage of NCS is 0.36% and decreases when the quantity of NCS is 0.4%. Decrease in the value of UCS at 0.4% of NCS is probably due to the high agglomeration of the soil particles with the stabilizers. This is also opined by Bahmani et al, that the Nano particles represent themselves to be capable of increasing compressive strength of soil in lesser amount i.e. less than 0.4% of the weight of soil, and smaller sized Nano particles perform better in comparison with larger ones (Bahmani et al. 2014).

The overall experimentation program shows that lime along with NCS gives maximum strength, which is probable outcome of the flocculation reaction that leads to densification of the crystallized compounds of pozzolanic type, eventually reducing the void ratio in the soil (Moghal et al. 2015). As the curing period increases, the strength characteristics improve due to the continuation of the process of flocculation and settlement of the gel formed due to the pozzolanic behaviour of NCS in the soil.

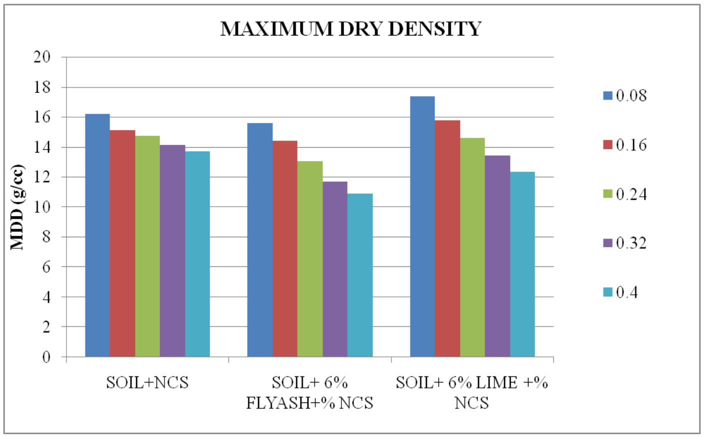

Fig 5.5 Plot showing the Variation in maximum dry density of soil with different mixtures

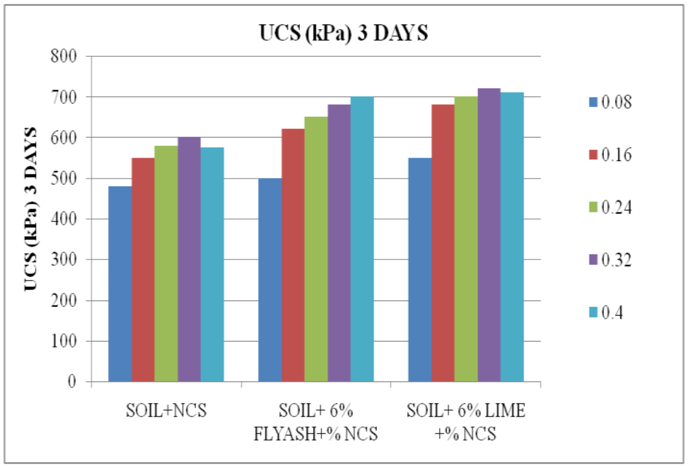

Fig 5.6 Plot showing the Variation in UCS (kPa) 3 DAYS of soil with different mixtures

VI. CONCLUSIONS

Present study appraises the strength characteristics of the soil with different dosages of the NCS, Fly ash and Lime.

- The combination chosen was 6% lime and 6% Fly ash separately with different dosages of NCS i.e. 0.08% to 0.40% with an increment of 0.08% by weight of the dry soil.

The following conclusions are drawn:

- Use of NCS alone as a stabilizer in soil makes soil perform better in withstanding loads due to the reduction in the voids, which are filled by the minute Nano Particles.
- The use of NCS with Lime and Fly ash reflected reduction in Plasticity index due to the increase in plasticity showing improvement in the soil strength.
- Mix 1 shows minimum reduction in MDD and Mix 2 and Mix 3 show marginal difference i.e., 33.10 % and 33.33 % respectively.
- Presence of NCS allows for better blending with the soil particles in triggering pozzolanic reaction eventually producing CSH gel like structures that in turn makes the soil mass denser and more resistant to the loads acting on it.
- The Mix 3 is found to give maximum compressive strength when compared to Mix 1 and Mix 2.
- Use of lime in the stabilization also arrests the expansion of soil simultaneously with improvement of load resisting behaviour.

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