EFFECT OF CALCIUM EXCHANGE CAPACITY ON THE PROPERTIES OF BLACK COTTON SOIL

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ABSTRACT:- The quality of a pavement depends on the strength of its sub-grade. The sub-grade acts as a support for the entire pavement system. In case of flexible pavement the sub- grade must be uniform in terms of geotechnical properties like shear strength, compressibility etc. Materials selected for construction of sub-grade must have to be of adequate strength and at the same it must be economical for use. They must also be ensured for the quality and compaction requirements. If the natural soil is very soft and weak it needs some improvement for use as sub-grade. It is, therefore, needed to stabilize the existing weak soil to achieve increased strength and reduced compressibility.

In view of this the present investigation has been carried out with easily available materials like lime and rice husk ash mixed individually and in combinations with different proportions. The different percentages of lime with respect to weight of dry soil were 2%, 4%, 6%, 8% 10% and for rice husk ash (RHA) were 2%, 4%, 6%, 8% and 10%. In each case the stabilized soil was compacted at optimum moisture content (OMC), 2% above and 5% above optimum moisture content (OMC+2, OMC+5). In each case California Bearing Ratio (CBR) tests and in case of compaction at OMC Unconfined Compressive Strength (UCS) tests were performed. The effect of curing on UCS samples up to 180 days with the intervals of 30 days was also studied.

It was found that CBR of original soil improved from 4.25% to a maximum value 28.25% when mixed with combination of 6% lime and 9% rice husk ash (RHA) under unsoaked conditions and from 3.5% to 29.82% when mixed with a combination of 6% lime and 9 % rice husk ash (RHA) with respect to dry weight of soil under soaked conditions at optimum moisture content (OMC). The unconfined compressive strength (UCS) of original soil improved by 253% when mixed with 6% lime and 6% rice husk ash (RHA), however the maximum value of UCS is attained by a value of 285% when mix proportion of 4% lime and 9% rice husk ash.

Based on the laboratory test results correlations have been developed between California Bearing Ratio (CBR) for different placement of moisture contents and also respective values of Unconfined Compressive Strength (UCS) considering each of them as function of different soil parameters.

The study incorporates an exhaustive and systematic experimental programmer. This helps in searching the most cost effective design mix of rice husk ash and lime admixtures with near surface alluvial soil, extensively used for construction of sub- grade.

It is concluded from this study that desired CBR and UCS values may be obtained on mixing a limited quantity of lime with soil when rice husk ash is also used as an auxiliary stabilizer making the mix cost effective.

1. INTRODUCTION

In recent times all over the world the use of alternative materials in the field of construction is increasing. This is to meet the necessity of ground improvement by soil stabilization. In this respect easily available and cheep materials, particularly some recycled waste like fly-ash and rice husk ash are becoming utilized for construction of road subgrade. The improvement of subgrade is being done by addition of appropriate admixtures.

India has a road network of more than 33lakhs km which is the second largest road connecting system in a country in the world. At 0.66 km of roads per square km of land, the quantitative density of India‟s road network is similar to that of the United States (0.65). About 65% of fright and 80% of passenger traffic area carried by the roads. In spite of having the biggest railway network, the road transport has remained a preferred choice in our country. This is because of its flexibility, accessibility to remote areas and adaptability to changes for achieving the desired objective of connectivity. The overall development of any country depends on a good and well- connected road network. Roads are one of the strongest measures of economic activity and the development of any nation.

Again due to the rapid economic growth and industrialization throughout the world, a huge quantity of waste materials (agricultural, industrial and others) are being generated, creating a tremendous negative impact on the environment as well as public health and ecology system. Accumulation of various waste materials is now becoming a major concern to the environmentalist. So the safe disposal of these waste materials is very vital issue and challenging task for the engineers and technologists. This problem can be greatly mitigated by the bulk utilization of such waste materials mainly in the field of Civil Engineering.

The present investigation has been carried out to study the strength improvement of soft subgrade with the lime and rice husk ash because they are easily available. Both the materials-lime and rice husk ash have been mixed individually and also in combination in different proportions with a locally available clayey soil. The major parameter for determining the improvement of soil is California Bearing Ratio (CBR) under soaked and unsoaked conditions at the different moisture contents and corresponding Unconfined Compressive Strengths (UCS). Effect of curing period on improvement of strength of soil has also been examined. This has been carried out at the optimum moisture content (OMC) of soil and above it. Based on the laboratory test data an attempt has been made to develop an equation of CBR considering it as a function of different soil parameters such as atterberg limits, compaction characteristics and strength by multiple linear regression analysis.

Further attempt has also been made to gain an insight into the reasons of strength increase by identify the micro fabric structure of soft cohesive soil.

This method has the advantage of quantifying the micro fabric in a way that may not be possible with optical and electron microscope methods. After scrutiny of laboratory test results a few soil samples have been selected for this analysis on the basis of occurrence of the higher and lower CBR values in different mixes of Soil- Lime and RHA under soaked and un-soaked conditions.

OBJECTIVES

The main objectives of the present study are as follows:-

- To examine the applicability, effectiveness and suitability of mixing lime and some locally available agricultural waste materials such as Rice Husk Ash(RHA) in isolation and in different combinations as ground improving materials for use in soft cohesive sub-grade of a flexible pavement.
- To find out the best possible design mix proportion of the chosen soil and admixtures used which gives maximum strength of stabilized soil compared to that of the original soil.

II. METHODOLOGY

Materials :-

SOIL:- The soil used for this study was collected from Gandhi Nagar in Kakinada Municipal Corporation area in Andhra Pradesh, India at a depth of 2.5 to 3.5 m below the ground level using the method of disturbed sampling.

LIME: Lime is an unparalleled aid in the modification and stabilization of soil beneath road and similar construction projects. Use of lime can substantially increase the stability, impermeability, and load-bearing capacity of the sub-grade soil.

Lime can be used either to modify some of the physical properties and thereby improve the quality of soil or to transform the soil into a stabilized mass, which increases its strength and durability. The amount of lime additive depends upon either the soil to be modified or stabilized. The hydrated lime used in this study was obtained from the local market at Kakinada .

Table: 1: Chemical Properties of Hydrated Lime

Constituents	Weight percentage
SiO_2	38.271
Fe_2O_3	0.189
CaO	57.857
K_2O	0.065
MgO	0.643
TiO_2	0.026
Na_2O	0.076
SO_2	2.873

RICE HUSK ASH (RHA):-Rice husk is an agricultural waste material obtained from milling of rice, in India it is approximately 120 million tons. In developed countries, when the mills are typically large, disposal of the husks is a big problem for the environment and also burning in open place is not desirable, so the majority of the husk is currently used for land filling. This waste material if suitable can be used for the economic utilization in construction of road system. A systematic detailed investigation should be undertaken to make possible use of rice husk ash (RHA) particularly in weak soils to enhance the quality of such soil so that such improved soil can be cost effective for constructions works. In this study the rice husk ash (RHA) was obtained from local rice mill at the Kakinada , India.

Table 2: Physical Properties of RHA

Basic Properties of RHA	Value
Liquid Limit (%)	NP
Plastic Limit (%)	NP
Plasticity index (%)	NP
Specific Gravity	1.96
Maximum Dry Density(gm/cc)	0.85
Optimum Moisture Content (%)	32
Angle of internal friction(°)	38

CBR at OMC Unsoaked (%)	8.75
CBR at OMC Soaked (%)	8.15

METHODOLOGY:-All the tests of soil before and after stabilization with different RHA and lime contents were carried out as per the procedures recommended in the relevant IS codes. For laboratory tests, specimens of soil with and without admixtures were prepared by thorough mixing the required quantity of soil and stabilizers in pre-selected proportions in dry state and then required quantity of water was added and mixed thoroughly to get a homogeneous and uniform mixture of soil and admixtures. The California Bearing Ratio tests were performed under both soaked and unsoaked conditions, with different water content such as OMC, OMC+2 and OMC+5. The 2%, 4%, 6%, 8% and 10% proportions were used in cases of lime and 2%, 4%, 6%, 8 %, 10% for RHA. They were mixed with original soil individually and also in combination of both the admixtures.

PREPARATION OF SAMPLE: The soil sample collected from the site was oven dried and sieved through 2.36 mm IS sieve and then dried in an oven at 105°C for 24 hours. The processing of RHA was done in the similar manner as that of soil. To mix the rice husk ash and lime with soil, the required quantity of sieved, oven dried soil was first weighed and poured into a mechanical mixture. Then the required quantity of lime and RHA, as required, was added to the soil and mixed uniformly. Proper care was taken to ensure a uniform mixture of soil-lime-RHA. The soil or the amended soil samples were tested as per the test programme.

MECHANISM OF LIME STABILIZATION:- Lime stabilized soils are generally used as sub-bases and bases of pavements to improve the bearing capacity of soft clay soil. It has also been used as a stabilizer for soils on embankment slopes and canal lining. When lime is added to clayey soils it lowers the liquid limit of soil and reduces the plasticity index. This renders clayey soil friable, easy to be pulverized, reduces swelling, decreases the OMC required for compaction. Normally 2 - 8% of lime may be required for coarse grained soils and 5 - 10% for plastic soils. It has been found that the strength of soil lime mix increases with addition of materials lime cement, rice husk ash (RHA),fly ash etc. Lime stabilization with hydrated lime or fat lime is an effective measure in improving the engineering properties of soft clay soils. It improves the strength, stiffness and durability of fine grained soils. Lime has also been used as a stabilizer for soils on embankment slopes and canal lining, in the base courses of pavements, under concrete foundations. Introduction of lime to soils produces a maximum density under higher optimum moisture content than in the untreated soil. Lime stabilization has extensively been used for stabilizing highly unstable plastic and swelling clayey soils such as black cotton soils. Treatment with lime helps in decreasing the swelling potential and swelling pressures of such clayey soils.

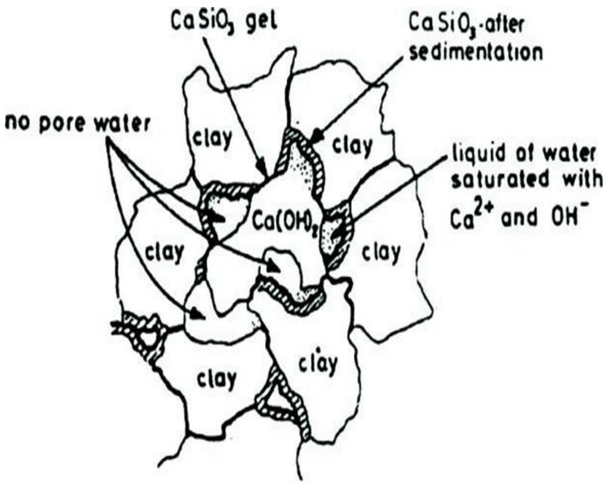

Fig. 1: Principle of soil stability with unslaked lime

Cation Exchange and Flocculation-Agglomeration Reactions:-

These reactions result from the replacement of univalent sodium (Na") and hydrogen (H) ions of soil with divalent (Ca2+) calcium ions of lime. This reaction binds clay, resulting in reduction of clay content and plasticity. Lime contents of 3% to 18% by volume are used to reduce plasticity of clays and render them manageable for compaction, manipulation, or stabilization with other chemicals. This is referred to as "lime modification" of soils. The reaction usually takes place within 96 hours. Saturated soils often require only crude mixing with light equipment (i.e., farm discs pulled by light tractors) or by hand. Since lime has a strong affinity for water and the resulting reaction is a harsh one. The reaction breaks down clay lumps by drawing water from the clay, thus creating a drier material. Agglomeration reaction of lime 'and soil is used to destroy collapsible characteristics of some silts. Approximately 6% to 9% percent by volume of lime mixed with collapsible silts destroys clay buttresses between silt particles and renders soils stable after 72 hours. Swell potential of clays can be reduced significantly by modifying them with 6% to 12% lime by volume. Swell potentials of 7% to 8% can be reduced to 0.1 to 0.2 percent by lime modification.

Cementation or Pozzolanic Reactions :-When SiO2 and Al2O3, Fe2O3 of soil react with available calcium in lime, they produce very stable calcium silicates and aluminates that act as natural cement (tobermorite gel) similar to Portland cement. Soils with plasticity indices as high as 37 can be stabilized with single application of 9% to 24% by volume of hydrated lime [Ca(OH)2,Ca(OH)2.MgO] or quicklime (CaO, CaO, MgO). Soils with higher plasticity can be stabilized with double application of lime. In this case part of the lime is applied to reduce plasticity and the other part is applied thoroughly and uniformly to obtain cementation and thus stabilization. Cementation is a time- dependent slow reaction. Production of natural cements depends on the presence of pozzolanic clays. Soil-lime mixtures also possess autogenous curing properties. As the pozzolanic reaction continues, the curing effect remains effective for many years.

Carbonation: Carbonation is an undesirable reaction that occurs when the lime added to soil does not react with soil, but draws CO2 from air or soil to form CaCO3. This occurs when the soil does not contain adequate amount of pozzolanic clay or because excessive amount of lime has been added. CaCO3 is a plastic material. Therefore, excessive lime addition to soil does not produce beneficial results.

MECHANISM OF STABILIZATION WITH RICE HUSK ASH (RHA) :-Rice Husk Ash is a pozzolanic material which contains 80-85% silica. This is therefore highly reactive and depending upon the temperature of incineration. Pozzolanic are defined as siliceous or siliceous and aluminous materials which in themselves process little or no cementing property, but will in a finely dispersed form in the presence of water chemically react with calcium hydroxide at ordinary temperature to form compounds possessing cementations properties. When water is added to a mixture with pozzolanic material it acts as cement, in some cases providing a stronger bond than cement alone.

The characteristics of the ash are dependent on the components, temperature and time of burning. During the burning process, the carbon content is burnt off and all that remains in the silica content. The silica must be kept at a non-crystalline state in order to produce an ash with high pozzolanic activity. If the rice husk is burnt at too high temperature or for too long period the silica content will become a crystalline structure. If the rice husk is burnt at too low temperature or for too short period of time the rice husk ash will contain too large amount of un-burnt carbon. Carbon does not possess pozzolaic properties, thus it does not take part in the strength development process. It acts more or less as filler materials. (V.M.Malhotra, P.K.Mehta, 1996)

RHA, LIME AND SOIL REACTIONS: The additions of lime to clayey soils lead to cation exchange and pozzolanic reactions. The cation exchange is the first reaction that takes place immediately and causes the individual clay particles to change from a state of mutual attraction typically due to excess Ca2+ replacing dissimilar cation from the exchange complex of the soil.

Some components of natural soils, notably clay minerals, are pozzolanic and the lime-soil pozzolanic reactions results in slow, but long term, cementing together of soil particles at their point of interaction. When the lime is added, the PH of the soil is raised, typically to about 12.4 and this highly alkaline environment promotes the dissolution of the clayey particles and the precipitation of hydrous calcium aluminates and silicates that are broadly similar to the reaction products of hydrated cement (Mtallib, M. O.A. 2011). The essence is to replace cement with RHA to get a more economic blend.

Table 3: Test Programme

Sl. No	Test	No of Tests
1	Grain Size Distribution	5
2	Atterberg Limits	
	a)Liquid Limit	30
	b)Plastic Limit	30
3	Standard Proctor Compaction Test	3
4	CBR Test at OMC	
	a)Soaked condition	30
	b)Unsoaked condition)	30
5	CBR Test at OMC+2%	
	a)Soaked condition	30
	b)Unsoaked condition)	30
6	CBR Test at OMC+5%	
	a)Soaked condition	30
	b)Unsoaked condition)	30
7	UCS with curing period 0 to 180 days with a intervals of 30 days	210

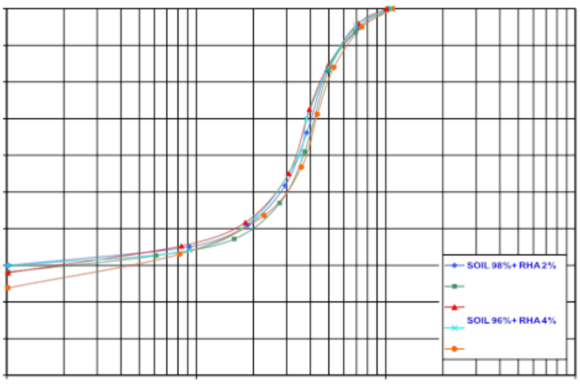

Fig. 2: Variation of Particle Size Distribution with Soil-RHA mixes (0% LIME)

MAXIMUM DRY DENSITY:-The variations of maximum dry density (MDD) with the different percentages of lime and rice husk ash (RHA) combinations are shown in Fig 4.103. The maximum dry density (MDD) generally decreases with increasing lime content. The maximum dry density (MDD) is abrupt but linear like the soil rice husk ash (RHA) mixture. The decrease in dry density indicates that it required low compaction energy than the virgin soil to attain its maximum dry density (MDD), as a result the cost of compaction will be decreasing.

This is due to the flocculation and agglomeration of clay particles caused by cation exchange reaction leading to corresponding decrease in dry density. The decrease in MDD of the lime treated soil is reflection of the increased resistance offered by the flocculated soil structure to the compactive effort.

The maximum dry density (MDD) is generally reduced with the increase in combined amount of lime and rice husk ash (RHA) combination. The decreasing trend of maximum dry density (MDD) can be attributed to the cationic exchange of the lime which induces flocculation and agglomeration of the clay particles. Again decrease in maximum dry density (MDD) with addition of rice husk ash (RHA) may be attributed to the replacement of soil with the rice husk ash (RHA) which have relatively low specific gravity (1.95) as compared to that of original soil, (specific gravity = 2.63). The decrease in maximum dry density (MDD) may also be attributed to coating of the soil particles by rice husk ash (RHA)which results in larger particles with larger voids and hence lesser density (Alhassan, 2008; Okafor et al. 2009).

OPTIMUM MOISTURE CONTENT:- The results of the optimum moisture content (OMC) for soil-lime and rice husk ash combinations with different percentages. For soil-lime at 0% rice husk ash (RHA), generally the optimum moisture content (OMC) increases with increasing lime content up to 6% and then decreases.

The increase in optimum moisture content (OMC) in spite of the reduced the surface area is caused by flocculation and agglomeration, which is due to the additional fine contents requiring more water in addition to the free lime that needs more water for the pozzolanic reactions.

The possible cause of increased water demand with increase of lime content may be the requirement of more water for dissociation of lime into Ca++ ions and OH- ions to supply more Ca++ ions for the cation exchange reaction. The increase in OMC due to addition of RHA may be attributed to the fact that RHA decreases the quantity of free silt and clay fraction and as a result quantity of coarser materials with greater surface area increases. Hence more water is required to compact the soil-RHA mixtures.

STRENGTH PROPERTIES:- In this section the strength characteristics of original soil and admixture mixed soil in terms of CBR and UCS tests have been presented. The CBR tests are performed with different moisture contents such as OMC, OMC+2% and OMC+5% and load vs. penetration curves for various moisture contents are presented in Fig. 4.9 to Fig.4.98.The general nature of CBR values of lime admixed soil is increasing with the increase in lime content and in all cases the range of soaked CBR is more than unsoaked CBR. In UCS tests the curing effects have studied upto 180 days with the intervals of 30 days. The curing has marked influence in the strength property of soils mixed with stabilizers like rice husk ash and lime.

CALIFORNIA BEARING RATIO (CBR) AT OMC, (OMC+2%), AND (OMC+5%)

CBR at OMC:- The variations of California Bearing Ratio (CBR) with different percentage of soil lime and rice husk ash combinations at the optimum moisture content are presented in Fig. 4.105 and Fig. 4.106 for unsoaked and soaked conditions respectively. This plots show that the California Bearing Ratio (CBR) value increases with increase of lime content, as well as with increase of rice husk ash (RHA) content, when mixed individually and also in combination with the original soil. The maximum California Bearing Ratio (CBR) value at OMC of 28.25% is found to occur with the combination of 6% of lime and 9% rice husk ash (RHA) contents under un-soaked condition and the maximum value increases to 29.82% for 6% of lime and 6% rice husk ash (RHA) combination under soaked condition. The California Bearing Ratio (CBR) value is found to increase appreciably with addition of rice husk ash (RHA) at lower lime content when compared with the original soil. This is probably due to the chemical action of lime.

In all the cases of soil lime and RHA combinations, the soaked CBR value is more than the unsoaked CBR. The increase in CBR value with the addition of lime is due to the formation of various cementing agents due to pozzolanic reaction between the amorphous silica or alumina present in natural soil and lime. This reaction produces stable calcium silicate hydrates and calcium aluminates hydrates as the calcium from the lime reacts with the aluminates and silicates of the soil.

CBR AT WATER CONTENT ABOVE OMC (OMC+2%, OMC+5%)

The variation of California Bearing Ratio (CBR) with soil lime and rice husk ash combinations at the water content of the 2% more than the optimum moisture contents (OMC+2%) are shown in Fig. 4.107 and Fig.4.108 for soaked and unsoaked conditions respectively. The plots show that the California Bearing Ratio (CBR) value increases with increase of lime content, as well as with increase of rice husk ash (RHA) content, when mixed individually and also in combination with the original soil. The maximum California Bearing Ratio (CBR) value of 22.14 % is found to occur with the combination of 6% of lime and 9% rice husk ash (RHA) contents under un-soaked condition and the maximum value increases to 24.10 % for 6% of lime and 9% rice husk ash (RHA) combination under soaked condition. When water content is increased further i.e. 5% more than the optimum moisture contents (OMC+5%) maximum California Bearing Ratio (CBR) value of 20.33% occurs under un-soaked condition and in soaked condition the maximum value obtained is 21.73% for 6% of lime and 9% rice husk ash (RHA) combination as presented in Fig. 4.109 and Fig. 4.110.The California Bearing Ratio (CBR) value is found to increase appreciably with addition of rice husk ash (RHA) at lower lime content when compared to the original soil under similar condition. This is probably due to the chemical action of lime. It is found that with increase of water content with respect to optimum, the maximum values of California Bearing Ratio (CBR) also drops when compared to the relevant values corresponding to tests done at optimum moisture contents (OMC). This is due to the pozzolanic reaction between small amount of CaOH present in original soil and RHA in presence of moisture. The mechanism of compaction which does not permit water into the sample beyond OMC and rather compaction energy is utilized in overcoming large shear strain.

UNCONFINED COMPRESSIVE STRENGTH (UCS) WITH CURING EFFECTS:-The Unconfined compressive strength (UCS) is the most common and acceptable method for determining the strength characteristics of soil. It is one of the tests adopted for the determination of the strength parameters of the soil. The strength characteristics in terms of UCS of stabilized and unstabilized soil. The variation of unconfined compressive strength (UCS) with the increase of lime content and rice husk ash (RHA) content separately and in combination over a curing period upto 180 days. In general the UCS values of soil-lime mixture increase with the increase of lime content and also with the curing period. The gain in strength of lime stabilized soil is primarily the pozzolanic reaction between silica or alumina present in natural soil and lime to form various cementing agents.

Percentage Improvement of UCS (With respect to Original Soil): It appears from this table, that unconfined compressive strength (UCS) improved by 127% for ordinary soil, but when with the addition of 8% lime it is improves by 251% and addition of 9% rice husk ash (RHA) it improves by 188%. The effect of lime is more predominant during curing and this is due to chemical action of lime. In case of rice husk ash (RHA) the pozzolanic action is not so predominant and it is of a little lesser degree.

It is further appears from Fig.4.115 that maximum strength improvement occurs for 9% rice husk ash (RHA) and 4% lime is sufficient to get the maximum strength with curing time of 180 days i.e. 285%. This is due to the enhanced supply of silica by RHA for reaction with lime. From the table it appears that as the percentage of rice husk ash (RHA) increases the percentage of lime required to achieve the maximum strength decreases. This indicates that with a little addition of rice husk ash (RHA) the requirement of lime content becomes less for achieving the maximum strength. This can make the mixture maximum cost effective, because the rice husk ash (RHA) is cheap and easily available compared to lime.

CONCLUSIONS

The following conclusions can be drawn from the present investigation

- The treatment of soil with addition of admixtures such as lime and RHA has a general trend of decrease in liquid limit and increase in plastic limit and decrease of plasticity index.
- The specific gravity decreases with increase of addition of lime up to 2% irrespective of RHA content. But with addition of lime more than 2%, it again increases asymptotically to a constant value and further increase in RHA content it decreases for any lime content,
- The liquid limit decreases for all soil-lime-rice husk ash combinations and the stabilized soils appear to be suitable for construction as pavement materials for the flexible pavements as is seen from CBR values.
- In general the plastic limit increases with the increase in lime percentage as well as rice husk ash content and up to 6% and 12% lime and RHA contents respectively. Beyond these limits it is more or less constant or shows slightly decreasing trend for all cases.
- The addition of admixtures with the soft sub-grade decreases the Maximum Dry Density and increases the Optimum Moisture content. The maximum dry density is generally reduced with the increase in lime and rice husk ash contents both separately for all cases.
- The optimum moisture content increases with increasing lime content up to 6% and RHA content up to 12% and then decreases.
- The strength characteristics in terms of CBR value is found to increase appreciably with addition of RHA at lower lime content when compared to the original soil. This is due to the pozzolanic action of lime and RHA.
- Soil, when mixed with lime and RHA combinations the CBR values increase appreciably both under soaked and un-soaked conditions.
- The maximum CBR value of 28.25% is found to occur with the combination of 6% of lime and 8% RHA contents under un-soaked condition and this value increases up to 29.82% for 6% of lime and 6% RHA combination under soaked

condition at the optimum moisture content. This should be considered for estimation of optimum quantity of lime rice husk ash to be used for working in the field.

- The maximum CBR value of 22.14% is found to occur with the combination of 6% of lime and 9% RHA contents under un-soaked condition and this value increases up to 24.10% for 6% of lime and 9% RHA combination under soaked condition at the 2% higher than the optimum moisture content.
- The maximum CBR value of 20.33% is found to occur with the combination of 6% of lime and 9% RHA contents under un-soaked condition and this value increases up to 21.73% for 6% of lime and 9% RHA combination under soaked condition at the 5% higher than the optimum moisture content.
- The curing period has the influence on the UCS value of admixture contained soil.
- The UCS value increases with the curing period for a fixed lime and RHA content, up to 9% of RHA and 8% of lime individually and beyond these limiting values the unconfined compressive strength decreases.
- It may be inferred that at 3% to 6% of RHA and 6% lime mixes the maximum UCS value is achieved as 346kN/m2, but increase of RHA content further to 9% even up to 12% the higher UCS value is achieved as 377 Kn/m2 with only 4% of lime content which may lead to cost effective construction.
- The maximum increase in UCS by 285% with the addition of 4% lime and 9% RHA and which appears to be the maximum degree of improvement with lime and RHA respectively over a curing period of 180 days. This is due to the enhanced supply of silica from RHA for reaction with lime.

REFERENCES

1. Roy, A. (2014), „Soil Stabilization using Rice Husk Ash and Cement‟, International Journal of Civil Engineering Research, Vol-5, No-1, P-49-54.
2. Shrivastava, D., Singhai. A.K, Yadav. R.K. (2014), „Effect of Lime and Rice Husk Ash on Index Properties of Black Cotton Soil‟, International Journal of Engineering Sciences and Research Technology (IJESRT), Vol-3(4), P-4030- 4033.
3. Prasad, D., Vaishali. R.J. (2014), „Effect of rice Husk Ash on Lime Stabilized Black Cotton Soil‟, International Journal of Applied Engineering Research, Vol- 9, No-2, P-219-222.
4. Sabat, A.K. (2014), „Engineering properties of an Expansive Soil Stabilized with Rice Husk Ash and Lime Sludge‟, International Journal of Engineering and Technology (IJET), Vol-5, No-6, P-4826-4833.
5. Shrivastava, D., Singhai, A.K., Yadav, R.K. (2014), „Effect of Lime and Rice Husk Ash on Engineering properties of black Cotton Soil‟, International Journal of Engineering Research and Science & Technology(IJERST), Vol-3, No-2, P- 292-296.
6. Mohammed, Y.Fattah., Falah, H.Rahil., Kawther, Y.H.AL-Soudany. (2013), „Improvement of Clayey Soil Characteristics Using Rice Husk Ash‟, Journal of Civil Engineering and Urbanism, Vol-3, Issue-1,P-12-18.
7. Elsharief, A.M., Elhassan, A.M., Mohamed, E.M. (2013), „Lime Stabilization of Tropical Soils from Sudan for Road Construction‟, International Journal of Geomate, Vol-4, No-2, P-533-538.
8. Ramasubbarao, G.V., Siva, Sankar.G. (2013), „Predicting Soaked CBR Value of Fine Grained Soil Using Index and Compaction Characteristics‟, International Journal of Civil Engineering, Vol-7, No-3,P-354-360.
9. Gandhi, K.S. (2013), „Stabilization of Expansive Soil of Surat Region using Rice Husk Ash & Marble Dust‟, International Journal of Current Engineering and Technology, Vol-3, No-4, P-1516-1521.
10. Ogundipe, O.M. (2013), „An Investigation inti the use of Lime4 Stabilized Clay as Subgrade Materials‟, International Journal of Scientific & Technology Research, Vol-2, Issue-10, P-82-86.
11. Oyediran, I.A., Okosum, J. (2013), „An attempt to improve geotechnical properties of some highway lateritic soils with lime‟, RMZ-M&G, Vol-60, P- 287-296
12. Muhmed, A., Wanatowski, D. (2013), „Effect of Lime Stabilization on the Strength and Microstructure of Clay‟, Journal of Mechanical and Civil Engineering, Vol-6, Issue-3, P-87-94
13. Rao, Koteswara. D., Rameswara, Rao. G.V.V., Pranav, P.R.T. (2012), „A Laboratory Study on the Affect of Rice Husk Ash and Lime on the properties of Marine Clay‟, International Journal of Engineering and Innovative Technology (IJEIT), Vol 2, Issue-1, P-345-353.
14. Biswas, S., Biswas, A., Dighade, A. (2014), „Utilization of Rice Husk Ash with Lime in Subgrade Soil for a Rural Road‟, Proceedings published in International

Journal of Computer Applications (IJCA), P-1-3.

15. Sarkar, G., Islam, R., Alamgir, M., Rokonuzzaman. (2012), „Interpretation of Rice Husk Ash on Geotechnical Properties of Cohesive Soil‟, Global Journal of Researches in Engineering Civil and structural Engineering, Vol-12, Issue-2, P- 1-7.
16. Mishra, N.K., Rath, S., Pradhan, P.K. (2012), „Lime Stabilization of Weak Sub- Grade for Construction of Rural Roads‟, International Journal of Earth Science and Engineering, Vol-5, No-3, P-554-561.
17. Saklecha, P.P., Katpatal, Y.B., Rathore, S.S. (2011), „Spatial Correlation of Mechanical Properties of Subgrade Soil for Foundation Characterization‟, International Journal of Computer Applications, Vol-36, No-11, P-20-24.