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EXPERIMENTAL INVESTIGATION ON STABILIZATION OF SUBGRADE MATRIALS USING RICE HUSK ASH AND LIME

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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 3%, 6%, 9% and 12%. 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 upto 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 6% 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. In this respect statistical analyses have been done by multiple linear regression models. Standard error has been found to be minimum when the model includes index properties (LL, PL & PI) and compaction characteristics (OMC & MDD) of the soil. This is in comparison with the models done separates with either of the sets of property.

Further attempt has also been made to gain an insight into the reasons of strength increase by identifying the microfabric structure of soil and soil-lime-RHA mixes.

Key Words:Subgrade, Stabilization, Expansive soils, RHA, Lime.

I. 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 utilised 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.

Out of many stabilizing materials lime improves the soil much with its little addition by pozzolanic reaction. Lime reduces the plasticity index of soil making it more friable and easy for handling and pulverized. There are generally an increase in Optimum Moisture Content and decrease in Maximum Dry Density but the strength and durability increases. Hydrated (slaked) lime is very useful in treating heavy, plastic clayey soils. Lime may be used alone or in combination with cement, fly ash, or other pozzolanic materials like rice husk ash etc. Lime has been mainly used for stabilizing the road bases and sub grades.

Rice husk is an agricultural waste material obtained from milling of the rice. About 770 million tons of rice husks are produced annually in Asia. In India it is approximately 120 million tons per annum. In developed countries, where the mills are typically large, disposal of the husks is a big problem for the environment and also burning them in an 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. Therefore a systematic detailed investigation should be undertaken to make possible use of rice husk ash (RHA) to improve the quality of weak subgrade soil so that it can be used with desired improvement for cost effective construction of good quality of subgrade.

OBJECTIVES

The main objective is to investigate the stabilization mechanism of some of the commercially available additives along with some marginal materials to better understand their potential usage in pavement construction. Experiments are performed in the laboratory to determine whether these products improve the properties of the soils. 1. To study the improvement of geotechnical and engineering properties of Lateritic soils and Black Cotton soil by stabilizing with different stabilizers at varying curing periods. 2. To qualitatively evaluate the durability of treated specimens with regard to wet-dry and freeze-thaw cycles. 3. To evaluate the Resilient modulus, Indirect Tensile strength and Fatigue behavior of stabilized soils.

II. MATERIALS USED

The materials used in the present study were locally available clayey soil, lime and rice husk ash. The physical properties of these materials are summarized one by one as follows:

SOIL

The soil used for this study was collected from Vijayawada Municipal Corporation area in a.p, 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 Jadavpur, Kolkata.

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 Bashirhat sub division in North 24 Parganas District of West Bengal, India.

III. 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 3%, 6%, 9% and 12%.

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.

SPECIFIC GRAVITY:

The determination of specific Gravity of soil is necessary to have an idea of unit weight of different mixes. It is the ratio of the weight in air of a given volume of soil solids at a stated temperature to the weight in air of an equal volume of distilled water at that temperature. The specific gravity test was conducted on the original soil specimen in accordance with IS 2720 (part3/Sec1).

GRAIN SIZE ANALYSIS

This test had been carried out for finding grain size of different soil-lime-RHA mixes. The results of grain size analysis are presented graphically in the form of a grain size distribution curves in which the cumulative percentage finer than known equivalent grain size are plotted against these sizes on a logarithmic scale.

LIQUID LIMIT

The Liquid Limit is defined as the water content, in percent at which a pat of soil in a standard cup and cut by a groove of standard dimensions will flow together at the base of the groove for a distance 13 mm when subjected to 25 shocks from the cup being dropped 10 mm in a standard liquid limit apparatus (Casagrande‟s apparatus) operated at a rate of two shocks per second.

In this test 200g air-dried soil sample passing through IS 425µ sieve has been mixed with water to form a thick homogeneous paste.

The Liquid limit test was conducted on different soil-lime-RHA mixes.

PLASTIC LIMIT

The Plastic limit is the water content in percent at which a soil can no longer be deformed by rolling into 3 mm diameter threads without crumbling.

About 50g of the oven dry sample has been taken from the material passing the 425µ and then mixed with water till it become homogenous and plastic to be shaped into a ball. The sample was rolled on a glass plate to form threads which cracked at approximately 3 mm diameter.

The Plastic limit test has been conducted on different Soil-lime-RHA mixes in accordance with IS 2720 (part5).

STANDARD PROCTOR COMPACTION TEST

About 2.5 kg of air-dried soil sample passing on 4.75 mm sieve mixed thoroughly with small quantity of water. The sample was mixed with suitable amount of water of 5% at the initial stage and later increased to 10%, 15%, 20% etc. The specimens of Proctor mould 100 mm diameter and127.5 mm of height. The sample was put in this mould in 3 layers with each layer compacted with 25 blows using 2.6 kg hammer at a drop of 310 mm.

The standard compaction test was conducted on different soil-lime-RHA mixes with a combinations to find out the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) in accordance with IS 2720 .

CALIFORNIA BEARING RATIO (CBR)

The CBR test is basically a penetration test, in which a cylindrical plunger of 5 cm diameter is penetrated into the soil mass contained in a compaction mould of 15 cm diameter and height 175 cm. The CBR mould is provided with a detachable perforated base plate of 1 cm thickness and 23.5 cm diameter. CBR is the ratio of force required to penetrate a soil sample with a cylindrical plunger of 5 cm diameter at the rate of 1.25 mm / min to that required for corresponding penetration of a standard material for which CBR is considered as 100%.

About 5 kg of air-dried soil sample retained on 4.75 mm sieve mixed with suitable amount of water (at optimum moisture content) of its weight. The sample was put in CBR mould in 3 layers with each layer compacted with 55 blows using 2.6 kg hammer at a drop of 310 mm (standard proctor test). The compacted soil and the mould were weighed and placed under CBR testing machine following the standard procedure. Load was recorded at penetration of 0.0, 0.50, 1.0, 1.5, 2.00, 2.5, 3.0, 4.0, 5.0, 7.5, 10 and 12.5mm.

The CBR values are usually calculated for penetration of 2.5 mm and 5.0 mm. Generally, the CBR value at 2.5 mm penetration is grater than that at 5.0 mm penetration and in such case the former shall be taken as the CBR value for design purposes.

The CBR test was conducted on different soil-lime-RHA mixes under both unsoaked and soaked conditions in accordance with IS 2720 (part16). The tests was conducted at Optimum Moisture Content (OMC), 2% more than Optimum Moisture Content (OMC +2%) and 2% more than Optimum Moisture Content (OMC +5%).

UNCONFINED COMPRESSION STRENGTH (UCS)

The unconfined compression test has been done using a cylindrical soil sample with no lateral confinement. An axial compressive load is gradually applied to the soil specimen until it fails. The load is applied fairly rapidly, and allowing no drainage, thus producing undrained conditions. The remoulded soil sample was prepared in the laboratory with 38 mm diameter and 76 mm length from soil compacted in Proctor mould as done in Standard Proctor Compaction test.

The UCS test was conducted on the soil specimen and different soil-lime-RHA mixes with corresponding values of optimum moisture content, in accordance with IS 2720 (part10). UCS values were found out for samples prepared immediately as well as for samples which was allowed to cure upto 180 days. Samples were tested for different curing periods.

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.

IV. EXPERIMENTAL PROGRAM

Different tests had been done on soil-lime-RHA mixes to obtain different soil properties. The soil-lime-RHA mixes taken for experiments with different lime and RHA contains are presented in Table.

Table.1 Tests Conducted

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

V. RESULTS AND DISCUSSION

The results obtained in this research work were presented here.

SPECIFIC GRAVITY

The variations of specific gravity of soil, lime and rice husk ash combinations with different percentages of admixtures are given in details in Table 5.3 and shown in Fig. 5.99. It appears from the plot that specific gravity decreases with increasing addition of lime upto 2% irrespective of RHA content. But with addition of lime more than 2%, it again increases asymptotically to a constant value. But increase in RHA content it decreases for any lime content, however with high lime percentages although it follows similar patterns but rate of variation falls. Increase of specific gravity with addition of lime beyond 2% indicates effect of chemical action of lime being predominant above this percentage.

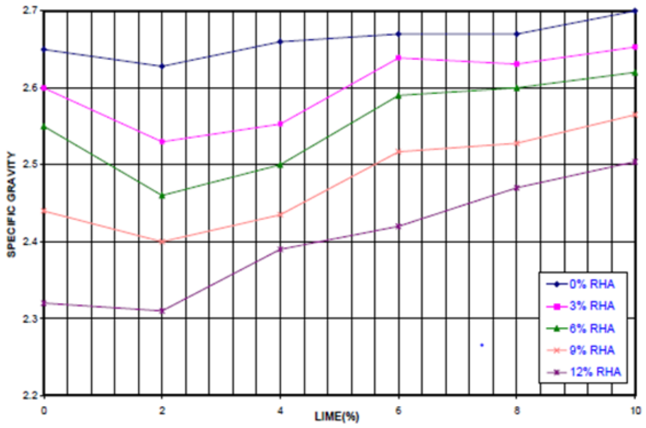

Fig.1: Variation of Specific Gravity with Lime content for different RHA contents

LIQUID LIMIT (LL), PLASTIC LIMIT (PL) AND PLASTICITY INDEX(PI)

When only lime is added liquid limit decreases with increasing lime percentage and plastic limit increases decreasing plasticity index. This also agrees with the result of grain size analysis. When only RHA is added liquid limit and plastic limit both increase but not appreciably and plasticity index almost remains in the range of that of original soil although effect of plasticity index is much pronounced when RHA content is as high as 12%.

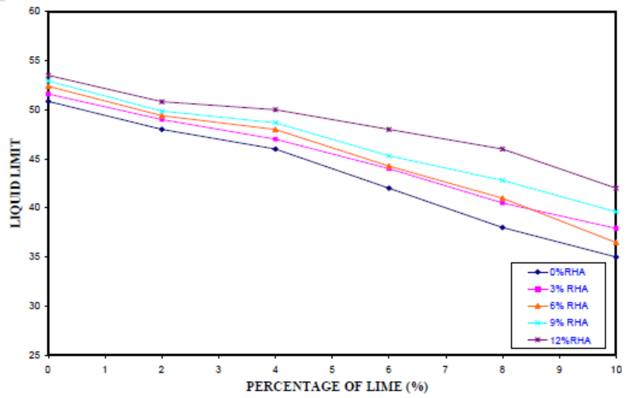

Fig. 2 Variation of Liquid Limit with Lime content for different RHA contents

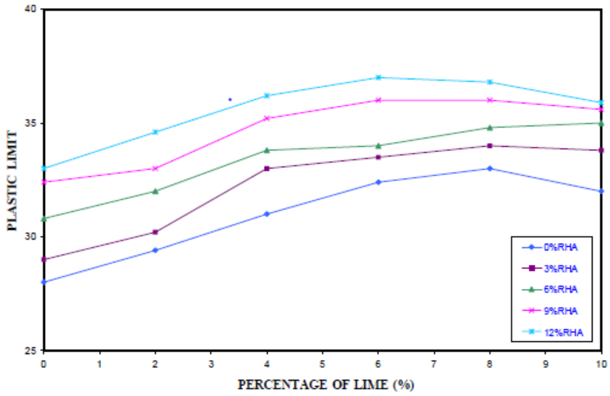

Fig. 3.Variation of Plastic Limit with Lime content for different RHA contents

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 . The maximum dry density (MDD) generally decreases with increasing lime content. From Fig , it can be seen that maximum dry density (MDD) continues to decrease with increase in lime content for a given rice husk ash (RHA) content The maximum dry density (MDD) is abrupt but linear like the soil rice husk ash (RHA) mixture.

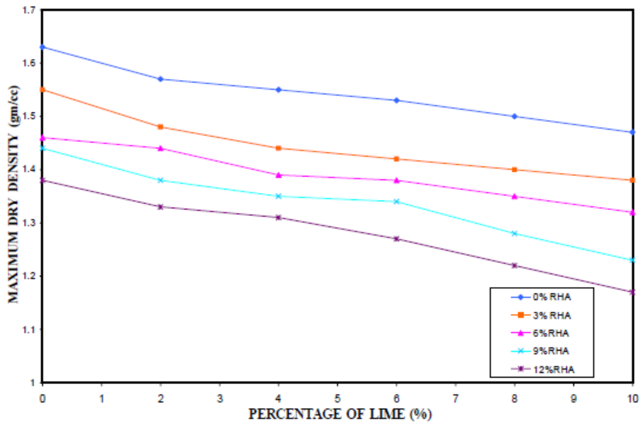

Fig. 4. Variation of Maximum Dry Density with Lime content for different RHA contents

OPTIMUM MOISTURE CONTENT

The results of the optimum moisture content (OMC) for soil-lime and rice husk ash combinations with different percentages are illustrated in the Fig.. 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.

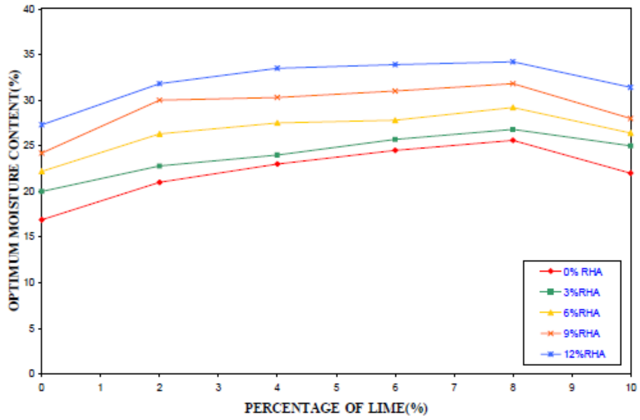

Fig. 5: Variation of Optimum Moisture Content with Lime content for different RHA contents

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. 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.

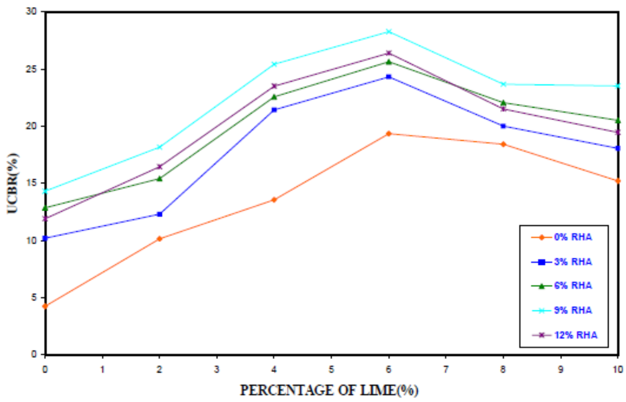

Fig. 6: Variation of California Bearing Ratio with Lime and RHA Combinations in unsoaked condition at Optimum Moisture Content

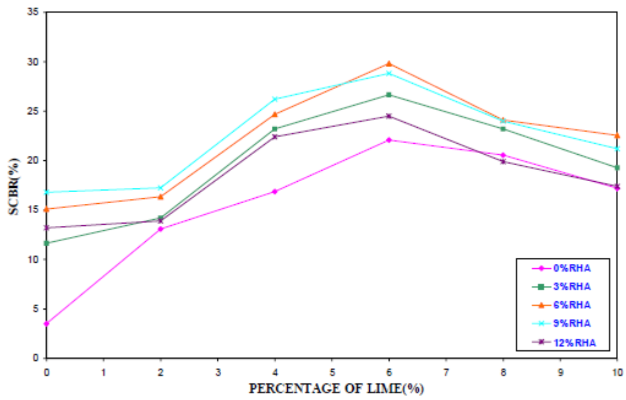

Fig. 7: Variation of California Bearing Ratio with Lime and RHA Combinations in soaked condition at Optimum Moisture Content

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 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 are shown in Fig. In general the UCS values of soil-lime mixture increase with the increase of lime content and also with the curing period.

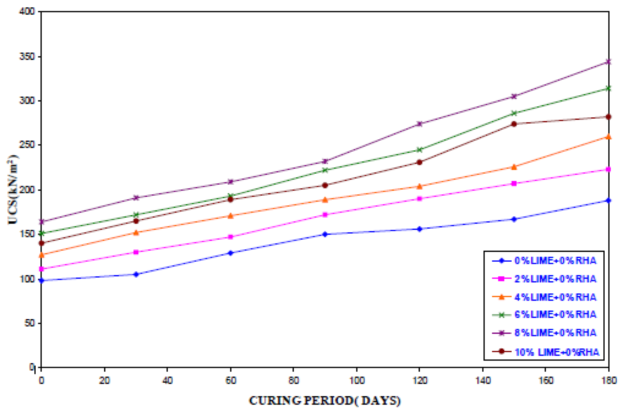

Fig. 5.111: Variation of UCS with Lime with a curing period up to 180 Days.

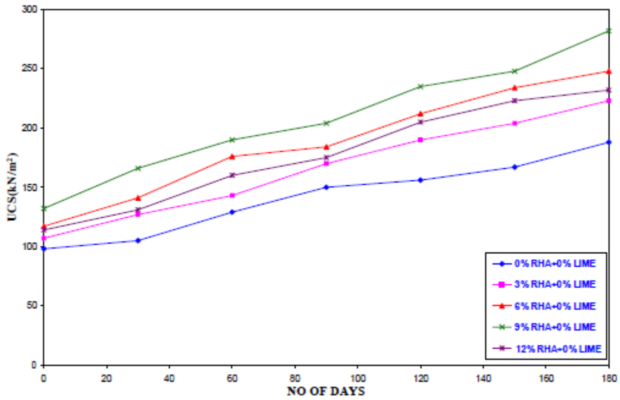

Fig. 8: Variation of UCS with RHA with a curing period up to 180 Days.

VI. CONCLUSIONS

These following conclusions are given based on the above experimental results.
In order to study improvement of clayey subgrade with addition of lime and rice husk ash as admixtures, a locally available clayey soil was collected from Vijayawada Municipal Corporation area in a.p, India. The soil was mixed with lime (2%, 4%, 6%, 8%, 10%) and RHA (3%, 6%, 9%, 12%) by weight individually and also in combinations. The geotechnical properties of clay such as specific gravity, atterberg limits was studied in case of soil, lime and RHA individually and for total 30 mixes with different combinations of soil, lime, RHA with different percentages by weight. The changes in compaction properties with addition of admixtures were also studied. The effects of improvement were studied by conducting CBR and UCS tests. The effect of curing on UCS values for different curing periods was also studied for a maximum period of 180 days. The CBR tests were conducted at different moisture contents e.g., OMC, OMC+2% and OMC+5% to study the strength improvement at higher water contents.

The following conclusions can be drawn from the present investigation
a) 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.

b) The specific gravity decreases with increase of addition of lime upto 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,

c) 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.

d) 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.

f) The optimum moisture content increases with increasing lime content up to 6% and RHA content up to 12% and then decreases.

g) 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.

i) The maximum CBR value of 28.25% 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 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.

j) 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.

k) 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.

l) 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, upto 9% of RHA and 8% of lime individually and beyond these limiting values the unconfined compressive strength decreases.
m) 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 upto 12% the higher UCS value is achieved as 377 kN/m2 with only 4% of lime content which may lead to cost effective construction.

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