EXPERIMENTAL STUDIES ON STABILIZATION OF SOILS WITH DIFFERENT CONVENTIONAL MATERIAL FOR USE IN SUBGRADE SYSTEM OF FLEXIBLE PAVEMENT IN TRANSPORTATION SYSTEM

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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) underunsoaked 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. 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.

Keywords—Flexible pavement, Rice husk ash, California Bearing Ratio, Unconfined compressive strength.

1. INTRODUCTION

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. 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.

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.

1.1. PRESENT STUDY

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 microfabric structure of soft cohesive soil. This has been done by conducting out semi quantative analysis with X-ray diffraction (XRD) and X-ray fluorescence (XRF) methods. X-ray diffraction is a technique that provides detailed information about the atomic structure of crystalline substances. This method has the advantage of quantifying the microfabric 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 unsoaked conditions. The interpretations of results of XRD and XRF tests have clearly indicated the reason of change of strength of soil-lime-RHA mixes with change of contents of lime and RHA. The previous studies focused on the use of transverse voids through the stems to achieve lighter members, the research in this paper studied the possibility of removing concrete from within the cross section of double-tee stems[12]. To suggest values of skew and span length that are likely to lead to longer lasting decks and superstructures[13]. The effects of functional obsolescence on the sustainability of 9 highway bridges are also discussed and a methodology is proposed for designing bridges to10 minimize obsolescence and maximize sustainability[14]. The challenges associated with TCIP construction are also discussed in that work. The authors' concluded in that work that this method of construction is not relevant to the current socio-economic context in India anymore because it is resulting in poor economy and quality of construction[15]. The Traditional Cast-In-Place (called as 'TCIP' hereafter) concrete frame and slab system is an outcome of a deep old practice in India among builders and masons with regard to building residential homes in India[16]. Growing population and limited buildable area in urban areas resulted in building vertically towards the sky. Tall buildings are the advancement of the multi- story buildings[17]. Tall buildings are vulnerable to heavy sway caused by the wind. Basically, wind flow is designated with its speed or velocity. The flow of wind in a terrain can be described using the boundary layer theory, where the ground acts as a viscous boundary layer. The wind flow is naturally turbulent. But, there is a mean wind speed, be it hourly mean or 3-sec averaged, that carries the turbulent wind. Thus, one can say that, the wind speed is fluctuating randomly about its mean wind speed[18].

2. REVIEW OF LITERATURE

Roy (2014) conducted the study of soil stabilization by using the rice husk ash (RHA) and cement. The experimental study established the suitability of locally available materials like rice husk ash (RHA) is used in the construction industry. The effective uses of rice husk ash (RHA) also minimize the waste disposal as well as environmental hazards[1].

Shrivastava et.al (2014), reported the effect of lime and RHA on the engineering properties of Black cotton Soil. The main objective in this study was to the feasibility of using rice husk ash with lime as soil stabilizing materials. A series of laboratory experiment were conducted on 5% lime mixed with black cotton soil blended with RHA in 5%, 10%, 15%, 20% by the weight of dry soil. The experimental result showed a significant increase in CBR and UCS[2].

Sabat (2014), investigated the changes in the engineering property of expansive soil due to addition of stabilizing with RHA and lime sludge. The soil sample mixed with different percentage of RHA such as 5%, 10%, 15%, 20% in combination with 5%, 10%, and 15% of lime sludge. The lime sludge used for this study, was collected from the paper manufacturing industry[3].

Fattah et al (2013), reported the improvement of clayey soil of Iraq by using the RHA. The experimental study carried out for the improvement of soil in three different locations of Iraq. The test programme conducted on this soil samples mixed with different percentages of RHA materials such as 2%,4%, 6%, 10% including Atterberg limit, Specific gravity, Consolidation And UCS etc. It is found from the experimental results that LL & PI decreased by 11-18% and 32-80%

respectively with the addition of 9% RHA but the enormous increase in UCS value with the RHA content between 6-8%.This improvement of UCS in addition of RHA content are shown in the Fig. 1[4].

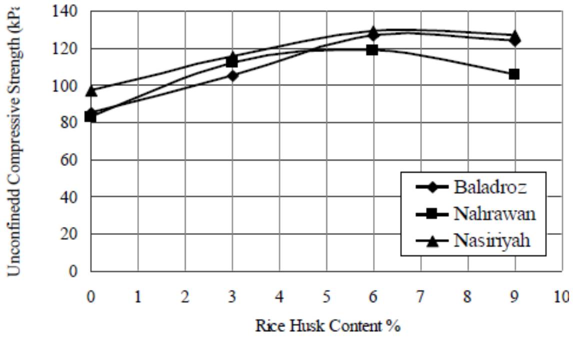

Fig.1: Effect of rice husk on unconfined compressive strength of soils

Elsharief et.al (2013), investigated the effects of hydrated lime for road design and construction in Sudan. They used three tropical clayey soil samples for these investigations. Soil 1 and Soil 2 were highly plastic expansive soil from eastern Sudan and soil 3 was red tropical clay from south Sudan. This Study includes the soil property such as attreberg limit, compaction, and permeability, CBR, Resilient Modulus (M_R) and UCS. The effect of salinity / sodicity on the plasticity and strength of the lime stabilized soil were also studied[5].

Ramasubbarao et al (2013), developed a regression based model for predicting the soaked CBR value of fine-grained sub-grade soil with the simple soil parameters with the help of multiple regression analysis. In this study they used soft computing system by multiple regression analysis for correlating the CBR value with the simple soil properties which includes index properties and compaction characteristics[6].

Gandhi (2013), reported the stabilization of expansive soil of Surat by using RHA and Marble dust. The work based on the experimental and theoretical analysis. This study consists of changes of its various properties and its mechanical capacities with the addition of rice husk ash and marble dust. The main objective of this investigation was to eliminate the economic and environmental cost by utilisation of additive[7].

Ogundipe (2013) investigated the use of lime stabilized clay as subgrade materials. The soil sample was collected from Ise / Ikere road of Ekiti state of Nigeria at a depth of 1.0 m below ground level. The main objective of this study was to determine the optimum lime content and level of improvement which could be achieved for stabilization. The investigation included the test carried out hydrometer test, specific gravity, Atterberg limits, compaction and CBR tests[8].

Oyediran (2013) reported the improvement of geotechnical properties of Lateritic soil with lime. The study area was southwestern part of Nigeria which underlined by the sedimentary rocks. The soils were treated with 0-20% of lime by mass and subjected to carry out the consistency limits, unconfined compressive strength and CBR tests. According to the test results, addition of lime showed the reducing the plasticity with an optimum range of 6-8% whiles the UCS and CBR increased. It was observed that addition of lime upto 6% there was a change of about 100% in UCS for all the soils.They concluded that the unsoaked and soaked CBR of all soils increased with the increasing lime content upto 33% and 40%[9].

Biswas et.al (2012) investigated the effects of addition of RHA in combination with a small amount of lime in different quantity to stabilize a highly plastic soil used in the sub-grade of rural road. They reported that RHA can be effectively utilized for back filling materials and also making the sub-grade of road pavement. In this study they used virgin soil, which was partially replaced by RHA and lime to improve its strength property as CBR value. In the experimental work they used 5%, 10%, 15% and 20% RHA mixed with in combination of 1%, 2%, and 3% of lime[10].

Rao et al (2012), conducted a laboratory experiment to study the effects of RHA and lime on marine clay. They used marine clay obtained from Kakinada sea port at a depth of 1.5 m from ground level. In this investigation they used RHA with a percentage of 15%, 20%, 25%, 30% mixed with a lime of 4%, 5%, 6%, 7%, 8%, 9% and 10% individually or in combinations[11].

2.1. PRESENT STUDY

1) 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.
2) To find out the best possible design mix proportion of the chosen soil and admixtures used which gives maximum strength of stabilized soil compared tothat of the original soil.

3. MATERIALS AND METHODOLOGY

The materials used in the present study were locally available clayey soil, lime and rice husk ash.

Table I. Engineering Properties of Soil

Basic Properties of Soil	Value
Sand (%)	5.5
Silt (%)	69
Clay (%)	28
Liquid Limit (%)	52
Plastic Limit (%)	29
Plasticity index (%)	24
IS Classification	CH
Specific Gravity	2.98
Maximum Dry Density(gm/cc)	1.80
Optimum Moisture Content (%)	16.32
CBR at OMC Unsoaked (%) at OMC	4.82
CBR at OMC Soaked (%) at OMC	3.80
Unconfined Compressive Strength(UCS) (kN/m^2)	98.24

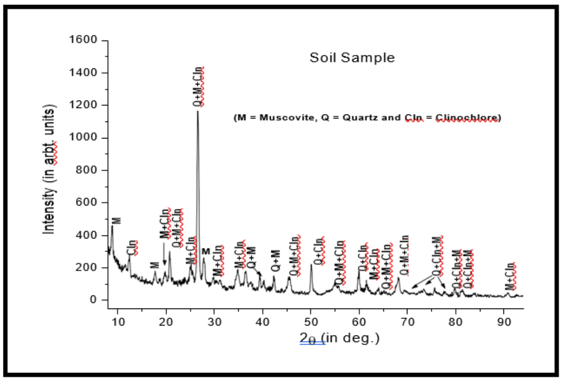

Fig.2: X-ray diffraction (XRD) pattern of the Soil sample

Table II. Chemical Properties of Hydrated Lime (From XRF analysis)

Constituents	Weight percentage
SiO_2	39.32
$Fe_2 O_3$	0.189
CaO	58.85
K_2O	0.065
MgO	0.643
TiO_2	0.026
Na_2O	0.076
SO_2	3.873

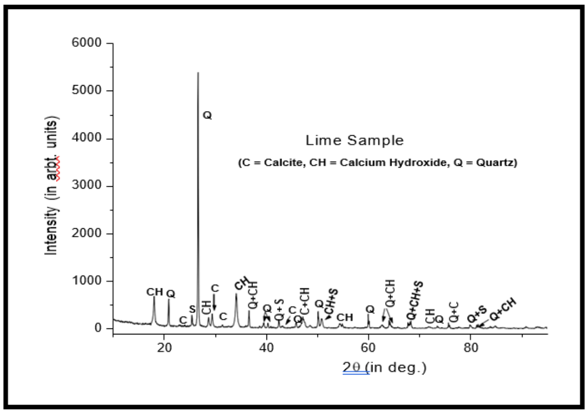

Fig.3: X-ray diffraction (XRD) pattern of the Hydrated lime

3.1 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. RHA has got numerous applications in silicon-based industries. Substantial research has been carried out on the use of RHA as a mineral admixture in the manufacture of concrete. RHA, in amorphous form, can be used as a partial substitute for Portland cement and as an admixture in high strength and high-performance concretes and also for soil stabilization and ground improvement.

Table III. Application of Rice Husk Ash

Sl.No	Feature	Application
1	Absorbent	For oils and chemicals
2	Insulator	As insulation powder in steel mills. In homes and refrigerants. In the manufacture of refractory bricks.
3	Release Agent	As a release agent in the ceramic industry.
4	Pozzolan	Cement industry Concrete industry
5	Aggregate and Fillers	Aggregates and fillers for concrete.
6	Soil Ameliorant	Soil ameliorant to help break up clay soils and improve soil structure.
7	Making silicon chips	In electronic industries.

The soil sample collected from the site was oven dried and sieved through 2.36 mm ISsieve 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. 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.

4. RESULTS AND DISCUSSION

Initially the geotechnical properties like Atterberg limit, grain size distribution and specific gravity of the soil and stabilized soil had been determined. The necessary experiment on made to determine the compaction characteristics i.e. optimum moisture content (OMC) and maximum dry density (MDD) by conducting Standard Proctor Compaction tests of those soils.

Table IV. Soil-Lime-RHA Mixes

SL.N O	OIL (%)	IME (%)	HA (%)	REMARK S
1	100	0		Only Soil
2	98	2		Soil-Lime Mixes
3	96	4		
4	94	6		
5	92	8		
6	90	10		
7	97	0		Soil-RHA Mixes
8	94	0		
9	91	0		
10	88	0	2	
11	95	2		
12	92	2		
13	89	2		
14	86	2	2	
15	93	4		
16	90	4		
17	87	4		
18	84	4	2	

19	91	6		Soil-Lime-RHA Mixes
20	88	6		
21	85	6		
22	82	6	2	
23	89	8		
24	86	8		
25	83	8		
26	80	8	2	
27	87	10		
28	84	10		
29	81	10		
30	78	10	2	

Table V. Soil-Lime-RHA Mixes

Sl.No	SOIL (%)	LIME (%)	RHA (%)	Specific Gravity
1	100	0	0	2.65
2	98	2	0	2.65
3	96	4	0	2.66
4	94	6	0	2.67
5	92	8	0	2.67
6	90	10	0	2.7
7	97	0	3	2.6
8	94	0	6	2.55
9	91	0	9	2.44
10	88	0	12	2.32
11	95	2	3	2.53
12	92	2	6	2.46
13	89	2	9	2.4
14	86	2	12	2.31
15	93	4	3	2.57
16	90	4	6	2.5
17	87	4	9	2.47
18	84	4	12	2.39
19	91	6	3	2.61
20	88	6	6	2.59
21	85	6	9	2.51
22	82	6	12	2.42
23	89	8	3	2.63
24	86	8	6	2.6
25	83	8	9	2.54
26	80	8	12	2.47
27	87	10	3	2.65
28	84	10	6	2.62
29	81	10	9	2.57
30	78	10	12	2.49

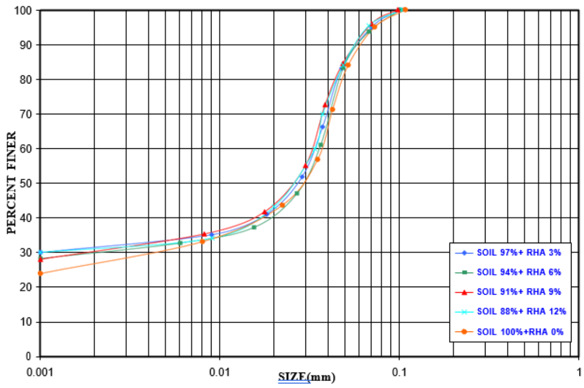

Fig.4: Variation of Particle Size Distribution with Soil-RHA mixes (0% LIME)

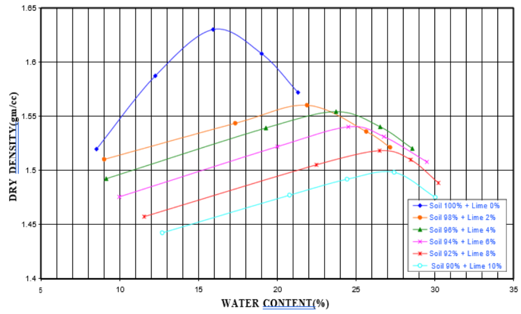

Fig.5: Variation of Dry Density with Water Content for different Soil-Lime mixes.

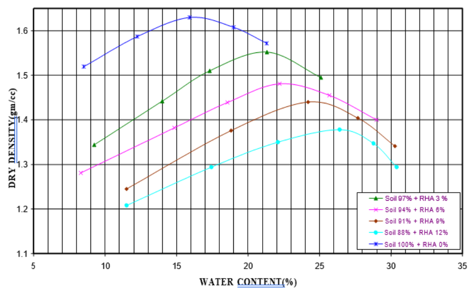

Fig.6: Variation of Dry Density with Water Content for different Soil-RHA mixes.

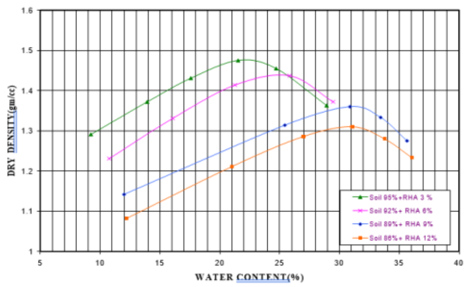

Fig.7: Variation of Dry Density with Water Content for different Soil-RHA mixes.

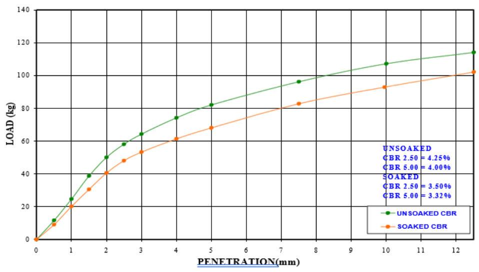

Fig.8: Variation of Load Vs Penetration Curve for unstabilized soil sample at OMC

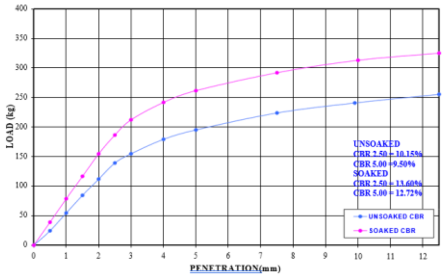

Fig.9: Variation of Load Vs Penetration Curve for soil sample mixed with 2% lime content at OMC

4.1 TEST RESULTS OF SPECIFIC GRAVITY

The variations of specific gravity of soil, lime and rice husk ash combinations with different percentages of admixtures. 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.

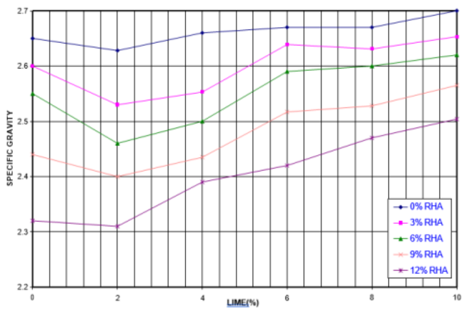

Fig.10: Variation of specific gravity with lime content for different RHA contents.

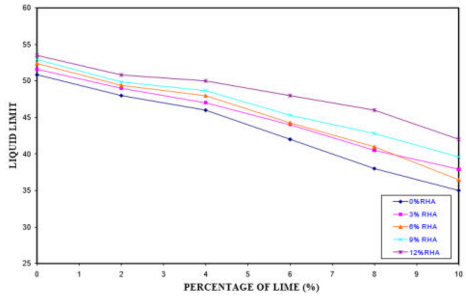

Fig.11: Variation of Liquid Limit with Lime content for differentRHA contents

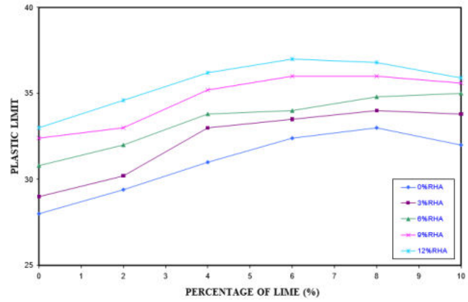

Fig.12: Variation of Plastic Limit with Lime content for different RHA contents

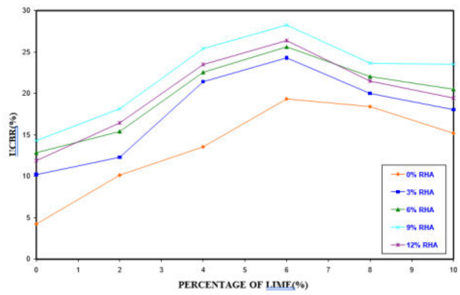

Fig.12: Variation of California Bearing Ratio with Lime and RHA Combinations in unsoaked condition at Optimum Moisture Content

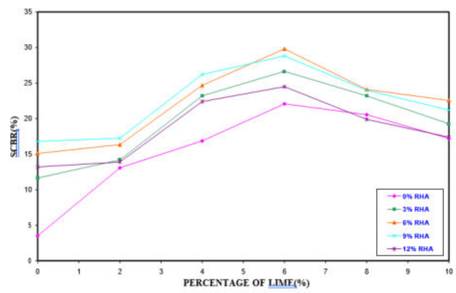

Fig.13: Variation of California Bearing Ratio with Lime and RHA

Combinations in soaked condition at Optimum Moisture Content

CONCLUSION

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.
e) 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.
h) 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 thefield.
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.

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