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Experimental Study on use of Rice Husk Ash and Lime in Stabilized Subgrade of Flexible Pavement

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Abstract: The quality of a pavement depends on the strength of its sub-grade, improving the quality of natural weak subgrade to enhance its strength and load bearing capacity is essential.If the natural soil is very soft it needs some improvement to act as a sub-grade. It is therefore, needed to replace the natural soil by stabilization with improved strength and compressibility characteristics.The Experimental works have been carried out with agricultural waste materials like and Rice Husk Ash (RHA) individually mixed with soil and also in combination with different percentage of Hydrated Lime with several mix proportions to study improvement of weak road subgrade.6,9,12 and 15 percentages of RHA were mixed with soil stabilized with 4, 6, 8 and 10 percentage of lime in different combinations and tested for California Bearing Ratio (CBR).The results shown marked improvement in CBR values of the mixed soils in comparison with that of the original soil.The high percentage of siliceous materials present in RHA promises it to be used as a potential soil stabilizing/improving material.

Keywords: Rice Husk Ash, Hydrated Lime, Soil subgrade, Soil stabilisation

Introduction

The potentiality of rice husk as a good source of high technological materials in road construction is the subject of this study. Every year approximately 600 million tons of paddies are produced globally. This gives around 120 million tons of rice husk (RH) and 21 million tons of rice husk ash (RHA) annually, and about 20 million tonnes of RHA is produced annually in India. Major four uses of rice husk ash are in the steel, cement, refractory bricks and semiconductor industry. Besides these, it can be utilized in several other applications. Emerging trend of using waste material in soil stabilizing or soil strengthening is being working out all over the world in present days. The main reason behind this trend is the excessive production of waste like fly ash, plastics, rice husk ash (RHA) which is not only hazards but also creating deposition problems.

Lime's dominant construction use today is in soil stabilization for roads, airfields, building foundation and earthen dams, where it upgrades low quality soils into usable base and sub base materials. It is also used as an additive in asphalt, in which it improves the cohesion of asphalt, reduces "stripping" and retards ageing process. Lime is routinely used as a soil modification agent to improve the performance of sub grade soils with the primary goal of reducing volume change. Effective mixing of lime and soil is critical to ensuring that the expected improvements occur throughout the soil mass. Lime also decreases the apparent amount of fines in a soil by causing flocculation and agglomeration of the clay particles (Little 1995). This results in an increase in the percentage of sand and silt size particles as measured by standard grain size distribution methods.

Using some of these waste materials in construction practice will reduce the problem in a great extent. Present study concentrates on how rice husk waste can be used in construction of roads, step by step procedure of various tests to be conducted on the experimental model section of road block.

Experimental Methodology

All the tests of soil before and after stabilization with different mixtures of RHA and lime will be carried out as per the Indian standard. For laboratory tests specimens of soil with and without admixtures has to be prepared by thoroughly 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. To maintain the homogeneity and uniformity of mix proportions, the California Bearing Ratio tests has to be performed under both soaked and un-soaked conditions, so as to ensure uniformity in proportion of materials and water content. The 2%, 4%, 6%, 8%, 10% proportions may be used in cases of lime and 3%, 6%, 9%, 12% for RHA. They will be mixed with original soil individually and also in combination of both the admixtures and laboratory results has to be analysed according Indian standardization of design criteria.

Objectives

1. To evaluate the effectiveness of use of RHA with Lime in enhancing the performance of flexible pavements.
2. To study the load bearing capacity & stability of the sub grade layers.
3. To find out the best possible design mix proportion of soil and admixtures which gives maximum strength of stabilized soil compared to that of the original soil.

Materials Used

The materials used in the present investigation were Rice husk ash, Hydrated Lime and locally available soft soil.

a. Soil

The soil used in the study was obtained locally collected at a depth of 1.5m from ground level and has been collected from an excavation site near Uttarahalli,Bangalore, Karnataka State, India. On visual inspection it was found to be reddish brown soil and from HRB classification it is found to be of category A-4(Silty soil with moderately plastic in nature). Evaluated properties of the soil are shown in table 1. Based on Liquid Limit, Plasticity Index and Unified Soil Classification system the soil may be classified as SM (Sandy Silt and Silty sand mixtures).

Table 1: characteristics of soil

Sl. No	Characteristics	Value
1	Specific Gravity	2.5
2	Liquid Limit(%)	31
3	Plastic limit (%)	22
4	Plasticity Index(%)	9
5	Classification of soil	A-4
6	Maximum Dry Density MDD(gm/cc)	2
7	Optimum Moisture Content OMC (%)	10.1
8	Unsoaked CBR(%)	1.65
9	Soaked CBR(%)	3.1

b. Lime

Commercial grade lime mainly consisting of 58.67% CaO and 7.4% Silica was used in the study and some chemical constituents are listed below table 2.

Table 2: Chemical constituents of Lime

Constituents	Weight (%)
SiO2	4.11
Al2 O3	3.11
Fe_2 O3	2.70
Ca CO_3	3.80
CaO	63.70
$CaSO_4$	19.26
MgO	1.62
Loss on ignition	1.70

c. Rice Husk Ash

Locally available Rice Husk Ash was used in the present work and itwas obtained from a local rice mill at Mysore road, Bangalore, Karnataka State, India. Some of the Chemical constituents of RHA are listed in table 3

Table 3: Chemical constituents of Rice Husk Ask

Components	% present in RHA
SiO2	93.2
Al2O3	0.59
Fe2O3	0.22
CaO	0.51
MgO	0.41
K_2O	2.93
Loss in Ignition	1.19

Experimental Work

Detailed experimental study was under taken to investigate the characteristics and behaviour of typical locally available soil mixed with lime and waste materials like and Rice Husk Ash (RHA) in different percentage and in several combinations from the view point of applicability of such materials in road subgrade. Even experimental works have been done to investigate the behaviour of soils with and without adding admixtures.

Routine tests were carried out for characterization such as Liquid Limit, Plastic Limit and strength properties for unstabilized soil and the relevant IS code followed for experimental work have been listed in table 4.

Table 4: Relevant IS Code followed for Experimental Work

Sl. No	Name of Tests	Relevant IS code followed
1	Specific Gravity	IS : 2720, Part-3, 1980
2	Atterberg Limits	IS : 2720, Part -5,1985
3	Classification and Identification of soil	IS : 2720, Part-1498,1970
4	Grain size analysis	IS : 2720, Part-4,1985
5	Water content determination	IS : 2720, Part -2, 1973
6	Laboratory CBR	IS :2720, Part-16,1979

All the tests of original soil were carried out as per the standard practice as laid out in the relevant IS code of practice. For tests of specimens of mixed/stabilized soils, specimens were prepared by thoroughly mixing the required quantity of soil and stabilizers in preselected proportion in dry state and then required quantity of water was sprinkled and mixed thoroughly to get a homogeneous and uniform mixture of soil and admixtures.

For laboratory CBR tests, specimens were prepared in the CBR mould as per the standard practice. Immediately after preparation of specimen the same tested for unsoaked condition and then it was submerged for four days for soaked tests.

For *Atterberg's limit* test on mixed soils, specimens were prepared by mixing soil and stabilizers in dry state as per the preselected proportions thoroughly and then water was added as per the standard practice. To investigate the effect of mixing RHA lime combination with the original soil to be used for construction of road subgrade, RHA was mixed in various proportions of 6%, 9%, 12%, 15% and lime in the proportions of 4%, 6%, 8%, 10%. To determine the moisture content dry density relationship, CBR of stabilized soil, Standard Proctor Test (IS 2720, Part-7, 1980) was carried out. Specimens for CBR tests were compacted at moisture content equal to Optimum Moisture Content and the results are tabulated in table 5.

Table 5: Consistency limits for soil with varying percentage of Lime and RHA

SOIL (%)	LIME (%)	RHA (%)	L.L (%)	P.L (%)	P.I (%)
100	0	0	31	22	9
90	4	6	36.494	32.33	4.164
85	6	9	38.302	33.172	5.13
80	8	12	39.013	35.964	3.049
75	10	15	39.594	36.556	3.038

Standard Proctor Test

Standard proctor test have been conducted to determine the optimal moisture content at which a given soil type will become most dense and achieve its maximum dry density.Thus, the routine laboratory tests with different mix proportions involves conducting Standard Proctor Test as per IS: 2700(Part-VII), 1980/87 on both unstabilized and stabilized soil mixes to determine their individual OMC and MDD and the results are tabulated in table 6.

The Optimal moisture content and Maximum dry density for normal soil were:

- *Optimum Moisture Content =10.1%*
- *Maximum Dry Density =2g/ cm^3*

Table 6: Compaction characteristics of soil with varying percentage of Lime and RHA

Soil	Lime	R H A	O M C	M D D(g/cc)
90%	4%	6%	14%	1.560%
85%	6%	9%	18%	1.379
80%	8%	12%	20%	1.340
75%	10%	15%	22%	1.310

***CBR Test** for soil and soil mixed with admixtures*

California Bearing ratio is a penetration test used for evaluation of mechanical strength of road subgrades and basecourses. The test is performed by measuring the pressure required to penetrate a soil sample with a plunger of standard area and the test results are tabulated in table 7.

Table 7: CBR test results for both soaked and unsoaked condition.

SL NO	SOIL %	LIME %	R H A %	CBR SOAKED %	CBR UNSOAKED %
1	100	0	0	1.65	3.1
2	90	4	6	18.8	8.8
3	85	6	9	29.02	15.32
4	80	8	12	35.56	26.97
5	75	10	15	25.75	15.12

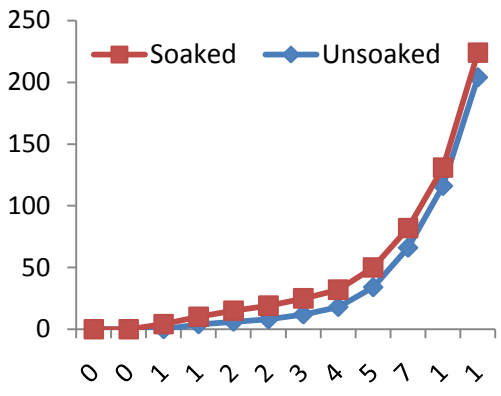

Figure 1a: CBR for Virgin soil

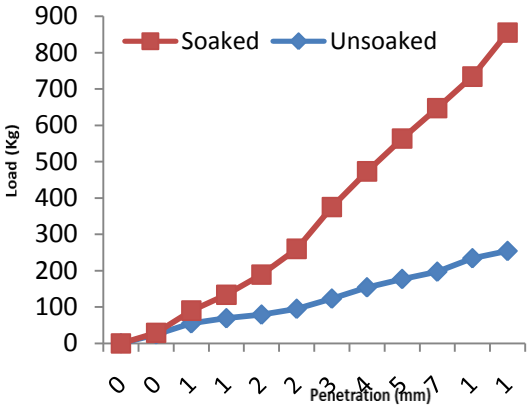

Figure 1b: CBR for 4%Lime + 6% RHA

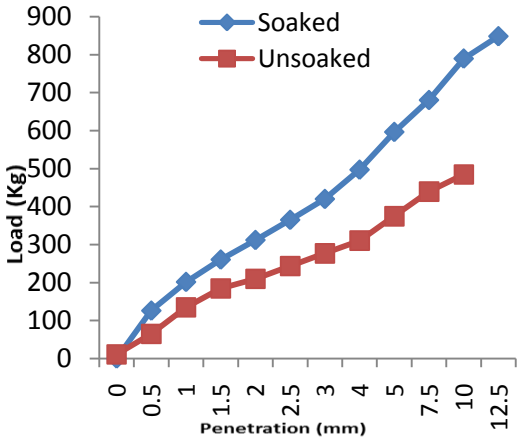

Figure 1c: CBR for 6%Lime + 9% RHA

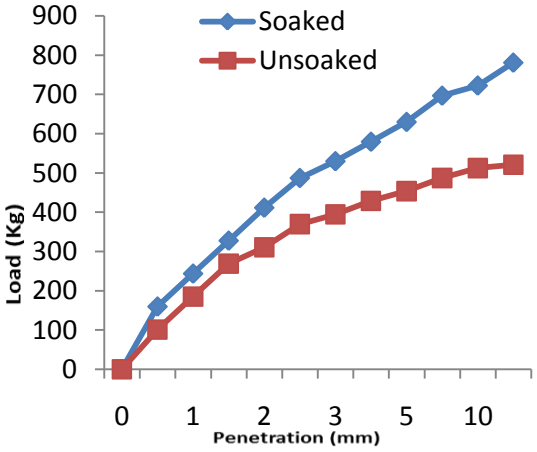

Figure 1d: CBR for 8%Lime + 12% RHA

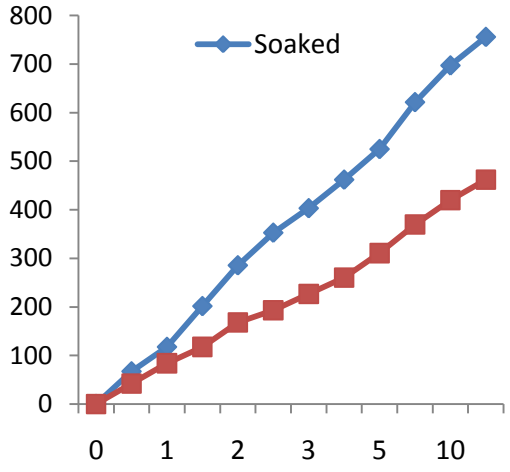

Figure 1e: CBR for 10%Lime + 15% RHA

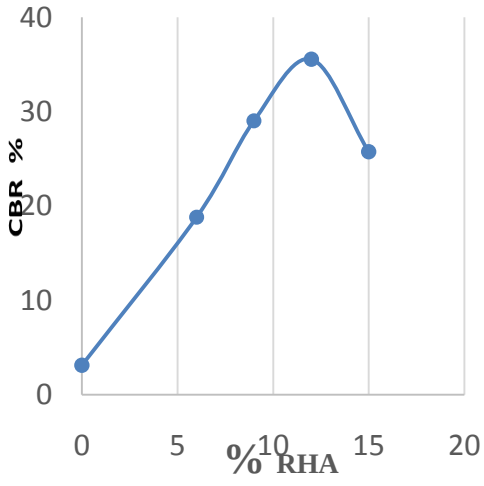

Figure2: Variation of CBR value with RHA

Results and Discussion

Effects of Lime and RHA on Compaction Characteristics of soil

The results indicated in Table 6 with increase in lime content, OMC of the soil lime mix increases gradually with same compactive effort. While the virgin soil has an OMC of 10.1% addition of 4% lime and 6% RHA with soil raise the OMC to 14% and an addition of 6% lime and 9% RHA raise the OMC of mixed soil up to 18%.

The increase in OMC with increased lime and RHA content is in agreement with most of the researchers in this area. The possible cause of increased water demand with increased lime content may be the requirement of more water for the dissociation of lime into Ca and OH ions to supply more Ca ions for the cation exchange reaction.

It can be seen from the results of table 6 with the increase in lime and RHA contents MDD decreases gradually. While the virgin soil has the MDD of 2gm/cc an addition of 4% lime and 6% RHA reduces the MDD to 1.560 gm/cc and addition of 6% lime and 9% RHA further reduces the MDD of mixed soil to 1.379 gm/cc. The decrease results from the flocculation and agglomeration of clay particles caused by cation exchange reaction leading to corresponding decrease in dry density. The decrease in the MDD of the lime treated soil is reflective of the increased resistance offered by the flocculated soil structure to the compactive effort. This agrees with the findings of the other investigators of this area.

Effect of RHA Lime addition on strength characteristics of soil

From figure 1a,1b,1c,1d,1e shows that the variation of CBR of soil- lime RHA combination with RHA content for a given percentage of lime. For both unsoaked and soaked conditions. From curve, we see that for 4% lime and 6% RHA addition, the CBR value for both unsoaked and soaked conditions increase gradually to a value slightly more than those of 0% RHA content (soil+4% lime mixture) at 6% RHA content, but at 12% RHA content(Figure 1d) both the unsoaked and soaked CBR reach to a peak value of 26.97% and 35.56% respectively and thereafter CBR values for both the conditions continue to drop with further addition of RHA. This suggests that for each given percentage of lime content, there exists an optimum amount of RHA which gives maximum value CBR. This is due to the fact that addition of RHA make available additional amount of silica than that present in natural soil only. This enhances the lime pozzolanic reaction and as a result CBR value increases. But further addition of RHA at 15% with lime content 10% (Figure 1e) , manifests as free RHA which is in excess of RHA required for lime pozzolanic reaction and this additional RHA occupies the space in between the soil particles in the specimen and thus reduces the bond and CBR value of the soil lime RHA mixture.

From the above discussion an inference may be drawn that with the increase in admixtures content CBR values for both unsoaked and soaked conditions increase .Out of the above discussed four cases, we seen that the combination of 8% lime + 12% RHA gives the highest value of CBR of 35.56% and 26.97% for soaked and unsoaked conditions respectively, that is more than 21 times for soaked and8.5 times for Unsoaked condition has been increased compared to that of original soil.

Conclusion

General increase in OMC and decrease in MDD was found when lime was added with RHA. Addition of RHA with lime found to improve the strength characteristics substantially. This is due to the increased pozzolonic activities in presence of lime and RHA. Addition of lime and RHA with soil improves the CBR value of soil for both unsoaked and soaked conditions sharply. 8% Lime and 12% RHA was found to be the maximum value of CBR for both the conditions

For every percentage of lime there seemed to have an optimum RHA content to attain maximum value of strength. Similarly for every given percentage of RHA, increase in lime content increases the value of CBR.Rice Husk Ash has very high potential to be used as soil stabilizer when mixed with lime.

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Biography

Naveen Kumar A.B was born in Hassan, India, in 1988. He received the B.E. degree in Civil Engineering from the Visvesvaraya Technological University, India, in 2009, and the M.Tech. Degrees in Highway Technology from the R.V College of Engineering(RVCE) Bangalore, India, in 2012 and pursuing his Ph.D. Degree from the VisvesvarayaTechnological University, India.In 2009, he joined the Department of Civil Engineering, in KS Polytechnic, India as a Lecturer, and he was anAssistant Professor, in YellammaDasappa Instituteof Technology,from 2012 to 2014, later he joined as an Assistant Professor in S.J.B Institute of Technology (SJBIT), Bangalore, India from 2014 to 2016. Currently he is working as a Faculty Member in Civil Engineering Department, Mettu University, Mettu, Ethiopia. His current research interests include stabilization of flexible pavement layers, Transportation Engineering, Traffic Engineering, Railway Engineering, utilization of recycled materials for road construction. He has published research articles in reputed national and international journals and also presented research papers in various conferences. He is a Life Member for reputed journals like IJMER and etc. He got the best Academic and Performer Awards also.