

A Comparative Study of the Effects of Rice Husk Ash and Lime on the Geotechnical Properties of Lateritic Soil for Use as Highway Materials

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ABSTRACT: The lateritic soil used in this study was identified as A-7-6 (8) group soil in accordance with AASHTO classification system. The soil was stabilized admixing rice husk ash (RHA) and lime in different quantities. The mixing quantities of RHA were 0, 4, 8, 12, 16, 20 and 24 percentages and lime were 0, 2, 4, 6, 8, 10 and 12 percentages of the weight of lateritic soil. Atterberg limits, standard Proctor compaction, unconfined compression and California bearing ratio (CBR) tests were conducted on lateritic soil with various percentages of these two stabilizers in order to examine their influences. This study presents the potentials of RHA compared to lime in lateritic soil stabilization. Based on the test results, the required percentages of RHA and lime were determined for economical stabilization of lateritic soil and this study recommends 4% lime and 17% RHA for sub-base materials in highway construction.

KEYWORDS: Lateritic soil, rice husk ash, lime, compressive strength, CBR value, sub-base materials, highway construction.

I. INTRODUCTION

In the third world countries, the necessity of locally manufactured construction materials is increasing due to uprising demands for new roads and housing units enforced by the growth of population. Over the years, the availability of conventional materials has not been sufficient to meet the demands of growing population. This has necessitated the search for materials capable of being utilized as substitutes of cement and/or decreasing the quantity of cement in use. These shortage problems of conventional construction materials can be solved by using abundant local waste materials. The utilization of these materials is advantageous from the point of view of reducing construction cost and protecting the environment from pollution. Two types of such local materials are lateritic soils and rice husks. These materials are abundant all over the tropical and sub-tropical regions of the world. Rice is grown in more than 75 countries. There are areas where accumulating heaps of rice husks is a significant problem. Apart from saving storage and disposal cost, their use in construction works reduces the construction cost and protects the environment from pollution.

Laterites are very important soil resource in many civil engineering projects. These are generally used as materials for construction purposes in the construction industries as well as providing support to various kinds of super structures. They are used as sub-grade, sub-base and base materials beneath pavements of roadway and airfields in transportation engineering. The main purpose of this study is to reduce the construction cost and to protect environment from contamination by using abundant local waste materials.

II. OBJECTIVE

The objectives of this research work are as follows:

- To observe the influences of RHA and lime on Atterberg limits, compaction characteristics, unconfined compressive strength and CBR value of lateritic soils.
- To compare the potentials of RHA with that of lime in lateritic soil stabilization.
- To determine the optimum percentages of RHA and lime for use in highway construction.

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III. RELATED WORK

Alhassan [1] has studied potentials of rice husk ash for soil stabilization. Ajayi [2] has studied effect of lime variation on the moisture content and dry density of lateritic soil in Ilorin, Nigeria. Osula [3] has worked on the modification of lateritic soil with cement and lime. Portelinha et al. [4] showed that addition of 2% and 3% lime or cement was enough to change the soil workability and mechanical strength. Hydrated lime and Portland cement have been considered as excellent stabilizers for the improvement of different soils and have been extensively used in the past decades. Beneficial effects of compacted soil-lime and soil-cement mixtures on geotechnical properties have been discussed in the technical literature presented in [5-8]. Sujit and Hussain [9] have used lime as a stabilizer. Problem lateritic has been treated with lime for modification by Osula [10]. It has been reported by Ola [11] that Nigerian lateritic soils could be potentially stabilized with lime. Lazaro and Moh [12] studied lime-RHA mixtures as a stabilizer with deltaic clays and found that considerable improvement of the deltaic clays could be obtained by the addition of RHA. Besides the above research work, many other studies have been performed on lateritic soils in the past decades. Some of them have been presented in the literatures of Maignien [13], Lyon Associates [14] and Gidigas [15].

IV. TEST MATERIALS

Rice husk ash, lateritic soils and lime are selected materials which have been used in this investigation.

Rice Husk Ash

The properties of RHA depend greatly on whether the husks had undergone complete destructive distillation or had only been partially burnt. This was reported by Houstin [16] who also classified RHA into: (1) high-carbon char, (2) low-carbon char and (3) carbon-free (pink or white) ash.

Well burnt RHA passing No. 200 sieve (0.075 mm) was used in this investigation. Rice husks were burnt with the help of a simple combustion chamber designed by William and Sompong [17]. Chemical composition of the investigated RHA is shown in Table 1 and also compared with other RHA given by Korisa [18] and Lazaro and Moh [12].

Table 1 Chemical composition of rice husk ash

Chemical composition %	Korisa		Lazaro & Moh	Used RHA
	Sample 1	Sample 2		
Silicon dioxide (SiO ₂)	94.50	93.50	88.66	89.5
Calcium oxide (CaO)	0.25	2.28	0.75	0.11
Magnesium oxide (MgO)	0.23	–	3.53	1.70
Sodium oxide (Na ₂ O)	0.78	–	–	0.57
Potassium oxide (K ₂ O)	1.10	3.15	–	2.01
Ferric oxide (Fe ₂ O ₃)	Traces	1.01	0.36	0.76
Phosphorus oxide (P ₂ O ₅)	0.53	–	–	–
Aluminium oxide (Al ₂ O ₃)	Traces	Traces	1.48	1.39
Manganese oxide (MnO ₂)	Traces	Traces	–	0.07
Carbon dioxide (CO ₂)	–	–	0.51	–
Loss on ignition	–	–	3.80	3.59

Lateritic Soils

The word 'laterite' was first used by Buchanan [19] in 1807 to describe as ferruginous, vesicular, unstratified and porous materials with yellow ochres caused by its high iron content. This material was abundantly available in Malabar,

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India. It was locally used as bricks for buildings; hence, the name 'laterite' came from the Latin word 'later' meaning brick.

The used lateritic soil was reddish brown in colour. General properties of original soils were determined by various laboratory tests and are shown in Table 2. This lateritic soil was identified as A-7-6 (8) group soil in accordance with AASHTO method of classification.

Table 2 Properties of original lateritic soil

Properties	Results
Natural moisture content (%)	8.02
Liquid limit (%)	49.80
Plastic limit (%)	22.60
Plasticity index (%)	27.20
Specific gravity	2.64
% passing No. 200 sieve	45.30
Unconfined compressive strength (kPa)	211.20
California bearing ratio (%)	7.73
Cohesion (kPa)	123.00
Angle of internal friction (degree)	12.80
Group index	7.73

V. METHODS

Different Laboratory Tests and Mix Proportions

A series of laboratory tests were carried out in this study. These tests were atomic absorption spectrophotometer, natural moisture content, specific gravity, grain size analysis, standard Proctor compaction, unconfined compression and California bearing ratio (CBR).

All these tests were carried out in accordance with British Standard Specification (BS 1377:1975). Various percentages of RHA and lime are mixed with soil. Percentages of RHA were 0, 4, 8, 12, 16, 20 and 24. Percentages of lime were 0, 2, 4, 6, 8, 10 and 12.

VI. EXPERIMENTAL PROCEDURES

Atomic Absorption Spectrophotometer

The Chemical components of RHA and lateritic soil were determined by atomic absorption spectrophotometer. In order to determine the chemical composition, one gram of dried sample was taken and properly digested. The digested sample was diluted as required for the determination of various elements.

Grain Size Analysis

Wet sieving and hydrometer methods were carried out for grain size analysis of the investigated soil. The wet sieving method was followed in order to avoid false larger size of soil grains and obtain an accurate grain size distribution curve.

Standard Proctor Compaction Test

Fourteen standard Proctor compaction tests were performed to determine the optimum moisture contents and maximum dry densities of various mix proportions of RHA and lime. The standard Proctor compactive energy was utilized because this can be easily achieved in the field.

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Preparation of Soil Specimens

RHA and lime were separately mixed with soil in a large tray. Mixing was carried out thoroughly and properly by hand. All soil specimens for unconfined compression and CBR tests were prepared at required optimum moisture contents and maximum dry densities predetermined by the standard Proctor compaction test. During the preparation of soil specimens for all tests, the soil samples were compacted at the same compactive energy per volume as in the standard Proctor compaction test.

Unconfined Compression Test

Fourteen sets of soil specimens were prepared for unconfined compression tests. Every set consisted of three specimens to give the average value. The dimensions of every specimen were 39 mm in diameter and 78 mm in height. A height-diameter ratio of 2 was followed. Samples were air cured at room temperature for required time before being loaded in compression. The room temperature was maintained at about 20° C and the humidity was very high. Samples were sheared at strain-controlled test and the rate of strain was 1.14 mm min⁻¹.

California Bearing Ratio Test

Thirteen soil samples were prepared in the CBR mold. Penetration testing in CBR tests was carried out with the help of a plunger of cross-sectional area of 19.35 cm². The rate of penetration was 1.27 mm min⁻¹. CBR value was calculated on the load ratio at 2.54 mm penetration, since the load ratio at 5.08 mm penetration was always less.

VII. TEST RESULTS AND DISCUSSION

Chemical Composition of Used RHA

Chemical analysis showed that the main constituent of RHA was silica (89.5%). The total percentage composition of silicon dioxide, aluminium oxide and ferric oxide was found to be 91.65. This value was much higher than the required value of 70% minimum for pozzolans (ASTM C618). The used RHA particles were finer than 0.075 mm. During the preparation of all soil specimens, RHA was compacted with the soil in the mold. Obviously, ash particles became much finer than 0.075 mm. It is not unlikely that RHA would be as fine and reactive as fly ash.

Grain Size Analysis

Wet sieving and hydrometer methods were carried out to determine the grain size distribution of the investigated soil. Grain size distribution curve is shown in Fig. 1.

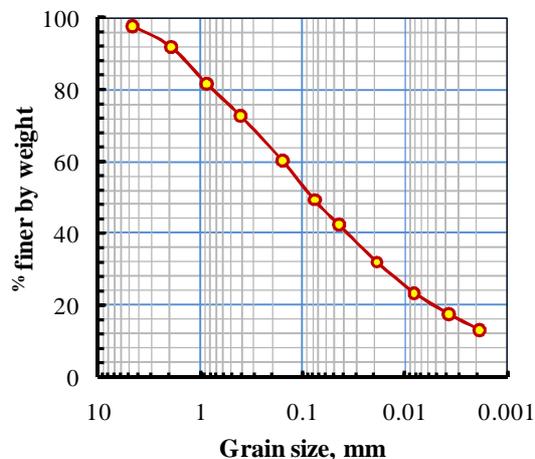


Fig. 1 Grain size distribution curve of lateritic soil

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Atterberg Limits of Stabilized Soils

Summary of the results of Atterberg limits of lateritic soil with various percentages of RHA and lime are shown in Table 3. The trend of changes of liquid limits, plastic limits and plasticity indices of the soil with various parentages of RHA and lime are presented in Fig. 2. Liquid and plastic limits increase linearly with increase in both RHA and lime. But, the plasticity index decreases linearly as the percentage of RHA and lime increases. It is clear from the figure that lime is more effective than RHA. The rate of change of Atterberg limits is higher in case of lime compared to RHA. It is the opinion of the author that when RHA and lime are mixed with fine grained cohesive soils, it causes the flocculation of soil particles. This is why the plasticity index decreases. This decrease in plasticity index indicates the improvement of the soil.

Table 3 Effect of stabilizers on Atterberg limits of lateritic soil

RHA %	LL %	PL %	PI %	Lime %	LL %	PL %	PI %
0	49.8	22.6	27.2	0	50.2	24.9	25.3
4	51.4	26.1	25.3	2	50.9	29.9	21.0
8	52.2	29.5	22.7	4	51.7	33.8	17.9
12	52.6	31.9	20.7	6	52.3	38.3	14.0
16	53.4	35.2	18.2	8	53.3	42.9	10.4
20	54.3	38.6	15.7	10	54.0	47.7	6.3
24	-	-	-	12	54.1	51.3	2.8

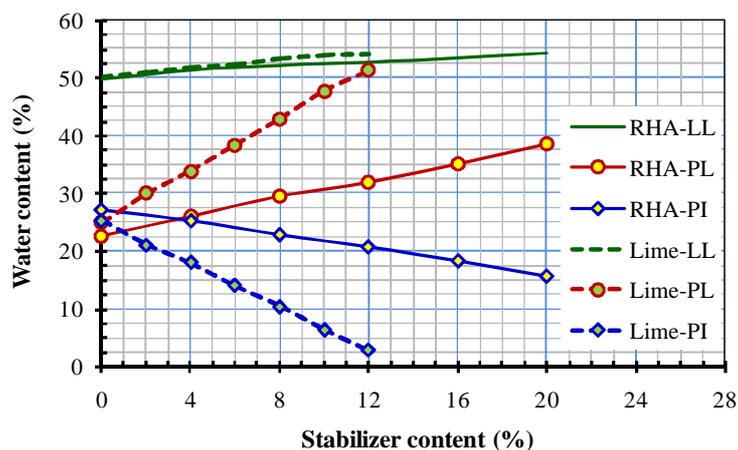


Fig. 2 Variation of Atterberg limits of lateritic soil with stabilizer contents

Compaction Characteristics of Stabilized Lateritic Soils

A summary of the results of standard Proctor compaction tests on lateritic soil stabilized with various percentages of RHA and lime are shown in Table 4. The trend of changes of maximum dry density and optimum moisture content with increase in stabilizer content is also presented in Fig. 3 (a) and Fig. 3(b). Maximum dry density decreases with increase in both RHA and lime. The rate of decrease of maximum dry density is higher for RHA compared to lime. This decrease in maximum dry density is due to two reasons. Firstly, the specific gravities of RHA and lime are lower compared to soil. Secondly, the stabilizer content coats the soil grain to form larger aggregates which consequently results larger voids in the soil. However, the voids between the larger soil particles can be filled up with stabilizer, if

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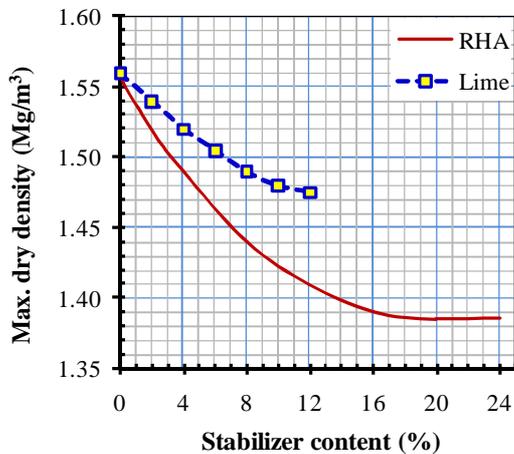
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optimum percentage of stabilizer, i.e., considerable amount of stabilizer is mixed. Then, it will compensate some degree in dry density.

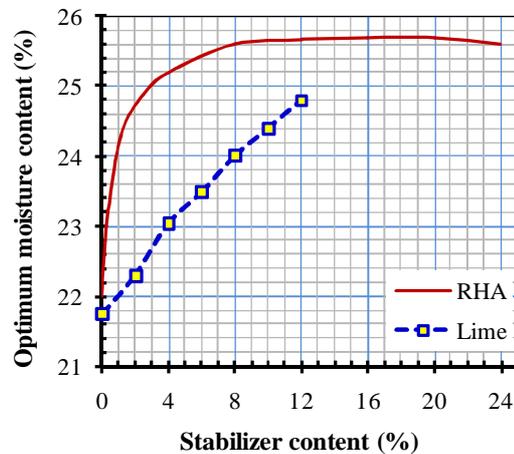
The optimum moisture content (OMC) of the soil increases with increase in stabilizer contents. The rate of change in OMC is higher for RHA. This increase in OMC is due to the pozzolanic reaction of the stabilizer with the soil constituents which tends to increase moisture contents.

Table 4 Effect of stabilizers on compaction characteristics of lateritic soil

RHA %	$Y_{d(max)}$ Mg/m ³	OMC %	Lime %	$Y_{d(max)}$ Mg/m ³	OMC %
0	1.563	22.00	0	1.560	21.75
4	1.490	25.20	2	1.540	22.30
8	1.440	25.60	4	1.520	23.04
12	1.410	25.67	6	1.505	23.50
16	1.390	25.70	8	1.490	24.02
20	1.385	25.70	10	1.480	24.40
24	1.386	25.60	12	1.475	24.80



(a)



(b)

Fig. 3 Variation of (a) maximum dry density and (b) optimum moisture content of lateritic soil with stabilizer contents

Unconfined Compressive Strength (UCS)

Summary of UC strengths of stabilized lateritic soils are shown in Table 5. The nature of changes in UC strengths with increase in stabilizer contents are also presented in Fig. 4. UC strength increases almost linearly with increase in RHA up to 20% ash contents. Maximum UC strength of 416 kPa is attained at 20% RHA content after that it starts to decrease.

UC strength of lime-stabilized soils also increases almost linearly up to 4% lime. After addition of 4% lime, UC strength becomes constant. Maximum UC strengths of lime stabilized soils are 601.2 and 749 kPa for 1-day and 7-day cured specimens respectively. The increase in UC strength is higher for lime compared to RHA. UC strength test results give the evidence of considerable improvement of RHA and lime stabilized soils.

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Table 5 Effect of stabilizers on unconfined compressive strength (UCS) of lateritic soil

RHA	UCS 1-day cured	Lime	UCS	
			1-day cured	7-day cured
%	kPa	%	kPa	kPa
0	211.2	0	210.7	211.0
4	217.0	2	314.1	513.5
8	250.2	4	601.2	749.0
12	303.2	6	578.8	742.6
16	371.6	8	563.6	727.0
20	416.0	10	567.2	716.0
24	348.5	12	577.6	732.3

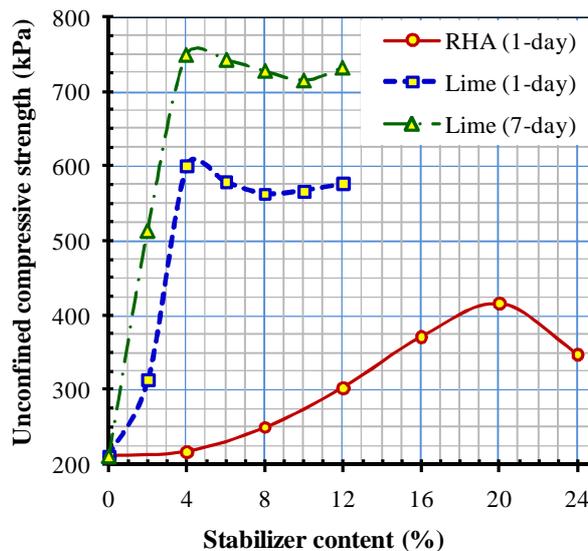


Fig. 4 Variation of unconfined compressive strength of lateritic soil with stabilizer contents

CBR Tests

Results of CBR tests on lateritic soils stabilized with various percentages of RHA and lime are shown in Table 6. The trend of changes in CBR value is also presented in Fig. 5. The CBR value increases with increase in RHA contents. This increase is almost linear up to 17% ash. After reaching 17%, CBR value starts to decrease. Maximum CBR value of 77% is attained approximately at 17% RHA contents. CBR value also increases with increase in lime contents. This increase is almost linear up to 4% lime. Maximum CBR value of 59.4% is obtained at 4% lime and after reaching 4% it starts to decrease. Results of CBR tests show that the considerable improvement of lateritic soil has taken place when stabilized with RHA and lime.

CBR is a means of classification the suitability of a soil for use as a subgrade, sub-base or base material in highway construction. It was developed by the California Division of Highway Department in 1929.

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Table 6 Effect of stabilizers on California bearing ratio (CBR) of lateritic soil

RHA %	CBR %	Lime %	CBR %
0	7.73	0	9.7
4	11.96	2	25.5
8	22.03	4	59.4
12	44.82	6	59.4
16	76.02	8	46.6
20	77.68	10	35.9
24	–	12	34.0

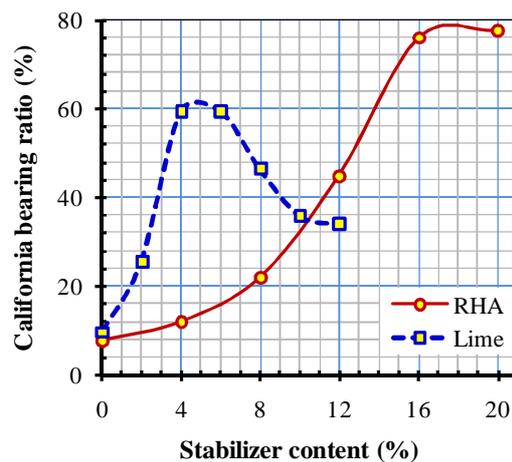


Fig. 5 Variation of California bearing ratio of lateritic soil with stabilizer contents

VIII. CONCLUSIONS

Based on laboratory tests conducted on lateritic soil with various percentages of RHA and lime, the following conclusions can be drawn:

Atterberg limits

The plasticity index of lateritic soil decreases with the addition of RHA and lime. This decrease in the plasticity index of lateritic soil indicates the improvement of the soil.

Unconfined Compressive Strength (UCS)

UC strength of lateritic soil increases with the addition of RHA and lime. Optimum percentage of RHA which gives the maximum compressive strength of 416 kPa for 1-day air cured specimen is 17. Optimum percentage of lime is 4 which yields the maximum compressive strengths of 601.2 and 749 kPa for 1-day and 7-day air cured specimens respectively. Increase in compressive strength of lateritic soil is an evidence of the improvement of soil.

CBR Value

Optimum percentages of RHA and lime at which maximum CBR could be obtained are determined as 17 and 4 respectively. Maximum CBR value for RHA and lime are 77 and 59.4% respectively. This increase in CBR value shows the improvement of the lateritic soil.

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To find the suitability of any type soil for use as a subgrade, sub-base or base material in highway construction, the parameter normally used is CBR value.

Based upon CBR value:

- a) The investigated lateritic soil can be stabilized with 4% lime for sub-base materials.
- b) The lateritic soil can be used as sub-base materials, if it is stabilized with 17% RHA.

Since RHA and lateritic soils are abundant supply all over the tropical and sub-tropical countries of the world, RHA can be potentially utilized as a substitute for lime and cement in order to reduce the construction cost, particularly in the rural areas of the less-developed countries.

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