02 May 2013, 4:00 pm - 6:00 pm

Evaluation of Strength of Clayey Soil by UCS Test with Addition of Rice Husk Ash and Lime

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ABSTRACT

The present study investigates the benefits of using rice husk ash (RHA) with clayey soil as the subgrade material in flexible pavements with addition of small amount of lime. Four ratios of RHA of 5%, 10%, 15% and 20% mixed with the clayey soil by weight of soil sample. Further for getting the better performance, lime has been added in this study in the varying proportions from 1% to 3% by weight of soil. The compaction characteristics and unconfined compressive strength tests were conducted on these different mixed soils. The test results shows that the rice husk ash can be used advantageously with addition of clayey soil and lime as cost effective mix for construction of subgrade of the roadway pavement.

INTRODUCTION

Rural roads connectivity is one the key components for rural development, as it elevates the access to economic and social services, generating increased agricultural income as well as employment. While constructing such roads, the provisions based on the parameters that affect the sustainability are to be made, but at minimum cost. However such cost becomes higher for construction of roadway pavement due to non-availability of conventional filling materials because variety of reasons e.g. land acquisition problem, densely population area etc. On the other hand, large amount of waste materials produced annually throughout the world due to rapid economic growth and industrialization, creates a tremendous threat to public health and ecology. So utilizing some of these wastes as alternative materials for construction of road, no doubt, is a gainful solution. However, prior to adoption of such materials in practice, systematic experimentation is needed to seek their suitability. By considering this situation, a large number of investigators made their investigations in this field over last few decades. Bhasin et al. (1985) reported the improvement in the soaked CBR of soil on addition of rich husk ash and lime sludge and further extended their investigation on stabilization of black cotton soil by using RHA with or without lime. Emhammed *et al.* (2003) studied the chemical stabilization of soil by using cement and rice husk ash to reduce the plasticity of soil and also to decrease the maximum dry density with increasing moisture content. Ali et al. (2004) carried out an investigation on the influence of RHA and lime on Atterberg limits, strength, compaction, and swell and consolidation properties of bentonite. An experimental study has been done for determining the stabilizing effect on clayey soil by using rice husk ash from rice mill and lime sludge from a paper factory (Chandra et al. 2005). Properties of poor clayey subgrade soil can be improved with the use of additives like rock floor, flyash and lime (Wagh, 2006) and this treatment results in higher CBR value. Ravi Shankar et al. (2008) made a study to modify the characteristics of lateritic soil with addition of pond ash and cement. Hossain *et al.* (1991) conducted a study to examine the characteristics of alluvial silty soils with ordinary Portland cement and Portland cement-rice husk ash blend to assess their applicability for low volume road construction. So by considering this aspect, an exhaustive programme was undertaken at Bengal Engineering and Science University, Shibpur by the author to study possible uses of rice husk ash for stabilizing the clayey soil in the construction of subgrade of flexible pavement, by adding lime in small percentage, and also to evaluate the cost-effective mixing proportion and the results of those tests are reported in this paper.

EXPERIMENTAL PROGRAM

Different geotechnical characteristics were determined by carrying out laboratory tests as per Bureau of Indian Standard (BIS) procedures.

Test Materials

Investigation involves use in different ratios of rice husk ash (RHA) and lime in soil and studies their effects on different characteristics of the improved mix. The properties of materials are described below.

Soil: Soil used in this study is alluvial soil of blackish gray clayey silt, collected from shallow depth from the nearby field of Bengal Engineering and Science University, Shibpur campus, W.B. in India. Evaluated properties for the soil are:

L.L.= 59.0 %
P.L.= 35.0 %
P.I. =24.0 %

Based on liquid limit and plasticity index the soil may be classified as "CH"

Light compaction results shows that maximum Proctor's density and Optimum moisture content are1.57 g/cc and 20.0% respectively and Specific gravity is 2.65.

From the grain size distribution analysis, it was found that the soil gradation consists of 8.0% Sand, 55.0%Silt and 37.0% Clay.

Bearing power of this soil in terms of California Bearing Ratio (CBR) indicated unsoaked and soaked CBR are 8% and 3% respectively.

Rice husk ash: Rice is one of the most cultivated and consumed cereal in the world. The processing of rice is characterized by the removal of its husk known as 'rice husk', which does not degrade easily and whose storage is a threat to the environment and land use. The husk surrounding the kernel of rice accounts for approximately 20% by weight of the harvested grain (paddy) (Mahin, 1990). Annual production of rice husk in India is about 22.31 million tons and study indicates that one ton of paddy produces about 250 kg of rice husk (Chandra *et. al.,* 2005). After burning such rice husk in a boiler or in open fire, the ash is produced as by product known as Rice husk ash. It is a predominantly siliceous material annually generated about 4.73 million tones (Chandra et al. 2005). But rice husk ash used in the present study was obtained from local rice mill at Burdwan. Specific gravity of rice husk ash is 1.95

Maximum Proctor's density and Optimum moisture content in light compaction was observed to be0.93 g/cc and 29% respectively. Grain size distribution indicated as following:- Sand size particles = 72.0%, Silt size particle = 28.0%, and bearing power of RHA in terms of California Bearing Ratio (CBR) in soaked condition is 13.72%.

The chemical analysis shows that the major constituents of Rice husk ash as 67.30% of SiO_2, 4.90% of Al_2O_3, 0.95% of Fe_2O_3, 1.36% of CaO, 1.81% of MgO, 17.78% of Loss of Ignition (Oyetola & Abdullahi, 2006).

Lime: Lime has been collected from the nearby market at Howrah, West Bengal, India and tested in the laboratory of the Department of Chemistry, Bengal Engineering and Science University, Shibpur. The constituents of lime by weight were 1.85% of SiO_2, 0.31% of Al_2O_3, 0.14% of Fe_2O_3, 55.48% of CaO, 0.10% of MgO, 0.15% of Na_2O, 0.43% of K_2O and 41.23% of LOI.

Proportions of Materials

To examine the effect of mixing rice husk ash (RHA) as admixture with the soil to be used as materials for construction of subgrade for roads, RHA was mixed with the soil in various proportions of 5%, 10%, 15% and 20% respectively, by weight of soil sample. Further for getting the better performance of lime, the same has been added with the mixed soil in the study in the varying ratio from 0% to 3% by weight of soil to make an attempt to use them in the cost effective mix in the construction of flexible road pavement. All the mixing proportion has been shown in the Table 1

Table 1 Details of mixing proportion of Rice husk ash (RHA) and lime with soil

Mix. No	Soil (%)	RHA (%)	Lime (%)
1	100	0	0
2	100	5	0
3	100	10	0
4	100	15	0
5	100	20	0
6	100	0	1
7	100	5	1
8	100	10	1
9	100	15	1
10	100	20	1
11	100	0	2
12	100	5	2
13	100	10	2
14	100	15	2
15	100	20	2
16	100	0	3
17	100	5	3
18	100	10	3
19	100	15	3
20	100	20	3

TEST RESULTS AND DISCUSSION

The experimental results of compaction tests and unconfined compressive strength (UCS) tests are presented in this section.

Compaction Characteristics

The effect of adding lime in varying percentage from 0% to 3%, on the maximum dry density and optimum moisture content of the soils mixed with rice husk ash in increasing proportion from 0% to 20% are plotted in Figures 1 and 2 respectively.

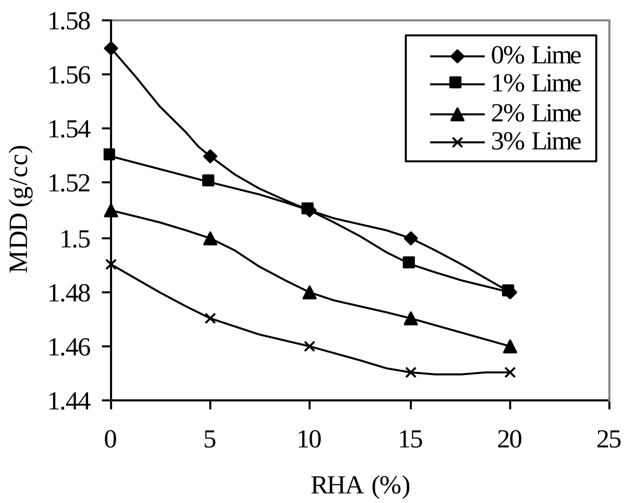

Fig. 1. Variation of MDD of Rice husk ash mixed with alluvial soil with varying percentage of Lime

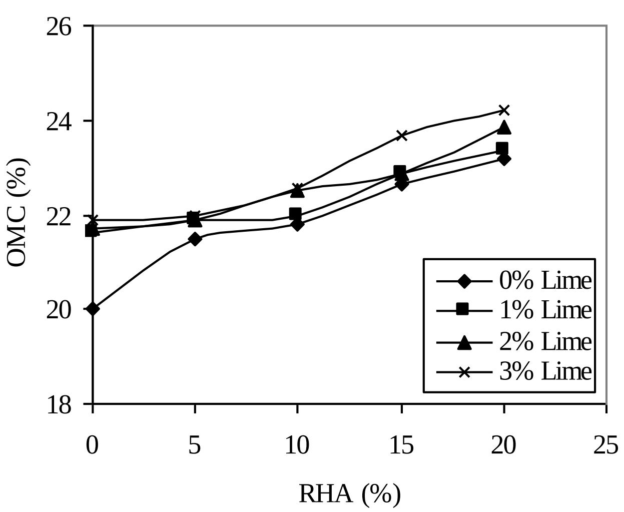

Fig. 2. Variation of OMC of Rice husk ash mixed alluvial soil with varying percentage of Lime

From the Figs. 1 and 2, it is observed that addition of varying proportions of rice husk ash and lime have considerable effect on the maximum dry density (MDD) and optimum moisture content (OMC) of the clayey soil. Maximum dry density of tested soil is 1.57 g/cc and however with the increasing proportion of RHA from 0% to 20%, this value decreases gradually and become to 1.48 g/cc for mixing of 20% RHA with the tested soil without mixing any lime. The decreasing value of MDD with increasing percentage of rice husk ash to the soil is expected as rice husk ash itself has a low value of MDD (0.93 g/cc).

Further for addition of lime with the soil in increasing percentage from 1% to 3%, maximum dry density decreases compared to that of the virgin soil and becomes 1.53 g/cc, 1.51g/cc and 1.49 g/cc respectively without addition of any RHA. However addition of RHA in increasing amount from 5% to 20%, these values decrease gradually again for added proportion of lime from 1% to 3% in all the cases of mixed soils and become as 1.48 g/cc, 1.46 g/cc and 1.45 g/cc for increasing amount of lime as 1%, 2% and 3% respectively with soil and 20% RHA. This reduction in MDD may be due to the elimination of gaseous material formed during the chemical reaction among the lime, RHA and soil as well as may be due to the change in the gradation of the mix.

But the opposite trend is observed in optimum moisture content (OMC) as shown in the Figure 2. This figure indicated that addition of RHA in increasing percentage increases OMC gradually compared to that of the virgin soil and found to be 21.50%, 21.80%, 22.65% and 23.20% for addition of 5%, 10%, 15% and 20% RHA respectively without mixing of any lime, where the optimum moisture content of tested soil is 20%. Further for mixing of lime in increasing ratio from 1% to 3% with the RHA added soil, these values increase gradually in all the cases for added proportion of lime. This increment possibly be occurred due to higher demand of water due to occurring the chemical reaction among the lime, RHA and soil.

Strength Characteristics

The unconfined compression test is a special case of the triaxial compression test in which axial compressive stress only is applied to the cylindrical specimen. In the case of unconfined compressive strength (UCS) tests, size of samples was 3.8 cm in diameter and 7.6 cm in height i.e. height to diameter ratio of 2 are normally used. The sample fails either by shearing on an inclined plane or by bulging.

Now for determining the quantitative information about the strength properties of the mixed soil in terms of UCS, having different varying percentages of rice husk ash from 5 to 20% were mixed with soil and UCS tests were conducted on various mixes. Further for knowing the performance of lime on the RHA mixed soil, the said tests were done on the mixed soil with addition of lime as shown in the Table 1. All the tests were conducted as per the standard procedure laid down in the relevant BIS codes. Laboratory test results of different mixes of soil are shown in Figure 3.

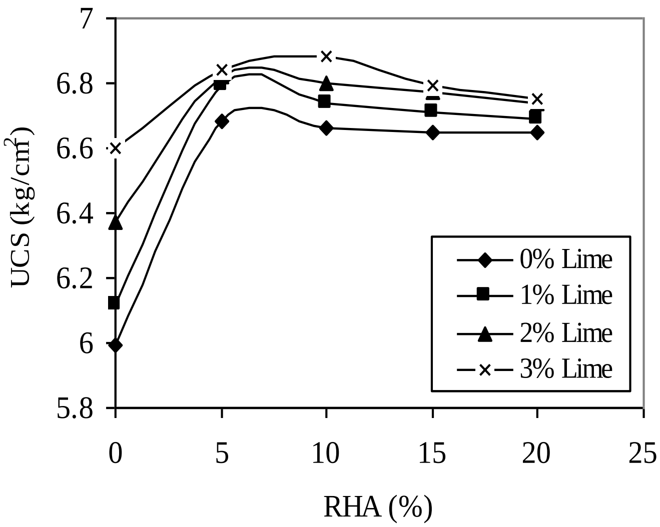

Fig. 3. Variation of unconfined compressive strength of RHA mixed alluvial soil with varying percentage of Lime

The UCS results indicated that the unconfined compressive strength of the tested soil is 5.99 kg/cm^2, but with the increasing proportions of rice husk ash, this value increases gradually and for mixing of 5% RHA with soil, the said value becomes 6.68 kg/cm^2. However further increment of RHA, this value decreasing gradually with small variation and for addition of 20% RHA, this value remains as 6.65 kg/cm^2 without mixing of any lime.

Further mixing of lime with the soil in increasing percentage from 1% to 3%, the UCS values increase to that of the virgin soil and becomes 6.12 kg/cm^2, 6.37 kg/cm^2 and 6.60 kg/cm^2 respectively without addition of any RHA.

However addition of RHA in upto 5%, these values increase gradually for the added proportion of lime from 1% to 3% in all the cases of mixed soils and become as 6.79 kg/cm^2, 6.82 kg/cm^2 and 6.84 kg/cm^2 respectively for increasing amount of lime as 1%, 2% and 3% respectively. But further mixing of RHA in increasing quantity, these values decrease gradually for the added proportion of lime from 1% to 3% in all the cases, except 10% RHA when mixed with the tested soil and 3% lime and this value increases to 6.88 kg/cm^2 and this value indicated the highest amount among all the mixes as shown in the Table 1.

<u>Influence of Curing Period</u>

To study the influence of the curing period on the UCS of tested soil stabilized with lime and RHA, the specimens were kept in the desiccators for 28 days. Thereafter UCS tests were conducted on these cured samples and results shown in the Figure 4.

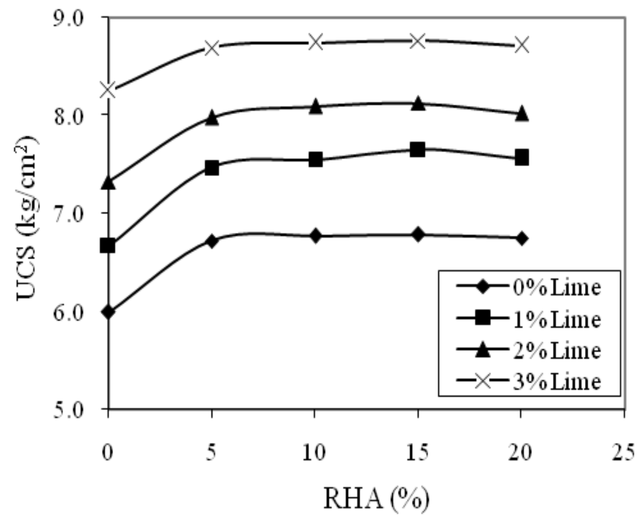

Fig. 4. Curing Effect on unconfined compressive strength of RHA mixed alluvial soil with varying percentage of Lime

Figure 4 shows that the values of unconfined compressive strength of tested soil stabilized with varying proportion of lime and RHA increases with increase in curing period for each lime content and such increment is nearly 30% more for addition of lime and RHA @ 3% and 15% respectively with the tested soil at 28 days curing period. This enhancement of unconfined compressive strength is may be due to the formation of pozolanic reaction products i.e., active participation of lime and RHA added to alluvial soil.

CONCLUSION

From this experimental study, the following conclusions can be made:

i) Utilization of waste materials like rice husk ash in bulk quantity in the construction of subgrade/embankment for road project can reduce the accumulation hazard and environmental pollution.

ii) Addition of rice husk ash and lime in increasing proportion with the alluvial soil decreases the maximum dry density of the mixed soil. However the optimum moisture content of the mixed soil increases gradually with the increased percentage of rice husk ash and lime due to higher demand of water of rice hush ash for achieving maximum density compared to the virgin soil and as well as chemical reaction among these materials.

iii) The unconfined compressive strength increases gradually for addition of increasing amount of lime with the alluvial soil. Further mixing of rice husk ash upto 5% with clayey soil and with the increasing amount of lime upto 3%, this value increases again. However significant increment in the UCS value has been observed when 10% rice husk ash added with soil and 3% of lime and this value become as 15% more than the corresponding value of the virgin alluvial soil. So this mixed soil can be used as construction of subgrade of roadway pavement and will act as cost effective mix by reducing the individual layer thickness of pavement.

iv) After curing, the contribution of lime is become more prominent to enhance unconfined compressive strength of tested soil stabilized with varying proportion of lime and RHA.

ACKNOWLEDGEMENT

The cooperation and support of University Grants Commission, New Delhi, India, is gratefully acknowledged.

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