Effect of Rice Husk Ash on the Behaviour of Highly Compressible Clay

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Abstract. This study explores the possibility of using rice husk ash blends for soil improvement. The results of the study show that rice husk ash renders the soil less plastic. The liquid limit, plasticity index and flow index of the rice husk ash – clay blends show a significant decrease with the increase in ash content. The compaction curves tend to shift to the right. The optimum moisture content increases and dry density decreases with the increase in ash content. The addition of rice husk ash not only increases the unconfined compressive strength of the clay soil but also the post peak strength of the blends. An increase of approximately 100 % is observed at 5 % ash addition. The California Bearing Ratio (CBR) of the clay – rice husk ash blend is 37 % more than the untreated soil. The results of the investigation emphasize the benefit of rice husk ash replacement with in-situ soil for improving the geotechnical properties.

Keywords: Rice husk ash, plasticity index, unconfined compressive strength, California bearing ratio.

1 Introduction

A good foundation is necessary is for a stable structure. If the selected site is not suitable for construction by virtue of the poor geotechnical properties of the soil (e.g: soft clay), and if that site cannot be avoided, ground improvement techniques are implemented. The various materials used for ground improvement are, cement, lime, fly ash, bitumen, inorganic ashes of industrial and agricultural products like the ground granulated blast furnace slag (Sharma and Sivapullaiah 2016), ground nut shell ash (Sujatha et al. 2016), etc. Cementitious properties possessed by the materials, helps the soil to gain adequate bearing capacity. The CBR of the soil is 4 to 10 times higher than that of untreated soil, when replaced with 6% lime and treated for two hours (Ankit et. al. 2013). Also, an increase in unconfined compressive strength of 47% is observed when 12% of soil is replaced with rice husk ash (Brooks 2009).

In this study, the soil is replaced with various percentages of rice husk ash (RHA) and the geotechnical properties of soil – RHA blends are investigated. The primary objective of using rice husk ash is due to its abundant availability and immediate need to be disposed with economic value. According to a data given by Ministry of Environment, Forest and Climate Change, 4.65-5.68 million tonnes of RHA (15-18% of rice husk) is generated by India in 2014. Hence, the use of RHA for ground improvement will result in the utilization of large volume of RHA and will enable it to be properly disposed. It is also an economic alternative to traditional admixtures like lime, cement, bitumen, etc. (Brooks 2009; Hussain and Dash, 2015; Qiang and Chen, 2015; Harichane et al., 2018). Rice husk ash is not hazardous in nature and is also easier to handle.

2 Materials and methods

2.1 Materials

Soil. The soil used for the experimental investigations was clay soil extracted from Thirumalaisamudram village, Thanjavur District, Tamil Nadu. The geotechnical properties of the soil are given in Table 1.

Table 1. Geotechnical properties of soil

Geotechnical Property	Value
Specific Gravity (G)	2
Liquid Limit (%)	60
Plastic Limit (%)	20.64
Plasticity Index (%)	39.36
Shrinkage Limit (%)	8.27
Shrinkage Index (%)	12.37
Shrinkage Ratio	2.05
OMC (%)	15
Maximum dry density (kN/m^3)	13.05
Unconfined compressive strength (kPa)	90.59
Undrained cohesion (kPa)	45.29
CBR	3.69

The soil is classified as highly compressible clay according to Indian Standard soil classification system. The unconfined compressive strength of the soil shows that it falls in the moderately stiff consistency when moulded at its optimum moisture content.

Rice Husk Ash (RHA). The rice husk ash is brought from Mannargudi district, Tamil Nadu. The ash is greyish white in colour, and it’s incineration temperature is about 600 degrees Celsius. It has significant silica content, making the ash a good pozzolanic material. The percentage of elements (in oxide form) present in rice husk ash is given in Table 2.

Table 2. Percentage of elements (in oxide form) of RHA

Formula	SiO_2	K_2O	P_2O_5	CaO	Na_2O	SO_3	Cl	Fe_2O_3	Al_2O_3	PbO
Concentration (%)	95.6	1.29	0.85	0.65	0.26	0.14	0.14	0.13	0.12	0.09

2.2 Methods

The obtained soil sample is air dried for 24 hours, followed by oven drying for 24 hours, to prevent higher water absorption. Then, soil samples are blended with rice husk ask in percentages of 2.5%, 5%, 7.5%, 10% and 12.5%. All samples were mixed with the required water content and were sealed in air-tight packs for 24 hours to allow the soil reach equilibrium water content. The experiments were carried as per IS 2720 specifications.

Consistency Limits.

Liquid and plastic limit. The tests are done in accordance to IS 2720 (Part V)-1985. Samples passing through 425 micron are used.

Shrinkage limit. This test is done as prescribed in IS 2720 (Part VI) 1972-78. The sample is mixed with a water content slightly above liquid limit, and oven dried for 24 hours.

Compaction. Standard Proctor Test is done, and in accordance with IS 2720 (Part VII)-1965. The sample is 100 mm in diameter, and 127.3 mm in height. The results obtained in this experiment is vital, as it directly influences CBR value, compressibility, compressive strength, etc.

Unconfined Compressive Strength. The test is done according to the procedure stipulated in IS 2720 (part X)-1991. 300 grams of sample is mixed at OMC, and then kept in a airtight container for 24 hours, for the soil to attain equilibrium moisture content. Then, the soil is moulded to 40 mm in diameter, and 80 mm in height.

California Bearing Ratio. The test is done in accordance to IS 2720 (Part XVI)-1987. Five kilograms of sample is mixed at OMC, and then kept in a airtight container for 24 hours, for the soil to attain equilibrium moisture content. Then, the soil is moulded to 150 mm in diameter, and 175 mm in height.

3 Results and discussion

3.1 Consistency Indices

The addition of rice husk ash to soil decreases the liquid limit to considerable amounts, but increases the plastic limit t of the blends (Fig. 1). Decrease in liquid limit indicates a decrease in the compressibility of the soil. Plasticity index shows a significant reduction indicating the change in plastic behaviour of the soil. Reduction in plasticity index of the soils indicates a better bearing material. The reasons for this trend can be due to the non-plastic nature of rice husk ash and its tendency to form flocs that leads to increase in particle size (Rathan et. al. 2016), decrease in plasticity and high shear strength (Rathan et al. 2016) as a result of the physio-chemical interaction between the charged clay surface and RHA particles (Rathan et al. 2016).These changes lead to a shift in the classification of these soil-RHA blends from high compressible clay to silt (blend) of low compressibility (Fig. 2).

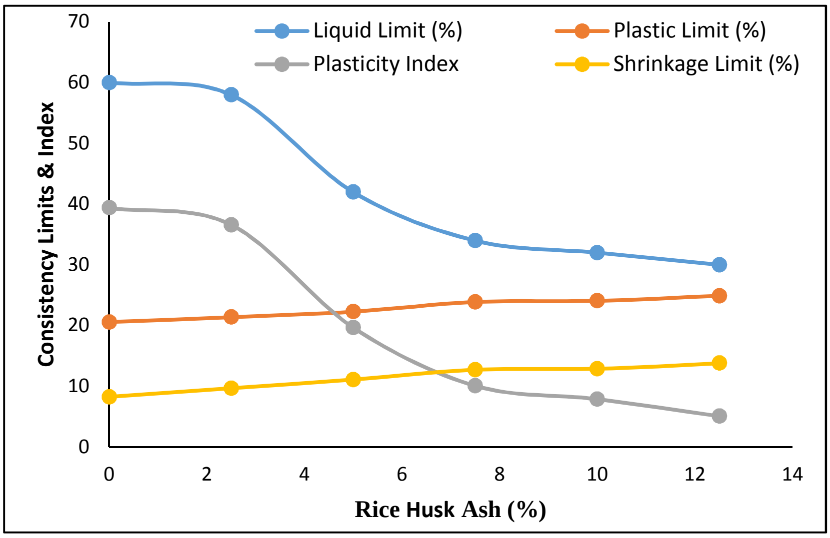

Fig. 1. Effect of Rice Husk Ash on Consistency Limits and Index

The shrinkage limit of the soil increases gradually up to 13.82 % at 12.5 % RHA addition (Fig. 1) indicating that RHA controls the volume change susceptibility of the clay soil. Shrinkage limit of RHA blend shows an increase of nearly 67 % at 12.5 % addition. This again indicates that RHA addition improves the soil as a better bearing medium.

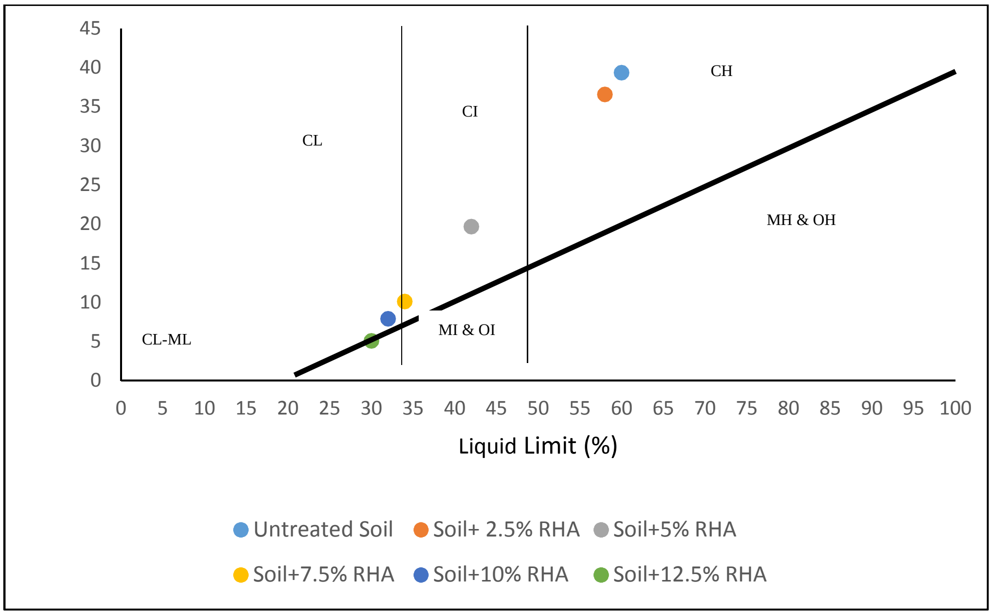

Fig. 2 Effect of Rice Husk Ash on Classification of Soil

3.2 Compaction

The compaction curves are flatter with increase in RHA content and indicates that the soil can be compacted over a range of water contents (Sujatha et al. 2017), thereby reducing the moisture sensitivity. This characteristic can be beneficially applied in the field by compacting the soil on the dry side of optima with higher shear strength and better drainage capacity to an almost equivalent dry density.

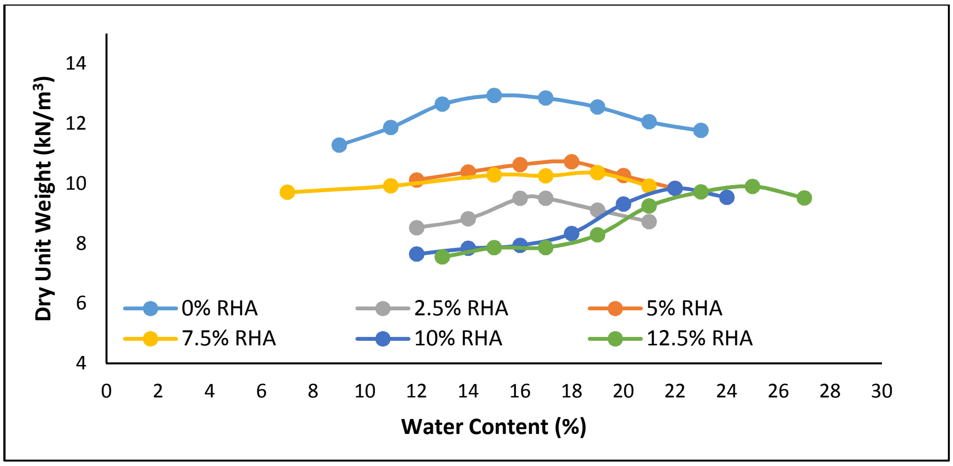

Fig. 3. Compaction curves for different samples

Maximum dry density decreases, and optimum moisture content increases on addition of rice husk ash to the soil (Fig. 4). RHA is lighter than soil particles and when replaced with soil the dry density decreases with the increase in RHA content (Sujatha et al. 2016). The reason for the increase in OMC with increase in RHA content can be attributed to the formation of flocs that increase the void ratio of the soil – RHA blends. These voids entraps water in them increasing its water holding capacity (Harichane et. al. 2018). This is evident from figure 4 which shows an increase in void ratio with increase in RHA content.

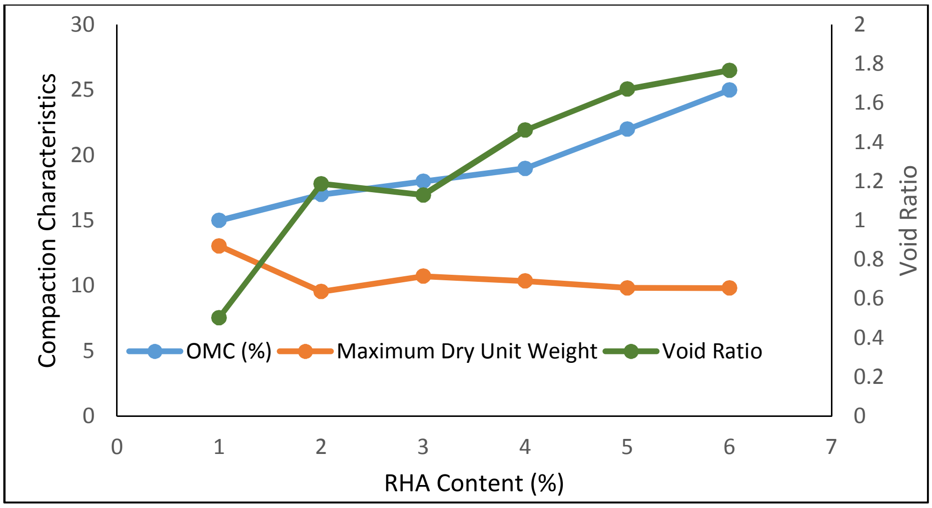

Fig. 4 Variation of Compaction Characteristics with RHA Content

3.3 Unconfined compressive strength (UCC)

Soil samples blended with rice husk ash exhibit a clear peak than that of the untreated soil sample. The failure stress increases up to 5% RHA addition and then decreases, but then, is still higher than that of untreated soil. At 5% RHA, the failure stress is nearly twice than untreated soil. Figure 5 shows the stress -strain behaviour for various soil-RHA blends, and Figure 6 depicts the variation in unconfined compressive strength of the soil-RHA blends.

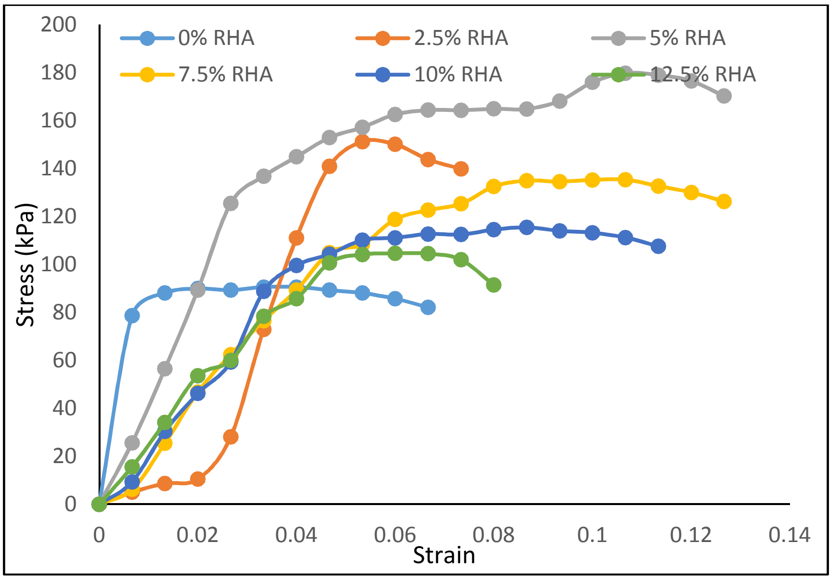

Fig. 5. Stress - Strain curves for various samples

Upon investigating the surface characteristics of rice husk ash, it possesses negative zeta potential, indicating the formation of negatively charged calcium silicate (Gayani et. al. 2014). The increase of UCC is due to the presence of silicon dioxide and calcium oxide in rice husk ash, which reacts in the presence moisture to form calcium silicate, resulting in strong and stable Calcium-Silicon-Oxygen bonding, and thus improving the strength of clay-RHA blends. Also, the reason for the decrease of UCC of successive samples can be attributed to more accumulation of similar charged RHA particles, thus resulting in repulsion.

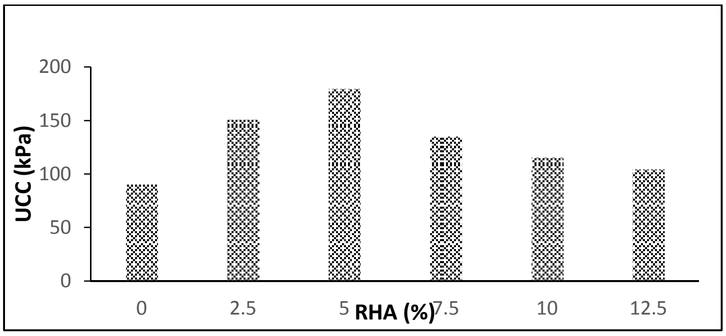

Fig. 6. Variation in UCC for various samples.

3.4 California Bearing Ratio (CBR)

The variation of CBR is quite similar to that of UCC. CBR value increases from the sample untreated soil to 5% soil-RHA blend, and then decreases. The CBR value of 12.5 % soil-RHA blend is less than that of the untreated soil. Table 3 shows the variation of CBR values of various soil – RHA blends.

Table 3. Variation of CBR values of soil-RHA blends

RHA (%)	Soil	2.5	5	7.5	10	12.5
CBR Value	3.83	4.76	5.15	3.96	1.19	1.02

At 5% RHA, CBR value increases by about 37 %, when compared to that of untreated soil. The reason for the increase is due to reaction of high amount of silica in rice husk ash, with calcium to generate pozzolanic materials, which improves the strength of soil-ash blends (Brooks et. al. 2009). Also, the reason for the decrease of CBR value of succeeding samples with RHA content greater than 5 % is due to increasing availability of non-plastic fines, which tends to reduce the bonding between particles, hence the reduction in CBR value is noted.

4. Conclusions

The effects of geotechnical properties on addition of rice husk ash were analyzed, and are as follows. The liquid limit of the soil showed a steep decrease, while the plastic limit showed a marginal increase, on addition of rice husk ash. The shrinkage limit of the soil marginally increases upto sample 7.5 % RHA, and marginally decreases for further addition of RHA. The optimum moisture content increases, and the maximum dry density of the soil decreases, on addition of rice husk ash. The unconfined compressive strength of soil steeply increases at 5 % addition of RHA, and then decreases on increasing the RHA content further. The California Bearing Ratio of the soil increases by nearly 37 % at 5% RHA content. Results indicate that 5 % RHA addition to soil can improve the strength optimally. However, there are some practical hurdles in implementing this method of ground improvement. India is a tropical country, and Tamil Nadu lies on the peninsular region, and is subjective to seasonal winds and monsoons. The optimum moisture content might be lost at hotter temperatures, or the heat of hydration, which brings the strength in soil, might not be sufficient in colder temperatures. Also, people residing nearby construction sites might face dust issues, due to wind. Also, the properties of rice husk ash depend on the incineration temperature and grinding method which is a major limitation. In spite of being an economical ground improvement method, further research is required for it's practical implementations.

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