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Stabilization of Subgrade Clayey Soil using Rice Husk Ash and Plastic Bottles

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Abstract

In developing countries like India the biggest handicap to provide a complete net -work of road system is the limited finances available to build road by the conventional methods. The construction cost can be considerably decreased by selecting local materials including local soils for the construction of the lower layers of the pavement especially the sub-grade. Civil Engineers are in search of new competitive materials, which can be suitable and effectively used to face many challenges that have cropped up with time in the world. In India 20% the land areas is clay soils and are expansive in nature. These lands are found to be expensive for construction as well as maintenance of roads. Rice husk ash (RHA) is a pozzolanic material that could be potentially used in soil stabilization, though it is moderately produced and readily available. Plastic bottles is considered as a waste material which cause environmental issue. This paper compares the strength of clayey soil reinforced with waste plastic bottles and RHA with 0%, 10%, 20% 30%, 40%, 50% by weight of soil. The results indicate that the proposed method is very effective to improve the engineering properties of the clayey soil in terms of index properties, bearing capacity, compressive, and shear strength, which further enhanced the stability.

Keywords: *Engineering properties, Rice husk ash, Soil stabilization, Plastic wastes, Subgrade*

I. INTRODUCTION

Clay is a fine-grained natural rock or soil material that combines one or more clay minerals with traces of metal oxides and organic matter. In clayey soil deposits, the in situ soil may be very weak and indicate a large elastic settlement. Thus, soil improvement could either be by modification or stabilization or both.

Soil modification is the addition of a modifier to a soil to change its index properties, while soil stabilization is the treatment of soils to enable their strength and durability to be improved such that they become totally suitable for construction beyond their original classification. So in this study we use rice husk ash and raw plastic bottle as reinforcement to improve the stability of clayey soil.

The increase in cost of construction material and the scarcity of raw material motivated the researchers and planners to find waste material or substitute material that are environmentally friendly and economically sustainable.

Waste materials such as rice husk ash, blast furnace slag, fly ash, bottom ash, and cement kiln are pozzolanic in nature and reduce the water absorption and bind the clay particles. The soil behaves nonlinearly under cyclic loading such as earthquakes and heavy traffic and its stabilization is very important for the design of civil engineering structures such as embankments, road pavements, and railways.

II. MATERIAL USED

The soil sample collected from Alappuzha. The rice husk ash used in this investigation were supplied by local companies. The chemical and physical properties of RHA are presented in Table 1. In this studies waste plastic water bottles were used. The waste plastic bottle used is of grade1 which represents PET or polyethylene terephthalate. The plastic water bottles were cut to obtain a uniform cylindrical shape of 6 cm height and 3.5 cm diameter.

Table 1: Constituents of RHA

Constituent	%
Silica – SiO_2	90.23
Alumina –Al_2O_3	2.54
Carbon	2.23
Calcium Oxide – CaO	1.58
Magnesium Oxide – MgO	0.53
Potassium Oxide– KaO	0.39
Ferric Oxide – Fe_2O_3	0.21

III. METHODOLOGY

Initially the sample is checked whether it is clayey or not by conducting hydrometric analysis. The tests conducted on the clayey soil samples includes determination of the physical and chemical properties of soils at their natural state and that tests conducted on the clayey soil samples mixed with different percentages of rice husk materials (10%, 20%, 30%, 40%, 50%) includes Atterberg's limits, specific gravity, unconfined compression test and consolidation test.

From the above experimental results optimum percentage of rice husk ash was fixed. Next the CBR value test to determine the strength of clayey soil – RHA mix with raw plastic bottle reinforcement is conducted.

IV. RESULTS AND DISCUSSIONS

A) Hydrometer Test Results

Graph showing the variation of size of particles in a soil sample is shown in fig1.From graph it was noted that the curve comes under particle size less than 0.002mm, hence the sample can be classified as clay.

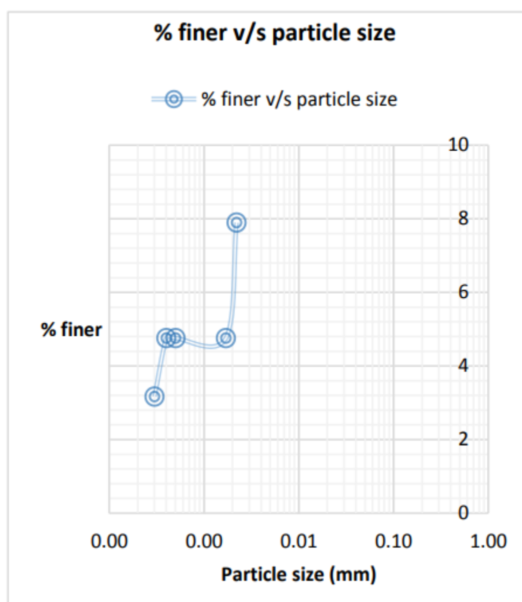

Fig 1: Gradation Curve

B) ***Atterberg's Limits Test***

The results obtained from Atterberg's limit test on virgin clayey soil are shown in table 2

Table 2: Result of Atterberg's Limits on Virgin Clayey Soil

INDEX PROPERTIES	VALUE (%)
Liquid Limit	68
Plastic Limit	35
Plasticity Index	33

Table 3: Variation of Plasticity Characteristics with Various % of RHA

% RHA	LL (%)	PL (%)	PI (%)
0	68	35	33
10	41	14	27
20	40	13.6	26.4
30	31	7	24
40	45	17	28
50	46	17.26	28.74

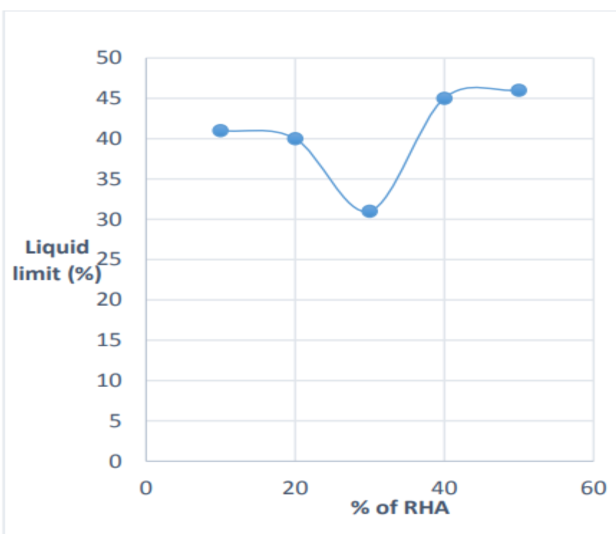

Fig 2: Variation of Liquid Limit for Various % of RHA

From fig 2 it was observed that liquid limit decreases up to 30% of RHA and then an increase is observed for further increase of RHA percentage. The liquid limit of clayey soil is essentially controlled by the thickness diffused double layer and the shearing resistance at particle level. The addition of RHA results in the decrease of liquid limit due to the effect of reduction in the diffused double layer thickness as well as due to the effect of dilution of clay content of the mix.

Fig 3 shows variation of plastic limit of the samples with various percentages of RHA.

It was observed that plastic limit decreases up to 30% of RHA and then an increase is observed for further increase of RHA percentage. This is because of the fact that as the quantity of RHA in the mix increases amount of soil to be flocculated decreases and also the finer particles of RHA may be incorporated in the voids of flocculated soil. This leads to the decrease in the water held in the pores leading to the decrease of the plastic limit.

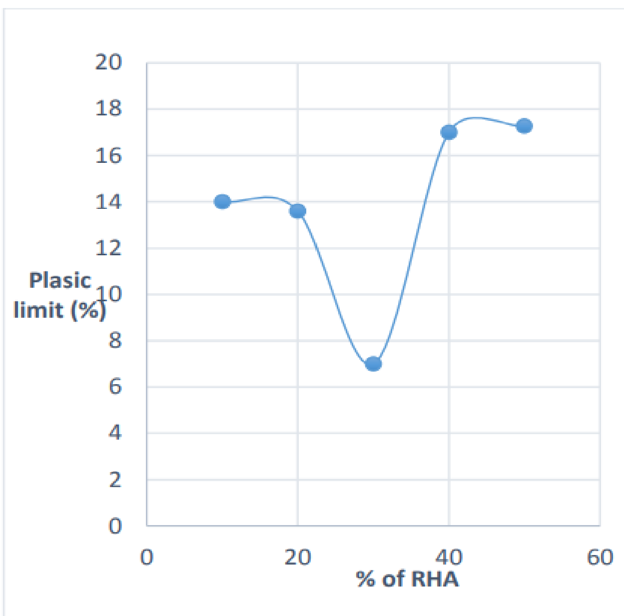

Fig 3: Variation of Plastic Limit for Various % of RHA

From Atterbergs limits test analysis the optimum percentage of RHA to be added is confirmed as 30%.

C) Standard Proctor Test

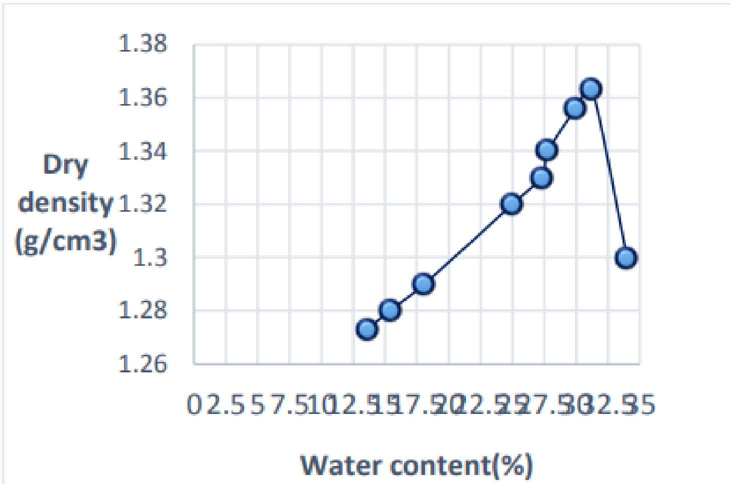

Fig 4: Graph Showing Dry Density V/S Water Content of Virgin Clay

From fig 4 it can be observed that with the increase in water content, the dry density increases up to 31% of moisture content and with further increase in water content, the dry density decreases gradually. The maximum dry density and optimum moisture content obtained were 1.363 g/cc and 31.25% respectively.

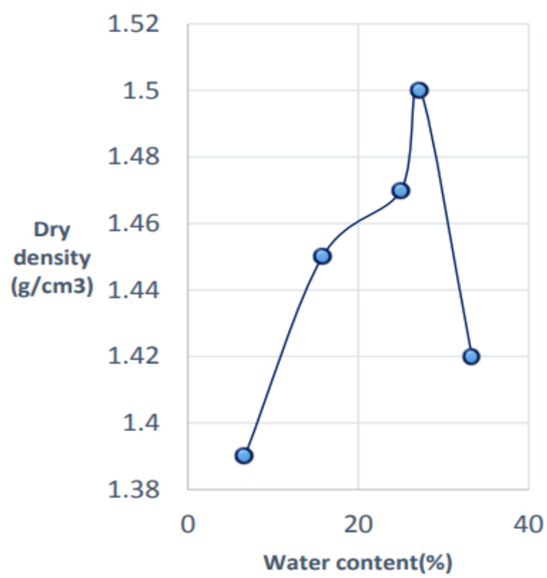

Fig 5: Graph Showing Dry Density V/S Water Content of 30% RHA Mixed Clay

From fig 5 it can be observed that with the increase in water content, the dry density increases up to 27% of moisture content and with further increase in water content, the dry density decreases gradually. The maximum dry density and optimum moisture content obtained were 1.5 g/cc and 27.27% respectively. By comparing the both graphs, it is observed that the dry density of soil stabilized with optimum percentage of RHA increased by 10 % along with a decrease of water content by 15%.

D) Unconfined Compressive Strength

Table 4: Variation of Unconfined Compressive Strength and Shear Strength

%RHA	Unconfined compressive strength(MPa)	Shear strength(MPa)
0	.011	.0055
30	.034	.017

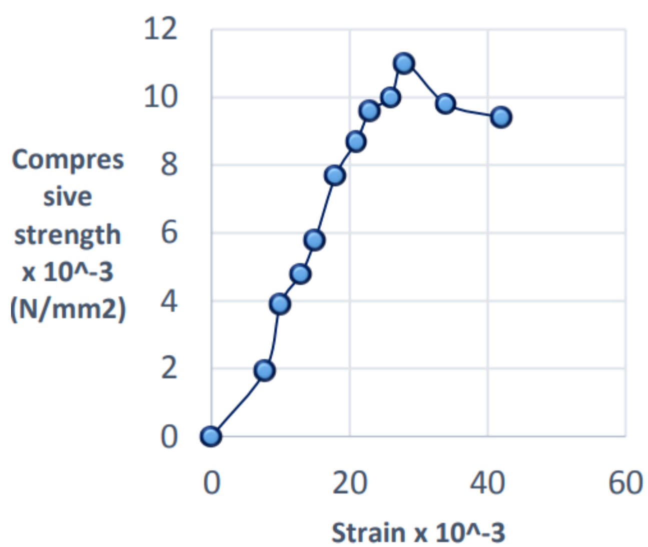

Fig 6: Graph Showing Unconfined Strength for Virgin Clay

From fig 6 it was observed that maximum compressive strength was obtained for a strain of 0.028. The maximum unconfined compressive strength and shear strength obtained were 0.011N/mm2 and 0.0055N/mm2 respectively.

From fig 7 it was observed that maximum compressive strength was obtained for a strain of 0.044. The maximum unconfined compressive strength and shear strength obtained were 0.034N/mm2 and 0.017N/mm2 respectively.

By comparing the both graphs, it was observed that the shear strength of soil stabilized with optimum percentage of RHA increased by 68%.

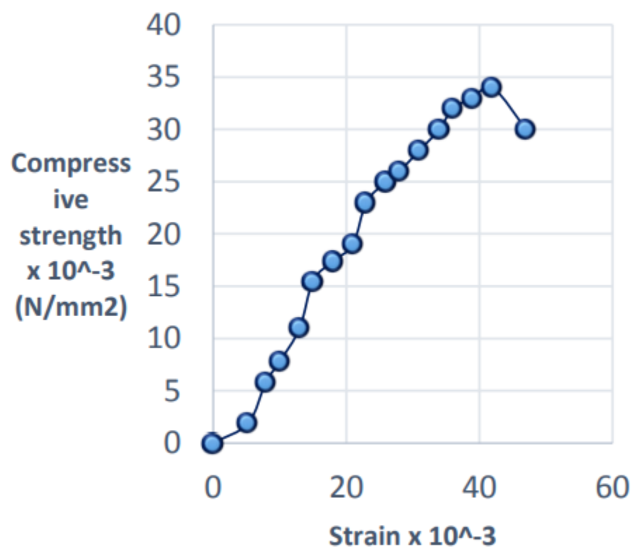

Fig 7: Graph Showing Unconfined Strength of 30% RHA Mix Clay

D) California Bearing Ratio

Table 5 gives the value of CBR for 0% and 30% of RHA. With the addition of RHA there was increase in CBR about twice as that of initial. The low CBR of the virgin clayey soil (as compared to the clay- RHA mix) is attributed to its inherent low strength which is due to the dominance of clay fraction. Addition of RHA to the clayey soil increases gradually the CBR of the mix. This is due to the frictional resistance contributed from the RHA in addition to the cohesion from the clayey soil.

Table 5: Unsoaked CBR Value

% RHA	CBR VALUE (%)	
	2.5 mm PENETRATION	5mm PENETRATION
0	1.65	1.54
30	3.64	3.8

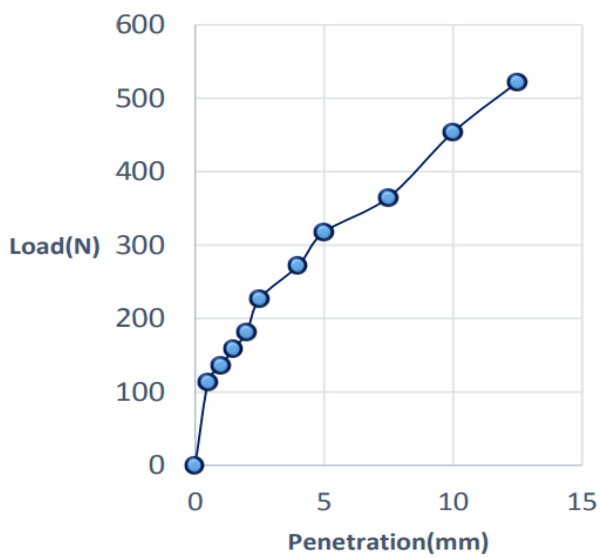

Fig 8: Load v/s Penetration Curve of Virgin Clayey Soil

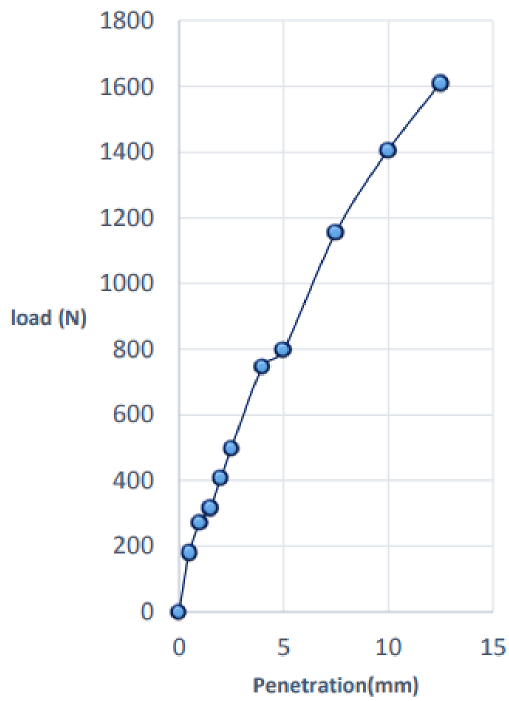

Fig 9: Load v/s Penetration Curve of 30% RHA Mixed Clay

Figures 10-12 shows the CBR value of clayey soil treated with optimum percentages of RHA and reinforcement as plastic bottles at various depth.

Table 6: Variation of CBR Value for Various Positions of Bottle.

POSITION OF bottle in clay + RHA (30%) mix	CBR VALUE(%)	
	2.5 mm PENETRATION	5mm PENETRATION
h/3 mid depth	3.806	4.07
2h/3 depth from bottom	4.96	5.07
h/3 mid depth + sand filling	6.29	7.5

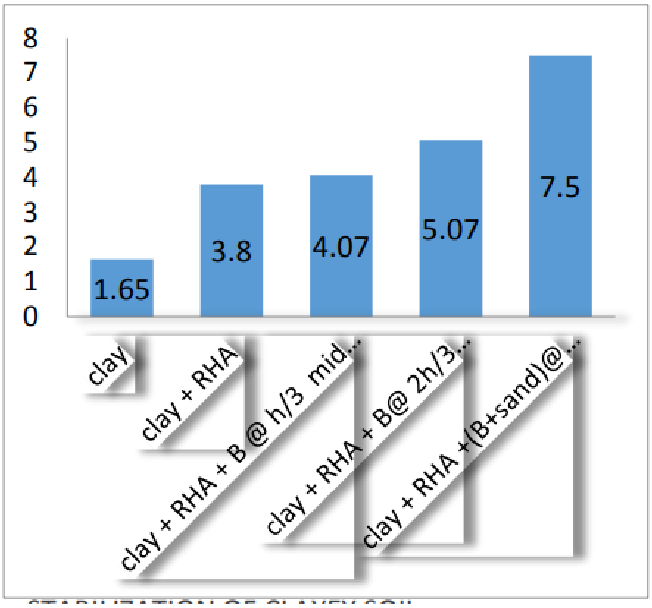

Fig 13: Bar chart showing variation of CBR

Fig 13 shows the variation of CBR value for various position of plastic bottle in optimum RHA-clay mix.

Test Results of Treated Soil Vs Virgin Clay

Table 7: Comparison of Various Test Results

Sl.no	Test conducted	RESULTS	
		Virgin clay	Treated clay
1	Plastic limit	35%	7%
2	Liquid limit	68%	31%
3	Plasticity index	33%	24%
4	Dry density	1.363g/cc	1.5g/cc
5	OMC	31.25%	27.27%
6	UCS	.011 N/mm^2	.034 N/mm^2
7	CBR	1.65%	7.5%

CONCLUSION

Stabilization of clayey soil is very important in pavement construction. From the literature studies it is clear that the RHA and plastic bottle are effective in stabilizing the subgrade soil. The liquid limit and plastic limit of the soil decreases with the addition of RHA which indicates a desirable change as the soil + RHA mix can gain shear strength at an early stage than the virgin soil with the change in the water content. The relative decrease in the plasticity index is another favorable change, since it increases the workability of these soils. Addition of RHA brings in an improvement in the compaction parameters of the clayey soil, by increasing the maximum dry density of soil with decrease in the corresponding values of optimum moisture content. The unconfined compressive strength of the clayey soil increases upon the addition of RHA.

Furthermore, the following conclusions can be drawn from this paper:

- The plasticity of the optimum mix decreases to 30% with the addition of optimum percentage of RHA to virgin clayey soil.
- The liquid limit decreases to 55% while plastic limit decreases to 80% with the addition of optimum percentage of RHA to virgin clayey soil.
- Unconfined compressive strength of clayey soil increases with optimum percentage of RHA to 68%.
- Regarding the strength behaviour, the waste plastic bottle reinforced stabilized soil meet the requirements as subgrade.
- The CBR value of the soil increased up to 2.5 times by mixing with optimum percentage of RHA.
- The CBR value increased considerably up to 3.5 times by placing waste plastic bottle at a height of 2h/3 distance from bottom to the RHA clay mix.

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