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Use of Zycobond in Enhancing The Strength of Expansive Soil Modified With Rice Husk Ash (RHA)

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Abstract. Expansive soil is one such difficult soil that geotechnical engineers find annoying. They absorb water and expand during the monsoon, but they diminish throughout the summer when the water evaporates. Soil stabilization is a technique for improving the geotechnical assets of soil. It allows efficient usage of industrial leftovers as a stabilizer. An attempt is made in this paper, to investigate the impact of industrial waste, Rice husk ash (RHA), and an acrylic polymer, Zycobond on the properties of expansive soil. The proportion of Rice husk ash (RHA) as a replacement was varied from 0% to 20% with an increment of 5% and further Zycobond was added with varying percentages from 0% to 2.0% with an increment of 0.5%. Tests were conducted to assess the properties of expansive soil blended with RHA and Zycobond. The results were analyzed and found that the optimum percentages of RHA were 15% and Zycobond was 1.5% respectively. Further, Static model plate load tests were conducted on only expansive soil and expansive soil blended with RHA and Zycobond. Hence the study yielded a better alternative for improving the expansive soil and effective usage of industrial waste RHA giving us a two-fold advantage.

Keywords: Expansive Soil, Rice Husk Ash (RHA), Zycobond, Stabilization, Model Plate load Test.

1 Introduction

Several Indian states contain large amounts of expansive soils. Expansive soils are popularly known as black cotton soils (BC soils), because of their suitability for growing cotton, covering almost 20% of the geographical land available in India [1]. Expansive soils are prone to large volume fluctuations, particularly when in contact with water, resulting in issues such as excessive settlement and fractures in the underlying structures [2]. To cope with expansive soils, the current method is to change their qualities with additives such as RHA and Zycobond to make them appropriate for the building of overlying structures. The rice husk is a by-product of the rice milling process. Every year, around 100 million tons of the husk are produced worldwide [3]. Various percentages of Rice husk ash were added to expansive soils in the current study, and then the optimum percentage of mix is obtained and combined with chemical named Zycobond is mixed with soil to observe the influence of these mixes was evaluated in terms of plasticity, compaction, swell, and strength properties.

2 Materials used

2.1 Expansive soil

Natural expansive soil was extracted at a depth of 2 m below ground level from the agricultural fields of turupulanka near Amalapuram, East Godavari district, Andhra Pradesh. The soil ranges in color from dark grey to black. The dirt was air dried, crushed by hand, and then passed through a 4.75 mm is sieve. According to IS classification, this soil is an inorganic clay with a high compressibility (CH). Table 1 shows the expansive soil's qualities as determined by relevant I.S. code regulations.

Table 1. Physical Parameters of the Expansive soil

S. No	Property	Value
1	Specific Gravity	2.63
2	Differential Free Swell-DFS (%)	120
	Atterberg Limits	
3	Liquid limit -LL (%)	78
	Plastic limit -PL (%)	33.42
	Plasticity index -I_P (%)	44.58
4	Classification of Soil	CH
	Grain Size Distribution	
5	Gravel (%)	0
	Sand (%)	6
	Silt (%)	25
	Clay (%)	69
	Compaction Properties	
6	Optimum moisture content -OMC (%)	27.24
	Maximum dry density -MDD (g/cc)	1.514
	California Bearing Ratio Values	
7	California bearing ratio -CBR (%)	1.344
	Unconfined Compressive strength of sample prepared at OMC & MDD	
8	Unconfined compressive strength -UCS (kPa)	74

2.2 Rice husk ash

Natural expansive soil was extracted at a depth of 2 m below ground level from the agricultural fields of turupulanka near Amalapuram, East Godavari district, Andhra Pradesh.

Table 2. Physical Properties of RHA

S. No	Property	Value
1	Specific Gravity	2.01
	Grain size analysis	
	% Gravel	0
2	% Sand	26
	% Silt	22
	% Clay	42

Table 3. Chemical Composition of RHA

S. No	Chemical composition	Percentage (%)
1	SiO_2	92.4
2	Al_2O_3	0.06
3	Fe_2O_3	0.07
4	CaO	0.34
5	MgO	0.36
6	K_2O	1.42
7	Na_2O	0.12
8	P_2O_5	0.86
9	Loss in ignition	4.31

2.3 Zycobond

Zycobond is a commercially available chemical stabilizer in the form of a sub-micron acrylics co-polymer emulsion for a life span for soil particle binding. It is purchased from Zydex industries in India Mart website the characteristics of Zycobond are shown in the table below.

Table 4. Chemical Composition of Zycobond

S. No	Component	Concentration (%)
1	Quaternary Ammonium compounds	1-5
2	Methanol	0.1-0.2
3	Acetic acid	0.2-1
4	Acrylic Co polymer	34-36
5	Water	62-65

Table 5. Physical properties of Zycobond

S. No	Physical Property	Value
1	Color	Milky White
2	Odour	No
3	Flashpoint	above 100 ^{0}C
4	Soluble in Water	Dispersible
5	pH value	5-6

2.4 Gravel

It is collected from Surampalem area and the collected soil is air dried for a period of time the air-dried gravel is pulverized and sieved through 4.75mm calculate the physical properties of gravel and required property of gravel is taken for Static Plate Load Test.

Table 6. physical properties of Gravel

S. No	Property	Values
1	Specific Gravity	2.65
2	Grain Size Distribution	
	Gravel (%)	65
	Sand (%)	25
	Silt and Clay (%)	10

3 Sample preparation

The black cotton soil (BCS) and RHA were first oven dried in the laboratory for 24 hours at 105 degrees Celsius. Thereafter, the soil and RHA were crushed and put through a 4.75 mm sieve. By thoroughly mixing RHA into the soil, composite samples of soil-RHA were generated. The proportion of the dry weight of expansive soil in the total dry weight of the composite sample is used to calculate the quantity of RHA in the composite sample. Figure 1 represents the composite mixes utilized in the experiment. Atterberg limits, differential free swell tests, and conventional proctor compaction tests were performed on specimens made with each of these mixes. Furthermore, soaking CBR tests, unconfined compressive strength tests and static plate load tests were performed on specimens compacted to their respective maximum dry density at the appropriate optimal moisture content with each of these mixtures. All tests were performed in accordance with the standard process outlined in the different Indian Standards codes of practice (IS 2720).

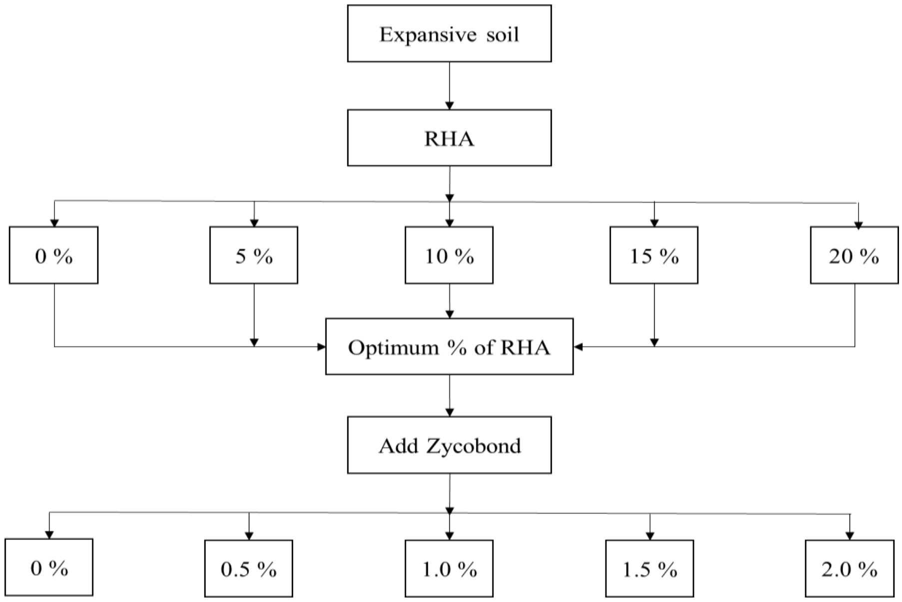

Fig. 1. Flowchart of Experimental proportion of RHA and Zycobond

4 Results and discussion

4.1 Effect of RHA and Zycobond on Differential free swell

Standard procedures recommended in the respective I.S Code of practice [IS: 2720 (Part – 40): 1977 was followed while finding the Differential Free Swell Value for the sample used in the investigation. DFS values decreased continuously upon the addition of RHA and Zycobond as shown in Fig. 2. and Fig. 3. addition of RHA and Zycobond has shown decrement in the value of DFS from 120 % to 31.0 % on the addition of RHA in proportions of 5%, 10%, 15% and 20% and Zycobond in proportions of 0.5%, 1.0%, 1.5% and 2.0%.

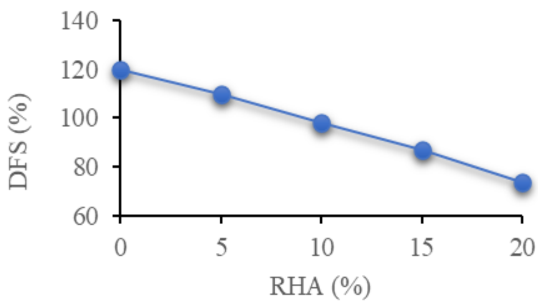

Fig. 2. DFS Values of Expansive Soil with Varying Percentages of RHA

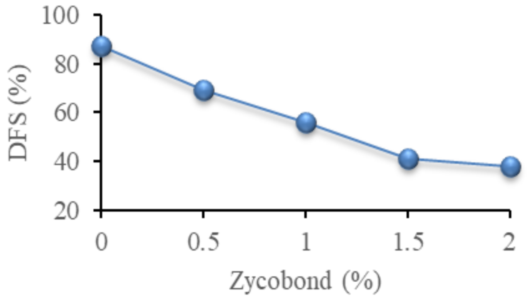

Fig. 3. DFS Values of 85% ES+15% RHA with Varying Percentages of Zycobond

4.2 Effect of RHA and Zycobond on Atterberg limits

The maximum water concentration at which the interaction between clay particle is lost indicates that the liquid limit has been reached. Liquid Limit values were continuously decreasing and plastic limit values were increasing with increasing percentage of RHA which resulting in decreased PI as shown in the Fig. 4. & Fig. 5.

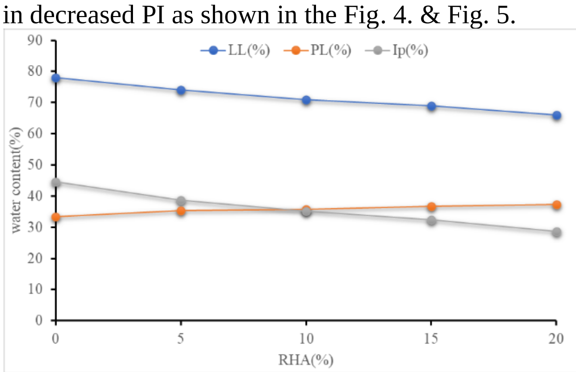

Fig. 4. LL, PL, I_P values of Expansive Soil with Varying Percentages of RHA

The addition of RHA has shown decrement in liquid limit value from 78% to 74%, 71%, 69% and 66% at with 0%, 5%, 10%, 15% and 20% RHA respectively, and the Plastic limit levels have risen from 33.42% to 35.37%, 35.8%, 36.68% and 37.26% for the same percentages of RHA, eventually decreasing the plasticity index values of expansive soil.

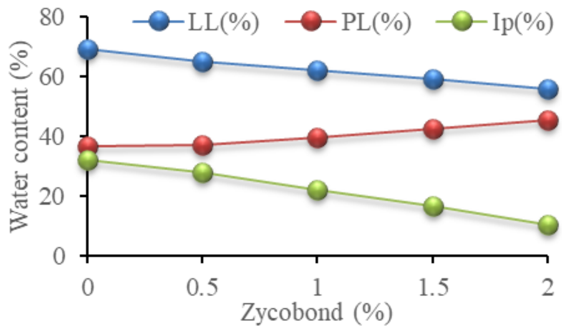

Fig. 5. LL, PL, I_P Values of 85% ES+15% RHA with Varying Percentages of Zycobond

Thereafter addition of 15% RHA with Zycobond in increments of 0.5%, 1%, 1.5%, and 2% have shown decrement in liquid limit value from 69%, 65%, 62%, 59% and 56% respectively, and the plastic limit values increased from 36.68%, 37.13%, 39.79%, 42.45% and 45.38% for the same percentages of Zycobond eventually decreasing the plasticity index values of expansive soil.

4.3 Effect of RHA and Zycobond on Compaction characteristics

Compaction tests were performed using modified proctor compaction apparatus to determine the optimum moisture content and maximum dry density of different proportions of expansive soil blended with different percentages of RHA, with the goal of determining the optimum percentage of RHA of 5%, 10%, 15%, and 20%, respectively, and the results are presented in Fig.6 to Fig.8 Following the determination of the ideal quantity of RHA, Zycobond was combined with 0.5 %, 1 %, 1.5 %, and 2 % of expansive soil – RHA mix to determine the optimal proportion.

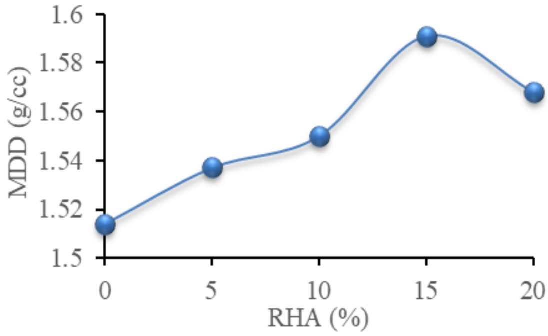

Fig. 6. MDD Values of Expansive Soil mixed Varying Percentages of RHA

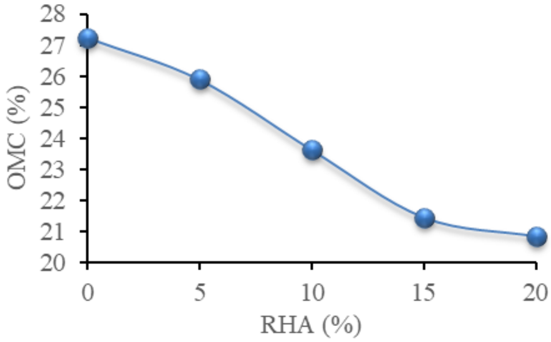

Fig. 7. OMC Values of Expansive Soil mixed Varying Percentages of RHA

From the Fig. 6. and Fig. 7. addition of RHA has shown decrement in OMC Values from 27.24%, 25.89%, 23.62%, 21.44%, 20.83% at 0%, 5%, 10%, 15%, 20% RHA respectively and MDD values increased from 1.514, 1.537, 1.55, 1.591, 1.568 g/cc for the same percentages of RHA.

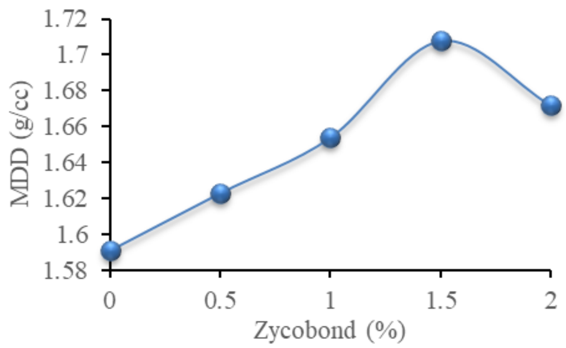

Fig. 8. MDD Values of 85% ES+15% RHA with Varying Percentages of Zycobond

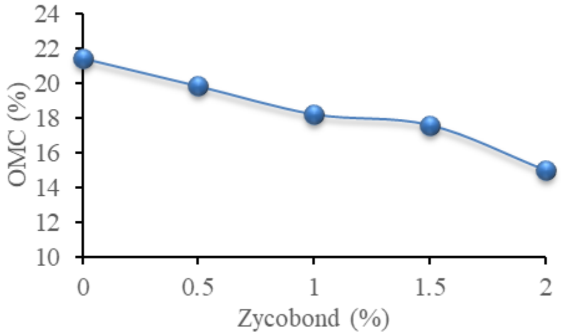

Fig. 9. OMC Values of 85% ES+15% RHA with Varying Percentages of Zycobond

From Fig. 8. and Fig. 9. addition of 15% RHA with Zycobond in increments of 0.5%, 1%, 1.5% and 2% has shown decrement in OMC values from 21.44%, 19.83%, 18.21% 17.59% and14.98% respectively, and MDD values increased from 1.591,1.623,1.654,1.708 and 1.672 g/cc for the same percentages of Zycobond.

4.4 Effect of RHA and Zycobond on CBR characteristics

The CBR curves for different soil and RHA mix proportions are 0 percent, 5%, 10%, 15%, and 20% for soaking CBR graphs for all mixtures and associated values are provided in the fig. 4.10 to 4.11. The compaction test yields the wet CBR values of various combinations of expanding soil, RHA, and Zycobond utilizing OMC. When full saturation is anticipated to occur, the soaked CBR after 4 days in water is calculated.

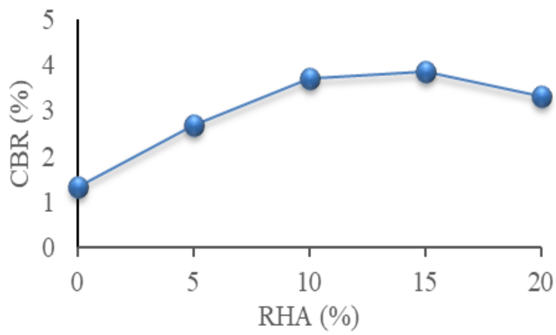

Fig. 10. CBR Values of Expansive Soil with Varying Percentages of RHA

From the Figs. 10, the addition of RHA has shown increment in CBR values from 1.344%, 2.67%, 3.71%, 3.85% and 3.3% at with 0%, 5%, 10%, 15% and 20% RHA respectively. when the %RHA is increasing the density of soil increases upto the optimal % RHA and then decreases due to density of soil decreases.

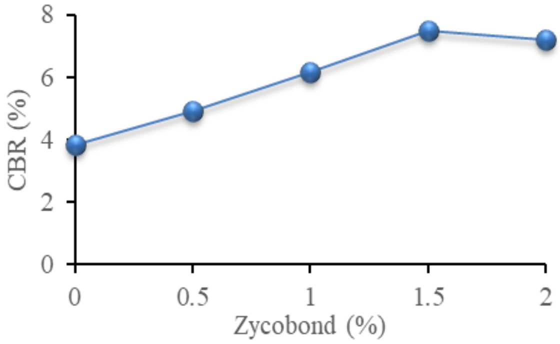

Fig. 11. CBR Values of 85% ES+15% RHA with Varying Percentages of Zycobond

From the Fig. 4.11. the addition of 15% RHA with Zycobond in increments of 0.5%, 1%, 1.5% and 2% has shown increment in CBR values from 4.92%, 6.15%, 7.5% and 7.18% respectively.

4.5 Effect of RHA and Zycobond on UCS characteristics

Unconfined compressive strength is one of the most commonly cited qualities of stabilized soils. The samples were compacted to obtain maximum dry density at optimum water content. The mould is made of steel and has an interior dia of 38 mm and a height of 76mm.

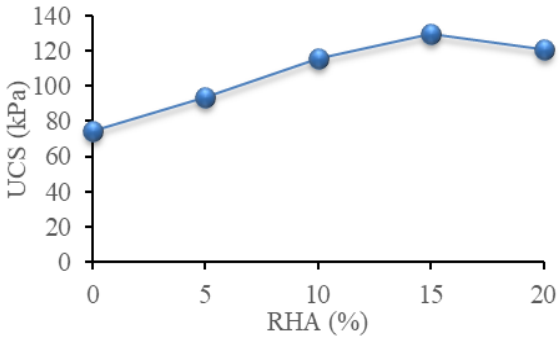

Fig. 12. UCS Values of Expansive Soil with Varying Percentages of RHA

From the Fig. 4.12, the addition of RHA has shown increment in UCS values from 74 to 93.8, 115.4, 129.3, and 120.7 kPa at 0%, 5%, 10%, 15% and 20% RHA respectively.

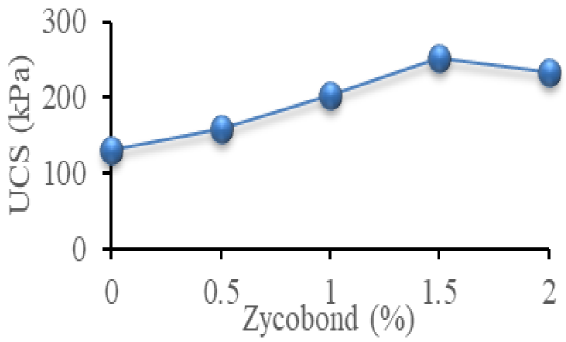

Fig. 13. UCS Values of 85% ES+15% RHA with Varying Percentages of Zycobond

From the Fig. 4.13, the addition of 15% RHA with Zycobond in increments of 0.5%, 1%, 1.5% and 2% has shown increment in UCS values from 157.2, 203.5, 251.8, 233.1 kPa respectively.

4.6 Curing's Effect on the Penetrating Characteristics of Expansive Soil Treated with the Optimal Amounts of RHA and Zycobond (i.e., 85%ES+ 15% RHA + 1.5 % Zycobond)

Table 7 indicate the Curing has an influence on the penetration and strength attributes of expansive soil treated with the optimum blend of RHA and Zycobond. The results demonstrate that after 28 days of curing the treated expansive soil, the CBR value raises to 24.66% and for UCS it raises to 27.4%.

Table 7. CBR and UCS Values of Expansive Soil Cured for Different Time Periods using the Optimal Combination of RHA and Zycobond

S. No	Curing (Days)	CBR (%)	UCS (kPa)
1	0	7.5	251.8
2	7	8.41	286.5
3	14	8.9	311.2
4	28	9.35	320.8

4.7 Effect of RHA and Zycobond on Static Plate Load Tests

The importance of static plate load testing in establishing the ultimate load bearing capability of foundation beds can always be emphasized. Plate load tests on untreated and treated expansive soil beds were performed in the laboratory in accordance with the IS code of practice, i.e., 1888-1982.

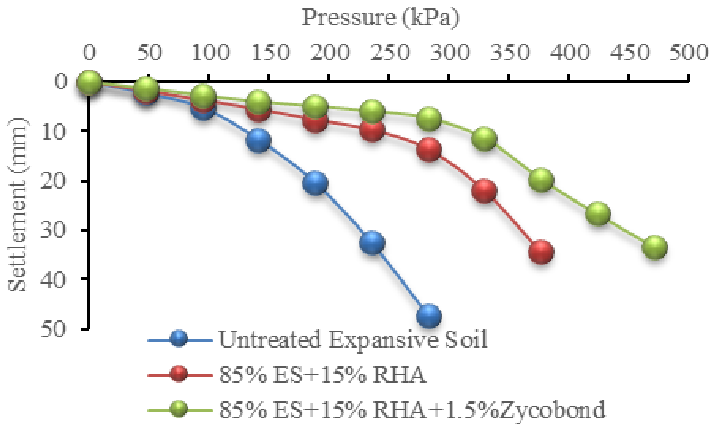

Fig. 14. Static Plate Load Test Results of Untreated and Treated Foundation Beds

According to Fig. 14, the Ultimate static load of Expansive soil, Expansive soil with Optimum percentage of RHA and Expansive soil with Optimal percentages of RHA and Zycobond is 160.53kPa, 263.56kPa and 297.71kPa and settlements for same proportions are 14.97mm, 11.42mm and 8.26mm respectively. These enhancements demonstrate the hardening of the foundation bed.

5 Conclusions

The following conclusions can be drawn from the present study

1. It is evident that Liquid limit value decreased by 24.35 % and Plastic limit value increased by 27.01 % and Plasticity index value decreased by 62.87% on treating with RHA and Zycobond.
2. It is clear that OMC value decreased by 35.42 % and MDD value increased by 12.81 % for the Expansive soil treated with RHA and Zycobond.
3. It is evident that the CBR value improved by 82.08 % of the Expansive soil.
4. It is clear that UCS value improved by 70.61 % of the Expansive soil.
5. The CBR value improves by roughly 24.66 % when treated expansive soil is cured for 28 days. Strength shows a similar rising pattern, with a gain of roughly 27.40 % over the period of 28 days.
6. Overall, it can be concluded that 15% RHA and 1.5% Zycobond stabilized soil can improve the strength characteristics considerably on expansive clay beds.

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