Performance Evaluation of Rice Husk Ash and Phospho Gypsum in Stabilizing the Problematic Expansive Soil

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Abstract. Various remedial measures adopted to overcome the problems posed by expansive soils like soil replacement, moisture control, pre-wetting, lime stabilization have been practiced with varying degrees of success. However, these techniques suffer from certain limitations with respect to their adaptability. Stabilization using solid wastes is one of the emerging techniques to improve the engineering properties of expansive soils to make them suitable for use in construction. This paper presents an attempt made to study the influence of two wastes, Rice Husk Ash (RHA), an agro waste and Phospho Gypsum (PG), an industrial waste from fertilizer industry, in different percentages, as stabilizing materials to improve the properties of problematic expansive soil. The percentage of Phospho Gypsum (PG) was varied from 0% to 8% with an increment of 2% in combination with 0%, 5% and 10% percentages of Rice Husk Ash (RHA). Different tests in the laboratory were conducted to evaluate the characteristics of treated expansive soil. The analyzed results clearly depict that the combination of 10% RHA + 6% PG had significantly improved the Soaked CBR value and Unconfined Compressive Strength (UCS) by about 3 times and 96% respectively, when compared to that of virgin expansive soil. The parametric evaluation summarizes that the combined effect of waste materials Phospho Gypsum (PG) and Rice Husk Ash (RHA) had shown promising influence on the strength characteristics of expansive soil, thereby giving a two-fold advantage in improving problematic expansive soil and also solving a problem of waste disposal.

Keywords: Expansive Soil; Rice Husk Ash (RHA); Phospho Gypsum (PG); Stabilization

1 Introduction

Expansive soils were being a tough task for Civil Engineers in the design and construction of Infrastructure projects. The major problems with clays, including low strength and high compressibility, can cause severe damage to civil engineering structures and can lead to very serious economic loss and environmental hazards. Therefore, these soils must be treated before commencing the construction operation to achieve desired properties. This has led to the development of soil stabilization techniques. Since the nature and properties of natural soil vary widely, a suitable stabilization technique has to be adopted for a particular situation after considering the soil properties. The chemical technique is a common soil stabilization approach, since it produces a better quality soil with higher strength and durability than mechanical and physical techniques. Soil stabilization can be explained as the alteration of the soil properties by chemical or physical means in order to enhance the engineering quality of the soil. The main objectives of the soil stabilization are to increase the bearing capacity of the soil, its resistance to weathering process and soil permeability. The long-term performance of any construction project depends on the soundness of the underlying soils. Unstable soils can create significant problems for pavements or structures. Therefore, soil stabilization techniques are necessary to ensure better stability of soil so that it can successfully sustain the load of the superstructure especially in case of soil which are highly active, also it saves a lot of time and millions of money when compared to the method of cutting out and replacing the unstable soil. This paper deals with a parametric study on the influence of an agro-industrial waste, Rice Husk Ash and a fertilizer industrial waste, Phospho Gypsum in stabilizing the problematic expansive soil.

2 Research Background

Expansive soils were being a tough task for Civil Engineers in the design and construction of Infrastructure projects. Therefore, it is important to remove the existing problematic expansive soil and replace it with a non-expansive soil or improve the properties of the problematic soil by stabilization. The road network is planned and developed for fulfilling the requirements of transportation, keeping the total transportation cost in mind. In the process of network development, many a times, the alignment of the road may have to be finalized through the soil sub grades, which may not be suitable to bear the traffic loads with adequate strength (Chandrasekhar et al, 1999). The different techniques in use are chemical additives (cement, lime, salt treatments and organic compounds), pre-wetting, soil replacement, moisture control, surcharge loading and thermal methods (Nelson and Miller, 1992). Every method has got its own merits and demerits including cost factor. Among several techniques adopted to overcome the problems posed by expansive soils, lime stabilization gained prominence during the past few decades due to its abundance and adaptability (Snethan 1979). Chemical additives, such as lime, cement, fly ash, and other chemical compounds have been used in expansive soil stabilization for many years with various degrees of success (Al-Rawas et al, 2002). The recent research in the field of geotechnical engineering and construction materials focuses on agricultural and industrial wastes being locally available and has disposal problem.

Jasvir Singh et al (2017) presented the laboratory study of clayey soil stabilized with fly ash (FA) and rice husk ash (RHA). The soil was stabilized with different percentages of FA (i.e., 0, 8, 14, 18, and 24%) and RHA (i.e., 0, 4, 8 12, 16, and

20%). The Atterberg's limits, specific gravity, California bearing ratio, and unconfined compressive strength tests were performed on raw and stabilized soils. Results indicated that addition of FA and RHA reduces the plasticity index (PI) and specific gravity of the soil. It is observed that there is remarkable influence on CBR values of expansive soil at the 8% FA as the replacement and the addition of 12% RHA as an optimum percentage. Dahale et al (2016) had reported the results of laboratory investigation carried out on problematic clayey soil stabilized with fly ash and hydrated lime. Experimental program shown that fly ash alters the strength properties of clayey soils significantly. Up to 50% of fly ash found effective in increasing strength properties and higher doses cause overall strength reduction.

Rathan Raj et al (2016) had used Rice Husk Ash for stabilization of problematic soil, to study the effects of same on the index and engineering characteristics of problematic soil. The rice husk ash is mixed with soil in various proportions like 5%, 10%, 20%, 30%, 40%, 50% and 80%. The various tests were conducted on these proportions and optimized proportion is arrived. The liquid limit and the FSI of the soil decreased steeply with the increase in the % of RHA. The undrained cohesion value of the soil mixed with RHA for clay soil decreased from 60 kN/m^2 to 30 kN/m^2 and angle of internal friction value increased from 17°5' to 38°. The unsoaked CBR value in the case of addition of RHA to clay soil increased from 3.2% to 9.3% and the soaked CBR value 2.4% to 4.4%.

Roshini et al (2015) evaluated the potential of Phosphogypsum (PG) and Wood Ash (WA) to stabilize expansive soil. Results showed that the strength parameters of the soil are improved substantially by the addition of 4% Phosphogypsum (PG) and 12% Wood Ash (WA). CBR and UCS values were increased due to the formation of cementitious compounds as a result of a chemical reaction between Phosphogypsum (PG) and Wood Ash (WA).

The study carried out by Koteswara Rao et al (2011) on the expansive soil with rice husk ash, lime and gypsum resulted in considerable improvement in the strength characteristics of the expansive soil. It was observed that the liquid limit of the expansive soil has been decreased by 22% with the addition of 20% RHA+5% Lime. It is observed that there is remarkable influence on the strength and CBR values of expansive soil at 20% RHA + 5% Lime + 3% Gypsum which is an optimum percentage.

3 Experimental Methodology

Tests were conducted in the laboratory on the expansive soil to study the behaviour of expansive soil, when it is treated with an agro-industrial waste, Rice Husk Ash and a fertilizer industrial waste, Phospho Gypsum. Compaction, California Bearing Ratio and Unconfined Compressive Strength tests were conducted as per IS code of practice.

3.1 Materials Used

The details of the various materials used in the laboratory experimentation are reported in the following sections.

3.1.1. Soil. The soil used was a typical expansive soil collected from Appaniramuni Lanka, Near Dindi village, Sakhinetipalli Mandal, East Godavari district, Andhra Pradesh State, India.

3.1.2 Rice Husk Ash (RHA). For the present study, the Rice Husk Ash (RHA) has been brought from the captive Power Plant of Ms. Lalitha Rice Mill, Peddapuram, East Godavari district, Andhra Pradesh State, India.

3.1.3 Phospho Gypsum (PG). For the present study, the Phospho Gypsum (PG) has been brought from the fertilizer industry Ms. KPR Fertilizers, Balabadhrapuram, East Godavari district, Andhra Pradesh State, India.

3.2 Sample Preparation

The soil was initially air dried, pulverized and then was sieved through a 4.75 mm sieve, prior to the testing. The samples were prepared by mixing the pulverized and sieved soil with the needed stabilizing agents in dry condition and then required amount of water is added to make a consistent mix by thorough mixing. The following table lists the different variables and their respective contents used in the present study.

Table 1. Different Variables Studied

Stabilizing Agent	Percentages Varied
Rice Hush Ash	0, 5, 10
Phospho Gypsum	0, 2, 4, 6, 8

4 Discussion of Results

4.1 General

In the laboratory, various experiments were conducted by blending different percentages of Rice Husk Ash (RHA) and Phospho Gypsum (PG) with the expansive soil. Compaction, CBR and UCS tests were conducted as per IS codes of practice, with a view to determine the optimum combination of Rice Husk Ash (RHA) and Phospho Gypsum (PG) as an addition to problematic expansive soil to improving its properties.

4.2 Combined Effect of Rice Husk Ash (RHA) and Phospho Gypsum (PG) as Additives on the Compaction Properties of Problematic Expansive Soil

The influence of combination of Rice Husk Ash (RHA) and Phospho Gypsum (PG) on the compaction parameters of expansive soil is clearly presented in figures 1 & 2. The percentage of Rice Husk Ash was varied from 0%, to 10% with an increment of 5%. From the figures 1 & 2, it was observed that the treatment as combination with 10% RHA + 6% PG has considerably improved the expansive soil. It can be inferred from the graphs, that there is a gradual improvement in the maximum dry density by about 9.6% when compared to that of virgin expansive soil. Also the corresponding optimum moisture content had shown a reduction by about 14 %.

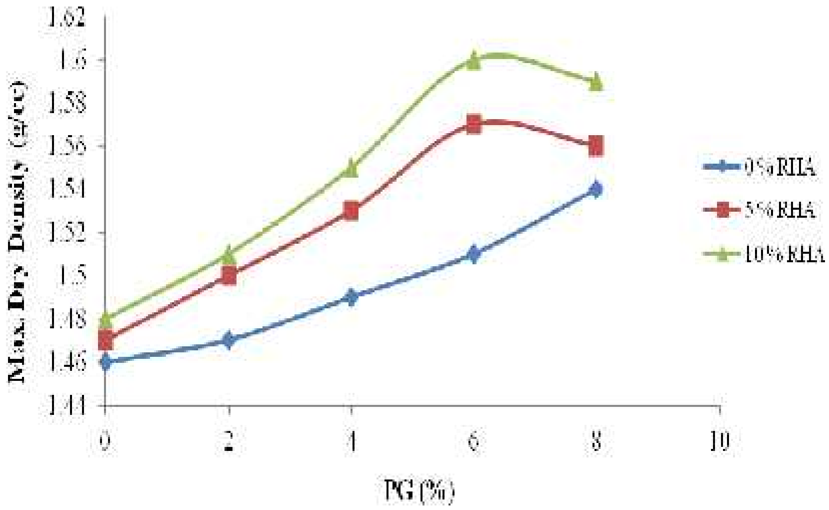

Fig. 1. Plot Showing the Variation of MDD Values with Percentage of PG for Different Percentages of RHA.

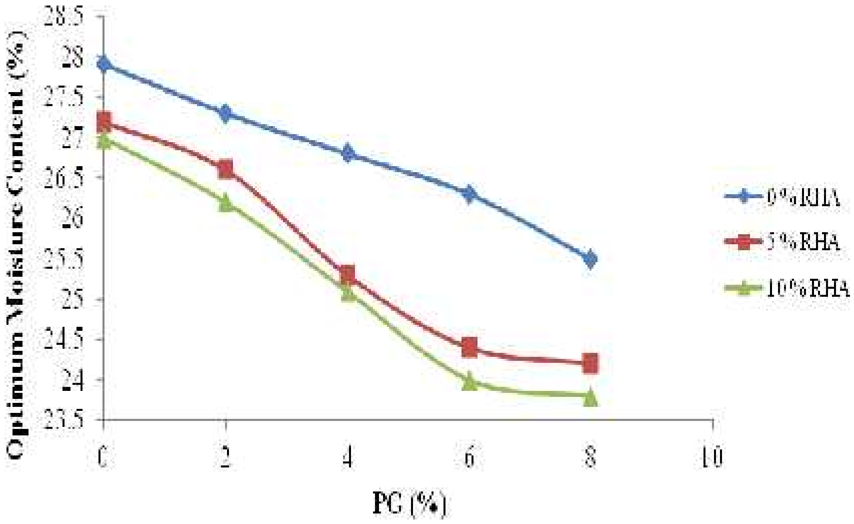

Fig. 2. Plot Showing the Variation of OMC Values with Percentage of PG for Different Percentages of RHA.

4.3 Combined Effect of Rice Husk Ash (RHA) and Phospho Gypsum (PG) as Additives on the Penetration Properties of Problematic Expansive Soil

The influence of combination of Rice Husk Ash (RHA) and Phospho Gypsum (PG) on the CBR values of expansive soil is clearly presented in figures 3 & 4. The percentage of Rice Husk Ash was varied from 0%, to 10% with an increment of 5%. From the figures 3 & 4, it was observed that the treatment as combination with 10% RHA + 6% PG has substantially improved the penetration properties of expansive soil. The graphs depict the improvement in the CBR values both Unsoaked and Soaked by about 155% and 310 respectively, when compared to that of virgin expansive soil.

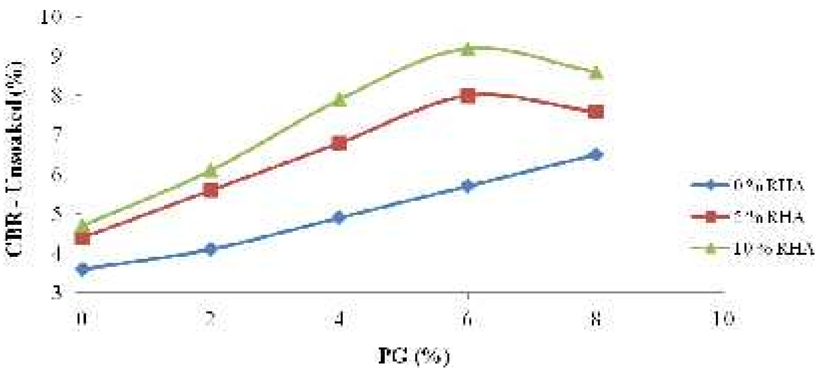

Fig. 3. Plot Showing the Variation of CBR - Unsoaked Values with Percentage of PG for Different Percentages of RHA.

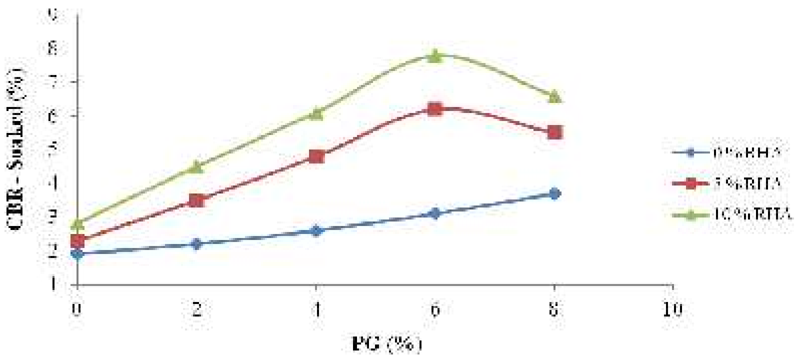

Fig. 4. Plot Showing the Variation of CBR - Soaked Values with Percentage of PG for Different Percentages of RHA.

4.4 Combined Effect of Rice Husk Ash (RHA) and Phospho Gypsum (PG) as Additives on the Unconfined Compressive Strength (UCS) of Problematic Expansive Soil

The influence of combination of Rice Husk Ash (RHA) and Phospho Gypsum (PG) on the Unconfined Compressive Strength (UCS) of expansive soil is clearly presented in figure 5. The percentage of Rice Husk Ash was varied from 0%, to 10% with an increment of 5%. Figure 5 clearly shows that the combination of 10% RHA + 6% PG had significantly improved the Unconfined Compressive Strength (UCS) by about 96%, when compared to that of virgin expansive soil.

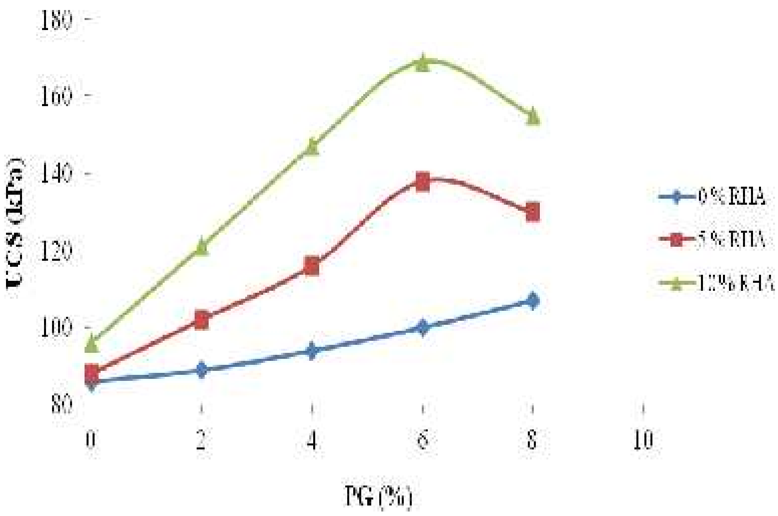

Fig. 5. Plot Showing the Variation of Unconfined Compressive Strength Values with Percentage of PG for Different Percentages of RHA.

4.5 Effect of curing on the Penetration and Strength Properties of Problematic Expansive Soil treated with optimum percentages of RHA and PG

Figures 6 & 7 show the performance impact of curing on the penetration and strength characteristics of expansive soil treated with optimum combination of Rice Husk Ash (RHA) and Phospho Gypsum (PG). Figures 6 and 7, clearly depicts the variation of CBR and UCS values respectively, of expansive soil treated with optimum combination of RHA and PG (i.e. 10% RHA + 6% PG) cured for different time periods. The results ascertain that there is a significant increase in the CBR values both unsoaked and soaked by about 36% and 32%, when the treated expansive soil is cured for 28 days. The same trend of improvement in strength is seen with an increase of by about 60% for 28 days of curing.

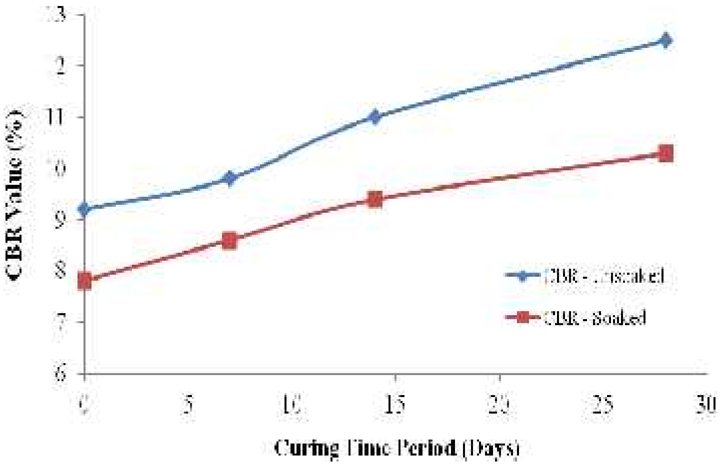

Fig. 6. Plot Showing the Variation of CBR Values of Expansive Soil Treated with Optimum Combination of RHA and PG cured for Different Time Periods.

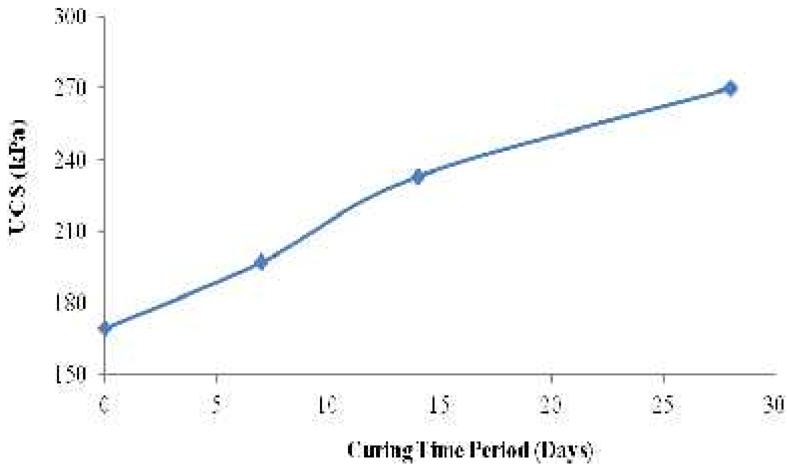

Fig. 7. Plot Showing the Variation of UCS Values of Expansive Soil Treated with Optimum Combination of RHA and PG cured for Different Time Periods.

Finally from the above discussions, it is evident that the addition of Rice Husk Ash (RHA) and Phospho Gypsum (PG) to the virgin expansive soil showed an improvement in compaction, penetration and strength properties to a significant extent. When the Rice Husk Ash (RHA) was only added there is a mild increase and on further blending it with Phospho Gypsum (PG), the improvement was more pronounced. The above said stabilizing agents in combination made the problematic expansive soil with a better particle orientation under compaction, there by improved strength and penetration characteristics for 10% RHA + 6% PG. This is due to the pozzolanic reactions between soil, RHA and PG resulting in the formation of better compact soil matrix with a better inter particle cohesive bond strength. This made the problematic expansive soil, which if not stabilized is a discarded material, a useful fill material with better properties. It can be summarized that the materials Rice Husk Ash (RHA) and Phospho Gypsum (PG) had shown promising influence on the properties of expansive soil, thereby giving a two-fold advantage in improving problematic expansive soil and also solving a problem of waste disposal.

5 Conclusions

The following conclusions are made based on the results discussed in this investigation.

i) The addition of non plastic, silica-rich waste material Rice Husk Ash (RHA) and other waste material, Phospho Gypsum (PG) as a binder bonded the soil particles closer with a better particle orientation, thereby makes the problematic virgin expansive soil, a soil with better and enhanced properties.

ii) There is a gradual improvement in the maximum dry density and the corresponding optimum moisture content had shown a reduction on the addition of RHA + PG when compared to that of virgin expansive soil.

iii) It was observed that the treatment as combination with 10% RHA + 6% PG has significantly improved the penetration and strength properties of properties expansive soil.

iv) There is a significant increase in the CBR and UCS values, when the expansive soil was treated with optimum combination of RHA and PG (i.e. 10% RHA + 6% PG) and cured for 28 days.

v) The materials Rice Husk Ash (RHA) and Phospho Gypsum (PG) had shown promising influence on the properties of expansive soil, thereby giving a two-fold advantage in improving problematic expansive soil and also solving a problem of waste disposal.

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