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An experimental study of black cotton soil stabilized with rice husk ash, cement clink dust and calcium chloride

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ABSTRACT

An experimental examination is conducted to study the effect of rice husk ash (RHA), cement clink dust and calcium chloride ($CaCl_2$) on the black cotton soil to check the stabilization based on engineering property of the black cotton soil. The engineering property of stabilization soil such as moisture content, specific gravity, liquid limit, plastic limit, OMC & MDD and CBR value of the soaked and unsoaked sample is evaluated. The different percentage of RHA is mixed in natural soil in 5%, 10%, 15%, and 20% and all the test can be performed and determine the all test value and CBR value, it was observed that the maximum CBR value is obtained in 15% RHA is mixed in the soil. After that two more-admixture cement clink dust and calcium chloride are a mix in 20% and 2% respectively and perform the experiment and determine CBR value. After calculating all the value, it is seen the maximum CBR value is obtained when 15% RHA, 20% CKD and 2% $cacl_2$ is a mix in the soil. The value of liquid limit and plastic limit in given sample is 35.57 and 26.07 respectively. It is seen that the CBR value increases the new CBR value of this sample in 2.5 mm penetration in soaked and unsoaked soil is 5.77 and 7.58 respectively, and CBR value in 5mm penetration in soaked and unsoaked soil 6.98 and 8.18 respectively. The new CBR value is 2.5mm penetration in soaked and unsoaked soil is 128.97% and 44.15% increase.

Keywords— *Rice Husk Ash (RHA), Cement Clink Dust (CKD), Soil Stabilization, Specific Gravity, Grain Size Distribution, Liquid Limit, Plastic Limit, Plasticity Index, OMC, MDD, CBR*

1. INTRODUCTION

The soil is defined as sediments or other accumulation of mineral particles produced by the physical or chemical disintegration of rocks. Soil stabilization is defined as the alteration or preservation of one or more soil properties to enhance the engineering characteristics and performance of a soil. Stabilization consists of various methods such as grain size distribution, moisture content, liquid limit, plastic limit, standard proctor's compaction test and California bearing ratio test on the soaked and unsoaked sample. For this study, the natural soil has been collected from LNCT campus, Bhopal.

2. LITERATURE REVIEW

Kumar and Sharma, (2017) conducted experimental investigations on Rice husk ash (RHA), RBI Grade 81 (stabilizer) and their combinations with soils in different proportions maximum up to 20% of fresh soil and treated soils. Mechanical properties are evaluated through consistency limits, light compaction test, unconfined compressive strength (UCS), modulus of elasticity and California bearing ratio (CBR) test. The chemical reaction identification tests like scanning electron microscopy (SEM) and Energy dispersive spectrum (EDS) were conducted on pure clay and optimum mix of clay, RHA and stabilizer. The optimum mix was obtained from the Atterberg's limits tests as per IS 86:10:04(Clay: RHA: RBI grade 81). UCS and CBR tests were conducted on the optimum mix for 3, 7- and 28-days curing periods. Comparatively with clay optimum mix shows an increase in the percentage of 782% and 166% in UCS and CBR respectively. Correlation between strength, modulus of elasticity, and the CBR test was also established.

Verma, et al, (2018) performed the experimental work to obtain geotechnical properties of fly ash, rice husk, and lime for its application in the stabilization of soft soil. The geotechnical properties of fly ash will be evaluated by various laboratory tests to investigate the feasibility of using fly ash in soil stabilization. Construction on soft soil is one of the most frequent problems.

Behak, (2017) adopted agricultural waste materials like rice husk ash (RHA) and cheaply available lime mixed with clayey soil to improve weak subgrade in terms of compaction and strength characteristics. In this investigation, lime and rice husk ash (RHA) were added 5%, 10% 15% and 20% by weight of soil. Various tests were conducted on these mixes in order to find an optimum proportion.

3. MATERIALS

3.1 Rice husk ash (RHA)

Rice husk ash (RHA) is a pozzolanic material that could be potentially used in soil stabilization, though it is moderately produced and readily available. When rice husk is burnt under controlled temperature, ash is produced and about 17%-25% of rice husk's weight remains to ash. Rice husk ash and rice straw and bagasse are rich in silica and make an excellent pozzolana. Pozzolanas are siliceous and aluminous materials, which in itself possess little or no cementations value, but in the presence of moisture, chemically react with calcium hydroxide at ordinary temperature to form compounds possessing cementations properties. Rice husk is an agricultural residue abundantly available in rice producing countries. RHA is obtained from the burning of rice husk which is the by-product of rice milling. The chemical composition of RHA is given in Table 1.1. Mentioned in (Subbarao, 2011)

Table 1: Chemical composition of rice husk ash.

Constituent	Percentage
Silica (SiO2)	91.1
Alumina (Al2O3)	0.4
Calcium oxide (CaO)	0.4
Ferric oxide (Fe2O3)	0.4
Sodium (Na2O)	0.1
Sulphur (Na2O)	0.1
Magnesium oxide (MgO)	0.5
Potassium oxide (KaO)	2.2
Loss on ignition	4.8

Fig. 1: Rice Husk Ash (RHA)

3.2 Cement Kiln Dust (CKD)

Cement kiln dust (CKD) is a by-product of the cement manufacturing process. Despite the fact that usually, its composition is similar to partially calcined raw feed, the variability in raw materials, fuel, type of process, dust collection systems and product specifications influence both the physical and chemical characteristics resulting in a highly variable material.

Fig. 2: Cement kiln dust

3.3 Calcium Chloride ($CaCl_2$)

Calcium chloride ($CaCl_2$) has been used primarily as a dust palliative in roadway maintenance as well as an accelerator in cement manufactures as soil stabilization products Calcium chloride has been used as an accelerator, and it was found that pre-grinding of rice husk ash with a calcium chloride accelerator lead to significant improvement in high early strength. Calcium chloride is an important calcium salt that has many household and industrial applications. The chemical formula of calcium chloride is $CaCl_2$, and its molar mass is 110.983g/mol. It is an ionic compound consisting of the calcium cation (Ca^{2+}) and two chlorine anions (Cl^-).

Fig. 3: Calcium Chloride ($CaCl_2$)

4. EXPERIMENT WORK AND RESULTS

Soil samples are taken as follows:
Sample -1 soil sample mix with 5% Rice husk ash - (S1)
Sample -2 soil sample mix with 10% Rice husk ash - (S2)
Sample -3 soil sample mix with 15% Rice husk ash - (S3)
Sample -4 soil sample mix with 20% Rice husk ash - (S4)
Sample -5 soil sample mix with RHA, CKD, and $CaCl_2$ - (S5)

The experimental work consists of the following steps:
1. Grain Size Distribution
2. The moisture content of the soil
3. The specific gravity of soil
4. Soil index properties (Atterberg Limits)
   i) Liquid limit
   ii) Plastic limit, and
   iii) Plasticity Index
5. Maximum dry density (MDD) and the corresponding optimum moisture content (OMC) of the soil by standard Proctor compaction test
6. Soil strength by California bearing ratio (CBR) Test
7. The various Properties of soil samples mixed with rice husk ash (RHA), calcium chloride ($CaCl_2$) and cement kiln dust (CKD).
8. The strength of soil samples mixed with rice husk ash (RHA), calcium chloride and CKD by California bearing ratio (CBR) Test.

Table 2: Representation of index properties of soil

Property	Value	Remark
Water Content		…….………………………
Specific Gravity	2.53	The soil is coarse-grained soil
Liquid Limit	60.60	High compressibility
Plastic Limit	39.07	……………………………
Plasticity Index	21	The soil is high plastic

4.1 Comparison of all result

Table 2: Comparisons test result

S. No.	Test		Expensive soil	5% RHA	10% RHA	15% RHA	20% RHA	15% RHA +20 CKD +2% $Cacl_2$
1.	Specific gravity		2.503	2.55	2.691	2.705	2.74	2.78
2.	Liquid limit		60.598	55.78	48.32	43.03	39.91	35.57
3.	Plastic limit		39.07	30.60	30.60	27.85	26.685	26.07
4.	Plasticity index		21.53	25.2	17.66	15.18	13.24	9.5
5.	OMC		1.649	1.707	1.686	1.693	1.715	1.715
6.	MDD		24.97	28.30	29.65	35.52	31.20	24.40
7.	CBR % 2.5mm	Soaked	2.52	2.70	3.97	4.87	4.69	5.77
		Unsoaked	5.05	6.13	6.31	7.22	6.68	7.58
8.	CBR % 5mm	Soaked	2.70	3.00	4.21	6.05	4.93	6.98
		Unsoaked	5.17	6.25	6.61	7.58	6.13	8.18

Table 3: comparison CBR % at different percentage of RHA

S. No.	Test		Expensive soil	5% RHA	10% RHA	15% RHA	20% RHA	15% RHA +20 CKD +2% $Cacl_2$
1.	CBR % 2.5mm	Soaked	2.52	2.70	3.97	4.87	4.69	5.77
		Unsoaked	5.05	6.13	6.31	7.22	6.68	7.58
2.	CBR % 5mm	Soaked	2.70	3.00	4.21	6.05	4.93	6.98
		Unsoaked	5.17	6.25	6.61	7.58	6.13	8.18

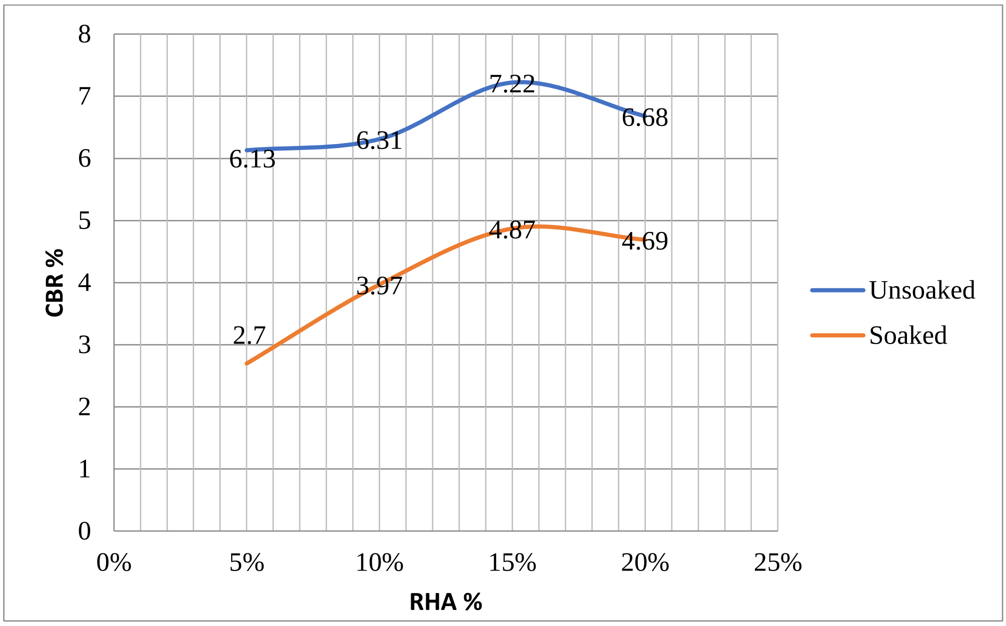

Fig. 1: CBR value at different percentage of RHA

Table 4: Comparison of OMC, MDD and CBR% of soil without rice husk ash, soil with 5% RHA, 10% RHA, 15% RHA and soil with 20% RHA

Property	Natural soil	Natural soil + 5% RHA	% Increase /Decrease	Natural soil + 10% RHA	% Increase /Decrease	Natural soil + 15% RHA	% Increase /Decrease	Natural soil + 20% RHA	% Increase /Decrease
OMC	1.649	1.707	3.52% Increase	1.686	2.24% Increase	1.693	2.67% Increase	1.715	4.00% Increase
MDD	24.97	28.30	13.34% Increase	29.65	18.74% Increase	35.52	42.25% Increase	31.20	24.95% Increase
CBR % soaked	2.52	2.70	7.14% Increase	3.97	57.54% Increase	4.87	93.25% Decrease	4.69	86.11% Decreases
CBR % unsoaked	5.05	6.13	21.39% Increase	6.31	24.95% Increase	7.22	42.97% Increase	6.68	32.28% Decreases

Table 5: Comparison of OMC, MDD and CBR% of soil without rice husk ash, soil with 15% RHA with 20 % CKD and 2% $Cacl_2$

Property	Natural soil	Natural soil + 15% RHA	% Increase /Decrease	Natural soil + 15% RHA +20% CKD + 2% $Cacl_2$	% Increase /Decrease
OMC	1.649	1.693	2.67% Increase	1.715	4.00% Increase
MDD	24.97	35.52	42.25% Increase	24.40	2.34% Increase
CBR % soaked	2.52	4.87	93.25% Decrease	5.77	128.97% Increase
CBR % unsoaked	5.05	7.22	42.97% Increase	7.58	44.15% Increase

5. CONCLUSIONS

The stabilization of expansive soil has drawn attention to avoid its disastrous effect on infrastructural components like road, building etc. In this work, a new idea of stabilizing the expansive soil using Rice husk ash and one admixture calcium chloride mix in soil and effect was discussed.

Based on the obtained results and discussion thereof the following conclusions can be made:

- In the first case, the property of natural soil determines the liquid limit and plastic limit of natural soil 60.598 and 39.07 respectively. And CBR value is determined in 2.5mm penetration in soaked soil 2.52 and unsoaked soil 5.05. The CBR value is determined in 5mm penetration in soaked soil 2.70 and unsoaked soil 5.17.
- The optimum moisture contains in natural soil is 1.649 and maximum dry density is 24.97.
- After that rice husk is a mix of natural soil in the different percentage that is 5, 10, 15and 20% and the entire test can be performed and compare all the result obtained. It is seen that the maximum CBR value is obtained in 15% RHA is mixed in the natural soil.

The CBR value of 5% RHA is mixed in natural soil in 2.5mm penetration for soaked 4.87 and unsoaked 7.22 and 5mm penetration for soaked soil 5.05 and unsoaked soil 7.58 respectively.

- The optimum moisture contains in 5% Rice husk ash is mixed in natural soil is 1.693 and maximum dry density is 35.52.
- It is observed that the 15% RHA is a mix in natural soil is given maximum strength and bearing capacity, in this sample 20% Cement clink dust and 2% $cacl_2$ is also mixed and performed all the test. The value of liquid limit and plastic limit in given sample is 35.57 and 26.07 respectively. It is seen that the CBR value increases the new CBR value of this sample in 2.5 mm penetration in soaked and unsoaked soil is 5.77 and 7.58 respectively, and CBR value in 5mm penetration in soaked and unsoaked soil 6.98 and 8.18 respectively. The new CBR value is 2.5mm penetration in soaked and unsoaked soil is 128.97% and 44.15% increase.
- The optimum moisture contains in 5% Rice husk ash, 20% cement clink dust and 2% $Cacl_2$ is mixed in natural soil is 1.715 and maximum dry density is 24.40.

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