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Compressibility Behaviour of Black Cotton Soil Admixed with Lime and Rice-Husk Ash

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ABSTRACT: Black cotton soil covers about one-fifth of the area of our country. Owing to its undesirable engineering properties such as high swelling and shrinkage, the soil is not good either as foundation or embankment material. To make the best use of black cotton soil, its properties are to be modified to suit the requirements in any specific case by means of stabilization. Therefore, it is necessary to properly choose the stabilizer through careful investigation to improve the strength, compressibility and permeability characteristics. At the same time, the economics of the process of the stabilization should also be considered. In this paper the results obtained by studying the compressibility behavior of black cotton soil admixed with lime and rice-husk ash is presented. For the purpose of comparison similar studies have been carried out with admixtures such as lime and rice-husk separately.

Keywords:-Black Cotton Soil; Shrinkage; Swelling; Stabilization; Lime; Rice-Husk Ash:Compaction Characteristics Consolidation Characteristics; Coefficient of Stability.

I.INTRODUCTION

Expansive soils, well-known as Black Cotton Soils in India, occupy about one-fifth of land area of the country. Black Cotton Soils are residual deposits formed from basalt or trap rocks. They contain significant amount of montmorillonite material. These soils are very hard in dry state but lose their load carrying capacity when once they are allowed to imbibe water. They have high shrinkage and swelling characteristics. In general, these expansive soils are very much sensitive to changes in environment. The environment includes the stress system, the chemistry of pore water in the system, the seasonal variations in ground water table with consequent changes in natural moisture content and temperature variations. These properties have made the soil unsuitable for civil engineering purposes either as foundation or embankment material.

The engineering properties of soils, especially of clays, can be improved to a great extent by stabilizing with lime. Further, it has been found that, by increasing pozzolanic action, the stabilization by lime is highly effective. In rice-producing countries such as India, rice-husk ash for stabilization appears to be a successful solution since rise-husk ash, primarily being siliceous material, acts as a pozzolona. Hence, in this investigation, the compressibility behavior of Black Cotton Soil treated with lime and rice-husk ash has been studied. For the purpose of comparison, similar studies have been carried out with admixtures such as lime and rice-husk ash separately.

Ramaiah et al (1972) studied the behavior of Black cotton soil admixed with lime and rice-husk ash in various proportions. It was found that this admixture decreases the maximum dry unit weight, increases the optimum moisture content, decreases the flexibility as indicated by axial strain at failure and also increases the compressive strength of the stabilized soil.

Sivanna et al (1977) investigated consolidation characteristics of block cotton soil admixed with lime and rice-husk ash. It was shown that rice-husk ash with lime not only accelerates the settlement rate but also reduces the total settlement. Besides, the quantity of lime could be reduced 50% using rice-husk ash as admixture for almost the same characteristics as obtained for lime admixed soil.

Use of rice-husk ash along with lime for stabilization of deltaic soils and black Cotton Soils has been studied by Rajan et al (1982) in Karnataka engineering research station, Krishnarajasagara. It was felt that rice-husk ash behaves as pozzolanic material in the presence of lime. It was observed that there was improvement in the consolidation properties of the soils stabilized with lime and rice-husk ash.

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Vol. 3, Issue 4, April 2014

Jyothi and Ramana Sastry (1991) investigated the behavior of expansive soils treated with lime. It was observed that, in general, the coefficient of consolidation increases whereas both the compression index and swelling index decrease with increase in lime content.

Muntohar (2002) carried out a series of laboratory experiments individually and in combination of RHA and lime in stabilizing expansive soils in Indonesia. He found that the geotechnical properties of expansive soils improved with addition of RHA and lime. RHA and lime altered the texture of clay soil by reducing the fine particles. The admixtures also found to reduce the liquid limit, swelling potential of expansive soils and also the compressibility characteristics.

Ali et al (2004) carried out an investigation to study the influence of RHA and lime on Atterberg limits, strength, compaction swell and consolidation properties of bentonite. The results indicated that the plasticity properties of bentonite were significantly modified upon the addition of RHA and lime. The RHA and lime have noticeable influence on compaction, swell and consolidation properties of bentonite soil particularly at 15% RHA and 8% lime contents individually and combinedly at 15% RHA +4% Lime.

Adrian (2011) conducted one dimensional laboratory consolidation tests on compacted lateritic soils treated with up to 16% Rice-Husk Ash (RHA), to assess its consolidation properties. Specimens were prepared at three different moulding water contents (2% dry of optimum, optimum moisture content and 2% wet of optimum) and compacted using the British Standard Light compactive effort. Pre-consolidation pressure increased with RHA content, it also decreased before increasing with increased moulding water content. Reductions in compression index (Cc) and Swell Index (Cs) with increased RHA content were recorded. Cc and Cs generally decreased before increasing with increased moulding water content. The coefficient of volume compressibility (Mv) decreased and increased with higher RHA content; they were also affected by the soil particle state with increasing pressure. The co-efficient of consolidation (Cv) showed no observable trend with increased RHA content but generally increased with higher consolidation pressure on the dry and wet side of optimum compacted states.

Ashwani Jain (2013) have been conducted One-dimensional consolidation tests to study the effect of addition of various percentages of rice husk ash on compressibility characteristics of highly plastic clay soil. It has been observed due to the addition of rice husk ash to the parent clay, Compression index (Cc) has been found to decrease significantly with increase in percentage of rice husk ash, hence decreasing consolidation settlement of parent material. It has also been observed that the time required for achieving a given degree of consolidation decreases with increase in the percentage of rice husk ash at a particular effective stress. Overall, it has been observed that rice husk ash effectively increase one-dimensional stiffness and therefore, reduce settlement.

II.EXPERIMENTAL INVESTIGATIONS

A. Materials used

The following materials have been used in this investigation.

1.Soil:- The soil used in this investigation is obtained from Bairagipatteda near All India Radio station, Tirupati. The properties of the soil are given in Table 1.The soil is classified as CH-group and is of highly expansive nature.

Table 1: Properties of Untreated soil

Sl.No.	Property	Value
1.	Grain size distribution	
	Gravel (%)	0
	Sand (%)	10
	Silt & Clay (%)	90
2.	Atterberg Limits	
	Liquid limit (%)	62
	Plastic limit (%)	30
	Shrinkage limit (%)	16

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 3, Issue 4, April 2014

Sl.No.	Property	Value
3.	Differential Free Swell Index (%)	80
4.	Swelling Pressure (kN/m^2)	210
5.	Specific Gravity	2.67
6.	Compaction Characteristics	
	Maximum Dry Unit Weight (kN/m^3)	15.7
	Optimum Moisture Content (%)	23.2
7.	Unconfined Compressive Strength (kN/m^2)	105
8.	Shear Strength Parameters as obtained by Undrained Compression test.(Triaxial compression Test)	
	Cohesion(kN/m^2)	62.4
	Angle of Internal Friction (Degrees)	6

2.Lime

Commercially available lime was slaked with clean water and allowed to dry and later sieved through I.S.425 micron sieve was taken for the study. The chemical composition of lime is given in Table 2.

Table 2: Chemical Analysis of Slaked Lime

i)	Silica	4.02%
ii)	Insoluble matter	5.64%
iii)	Ferric Oxide	1.92%
iv)	Alumina	1.36%
v)	Calcium Oxide	59.42%
vi)	Magnesia	0.92%
vii)	Loss on ignition	26.72%

3.Rice-husk ash

The secondary additive, namely rice-husk ash is obtained by burning locally available rice-husk at a temperature of about 600^{0}C in an open kiln for about twenty four hours. After complete burning, the burnt material was sieved through I.S.425 micron sieve and minus 425 μ-fraction was taken for the study. The chemical analysis of rice-husk ash is given in Table.3.

Table 3: Chemical Analysis of Rice-Husk Sample

i)	Silica	90.80%
ii)	Inorganic matter	3.50%
iii)	Ferric Oxide	0.35%
iv)	Alumina	1.72%
v)	Calcium Oxide	1.57%
vi)	Magnesia	1.20%
vii)	Sodium Oxide	0.05%
viii)	Potassium Oxide	0.34%
ix)	Loss on ignition	0.57%

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Vol. 3, Issue 4, April 2014

B.TESTS CONDUCTED

The following tests have been conducted in this investigation.

1. Compaction tests

Standard Proctor tests have been conducted on the soil with different percentages of lime and rice-husk ash separately and in combination in different proportions namely 1:1, 1:2, 1:3 and 1:4, ranging from 2 to 8% in increments of 2%, for the determination of optimum moisture content and maximum dry unit weight. The tests are conducted in accordance with I.S. 2720 (Part VII).

2. Consolidation tests

The air-dried soil passing through I.S.4.75 mm sieve is mixed with lime or rice-husk ash or lime and rice-husk(in different proportions, namely 1:1,1:2,1:3and 1:4) and water at optimum moisture content and kept in air tight polythene bags for a day, as is done in the case of compaction tests. The cured soil is compacted in Proctor's mould and the required specimen is cut from the compacted soil for use in the consolidation test. The method and procedure adopted are as per I.S. 2720(Part XV).

III.RESULTS AND DISCUSSIONS

A.Compaction Behaviour

Fig.1 depicts the relationship between the optimum moisture content and per cent lime content. It is found that the optimum moisture content increases with percent increase of lime content. The variation of maximum dry unit weight with per cent lime content is also shown in Fig.1.From the figure it is observed that the Maximum dry Unit Weight decreases as the per cent lime content increases.Figs.2 and 3 represent for rice-husk, and lime and rice-husk ash in combination for 1:1 proportion respectively. Similar trend is observed in both these cases.

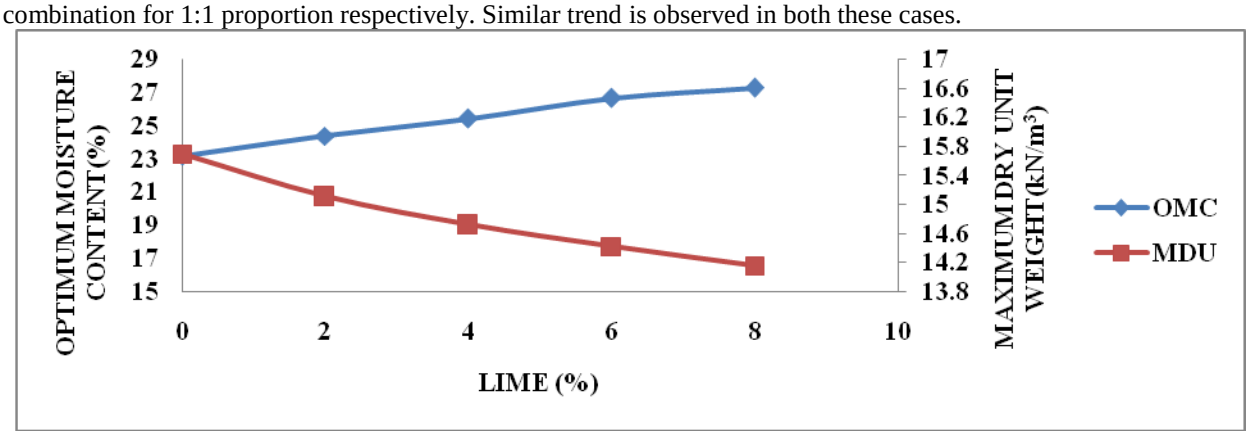

Fig.1: Effect of Lime on Maximum Dry Unit Weight and Optimum Moisture Content

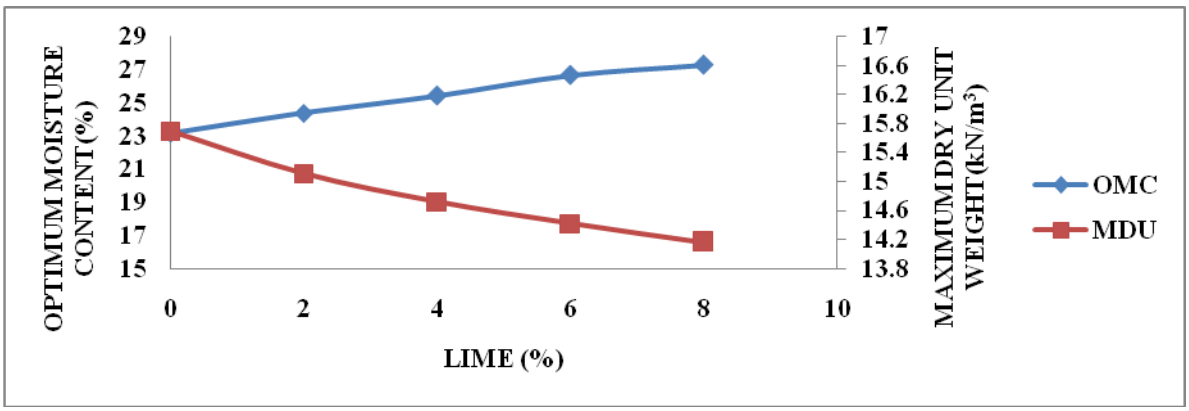

Fig.2: Effect of RHA on Maximum Dry Unit Weight and Optimum Moisture Content

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 4, April 2014

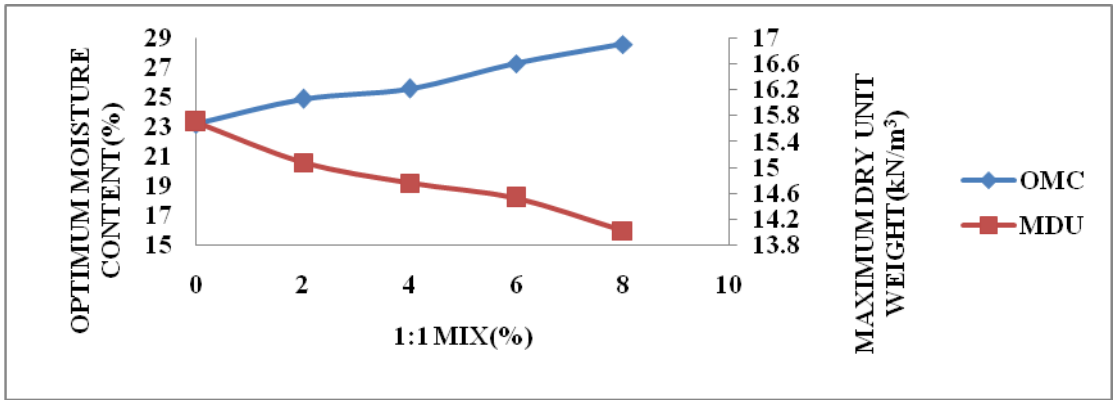

Fig.3: Effect of Lime & RHA (1:1) on Maximum Dry Unit Weight and Optimum Moisture Content

B.COMPRESSIBILITY BEHAVIOUR

1.Pre-consolidation pressure: The variation of pre-consolidation pressure with respect to percentage admixture for lime, rice-husk ash, and 1:1 mix is represented in Fig.4.From the figure it is observed that up to 2% of lime content pre-consolidation pressure decreases and afterwards it increases and attains peak value at 6% lime content. It once again decreases beyond 6% of lime content .The increase in pre-consolidation pressure with increase in lime content is due to cementation effect. It is understood that at low percentages slight decrease in pre-consolidation pressure is due to inadequate quantity of lime to cause cementation effect to the full extent. In case of rice-husk ash at low percentages (up to 4%) the trend is reversed. Later, it increases with increase in rice-husk ash content. Between 4% and 6% the rate of increase is high. In case of 1:1 mix it continuously increases with percentage of admixture up to 6%.Afterwards there is a marginal reduction in p_c value. It indicates that rice-husk ash when used with lime enhances the pozzolanic action. Black Cotton Soil treated with lime and RHA in 1:1 proportion induces some extra pre-consolidation effect.

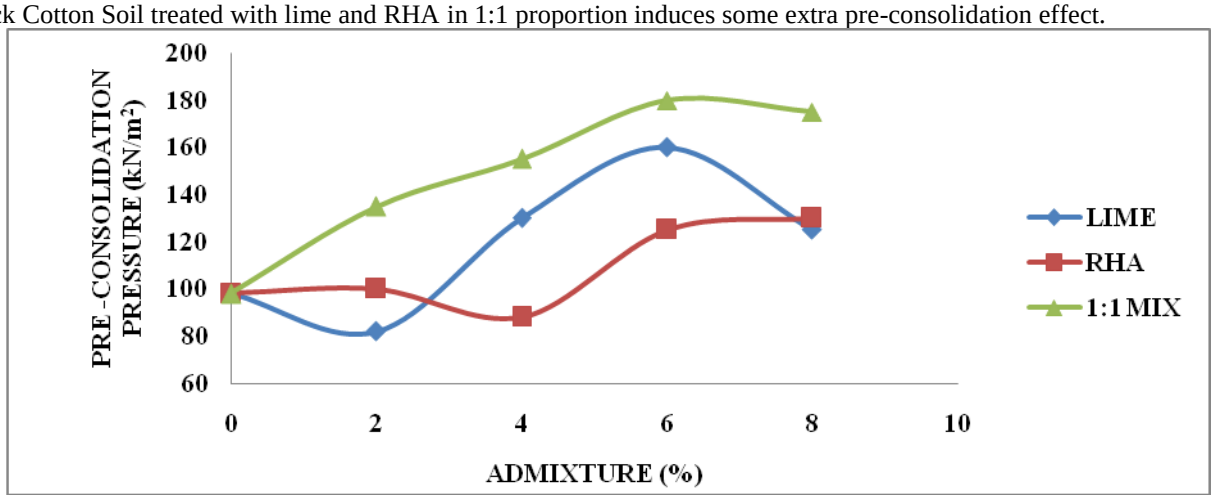

Fig.4:Pre-Consolidation Pressure versus per cent Admixture

2.Compression index: Compression indices for different percentages of lime, R.H.A, lime and RHA in combination for various proportions namely 1:1, 1:2, 1:3 and 1:4, are calculated and presented in Fig.5. The compression index of the untreated soil is 0.266, which decreases on treatment with lime and RHA separately as well as in combination. The curve for RHA lies at the top. Further, as the lime content in the proportion increases, the curves for different proportions fall one below the other in succession, the curve for lime being at the bottom. Though the general trend is similar, the curve for lime at lower percentages is flatter indicating its less effectiveness in reducing compression index while at higher percentages the curve is steeper indicating its high effectiveness in reducing the same.

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Vol. 3, Issue 4, April 2014

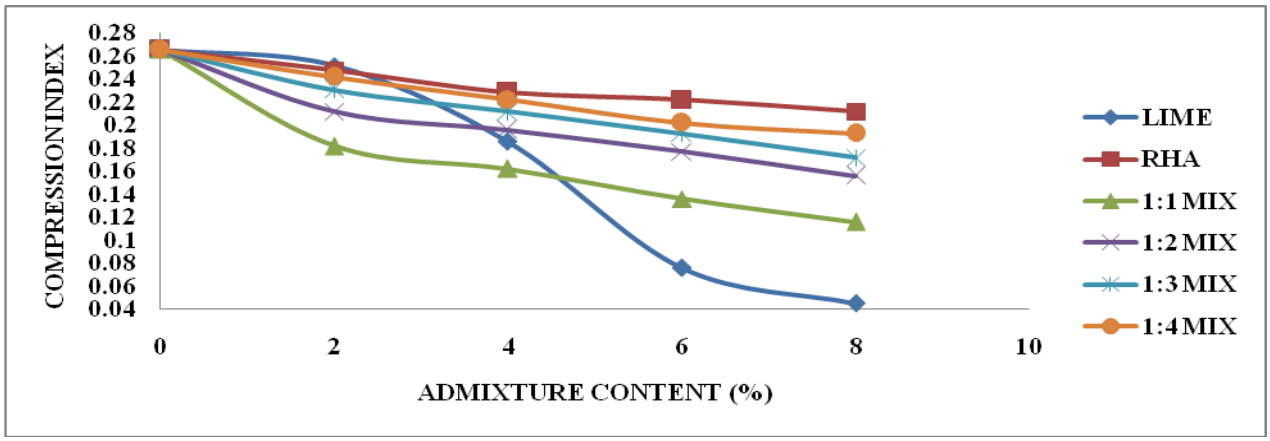

Fig.5: Variation of Compression Index with per cent Admixture

Fig.6 shows the variation of percentage reduction in compression index to that of percentage reduction in lime content for 1:1 mix. It can be seen from the curve that there is a considerable reduction in lime quantity for reducing the settlements by a specified extent.

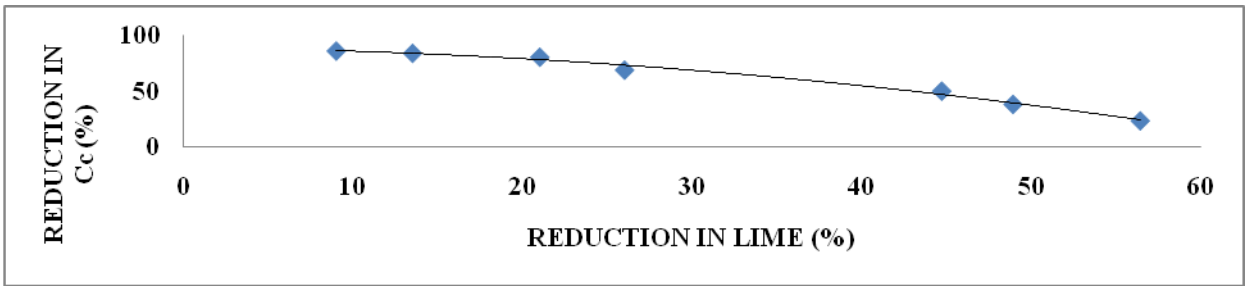

Fig.6: Relationship between reduction in Compression Index and reduction in Lime for 1:1 mixes.

3.Coefficient of Consolidation: The graphical construction suggested by Taylor (1948) has been made use of for computing C_V. From figures 7, 8 and 9 it is observed that coefficient of consolidation increases with the increase of admixture content. From the figures it is observed that coefficient of consolidation decreases with increase of consolidation pressure. The time for 90% consolidation has been found to decrease with increase of percentage of admixture, indicating the significant increase of rate of consolidation.

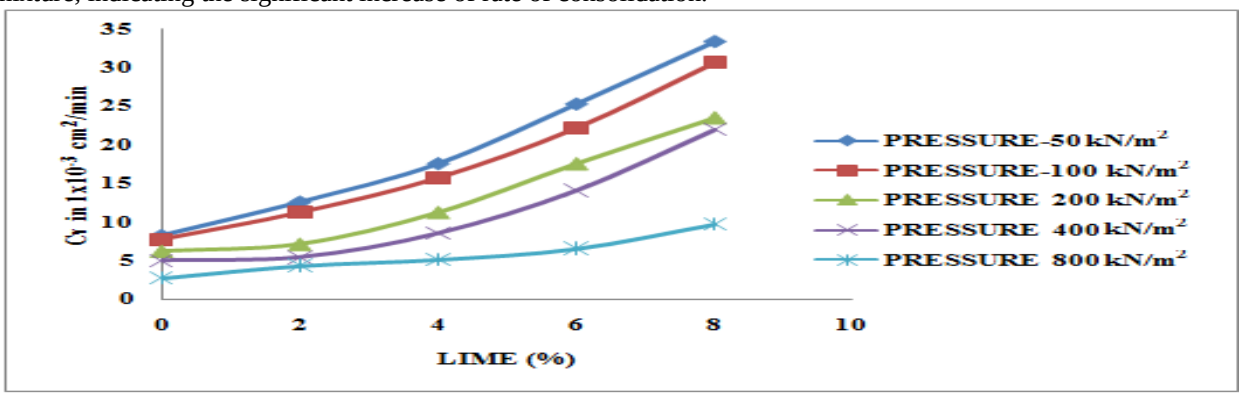

Fig.7: Relationship between c_v and per cent Lime

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 4, April 2014

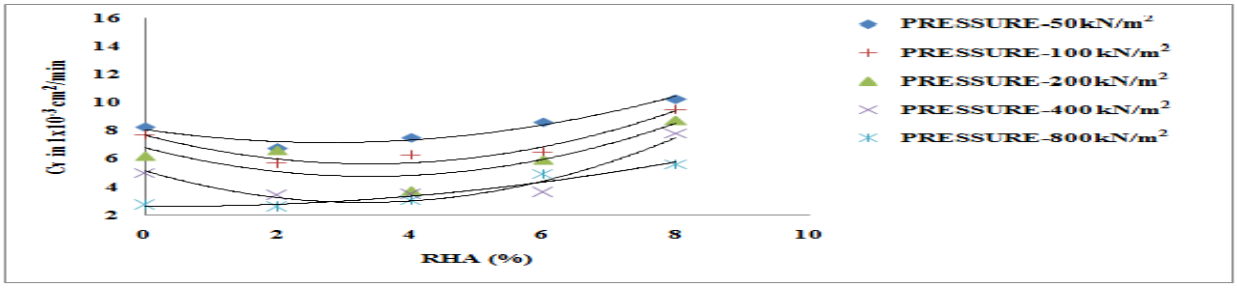

Fig.8: Relationship between c_v and per cent RHA

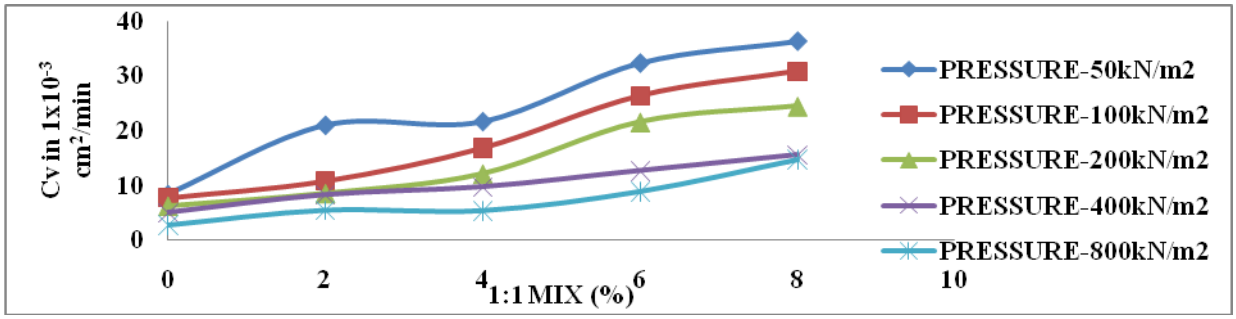

Fig.9: Relationship between cv and per cent Lime &RHA (1:1mix)

4.Swelling Index: The values of swelling index are computed from rebound portion of e-logp curve for various percentages of admixtures and are represented graphically in Fig.10. It is observed from the figure that the values of swelling index are very much reduced with lime treatment. The curve for rice-husk ash lies at the top, from which it can be concluded that rice-husk ash is less effective among all the admixtures in reducing the swelling index. As the proportion is changed with rice-husk ash and increase in lime, the curve for different proportions fall one below the other in succession, the curve for lime being at the bottom. It is obvious from the figure that the curves are very steep up to 4% of admixture from which it can be concluded that swelling index decreases rapidly with increase in admixture content up to 4%.

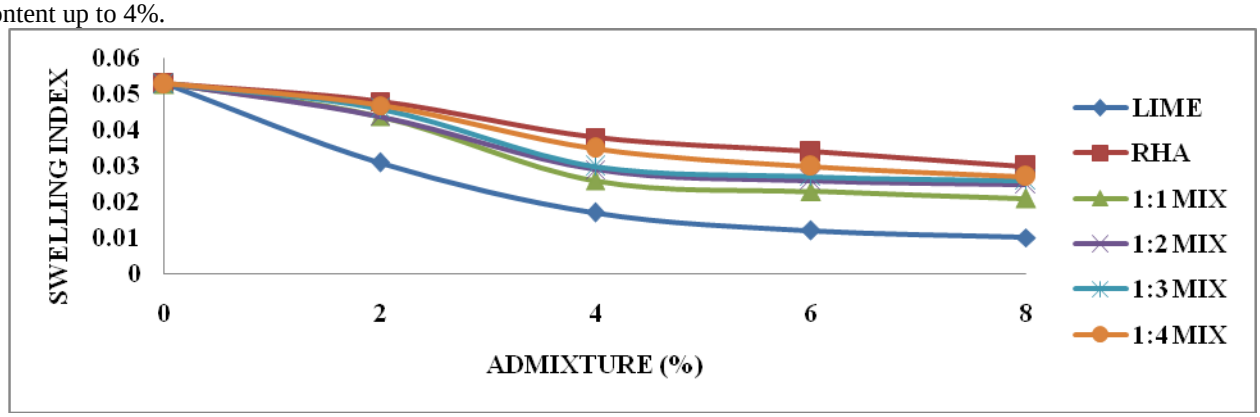

Fig.10: Swelling Index Versus per cent Admixture

5.Coefficient of Stability: According to Jyoti and Ramana Sastri (1991) the coefficient of stability (S_c) is defined as the ratio of void ratio after the consolidation has been completed under the maximum consolidation pressure (i.e. 800kPa) to the final void ratio obtained after rebound on removal of the pressure to 5kPa.

The values of coefficient of stability at 0%, 2%, 4%, 6% and 8% of admixtures namely lime, RHA, lime and RHA in combination for 1:1 proportion are given in Table 4. From the table it can be inferred that the coefficient of

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International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 4, April 2014

stability increases with lime content. Similar trend is observed for RHA and for 1:1 mix of lime and RHA .This is an index of the stability of soil against the deleterious effects of water following the load removal. The higher the coefficient, the greater will be stability of the soil.

Table 4: Coefficient of Stability

PERCENTAGE OF ADMIXUTURE	COEFFICIENT OF STABILITY		
	LIME	RHA	1:1 MIX
0	0.797	0.797	0.797
2	0.841	0.831	0.865
4	0.952	0.832	0.885
6	0.962	0.886	0.918
8	0.966	0.883	0.929

VI.CONCLUSIONS

Based on the results reported in this investigation, the following conclusions are drawn.

1. Optimum moisture content increases as the percentage of lime or RHA or lime & RHA increases
2. Maximum dry unit weight decreases as the percentage of lime or RHA or lime& RHA increases
3. 1:1 mix is more effective than all other admixtures investigated in indicating extra pre-consolidation effect to the soil.
4. Compression index as well as swelling index decreases as the percentage of admixture increases
5. 1:1 mix is more effective and economical among all the admixtures in reducing compression index
6. Coefficient of consolidation increases as the percentage of admixture increases.
7. Coefficient of consolidation decreases as the consolidation pressure increases.
8. Coefficient of stability increases as the percentage admixture increases.

Hence the compressibility characteristics of Black Cotton Soils can be improved to a great extent by stabilizing either with lime or lime and rise-husk ash in combination in 1:1 proportion. In rice -producing countries, such as India, the secondary additive rice-husk ash not only brings down the cost of stabilization but also appears to be a successful solution for improving the engineering properties of Black Cotton Soils .Thus economy in stabilization can be achieved.

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