Consolidation Characteristics of Highly Plastic Clay Stabilised With Rice Husk Ash

Ashwani Jain, Nitish Puri

Abstract - One-dimensional consolidation tests have been conducted to study the effect of addition of various percentages of rice husk ash on compressibility characteristics of highly plastic clay soil. Statically compacted soil specimens have been prepared at optimum moisture content and maximum dry density by adding 4, 8, 12, 16 and 20% by weight of rice husk ash to the parent soil. Specimens have been subjected to increments of vertical pressure of 0.25, 0.50, 1.00, 2.00 and 4.00 kg/cm^2 in a fixed ring consolidometer. It has been observed due to the addition of rice husk ash to the parent clay, the optimum moisture increases and maximum dry density decrease with increase in percentage of rice husk ash. Coefficient of compressibility (a_v) and coefficient of volume compressibility (m_v) show no significant trend for variation in values with change in proportion of rice husk ash in the soil at a particular effective stress. It has been observed that there is decrease in the values of these parameters with increase in effective stress for a particular percentage of rice husk ash. Compression index (C_c) 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.

Keywords: Rice husk ash (RHA), stabilization, compressibility, characteristics, maximum dry density and optimum moisture content.

I. INTRODUCTION

Soil stabilization, in the broadest sense, is modification of soil properties to improve its engineering performance. However the original objective of the soil stabilization is to increase the strength or stability of soil but now-a-days stabilization is used to increase or decrease almost every engineering property [3]. Over the last few years, the use of industrial wastes has increased as stabilizing materials for naturally occurring fine grained soils.

These waste products pose a serious environmental problem if not disposed of properly. Their use serves two purposes; firstly the disposal of waste material and secondly, use as construction material [2]. The purpose of present study is to see the effect of rice husk ash (a waste from agriculture industry) in improving consolidation characteristics of clayey soils.

Manuscript received on January, 2013.

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A better understanding of these characteristics will enhance the usage of these materials in geotechnical engineering works in places where they are abundant and thereby making clays suitable for foundation purpose. The study also focuses at reduction of huge stockpile of the various industrial wastes and their potential impact on the environment. In the present work, compressibility characteristics have been studied for locally available highly plastic clay treated with different percentages of rice husk by conducting a series of one dimensional consolidation tests.

II. NEED OF PRESENT STUDY

Good serviceability by any structure can only be expected when its foundation satisfies the following three basic criteria; a) Location and depth criterion, b) Shear failure or bearing capacity criterion and c) Settlement criterion. Magnitude and rate of settlement for foundations due to structural loads must be predicted before construction. If the settlement is excessive, meaning more than what is permissible for the structure, it may cause structural damage or malfunctioning, especially when the rate of such settlement is rapid.

Hence, proper investigation of soil profile beneath the proposed structure as well as proper designing of structures on the basis of settlement criterion in such type of soils is a must. That is why, geotechnical engineers are frequently asked to do the investigation on differential settlement problems.

In general, it is observed that more attention has been paid to determination of shear strength characteristics of stabilized soils.

However, shear strength is not the only criterion controlling design as settlement under safe load may exceed allowable limits [8].

III. MATERIALS

A. Highly plastic clay

Clay used in the experiments was collected from Samani, Traffic Police Post, GT Road, District Kurukshetra, Haryana. The soil is classified as highly plastic clay, CH, as per IS: 1498 (1970) [4].

B. Rice husk ash

It was collected from Kohinoor Foods Limited, GT Road, Murthal, District Sonipat, Haryana. The material is classified as ML, silt of low compressibility, as per IS: 1498 (1970) [4]. Physical properties of these materials are reported in the Table 1.

Table1. Physical properties of clay and rice husk ash

Physical Properties		Materials	
		Parent Clay	Rice husk ash
Grain Size Distribution Data	Gravel (%)	0	0
	Sand (%)	6.75	23.22
	Clay + Silt (%)	93.25	76.78
Specific Gravity		2.48	1.95
Liquid Limit		54	NP
Plastic Limit		25	
Plasticity Index		29	
Is Classification		CH	ML
OMC (%)		23.5	-
MDD (g/cc)		1.56	-

IV. SAMPLE PREPARATION

The whole process of sampling can be divided into three parts:

A. Composition of specimens

Specimens of parent clay and clay treated with 4, 8, 12, 16 and 20% by weight of rice husk ash passing 425 micron IS sieve were prepared at maximum dry density and optimum moisture content as per IS: 2720 (Part 7) (1974) [5].

B. Mixing

Oven dry soil was dry mixed with various percentages of rice husk ash.

Sufficient quantity of water was then added to bring the moisture content to the desired level. The mixture was then manually mixed thoroughly with a spatula. All the specimens were kept in polythene bags for maturing for five days.

C. Static compaction

Cylindrical specimens were compacted by static compaction in 10 cm diameter consolidation ring to the required height of 2.5 cm. The inner surface of the ring was smeared with mobile oil to help minimize friction between inner surface of the ring and the soil sample during consolidation process. The wet homogenous mixture was placed inside the specimen ring using spoon and leveled. Sample was placed in specimen ring with extension collar attached to it and both the exposed sides of the sample were covered with filter papers.

After that porous stone and pressure pad were inserted into the extension collar and the whole assembly was statically compacted in loading frame to the desired density. The sample was kept under static load for not less than 20 minutes in order to account for any subsequent increase in height of sample due to swelling.

V. TESTING AND RESULTS

A series of one-dimensional consolidation tests were conducted to determine the compressibility characteristics of untreated clay and clay stabilized with rice husk ash to evaluate its effect in reducing compressibility of the soil. These characteristics have been illustrated by establishing the relationships between void ratio and effective stress. In order to determine rate and magnitude of consolidation, coefficient of compressibility, coefficient of volume compressibility, compression index and coefficient of consolidation have been calculated from the observations taken during the tests [6].

Standard Proctor tests were conducted to determine optimum moisture content and maximum dry density of parent clay and clay stabilized with 4, 8, 12, 16 and 20% of rice husk ash passing 425 micron IS sieve. These tests were conducted in order to prepare specimens at maximum dry density by adding desired optimum moisture content as per specifications of IS: 2720 (Part 7) (1974) [5].

A. Moisture – Density relationships

For parent clay OMC and MDD have been observed as 23.5% and 1.56 g/cc respectively. For clay stabilized with Rice husk ash OMC varies from 23.7 to 33% and MDD varies from 1.553 to 1.28 g/cc, with increase in percentage of rice husk ash. It has been observed that there is an increase in OMC and decrease in MDD due to an increase in percentage of rice husk ash.

The presence of rice husk ash having a relatively low specific gravity may be the cause for reduction in density. The increase in OMC may be due to absorption of water by rice husk ash for hydration of free lime. The compaction parameters of stabilised samples are reported in a table below.

Table 2. Compaction parameters of stabilized samples

Percentage of rice husk ash stabilization	MDD (g/cc)	OMC (%)
4%	1.553	23.7
8%	1.444	25
12%	1.412	26
16%	1.39	28.5
20%	1.28	33

Figure 1 (a) to 1 (f) shows moisture content vs. dry density curves for parent clay and clay stabilised with 4,8,12,16 & 20% of RHA respectively.

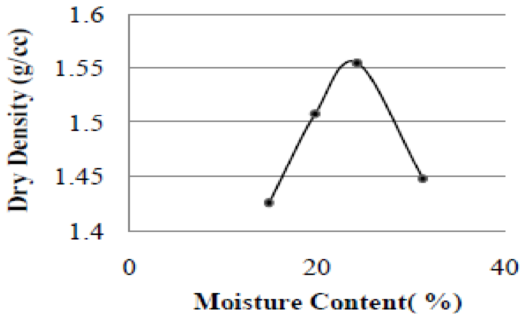


Figure 1(a)

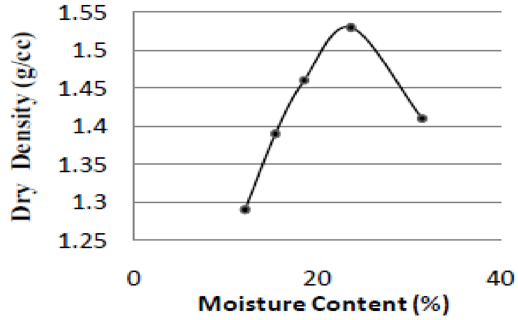
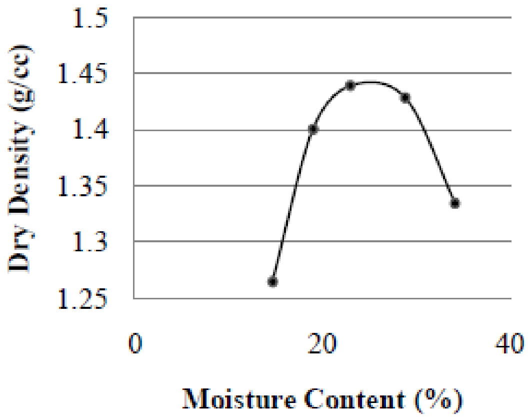


Figure 1(b)



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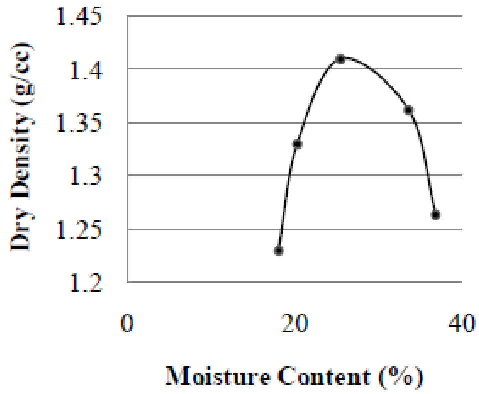

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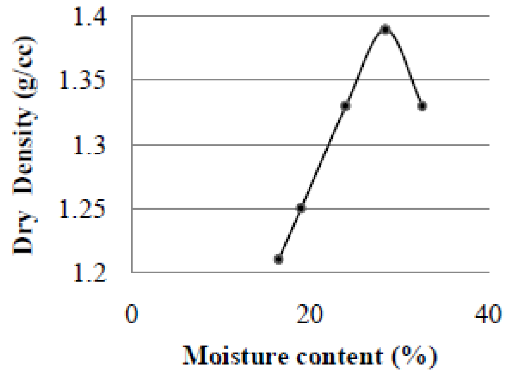


Figure 1 (e)

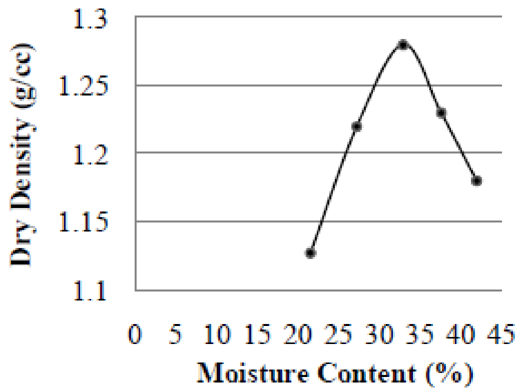


Figure 1(f)

B. Coefficient of compressibility (a_v)

Based on the analysis of variation in equilibrium void ratio for various values of effective stress, the coefficient of compressibility (a_v) values, for all stabilized clay samples have been determined over a range of consolidation pressures. For parent clay the value of a_v decreases from 13.9 x 10^{-2} to 5.97 x 10^{-2} cm^2/kg as the pressure increases from 0.25 kg/cm^2 to 4.0 kg/cm^2, which shows that compressibility of soil decreases with the increase in effective stress. It has been observed that values of a_v vary from 9.3 x 10^{-2} to 0.60 x 10^{-2} cm^2/kg for various percentages of rice husk ash at different effective stresses. It has been observed that there is a decrease in the value of a_v with an increase in effective stress at a particular percentage of rice husk ash. No significant trend has been observed for the variation of a_v at various percentages of rice husk ash for a particular effective stress. In general, a_v decreases with increase in rice husk ash content. This may be attributed to the addition of non-plastic material to the parent soil. The values of coefficient of compressibility (a_v) are reported below.

Table 3. Coefficient of compressibility (a_v) in cm^2/kg x 10^{-2}

Pressure Increment	Values Of a_v For Various Percentages Of Rice Husk Ash Stabilization					
	0 %	4 %	8%	12%	16%	20%
0.25 kg/cm^2	13.9	7.21	9.3	3.91	6.57	4.05
0.5 kg/cm^2	10.5	7.02	5.04	2.75	5.37	4.01
1.0 kg/cm^2	7.26	7	4.67	2.65	4.55	3.5
2.0 kg/cm^2	6.53	5.91	4.53	2.52	4.46	1.41
4.0 kg/cm^2	5.97	5.9	4.22	1.31	3.64	0.60

C. Coefficient of volume compressibility (m_v)

Based on the analysis of variation in equilibrium void ratio for various values of effective stress, the coefficient of volume compressibility (m_v) values, for all stabilized clay samples have been determined over a range of consolidation pressures. For parent clay the value of m_v decreases from 8.99 x 10^{-2} to 3.82 x 10^{-2} cm^2/kg as the pressure increases from 0.25 kg/cm^2 to 4.0 kg/cm^2, which shows that volume compressibility of soil decreases with the increase in effective stress.

It has been observed that values of m_v vary from 5.55 x 10^{-2} to 0.33 x 10^{-2} cm^2/kg for various percentages of rice husk ash at different effective stresses. It has been observed that there is a decrease in the value of m_v with an increase in effective stress at a particular percentage of rice husk ash. No significant trend has been observed for the variation of m_v at various percentages of rice husk ash for a particular effective stress. In general, m_v decreases with increase in rice husk ash content. This may be attributed to the addition of non-plastic material to the parent soil. The values of coefficient of compressibility (m_v) are tabulated in Table 4.

Table 4. Coefficient of volume compressibility (m_v) in $cm^2/kg \times 10^{-2}$

Pressure Increment	Values Of m_v For Various Percentages Of Rice Husk Ash Stabilization					
	0 %	4 %	8%	12%	16%	20%
0.25 kg/cm^2	8.99	4.85	5.55	2.32	3.84	2.2
0.5 kg/cm^2	6.56	4.6	3.18	1.61	3.12	2.19
1.0 kg/cm^2	4.87	4.55	2.83	1.61	2.73	1.96
2.0 kg/cm^2	4.62	3.82	2.6	1.48	2.64	0.76
4.0 kg/cm^2	3.82	3.77	2.59	0.77	2.2	0.33

D. Compression index (C_c)

Based on the analysis of pressure-void ratio curves on semi-log plot i.e. virgin compression curves, compression index (C_c) values, for all stabilized clay samples have been determined.

The value of C_c for parent clay is observed as 0.458. It has been observed that values of C_c vary from 0.508 to 0.181 for various percentages of rice husk ash. It has been observed that there is a general decrease in value of C_c with an increase in rice husk ash content.

This may be attributed to the increased tendency of soil treated with rice husk ash to resist compression due to the formation of pozzolanic products within the pore spaces. The values of C_c obtained from virgin compression curves (pressure-void ratio curves on semi-log plot) are reported in Table 5.

Table 5. Values of Compression index (C_c)

Percentage of rice husk ash stabilization	Compression Index (C_c)
4%	0.508
8%	0.340
12%	0.245
16%	0.238
20%	0.181

Figure 7 (a) to (f) shows virgin compression curves for parent clay and clay stabilised with 4, 8, 12, 16 & 20% of RHA respectively.

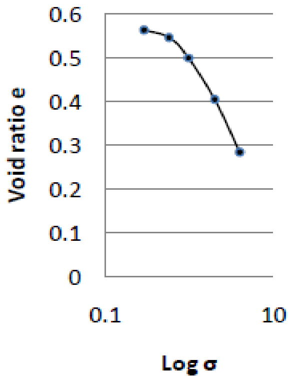
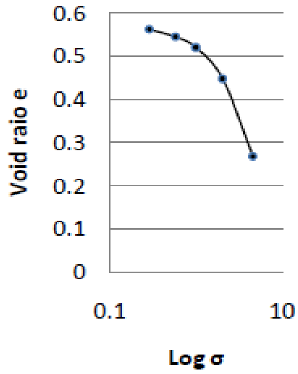


Figure 2 (a)



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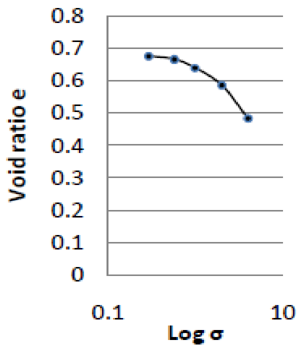
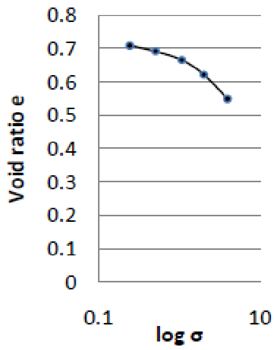


Figure 2 (c)



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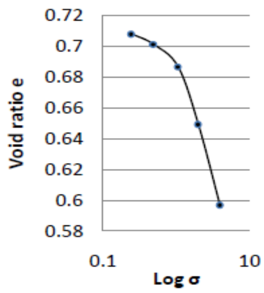

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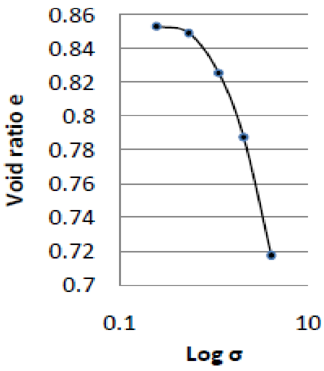

Figure 2 (f)

E. Coefficient of consolidation (C_v)

Based on the analysis of variation of dial gauge readings at various time intervals for a particular stress level with respect to square root of time, the coefficient of consolidation (C_v), for all stabilized clay samples have been determined over a range of consolidation pressures. For parent clay, the value of C_v decreases from 0.347 x 10^{-3} to 0.0732 x 10^{-3} cm^2/sec as the pressure increases from 0.25 kg/cm^2 to 4.0 kg/cm^2, which shows that the time required for the soil to reach a given degree of consolidation increases with increase in effective stress. It has been observed that the values of C_v vary from 0.151 x 10^{-3} to 1.4899 x 10^{-3} cm^2/sec for various percentages of rice husk ash at different effective stresses.

It has been observed that the value of C_v decreases with the increase in effective stress at a particular rice husk ash content. It shows that the time required reaching a given degree of consolidation increases with increase in effective stress at particular rice husk ash content. In general, the value of C_v increases with increase in percentage of rice husk ash at a particular effective stress. It shows that with increase in percentage of rice husk ash, time required for a given degree of consolidation decreases. This behavior may be attributed to the addition of non-plastic material to the soil. The values of C_v are reported in Table 6.

Table 6. Values of Coefficient Of Consolidation (c_v) in cm^2/sec x 10^{-3}

Pressure Increment	Values Of C_v For Various Percentages Of Rice Husk Ash Stabilization					
	0 %	4 %	8%	12%	16%	20%
0.25 kg/cm^2	0.35	0.58	0.85	1.09	1.49	1.28
0.5 kg/cm^2	0.17	0.29	0.42	0.54	0.76	0.64
1.0 kg/cm^2	0.11	0.18	0.27	0.34	0.49	0.50
2.0 kg/cm^2	0.09	0.15	0.22	0.29	0.40	0.34
4.0 kg/cm^2	0.07	0.12	0.18	0.23	0.33	0.27

The variation of coefficient of consolidation with effective stress for various percentages of rice husk ash is shown in Figure 3.

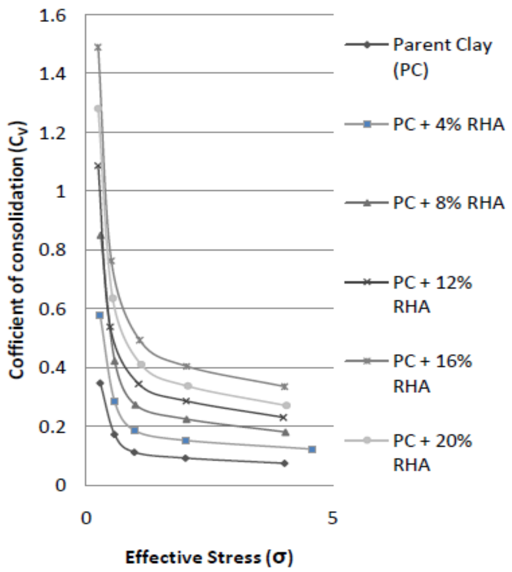

Figure 3. Variation of coefficient of consolidation with effective stress for various percentages of rice husk ash

VI. CONCLUSIONS

The study demonstrates the influence of rice husk ash on the compressibility characteristics of highly plastic locally available clay. The following conclusions have been drawn based on the laboratory investigations carried out in this study:

1. The addition of rice husk ash to the parent material results in an increase in optimum moisture content and decrease in maximum dry density with increase in rice husk ash content.
2. Compressibility analysis of the parent clay and clay stabilized with various industrial wastes indicates that coefficient of compressibility (a_v) shows no significant trend with the variation in the percentage of rice husk ash for a particular effective stress.
   However, a decrease in value of a_v has been observed with an increase in effective stress at a particular percentage of rice husk ash.
3. Study of consolidation parameters of parent clay and clay stabilized with various percentages of rice husk ash indicates that coefficient of volume compressibility (m_v) shows no significant trend with the variation in the percentage of rice husk ash for a particular effective stress. However, a decrease in value of m_v has been observed with an increase in effective stress at a particular percentage of rice husk ash.
4. The use of rice husk ash lowers the slope of virgin compression curves, thereby reducing the values of C_c. It has been observed that rice husk ash is helpful in reducing compression index and hence decreasing the consolidation settlement of the parent soil. This can be attributed to the formation of pozzolanic products within the voids of clay [1].
5. Further, it has 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.

The study shows that treatment of soil with rice husk ash is an effective method of stabilization of problematic soils. To summarize, use of rice husk ash is a beneficial proposition which is economical and environment friendly as well. Results of this study can be used in designing foundations on compacted stabilized clay beds [7]. The optimal percentage of stabilizer for a particular project can be worked out keeping in view the other criterion for design, i.e. the shear strength criterion or bearing capacity criterion.

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