Compression Index of Highly Plastic Clay Stabilized with Waste Materials

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Abstract

One-dimensional consolidation tests have been conducted to study the effect of addition of various percentages of rice husk ash, fly ash and stone dust on compression index of highly compressible clayey 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 various industrial waste materials 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. The addition of rice husk ash to parent material results in an increase in optimum moisture content and decrease in maximum dry density as the rice husk ash content increases. However, no significant change has been observed in the value of maximum dry density for the range of percentage of fly ash added to the soil while a decrease in optimum moisture content with increase in fly ash content has been observed. The use of stone dust as an additive in parent clay results in decrease in optimum moisture content and increase in maximum dry density. Compression index (C_c) has been found to decrease significantly with increase in percentage of additives, though rice husk ash seems to be more helpful in reducing compression index and hence decreasing consolidation settlement of parent material.

Keywords: Consolidation, rice husk ash, fly ash, stone dust, compression index

1. Introduction

It is a well-established fact that when a material is stressed, it undergoes strain. Soil is no exception. When soil is loaded because of the construction of a structure, its volume decreases due to rearrangement of soil particles. If it is assumed that both the soil particles and water in the voids are incompressible and the soil is completely saturated, change in volume of the soil can occur only if water is forced out of the voids. The vertical downward displacement brought about by this volume change shows itself as settlement of the structure standing over the soil. Since the rate at which water moves out of the voids is dependent on permeability of the soil, settlement of the structure itself is a function of permeability of the soil and is, thus, time dependent. While the rate of volume change is related directly to permeability of the soil, the amount of deformation per unit increase in stress depends on a property of soil called its compressibility, which is an engineering property of soil.

The total vertical deformation of a soil layer under stress is, thus, directly proportional to (a) compressibility of the soil, (b) magnitude of stress increase, and (c) volume of the soil or thickness of the layer. The first one is a soil property, the second, a loading condition, and the third, a subsoil boundary condition.

Geotechnical engineer is called upon to predict the magnitude of settlement and rate of settlement of foundations due to structural loads. 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. The total settlement of a loaded soil can be recognized as having three components: the immediate settlement, the settlement due to primary consolidation and the settlement due to secondary consolidation or creep.The immediate settlement or distortion settlement occurs almost immediately after the load is imposed as a result of distortion of the soil without any volume change. This is, of course, an idealized condition. There is such a negligible flow of water out of the soil mass that the volume remains essentially the same unless the soil is either partially saturated or extremely pervious. The immediate settlement is usually determined by using the elastic theory, even though the deformation itself is not truly elastic. In the design of shallow foundations, computation of immediate settlement has to be made.

The squeezing out of pore water from a loaded saturated soil causing a time-dependent decrease in volume is known as primary consolidation. Here, the rate of flow is controlled by the pore pressure, the permeability and the compressibility of soil. With the passing of time, as the pore pressures dissipate, the rate of flow will decrease and eventually, the flow ceases altogether, leading to a condition of constant effective stress. This signifies the end of primary consolidation. Some soils exhibit time-dependent settlement at constant effective stress in the post-primary consolidation period. This is known as secondary consolidation or creep settlement. Secondary consolidation becomes important for certain types of soils, such as peats and soft organic clays. For stiff clays or pre-consolidated clays, this component is relatively minor, as primary consolidation accounts for a major share of the total settlement.

Consolidation of clayey soils is of great concern to engineers engaged in design and construction of foundations, embankments, bridge abutments, earth dams and fills. The existing soil at a construction site may not always be totally suitable for supporting structures. Various techniques to improve consolidation characteristics are:

a) Acceleration of consolidation by providing ‘sand drains’.
b) Soil stabilization by admixtures.

Soil stabilization, in the broadest sense, is the alteration of any property of soil to improve its engineering performance. While certain forms of soil stabilization are relatively new, the art itself is far from young. Thousands of year ago, Neolithic man employed compacted soil in the building of his structures for the burial of his dead. Although the original objective of the soil stabilization was to increase the strength or stability of soil, gradually, techniques of soil treatment have been developed until soil stabilization is now used to increase or decrease almost every engineering property of soil. Over the last few years, the use of fly ash and other industrial wastes has increased as stabilizers for naturally occurring fine-grained soils. These waste products pose a serious environmental problem if not disposed of properly. Their use serves two purposes; first the disposal of waste material and second, use as construction material.

The purpose of present study is to see the effect of waste materials in improving compressibility characteristics of clayey soils.

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.

2. Scenario of waste generation in Haryana

In Haryana, a large number of crusher units are working which produce huge quantity of stone dust. Stone dust not only pollutes water, air and land but its disposal also is a great problem. Due to the high demand for rubble and aggregates for construction purpose, rubble quarries and aggregate crushers are very common. Out of the different quarry wastes, stone dust is one which is produced in abundance. About 20–25% of the total production in each crusher unit is left out as the waste material which is mostly stone dust.

Rice milling generates a byproduct known as husk. This surrounds the paddy grain. During milling of paddy, about 78% of weight is received as rice, broken rice and bran. Rest 22% of the weight of paddy is received as husk. This husk is used as fuel in the rice mills to generate steam for the parboiling process. This husk contains about 75% organic volatile matter and the balance 25% of the weight of this husk is converted into ash during the firing process which is known as rice husk ash (RHA). For every metric ton of paddy milled, about 220 kg (22%) of husk is produced, and when this husk is burnt in the boilers, about 55 kg (25%) of RHA is generated. India is a major rice producing country, and the husk generated during milling is mostly used as a fuel in the boilers for processing paddy, producing energy through direct combustion and / or by gasification. About 24 million metric ton of RHA is produced annually and only 20% of this is utilized. This RHA is a great environment threat causing damage to the land and the surrounding area in which it is dumped.

Nearly 53% of India’s total installed power generation capacity is produced by coal-based thermal power plants. The combustion of powdered coal in thermal power plants produces ash, which contains 80% flyash and 20% bottom ash. Ministry of Power as well as Planning Commission indicate that the coal requirement and generation of flyash during the year 2031-32 would be around 1800 million metric ton and 600 million metric ton respectively. The problem of effective utilization of coal ash has been given wide attention during the last fifteen years in India.Until now only 50% utilization of flyash and bottom coal ash has been made possible. No planning has been made to use the rest 50% of flyash and coal ash.These waste materials are threat to environment as well as are hazardous to human health. Hence, there is a need to look for methods and techniques for bulk utilization of these industrial wastes.

3. Materials and Methods

3.1 Materials

Highly compressible clay used in the experiments has been collected from Samani, Traffic Police Post, GT Road, Kurukshetra. The soil is classified as highly compressible clay, CH, as per IS: 1498 [1]. The grain size distribution and the physical properties of soil are reported in Table 1.

Rice husk ash has been collected from Kohinoor Foods Limited, GT Road, Murthal. The material is classified as ML, silt of low compressibility, as per IS: 1498 [1]. The grain size distribution and the physical properties are reported in Table 1.Fly ash was collected from the first hopper at Panipat Thermal Power Plant, Village Assan, Jind Road, Panipat. Fly ash is classified as ML as per IS: 1498 [1]. The grain size distribution and the physical properties are reported in Table 1.Stone dust was collected from Everest Construction Pvt. Ltd. V.P.O, Khizrabad, District Yamunanagar. The material is classified as SM, sand with silty fines as per IS: 1498 [1]. The physical properties and grain size distribution curve are reported in Table 1. Fig. 1 shows the location of procurement sites for various materials used in the study.

Table 1. **Material properties**

Physical Properties		**Materials**			
		Parent clay	**Rice husk ash**	**Fly ash**	**Stone dust**
Grain Size Distribution	Gravel (%)	0	0	0	8.67
	Sand (%)	6.75	23.22	7.5	79.81
	Clay + Silt (%)	93.25	76.78	92.5	11.49
Specific gravity		2.48	1.95	2.09	2.64
Liquid limit		54	NP	NP	NP
Plastic limit		25			
Plasticity Index		29			
IS Classification		CH	ML	ML	SM
OMC (%)		23.5	-	-	-
MDD (g/cm^3)		1.56	-	-	-

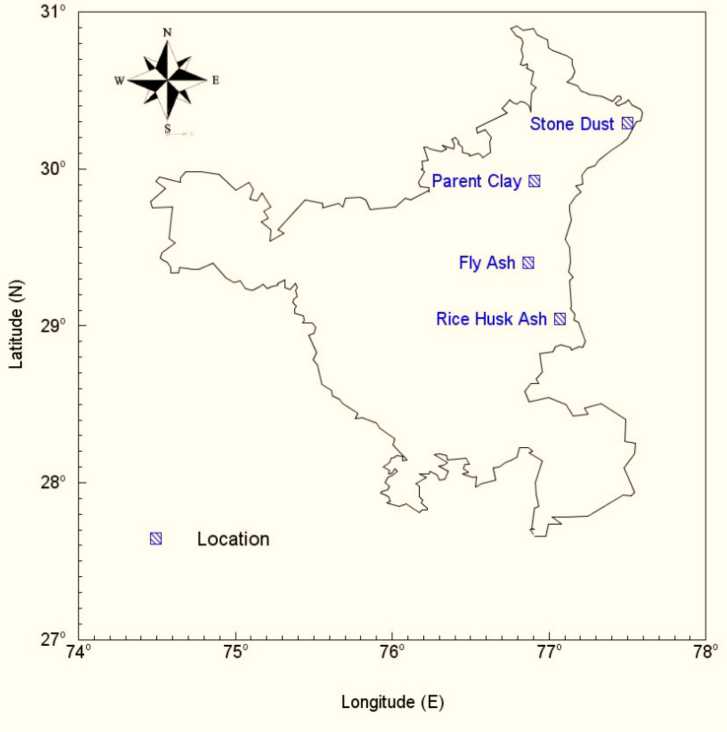

Figure 1. Location of various procurement sites

3.2. Methods

3.2.1 Standard Proctor test

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 various industrial waste materials passing 425 μ 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) [2].

3.2.2 Sample preparation

3.2.2.1 Composition of specimens

Specimens of parent clay and clay treated with 4, 8, 12, 16 and 20% by weight of various industrial waste materials passing 425 μ IS sieve were prepared at maximum dry density and optimum moisture content as per IS: 2720 (Part 7) [2].

3.2.2.2 Mixing

Oven dry soil was dry mixed with various percentages of additives. 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.

3.2.2.3 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 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.

3.2.3 One dimensional consolidation test

A series of one-dimensional consolidation tests were conducted as per the specifications of IS: 2720 (Part 15) [3] to determine the compressibility index of untreated clay and clay stabilized with waste materials to evaluate the effect of different waste materials in reducing compressibility index of the soil. These characteristics have been illustrated by establishing the relationships between void ratio and effective stress. In order to determine magnitude of consolidation, coefficient of compressibility,has been calculated from the observations taken during the tests.

4. Results and Discussion

The objective of the present study is to investigate consolidation characteristics of highly compressible locally available clay soil treated with 4, 8, 12, 16 and 20% by weight of fly ash, rice husk ash and stone dust. This has been done to make the soil suitable for foundation constructions or sub-grades over it.:

4.1 Moisture-density relationship

Standard Proctor tests have been conducted to determine optimum moisture content (OMC) and maximum dry density (MDD) of clay stabilized with various varying percentages of industrial waste materials. Figure2 and Figure3 show comparison of MDD and OMC for clay stabilized with different industrial wastes.

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 could be due to absorption of water by rice husk ash for hydration of free lime.

For clay stabilized with Fly ash OMC varies from 23.5 to 19% and MDD varies from 1.564 to 1.544 g/cc, with increase in percentage of fly ash. It has been observed that there is a decrease in OMC with increase in fly ash content. There is no significant change in value of MDD for the range of percentage of fly ash added to the soil, though a decreasing trend has been observed. Decrease in OMC of the soil with increase in fly ash content could be attributed to addition of non-plastic silty material to parent clay and absence of free lime in fly ash.

For clay stabilized with Stone dust OMC varies from 22.5 to 19 % and MDD varies from 1.624 to 1.662 g/cc, with increase in percentage of stone dust. It has been observed that with increase in the percentage of stone dust OMC decrease and MDD increases. The decrease in OMC with increase in stone dust content could be attributed to the addition of material which is classified as silty sand to the parent material. The presence of stone dust having higher specific gravity could be the cause for increase in density.

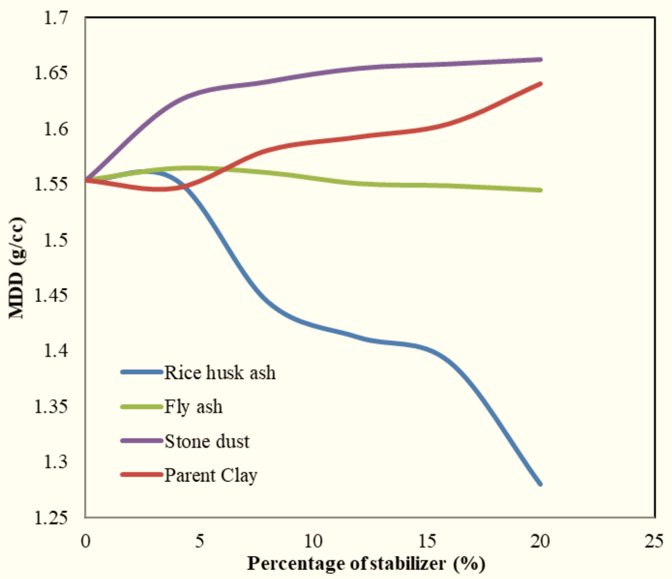

Figure 2. Maximum dry density for various soil samples

4.2 Compression index (C_c)

Based on the analysis of pressure-void ratio curves on semi-log plot, 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. A typical pressure-void ratio curve for parent clay has been presented in Figure 4.

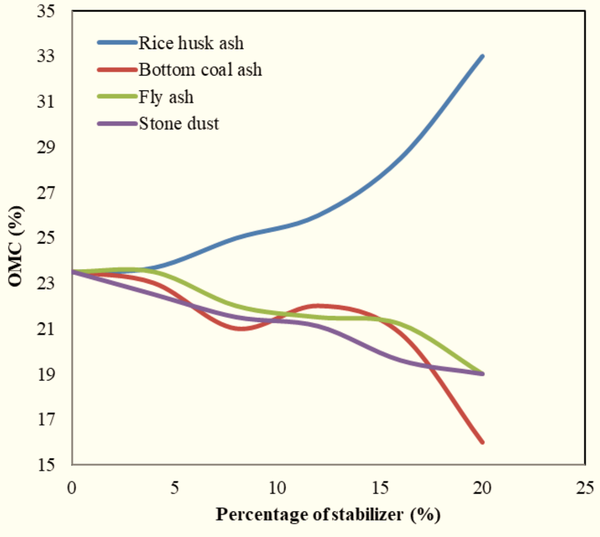

Figure 3. Optimum moisture content for various soilsamples

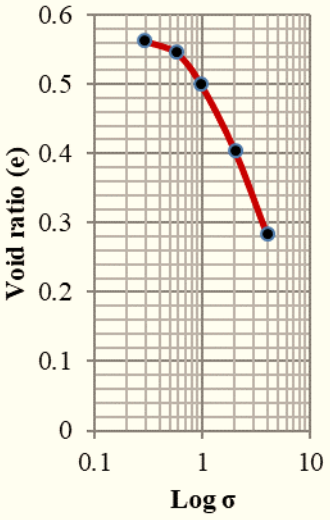

Figure 4. Pressure-void ratio curve for parent soil

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 could 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 vary from 0.441 to 0.326 for various percentages of fly ash. It has been observed that there is a decrease in value of C_c with an increase in fly ash content. This could be attributed to the addition of non-plastic silty material to parent clay.

The values of C_c vary from 0.452 to 0.255 for various percentages of stone dust. It has been observed that there is a decrease in value of C_c with an increase in stone dust content. This could due to the addition of material which is classified as silty sand to the parent material.

Figure 5 shows variation in C_c value for different percentages of various stabilizers. It has been observed that out of the three industrial wastes, rice husk ash is more helpful in reducing consolidation settlement of the parent soil over a large range of effective stresses. These values of C_c for soil treated with various percentages of industrial wastes will help in proper designing of the foundation on the basis of settlement criteria [4].

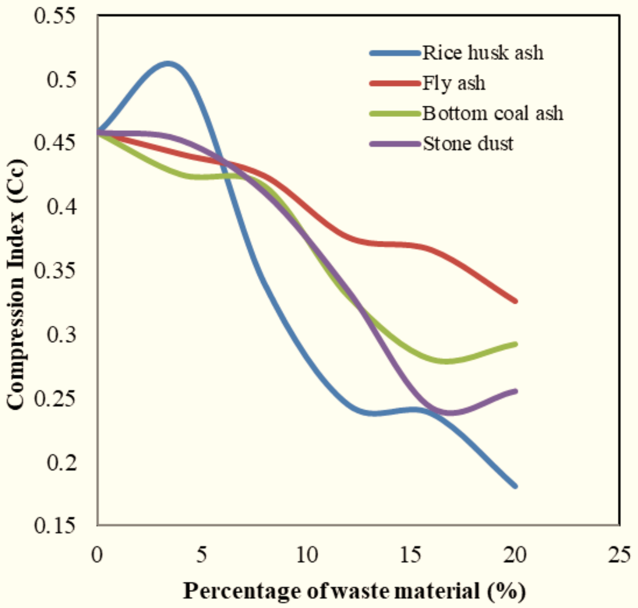

Figure 5. Variation of compression index for various soilsamples

5. Conclusion

The study demonstrates the influence of rice husk ash, fly ash and stone dust on the compression index of highly compressible locally available clay. 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. No significant change has been observed in the value of maximum dry density for the range of percentage of fly ash added to the soil, while a decrease in optimum moisture content with increase in fly ash content has been observed. The use of stone dust as an additive in parent clay results in a decrease in optimum moisture content and increase in maximum dry density with an increase in percentage of stone dust.The use of rice husk ash, fly ash and stone dust as additives lowers the slope of virgin compression curves, thereby reducing the values of C_c. It has been observed that out of the three industrial wastes, addition of rice husk ash is more helpful in reducing compression index and hence decreasing the consolidation settlement of the parent soil.The study shows that treatment of soil with rice husk ash, fly ash and stone dust is an effective method of stabilization of problematic soils. To summarize, use of industrial wastes 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. 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.

Acknowledgement

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Conflict of Interest

The authors declare that they have no conflict of interest and adhere to copyright norms

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