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COMPRESSIBILITY CHARACTERISTICS OF COMPACTED BLACK COTTON SOIL TREATED WITH RICE HUSK ASH

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Abstract
One dimensional consolidation studies on compacted black cotton soil treated with up to 16% rice husk ash (RHA) at the British Standard light compactive effort was carried out to access the compressibility characteristics. The consolidation characteristics of black cotton soil containing 0, 4, 8, 12, and 16% RHA were observed at different moulding water contents (2% dry of optimum, optimum moisture content and 2% wet of optimum) simulating different field placement conditions. Variations of the soil's index properties with ash treatment were also observed. The Atterberg limits showed improved index properties; plastic limit of the soil was found to increase while the liquid limit and plasticity index decreased with increased RHA treatment. The optimum moisture content (OMC) was observed to increase while Maximum Dry Density (MDD) decreased with increased RHA treatment. The swelling pressure decreased with increased RHA content. The consolidation parameters also showed appreciable changes; with the gross yielding stress irrespective of the particle state increasing with increased RHA treatment. The compression index decreased with increased RHA content but increased with increasing moulding water content. The coefficient of volume compressibility, coefficient of consolidation generally decreased with increased loading pressure and RHA treatment for up to 8%. The coefficient of permeability decreased with increased RHA content for up to 8%. These results show an overall improvement in the consolidation properties for up to 8% treatment; suggesting the suitability of the material in fills for embankment and low lying marginal land for foundation works. This also helps in ameliorating the environmental problems associated with the disposal of waste rice husk ash.

Keywords: Black Cotton soil, Consolidation, Gross yielding stress, coefficient of volume compressibility, compression index, coefficient of consolidation, swelling pressure.

1. Introduction

The consolidation of compressible soils is largely of concern to the foundation engineer. Consolidation of poorly compacted soils (either natural soil or fill) when loaded with the weight of a foundation (buildings, roads, embankment etc) is a major geotechnical challenge. Consolidation theory deals with the response of soil systems to imposed load and predicts stresses and displacements of the loaded soil as a function of space and time. This concept is fundamental to the practice of geotechnical engineering where the interaction of soil and water dominates [1]. Consolidation process is even more complex because of the fact that compacted soils are mostly unsaturated. The settlement of structures like embankments, bridge abutments and buildings can produce large displacement, which could be differential and hence produce stresses on the structures over them. This leads to severe cracks and ultimately failure. In engineering practice, reasonably good predictions of a structure's settlement can be made from soil consolidation parameters obtained from the results of carefully run laboratory tests [2].

Black cotton soil is an expansive soil that typically occurs in arid and semi- arid regions of the tropical/temperate zones marked with dry and wet seasons, with low rainfall, poor drainage and exceeding great heat [3 – 5]. Black cotton soils are problematic to civil engineers, because of their unconventional behavior. These soils show large volume changes with respect to variation in seasonal moisture content and form a major soil group found in North Eastern part of Nigeria. They are characterized by high shrinkage and swelling properties.

Black cotton soil, because of its swelling and shrinkage characteristics is a challenge to geotechnical engineers. It is very hard when dry, but losses its strength completely when in wet condition. It exhibits very low bearing capacity, low permeability and high volume change due to the presence of montmorillonite and illite clay minerals. These properties make them unsuitable for construction of embankment, highway, building or any other load bearing engineering structure in their natural state [6 – 8]. These soils when subjected to vehicular traffic in road pavement gets heaved and crack due to swelling and shrinkage.

Modification of black cotton soil by chemical admixtures is a common method for stabilizing the swell-shrink tendency of expansive soils. Advantages of chemical stabilization are that they reduce the swell-shrink tendency of the expansive soil and also render the soils less plastic. In line with that, developing a cheaper material which could be added to expansive soils like black cotton soil to improve its engineering properties becomes necessary especially in the developing countries, where infrastructural development is still a challenge. Research has been on-going, on the possibility of using rice husk ash because of its pozzolanic behaviour in treatment of deficient soils [9 – 12].

Rice husk is one of the major agricultural by-products of the rice milling industries and it is available in all parts of the world. Rice husk constitutes about 20% of the weight of rice. It contains about 50% cellulose, 25–30% lignin, and 15–20% of silica [13]. When rice-husk is burnt, rice-husk ash (RHA) is generated. On burning, cellulose and lignin are removed leaving behind silica ash. The ash is mainly derived from the *opaline,* which is present in the cellular structure of husk and about 90 % of which is silica. The silica content in the rice husk depends on the following: (a) the variety of the rice, (b) soil and climate conditions, (c) prevailing temperature, and (d) agricultural practices ranging from application of fertilizers and insecticides etc. The normal method of conversion from rice husk to ash is by incineration [14]. The burning could be in open heaps, or in a specially designed furnace. About 80% of the organic matter of the husk is burnt off and the resulting ash is the silica-rice husk ash. Rice husk starts to burn at about 350^{o}c and this cause a loss in weight in the husk [15].

Rice husk, which is a waste produced during milling constitutes nuisance to the environment where it is dumped. Disposing this waste safely is often a burden on the producers.

There exist little data in literature concerning the compressibility characteristics or behaviour of compacted black cotton soil treated with rice husk ash when subjected to time dependent one dimensional compression; hence this work aims at understanding the consolidation properties of compacted black cotton soil treated with rice husk ash. A better understanding of these properties will enhance the usage of the material in geotechnical engineering works. The work covers the characterization and one-dimensional consolidation test on black cotton soil treated with up to 16% rice husk ash, compacted using the British Standard Light (BSL) compactive effort that is easily achieved in the field under varying moisture content between 2% dry of optimum and 2% wet of optimum moisture simulating the variation in moisture content that do likely occur in the field.

2. Materials and methods of testing

2.1 Materials

2.1.1 Soil

The soil sample used for this study was collected from a burrow pit located in Baure, Deba local government area of Gombe state, in the North Eastern part of Nigeria. It was collected by method of disturbed sampling at depths of 0.5 – 1.0m below the ground level in order to avoid organic matter. The soil samples were sealed in bags and then transported to the laboratory. Results of previous work on soil samples within this area had shown montmorillonite to be the predominant clay mineral in the soil [16 – 17]. The soil is classified as A-7-5 and CH in accordance with AASHTO soil classification [18] and Unified Soil Classification System, USCS [19], respectively. A summary of the engineering properties of the natural soil is shown in Table 1.

Table 1 Index Properties of the natural soil

Property	Natural Soil
Specific Gravity	2.31
Natural Moisture Content (%)	16.14
Liquid Limit (%)	69.5
Plastic Limit (%)	28.8
Plasticity Index (%)	40.7
AASHTO Classification	A-7-6
USCS Classification	CH
Group Index	45
Maximum Dry Density (Mg/m^3)	1.48
Optimum Moisture Content (%)	26.0
Cation Exchange Capacity (cmol/kg)	33.6
Colour	Grayish black
Percentage of fines	94.85

2.1.2 Rice Husk Ash (RHA)

The Rice Husk Ash used for this research work was obtained locally from Funtua town of Katsina State, Nigeria. Raw husk of parboiled rice was collected from the local milling industry and burnt for 7 days in an open place. For the initial 24 hours of burning, the husk remained charcoal (dark) but gradually turns to gray ash with continuous heating. After it was collected to laboratory, the ash was sieved through sieve with 75µm aperture size and kept in tight polythene bags to avoid any form of hydration. The ash obtained was used to treat black cotton soil in percentages of 0, 4, 8, 12 and 16% respectively by weight of the dry soil to give five different soil-rice husk ash mixtures with 0% as the natural soil. Oxide composition of the rice husk ash used in this study was obtained through a Compact Energy Dispersive X-ray Spectrometer Method (Mini Pal), designed for elementary analysis of a wide range of samples. The test was carried out at the Centre for Energy Research Technology (CERT), Ahmadu Bello University Zaria, Nigeria. The Oxide Composition is as shown in Table 2.

Table 2: Oxide Composition of rice husk ash used

Oxide	Concentration (%)
Al_2O_3	1.50
SiO_2	51.30
SO_3	0.63
CaO	3.12
Fe_2O_3	4.49
L.O.I	4.50

Thus, following the ASTM C618 [20] classification of Pozzolanas,

$SiO_3 + AlO_3 + Fe_2O_3 = 57.29\% > 50\%$

$SiO_3 = 0.63\% < 5\%$

L.O.I. $= 4.5 < 6.0$

Therefore the RHA used falls under class C pozzolanas.

2.2 Methods

2.2.1 Index properties

Laboratory tests were conducted to determine the index properties of the natural soil and soil- rice husk ash mixtures in accordance with British Standards [21].

2.2.2 Compaction

British standard light compactive effort was used. Air dried soil samples passing through British Standard sieve with 4.76mm aperture mixed with 0%, 4%, 8%, 12% and 16% rice husk ash by weight of dry soil were used. British Standard Light effort was carried out in accordance with British Standard [21].

2.2.3 Consolidation Test

One dimensional consolidation test was carried out in accordance with British Standard [21] and as described by Head [22].

2.2.4 Experimental Program

Black cotton soil-rice husk ash mixtures were compacted at 2% dry of optimum, at optimum moisture content, and 2% wet of optimum simulating the variation in moisture that might occur in the field. These specimens were cored into the oedometer ring and placed in the consolidometer setup. Pressure increment was $100kN/m^2$, $200kN/m^2$, $400kN/m^2$ and $800kN/m^2$ during the loading stage and unloaded up to $200kN/m^2$. Compression readings were recorded between 10 sec and 24 hours during the loading stage for each incremental load. The Taylor method (Square Root of Time Method) was used to analyze experimental results. The gross yielding stress was obtained from the void ratio - pressure curve using the procedure proposed by Casagrande [23] and Burland [24]. In order to check the reproducibility of the test results, consolidation tests evaluating the compressibility characteristics (void ratio, compression index, gross yielding stress, coefficient of volume compressibility and coefficient of consolidation) were repeated on six of the fifteen samples, which were chosen at random. The differences in test results between the two tests were within $\pm 10\%$.

2.2.5 Swelling Pressure

This was obtained using the Potential Volume Change (PVC) machine. Compacted specimen were placed in the PVC machine, After compaction and the apparatus set up, the proving ring dial gauge was set at zero and water was placed in the containing cell to ensure complete saturation throughout the experiment. The soil sample was allowed to swell freely with the readings taken from the proving ring dial gauge until steady readings were obtained. The swelling pressure was determined subsequently.

3. Discussion of Test Results

3.1 Index Properties

The Atterberg limit results showed improved index properties with a decrease in liquid limit (from 69.5 to 55%), an increase in plastic limit (from 28.8 to 34.5%) and a decrease in plasticity index (from 40.7 to 20.5)% with increased rice husk ash content for up to 16% treatment. Okafor and Okonkwo [9] considered the reduction to be as a result of replacement of soil fines by rice husk ash content. They asserted that rice husk ash has high affinity for water therefore decreasing the liquid limit. According to Yesilbas [25], there is usually significant decrease in liquid limit values of the samples with the increasing amount of stabilizer content. These changes are also probably due to physico-chemical reaction (i.e., cation exchange) that depends on particle surface ion hydration and inter-particle attractive forces [26]. These results are in agreement with the works of other researchers [27 – 29] when fly ash was used. The decrease in plasticity index and liquid limit with increased rice husk ash treatment show that the engineering properties of the soils are improved.

The specific gravity also decreased from 2.31 to 2.03 for up to 16% rice husk ash treatment.

3.2 Compaction Characteristics

The compaction characteristics of black cotton soil with RHA are shown in Figure 1. It is observed that the Maximum Dry Density (MDD) decreased with increased RHA content for up to 16% treatment. It decreased from 1.48Mg/m^3 to as low as 1.278 Mg/m^3 at 16% RHA content. On the other hand, the Optimum Moisture Content (OMC) increased from 26% to 33.5%. Muntohar [14] observed a similar trend when a very expansive soil from Indonesia that was treated with RHA and Lime. He attributed the diminishing MDD of the soil to the relatively low specific gravity of the admixtures while the increase in OMC might have been caused by absorption of moisture by the additives to precede chemical reaction. Okafor and Okonkwo [9] made the same conclusion when they observed similar trend in RHA treated lateritic soil; but further attributed the low MDD to the coating of the soil particles by the RHA which results in larger particles with larger voids hence less density. They also suggested that the OMC increased due to reduction of free silt and free clay fraction in the soil forming a coarser material, a process requiring water to take place, thus more water is absorbed as RHA content increases.

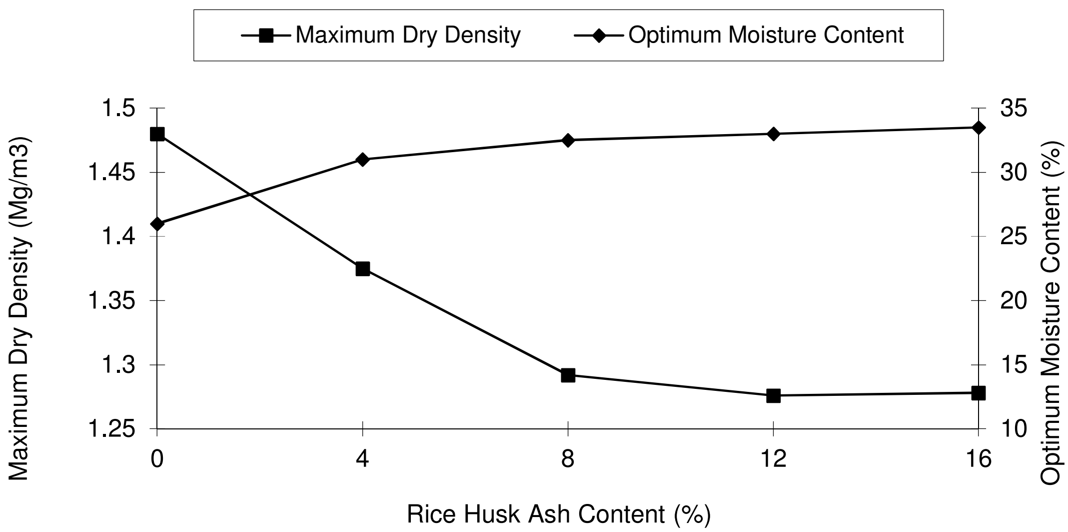


Figure 1: Variation of maximum dry density and optimum moisture content with RHA Content

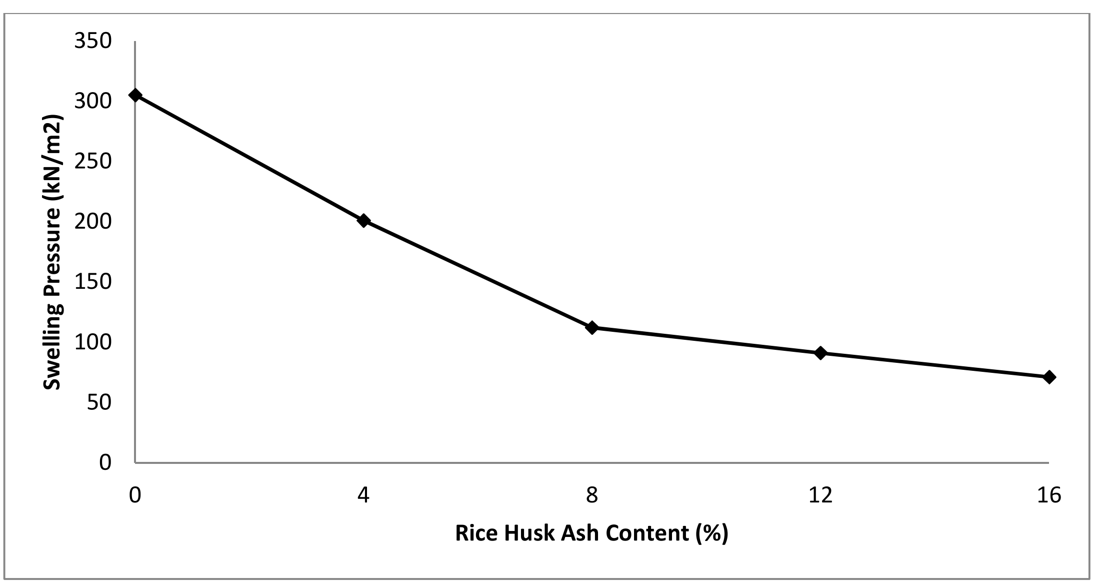


Figure 2: Variation of swelling pressure with rice husk ash content

3.3 Swelling Pressure

Expansive soils are known to have great swelling ability because of the presence of swelling dominant clay minerals such as the smectite group. The swelling pressure as shown in Figure 2 decreases with increase in RHA treatment. The swelling pressure decreased from 305kN/m^2 at 0% RHA content to as low as 71 kN/m^2 at 16% RHA content. This implies that as more rice husk ash is added, the lesser the swelling potential of the compacted soil and hence the more stable the material is. Yasilbas [25] also discovered that all of the stabilizers he used caused considerable reduction in the swelling potential of expansive soils; he added that it is also consistent that swelling potential decreases with the amount of stabilizer.

Observation made by Muntohar [14] also fully agreed with that. He found out that RHA could reduce the swelling potential of the expansive soil he used by up to 64%. According to Brooks [30] the reduction may be due to the cation exchange in the soil – pozzolan mix during which sodium ions in the soil are substituted by calcium ions in the pozzolan.

3.4 Consolidation Characteristics

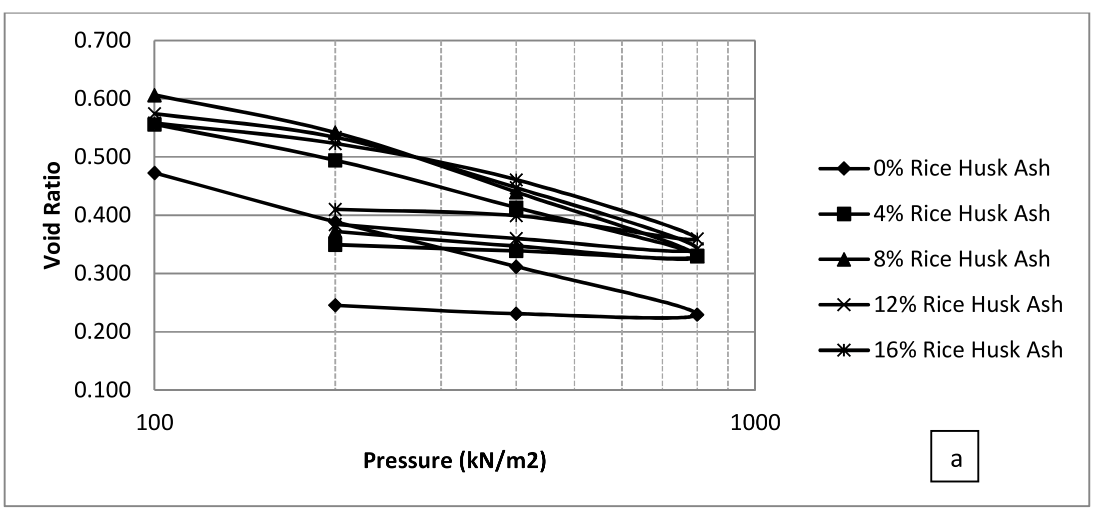
The consolidation characteristics of the various soil-RHA mixtures compacted at different moulding water contents were observed through the void ratio, gross yielding stress, compression index, coefficient of volume compressibility and the coefficient of consolidation. These are discussed under the effect of the rice husk ash content, effect of the moulding water content and effect of pressure

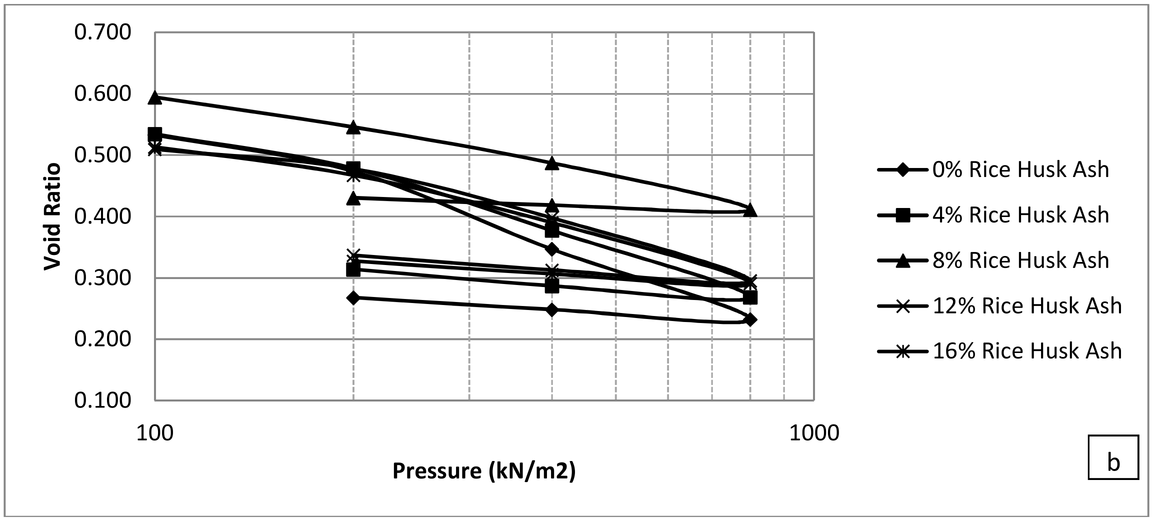
3.5 Void Ratio

The relationship between the void ratio and pressure is shown in fig 3. The results show a pattern similar to that of natural clay. The void ratio decreased with increased pressure during the loading stage from 100kN/m^2 to 800kN/m^2 and it increased as pressure was released during the unloading stage for all cases of ash treatment. The same variation were observed irrespective of the particle state at the dry side of OMC, optimum moisture content and wet side of OMC. The reason for this variation is the adjustment of the soil particles to fill up any available void present in response to pressure applied and the slight readjustment during pressure release.

On the dry side of OMC, during the loading stage for 100 and 200kN/m^2 pressure and increasing rice husk ash treatment the void ratio generally increased before decreasing at 12% RHA treatment; while for 400 and 800kN/m^2 pressure during loading the void ratio generally increased for up to 16% RHA content. Also, void ratio plots of higher RHA treatment generally plot below those of lower RHA content. At the OMC during the loading stage, irrespective of the pressure applied the void ratio generally increased for up to 8% RHA treatment before decreasing from 12% RHA content. Furthermore, higher RHA content except for 8% treatment generally plot above those of lower RHA treatment.

On the wet side of OMC, there was an increasing and decreasing pattern with void ratio at the different loading pressure and hence no clear trend could be observed. Generally at this particle state, void ratio of higher RHA treatment plot above those of lower RHA content except for the natural soil. These results show that the particle state of the soil as a result of the placement condition (moulding water content) seriously affects the void ratio.





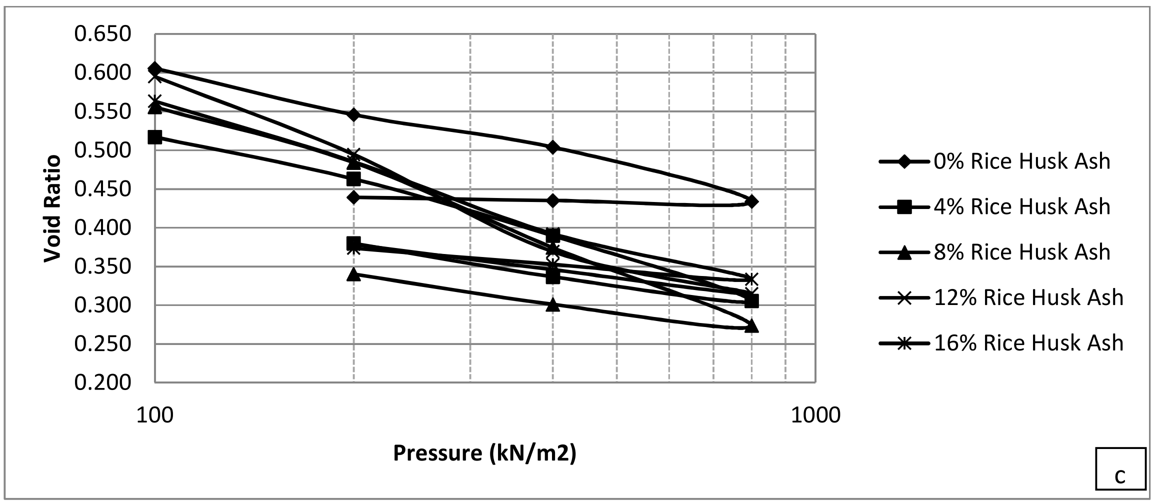


Figure 3 Variation of void ratio with pressure for specimens prepared at (a) 2% dry of optimum (b) optimum moisture content and (c) 2% wet of optimum.

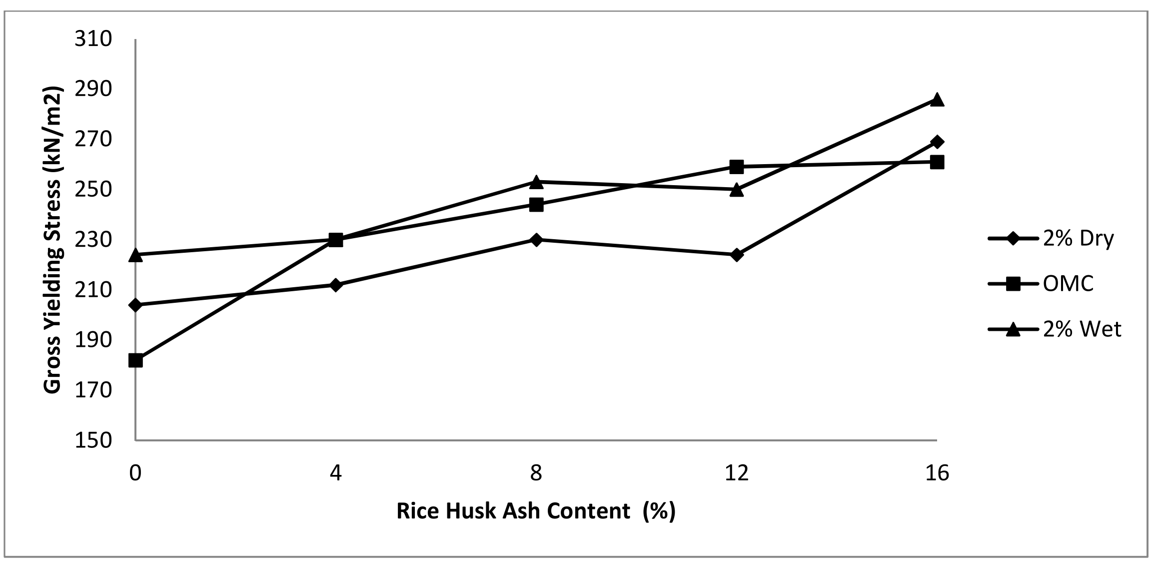


Figure 4: Variation of gross yielding stress with rice husk ash content.

3.6 Gross Yielding Stress (σ_{yv})

3.6.1 Effect of Rice Husk Ash Content

Burland [24] suggested using Gross Yielding Stress (σ_{yv}) to describe the critical stress separating small to moderate strains from large strains for non-structured soils (reconstituted/ remoulded soils); which encompasses the stress history of the soil resulting from mechanical compaction, cementation or binding of the soil particles due to physico-chemical changes; instead of pre-consolidation pressure which is an effect of the stress history of a soil that can be established from geological processes [31].

The relationship between gross yielding stress and rice husk ash content is shown in fig 4. The results show that there is a continuous increase in gross yielding pressure as the rice husk ash content of the black cotton soil increased from 0 to 16%. It increased from 204 to 269 kN/m^2 at the dry side of optimum; from 182 to 261 kN/m^2 at the OMC and from 224 to 286 kN/m^2 on the wet side of optimum. These results show that both increase in RHA content and moisture placement condition allow the gross yielding stress to increase.

The increase in gross yielding stress due to increased RHA treatment could have occurred in two ways; first, the RHA changes the soil's matrix by increasing the fines during compaction (since compaction was performed immediately after mixing which did not allow for the immediate agglomeration of fines) this makes the soil easier to compact and results in more intact alignment of the soil. Secondly, the pozzolanic reaction that continues after mixing by formation of calcium silicate hydrates increases the soil's strength and in turn makes the soil to require more pressure to consolidate. Brooks [30] in his study of fly ash and RHA stabilization of expansive soil showed tremendous increase in unconfined compressive strength as the ash content increases. The significance of these results is that black cotton soil is able to withstand increased yielding stress before settlement at higher RHA content.

3.6.2 Effect of water content with relative to optimum

The variation in gross yielding stress with water content relative to optimum is shown in Figure 5. The gross yielding stress generally increases irrespective of the RHA treatment with increase in water content relative to optimum except for the natural soil at the OMC and 16% RHA treatment on the dry side of optimum. Compaction under increasing moulding water from the dry to the wet side of optimum moisture content will result in soils containing smaller macro pores. The increasing water helps in deflocculating the particle structure and reducing the voids [32]. Softer wet clods of soils are generally easier to remould and it results in smaller inter-clod voids [33].

This could probably be due to the formation of pozzolanic products resulting from hydration and pozzolanic reactions that evolved between the rice husk ash and water present in the soil matrix. This means that the higher the water content in the matrix, the more the hydration effect caused by rice husk ash, and hence the more the gross yielding stress will continuously increase from the dryer side to the wetter side of optimum.

Since the gross yielding stress is the critical stress separating small to moderate strains from large strains, pressures applied to the foundation soil that exceed the gross yielding stress may cause substantial settlement. This means that as the gross yielding stress increases with increasing rice husk ash content the potential settlement decreases because the applied pressure will become relatively more difficult to exceed the increasing gross yielding stress.

3.7 Compression Index (C_C)

3.7.1 Effect of Rice Husk Ash content

Compression index is a very useful parameter in the determination of consolidation settlement of clayey soils; the greater the compression index the more prone a soil is to one dimensional consolidation. Figure 6 shows the relationship between the compression index of black cotton soil and the RHA content. The compression index generally reduces with increased RHA treatment in all cases except on the dry side of optimum moisture content where it started increasing slightly after 8% RHA treatment. The decrease in compression index could be as a result of increased formation of pozzolanic products within the pore spaces from physico-chemical changes which leads to a reduction in compression index. Similar results were obtained by other researchers [34 – 35] for soft soils with increased cement ratio. Montohar [14] observed that the addition of RHA and Lime reduced the compression index; according to him when the RHA content exceeds the amount required for reaction, they will be filled between the void of soil because their particle size is smaller than that of the soil. A more compact state of soil is probably attained; concomitantly the compressibility of soil diminishes. Okoro [36] also attributes the reduction to the replacement of fine clay particles with non-plastic fines.

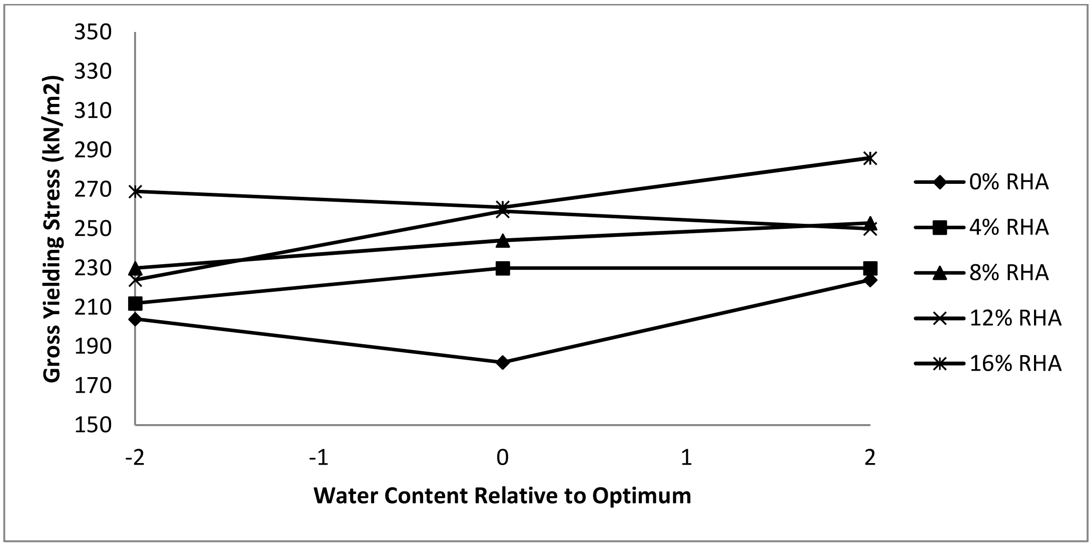


Figure 5: Variation of gross yielding stress with water content relative to optimum

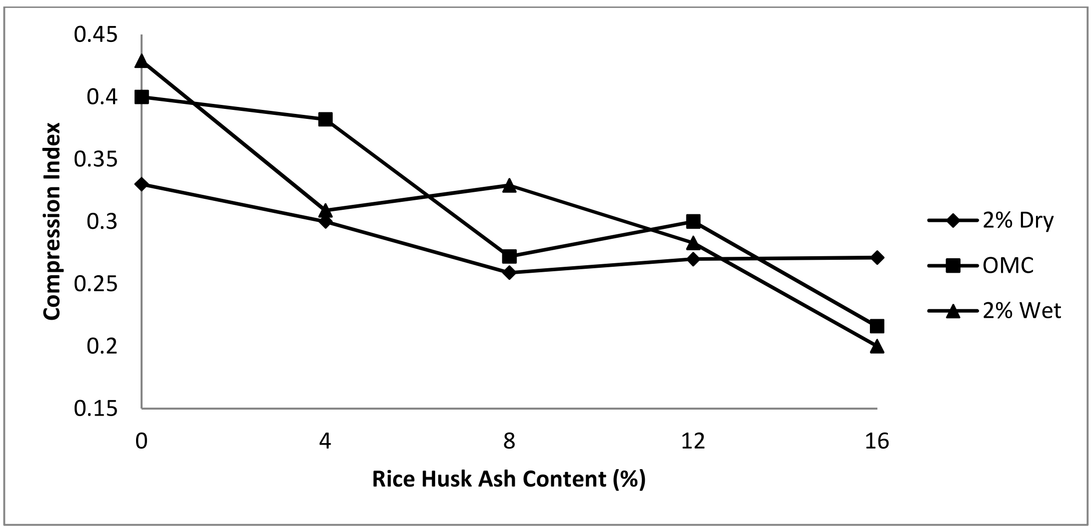


Figure 6: Variation of compression index with rice husk ash content

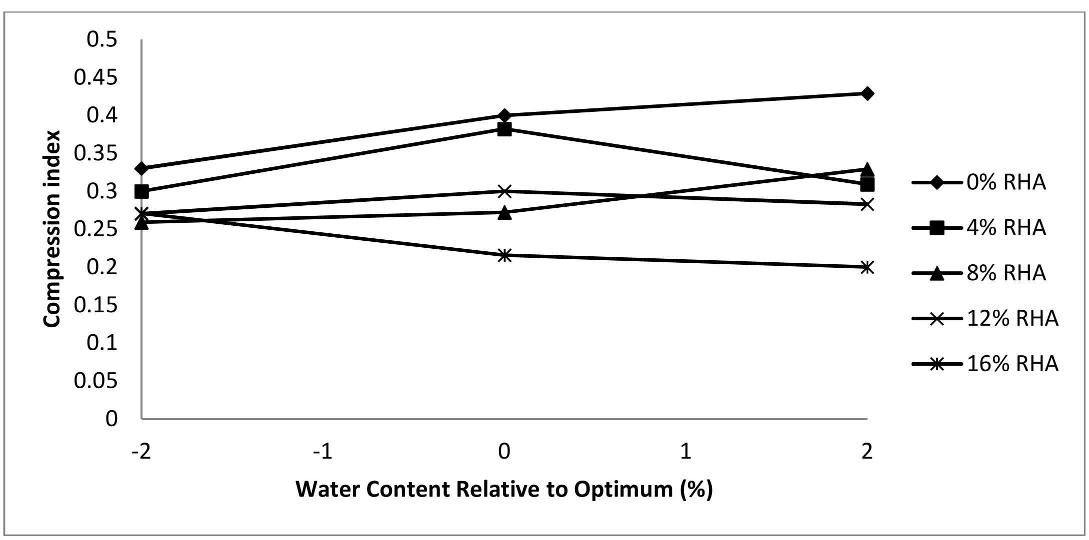


Figure 7: Variation of compression index with water content relative to optimum

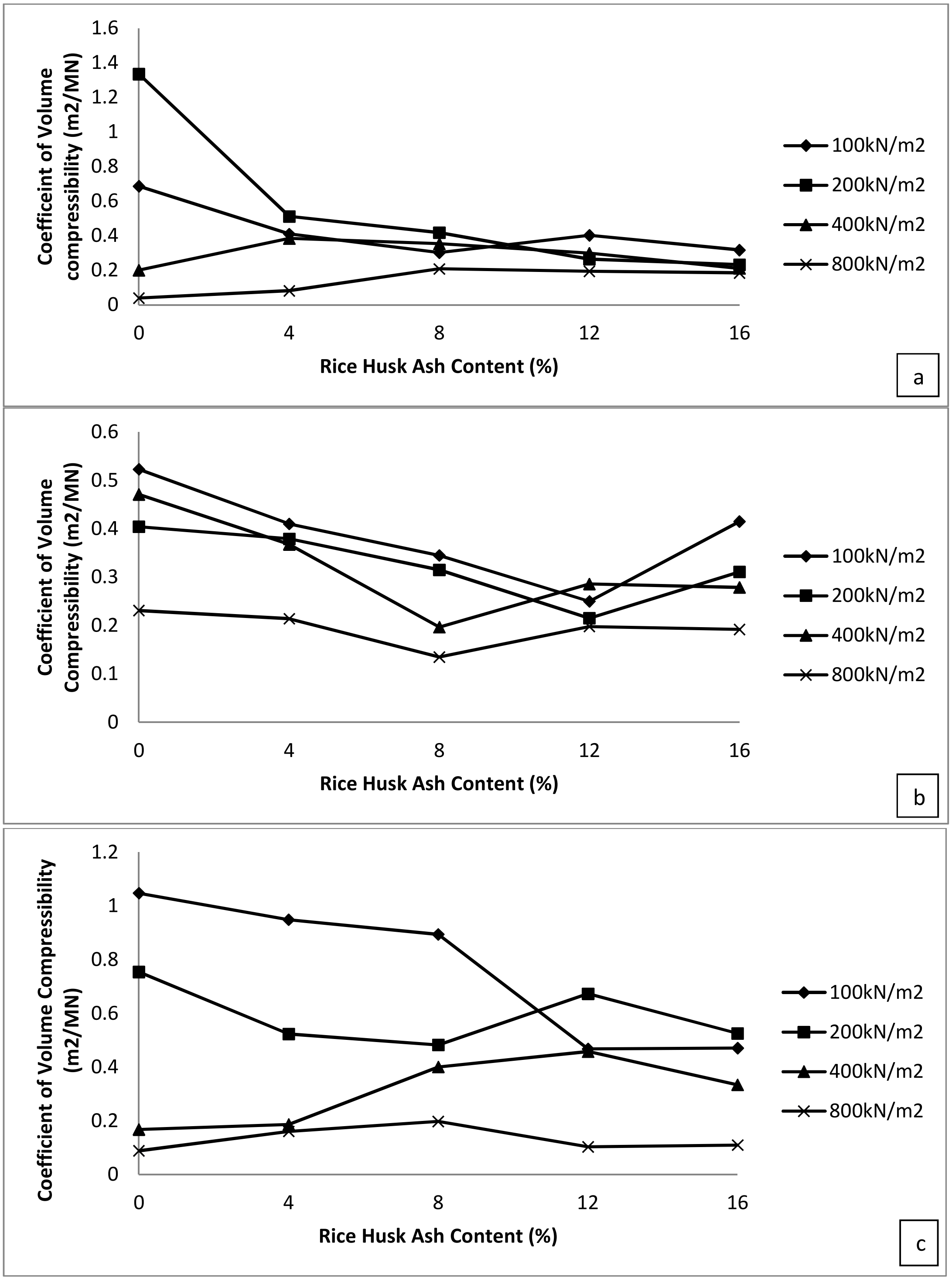


Figure 8: Variation of coefficient of volume compressibility with rice husk ash content for (a) 2% dry of optimum (b) optimum moisture content and (c) 2% wet of optimum.

3.7.2 Effect of water content relative to optimum

The variation of compression index with respect to moulding water content relative to optimum is shown in Figure 7. With increasing water content relative to optimum, the compression index increases for 0 and 8% RHA treatment, it increases before decreasing at 4 and 12% RHA treatments; while it decreased at 16% RHA treatment. Hence no specific trend can be attributed to the effect of the moulding water.

3.8 Coefficient of Volume Compressibility (M_V)

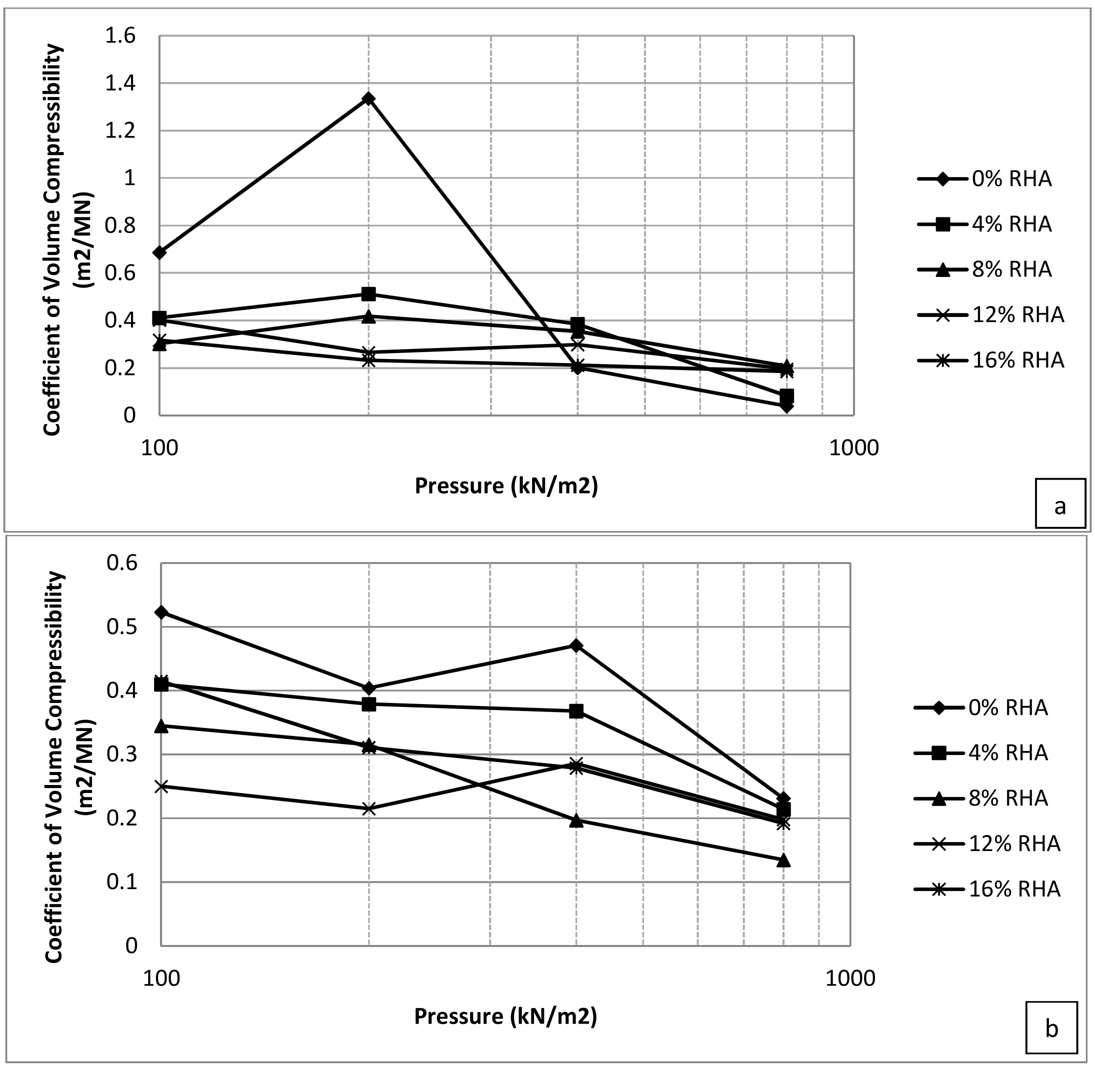
3.8.1 Effect of Rice Husk Ash Content

The effect of RHA content on the coefficient of volume compressibility (M_V) is shown in Figure 8. The coefficient of volume compressibility generally decreases with increased RHA treatment on the dry side of optimum moisture content; at OMC it decreased for up to 8 and 12% RHA treatment respectively before increasing. On the wet side of optimum moisture content, no clear trend could be established on the effect of RHA treatment due to high scattering of the data.

These results show that the influence of the soil particle orientation which varies greatly between the dry and wet side of optimum has more influence on coefficient of volume compressibility than the rice husk ash treatment. Kazamian and Huat [35] reported a decreasing coefficient of volume compressibility with increasing cement ratio. Montohar [14] also agreed with that. The pozzolanic reaction taking place and the more intact compaction achieved by increasing the RHA content are given the credit for the positive change.

3.8.2 Effect of Pressure

The variation of coefficient of volume compressibility with pressure is shown in Figure 9. Irrespective of the particle state (placement condition) or rice husk ash treatment, the coefficient of volume compressibility generally decreases with increase in consolidation pressure. The decrease may be attributed to the fact that initial loading increment causes the soil to attain very large compression by expulsion of voids. With further increment of the loading pressure, only little amount of compression is achieved. Similar results were obtained by other researchers [35, 37] as the change in volume per unit volume, per unit pressure will decrease with increasing consolidation pressure; as a result of consolidation due to that pressure change.



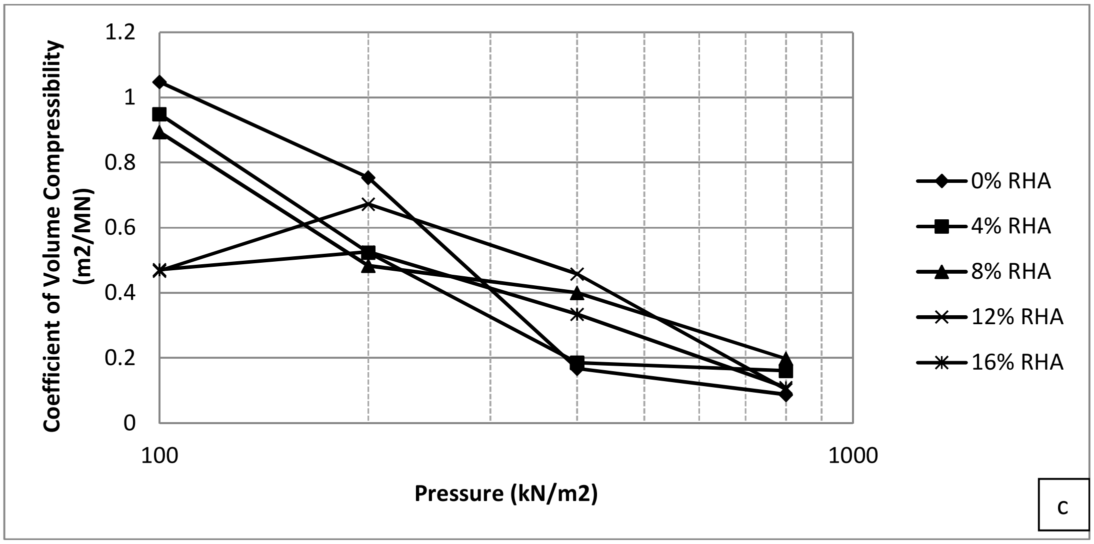


Figure 9: Variation of coefficient of volume compressibility with pressure for (a) 2% dry of optimum; (b) optimum moisture content; (c) 2% wet of optimum.

3.9 Coefficient of Consolidation

3.9.1 Effect of Rice Husk Ash Content

The relationship between the coefficient of consolidation and the RHA content is shown in Figure 10. The results show that the coefficient of consolidation on the dry and wet side of optimum moisture content generally decreases at the initial stage of rice husk ash treatment for up to 8%; thereafter it starts to increase. For specimens prepared at the OMC, the coefficient of consolidation decreased for up to 12% RHA treatment before increasing. This variation could be due to the formation of increased pozzolanic products from the rice husk ash [29].

Previous studies [38 – 39] had shown that the coefficient of consolidation in clays is influenced by mechanical and physicochemical factors that govern compressibility effects. Also Kazemian and Huat [35] observed that in fibrous rein-forced tropical peat treated with cement, there was a decrease in C_v with increased cement ratio. These results implies that the rate at which black cotton soil treated with RHA will undergo one-dimensional consolidation is gradually reduced as the RHA content is generally increased for up to 8% treatment irrespective of the soil state.

3.9.2 Effect of Pressure

The variation of coefficient of consolidation with pressure is shown in Figure 11. Generally, irrespective of the particle state and RHA treatment, the coefficient of consolidation decreases with increase in applied pressure. The lowest values of C_v were recorded on the dry side of optimum at 8% RHA treatment which decreased from 3.340 to 1.99 m^2/year; at the OMC it was recorded at 12% RHA content where C_V decreased from 4.679 to 1.587 m^2/year and on the wet side of optimum it was recorded at 16% RHA treatment where C_v values decreased from 4.945 to 2.134 m^2/year. These imply that increased pressure decreases the coefficient of consolidation of compacted black cotton soil treated with RHA, in agreement with the work of other researchers [37]. As the consolidation pressure increases beyond the gross yielding pressure the soil will settle faster. This could also be attributed to the consolidation being controlled by mechanical effects [39].

3.10 Coefficient of Permeability (k)

The relationship between the coefficient of permeability and rice husk ash content is shown in Figure 12. Results generally show a decreasing trend with increased RHA treatment for up to 12% and a slight increase from 12% to 16% treatment for 200, 400 and 800kN/^{2} loading pressure. At 100kN/m^2, the trend is irregular. As the RHA is increased, pozzolanic products are formed which block the pore spaces and hence reduce permeability, until the soil matrix is changed when the coefficient of permeability begin to increase [40]. Alhassan [41] also observed similar trend within a soil-lime specimen treated with RHA. He attributed the decrease to the formation of cementitious compounds by calcium from lime and the readily available silica and/or alumina from both the soil and RHA, which fills the soil voids thereby obstructing the flow of water.

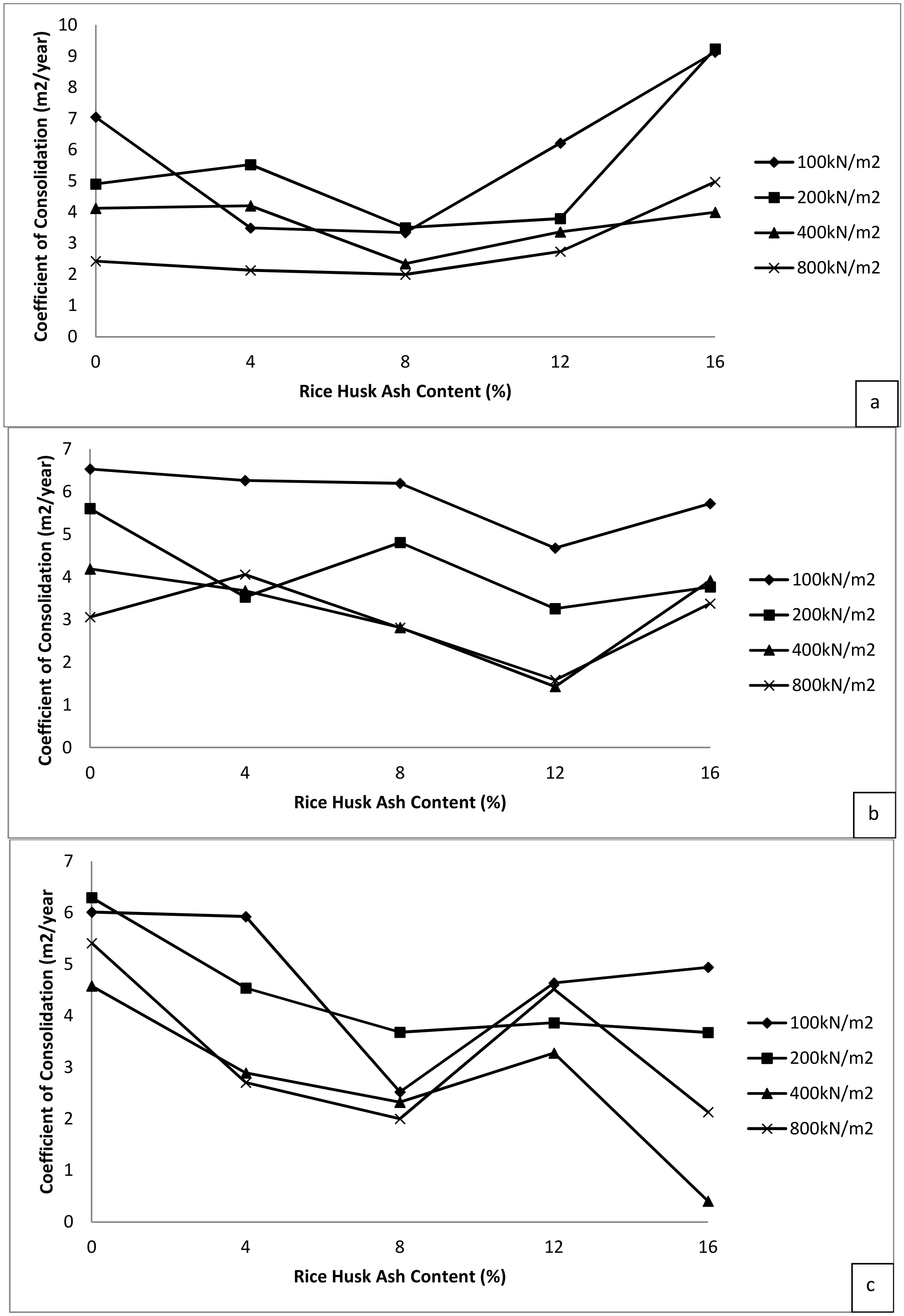


Figure 10: Variation of coefficient of consolidation with rice husk ash content for (a) 2% dry of optimum (b) optimum moisture content (c) 2% wet of optimum.

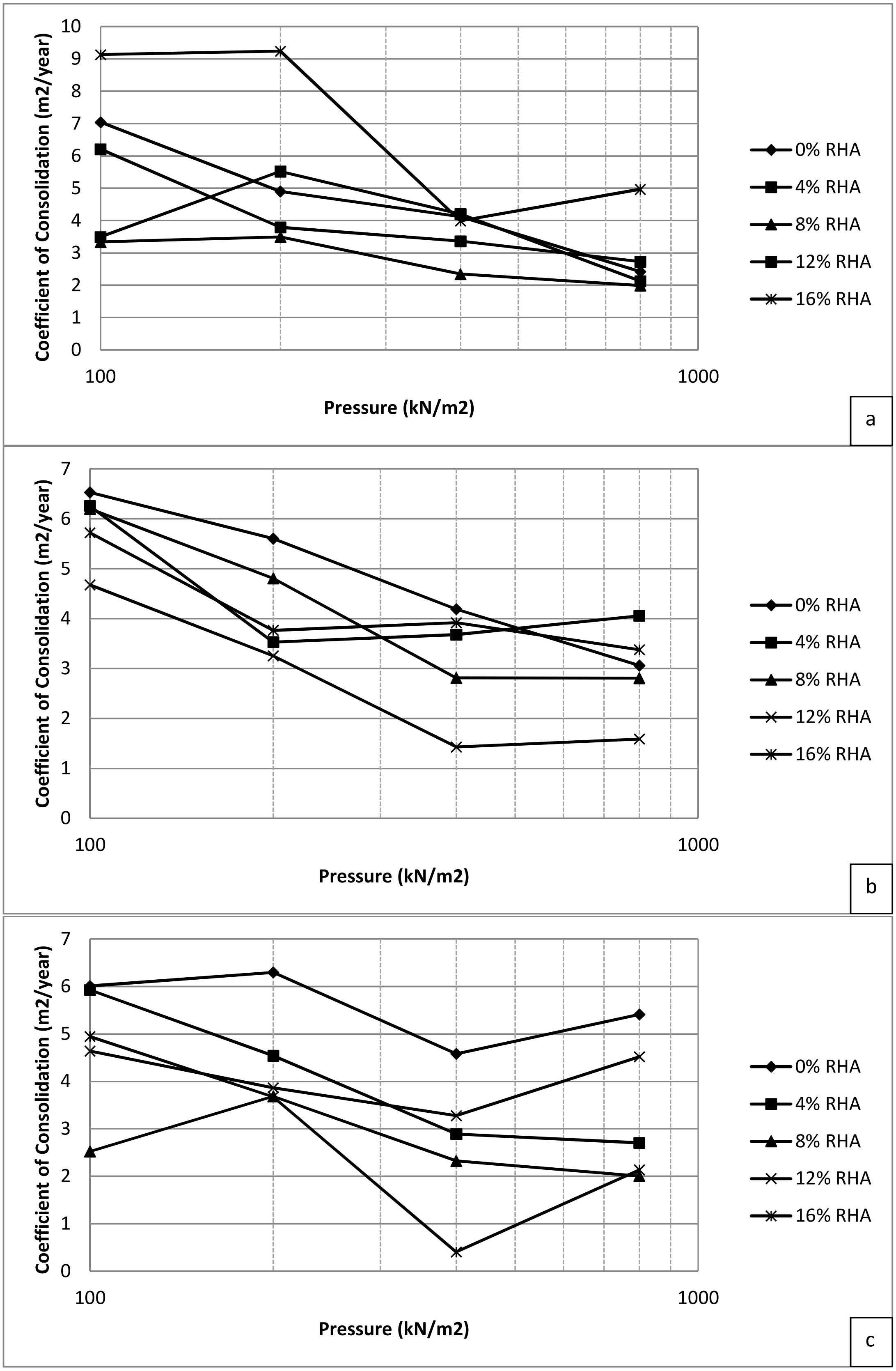


Figure 11: Variation of coefficient of consolidation with pressure for (a) 2% dry of optimum; (b) optimum moisture content; (c) 2% wet of optimum.

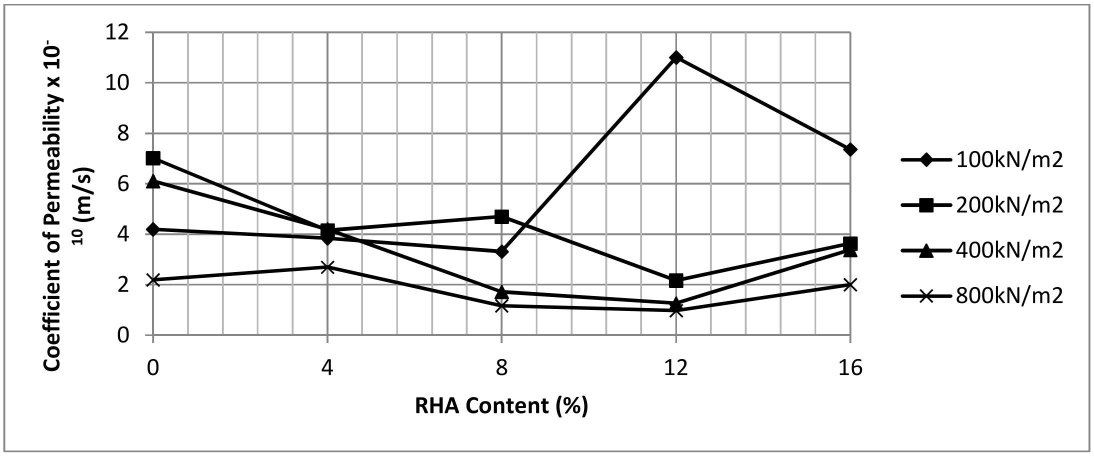


Figure 12: Variation of coefficient of permeability with RHA content at the optimum moisture content

4. Conclusion

Black cotton soil was classified as A-7-6(45) and CH using AASHTO and USCS classification system respectively was treated with up to 16% rice husk ash. Treated specimens were, compacted using British standard Proctor effort at different moulding water contents (2% dry of optimum, optimum moisture content and 2% wet of optimum) and subjected to one dimensional consolidation test; to assess their compressibility characteristics.

Index tests showed improved index properties with the liquid limit reducing from 69.5 to 55% while the plastic limit increased from 28.8 to 34.5% thereby reducing the plasticity index with up to 20% for up to 16% RHA treatment. The compaction characteristics showed a decrease in MDD from 1.48 to 1.28Mg/m^3 and increase in OMC from 26 to 33.5%. Swelling pressure decreased with up to 77% by the addition of 16% RHA.

The gross yielding stress increased from 182 to 261kN/m^2 with up to 16% RHA content and also with increased moulding water content. Increased RHA treatment caused reduction in compression index while increasing moulding water content increased the compression index. The coefficient of volume compressibility generally decreased with increased RHA treatment on the dry side of optimum and at OMC for up to 8 and 12% RHA treatment respectively, before increasing. On the wet side of optimum, no clear trend was established; show that the influence of the soil particle orientation which varies greatly between the dry and wet side of optimum has more influence on coefficient of volume compressibility than the rice husk ash treatment. Irrespective of the particle state (placement condition) or rice husk ash treatment, the coefficient of volume compressibility generally decreased with increase in consolidation pressure.

The coefficient of consolidation on the dry and wet side of optimum moisture content generally decreased with increased RHa treatment for up to 8% before increasing, while at the OMC it decreased for up to 12 RHA treatments before increasing. Irrespective of the particle state and RHA treatment, the coefficient of consolidation generally decreases with increase in applied pressure. The coefficient of permeability generally shows a decreasing trend with increased RHA treatment for up to 12% and a slight increase from 12% to 16%.

Based on the findings of this study, rice husk ash treatment of up to 8% will improve the compressibility characteristics of compacted black cotton soil irrespective of the placement condition between dry and wet of optimum. These also shows that the material will be suitable for fills in embankment works, reclaiming low lying marginal lands and foundation works. It will further reduce the environmental problems associated with the waste disposal of rice husk ash.

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