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Improvement of Clayey Soil Characteristics Using Rice Husk Ash

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ABSTRACT: Rice husk ash (RHA) is a pozzolanic material that could be potentially used in soil stabilization, though it is moderately produced and readily available. When rice husk is burnt under controlled temperature, ash is produced and about 17%-25% of rice husk's weight remains ash. This paper presents the results of experimental study carried out on three different soils improved with different percents of rice husk ash. Samples were brought from different sites of Iraq. The testing program conducted on the clayey soil samples mixed with different percentages of rice husk materials, included Atterberg limits, specific gravity, compressibility, unconfined compression test and consolidation test. It was found that the liquid limit of the three soils has been decreased by about (11 - 18) % with the addition of 9% RHA, while the plasticity index decreased by about (32 - 80) %. Treatment with rice husk showed a general reduction in the maximum dry unit weight with increase in the rice husk content to minimum values at 9% rice husk content. The optimum moisture content generally increased with increase in the RHA content. There is enormous increase in the unconfined compressive strength with increase in rice husk content for the soil to its maximum at RHA between (6 – 8) %.

Keywords: Clayey soil, improvement, rice husk ash, strength.

ORIGINAL ARTICLE

INTRODUCTION

Soil improvement could either be by modification or stabilization or both. Soil modification is the addition of a modifier (cement, lime etc.) to a soil to change its index properties, while soil stabilization is the treatment of soils to enable their strength and durability to be improved such that they become totally suitable for construction beyond their original classification. Over the times, cement and lime are the two main materials used for stabilizing soils. These materials have rapidly increased in price due to the sharp increase in the cost of energy since 1970s (Neville, 2000). The over dependence on the utilization of industrially manufactured soil improving additives (cement, lime etc), have kept the cost of construction of stabilized road financially high.

This hitherto, has continued to deter the underdeveloped and poor nations of the world from providing accessible roads to their rural dwellers who constitute the higher percentage of their population and are mostly, agriculturally dependent. Thus the use of agricultural waste (such as rice husk ash) will considerably reduce the cost of construction and as well reducing the environmental hazards they causes. It has also been reported by Sear (2005) that Portland cement, by the nature of it's chemistry, produces large quantities of CO_2 for every ton of it's final product. Therefore, replacing proportions of the Portland cement in soil stabilization with a secondary cementitious material like RHA will reduce the overall environmental impact of the stabilization process.

Rice husk is an agricultural waste obtained from milling of rice. About 10^8 tonnes of rice husk is generated annually in the world. Meanwhile, the ash has been categorized under pozzolana, with about 67-70% silica and about 4.9% and 0.95%, Alumina and iron oxides, respectively (Oyetola and Abdullahi, 2006). The silica is substantially contained in amorphous form, which can react with the CaOH librated during the hardening of cement to further form cementations compounds.

Laterite soil collected from Maikunkele area of Minna, classified as an A-7-6 on AASHTO classification, was stabilized with 2-8% cement by weight of the dry soil by Alhassan and Mustapha (2007). Using British Standard Light compaction energy, the effect of Rice Husk Ash on the soil was investigated with respect to compaction characteristics, California Bearing Ratio (CBR) and unconfined compressive strength (UCS) tests. Results obtained, indicated a general decrease in maximum dry density (MDD) and increase in optimum moisture content (OMC), all with increase in RHA content (2-8%) at specified cement contents. There was also a tremendous improvement in the CBR and UCS with increase in the RHA content at specified cement contents to their peak values at between 4-6% RHA. The UCS values also improved with curing age. This indicates the potentials of

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using 4-6% RHA admixed with less cement contents for laterite soil stabilization.

A field experiment in a pineapple plantation at Lampung Province of Indonesia was conducted by Ito et al. (2008) for months to investigate the effect of rice husk and tapioca wastes (cassava bagasse and cassava peel) used as organic amendments, on soil physical and biological properties. The treatments included control, rice husk mulch, cassava bagasse mulch, cassava peel mulch, cassava peel-soil mixture and black polyethylene film mulch.

The organic materials were applied manually. The soil physical and biological properties at the initial and final stages of the experiment were measured and compared. The results showed that the moderate rate of rice husk's decomposition process slightly increased the soil organic matter of surface layer that may had led to somewhat decreased particle density and available water content enhancement. On the other hand, cassava bagasse mulch decomposed within very short period after application and thus its roles especially in soil physical properties were no more noticeable in months after its application. Due to the slow decomposition rate, months were probably too short for cassava peel to contribute in changing soil physical properties.

Brooks (2009) made a trial to upgrade expansive soil as a construction material using rice husk ash and fly ash, which are waste materials. Remolded expansive clay was blended with RHA and fly ash and strength tests were conducted. The potential of RHA-fly ash blend as a swell reduction layer between the footing of a foundation and subgrade was studied. In order to examine the importance of the study, a cost comparison was made for the preparation of the sub-base of a highway project with and without the admixture stabilizations. Stress-strain behavior of unconfined compressive strength showed that failure stress and strains increased by 106% and 50% respectively when the fly ash content was increased from 0 to 25%. When the RHA content was increased from 0 to 12%, unconfined compressive stress increased by 97% while CBR improved by 47%. Therefore, an RHA content of 12% and a fly ash content of 25% were recommended for strengthening the expansive subgrade soil. A fly ash content of 15% was recommended for blending into RHA for forming a swell reduction layer because of its satisfactory performance in the laboratory tests.

Yadu et al. (2011) presented the laboratory study of black cotton soil stabilized with fly ash (FA) and rice husk ash (RHA). The samples of these soils were collected from a rural road located in Raipur of Chhattisgarh state. The soil was stabilized with different percentages of FA (i.e., 5, 8, 10, 12, and 15%) and RHA (i.e., 3, 6, 9 11, 13, and 15%). The Atterberg limits, specific gravity, California bearing ratio (CBR), and unconfined compressive strength (UCS) tests were performed on raw and stabilized soils. Results indicated that addition of FA and RHA reduces the plasticity index (PI) and specific gravity of the soil.

The moisture and density curves indicated that addition of RHA results in an increase in optimum moisture content (OMC) and decrease in maximum dry density (MDD), while these values decrease with addition of FA. The addition of stabilizers (i.e., FA and RHA) increased UCS and CBR values, indicating the improvement in the strength properties of the soil. Based on the CBR and UCS tests, the optimum amount of FA and RHA was found to be as 12% and 9%, respectively.

Koteswara et al. (2011) used rice husk ash, lime and gypsum as additives to the expansive soil which resulted in considerable improvement in the strength characteristics of the expansive soil. It was found that rice husk ash can potentially stabilize the expansive soil solely (or) mixed with lime and gypsum. The utilization of industrial wastes like RHA, lime and gypsum is an alternative to reduce the construction cost of roads particularly in the rural areas. It was observed that the liquid limit of the expansive soil has been decreased by 22% with the addition of 20% RHA+5% lime. It was noticed that the free swell index of the expansive soil has been reduced by 88% with the addition of 20% RHA + 5% lime. The unconfined compressive strength of the expansive soil has been increased by 548% with addition of 20% RHA+5% lime + 3% gypsum after 28 days curing.

Mtallib and Bankole (2011) carried out experimental study on lime stabilized lateritic soils using rice husk ash as admixture. The index property tests classified the soils as (A-7-6) under the AASHTO soil classification scheme. Index and geotechnical properties tests conducted on the soil containing lime and rice husk ash combinations showed significant improvement in properties. The Atterberg limits were significantly altered with lime and rice husk ash combination; the plasticity of the soils were significantly reduced from 18.10 to 6.70 for sample A and 26.6 to 5.92 for sample B at 6 % lime and 12.5% RHA combination. In terms of compaction characteristics, addition of lime and rice husk ash decreased the maximum dry density and increased the optimum moisture content. At 8% lime and 12.5% RHA, the values of MDD for samples A and B were 1.27 and 1.22 Mg/m^3 respectively. The California bearing ratio values peaked at 50% unsoaked values for 8 % lime and 10 % RHA combinations for sample A while that of sample B was 30% at 6% lime and 12.5% RHA combinations.

This paper presents the results of experimental study carried out on three different soils improved with different percents of rice husk ash.

MATERIAL USED

Soil Used

Samples were brought from different sites of Iraq. The first soil is brown clayey soil brought from Baladroz site east of Baghdad while the second soil is obtained from Al- Nahrawan city (23 km) east of Baghdad city and the third soil is brown clayey soil brought from Al-Nasiriyah city south of Iraq. Standard tests were performed to determine the physical and chemical properties of the soil. Details are given in Table 1.

Grain size distribution of the soils is shown in Figure 1. According to the unified soil classification system (USCS), the first and second soils are classified as CL while the third soil is classified as CH.

Table 1. Physical and chemical properties of the three soils used in experiments.

Index property	Baladroz site	Nahrawan site	Al-Nasiriyah site
Natural water content, w_c, %	2.1	2.0	3.0
Liquid limit, LL, %	42	43	63
Plastic limit, PL, %	18	22	26
Plasticity index, PI, %	24	21	37
Specific gravity, Gs	2.69	2.69	2.71
Gravel (larger than 4.75 mm)%	0	0	0
Sand (0.075 to 4.75 mm)%	3.3	33.7	0
silt (0.005 to 0.075 mm)%	31.7	16.3	28
Clay (less than 0.005 mm)%	65	50	72
Gypsum content %	2.92	13.18	11.84
SO_3 content %	1.36	6.13	5.51
Soil classification (USCS)	CL	CL	CL

Note: all tests were performed according to the ASTM (2002).

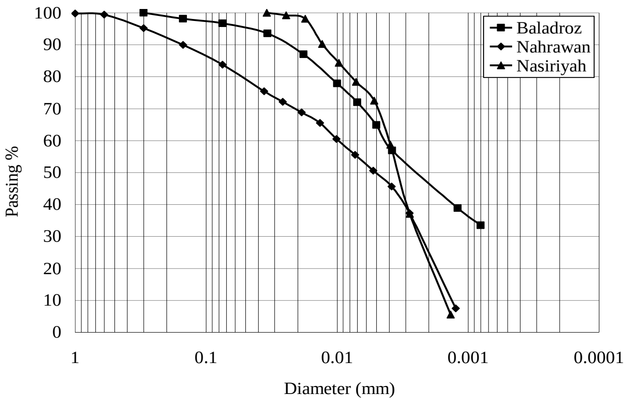

Figure 1. Grain size distribution of the three soils

Rice Husk Ash

Rice milling generates a by-product 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 boiling process. This husk contains about 75% organic volatile matter and the remaining 25% of the weight of this husk is converted into ash during the firing process, known as Rice Husk Ash (RH). This RH in turn contains around 85% - 90% amorphous silica. So for every 1000 kg 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. 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.

This RHA is a great environmental threat causing damage to the land and the surrounding area in which it is dumped. The chemical properties of rice husk are illustrated in Table 2 in addition to the geotechnical properties of this material.

In this study, the rice husk, shown in Figure 2, was collected from rice farms west of Baghdad city in Iraq.

Table 2. Chemical composition of RHA (after Oyetola and Abdullahi, 2006).

Index property	Index value	Rice Husk Ash Properties Values	Index value
SiO_2	86%	Liquid Limit (%)	Non-Plastic
Al_2O_3	2.6%	Plastic Limit (%)	Non-Plastic
Fe_2O_3	1.8%	Specific Gravity	2.04
CaO	3.6%	Maximum Dry Density (kN/m^3)	6.97
MgO	0.27%	Optimum Moisture Content (%)	45.5
Loss in ignition	4.2%	California Bearing Ratio (%)	15

Laboratory Studies

The testing program conducted on the clayey soil samples included determination of the physical and chemical properties of soils at their natural state. On the other hand, the testing program conducted on the clayey soil samples mixed with different percentages of rice husk materials, included Atterberg limits, **s**pecific gravity, compressibility, unconfined compression test and consolidation test.

Liquid limit: The liquid limit test was conducted on samples passing 0.425 mm (No. 40) sieve; clayey soils and soil mixed with (0, 3, 6 and 9%) rice husk using Casagrande's liquid limit apparatus as per the procedures laid down in ASTM D 4318-00.

Plastic limit: The plastic limit test was conducted on samples passing 0.425 mm (No. 40) sieve; clayey soils and soil mixed with (0, 3, 6 and 9%) rice husk, as per the specifications laid down in ASTM D 4318-00.

Specific gravity: The specific gravity test was conducted on the soil in accordance with ASTM D 854-02.

Compaction: The standard compaction tests were performed in accordance with ASTM D 1557. The specimens were of 102 mm diameter and 116 mm height. The degree of compaction of soil influences several of its engineering properties such as CBR value, compressibility, stiffness, compressive strength, permeability, shrink, and swell potential. It is, therefore, important to achieve the desired degree of relative compaction necessary to meet the required soil characteristics.

Unconfined compression test: This test was performed in accordance with ASTM D 2166-00. The sample sizes were of 38 mm diameter and 76 mm length. At the optimum moisture content (OMC) and maximum dry unit weight, the tests were performed.

Swelling: Consolidation test ASTM D 2435-02 setup was used for determining the cyclic swell-shrink behavior of the soil. The sample was 75 mm high and 19 mm in diameter. The sample was prepared at dry density of the standard compaction curve.

RESULTS

The study explains the effect of different rice husk percentages on different soil properties. The results of this study with their discussion are presented in the following paragraphs.

Effect on Atterberg's Limits

Liquid limit results for soil and rice husk combinations at different percentages are shown Figures 3. The general decrease in liquid limit at all soil-rice husk ash combination is attributed to the fact that the rice husk ash reaction forms compounds possessing cementitious properties calcium silicate cement with soil particles. This trend conforms to findings of Muntohar and Hantoro (2000) who found that the liquid limit reduces with increasing lime and rice husk ash combinations.

The variations of plastic limit for the soil- rice husk ash combination at different percentages are shown in Figure 4. For the soil- combinations at different percentage of RHA, there is a general increase in plastic limit with increasing RHA content. The cationic exchange reaction adduced for the liquid limit is also applicable here. The results are in agreement with Muntohar and Hantoro (2000) who found out that plastic limit increases with increasing lime and rice husk ash content.

Figure 5 shows the variations of the plasticity index for the soil - rice husk combination at different percentages. From the results, it is observed that the plasticity index decreases with increasing rice husk content at all percentages for all soil-rice husk stabilized samples.

Figure 2. Rice husk used in experiments.

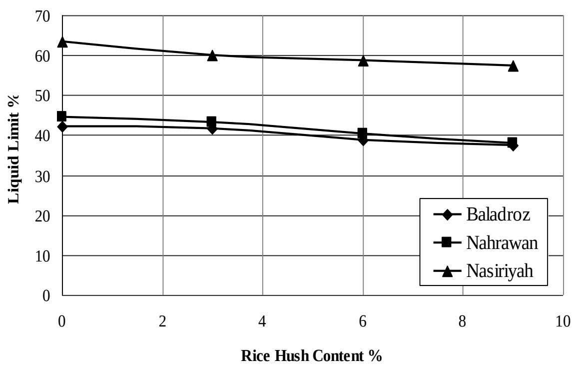

Figure 3. Effect of rice husk on the liquid limit of the three soils.

Effect on Specific Gravity

The variation of specific gravity for the soil- rice husk combination at different percentages are shown in Figure 6 which presents the variation of specific gravity of the soil mixed with different percentages of RHA. It can be seen that addition of RHA decreases the specific gravity of the soil. This decrease in specific gravity can be due to the lower value of specific gravity of RHA which is about 2.04.

Effect on Compaction Characteristics

The variations of maximum dry unit weight and optimum moisture content (OMC) with stabilizer contents are shown in Figure 7. Figure 8 indicates that the maximum dry unit weight decreases with increase in the RHA content while Figure 9 indicates that the OMC increases with increase in the RHA content.

The decrease in the maximum dry unit weight can be attributed to the replacement of soil by the RH in the mixture which has relatively lower specific gravity (2.04) compared to that of the soil which is between 2.69 to 2.71 (Ola 1975; Osinubi and Katte 1997). It may also be attributed to coating of the soil by the RHA which result to large particles with larger voids and hence less density (Osula, 1991). The decrease in the maximum dry unit weight may also be explained by considering the RH as filler (with lower specific gravity) in the soil voids.

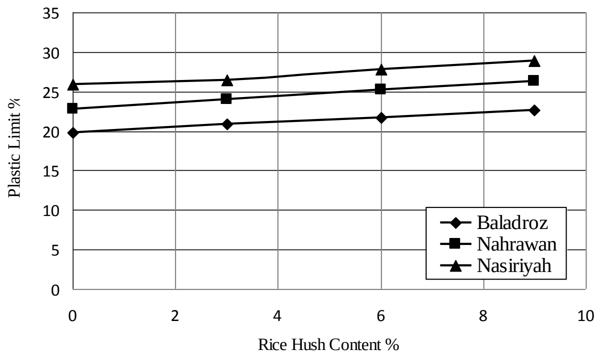

Figure 4. Effect of rice husk on the plastic limit of the three soils.

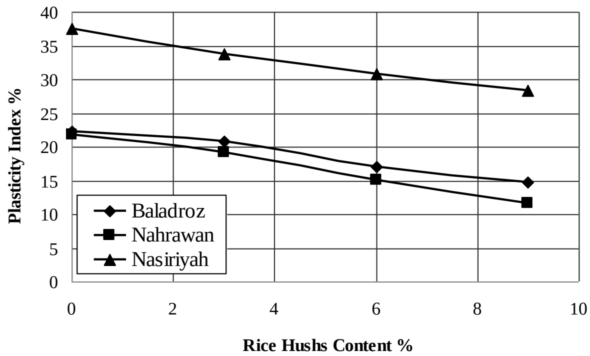

Figure 5. Effect of rice husk on the plasticity index of the three soils.

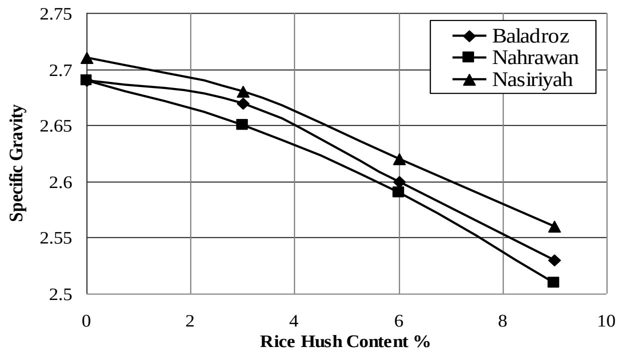

Figure 6. Specific gravity of the rice husk ash mixed soil.

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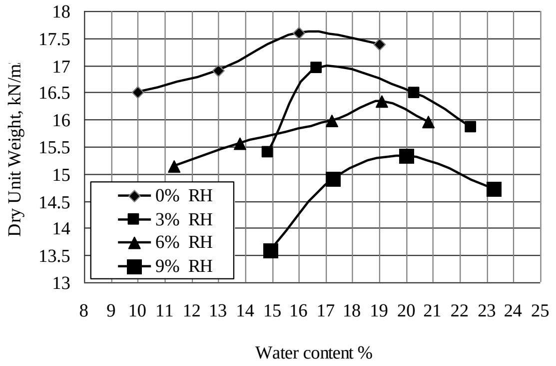
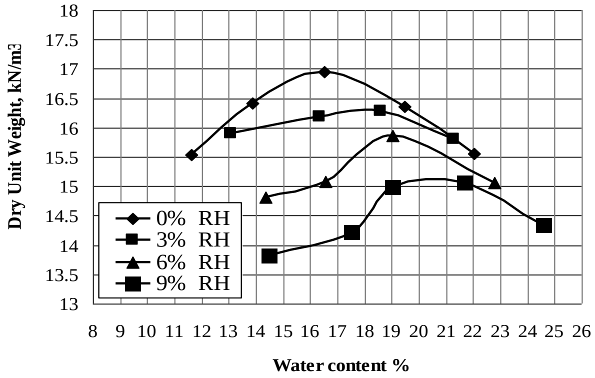
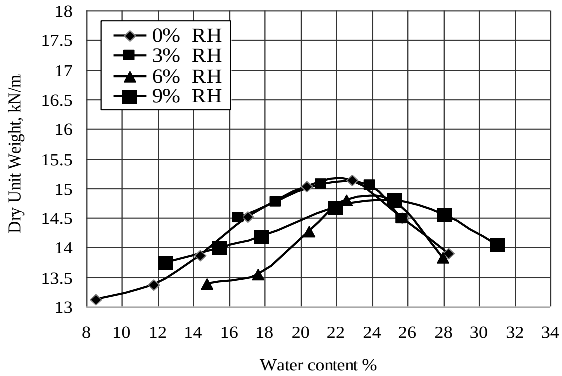


a. Baladroz soil.



b- Nahrawan soil.



c- Nasiryah soil.

Figure 7. Variation of the dry unit weight with moisture content for soils with different rice husk contents.

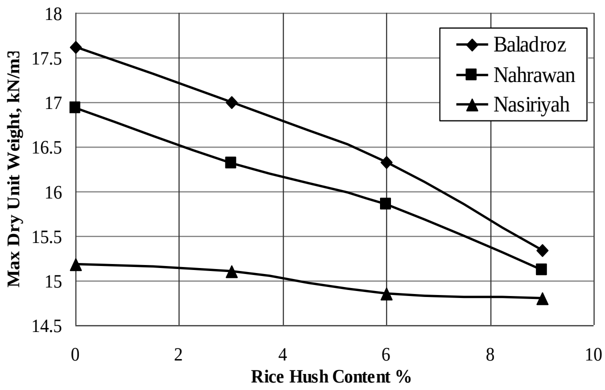


Figure 8. Maximum dry unit weights for soils mixed with different percentages of rice husk.

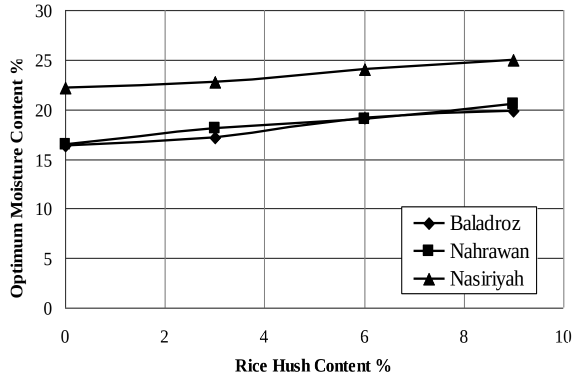
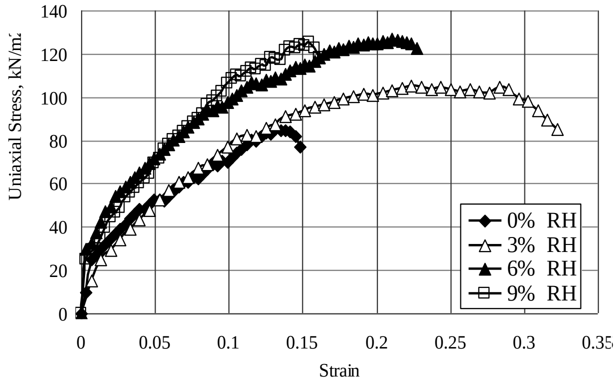
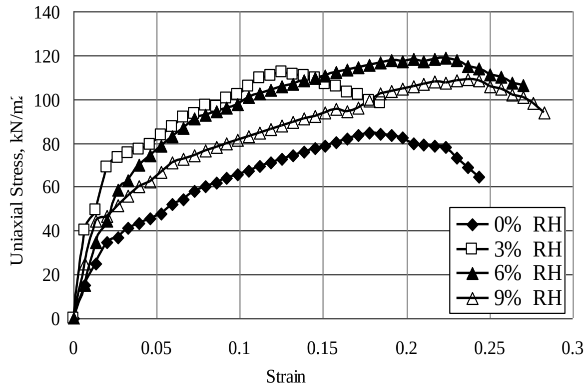


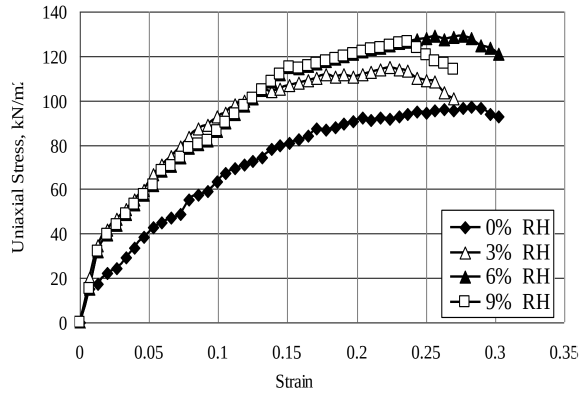
Figure 9. Optimum moisture content for soils mixed with different percentages of rice husk.



a. Baladroz soil.



b- Nahrawan soil.



c- Nasiryah soil.

Figure 10. Stress-strain curves from the unconfined compression test for soils mixed with different percentages of rice husk.

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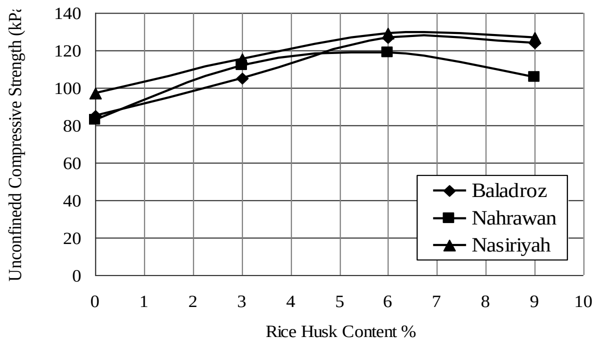
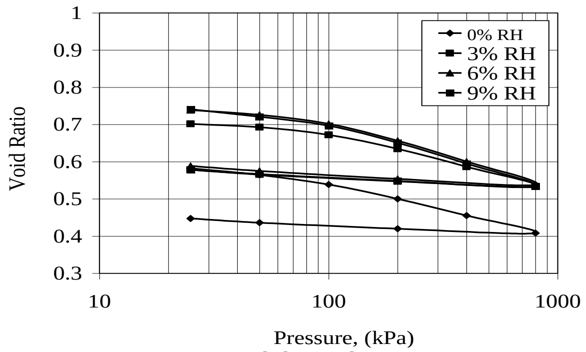
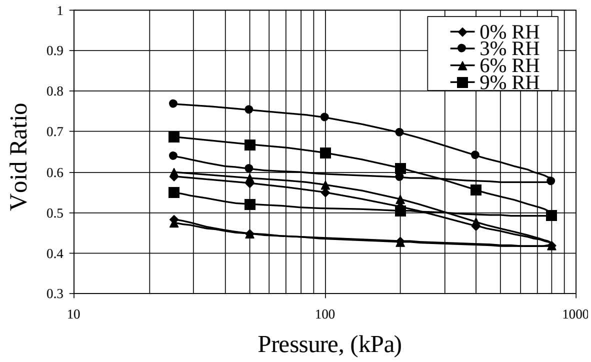


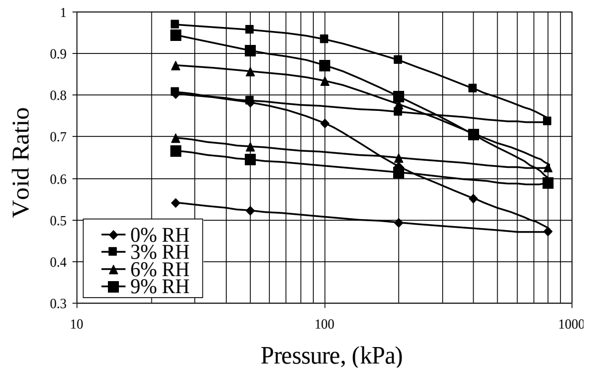
Figure 11. Effect of rice husk on the unconfined compressive strength of soils.



a. Baladroz Soil



b. Nahrawan Soil



c. Nasiriyah Soil

Figure 12. Pressure-void ratio relationship for the three soils.

There is increase in OMC with increase RH contents. The trend is in line with Ola (1975), Gidigasu (1976) and Osinubi (1999). The increase is due to the addition of RH, which decreases the quantity of free silt and clay fraction and coarser materials with larger surface areas were formed (these processes need water to take place). This implies also that more water is needed in order to compact the soil-RH mixtures (Osinubi, 1999).

The increase in OMC is due to the addition of rice husk, which decreases the quantity of free silt and clay fraction and coarser materials with larger surface areas are formed (these processes need water to take place).

The decrease in the maximum dry unit weight can be also attributed to the replacement of soil by the RHA which has relatively lower specific gravity (2.04) compared to the soil. It may also be attributed to coating of the soil cement by the RHA which result in large particles with larger voids and hence less density. The increase in density from minimum at 0% RHA content to 9% rice husk content can be due to molecular rearrangement in the formation of "transitional compounds" which have higher densities at 9% RHA content.

Effect on Unconfined Compressive Strength

Unconfined compressive strength (UCS) is the most common and adaptable method of evaluating the strength of stabilized soil. It is the main test recommended for the determination of the required amount of additive to be used in stabilization of soil (Singh and Singh, 1991). Variations of the UCS with increase in RH from 0% to 9% are shown in Figures 10 and 11. The UCS values increase with subsequent addition of RH to its maximum at between 6-8% RH after which it drops at 9% RH. The subsequent increase in the UCS is attributed to the formation of cementitious compounds between the CaOH present in the soil and RH and the pozzolans present in the RH. This decrease in the UCS values after the addition of 8% RH may be due to the excess RH introduced to the soil and therefore forming weak bonds between the soil and the cementitious compounds formed. These results are compatible with the findings of Yadu et al. (2011) who studied stabilization of black cotton soil with fly ash and rice husk ash.

Effect on Compressibility Characteristics

All samples were compacted at the maximum dry unit weight and optimum moisture content using the same compaction energy of the standard Procter test. All specimens were soaked in water. The results of consolidation test are presented as void – ratio versus logarithm of effective stress as shown in Figure 12 for all the tested specimens.

It is noticed that the addition of RHA leads to decrease the initial void ratio up to 6% RHA content, and then the RHA leads to increase the void ratio. Little effect of the RHA is noticed on the compression index and swelling index.

CONCLUSIONS

From the results of the investigation carried out within the scope of the study, the following conclusions can be drawn:

1. The liquid limit of the three soils has been decreased by about (11 - 18)% with the addition of 9% RHA, while the plasticity index decreased by about (32 - 80)%.

2. Treatment with rice husk showed a general reduction in the maximum dry unit weight with increase in the rice husk content to minimum values at 9% rice husk content. The optimum moisture content generally increased with increase in the RHA content.
3. There is enormous increase in the unconfined compressive strength with increase in rice husk content for the soil to its maximum at RHA between (6 – 8)%.

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