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IMPROVEMENT OF EXPANSIVE SOIL BY RICE HUSK ASH

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Abstract

Volumetric deformations appear on the extended soil and form a real threat to the stabilization of the structures and foundations. So, it becomes very important to determine the soil bulge properties (i.e., swelling and swell pressure). However, the bulge properties measurement is time-consumption and needs a particular and costly equipment. With this in view, by adding different types of additives to the soil like cement, steel fibers, stone dust, fly ash and silica fume, this study has been done to focus on treatment of expansive soil. A treatment of swelling/shrinkage using rice husk ash was studied in this work. In this investigation, the selected soil was prepared in laboratory, a different percentage of bentonite (30, 50 and 70% by weight) was mixed with the natural soil. The test program included, how was the Bentonite impacted on the soil, then studied the influence of the rice husk ash (RHA) on prepared soil after adding various percentages of rice husk ash (4, 8, and 12% by weight) to the prepared soils. By comparing these results with those of untreated soils (prepared soils), the influence of the admixtures was observed. The results show that, with the addition of rice husk ash the liquid limit, plasticity index and swelling and swell pressure were decreased. However, the plastic limit increased with increase in the rice husk ash contents. with the increase in rice husk ash percentage the maximum dry unit weight values decreased, and the optimum water contents increased. It is concluded that the stability of soil with rice husk ash maybe used as an effective method for the expansive clay treatment.

Keywords: Expansive soil, Free swelling, Improvement, Rice husk ash, Swell pressure.

1. Introduction

Soil improvement might be done by amendment or increased soil stability or both. Adding some materials like (lime, cement etc.) to the soil to change its characteristics is called soil amendment. While increased soil stability is the handling of soils to enhance their strength and resistance to become totally proper for construction. Long time ago, the main materials used for increasing soil stability were cement and lime. Raising up the cost of the energy since 1970s leaded to cost increasing of these materials [1]. Over reliance on the use of additives to improve the industrialized soil (lime, cement etc.) kept the construction cost of the stable road financially high.

The high cost of these materials prevented poor and underdeveloped countries from providing the necessary roads for their rural residents who depend on agriculture and who make up the highest proportion of the population of these countries. Therefore, the use of agricultural waste (rice husk ash) will lead to a significant reduction in the construction cost and also reduce the environmental risks it causes.

Sear [2] has mentioned in his report that, by virtue of the chemical nature of Portland cement, because it produces large quantities of carbon dioxide per ton of it, therefore, the replacement of Portland cement to increase soil stability with a cementitious material such as rice husk ash reduces the overall environmental impact of increasing soil stability. The rice milling operation produces agricultural waste called rice husk. Globally, the annual product of rice husk is approximately 108 tons. The ash has been classified under pozzolana material, with 67-70% silica, 4.9% and 0.95% Alumina and Iron oxides respectively [3-5]. Silica is often used in amorphous form, which can interact with filtered CaOH during the cement hardening process in order to form second cement compounds.

The influence with respect to compaction properties, California Bearing Ratio (CBR) and unconfined compressive strength (UCS) tests, of the Rice Husk Ash on the soils has been examined, by using British Standard Light compaction energy. With an increase in RHA content (2-8%) with specific cement contents, the final results indicated an increase in the optimum moisture content (OMC), and a general decrease in the maximum dry density (MDD). With an increase in the RHA content at specified cement contents to their peak, there was a large amendment in the CBR and UCS. For some months, a field experiment conducted by Komariah et al. [6] in a pineapple plantation at Indonesia to research the effect of rice husk and tapioca wastes (cassava bagasse and cassava peel which were used as organic amendments) on the soil physical and biological properties. The handling included, cassava peel-soil mixture, cassava peel mulch, cassava bagasse mulch, rice husk mulch and black polyethylene film mulch.

The organic materials have been applied manually. At the beginning and ending of the experiment, the biological and physical properties of soil were measured and compared. The results showed that the decomposition process of rice husk with a reasonable rate leads to increase the organic matter for the surface layer of soil, which might lead to a decrease in the density of particles and an enhancement in the available water content. Furthermore, after applying the cassava bagasse mulch, it decomposed in short time, thus, after months of its application, its roles especially in the physical properties of soil were no more noticeable. This may be attributed that the period of some months was a short time for the cassava peel to contributing in order to change the physical properties of soil and that due to its slow decomposition rate.

Brooks [7] conducted experiments on expansive soil using rice husk ash and fly ash, which are waste materials. He worked on reshaping the expansive soil by mixing it with rice husk ash and fly ash and then conducted strength tests on it. He studied the potential of these materials to reduce bloating between the base bed and the soil. The cost comparison of the highway project was made with or without the stability of the mixtures. It is found that when the fly ash content increased from 0 to 25%, the failure stresses and strains increased by 106% and 50% respectively as shown in the behaviour of unconfined compressive strength through stress-strain test, also unconfined compressive stress increased by 97% when the RHA content was increased from 0 to 12% while there was an improvement in CBR by 47%. Therefore, for strengthening the expansive subgrade soil, it is recommended to use the percentages content as 12% and 25% for RHA and fly ash respectively. The recommendation is to blend 15% of a fly ash with RHA in order to form expansion reduction layer due to its reasonable behaviour in the lab tests. Rao et al. [8] got a great amendment for the expansive soil in its strength properties after adding lime, gypsum, and rice husk ash to it. He found that the expansive soil can be stabilized by adding rice husk ash alone or blended with gypsum and lime.

Alternative materials can be used for the purpose of reducing the cost of road construction, especially in rural areas, where RHA, lime, and gypsum are an example of alternative materials. It was observed that when adding 20% RHA, 5% lime, and 3% gypsum to the expansive soil and after 28 days of handling, there was a significant decrease in the liquid limit by 22%, the free swell index reduced by 88%, and the unconfined compressive strength increased by 548%. [9-12] executed empiricist study on soils stabilized by adding a mixture of lime and RHA. The soil has classified as (A-7-6) under the AASHTO soil classification scheme depending on the tests of physical properties, these tests with the geotechnical properties' tests showed a large amendment in properties when they conducted on a soil which has lime and rice husk ash as additives.

The plasticity index has reduced very well after adding 6 % lime and 12.5% RHA to soil, the reduction in the sample A which contained 8% lime and 10% RHR, was from 18.10 to 6.70 and in the sample B, which contained 6% lime and 12.5% RHA was from 26.6 to 5.92. For the properties of compaction, the maximum dry density (MDD) has been decreased, for sample A was 12.7 kN/m3, and for sample B was 12.2 kN/m3, while the optimum moisture content has increased by adding lime and rice husk ash by 8% and 12.5% respectively. For the California bearing ratio, in the sample A, the values peaked at 50% of unsoaked values, and in the sample B, the values peaked at 30% of unsoaked values.

So the main objective of this study is directed to predict the plasticity, swelling %, and swelling pressure of expansive soil, by preparing the soil with different percentages of expansion by using natural clay mixed with different percentages of bentonite (30, 50, and 70%). The second objective and due to the huge production of rice husk as a waste material of rice processing and this huge production keeps increasing every day so use this material has attracted the attention of the researchers. So the second objective is to use rice husk ash with a different percentage to check the improvement in the properties of expansive.

2. Material Used

2.1. Soil used

The soil samples were prepared by mixing natural soil with different percentages of bentonite. The natural soil was located in Al-Nahrauan city which is 23 km east of Baghdad. The bentonite was obtained commercially. Table 1 contains the details obtained for the chemical and physical properties of natural soil.

Table 1. Physical-chemical properties of soil used.

Index-property	Natural soil	Bentonite
Natural water-content %	2.0	-
Liquid-limit %(LL)	44	512
Plastic-limit %(PL)	19	38
Plasticity-index %(PI)	25	474
Specific-gravity (GS)	2.69	2.26
Gravel-(larger than 4.75mm) %	0	-
Sand-(0.06 to 4.75mm) %	16	-
Silt-(0.005 to 0.075mm) %	34	-
Clay-(less than 0.005mm) %	50	-
Gypsum-content %	5.27	-
SO_3 content %	2.45	-
Soil symbols (USCS)	CL	-

The natural soil was dried in the laboratory at 60˚C for 48 hours then grinded and sieved (passing No. 40 (0.425mm) U.S).

Four types of soil samples were prepared and as followed: -

Soil type A: The normal soil was acquired from Al-Nahrauan city.

Soil type B: Mixing natural soil with 30% bentonite (% by dry weight)

Soil type C: Mixing natural soil with 50% bentonite.

Soil type D: Mixing natural soil with 70% bentonite

The physical, chemical-properties and classification indices of different soil types were listed in Table 2.

Table 2. The physical properties and classification indices of the four soils.

Soil type	Liquid Limit%	Plastic limit%	Plasticity Index%	Specific gravity	Max. dry unit weight (kN/m^3)	Optimum moisture content%
A	44	19	25	2.69	17.13	17.5
B	80	21	59	2.55	15.11	22.7
C	118	24	94	2.47	14.73	24.2
D	152	25	127	2.39	14.08	26

2.2. Rice husk

Husk is a waste material of rice processing, which is being around the grain in the rice field. After rice grinding, the output matter are rice, broken rice and bran, which is formed 78% of its weight, and 22% of its weight formed the husk. This husk is considered a good fuel used in rice mills to obtain the steam necessary for the boiling process. When the husk is burned, 75% of its weight is lost as volatile organic matter and the remaining 25% is converted to ash, called Rice Husk Ash (RHA), 85-90% of this RHA is amorphous silica. That means, we can get 55 kg (25%) of RHA from grinding 1 ton of rice. Furthermore, because it causes harm to the land and the area that surrounds it, RHA is considered a threat to the environment. Many ways to get rid of RHA through commercial use are being considered. RHA used in this study was brought from rice farm at west of Baghdad-Iraq, which is appeared in Fig. 1, Tables 3 and 4 represent the chemical composition, and geotechnical properties of rice husk respectively.

Fig. 1. Rice husk used in experiments.

Table 3. Chemical composition of rice husk.

No.	Index property	Index value
1	SiO_2	86%
2	Al_2O_3	2.6%
3	Fe_2O_3	1.8%
4	CaO	3.6%
5	MgO	0.27%
6	Loss in ignition	4.2%

Table 4. Geotechnical properties of rice husk.

No.	Index Property	Index value
1	Liquid Limit (%)	
2	Plastic Limit (%)	No-Plastic
3	Specific Gravity	2.04
4	Maximum Dry Unit Weight (kN/m^3)	6.97
5	Optimum Moisture Content (%)	45.5
6	California Bearing Ratio%	15

3. Sample Preparation

Three percentages of rice husk ash were used (i.e. 4, 8 and 12%). Two types of compactions were used; Procter compaction and static compaction. The samples were prepared at 17.13 kN/m3 as a dry unit weight and 17.5% as water content have been considered for all prepared samples.

4. Laboratory Testing Program

The laboratory work was divided into two stages. In the first stage, soil classification tests and compaction tests were conducted in the laboratory on samples prepared to determine their physical properties and be able to classify them properly.

The second stage consists of measurement of the free-soil swell and swelling pressure of the laboratory-prepared samples. A flow chart including the number and the type of every test conducted is outlined in Fig. 2.

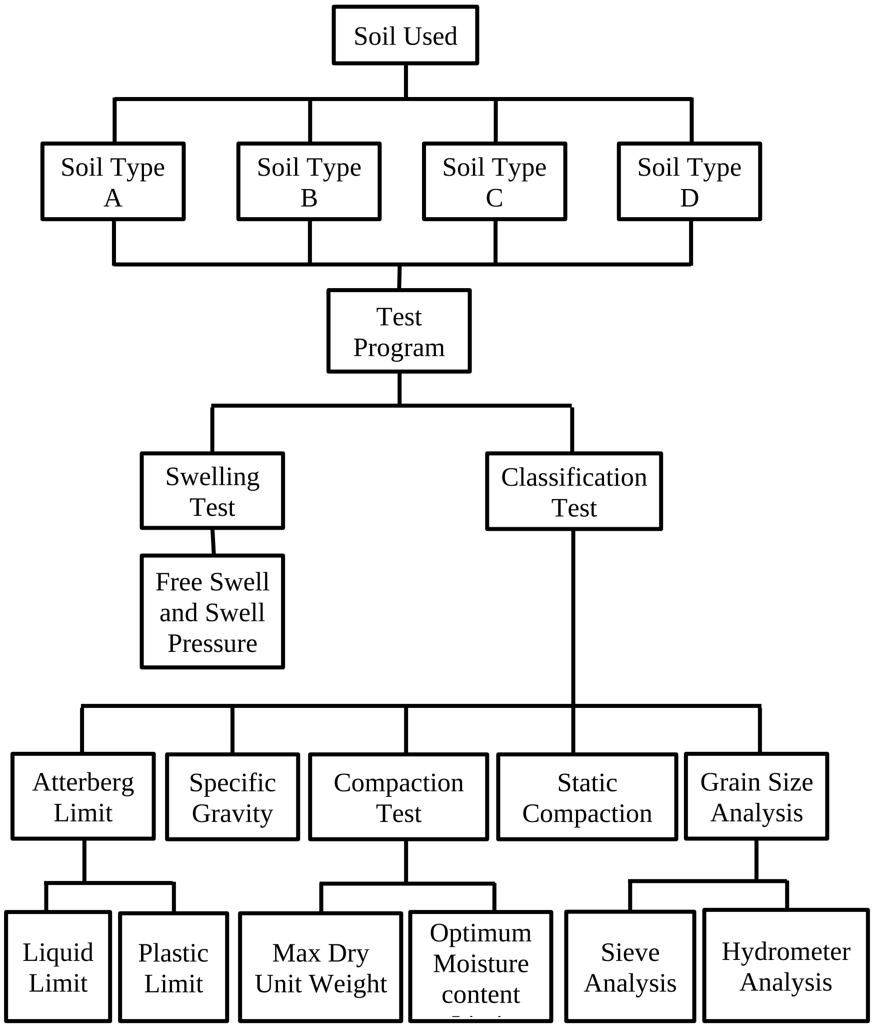


Fig. 2. Flow chart of the testing program.

5. Soil Classification Tests

The tests listed below were conducted on disturbed samples for the purpose of soil classification and geotechnical identification. Atterberg limits tests were conducted on the four soil types and Bentonite. ASTM procedure designated [13] was followed into concern the Atterberg limits. [14] standard was employed to find the specific gravity of the four soil types. The grain-size distribution tests-(i.e. sieve analysis and hydrometer) were conducted on the soil type A (natural soil) in accordance with [15]. Figure 3 shows the grain size distribution for the soil is of type A.

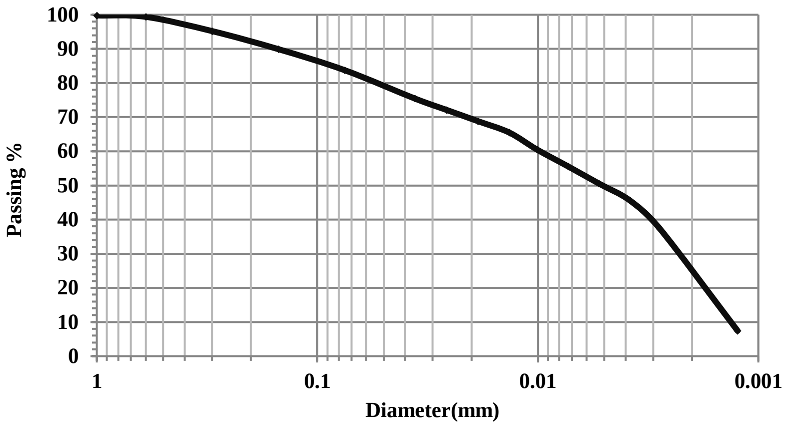


Fig. 3. Grain size distribution of soil type A (natural soil).

6. Compaction Characteristics

The compaction characteristics of the four types of soils were conducted in accordance with [16] and obtained using standard compaction effort.

7. Static Compaction

To get an initial water content, an air-dried soil with desired amount of distilled water has been mixed, by this method the samples were prepared for swelling, the mixing was done by hand and the mixture stored for one day in a desiccator in order get appropriate distributing for moisture . In this method, a compression testing machine with a special mold had been used, where a compression rate of 0.04mm/sec was applied statically by using a load on the soil sample until getting the desired height (1.5 cm), after getting the required height, this loading has continued for five minutes to avoid bouncing after decompression.

8. Swelling Characteristics

The swell-consolidation test [17] was selected for this study. The procedures adopted for determining the free swell and swelling pressure.

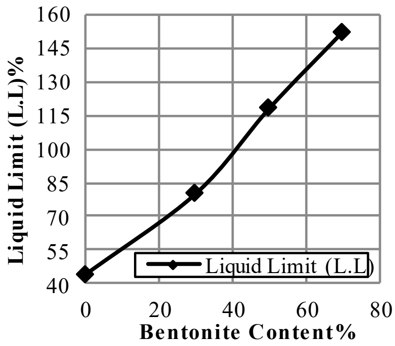
9. Discussion of Test Results

This study was performed on three types of expansive soil sample with three different expansion percentages. The test was split into two parts, the first part was done on samples that were prepared to study the influence of the added bentonite on the soil's characteristics, while the second was performed on prepared soils mixing with fly ash using three percentages. The second test was done on remoulding specimens to study the effect of added fly ash on the characteristics of the prepared soils.

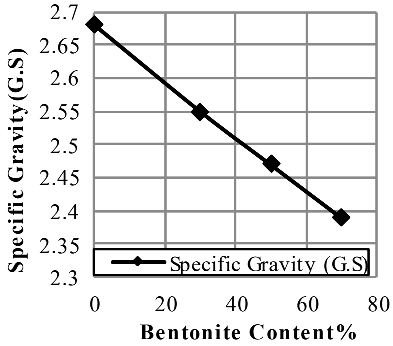
9.1. Effect of bentonite on the properties of natural soil

9.1.1. Effect of bentonite on the properties of natural soil

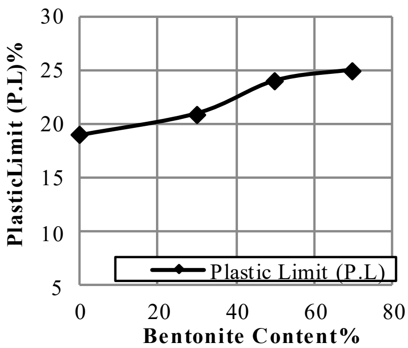
The results of liquid limit tests are indicated in Fig. 4(a) Adding 30, 50 and 70 percent of bentonite to the natural clayey soil leads to an increase in the LL, approximately to 80, 118 and 152 percent, respectively. The reason is the high activity of bentonite and its tendency to absorb water, the chemical composition of bentonite is the base sodium. Figure 4(b) showing how the specific gravity values of mixture of soil and bentonite are varying at several percent, it is clear to notice that a significant decrease in the specific gravity of the soil after adding bentonite was observed. The reason for this decrease is related to low value of Bentonite specific gravity which is about 2.26. In Figs. 4 (e), (f) and (g) the bentonite effect on the compaction-characteristics of mixtures is illustrated. It could be clearly observed that by increasing the bentonite content in the mixtures, the optimum-water-content-increases while the dry unit weight decreases. Due to the high activity of bentonite, the absorbed water surrounding the clay particles which has considerable volume, leads to an increase in the water-content-and decrease in the dry unit-weight [18].



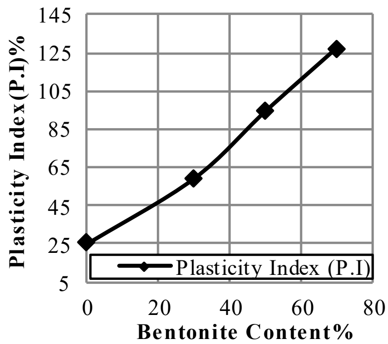
(a). Liquid limit %



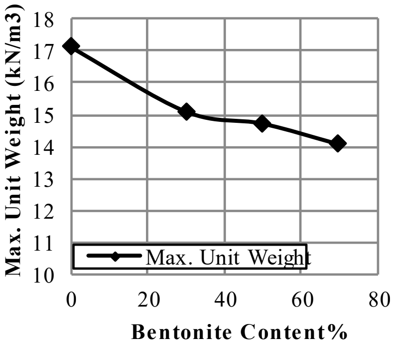
(b). Specific gravity %



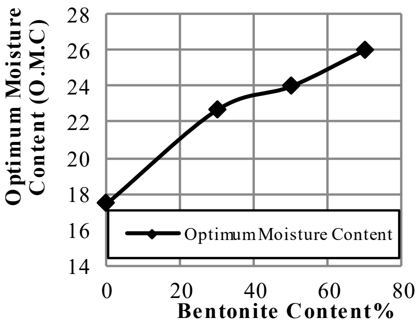
(c). Plastic limit %



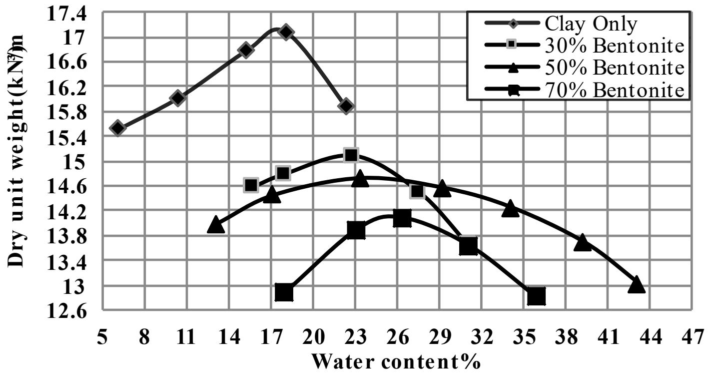
(d). Plasticity index %



(e). Max. unit weight



(f). Optimum moisture content.



(g). Compaction test.

Fig. 4. The effect of bentonite on the Atterberg's limit, specific gravity, and compaction characteristics.

9.1.2. Effect of bentonite on swell and swell pressure

Figures 5 to 7 and Table 5 show the effect of bentonite in different percent on the free swell and swell pressure of the natural sample. The results clearly show that-the-free-swell and swell-pressure were highly increased with increasing the percentage of bentonite due to the natural-sodium-bentonite which is high-swelling-clay-composed mainly-of sodium-montmorillonite.

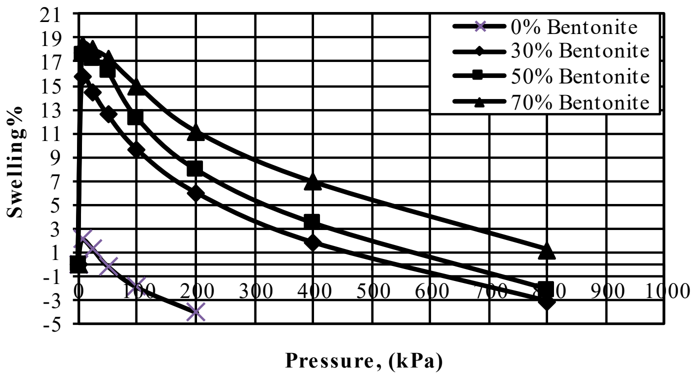


Fig. 5. Free swell percentage and pressure for all soils type used.

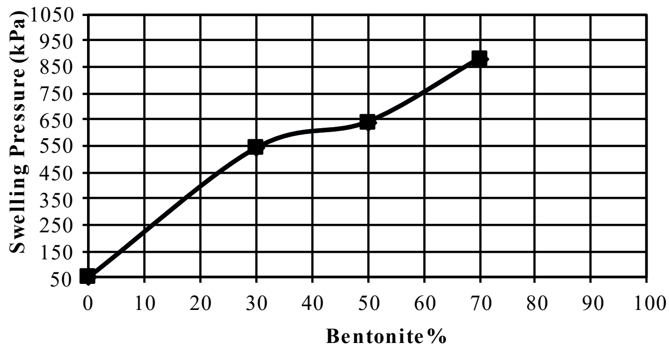


Fig. 6. Swelling pressure and bentonite percent for all soil types used.

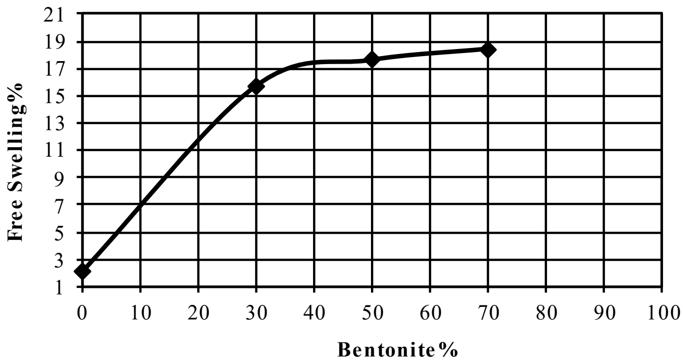


Fig. 7. Free swell and bentonite percent for all soil types used.

Table 5. Values of free swell and swelling pressure after adding bentonite to the natural soil.

Type of soil	Swelling pressure (kPa)	Free swell
A	50	**2.1**
B	540	**15.7**
C	640	**17.6**
D	880	**18.4**

9.2. Effect of rice husk on the properties of prepared soils

9.2.1. Effect of rice husk on Atterberg's limits

Figures 8 to 10 show the effect of rice husk ash in different percentages on the consistency limits (LL ,PL and P.I) respectively of the prepared soils (B, C and D).From these figures, it can be observed that-the-liquid-limit-slightly decreases and plastic limit increases slightly with increase of percentage of rice husk ash. So, a remarkable decreasing in the plasticity index was obtained for soil B as a result of change in liquid limit and plastic limit. While for soil C, Atterberg limits decrease with increasing of rice husk ash percentage. For soil D, the liquid limit decreases and plastic limit increases, therefore plasticity index also decreases. It can be noticed that there is a decrease in liquid limit and plasticity index after adding of rice husk ash and that because it covers and connects all the particles of clay which have a little cementitious value and big particles.

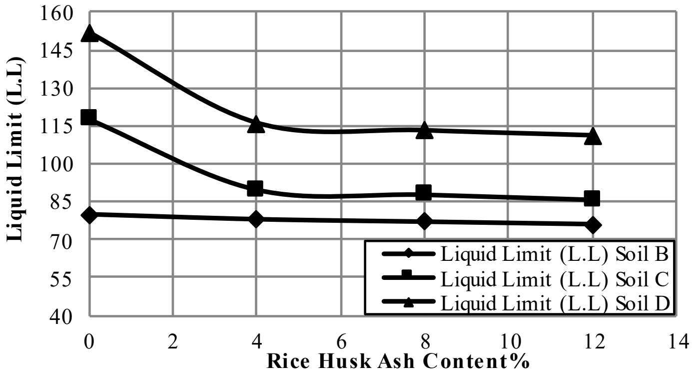


Fig. 8. Relationship between liquid limit and rice husk ash content for the prepared soils.

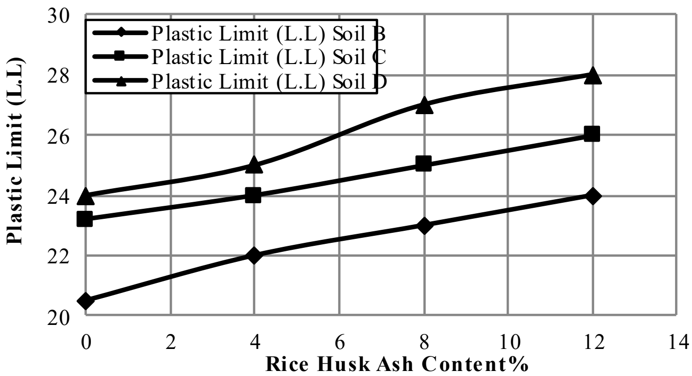


Fig. 9. Relationship between plastic limit and rice husk ash content for the prepared soils.

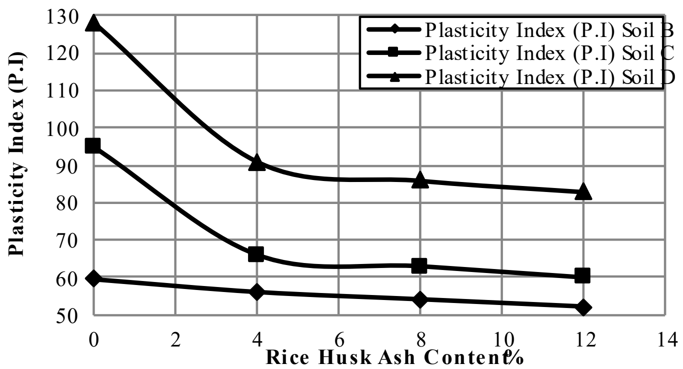


Fig. 10. Relationship between plasticity index and rice husk ash content for the prepared soils.

9.2.2. Rice husk ash affection on specific gravity for prepared soils

Figure 11 shows the rice husk ash influence in different percentages on the specific gravity of the prepared soils (B, C, and D). From this figure, it can be noticed that specific-gravity decreased with-increasing the percentage of rice husk ash content because of the low value-of-specific-gravity-of RHA 2.04.

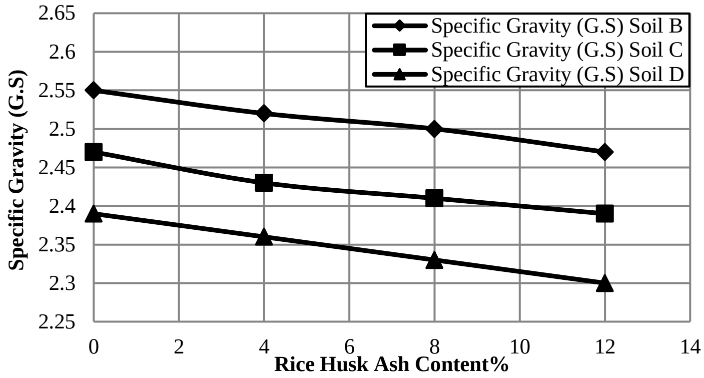


Fig. 11. Specific gravity and rice husk ash content for soils prepared.

9.2.3. Effect of rice husk ash on free swell and swelling pressure for prepared soil

Figures 12 to 20 show how the free swell and swelling pressure for the prepared soil were affected by adding RHA in several percentages. It can be noticed that with the increasing of RHA percentage to 4% there was a sharp decreasing in the free swell and swell pressure and then levelling out to a fix value, these results are compatible with the findings of [11, 12]. Therefore, 4% is considered the optimum percentage of RHA which shows the maximum reduction in the free swell and swell pressure. The reduction is due to the addition of non-expansive silt size particles to the expansive soil and the interaction between the soil and rice husk particles. As a result, the specific surface area and water affinity of the samples decrease, which signifies a reduced value of swell-shrinkage-such as free-swell, swelling-pressure.

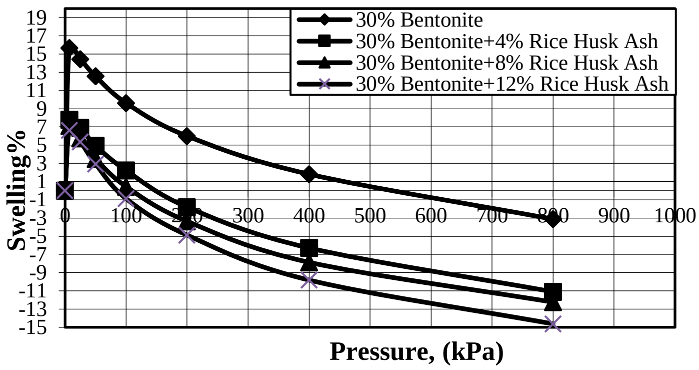


Fig. 12. Free swell percentage and pressure relationship (soil B).

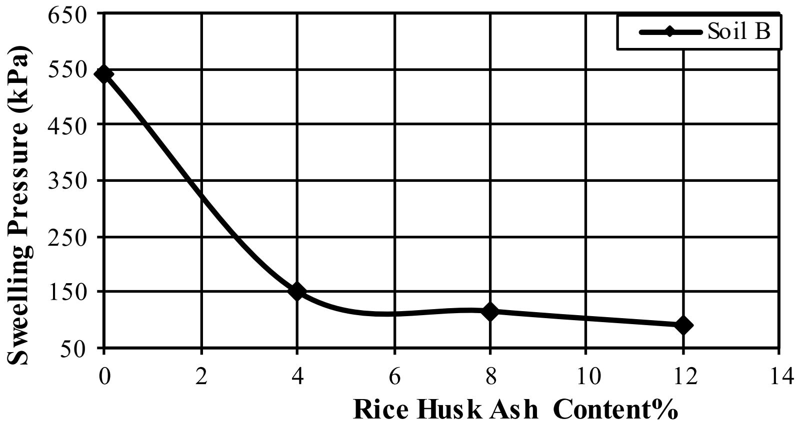


Fig. 13. Swelling pressure and rice husk ash content relationship (soil B).

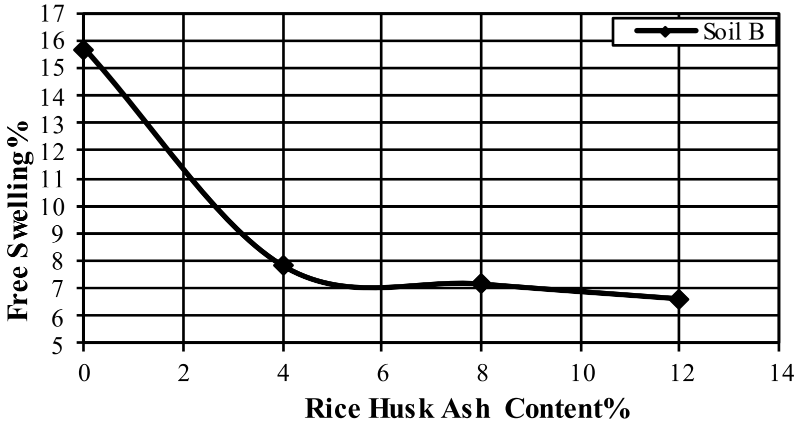


Fig. 14. Free swell and rice husk ash content relationship (soil B).

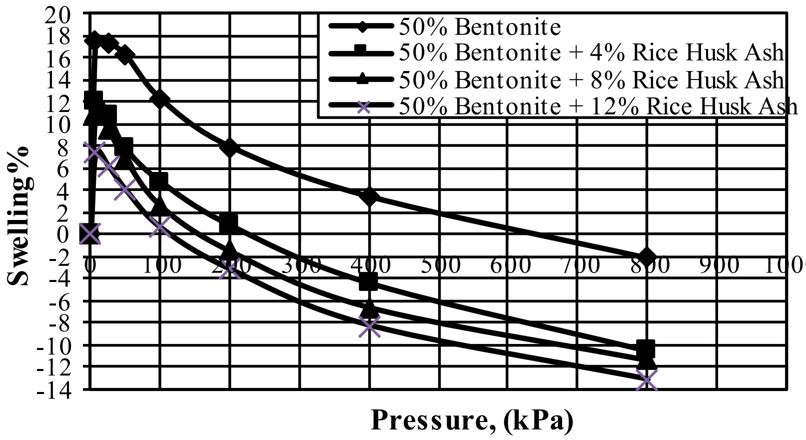


Fig. 15. Free swell percentage and pressure relationship (soil C).

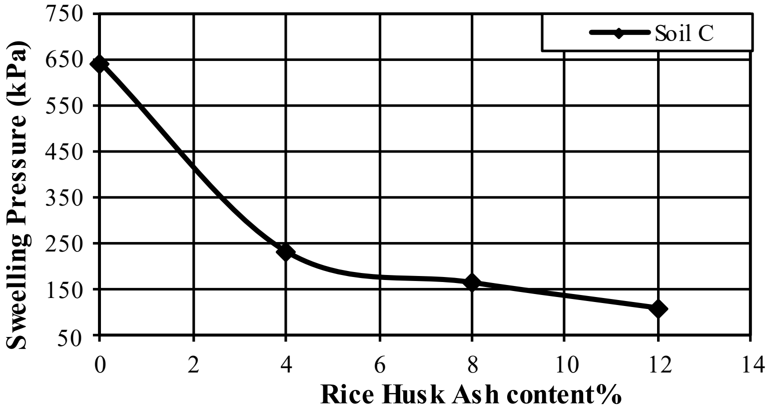


Fig. 16. Swelling pressure and rice husk ash content relationship (soil C).

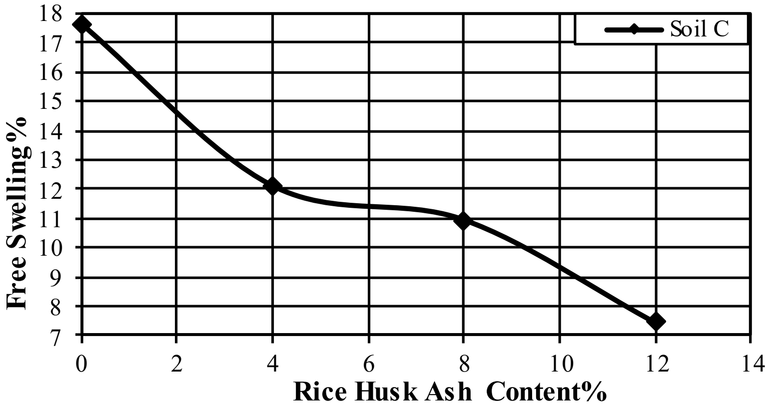


Fig. 17. Free swell and rice husk ash content relationship (soil C).

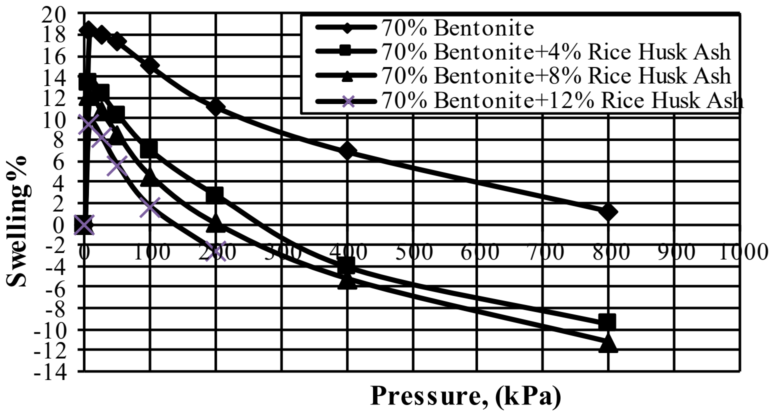


Fig. 18. Free swell percentage and pressure relationship (soil D).

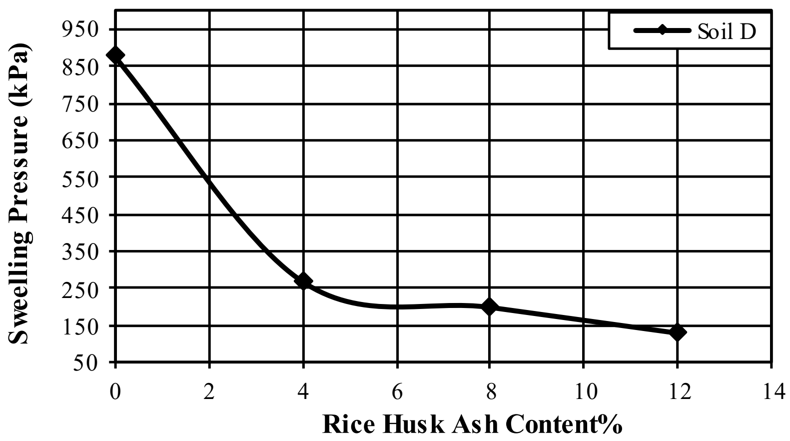


Fig. 19. Swelling pressure and rice husk ash content relationship (soil D).

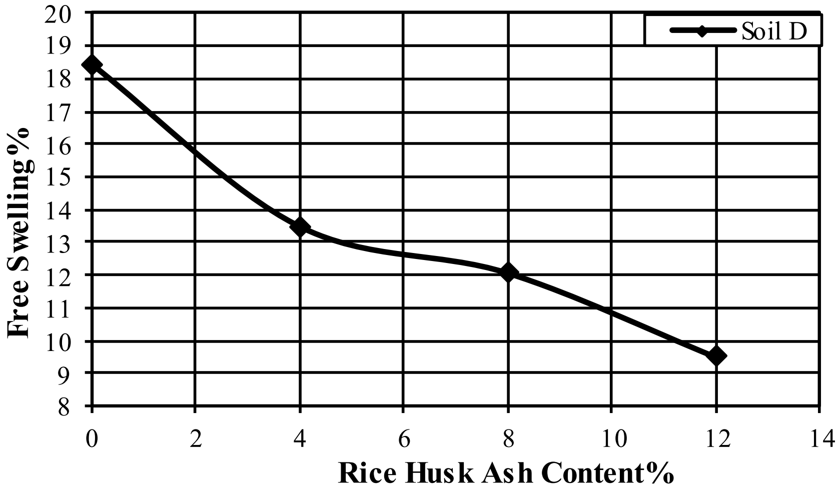


Fig. 20. Free swell and rice husk ash content relationship (soil D).

10. Conclusions

From the tests results, the main conclusions can be drawn as follows:

- The plasticity index increased significantly when the bentonite percentage increased. While it decreased when RHA percentage increased.
- The specific gravity decreased when bentonite percentage increased, also it decreased when RHA percentage increased.
- The max dry density decreased when bentonite percentage increased.
- The optimum moisture content increased when bentonite percentage increased.

Free swell and swell pressure highly increase with increasing bentonite percentage. Adding RHA with different percentages causes a decrease in the free swell and swells pressure. In addition, the optimum percentage of rice husk is 4% which gives the optimum reduction in the free swell and swell pressure.

Abbreviations

CBR	California Bearing Ratio
GS	Specific Gravity
LL	Liquid Limit
MDD	Maximum Dry Density
OMC	Optimum Moisture Content
PL	Plastic Limit
PI	Plasticity Index
RHA	Rice Husk Ash
UCS	Unconfined Compressive Strength

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