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Use of rice husk ash for soil stabilization

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Abstract: Rice husk is one of the largest farm refuse in Malaysia and is put into use as a fuel, building bricks, among other things. A large quantity is being disposed off by dumping or by burning and is becoming a menace. An attempt has been made in this investigation to make use of the rice husk ash to stabilize clayey soil along with lime. The effect of the quantity of the admixture of lime and rice husk ash on soil index properties, compaction and strength characteristics are studied. The influence of the ratio of the quantities of lime and rice husk ash for a given quantity of admixture on the soil behaviour are also investigated. It has been found that there is a decrease of maximum dry density and an increase of optimum water content when the soil is treated with the admixture of lime and rice husk ash. The plasticity index of the soil is decreased by treating the soil with the admixture of lime and rice husk ash. The effect is more significant after a curing period of 28 days. It has also been found that there is an optimum quantity admixture at which the soil attains peak strength. The peak strength increases as the curing time increases.

INTRODUCTION

Soil stabilization is the process of increasing or maintaining the stability of a soil mass which results in improving the engineering properties of soil. One of the methods of stabilizing soil is the use of special stabilizers such as lime, cement, bitumen and other chemicals. Soils which are free from organic matter usually show a significant improvement on stabilization with cement. This stabilization with cement is used where great strength is not needed. The most important property required is durability, which is the resistance to cycles of wetting and drying. Strength and durability has been found to go together. It is therefore much simpler to test specimens for compressive strength rather than durability.

Lime stabilization is mainly used in the construction of sub-bases and bases and for improving the subgrade of roads. This is particularly useful for heavy plastic clays which are difficult to be treated otherwise.

Lazaro and Moh (1970) have used rice husk ash (RHA) with lime to stabilize two types of clayey soils, namely, Bangkok clay (TH) from Thailand and Maligaya clay (PH) from Neuva Ecija, Philippines. They have concluded that the addition of an admixture of lime and RHA reduces the plasticity, and increases the compressive strength, of the tested soils.

Puzzolanic material, is a silicious, or silicious and aluminous, material which by itself possesses little or no cementatious value, but, which will in a finely divided form and in the presence of moisture chemically react with lime at ordinary temperatures to form compounds possessing cementatious properties, O'Flaherty (1978) and Lazaro and Moh (1970). Rice husk ash comes under the category of artificial puzzolanic material like that of waste products from industry, which include ground

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bricks, pulverised blast furnace slag, fly ash and burnt shale. The rice husk ash is a primarily silicious material and thus could act as puzzolan and be an additional source of reactive material.

In this investigation an attempt has been made to study the influence of the addition of an admixture of lime and RHA to the clayey soil obtained from Klang town area on the plasticity, strength and compaction characteristics of such a soil.

Mixtures of varying percentages of total weight of dry soil and admixture have been added and its influence on some engineering properties of the soil have been studied. The ratio of lime to RHA has also been varied for each quantity of admixture added and its effect has been studied on the engineering properties of soil.

EXPERIMENTAL INVESTIGATIONS

The soil has been collected at depths of about 1.5m from open pits near a house construction site at Klang town. The properties of the clayey soil are given in Table 1. The soil is classified according to Unified Classification System as CH.

TABLE 1

Textural composition			Physical properties			Engineering properties		
Sand (%)	Silt (%)	Clay (%)	L.L. (%)	P.L. (%)	P.I. (%)	opt. moist. (%)	Max. dry density (lb/ft^3)	q_u (lb/ft^2)
0	42	58	78	34	44	30.2	82.2 (1.31gm/c.c.)	46.6 (3.28 kg/cm^2)

No tests for the identification of clay minerals were carried out as this study is aimed primarily at the application of rice husk ash for stabilizing this type of soil and its effect on the various soil properties.

The RHA used in this investigation is a black ash from the Kedah burner unit supplied by the Standards and Industrial Research Institute of Malaysia (SIRIM). The composition of this RHA is given in Table 2. The RHA is oven dried and passed through BS 425 sieve for this investigation.

TABLE 2

Name of chemical	Quantity in percentage
Silicon Dioxide (SiO_2)	79.50
Aluminium Oxide (Al_2O_3)	5.43
Iron Oxide (Fe_2O_3)	0.11
Calcium Oxide	0.28
Magnesium Oxide	0.15
Potassium Oxide	1.07
Sodium Oxide	0.09
Ammonium Hydroxide group	5.54
Loss on ignition	9.20

Commercial lime is used for preparing the admixture of lime and RHA. The various quantities of admixtures used in this investigation are 5%, 10%, 15%, 20% and 25% of the total weight of the dry soil and admixture. The ratio of lime to RHA for each quantity of admixture has been varied as 5:5, 4:6, 3:7, 2:8 and 1:9.

Atterberg Limit tests have been carried out with the various quantities of admixtures of lime and RHA added to the soil. The tests have been carried out for O-day and 28-day curing times. The test results are presented in Table 3. The L.L. and P.L. tests have been carried out on air dried samples. The samples of two curing periods have been tested under exactly similar conditions.

TABLE 3

Quantity of admixture (%)	Ratio of lime and RHA	Curing time					
		Zero day			28 days		
		L.L. (%)	P.L. (%)	P.I. (%)	L.L. (%)	P.L. (%)	P.I. (%)
5	5:5	84	46	38	66	42	24
	3:7	85	46	40	70	43	27
	1:9	86	45	41	72	41	31
10	5:5	82	45	37	66	45	21
	3:7	88	51	37	70	45	25
	1:9	84	42	42	73	41	32
15	5:5	82	47	35	67	45	22
	3:7	85	50	35	69	45	24
	1:9	84	44	40	71	40	31
20	5:5	86	53	33	65	45	20
	3:7	85	50	35	70	48	22
	1:9	86	48	38	70	43	27
25	5:5	82	49	33	69	49	20
	3:7	82	49	33	71	50	21
	1:9	84	48	36	72	48	24

The shearing strength characteristics of the soil have been studied by carrying out the unconfined compressive strength tests. The soil specimens have been prepared at its corresponding maximum dry density and used for the test. The tests have been carried out for 3-day, 7-day and 28-day curing times. The test results are presented in Table 4.

Proctor compaction tests have been done for the soil with varying quantities of admixtures of lime and RHA and the effect of the same on the maximum dry density and the optimum moisture content was also studied (see Table 5).

ANALYSIS AND DISCUSSION

Effect on Atterberg Limits:

It can be seen from Tables 1 and 3 that all the soil samples which are treated with the admixture of lime and RHA showed a decrease in plasticity index when compared

TABLE 4

Quantity of admixture (%)	Ratio of Lime and RHA	Curing time		
		3 days	7 days	28 days
		Unconfined compressive strength (kg/cm²)		
5	1:9	2.39	2.69	3.43
	2:8	3.15	3.39	4.65
	3:7	3.40	3.72	5.40
	4:6	3.75	4.41	5.90
	5:5	3.86	4.87	6.43
10	1:9	3.86	3.91	4.66
	2:8	4.57	4.90	5.70
	3:7	4.66	5.36	6.52
	4:6	4.83	5.62	7.18
	5:5	5.00	5.80	7.55
15	1:9	2.25	2.79	2.80
	2:8	3.62	3.66	3.77
	3:7	3.64	4.16	4.54
	4:6	3.99	4.66	5.46
	5:5	4.13	5.06	6.29
20	1:9	1.58	1.76	2.11
	2:8	1.97	2.43	2.50
	3:7	2.44	2.73	3.10
	4:6	2.98	3.68	4.18
25	1:9	1.38	1.67	1.76
	2:8	1.86	2.16	2.55
	3:7	2.37	2.80	3.08
	4:6	2.80	3.08	4.02
	5:5	3.15	3.68	4.85

with the plasticity index of the untreated soil. The plasticity index was significantly lowered for the soil with admixture allowed for a 28-day curing time. This is due to the puzzolanic reactivity of silicious materials from both the RHA and the clayey soil. The effect is more pronounced as the curing time is increased. It can also be referred from Table 3 that the plasticity index of the soil decreases as the quantity of admixture of lime and RHA is increased. This shows that the reaction between lime and RHA has been well utilised. For a given quantity of admixture the plasticity index increases as the ratio of lime to RHA is decreased. This may be attributed to the insufficient lime for complete puzzolanic reaction to take place. This may be confirmed by further tests.

Effect on compaction characteristics of soil:

It has been observed that when the admixture of lime and RHA has been added to the soil, the maximum dry density decreases and the optimum moisture content increases irrespective of the ratio of lime to RHA in the admixture (see Table 5). The reduction in maximum dry density is due to the pesence of RHA, which is a light weight material with specific gravity of 2.06. The increase in optimum moisture content is due to the additional water required for the hydration of lime as well as to assist

TABLE 5

Amount of admixture (%)	Lime-RHA ratio	Maximum dry density (gm/cc)	optimum moisture content (%)
5	5:5	1.29	31.4
	3:7	1.28	32.0
	1:9	1.27	32.9
10	5:5	1.23	33.4
	3:7	1.22	34.9
	1:9	1.21	36.6
15	5:5	1.19	37.2
	3:7	1.15	37.7
	1:9	1.15	40.0
20	5:5	1.18	38.3
	3:7	1.11	42.0
	1:9	1.05	45.4
25	5:5	1.15	39.4
	3:7	1.11	42.6
	1:9	1.05	45.2

flocculation of the clay clods. Additional water might be absorbed by the fine RHA particles present. It should be noted that the reduction in maximum dry density need not imply that there is a corresponding reduction in strength attainable as the strength is primarily due to the puzzolanic reactivity which occurs after a considerable curing time.

Effect on strength characteristics of soil:

The unconfined compressive strength test values versus the quantity of admixture of lime and RHA for different ratios of lime and RHA are presented in Figures 1 to 3 for 3-day, 7-day and 28-day curing times. It can be seen from the Figures that the peak strength occurs at 10% of the admixture irrespective of the ratio of lime and RHA. Also for a given quantity of admixture, as the ratio of lime to RHA increases, the strength increases. This implies that the lime reacts more readily with the soil than the ash. It has been found that as the curing time increases, the strength increases (Table 4). The gain in strength is due to the increased puzzolanic reactivity with time between the lime and the silicious materials from both the RHA and the soil. Since lime carbonation was prevented during the curing period by properly sealing the containers containing the soil samples, it is reasonable to assume that any gain in strength in addition to the soil-lime reaction could be attributed to the puzzolanic reaction contributed by the presence of rice husk ash in the mixture.

It can be seen that the peak value of unconfined strength value of the treated soil is in the order of 760kN/m^2. This value is rather low for a treated soil. This is due to the presence of high carbon content in RHA used and is reflected in the percentage of ignition loss which is equal to 9.2% for this RHA. High carbon content is undesirable in stabilization as it is a weak material and lowers the strength. Carbonation of lime could have taken place due to the presence of carbon dioxide in the air and moisture

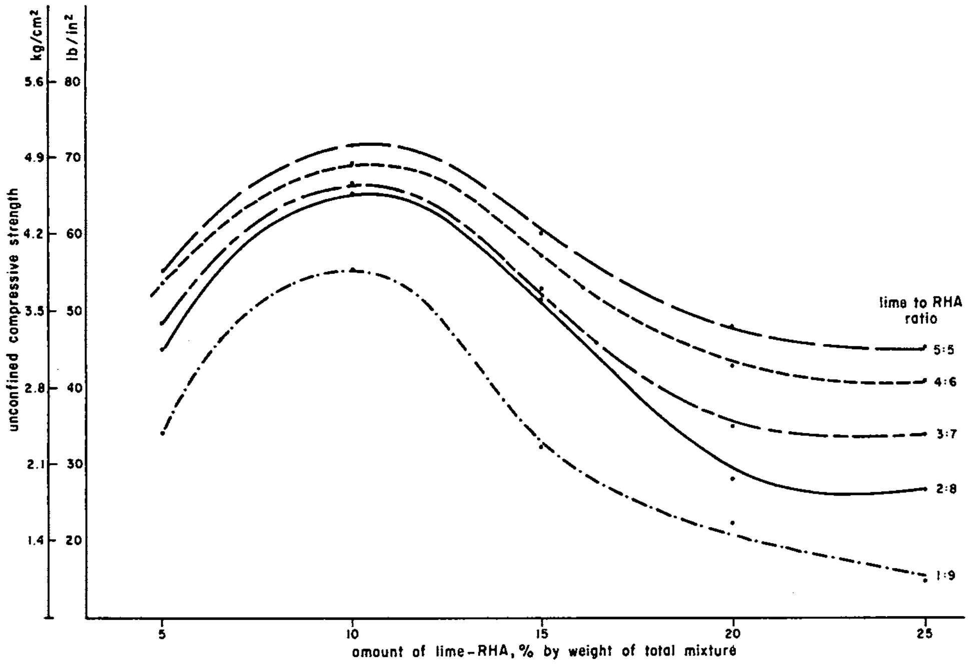

Fig. 1. Effect of amount of admixture on strength of lime-RHA stabilized soil (3-day strength values)

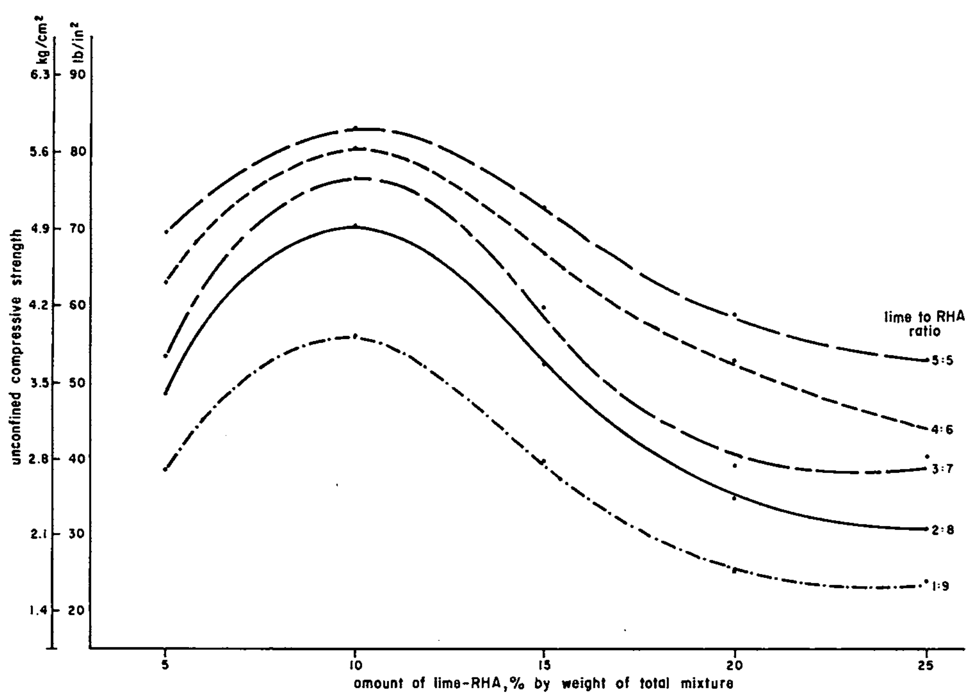

Fig. 2. Effect of amount of admixture on strength of lime-RHA stabilized soil (7-day strength values)

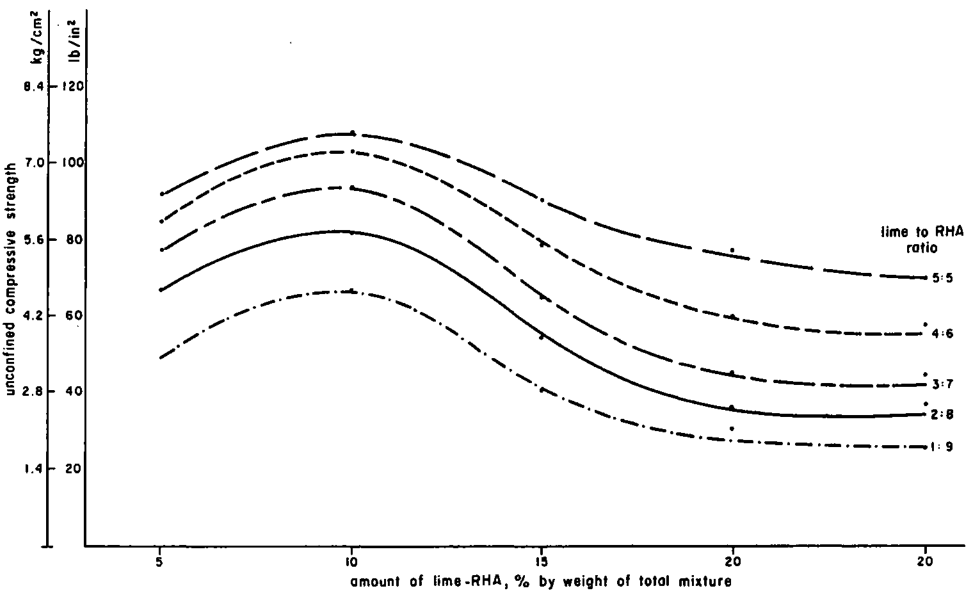

Fig. 3. Effect of amount of admixture on strength of lime-RHA stabilized soil. (28-day strength values)

from the soil. Carbonation leads to the formation of calcium carbonate which is a weak material compared with the hydrated products. Absence of free lime in RHA can also account for low strength values. Therefore, it can be concluded that RHA with a low percentage of ignition loss may be used for soil stabilization.

From the composition of RHA presented in this paper, one could observe that the main ingredient is finely divided silica and to some extent alumina. When lime is added to the soil, the puzzolanic reaction which involves lime and alumina and silica present in the soil takes place in the formation of hydrous calcium aluminates and silicates which are similar to the reaction products of hydrated cement. Therefore, the gain in strength due to cementation is a function of the type of the clay mineral present in the soil to be stabilized. For example, montmorrillonitic soils which contain large amounts of reactive silica may require several years before the puzzolanic reaction is completed whereas the soils like coarse sands and silts which contain low amounts of reactive silica and alumina will have little reaction with lime. The addition of RHA contributes to the increase in silica content and thereby increased puzzolanic reaction. In fact the stabilization of coarse sands and silts will be more effective with a lime and RHA admixture. Further studies are still in progress.

Stabilization with lime alone is not always suitable. Lime alone can be used for stabilization for montmorrillonitic soils and also very expensive as the quantity of lime needed for stabilization with lime alone will be high. A plot of strength values obtained for the soil treated with lime alone and the maximum strength envelope of the soil treated with lime-RHA admixture is presented in Figure 4. It can be seen from the Figure that for equivalent strength values, the amount of lime required for a lime-

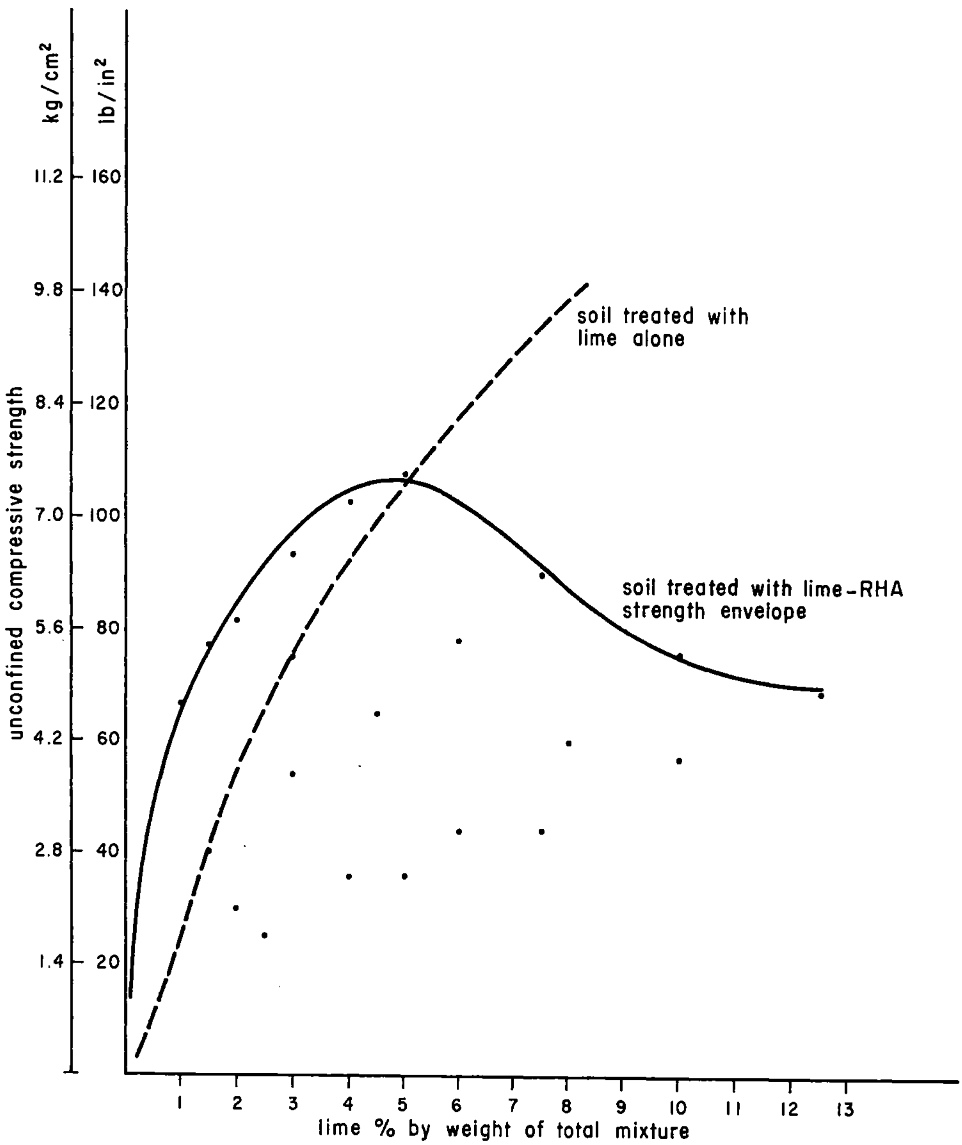

Fig. 4. Effect of RHA on optimum lime content for maximum strength (28-day curing)

RHA-soil system is less than that required for a lime-soil system. This is evident for lime percentages less than 5 % of the total mixture. Further studies in this direction are in progress.

The puzzolanic reaction between lime and soil is considerably influenced by the amount and type of the lime used. In general, the strength increases as the lime content increases, but for a given curing period, there is an optimum lime content. This has been clearly observed in the Figures 1 to 3 presented in this paper. The optimum quantity of admixture producing the maximum strength has been obtained as 10 % by weight of total mixture for the soil investigated and the lime used. This quantity will vary according to the type of the clay mineral present in the soil.

CONCLUSIONS

Based on the above experimental investigations, the following conclusions have been drawn:

i. Rice husk ash in combination with lime can be used for soil stabilization.

ii. The plasticity index of the soil is significantly reduced by the addition of the admixture of lime and RHA. This is more pronounced when a longer curing time is allowed.

iii. The maximum dry density is decreased and the optimum moisture content is increased when the soil is treated with the admixture of lime and RHA.

iv. The unconfined compressive strength of the soil is increased when the soil is treated with the admixture of lime and RHA. There is an optimum quantity of admixture at which the unconfined compressive strength is maximum. It has been found that the unconfined compressive strength value is maximum when the quantity of admixture added to the soil is 10% of the total weight.

v. As the curing time is increased, the strength of the treated soil is increased.

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