ISSN 1411-5360

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TEKNIK SIPIL

Volume 5 Nomor 1 Juni 2004

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FAKULTAS TEKNIK
UNIVERSITAS KATOLIK PARAHYANGAN

J. Tek. Sipil	Vol. 5	No. 1	Hlm. 1-84	Bandung Juni 2004	ISSN 1411-5360

ISSN 1411-5360

JURNAL
TEKNIK SIPIL

Volume 5 Nomor 1 Juni 2004

Alamat Redaksi/Penerbit : **Fakultas Teknik Universitas Katolik Parahyangan**
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STABILIZATION OF CLAY AND RESIDUAL SOILS USING CEMENT - RICE HUSK ASH MIXTURES

Ehammed A. Basha, Roslan Hashim and Agus Setyo Muntohar

Abstract

The well established techniques of soil stabilization often use such cementing agents as Portland cement, lime, etc. Replacement of those cementing materials with industrial or agricultural by-product is highly desirable. Rice husk ash is a very potential paddy crop waste as pozzolanic materials which result in a superior properties when combined with cement or other cementing agents. This paper presents the laboratory study on the stabilized soils with cement and rice husk ash. The experimental study included the evaluation of such properties of the soil as consistency limits, compaction, unconfined compressive strength, and X-Ray diffraction. Three types of soils are used in this study i.e granite residual soils, kaolinite clay and montmorillonite clay (bentonite). Test results show that both cement and rice husk ash reduces the plasticity of soils. In term of compactability, addition of rice husk ash and cement decreases the maximum dry density and increases the optimum moisture content. From the viewpoint of plasticity, compaction and strength characteristics, and economy, addition of 6 – 8 percent cement and 10 – 15 percent rice husk ash are recommended as an optimum amount for soils stabilization.

Key words: *soil stabilisation, chemical additives, cement, rice husk ash, residual soil, clay.*

INTRODUCTION

Stabilised soils are, in general, composite materials that result from combination and optimisation of the properties of individual constituent materials. The well-established techniques of soil stabilisation are often used to obtain improved geotechnical materials through either the addition to soil of cementing agents such as Portland cement, lime, asphalt, etc.

As a result of the increase in the amount of solid waste all over the globe, engineers and researchers carry out many investigations to find the uses for such wastes. Environmental and economic issues in many countries have inspired interests in the development of alternative materials that can fulfil design specifications. The transportation, construction, and environmental industries have the greatest potential for re-use because they use vast quantities of earthen materials annually. Replacement of natural soils, aggregates, and cement with solid industrial by-product is highly desirable. In some cases, a by-product is inferior to traditional earthen materials, but its lower cost makes it an attractive alternative if adequate performance can be obtained. In other cases, a by-product may have attributes superior to those of traditional earthen materials. Often select materials are added to industrial by-products to generate a material with well-controlled and superior properties.

Mehta (1985) studied the possibility of using fly ash in cement and concrete works. Investigators such as Gidley and Sack (1984) proposed several methods for utilizing some industrial wastes in engineering construction. Tay (1987) studied the use of sludge ash in portland cement concrete works. Other studies examined the possibility of improving soil properties such as increasing shear strength, reducing settlement, and minimizing swelling problems by using solid waste. Kamon and Nontananandh (1991) combine industrial waste with lime to stabilize soil. Atom and Al-Sharif (1998) evaluated burned olive waste for use as soil stabilizer, which a partial solution to the problems associated with the increase of olive waste in Jordan.

In the agricultural countries, there are problems regarding the abundance of agriculture wastes as shown in Figure 1. These plants obtain various minerals and silicates from earth in their bodies during growth process. Inorganic materials, especially silicates, are found in higher proportions in annually grown plants than in the long-lived trees. Rice, wheat, sunflower, and tobacco plants therefore contain higher amounts of silica in their cuticle parts. Inorganic materials are found in the forms of free salts and particles of cationic groups combined with the anionic groups of the fibres into such plants (Rydholm, 1965).

Figure 1 Rice husk disposal at the rice mill in Kuala Selangor, Malaysia

Incineration of organic materials, production of new crystalline phases, or crystallization of amorphous material are exothermic processes that lead to ash production and loss in the total weight. The result of burning organic materials is called thermal decomposition. The ash produced in this way is ground to a fine size and mixed with lime in order to obtain a material with a binding characteristic. The quality of this material depends on burning time, temperature, cooling time, and grinding conditions (James, and Rao, 1986a, 1986b). The primary objective of this study is to examine the potential of burnt agricultural by-products, rice husk, for using this material for stabilising soils. The effects on the consistency, density, and strength of some various soil types are studied.

EXPERIMENTAL INVESTIGATION

Materials Used

Clay and Residual Soils

Three different soil types were used in this study, i.e. residual soils, and commercial available soils. Residual granite soil is typically local Malaysia residual soil that was used in this study. Table 1 and Table 2 show the properties of the three soils types. Kaolin and bentonite, locally commercial product, were used. Figure 2 shows the diffractograph of the soils. Kaolinite clay mineral was identified in the residual soil by its strong diffraction line at 3.57 Å, which disappeared when heated to 550^o C. Kaolinite was also detected in the kaolin by its strong diffraction lines at 7.13 Å and 3.56 Å. The two peaks remain, even though their intensities were significantly reduced, after heating. Wyoming bentonite was predominantly comprised of Na-montmorillonite.

Table 1 Properties of the Residual Soil

Properties	Value
Physical properties:	
Natural water content	26%
Liquid Limit	36.77%
Plastic Limit	22.95%
Plasticity Index	13.82%
Linear Shrinkage	6.71%
Specific Gravity	2.37
Particles:	
Sand	46 %
Silt	44 %
Clay	10 %
Chemical:	
Silica (SiO_2)	71.16%
Alumina (Al_2O_3)	16.15%
Iron Oxide (Fe_2O_3)	4.98%
Potash (K_2O)	1.46 %
Magnesia (MgO)	0.25%
Loss on Ignition	5.61%

Rice husk ash

Rice husk was considered a valueless by-product of rice milling. At the mills, disposal of the husk was by burning them in heaps near the mills. Even though, the ashes have been potential pozzolanic materials suitable for use in lime - pozzolana mixes and for portland cements replacement (Payá, et. al, 2001). The ashes used in this study were obtained from burning of rice husk in the incinerator. The ashes are confirmed by X-ray diffraction test as amorphous reactive silica as illustrated in Figure 3. The properties of the ashes are presented in Table 3.

Cement

The cement used was general portland cement. The physical and chemical properties of the cement are given in Table 3.

Table 2 Properties of used clay (kaolin and bentonite)

Properties	Malaysia Kaolin	Wyoming Bentonite
Physical properties:		
Moisture Content	< 5%	Max. 12%
Specific Gravity	2.6	2.4 – 2.8
Particles:		
< 2 μm	26.0 %	
< 10 μm	85.0%	
< 74 μm		97% (wet)
< 44 μm		95% (wet)
Chemical:		
Silica (SiO_2)	45.0%	63.02%
Alumina (Al_2O_3)	33.0 %	21.08%
Iron Oxide (Fe_2O_3)	< 1.0 %	3.25%
Potash (K_2O)	< 2.0 %	2.57%
Magnesia (MgO)	< 1.0 %	2.67%
Loss on Ignition	10.5 %	0.72%

Laboratory Tests

Atterberg limits tests

The Atterberg consistency limits testing and reporting was carried out in accordance with British Standard methods - BS 1377: Part 2-1990 (British Standard Institution, 1990a). The residual soil was sieved with 425 mm sieving. Materials that retained on that sieve were rejected for this test. Since the kaolin and bentonite used were either fine, no sieving was carried out. The soils, then, were oven dried for at least 2 hours before the test. The tests were carried out on the soils with different proportion of cement and rice husk ash.

Compaction tests

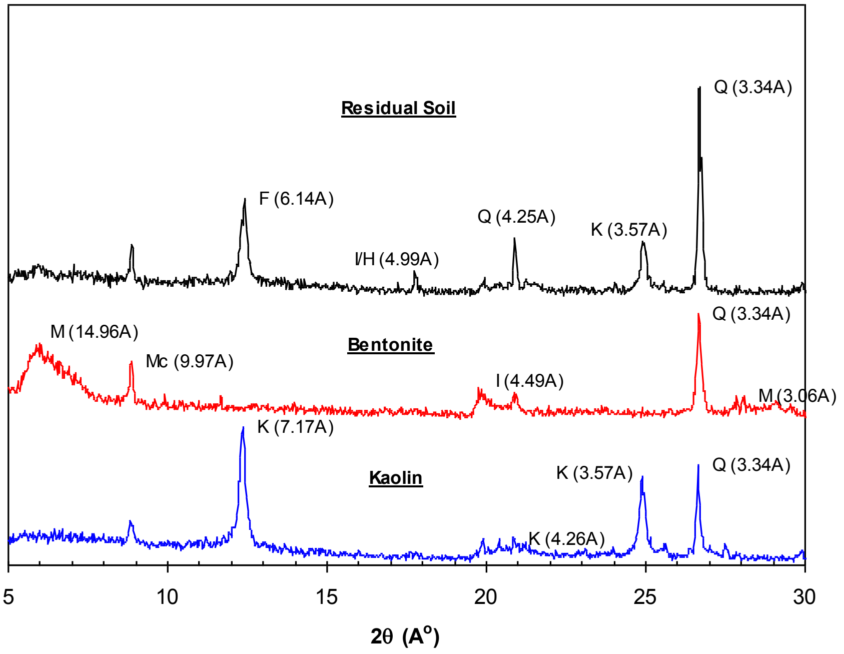
Proctor standard compaction test, BS 1377 – 1990: Part 4 (British Standard Institution, 1990b), was used to determine the maximum dry density (MDD) and the optimum moisture content (OMC) of the soils. The soil mixtures, with and without additives, were thoroughly mixed with various moisture contents and allowed to equilibrate for 24 hours prior to compaction. The first series of compaction tests was aimed at determining the compaction properties of the unstabilised soils. Secondly, tests were carried out to determine the proctor compaction properties of the clay upon stabilisation with varying amounts of cement and rice husk ash.

Table 3 Physical and Chemical Properties of the Cement and RHA.

Properties	Cement	RHA
Physical properties:		
Moisture Content		3.68%
Specific Gravity	3.12	2.08
Fineness	2975 cm^2/g	12.5% (Retained 45 μm sieving)
Chemical Composition:		
Silica (SiO_2)	20.44 %	93.15%
Alumina (Al_2O_3)	5.50%	0.21%
Iron Oxide (Fe_2O_3)		0.21%
Calcium Oxide (CaO)	64.86%	0.41%
Potash (K2O)		22.31%
Magnesia (MgO)	1.59%	0.45%
Loss on Ignition	1.51%	2.36%
pH	12.06	9.83
$3CaO.SiO_2$	66.48%	
$2CaO.SiO_2$	10.12%	
$3CaO.Al2O_3$	8.06%	
$4CaO.Al_2O_3.Fe_2O_3$	9.43%	
Free Lime	1.65%	

Unconfined compressive tests

Each specimens used in unconfined compressive tests were statically compacted in a cylindrical mould, 50 mm in diameter by 100 mm height, at optimum moisture content and maximum dry density. The test was conducted according to BS 1924 – 1990: Part 2 - Section 4 (British Standard Institution, 1990b). Specimens were, after moulded, cured in plastic bag for 7 days to prevent the moisture due to change. A series of specimens were soaked under water for 7 days to simulate the effect of heavy rainfall on the strength.



M: Montmorillonite, F: Feldspar, Mc : Muscovite, K : Kaolinite, Q : Quartz, I: Illite, H: Halloysite

Figure 2 X-Ray diffraction pattern of residual soil, bentonite, and kaolin

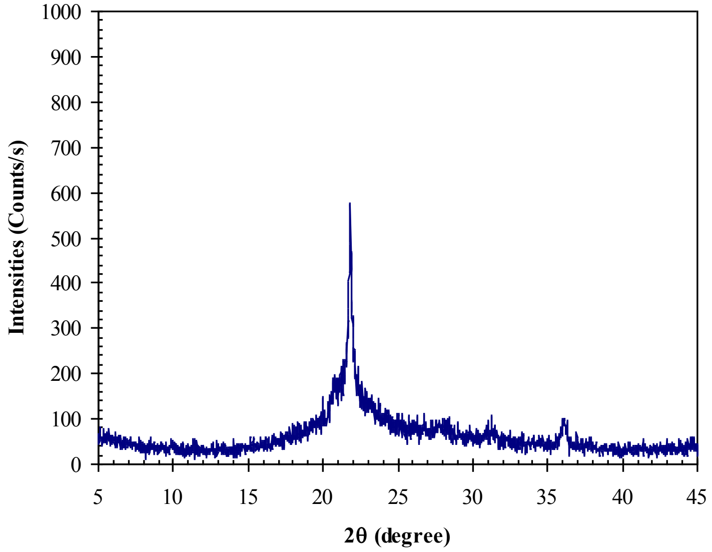
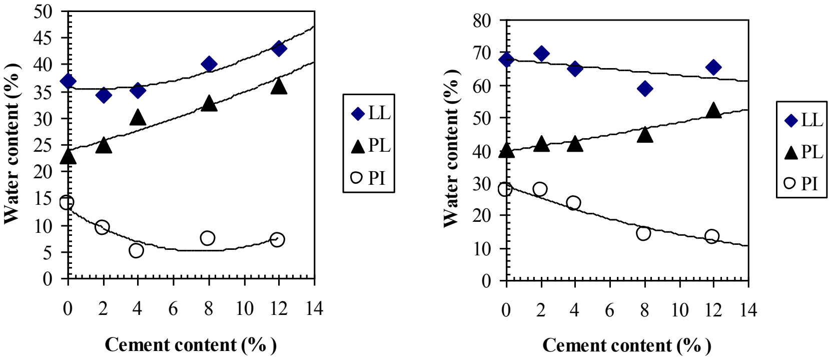


Figure 3 X-ray diffractograph of incinerated rice husk ash

RESULTS AND DISCUSSION

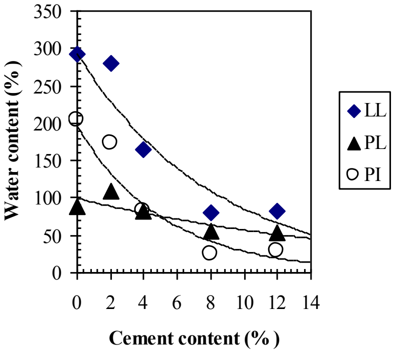
Effect on the consistency limits

The effect of cement and rice husk ash (RHA) stabilised soils on the liquid limit (LL) and plasticity index (PI) on the different soils are shown in Figure 4 and 5. In this context, it was illustrated a different characteristics of each soils. Reduction in plasticity of cement/RHA stabilised - residual soils as result of increase in liquid limits and plastic limits, in contrast with cement stabilised bentonite. For cement/RHA treated kaolin, liquid limits decreases while the plastic limits increase corresponds to cement/RHA increases.



(a) Residual soils

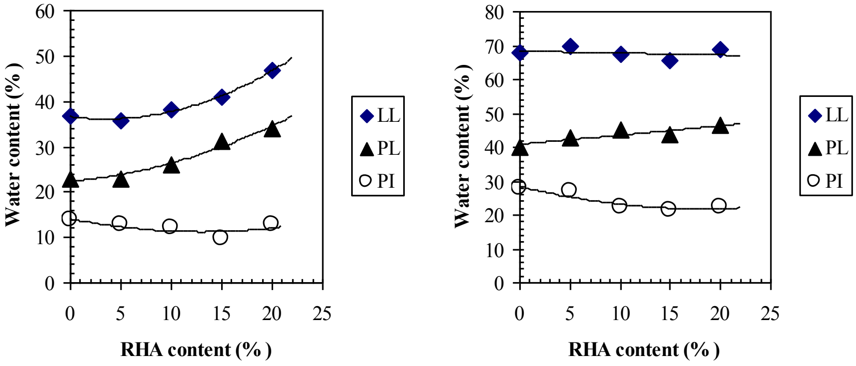
(b) Kaolin



(c) Bentonite

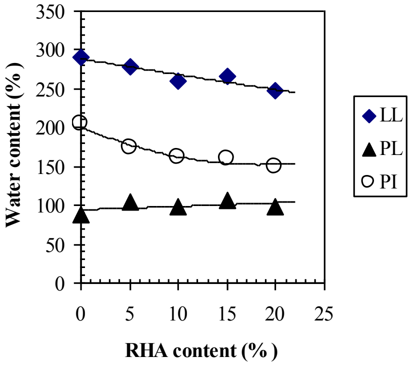
Figure 4 Variation of Consistency Limits with Cement Percentage

It has been observed that cement and RHA reduce the plasticity of all soils. Cement treated bentonite reduced significantly the PI of bentonite as shown in Figure 6(a), while blend of RHA with cement indicated no significant improvement. Cement – RHA mixture exhibited further improvement for kaolinite soils as illustrated in Figure 6(b). It proved that cement work effectively with bentonite or expansive clays. Grim (1968) mentioned that Ca^{2+} cation will easily replace Na^{+}, this term possible occurred in the cement stabilised bentonite. In general, 6 – 8 % of cement and 10 – 15 % RHA shows optimum amount to reduce plasticity of soils. Reduce in plasticity index is an indicator of improvement.



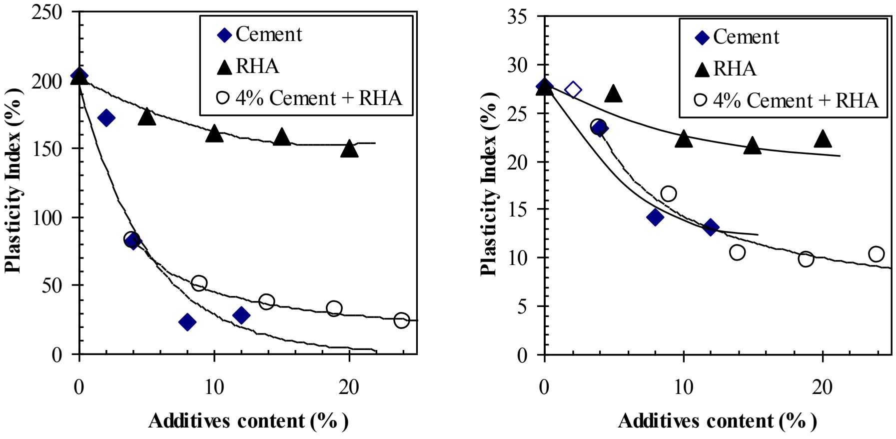
(a) Residual soils

(b) Kaolin



(c) Bentonite

Figure 5 Variation of Consistency Limits with RHA Percentage

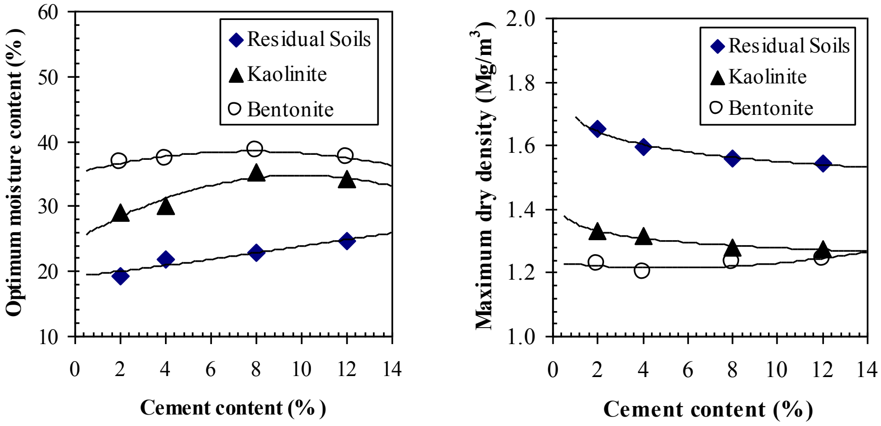


(a) Bentonite (b) Kaolin

Figure 6 Effectiveness of Additives on PI of Kaolin and Bentonite

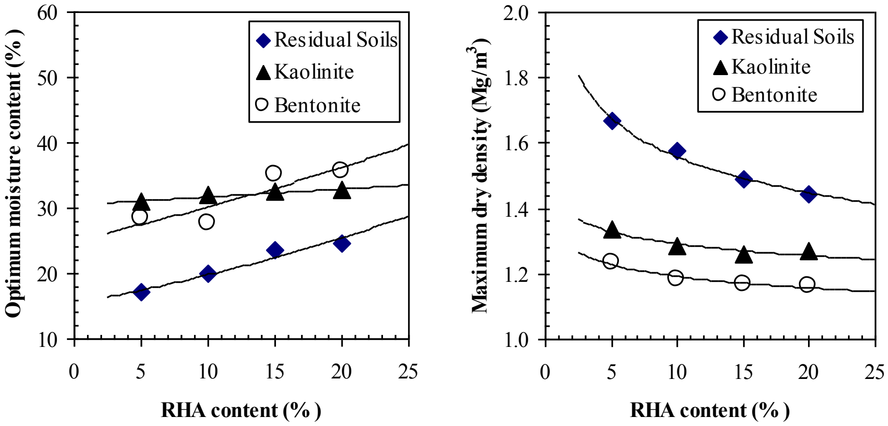
Effect on the compactability

Figure 7, 8, and 9 shows, respectively, the effect of the addition of cement, RHA, and cement – RHA mixtures on the compaction characteristics of the soils tested.



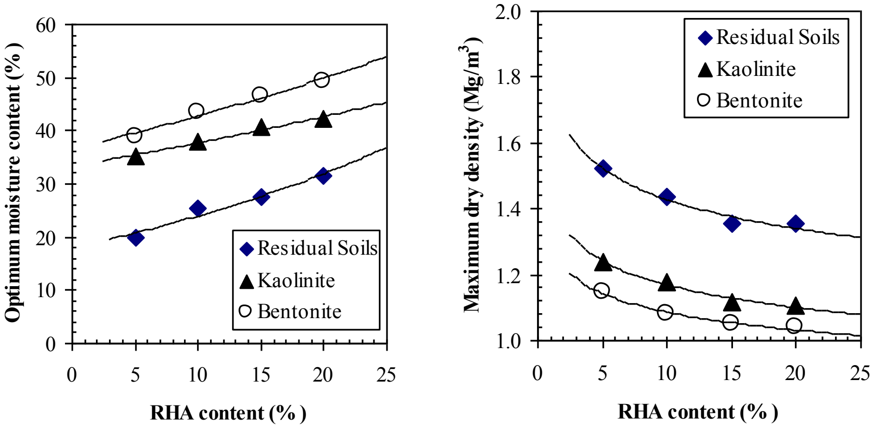
(a) OMC (b) MDD

Figure 7 Variation of Compaction Characteristics of The Soils With Cement Content



(a) OMC (b) MDD

Figure 8 Variation of Compaction Characteristics of the Soils With RHA Content



(a) OMC (b) MDD

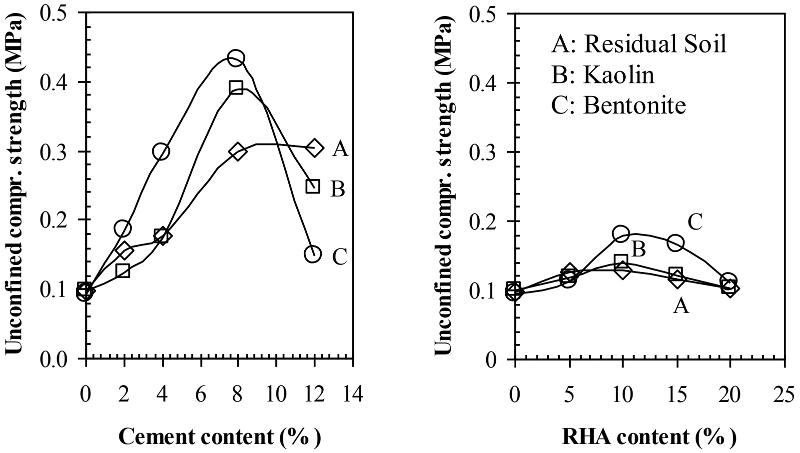
Figure 9 Variation of Compaction Characteristics of the Soils With 4% Cement - RHA Mixtures

Figure 7 show that adding cement slightly increased the OMC and diminish a small amount of the MDD correspond to increasing of cement percentage. Except for bentonite, a little increment of the MDD was observed associated with increases in cement content. In contrast with RHA stabilised soil, the MDD decreases further and at the same time the OMC increases as shown in Fig. 8. The same characteristics can be observed also when 4% cement was blended with RHA as illustrated in Fig. 9. The increase in optimum moisture content is probably a consequence of two reason: (1) the additional waster held with the flocculants soil structure resulting from cement interaction, and (2) exceeding water absorption by RHA as a result of its porous properties, as reported in Zhang et. al (1996). Principally, increase in dry density is an indicator of improvement. But unfortunately, both cement and RHA, instead, reduce the dry density. Rahman (1987) revealed an opinion that the change-down in dry density occurs because of both the particles size and specific gravity of the soil and stabiliser.

Decreasing of dry density indicates that it needs low compactive energy (CE) to attain its maximum dry density, as the result the cost of compaction will be economical (Muntohar and Hantoro, 2000).

Effect on the compressive strength

The effect of the addition RHA and cement individually on the unconfined compressive strength of various soils are shown in Figure 10. Cement is, undoubtedly, an effective additive to enhance the strength of tested soils. In Fig. 10a, it can be observed that the optimum cement content is 8%. It corresponds with optimum cement content that reached on the consistency limit. In contrast with RHA – soil mixtures, Figure 10b, the RHA slightly increase the strength because of the lack of cementitious properties in RHA as presented in Table 2. In agreement with Hossain (1986), hence, RHA cannot be used lonely for stabilisation of soil. This investigation shows that cement – stabilised can be intensified by adding between 15 – 20% of RHA as shown in Figure 11. The figure either shows that 4% cement mixed with residual soil and 20% RHA, kaolin with 4% cement and 15% RHA, and bentonite with 4% cement and 15% RHA have a strength respectively almost 4, 2, and 1.4 times that of a sample with 8% cement. A lesser amount of cement is required to achieve a given strength as compared to cement - stabilised soils. Since cement is more costly than RHA this can result in lower construction cost.



(a) Cement stabilised soil (b) RHA stabilised soil

Figure 10 Effect of the addition of RHA and cement of unconfined compressive strength

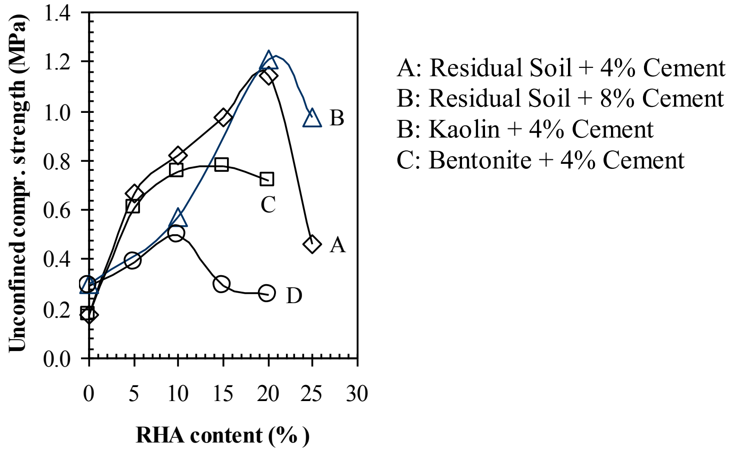


Figure 11 Effect of the addition of RHA on the 4% cement – soil mixtures

Resistance to immersion (Ri)

Resistance to immersion in the unconfined strength of 4% cement – RHA – residual soil mixtures are presented in Table 4. A stabilised soil should have the resistance of its integrity and services – strength along the lifetime of construction. This experiment exhibits that the by addition of RHA in cement – residual soil mixtures have better resistance subject to 7 days immersion. It can be seen that the strength of residual soil mixed with 4% cement and five different RHA content drop-down to 89%, 75%, 95%, 89%, 83%, and 57% respectively for 0, 5, 10, 15, 20, and 25 percent RHA. Mix of 5, 20 and 25 % RHA with 4% cement have greater reduction of strength than cement only. But, the strength raised are still higher than cement stabilised residual soil.

Table 4 Resistance to immersion in the unconfined strength of 4% cement – RHA – residual soil mixtures at OMC + 3% water content

Soil + Additives 4% Cement + RHA	Unsoaked MPa	Soaked MPa	Ratio Soaked/Unsoaked
0%	0.993	0.882	0.89
5%	2.203	1.654	0.75
10%	3.305	3.151	0.95
15%	3.72	3.309	0.89
20%	3.646	3.011	0.83
25%	3.299	1.873	0.57

CONCLUSIONS

The following conclusions can be drawn on the basis of the test results obtained from cement – RHA stabilised soils.

(1) Cement and rice husk ash reduced the plasticity of residual soil, kaolin, and bentonite. A considerable reducing was attained by cement-stabilised soils. Each soil type exhibited a specific characteristic of reduction.

(2) The maximum dry density of cement – stabilised residual soil and kaolin slightly decreased with increase in cement content, in contrast with cement-stabilised bentonite. Adding rice husk ash and cement increase the optimum moisture content of all soils.

(3) The unconfined compressive strength of cement – stabilised soils; whatever residual soil, kaolin, and bentonite; were enhanced by addition of RHA. Addition of RHA need a lesser amount of cement to achieve a given strength as compared to cement - stabilised soils. The resistance to immersion showed

a better improvement. Since cement is more costly than RHA this can result in lower construction cost.

(4) In general, 6 – 8 % of cement and 10 – 15 % RHA shows optimum amount to improve the properties of soils. Reduce in plasticity index and increasing of strength and resistance to immersion are indicator of improvement.

(5) Rice husk ash can potentially stabilise the expansive and non-expansive soils solely or mixed with cement. The utilising is an alternative to reduce construction cost, particularly in the rural area of developing countries.

REFERENCES

Mehta, P.K., 1985, *Influence of fly ash characteristics on the strength of portland – fly ash mixtures*, Cement Concrete Research, Vol. 15, pp. 669-674.

Gidley, J.S. and Sack, W.S., 1984, *Environmental aspects of waste utilization in construction*, Journal of Environmental Engineering, ASCE Vol. 110 (6), pp. 1117 – 1133.

Tay, J.H., 1987, *Sludge ash as filler for portland cement*, Journal of Environmental Engineering, ASCE Vol. 113, pp. 345 – 351.

Kamon, M., and Nontananandh, S., 1991, *Combining industrial wastes with lime for soil stabilization*, Journal of Geotechnical Engineering, Vol. 117, pp. 1 – 17.

Attom M.F., and Al-Sharif M.M., 1998, *Soil stabilization with burned olive waste*, Applied Clay Science, Vol. 13, pp. 219 – 230.

Rydholm, S.A., 1965, *Pulping Processes*, Interscience Publishers, New York, p. 1049 – 1053.

James, J., and Rao, S.M., 1986a, *Silica from rice husk through thermal decomposition*, Thermochimica Acta, Vol. 97, pp. 329 – 336.

James, J., and Rao, S.M., 1986b, *Reactivity of rice husks ash,* Cement and Concrete Research, Vol. 16, pp. 296 – 302.

Payá, J., Monzó, J., Borrachero, M.V., Mellado, A., and Ordoñez, L.M., 2001, *Determination of amorphous silica in rice husks ash by rapid analytical method*, Cement and Concrete Research, Vol. 31, pp. 212 – 231.

British Standard Institution, 1990a, *Methods of test for soils for civil engineering purposes*, BS 1377 – 1990: Part 2, and 4,.

British Standard Institution, 1990b, *Stabilized materials for civil engineering purposes*, BS 1924 – 1990: Part 2 - Section 4,.

Grim, R.E., 1968, *Clay Mineralogy*, 2nd Ed., Mc. Graw Hill, New York, USA, Ch. 7, p. 185 – 233.

Zhang, M.H., Lastra, R., and Malhotra, V.M., 1996, *Rice husk ash paste and concrete: Some aspects of hydration and the microstructure of the interfacial zone between the aggregate and paste*, Cement and Concrete Research, Vol. 26 (6), pp. 963 – 977.

Rahman, M.A., 1987, *Effect of cement-rice husk ash mixtures on geotechnical properties of laterite soils*, Journal of Soils and Foundations, Vol. 27 (2), pp. 61-65.

Muntohar, A.S., and Hantoro, G., 2000, *Influence of the Rice Husk Ash and Lime on Engineering Properties of Clayey Subgrade*, Electronic Journal of Geotechnical Engineering, Vol.5 – 2000, Paper#019, Oklahoma State University, USA.

Hossain, A.S.M.M., 1986, *Cement and cement – rice husk ash stabilisation of selected local alluvial soils*, M.S. Thesis, Department of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka.

CURRICULUM VITAE

Ehammed Abdurrahman Basha is Ph.D candidate at Department of Civil and Environmental Engineering, University of Malaya.

Roslan Hashim is Professor at Department of Civil and Environmental Engineering, University of Malaya.

Agus Setyo Muntohar is as Research Assistant University of Malaya.