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ENGINEERING BEHAVIOUR RICE HUSK ASH BLENDED SOIL AND IT'S POTENTIAL AS ROAD BASE CONSTRUCTION[ℜ]

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ABSTRACT

The rice husk ash (RHA) is high reactive amorphous silica, which is a suitable raw material for making pozzolanas. The outcomes of this study provide insight into engineering behaviour of open field-burnt rice husk ash mixed expansive soil from Yogyakarta, Indonesia. A series of laboratory tests has been performed subject to engineering properties such as indices properties, bearing of soil and shear strength properties. The experiment confirmed the ashes-lime mixtures diminished moderately the plasticity index of tested soil from 42% to 5% by blending of 6% lime and 13% RHA. Although decrease in dry density, the bearing of soils (California Bearing Ratio) value increases steeply from 3% to 16.3% at a 6% lime - 13% ash mixture. In associate with increase in CBR, the shear strength is also increase. All of these factors can be summarized to say that ashes enhance the engineering properties of lime–treated soils.

BACKGROUND

Indonesia as well as other countries in Southeast Asia has a significant amount of its land surface covered by Quaternary soft deposit. These soft deposits materials; frequently exist in areas where developments have taken place or are projected (**Figure 1**); contain many clay mineral are often a problematic and do not perform satisfactorily (Younger, 1991; Bergado et al., 1994).

Those soils appear high compressibility, low strength, and potential to swell – shrink highly. Low-bearing capacity and high swelling – shrinkage of subgrade usually inconvenient, frequently causes detrimental impact for highway or roadway works. As with other problematic soils, they can be improved on site if the cost of borrowing and hauling suitable soils is uneconomical. Improvement often uses additives such as cement, lime, bitumen, pulverised fuel ash, sodium silicates, sodium chloride or a combination of these.

Rice husks are residue produced in significant quantities on a global basis, especially the developing countries. While they are utilized as a fuel in some regions, in others they are abundant waste causing pollution and problem with disposal (**see Figure 2**). Cook (1986) estimated for one tonne of rice yield about 200 kg (20%) of husk and about 40 kg of ash. Indonesia produced paddy annually around 50 million tons for last five years. The amount of husks is 12.5 million tonnes; the ashes produced are approximately 4 million tonnes (Muntohar and Hashim, 2002). Chemically, RHA consists of up to 93 % silica exceeding that of fly ash. Rice husk ash in highly reactive form has been used as a suitable raw material for making hydraulic cement. However, the disposal of ashes can be turned for viable values.

RHA is potential be used solely as stabilizing agents for soil stabilization. Nevertheless, there was not worthy improvement because of lack in cemented materials. The uses can be applied to enhance lime or cement-stabilized soil (Muntohar & Hashim, 2002). RHA represented a potentially useful and cost-effective alternative to other soil stabilisers. However, soil stabilization using RHA, relatively new method, has not been fully accepted for use due to lack of substantial scientific proof of its effectiveness. This paper presents the influence of the RHA enhanced lime-stabilized clayey soil on the engineering properties. The outcomes of this study

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provide insight into engineering behaviour of rice husk ash mixed soil such used as road base construction.

EXPERIMENTAL WORKS

Sample Preparation

Soil sampling was carried out in pits excavated to a depth in excess of 0.5 m to expose fresh sample and avoid the influence of vegetation, in the Western of Yogyakarta. The soil contains predominantly of silt size particles. The soil properties are given in Table 1.

Table 1 Properties Of Soil Samples

Properties	Results
Nature moisture content, w_N (%)	71.4
Specific Gravity, Gs	2.63
Liquid Limits, LL (%)	73.6
Plastic Limit, PL (%)	32.3
Plasticity Index, PI (%)	41.3
Maximum Dry Density, γ_d (kN/m^3)	13.2
Optimum Moisture Content (%)	27.0
Coarse particle (%)	9.2
Fines particle (%)	90.8
Clay size (%)	10.0
Silt size (%)	80.8
CBR (%)	3.0
Compressibility Index (Cc) *	0.028
Activity (A = PI/Clay size)	3.1
Swelling potential (%) *	15.1

Note: * Compacted at MDD and OMC

Rice husk ash (RHA) was collected from brick industry, which used rice husk as fuel to produce fired-brick. The ashes were then ground and sieved passing through ASTM sieving No.200 (0.074 mm). This ash comprises of 89.1% silica (SiO_2). Although a little more costly, hydrated lime was preferred to quicklime, due to its safety and convenience in handling. Quicklime tends to burn exposed skin when moist due to highly exothermic reaction.

Laboratory tests

A series of laboratory tests were conducted namely the Atterberg limit, sedimentation and sieving test, Proctor Standard compaction, CBR test, and UU - triaxial test. The proportion of additives has been studied in Muntohar and Harimawan (1999), the optimum lime and RHA content are 6% and 10% respectively that should be added to clayey soils. The tests were carried out individually or in a combination in which the three different portions were varied at below the optimum, optimum, and exceeding optimum, namely 7, 10, and 13 percent for RHA and the lime content from 2, 6, and 10 percent (by the dry weight of soil). All the samples have been remoulded at their OMC and MDD. The samples were cured for 3 days and kept in plastic bags to prevent the loss of moisture and to allow modification process to proceed.

RESULTS AND DISCUSSION

The tests result such as liquid limits, plastic limits, particles composition, CBR, maximum dry density (MDD), optimum moisture content (OMC), and maximum axial stress, are presented in the Table 2.

Table 2 Engineering Properties Of Stabilized Clayey Soils

Soils Mixes	Code	LL %	PL %	PI %	Finer %	MDD kN/m^3	OMC %	CBR %	c kPa	ϕ Deg.
Original Soil	S	74	32	42	91	13.2	27	3.0	54	5
Soil + 7% RHA	R1	64	31	33	89	12.8	39	5.2	53	8
Soil + 10% RHA	R2	67	39	28	75	12.7	37	5.9	55	10
Soil + 13% RHA	R3	66	41	25	70	12.9	38	6.4	58	16
Soil + 2% Lime	L1	61	43	28	34	12.1	31	5.9	62	13
Soil + 6% Lime	L3	65	47	18	3	12.2	39	10.2	65	10
Soil + 10% Lime	L4	69	61	9	3	12.0	35	12.0	84	14
Soil + 7% RHA + 2% Lime	LR1	65	45	20	34	12.1	31	9.5	50	12
Soil + 10% RHA + 2% Lime	LR2	71	52	19	79	11.9	30	10.6	54	14
Soil + 13% RHA + 2% Lime	LR3	70	55	15	73	11.6	29	9.6	57	18
Soil + 7% RHA + 6% Lime	LR4	54	44	10	2	11.5	37	15.1	52	11
Soil + 10% RHA + 6% Lime	LR5	62	53	9	5	11.6	34	15.5	59	15
Soil + 13% RHA + 6% Lime	LR6	63	58	5	3	11.5	33	16.3	64	22

Note: LL: liquid limit, PL: plastic limit, PI: plasticity index, MDD: maximum dry density, OMC: optimum moisture content, Cc: coefficient of compression, c: cohesion, ϕ: internal friction angle.

Effect on consistency limit and physical properties

Consistency limits or Atterberg limits have been very extensively used in geotechnical engineering for identification, description, and classification of soils, and as a basis for preliminary assessment of mechanical properties of soils. Liquid limit and plastic limit are useful indicators to know the degree of expansion and strength of soils (Mitchell, 1993).

In all admixtures content, the liquid limits decreased, whereas, plastic limits increased. The overall effect is a marked reduction of the plasticity index as shown in **Figure 3**. It was observed that addition of RHA shows lesser reduction than lime-treated soil. Addition of lime exceed 6% result a marginal reduction. However, RHA – lime mixtures achieved considerable reduction of plasticity index, from 42% down to 5% at 6% lime – 13% RHA mix.

Reduction of fine particles may be inferred from flocculation of soil particle to be coarser particles. At ordinary temperatures and in the presence of water, RHA also can react with $Ca(OH)_2$, forming $Ca_{1.5}SiO_{3.5}\cdot xH_2O$. The reaction between the SiO_2 in RHA and $Ca(OH)_2$ can yields bonding gel (C-S-H) (Qijun Yu et al., 1999). It caused agglomeration of fine particles to become bigger particles. Reduces in plasticity index and fine particles is a sign for improvement.

Effect on the compactability

It has been observed that the OMC increase on addition of lime and RHA. This shows that both of additives consume much water to attain the maximum dry density subject to the same compactive efforts. The water was absorbed by the additives to carry on chemical reaction. This condition is an advantage when applied in the rain or winter seasons. Adding the RHA to lime-soil mixtures diminished the MDD to lower 11.50 kN/m^3 as attained from the LR4 and LR6 samples. The MDD of additives – soil mixtures is diminished by the presence of additives owing to its relatively low specific gravity.

Effect on the bearing of soils

The CBR is a value for determination the bearing of soil and also a parameter corresponds to strength of soil. Interestingly, although the dry density is lower than its natural, it does not mean lower CBR value. Instead, it has exhibited increasing of CBR values with increase in amount of additives as shown in **Figure 4**. This is a benefit because at a low compaction effort can be attain a higher strength. The CBR value of lime-treated soil is greater than RHA-treated soil but still higher than unstabilised soil. This is evidence that RHA cannot be used solely in the soil stabilisation. However, addition of RHA to 2% and 6% lime attained higher CBR than lime only. The gain of strength of lime – stabilised soil is regarded primarily as a result of pozzolanic reaction between amorphous silica and/or alumina in the soil and lime to form various types of cementing agents. By introducing RHA to the soil, additional amounts of amorphous silica are available for reaction with lime resulting in further increases in strength.

Shear strength characteristics

The shear strength parameter such as cohesion and internal friction angle of soil was obtained from UU triaxial test. The effect of admixture on the internal friction angle and cohesion has been presented in Table 2. The addition of additives tends to increase the internal friction angle of soil, but there is only a slight difference in the cohesion. Increase in internal friction angle (ϕ) implies that adding RHA enhanced the utility of lime-treated soil, particularly in embankment or slope works. More addition of lime shows brittle behaviour (see **Figure 5**) as shown by 10% lime. Adding RHA makes it more ductile, though the level of strength attained is not high.

Application remarks

In developing countries; such as Indonesia, Thailand, Malaysia, etc.; where rice husks are abundant and considered as waste materials, utilisation of RHA in the construction of roads, and other geotechnical works is intensely attractive. Increasing the CBR value is an advantage to improve the problematic subgrade or road-base. In this scheme used a small content lime, in this research suggest 2%, and added with RHA disposal lead to more valuable contribution. The use may be suitable for suburban or rural region in developing countries. This would generally lead to low construction costs, help alleviate disposal costs and environmental impact and conserve high – grade construction materials for higher priority uses.

The results obtained during this investigation as discussed in the previous sections showed encouraging signs for the used of RHA in soil improvement schemes. The results showed that although the RHA used in the study was obtained from an uncontrolled burning, it could still be effective in improving the properties of the clayey soil. Hence, it implies that the necessary technology required for controlled burning can be omitted reducing the cost of utilizing RHA for soil improvement.

CONCLUSIONS

The study has been successfully conducted to assess the engineering properties of clayey soils improved with RHA wastes and lime.

RHA and lime altered the texture of clay soil by reducing the fine particles. Lime and RHA reduce the liquid limits while the plastics limits increased. As a result, the plasticity indices decreased. Adding RHA to small content of lime reduced significantly the plasticity index.

In terms of compaction, the OMC moves to wet side, while the MDD diminished marginally. It indicates that the additives, especially RHA; imbibe much water to attain the MDD. Although low dry density, the CBR values increased significantly when RHA was added to lime-treated soil.

The internal friction angle and cohesion increases associated with adding RHA to lime-treated soils. Addition of lime up to 10 percent lime exhibited brittle failure. Whereas, soil treated with combination of RHA and lime revealed a ductile behaviour, but the strength increased marginally. Overall results confirmed that addition of RHA to lime-treated soils enhanced the properties and the utility in soil improvement scheme.

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AUTHOR BIOGRAPHIES

The author was born in Purworejo on 14th August 1975. The bachelor of engineering (Sarjana Teknik) was achieved in 1997 and appreciated a “Graduate Achievement Award” from Faculty of Engineering, Gadjah Mada University (Indonesia). After finished the study, then took position as Lecturer Assistant at the same university until joint with Department of Civil Engineering, Muhammadiyah University of Yogyakarta as lecturer in April 1999. Since 2001 until now, involved in a research at Department of Civil and Environmental Engineering, University of Malaya, Kuala Lumpur as Research Assistant. More than twenty papers have been published in journals/conferences at local/regional and international level since 1999 – 2002.

FIGURES

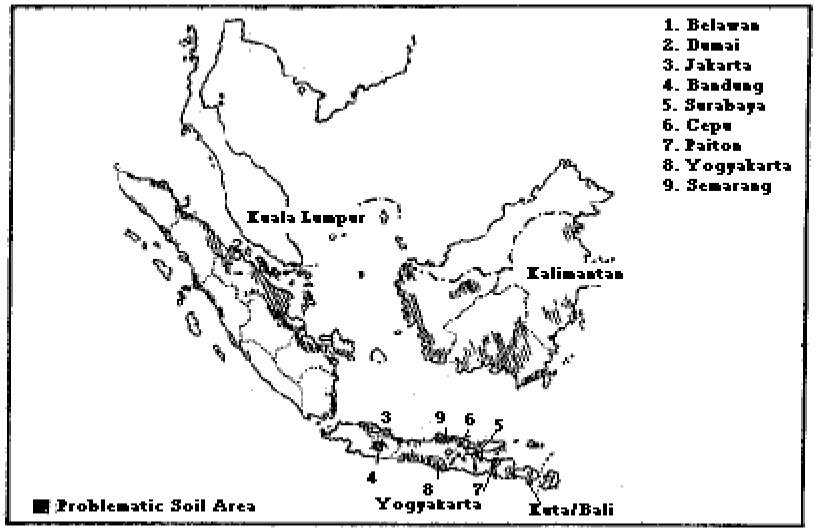

Figure 1. Location of major area of the soft soil in Indonesia.

Figure 2 Rice husks being used as fuel and resulted abundant disposal.

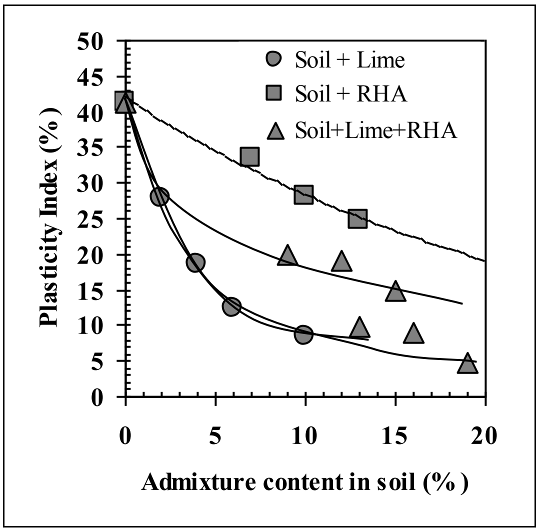

Figure 3 Effect of additive in reducing plasticity index

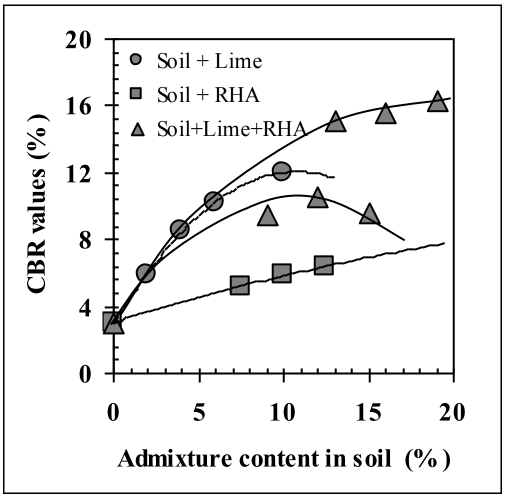

Figure 4 Effect of additives on the CBR

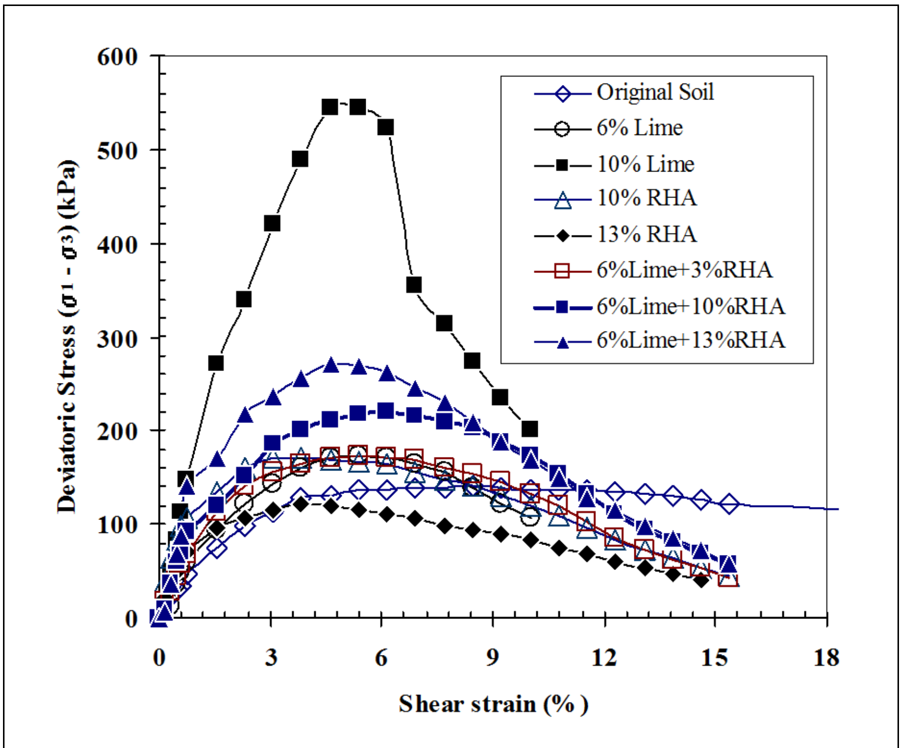

Figure 5 Stress – strain relationship of treated soil