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UTILIZATION OF UNCONTROLLED BURNT RICE HUSK ASH IN SOIL IMPROVEMENT

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ABSTRACT

Expansive soil has been a problem in Indonesia as in other countries. Current research found that there is a potential use of silica waste, resulting from burnt rice husk, as a pozzolanic material. This paper presents the results of study on the utilisation of ashes produced from uncontrolled rice husk burnt in Yogyakarta (Indonesia).

In this research, a series of laboratory tests has been conducted. The tests were carried out individually or in a combination in which the Rice Husk Ash (RHA) content were varied from 7.5, 10, and 12.5 percent, and the lime content from 2, 4, 6, and 10 percent (by the dry weight of soil). All the samples have been remoulded at their optimum moisture content (OMC) and maximum dry density (MDD). The research shows that lime – rice husk ash decreased the swell of expansive soil and improved its strength and bearing capacity.

Keywords: soil improvement, expansive soil, uncontrolled – burnt, rice husk ash.

INTRODUCTION

Several methods of soil improvement using pozzolanic materials have been developed and used successfully in practice. It has been applied in a variety of civil engineering works, like in the construction of base courses where good materials are not economically available; for reducing the permeability and compressibility of soils in hydraulic and foundation works; for stabilisation of slopes, embankments and excavations. A considerable amount of research concerning stabilisation of soil with additives such as cement, lime, lime – fly ash and salt, bitumen and polymers is available in the literature. But soil stabilisation with lime and rice husk ash (RHA) is a relatively new method.

In recent years the use of various waste products in civil engineering construction has gained considerable attention in view of the shortage and high costs of suitable conventional aggregates, the increasing costs of waste disposal and environmental constraints. Rice husk is major agricultural by–product obtained from the food crop of paddy. Generally, it was considered a worthless by–product of the rice mills.

Rice husk has a chemical composition, which typically corresponds to the following: cellulose (40 – 45 %), lignin (25 – 30 %), ash (15 – 20 %), and moisture (8 – 15 %). The ash is mainly derived from the *opaline,* which is present in the cellular structure of husk and about 90 % of which is silica. The silica content in the rice husk depends on the following: (a) the variety of the rice, (b) soil and climate conditions, (c) prevailing temperature, and (d) agricultural practices ranging from application of fertilisers and insecticides etc. The normal method of conversion from rice husk to ash is by incineration.

Chemically, RHA consists of 82 – 87 % silica exceeding that of fly ash. Materials, containing high reactive silica (SiO_2) is suitable to be used as lime-pozzolana mixes and as substitution of Portland cement [1, 2]. The high percentage of siliceous materials in the RHA makes it an excellent material for stabilisation.

Many industries used rice husk as a relatively cheap fuel. Concomitantly, abundance of the ash (RHA) can be a potential waste product. Indonesia produced paddy annually around 50 million tons for last five years. The amount of rice husk is 12.5 million tons; the ash produced is approximately 4 million tons [3]. This paper presents result of a study using open–field burnt RHA and lime on the selected geotechnical properties of expansive soil.

Note: Discussion is expected before November, 1st 2002. The proper discussion will be published in "Dimensi Teknik Sipil" volume 5 number 1 Maret 2003.

MATERIALS

RHA studied in this research was produced locally. This was obtained from rice husks burnt as fuel in a brick industry. The combustion process occurred under uncontrolled condition. As a stabilizing material, the RHA was sieved with ASTM sieve size #200 (0.074 mm). The lime, in this study, was used in powder-hydrated lime. This mixture is termed as lime-rice husk ash (LRHA). This admixture was used to modify the expansive soils from Kasihan terrain, in D.I. Yogyakarta Province. The properties of the soil are given in the Table 1.

Table 1. Properties of Tested Soil

Properties	Results
Nature moisture content, w_N (%)	71.38
Specific Gravity, Gs	2.63
Liquid Limits, LL (%)	73.59
Plasticity Index, PI (%)	41.25
Maximum Dry Density, γ_d (kN/m^3)	13.20
Optimum Moisture Content (%)	34.00
Coarse particle (%)	9.24
Fine particle (%)	90.76
CBR (%)	3.03
Compressibility Index (Cc) *	0.28
Activity	3.06
Swelling potential (%) *	15.13

* Compacted at MDD & OMC (remoulded)

The soil is classified into CH, clay with high plasticity. Any soil with PI > 35 % and swelling potential > 10 % can be categorized as very high expansive soil [4]. The chemical properties of the additives are presented in the Table 2 [5].

Table 2. Composition of Additives

Constituents	Clay (%)	RHA (%)	Lime (%)
SiO_2	51.39	89.08	0.00
Al_2O_3	17.21	1.75	0.13
Fe_2O_3	9.33	0.78	0.08
CaO	3.66	1.29	59.03
MgO	1.17	0.64	0.25
Na_2O	1.72	0.85	0.05
K_2O	0.39	1.38	0.03
MnO	0.25	0.14	0.04
TiO_2	0.98	0.00	0.00
P_2O_5	0.17	0.61	0.00
H_2O	4.23	1.33	0.04
Loss on ignition	9.48	2.05	40.33

EXPERIMENTAL WORK

To assess the effect of RHA on the expansive clays properties, the RHA was blended with lime as the lime-pozzolana mix. A series of laboratory tests were conducted namely the physical and index properties, compaction, CBR, consolidation, and UU-triaxial test. The tests were carried out individually or in a combination in which the RHA content was varied from 7.5, 10, and 12.5 percent, and the lime content from 2, 4, 6, and 10 percent (by the dry weight of soil). All the samples have been remoulded at their optimum moisture content (OMC) and maximum dry density (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, compressibility index, MDD, OMC, and maximum axial stress, are presented in the Table 3.

Table 3. Geotechnical Properties of Treated Samples

Mixes	Code	LL (%)	PL (%)	PI	Fine Particle (%)	MDD (kN/m^3)	OMC (%)	CBR (%)	Comp. Index Cc	Max. axial stress (kPa)	Swell (%)	Swell Pressure (kPa)
Original Soil	S	74	32	42	90.76	13.20	34.00	3.03	0.288	238	15.13	1155
Soil + 7.5% RHA	R1	64	31	33	88.81	11.80	39.40	5.18	0.031	254	9.28	1046
Soil + 10% RHA	R2	67	39	28	74.71	12.70	36.50	5.86	0.029	268	7.61	903
Soil + 12.5% RHA	R3	66	41	25	69.77	12.90	37.94	6.39	0.013	219	6.61	846
Soil + 2% Lime	L1	61	43	18	34.00	13.10	31.28	5.90	0.026	309	6.78	793
Soil + 4% Lime	L2	54	38	16	6.74	13.10	32.39	8.55	0.012	252	4.77	702
Soil + 6% Lime	L3	65	54	10	3.07	12.20	38.75	10.22	0.014	271	3.94	646
Soil + 10% Lime	L4	49	41	8	2.80	12.00	34.83	12.00	0.018	643	2.65	631
Soil + 7.5% RHA + 6% Lime	LR1	54	44	10	2.18	11.50	36.70	15.13	0.013	270	2.68	606
Soil + 10% RHA + 6% Lime	LR2	62	53	9	5.05	11.60	26.51	15.54	0.006	318	2.63	604
Soil + 12.5% RHA + 6% Lime	LR3	63	58	5	3.35	11.50	32.50	16.30	0.001	369	2.60	598

MDD = maximum dry density;
OMC = optimum moisture content

Consistency Limits

The effect of varying concentration of RHA, lime and LRHA on the expansive soil is shown in Figure 1.

In all admixtures content, the liquid limits decreased, whereas, plastic limits increased. Figure 2 shows effect of additives on the plasticity index. It is observed that addition of RHA show less reduction than lime. However, RHA–lime mixture achieved considerable reduction of plasticity index, approximately 90%, from 41.25% down to 4.74%.

Gromko [6] reviewed that plasticity index and, especially, shrinkage index are early indicators of potential expansion because most soil expansion occurs at water contents between these indices.

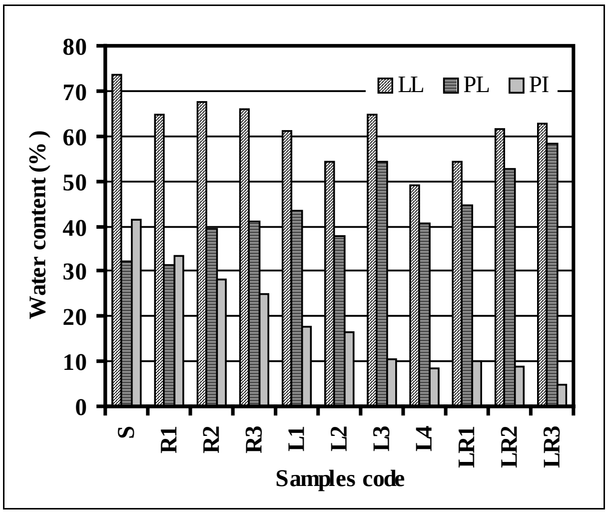

Figure 1. Consistency Limits of Samples

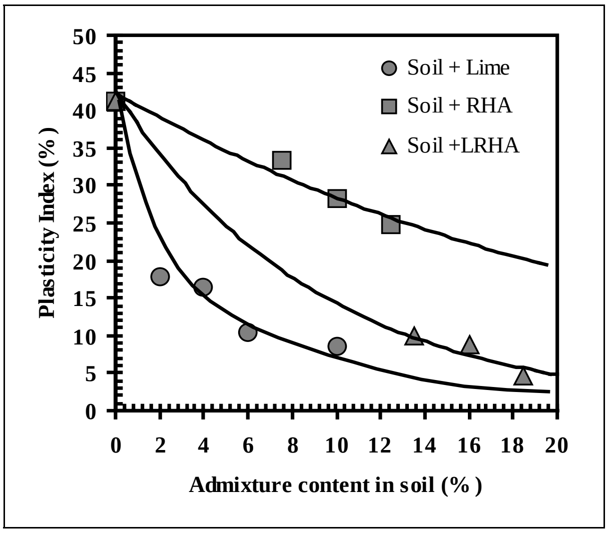

Figure 2. Variation of Plasticity Index With Admixture Content in Soil

Physical Properties

Reduction of fine particles may be inferred from flocculation of soil particle to be coarser materials. The effect of additives on the diminution of fine particles is illustrated in Figure 3.

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 bonded gel (C-S-H) [7]. It caused agglomeration of fine particles to become bigger particles, except with RHA where only slighter alteration was achieved as indicated in Figure 3.

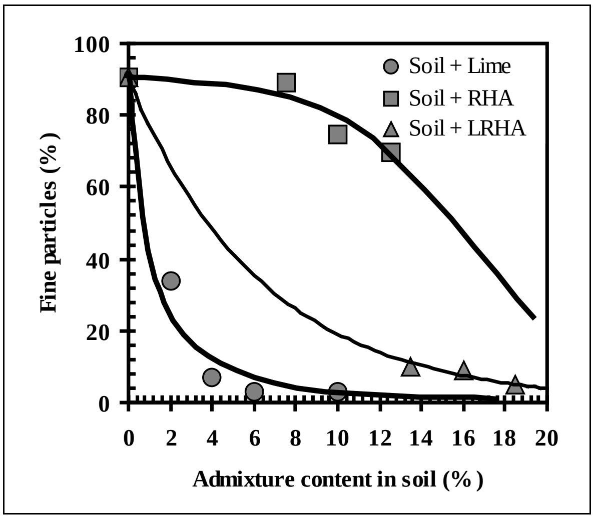

Figure 3. Effect of Admixture on The Fine Particle Content

Compaction, Consolidation, and CBR Characteristics

Figure 4 shows the compaction behaviour of several of the soil mixes. It has been observed that the OMC of expansive soil slightly lessened on the addition of lime to it, whereas, the addition of RHA increased the OMC. However, the admixtures diminished the MDD to a low 11.50 kN/m^3 as attained from the LR1 and LR3 samples. The MDD of additives – soil mixtures is reduced by the presence of additives owing to its relatively low specific gravity. The increase in OMC may be caused by the absorption of water by the additives to precede chemical reaction.

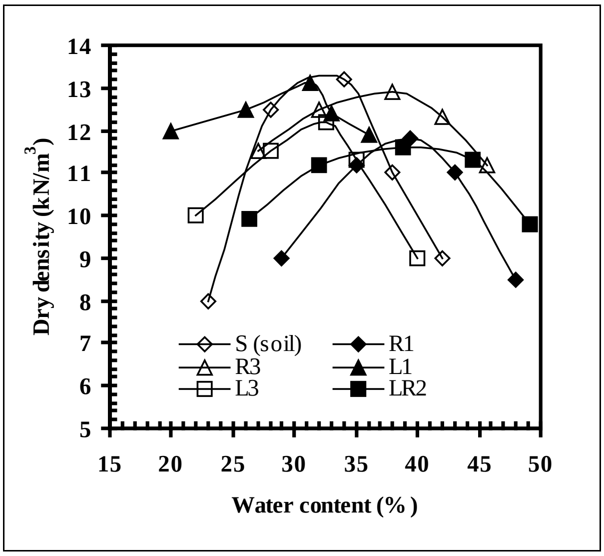

Figure 4. Standard Proctor's Test of Various Admixtures

Compression index (Cc) was obtained from the e–log p curves of the consolidation test (Fig. 5).

Effect of the additives on the compressibility of remoulded soil is shown in Figure 6. It reveals that lime is more effective, relatively, than RHA to reduce compressibility of soil. In general, the addition of the additives dropped the compressibility index from 0.28 (un-stabilized soil) to 0.001 (LR3). When the RHA content exceeds of the amount required for reaction, they will be filled between the void of soil because of their fines particles are finer than soil. A more compact state of soil is probably attained, concomitantly the compressibility of soil diminish.

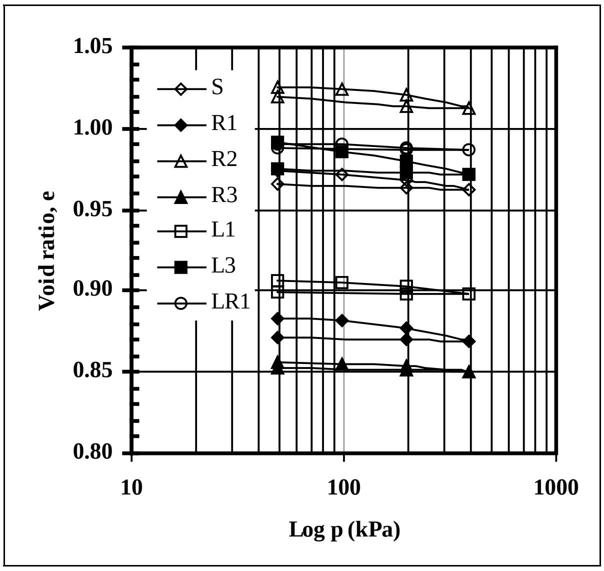

Figure 5. Consolidation Behaviour

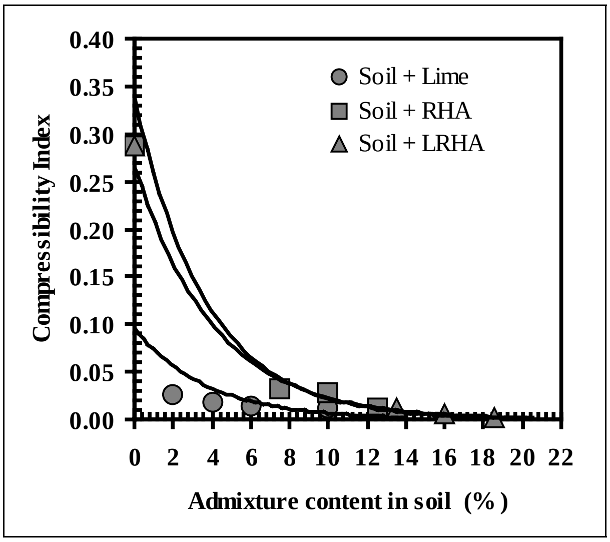

Figure 6. Compressibility Index (Cc) of Treated Soil

The CBR is also a value that corresponds to strength of soil. Figure 7 exhibits increasing of CBR values with increase in amount of additives. The CBR value of treated soil with lime is greater than soil treated with RHA.

RHA cannot be used solely in the soil stabilisation because of its lack of cementitious properties. However, addition of RHA with 6 percent lime attained highest CBR.

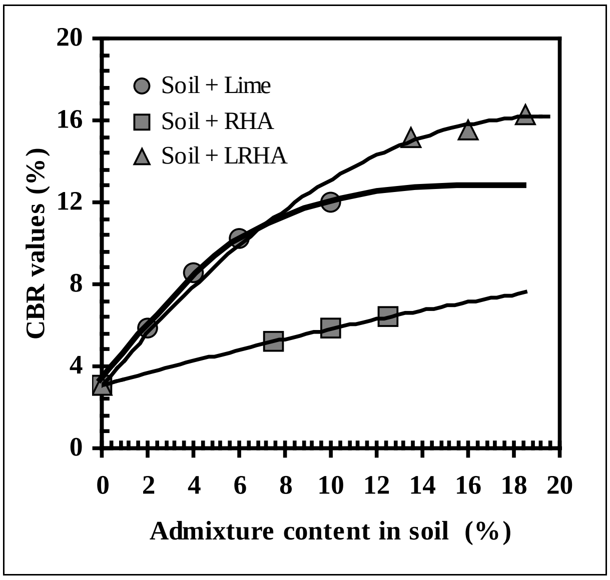

Figure 7. CBR Behaviour of Treated Expansive Clay

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.

Swelling Potential

The result of swelling potential of the natural expansive soil and treated soil is presented in Figure 8. Increasing the amount of admixture whether lime or RHA reduce the expansion. RHA can reduce the heave by 64% soil from its natural state (15.13%). In this case, lime was more effective reducing swelling than RHA. Mixing both of these materials give better result. For example with a combination of 6 % lime and 12.5 % RHA, the swelling potential is 2.60 %.

Seed et al [8] gave relationship between swelling potential, percentage of clay type, and plasticity index. Further, the value of swelling potential depends on the same factors that influence the soil volume change such as: mineral type and amount, density, load conditions, soil structure, and water content [6].

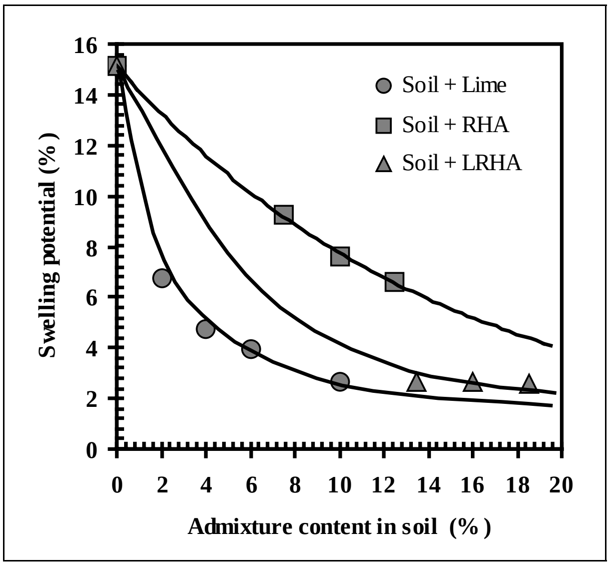

Figure 8. Swelling Potential of Treated Expansive Soil

Shear Strength Behaviour

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 is shown in Figure 9 and Figure 10 respectively. The addition of additives tends to increase the internal friction angle of soil, but there is only a slight difference in the cohesion.

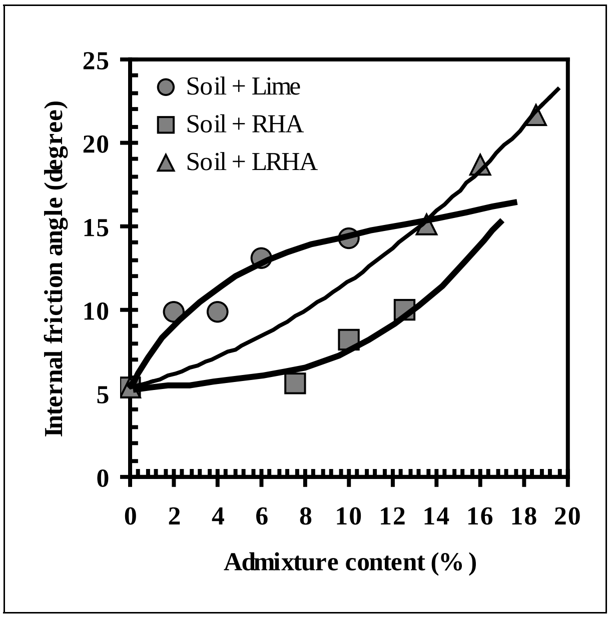

Figure 9. Internal Friction Angle With Admixture Variation

The addition of 10 percent lime (L4) shows brittle behaviour as shown in Figure 11. Adding RHA makes it more ductile, though the level of strength attained is not high. This is in agreement with Balasubramaniam et al [9].

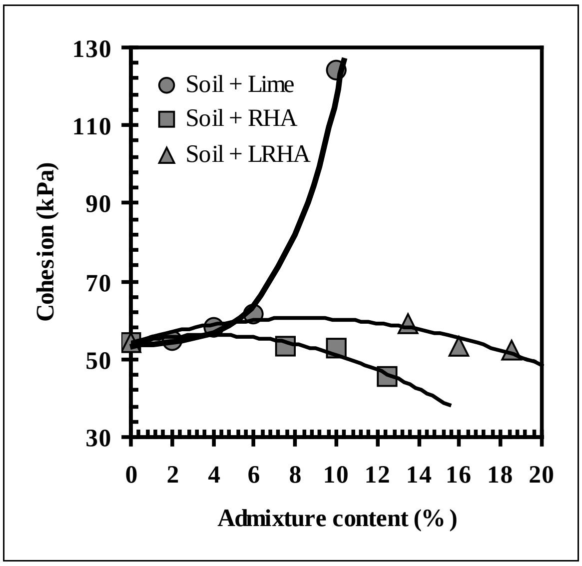

Figure 10. Variation of Soil Cohesion With Admixture

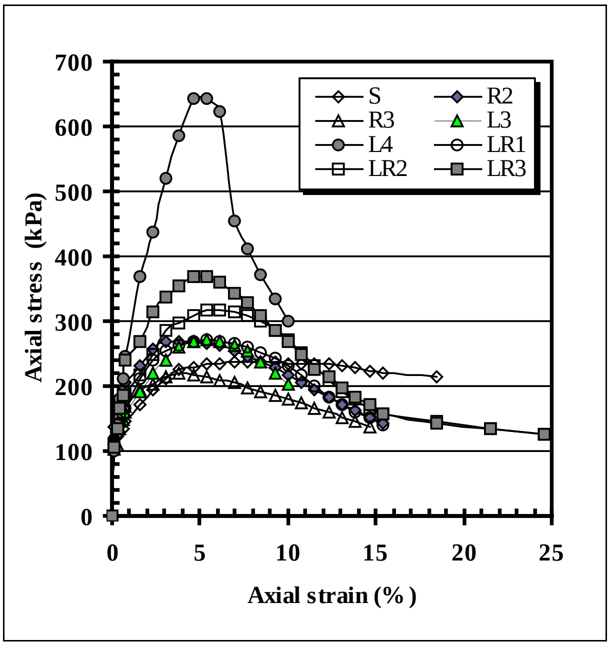

Figure 11. Axial Stress and Strain Under 98.10 kPa Cell Pressure.

Reducing the fine particles implies that LRHA altered the soil texture. Consequently, the swelling potential and compressibility were reduced while the soil bearing capacity was greater than before.

Application

In tropical 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, airfields, and other geotechnical works is intensely attractive. 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 expansive soil.

Hence, it implies that the necessary technology required for controlled burning can be omitted reducing the cost of utilizing RHA for soil improvement.

CONCLUSION

The study has been successfully conducted to assess the geotechnical properties of expansive 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 reduced. Swelling potential of expansive soil diminished with the addition of admixtures. The compressibility of soil reduces with blend of lime and RHA.

In terms of compaction, the OMC moves to wet side, and MDD enhanced marginally. It indicates that the additives, especially RHA; imbibe much water to attain the MDD.

Furthermore, the CBR values enhanced. Ten percent lime content produced brittle failure under compression. Whereas, soil treated with combination of RHA and lime revealed a ductile behaviour, but the strength increased marginally.

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