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Improvement of the bearing of soil by using lime – rice husk ash

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ABSTRACT: Rice husk ash is a potential pozzolanic material that can be used for stabilizing agent in the mixture with lime. This paper presents the results of studies in the use of rice husk ash (RHA), yield from rice husk combustion in Yogyakarta - Indonesia, to improve the bearing of soft soil. Laboratory tests have been conducted in this study, such as index properties, compaction, and California Bearing Ratio (CBR) tests. The results of the study show that lime and RHA can increase the bearing capacity of the subgrade. The bearing of treated soils with lime – RHA mixture enhanced multiplies associated with curing time. On the other side, the swell of expansive soil decreased to relatively non–swelling.

1 INTRODUCTION

Indonesia 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 (Fig. 1); contain many clay mineral are often a problematic and do not perform satisfactorily (Younger, 1991).

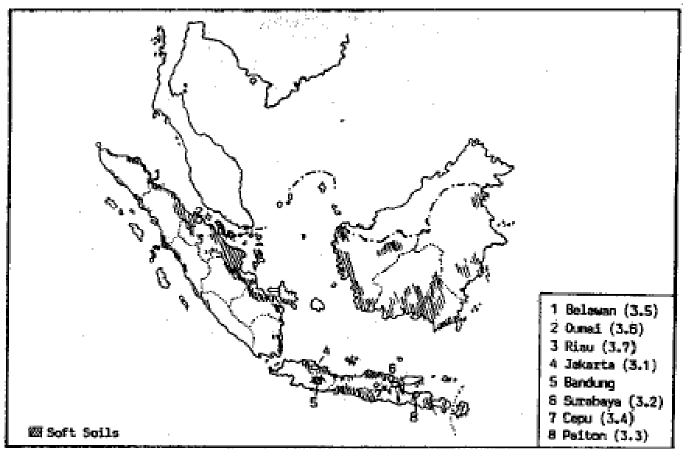


Figure 1. Location of major area of the soft soil in Indonesia

Those soils appear high compressibility, low strength, and potential to swell – shrink highly. Low-bearing capacity and high swelling – shrinkage of sub-grade 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. In this study, an agricultural by – product, rice husk ash (RHA), resulting from rice husk combustion, is utilised. RHA represent a potentially useful and cost-effective alternative to other soil stabilisers. However, RHA, relatively new method, has not been fully accepted for use due to lack of substantial scientific proof of its effectiveness. The focus of this paper is on the influence of the RHA and lime mixture on the bearing capacity of sub-grade.

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 (Muntohar, 2001). Chemically, RHA consists of 82 – 87 % silica exceeding that of fly ash. Materials containing high reactive silica (SiO_2) are suitable used to be lime-pozzolana mixes and as substitution of Portland cement (Paya et al., 2001, Jauberthie, et al., 2000). The high percentage of siliceous materials in the RHA makes it an excellent material for stabilisation.

Stabilisation project are almost always site-specific, requiring the application of standard test methods, along with fundamental analysis and design procedures, to develop an acceptable solution. As with any such process, adherence to strict environmental constraints is vital to project success. The use of cementitious materials makes a positive contribution to economic and resources sustainability because it allows enhancement of both standard and substandard in situ soils to levels consistent with the requirements of a given application.

2 SAMPLE PREPARATION, AND TESTING

Soil sampling was carried out in pits excavated, in the two locations, to a depth in excess of 0.5 m to expose fresh sample and avoid the influence of vegetation. First location, Kasihan, contains predominantly silt (Soil 1); other location is Ngramang which major consist of clay (Soil 2). The properties these soils are given in Table 1.

Table 1. Properties of soil samples

Properties	Soil 1	Soil 2
Nature moisture content, w_N (%)	71.48	45.45
Specific Gravity, Gs	2.63	2.62
Liquid Limits, LL (%)	73.59	81.55
Plasticity Index, PI (%)	35.25	58.40
Shrinkage Limits, SL (%)	13.82	13.76
Maximum Dry Density (MDD), γ_d (kN/m^3)	13.20	13.53
Optimum Moisture Content (OMC) (%)	34.00	26.62
Sand (%)	9.24	15.36
Silt (%)	80.76	40.64
Clay (%)	10.00	44.00
CBR unsoaked (%)	3.03	2.44
Activity	3.06	1.46
Colour	Black-grey	Black

RHA was obtained from the rice husk combustion as fuel of brick stone industry in Godean, Yogyakarta. The fraction used for the test was that passing the ASTM sieve size #200 (74 µm). Lime used is hydrated lime. These additives were mixed with soil individually or in a combination (by the dry weigh of soil) in which RHA content were varied from 8%, 10%, 12% for soil 1 and 2%, 4% for soil 2 and the lime content were 2% and 4%. The chemical constituents of these additives are presented in Table 2.

Table 2. Chemical composition of additives.

Constituents	Lime (%)	RHA (%)
SiO_2	0.00	89.08
Al_2O_3	0.13	1.75
Fe_2O_3	0.08	0.78
CaO	59.03	1.29
MgO	0.25	0.64
Na_2O	0.05	0.85
K_2O	0.03	1.38
MnO	0.004	0.14
P_2O_5	0.00	0.61
H_2O	0.04	1.33
Loss on Ignition	2.05	40.33

The CBR-laboratory test, unsoaked and 4 days soaked, was performed on samples compacted at OMC and MDD using Standard Proctor energy. Especially for soil 2, addition, Modified Proctor test was employed. Each of lime-RHA treated soils was cured for one day before perform the test. Curing time was considered at 3, 7, and 28 days for soil 2.

3 RESULT AND DISCUSSION

3.1 *Properties of original soil*

Table 1 describes the index and engineering properties of original soil (untreated). It can be summarised that soil samples have different classification. Soil 1 is classified into CL which major is silt, otherwise soil 2 is categorised as CH that reveals an expansive soil (Seed, et al., 1962). These soil samples have low strength and unsuitable for subgrade.

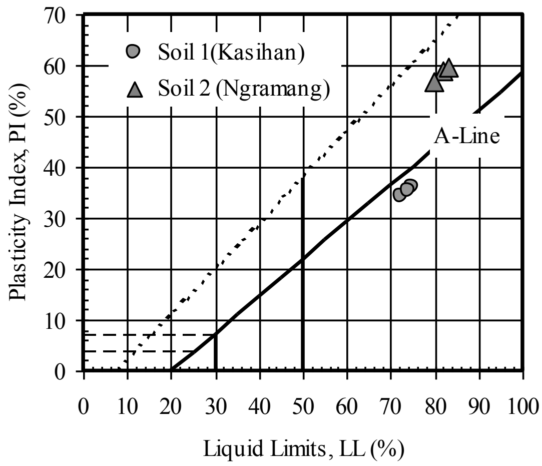


Figure 2. Plasticity chart of fine particles.

3.2 *Compaction*

Table 3 and 4 presents the result compaction test for treated soil 1 and soil 2 respectively.

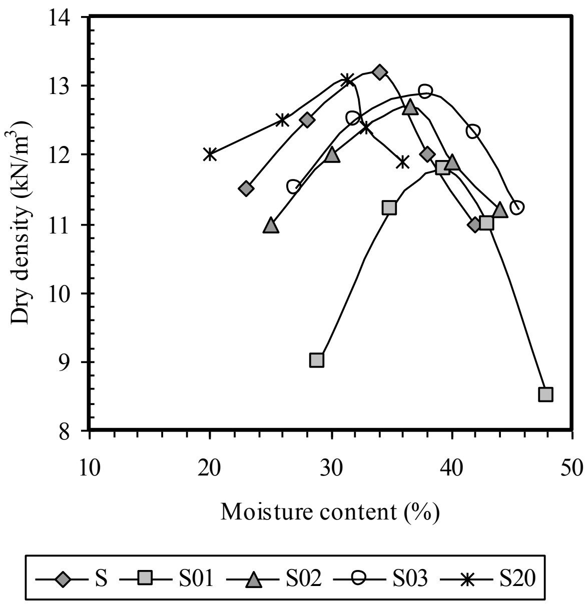
It has been observed that, generally, the MDD of soils decrease on the addition of additives, otherwise, the OMC of treated soil increase. Exception for soil 1, addition of lime and lime RHA mixture decrease the OMC. Both lime and RHA, RHA consumes much water to attain the MDD because of that materials is very porous (Zhang, et al, 1996). Compaction behaviour of each soil is shown in Figure 3.

Table 3. Standard Proctor compaction and CBR of soil 1

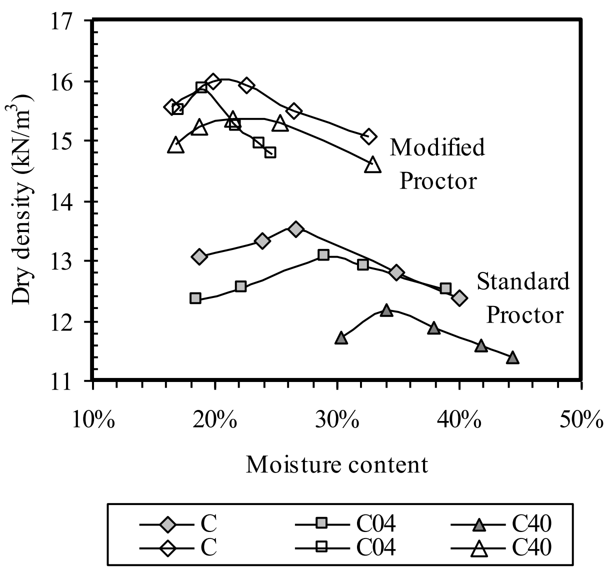
Mixture	Code	OMC (%)	MDD (kN/m^3)	CBR (%)
Silt	S	34.0	13.2	3.0
Silt + RHA:				
8%	S01	39.4	11.8	6.4
10%	S02	38.5	12.7	5.9
12%	S03	37.9	12.9	5.2
Silt + Lime:				
2%	S20	31.3	13.1	5.9
4%	S40	32.4	13.1	8.5
Silt + Lime + RHA:				
2% + 8%	S21	31.0	12.1	9.5
2% + 10%	S22	40.4	11.9	10.6
2% + 12%	S23	39.4	11.6	9.6
4% + 8%	S41	28.2	12.3	11.4
4% + 10%	S42	26.2	11.8	11.9
4% + 12%	S43	30.7	12.1	10.2

Table 4. Compaction characteristics of soil 2

Mixture	Code	Standard		Modified	
		OMC (%)	MDD (kN/m^3)	OMC (%)	MDD (kN/m^3)
Clay	C	26.6	13.5	19.8	15.9
Clay + RHA:					
2%	C02	30.3	13.0	19.5	15.6
4%	C04	29.0	13.1	19.0	15.8
Clay + Lime:					
2%	C20	32.7	12.7	21.8	15.6
4%	C40	34.1	12.2	20.9	14.7
Clay + Lime + RHA:					
2% + 2%	C22	34.6	12.6	20.2	15.1
2% + 4%	C24	45.8	12.5	21.4	15.4
4% + 2%	C42	45.3	12.3	21.7	15.0
4% + 4%	C44	30.5	12.7	21.2	14.8



(a)



(b)

Figure 3. Dry density and moisture content relationship for varies admixtures (a) soil 1, (b) soil 2.

In case of soil 2, the MDD of treated soil with additives can be enhanced by higher effort of compaction. Figure 3b exhibits that compacting the treated clay soil under Modified Proctor (2700 kNm/m^3) effort achieved higher MDD than Standard Proctor. However, it should be considered that the dense clay soils will swell more when they become wetted; compared with the same clay soils at a lower density and same initial water content (Gromko, 1974). This is particularly advantageous in the field in view of the need for strict density control, during placing and subsequent compaction under exposed conditions.

3.3 *California Bearing Ratio (CBR)*

CBR values are closely related to both the compressive strength and the bearing capacity of compacted subgrade or fills. Therefore, this test is most appropriate to quantify the suitability of any compacted subgrade or fills (Indraratna, 1994). Table 1 and 5 present the CBR values of soil 1 and soil 2.

Table 5. CBR * value for varies treated soil 2

Mixture Code	Unsoaked		Soaked
	Modified	Standard	
C	20.4	2.4	0.7
C02	21.9	6.2	1.9
C04	26.6	6.8	1.5
C20	19.2	6.4	4.9
C40	24.6	7.8	5.6
C22	30.9	6.1	5.1
C24	19.0	6.4	6.1
C42	23.4	10.9	6.9
C44	23.8	7.0	7.7

* The CBR value is in (%).

Stabilised soil with lime and RHA, generally, increased the CBR value for all soils. Lime enhanced the CBR more than RHA, however, blended both additives revealed an acceptable result. The highest CBR of soil 1 is 11.9% was attained at 4% lime and 10% RHA mixtures. In case of soil 1, silt soil, maximum CBR value was achieved at 10% RHA, more addition of RHA in this soil attributable decrease in CBR as illustrated in Figure 4.

Compare to soil 2, the highest value of the unsoaked CBR, compacted with Standard energy (600 kNm/m^3), was attained by mix 4% lime with 2% RHA is 10.9%. Furthermore, compare with Modified, indeed, higher compaction efforts has given higher strength than others as shown in Figure 5. The highest was attained 30.9% at 2% RHA and 2% lime mixture.

The influence of curing time and soaking on the CBR was studied in this research, especially for soil 2. The soaked condition simulates the behaviour of subgrade under heavy rainfall or flooded situations. Nevertheless, the degree of saturation of the soaked specimen might be

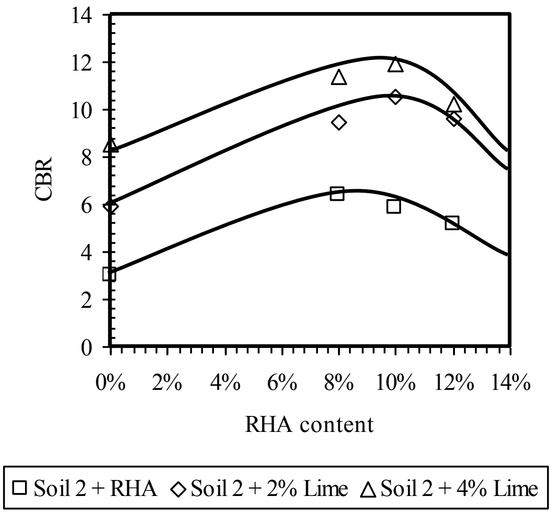


Figure 4. Effect of RHA content on the CBR of soil 1.

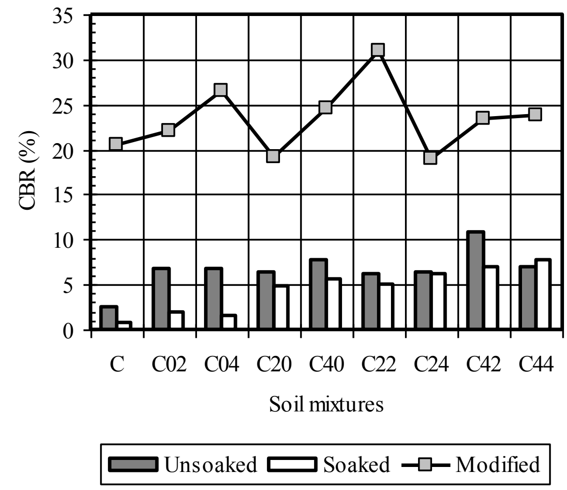


Figure 5. CBR values of the soil 2 with varies treatment.

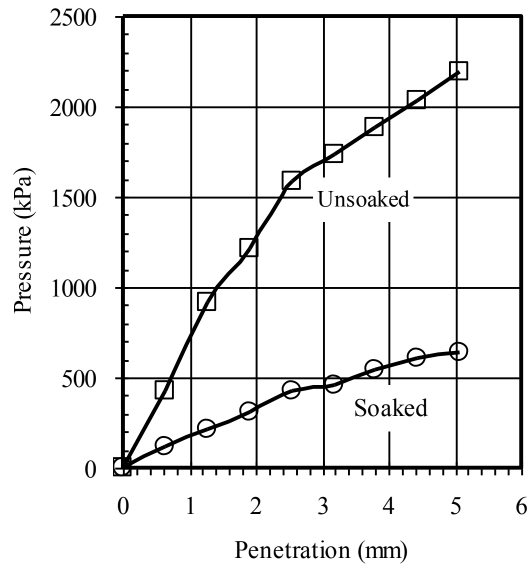


Figure 6. Effect of soaking on CBR values of soil 2.

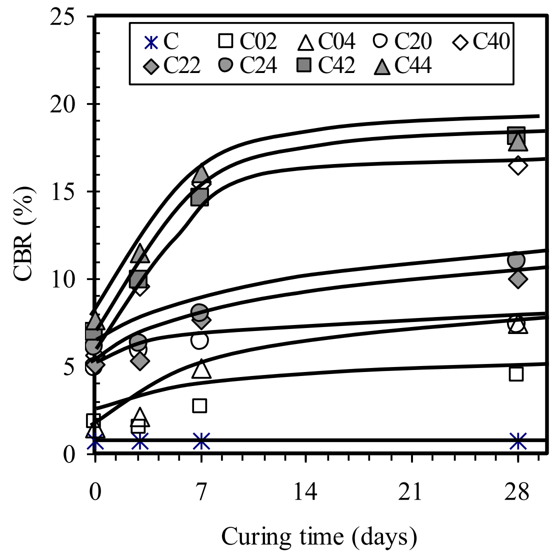


Figure 7. Effect of curing time on the 4 days soaked CBR value.

substantially higher that that of the subgrade soil under the proposed pavement (Chu & Chen, 1976). As illustrated in Figure 6, the effect of soaking is reflected by increased penetration at the same stress levels for the soil 2.

Considering the standard 2.5 mm penetration, a reduction in CBR from 2.4% to 0.7% is encountered as a result of four days soaking. This necessitates the requirement for the surface water proofing of road in order to maintain the desirable CBR.

Figure 7 shows the influence of curing on the 4 days soaked CBR of treated soil 2. Curing is important for chemically stabilised soils — particularly lime – stabilised soils — because lime – soil reactions are time and temperature dependent and continue for long periods of time (even years).

3.4 *Swelling characteristics*

The swelling of expansive soil (soil 2) was examined from soaked CBR test, soil 1 was not tested for swell test because the soils do not exhibit potential to more swell.

In this test method, CBR specimens are submerged in water, under a simulated surcharge pressure, for four days prior testing. The swell was measured for each curing time; the results are presented in Table 6.

On the whole, curing diminished the heave of expansive soil as referred in Figure 8. Though, particularly lime and lime–RHA treated soil, three days curing is enough to reduce swelling. RHA stabilised soil, indeed, demonstrated an attractive swelling characteristics. Soil mixture with 4% RHA, instead, augmented the swelling.

In this case, lime is more effective to reduce the heave of soil. Figure 8 exhibits that the heave has ceased before 24 hours after soaked. In contrast with RHA, the swell proceed after inundated with water and increase marginally until 4 days soaked.

Table 6. Swell of treated soil 2 at varies curing time

Mixture Code	Swell (%) at curing:			
	0 day	3 days	7 days	28 days
C	4.8			
C02	3.4	3.3	2.1	2.4
C04	5.0	3.9	2.8	2.4
C20	3.5	0.3	0.1	0.1
C40	0.1	0.0	0.0	0.0
C22	2.2	0.2	0.2	0.2
C24	2.3	0.2	0.2	0.3
C42	1.7	0.1	0.0	0.0
C44	0.1	0.0	0.0	0.0

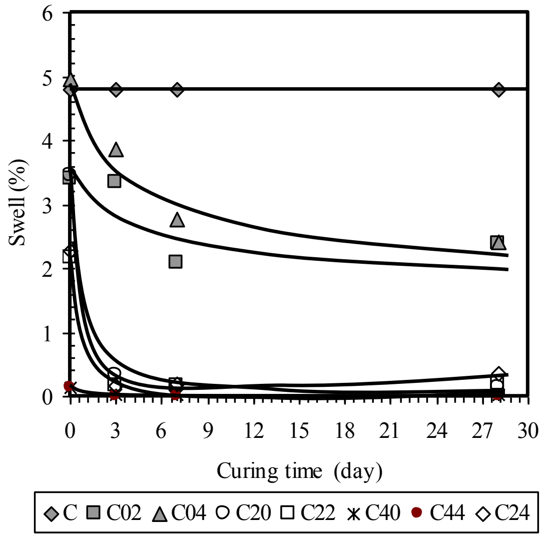


Figure 8. Effect of curing on the swelling of stabilised soil 2.

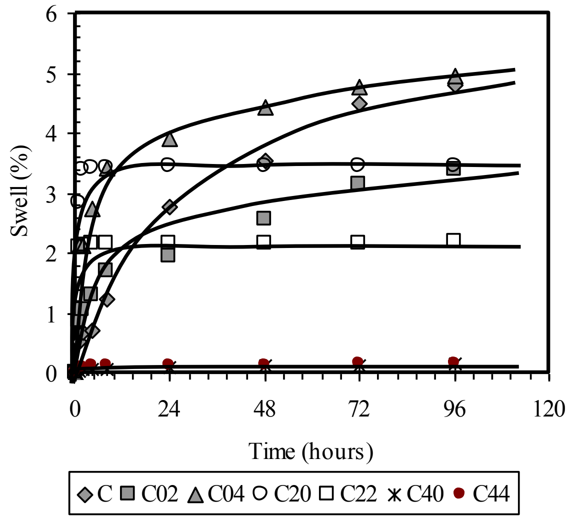


Figure 9. Time and swell relationship of stabilised soil 2.

Gromko (1974) pointed out that the value of the swell depends on the some factors that influence the soil volume change; such as mineral type, density, load condition, water content (dry clays will swell more than their wet counterparts because of the direct relation between water content and suction pressures).

It is important to blend RHA with lime, because that material cannot react with soil solely without presence lime or other cemented materials.

4 CONCLUSION

Lime and RHA added to soil in adequate amounts has a beneficial effect on the soil strength and is a viable material or stabilising certain soil types. It has the potential to significantly increase the soil strength (CBR) and decrease the swell in a relatively short time.

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