A Study of Expansive Clay Treated With *LRHA*

Agus Setyo Muntohar
Department of Civil Engineering, Muhammadiyah University of Yogyakarta, Indonesia
muntohar@telkom.net
Roslan Hashim
Department of Civil Engineering, University of Malaya, Malaysia
roslan@fk.um.edu.my

ABSTRACT: High swell and shrinkage is the characteristic of expansive clay soils. The soils swell in wet condition and tend to shrink in the dry. This form of behaviour will be a problem for roads and lightly loaded structures especially during seasonal fluctuation in groundwater table where the upper layer of the foundation soil will be affected. Chemical stabilizers, such as lime and Portland cement, are widely used to mitigate this problem. This paper presented the results of studies on the use of silica waste produced from rice husk combustion in Yogyakarta (Indonesia). The rice husk ash (RHA) and lime mixed, termed as lime-rice husk ash (LRHA) was used to stabilize expansive clay soil specimens. In the study, a series of laboratory tests was conducted. The results of the study show that LRHA reduced the heave of expansive clay and improved the geotechnical properties of specimens. The introduction of this soil stabilizer in road pavement construction will help to control volume compressibility due to moisture variation. This will reduce maintenance cost and will be economically attractive to community where financial resources are

INTRODUCTION

The studies of expansive clay soils have attracted a great deal of attention since many countries are somehow affected by these soils. In Indonesia, as an example, a study conducted by Munirwansyah (1989) found that more than 50% of roads were founded on laterite soil which have high swell potential and problematic when used for road construction. This phenomenon can be detrimental to the integrity of the road pavement. For example, in Yogyakarta Province, serious damage occurred on Wates Street due to this problem.

Expansive soils are not as dramatic as hurricanes or earthquake as they normally caused only property damage but not loss of life. In addition, they act more slowly and the damage spread over wide areas rather than being concentrated in a small locality. Nevertheless, the economic loss is large and much of it could be avoided by proper recognition of the problem and incorporating appropriate preventive measures into the design, construction, and maintenance of facilities (Coduto, 1994).

Lime, cement, and/or fly ash are widely used to chemically transform unstable soils into structurally sound construction foundation. In clay-bearing soils, these stabilizers induce a textural change resulting in greater ease of compaction and handling as well as moderate improvements in the resulting strength. This process is typically called modification. If sufficient content of lime, within each material, is applied to the soil under the right conditions, a pozzolanic reaction ensues, forming permanent cementitious product. This is the process of soil stabilization.

Rice husk ash (RHA) is a highly reactive pozzolanic material suitable for use in lime – pozzolana mixes and for Portland cements replacement. RHA contains a high amount of silica dioxide, and its reactivity towards lime depends on the combination of two factors, namely the non-crystalline silica content and its specific surface (Jauberthie et al, 2000; Payá et al, 2001). Based on this, the applicability to the geotechnical application in the field of ground improvement may be investigated. Balasubramaniam (et al, 1999) established that the addition of fly ash and RHA, into soft Bangkok clay, exhibited ductile behaviour associated with higher strain and low strength. Muntohar & Hantoro (2000) pointed out the addition of lime and RHA to expansive clay reduced the swell characteristic. The ductile behaviour was also observed.

Factors that should be considered in choosing stabilizing agents are cost and availability. RHA is very cheap and abundant in large areas of Indonesia, especially Yogyakarta. This paper discusses the effect of RHA-lime mix on the swell behaviour of expansive clay specimens as well as selected engineering properties such as CBR and compressive strength.

EXPERIMENTAL PROGRAM

Several series of tests were performed on the soil, at its natural conditions, to determine properties such as grain size distribution, consistency limits, maximum dry density and optimum moisture content, specific gravity, unconfined compression strength, CBR and swelling. Swelling potential of soil was examined under 50 kPa seating pressure, then swelling pressure was determined with zero swell method. These tests were also carried out on treated soil samples, blended with RHA and lime.

SAMPLE PREPARATION

The base clay used in this study was obtained at a depth of 0.5m to 1.0 m at Ngramang – Desa Kedung Sari, Region of Wates. A thin walled piston sampler was used to obtain 250 mm diameter and 500 mm long samples. The index and engineering properties of the base clay are given in Table 1.

Hydrated lime commercially produced by locally was used in this study. The RHA was taken from brick combustion at the local industries in Godean, Region of Sleman, Yogyakarta, Indonesia. The burnt temperature was not controlled. The chemical properties of both additives and the soil are presented in Table 2.

Table 1. Properties of the base clay samples.

Properties	Characteristics
Grain size:	
• Clay	40.00 %
• Silt	44.64 %
• Sand	15.36 %
Liquid limit (LL)	81.55 %
Plastics limit (PL)	23.15 %
Plasticity index (PI)	58.40 %
Shrinkage limit (SL)	13.76 %
California Bearing Ratio:	
• Un-soaked	2.44 %
• Soaked	0.70 %
Free swelling	21.84 %
Natural moisture content, (w_N)	45.45 %
Specific gravity (Gs)	2.63
Activity	1.46
Colour	Black – grey

The soil can be classified as a high plasticity *Clay* (Gs = 2.63; finer particle = 84.64%, clay = 40%). The soil fell into CH category based on the USCS while the AASHTO classification system grouped it as a A-7-6 soil. The ASTM classified the soil as expansive. Chen (1985) suggested that any soil with PI > 35 % and swelling potential > 10 % be categorized as having a very high swelling potential. In this case the LL and PI of the sample were respectively 81.55 % and 58.40 %.

Table 2. Chemical constituents of the additives and clay.

Constituents	Clay (%)	RHA (%)[a]	Lime (%)[b]
SiO_2	51.39	83.08	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	0.004
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
LOI	9.48	2.05	40.33

[a] open field burnt
[b] presented as a courtesy of producer, UD. Enam Delapan Mineral

A suitable amount of the soils were air-dried. For each test type, the samples were moulded at the maximum dry density and optimum moisture content with different percentage of the additives. The tests programme covered each stabilizer as sole additive as well as in combination. The lime content was varied from 2, 4, and 6 percent and so was the RHA. The effect of curing time was also considered with duration of 3, 7, 14 and 28 days. The treated samples were wrapped in an airtight plastic bag to prevent moisture loss.

RESULTS AND DISCUSSIONS

Consistency limits

Plasticity index (PI) is one of the characteristics that indicate the swelling potential of a soil. Seed (1962) proposed an equation that relate PI with swelling potential. Latter researchers also proposed alternative relationship between swelling potential, density, initial water content, and clay faction in soil (Basma et al, 1995).

The addition of lime resulted in reductions in PI due to increasing plastic limits (PL) whereas liquid limits (LL) decrease. These results were in agreement with those obtained by Indraratna (1996). The addition of RHA, in contrast with lime, caused LL to increase and reductions in PL. The curing time influenced the plasticity of the mixes. As presented in Table 3, the mix of 6 % lime and RHA show a significant reduction of PI at 14 days curing time.

Table 3. Plasticity indices for various mixes and curing times.

Mix	Code	Uncured	14 days
Original soil (Clay)		58.40 %	
Clay + 2 % Lime (L)	C20	16.93 %	18.23 %
Clay + 4 % Lime (L)	C40	9.79 %	16.66 %
Clay + 6 % Lime (L)	C60	9.28 %	15.38 %
Clay + 2 % RHA	C02	41.85 %	40.70 %
Clay + 4 % RHA	C04	41.03 %	40.05 %
Clay + 6 % RHA	C06	41.44 %	36.16 %
Clay + 6 % L + 2 % RHA	C62	10.66 %	6.37 %
Clay + 6 % L + 4 % RHA	C64	10.07 %	5.07 %
Clay + 6 % L + 6 % RHA	C66	9.30 %	2.75 %

Behaviour of compacted soil

A series of standard Proctor compaction test was carried out to determine the effect of admixtures on compaction characteristics. Figure 1 compare the compaction curves of various mixes with that of the natural clay. For all specimens, the dry unit weight decreased with an addition in additives. This is partly because the specific gravity of all additives is less than that of clay. In general, the optimum moisture content of blended samples increases with the percentages of additives. Both lime and RHA consume water during the hydration process, thereby increasing the optimum moisture content. This can be considered an advantage when working with wet fills.

As indicated by Figure 1, 4 % lime caused the maximum dry density to reduce from 13.39 kN/m^3 down to 12.01 kN/m^3. However, blended with 2 % RHA the maximum dry density was higher than the lime mix but less than that of the natural soil.

Swelling potential and swelling pressure

Figure 2 shows the swelling behaviour of tested samples, natural and treated soils. The swelling behaviour of natural soil (untreated) was observed for 5 days. However, the swelling ceased at approximately 3 days. For clay treated with lime and/or RHA, only marginal heave was observed after day one. The primary swelling of samples cured for 7 days (Fig. 3) ceased after 100 minutes.

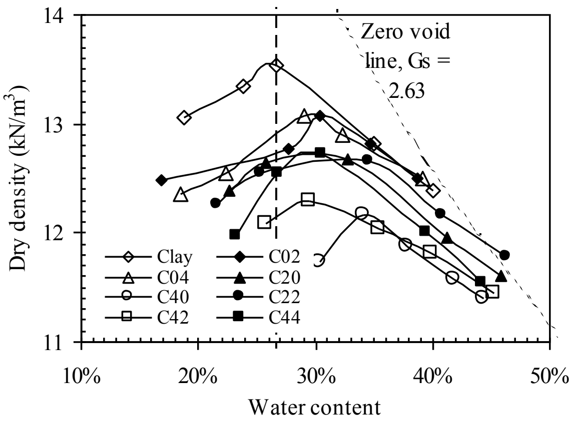

Figure 1. Water content and dry density under standard Proctor compaction test.

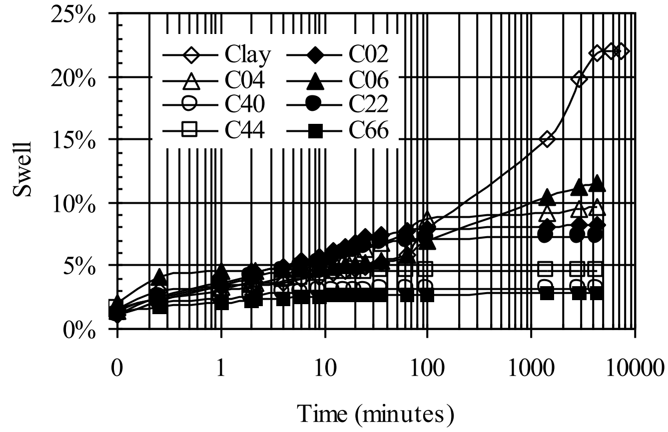

Figure 2. Swelling behaviour of uncured samples

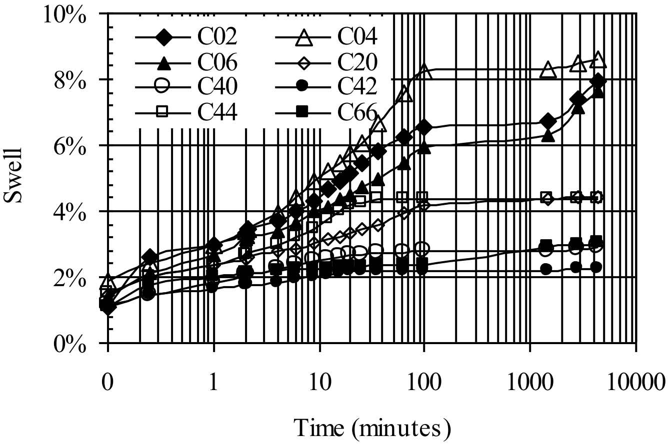

Figure 3. Swelling behaviour of 7 days cured samples.

Basically, lime is more effective than RHA to mitigate swelling. Addition of 2 – 4 % RHA is enough to reduce swelling as shown as in Figure 3. The swell potential reduced seven times from 21.84 % to 2.91 % with an addition of 6 % lime and 6 % RHA. Each additive, lime or RHA, significantly reduce swelling pressure five times, from 1690 kPa to 325 kPa, at 2 % additives.

Muntohar & Hantoro (2000) indicated that mixing soil with lime and RHA possibly alter the particle size of natural soil. Blending lime and RHA produced a bonded – gel as a result of pozzolanic reaction. In the presence of water, the amorphous silica contained in RHA can react with $Ca(OH)_2$ to form one kind of C-S-H gel ($Ca_{1.5}SiO_{3.5}\cdot xH_2O$). The C-S-H gel looks like flocks in morphology, with a porous structure and large specific surface (Qijun Yu, et. Al., 1999). It caused agglomeration of finer particle to become bigger particle and reduce clay-size fraction in the soil.

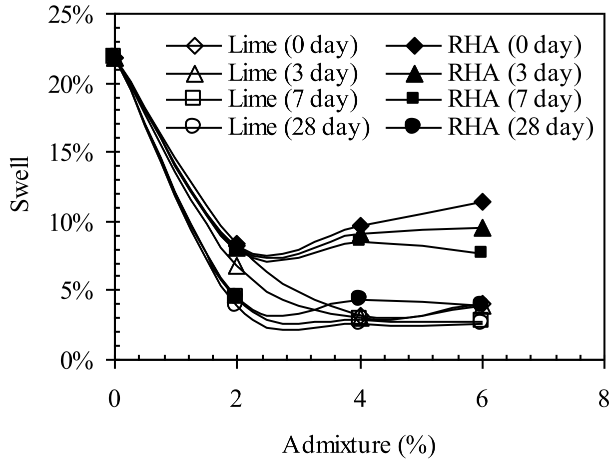

Figure 4. The swelling of soil for different admixture contents and curing time.

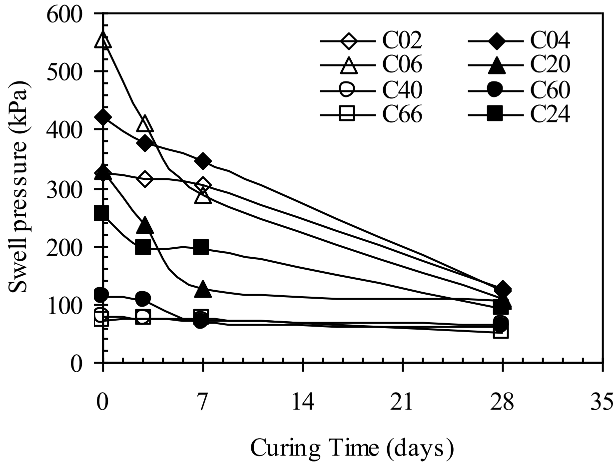

Figure 5. Swelling pressure due to varying of additive and curing time

Soil bearing capacity

Soil improvement is widely used in road constructions. Clay soil in wet condition has lower bearing capacity as indicated by its CBR value. This state is not desirable for road construction works. The effect of additives on CBR values of the specimens tested is shown in Figure 6.

The CBR values of the natural soil were 2.44 % and 0.7 % for unsoaked and soaked conditions, respectively. Addition of 4 % RHA enhanced its CBR nine times (6.21 %) for 28 day curing time. The 4 % lime and 4 % RHA mix attained an even higher value of 17.41 % at 28 days. This is a significant improvement. RHA on its own did improve the CBR values though lesser than lime. However, blended with lime better results was obtained. The effect of curing time until 7 days, obviously, increased the CBR steeply. Further curing time, for lime treated soil, referred marginal increasing, but exception for RHA – soil mix that exhibited rather steep slope until 28 days.

Similar results were obtained when unconfined compression tests were performed on the specimens (Figure 7).

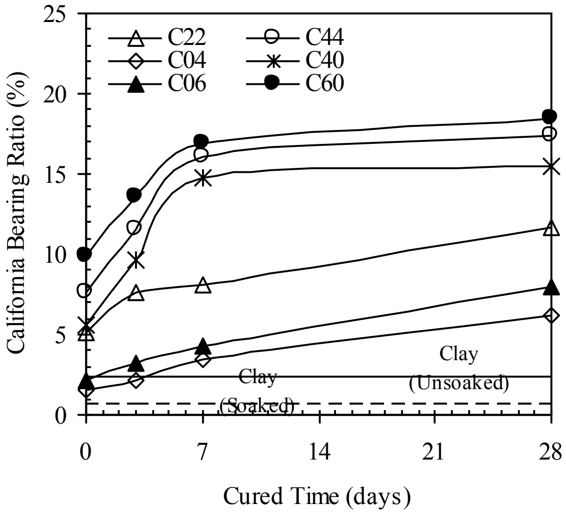

Figure 6. CBR values for different mixes and curing time

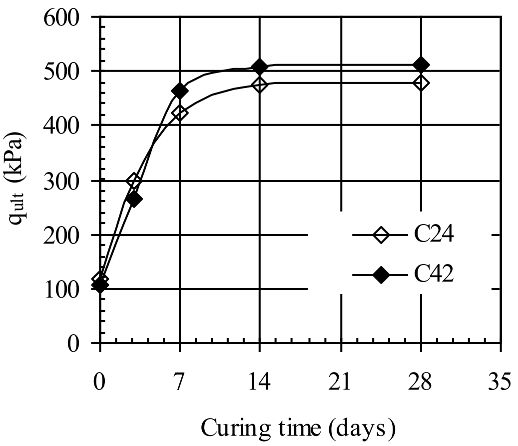

Figure 7. Effect of curing time on UCS

Economic consideration

Sometimes the damages from expansive soils are minor maintenance and aesthetics concerns, but often they are much worse, even causing major structural distress. When the swell potential is high the risk of serious damage to construction upon the soil is high. At the very least, a minor damage will be possible causing inconveniences. Lowering the swell potential will in turn reduce the economic losses. Bearing capacity of the soil or subgrade will also be increased that in turn cut the cost of construction. In other words, cost saving will make the project to be more economical. The utilization of waste materials such as RHA can help in the task of ground improvement. Indraratna (1996) also confirmed that the use of industrial waste materials was very advantageous to ground improvement.

CONCLUDING REMARKS

Soil stabilization with lime and RHA has been proven to improve the soil properties. The effect of LRHA to alleviate the problem of expansive soil has been shown. In this study the swelling potential of the investigated expansive clay was significantly reduced from 21.84% to 2.06%. The CBR value of the improved subgrade increased by twenty five times. Economically, using of RHA and lime in road construction is advantageous.

ACKNOWLEGMENT

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