Effect of Water Content on the Characteristics of Bagasse Ash-Calcium Carbide Residue Stabilized Organic Soil

J Hatmoko¹ and L Handoko²
¹,² Department of Civil Engineering Universitas Atma Jaya Yogyakarta, Jl. Babarsari No. 44 Yogyakarta, Indonesia

E-mail: john.trihatmoko@uajy.ac.id

Abstract. Research about chemically stabilized organic soil to improve shear strength has been done by many researchers. However, they have never undertaken the research about the effect of water content on physical and chemical characteristics of stabilized organic soil. A set of experimental program performed in this research were chemical composition of organic soil (OS), calcium carbide residue (CCR), and bagasse ash (BA); also the physical characteristics of OS. The admixture (60% CCR + 40% BA) was added to the soil with proportion 5, 10, 15, 20, 25 and 30% with various water content, and the samples were cured in 7, 14, 21, and 36 days-curing time. Then, the experiment of physical properties of the stabilized soil was undertaken. The physical characteristics of the stabilized soil change with respect to the water content, quantity of admixture and the curing times. On the high water content, the changes of the physical properties are more significant compared to that on the lower water content. The unit weight, specific gravity, and the degree of acidity increase whereas void ratio and organic content decrease according to the proportion of the admixtures and curing time.

1. Introduction

Organic soil is found all over the world including in Indonesia. The soil is categorized as soft soil having a low shear strength, high compressibility, low degree of acidity, low specific gravity, and high void ratio. Therefore, if it is used as the construction materials there will be some problems such as high settlement, creep and foundation failure. Practically, the soil is cut and replaced by the soil having better physical and mechanical properties such as sand, gavel or crushed stone. However, the problem is going to happen if the substitution materials is far away from the construction site. Then, soil improvement program is better alternative. Some research effort to improve engineering properties of organic soil with ordinary portland cement, lime, fly ash, calcium carbide have been successfully done [1-4]. Chemical stabilization by admixtures to improve engineering properties soft clay has been also perfectly done by many researchers [5-8], because clay is rich of mineral and silica (SiO₂) content that generate pozzolanic reaction. Even though organic soil has a lack of mineral, silica, and high water content the pozzolanic reaction still occur. However, formation of gel obtained from pozzlanic reaction fill the pore and cover the organic fiber [9]. It improves physical and mechanical properties of stabilized organic soil but the improvement is not as high as on clay stabilized soil. The chemical agent usually used to stabilize organic soil are cement, lime, fly ash, rice husk ash, bagasse ash or combination of those admixtures. Some research about using fly ash as an admixture for soft clay has been perfectly performed [10-14]. However, less research was done on organic stabilized soil. To stabilize organic soil is more difficult compared to that of soft clay [15,16], because organic soil does not have enough mineral, and has a low degree of acidity. Therefore, because of the
existence of fly ash is very limited, the use of the other admixture having similar chemical properties to fly ash to improve engineering properties of organic soil is interesting.

Bagasse ash (BA) is a waste residue of sugar factory. It contains high proportion of silica (SiO$_2$), alumina (Al$_2$O$_3$), ferrit (Fe$_2$O$_3$), however, it has low proportion of lime (CaO). Therefore other material containing high CaO such as calcium carbide is required to generate pozzolanic reaction. Calcium carbide residue (CCR) contains high calcium oxide (CaO). Reaction between calcium in the CCR and silica and alumina in BA derive calcium silicate hydrate (C-$S$-$H$) and aluminum silicate hydrate (C-$A$-$H$). And during long period of curing, there is formation of calcium-silicate-aluminate hydrate (C-$S$-$A$-$H$). Those hydrates are in the form of gel that improve physical and mechanical characteristics of stabilized soil. Stabilization of an organic soil with lime, cement, bagasse ash, fly ash, rice husk ash, fly ash + cement, bagasse ash + lime has been [17-19]. However, the research about bagasse ash-calcium carbide residue to alter the physical and chemical properties of organic soil such as water content (w), specific gravity (G), unit weight ($\gamma$), organic content (OC) and the degree of acidity (pH) was never performed. Therefore, the aim of this research are to study the changes of physical and chemical properties of organic soil stabilized by bagasse ash and calcium carbide residue.

Both organic and an organic soil are formed directly by physical or chemical weathering of rock. Structure of organic soil is derived from the mixing of organic matter and mineral, and it is generated from compaction of degradation of organic materials. Organic soil is usually lack of mineral and silica then a pozzolanic reaction due to addition of admixture on organic soil is not as fast as on clay. The pozzolanic reaction on organic soil delays due to organic content and a low degree of acidity. Pozzolanic reaction mechanism on organic soil has not known yet, however the mechanism has been proposed by [9, 16]. The pozzolanic reaction does not occur between admixture with the mineral in the soil but it happens between the materials in the admixtures. For example, reaction between SiO$_2$ in the fly ash and CaO in the CCR. The proposed pozzolanic reaction mechanism in organic soil are as follow: organic materials change composition and structure of gel calcium-silicate-hydrate, cementous materials forming soil particle chain, and the new hydration that will be formed. Organic matters contains humic acid that delay pozzolanic reaction. In the water, the weight of organic materials is more than 10 times of its dry unit weight delaying the hydration process. Organic materials construct complicated surfaces with alumina (Al$_2$O$_3$), silica (SiO$_2$) and ferrit (Fe$_2$O$_3$), then the complicated surfaces delay the hydration process. In this research, CCR and bagasse ash is used as admixture agents [9].

Calcium carbide residue (CCR) is a waste material derived from production of acetylene gas. Calcium carbide (CaC$_2$) is generated from chemical reaction between calcium carbide and charcoal. CaC$_2$ react with water (H$_2$O) to generate the acetylene gas (C$_2$H$_2$). The complete reaction can be reviewed on [20-23]. The use of CCR and rice husk ash improves significantly the unconfined compression strength of clay [7,8]. Bagasse ash (BA) is the residue generated from production of sugar. Original bagasse ash has low composition of SiO$_2$ + Al$_2$O$_3$ + Fe$_2$O$_3$, however, when the BA is burned to 300 °C, it contains of SiO$_2$ increases to 62.75%, and 85.21% for (SiO$_2$) + (Al$_2$O$_3$) + (Fe$_2$O$_3$) [25].

2. Experimental
2.1. Materials
2.1.1. Organic Soil
Organic soil was taken from Ketapang Regency, The Province of West Kalimantan, Indonesia. The soil is fibrous peat with 95% organic content, and it is considered as soil with high organic content. The water content is 498% due to the properties of fiber that absorb water. The Laboratory tests of physical properties of the soil use the standard ASTM-1984 (Peat Testing Manual), and the result is presented on Table 1. The soil sample is still on the range of the previous research [25-26]. Based on ASTM D-4427-92, the soil is classified as moderate fibrous peat with high degree of acidity.

2.1.2. Admixture
The admixture agents used in this research is the mixed of calcium carbide residue (CCR) containing high calcium (CaO), and bagasse ash (BA) that contains high pozzolanic compound SiO$_2$ + Al$_2$O$_3$ + Fe$_2$O$_3$.
Fe₂O₃ = 73.19% (Table 2). The high content of CaO on CCR, pozzolanic materials on BA, and the present of water, the pozzolanic reaction occurs showed by the form of the gels calcium silicate hydrate, aluminum silicate hydrate or calcium-aluminum-silicate hydrate. The formed gels covers the fiber on the peat, then there will be improvement of the properties of organic soil.

### Table 1. Physical properties of Organic Soil

| Soil Parameters                  | Sample | Previous Research [25, 26] |
|----------------------------------|--------|-----------------------------|
| Spec. Gravity (G)                | 1.47   | 1.4 – 1.7                   |
| Void Ratio (e)                   | 7.1    | 6.89 – 11.09                |
| The Unit weight (γ), (t/m³)      | 1.08   | 0.9 – 1.25                  |
| Degree of acidity (pH)           | 4.6    | 3 – 7                       |
| Water content (w), %             | 498    | 450 – 1500                  |
| Organic content (OC), %          | 95     | 62.5 – 98                   |
| Fiber content (Fc), %            | 53.1   | 39.5 – 61.3                 |

| Tabel 2. Chemical content of CCR and BA |
|----------------------------------------|
| Chemical content | CCR | BA |
| SiO₂             | 8.43 | 45.28 |
| Al₂O₃            | 1.67 | 15.15 |
| Fe₂O₃            | 0.91 | 12.76 |
| SiO₂ + Al₂O₃ + Fe₂O₃ = 73.19%         |

2.2. Procedure
Before mixed to the soil, calcium carbide residue (CCR) was oven dried and the bagasse ash (BA) was burned on 300 °C to get the higher SiO₂ + Al₂O₃ + Fe₂O₃ content. The admixture was prepared to the proportion of 40% BA + 60% CCR. The admixture, then, was mixed with the dry organic soil with the proportion of 5, 10, 15, 20, 25 and 30% with 498, 548 and 598% water content. To wait the pozzolanic reactions occurred, the stabilized soil then cured in 7, 14, 21, and 36 days of curing period. Finally, the specific gravity (G), the unit weight (γ), void ratio (e), degree of acidity (pH), organic content (OC) of stabilized soil were tested.

3. Results and Discussion
3.1. Water Content (w)
Figure 1 and 2 are presentation of the relation between water content and binder proportion with various curing times. With respect to admixture proportion, the average decrease of water content is 300%. For example at 36 days curing time, at the initial water content 498% and 548%, the water content decrease to 150 and 155%. The decrease of water content is probably due to water absorbent during pozzolanic reaction that generate cementous agents filling out the pore in organic soil and covering peat-fibers [10]. The decrease of water content, however, tends to be constant at 20% admixture and 21 days curing period because the ending of pozzolanic reaction. The trend is different from the stabilized an organic clay, the longer the curing period and the more admixture content, the pozzolanic reaction more intensively occur [6].
3.2. The Unit Weight ($\gamma$)
Due to addition of admixtures in the organic soil, the unit weight of stabilized soil improves parallel to the proportion of binder quantity (Figure 3). This improvement is due to the pozzolanic reaction generating calcium-silicate-hydrate or aluminum-silicate-hydrate that fill out the pore and cover the soil fibers. However, the improvement of the unit weight of stabilized soil goes slowly, and tends to be constant after 20% proportion of admixture and 21 days curing period. It is due to lack of mineral in organic soil. With respect to the water content, the unit weight of stabilized soil significantly improve on 21 days curing time for both 5% and 20% admixtures (Figure 4). On 36 days curing period, on the other hand, there is no improvement of the unit weight on both 5% admixture and slightly improvement on 20% admixture. On 5% of admixture, the pozzolanic reaction does not effectively occur, it results on small absorption of water for the reaction. On 20% admixture, however, the pozzolanic reaction intensively happen that result on the improvement of the unit weight of stabilized organic soil.
Figure 3. Proportion of admixture-Unit weight (w = 498%)

Figure 4. Water content – Unit weight (a: 5% Admixture, b: 20% Admixture )

3.3. Specific Gravity (G)
Specific gravity of original soil is 1.47 (Figure 5) that is far below the specific gravity of normal soil such as clay having G more than 2.5. For 0 days curing time with any initial water content, there is almost no changing of specific gravity due to lack of mineral on organic soil, than no pozzolanic reaction occur. It is different from that of on an organic soil. In the early period, an organic soil contain Na⁺ and K⁺ that can be changed by Ca²⁺ or Mg²⁺ in the admixture during reaction of cation changes, than specific gravity of soil improve on 0 day curing period [6]. On 7 days curing time and 498% water content, the specific gravity of stabilized soil improve to 1.95 with 20%, then small improvement and constant up to 30% of admixture agents. This trend is similar to the sample with 548 and 598%, however, the improvement of specific gravity is bigger compared to that of on 498% water content. The specific gravity goes to 2 and 2.1 for 548 and 598% water content.
Figure 5. Proportion of Admixtures – Specific Gravity (a : w =498%; b : w=548%)

Figure 6. Water content – Spec. Gravity (a: 10% Admixture, b: 25% Admixture)

Figure 6 is the presentation of the relation between water content and specific gravity. The behavior of the curves of 10% and 25% admixtures are similar. The significant improvement occur on 598% water content and 36 days curing time, because the pozzolanic reaction needs more water, and more curing time to get the best reaction.

3.4 Void Ratio ($e$)

Void ratio of original soil is 7.1. It decreases almost linearly with the binder proportion. After 20% proportion of admixture, there is no more significant decrease on void ratio (Figure 7). It means that 20% is optimum proportion of admixture. With respect to the water content, the decrease of void ratio on 598% water content is bigger compared to those on 498%. For example, at 36 days curing time, void ratio decreases to 3.4 on 498%, and to 2.9 on 598% water content. It is the fact that the water is required on pozzolanic reaction. Basically, the decrease of void ratio is because of filling out the pore by the gels formation as the product of pozzolanic reaction. However, the decrease of void ratio from 21 days to 36 days curing period is not significant, and tends to constant. This phenomenon indicates that after 21 days curing period, there is no pozzolanic happens.
3.5. Organic Content (OC) and Degree of Acidity (pH)
Similar to void ratio, organic content decreases with respect to the water content, binder quantity, and time curing (Figure 8). With respect to binder quantity, on 36 days curing period and on 498% water content, OC decrease from 95% to 51%. With respect to curing period, on 30% binder proportion and 598% water content, OC decrease from 60% (7 days) to 45% (36 days). Moreover, OC decreases with respect to the water content, for example, for 30% water content, 36 days curing time, OC decreases from 51% on 498% water content to 45% on 598% water content. All those phenomena show that cementous reaction require admixture, water and curing period.

Figure 8. Proportion of Admixture – Organic Content

Beside improving the unit weight, specific gravity, decreasing void ratio and organic content, the degree of acidity (pH) of stabilized organic soil increases with respect to the water content, binder proportion and curing period. Initial degree of acidity is 4.7%, it improves to 7.1 on 30% binder proportion, 36 days curing time and 598% water content. The improvement is because of characteristics of binder (40% CCR + 60%AAT) that can change the acidity of organic soil to neutral.
However, at 498% water content the improvement of pH is smaller than that of at 598% water content, that indicates the effect of water content to pH improvement.

4. Conclusion
A series of experimental program and analysis have been done, then the following conclusion can be drawn. The Ketapang Peat has high organic content, around 95%, that is classified as high organic content-peat. The binder was (40% bagasse ash + 60% calcium carbide residue). The bagasse ash has high content of silica, alumina and ferrit whereas calcium carbide has high CaO content, therefore combination of both materials with additional water generate the pozzolanic reaction. The addition of water content improves the specific gravity, unit weight, and the degree of acidity of organic soil. However, it decreases the void ratio and organic content of soil. Similarly, binder proportion and curing period improve the physical and chemical properties of stabilized organic soil. The optimum admixture proportion were found on 20%, and curing period were found on 21 days.

Acknowledgement
The authors would like to deliver special thanks to The minister of Research and Higher Education Republic of Indonesia for the funding of the research through the Fundamental Research of Higher Education Grant. Thank is also addressed to Research Institute and Public Affairs of Universitas Atma Jaya Yogyakarta.

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