Soft Clay Improvement Using Bamboo Leaf Ash on CBR Values

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Abstract. Soft and expansive clay is a soil type mostly found in Indonesia. Cement addition is one of the treatments common applied in soft clay improvement. However, its utilization requires to be controlled considering the effect to environment. Bamboo is a very abundant natural resource. On the other hand, bamboo leaf still requires attention in terms of management and utilization. In the form of ash, bamboo leaf contains high silica that could be used as pozzolan material. This research investigated the effect BLAsh addition in reducing cement utilization to the CBR value parameter of soft clay soil by experimental analysis. The total content of stabilizer material in the soft clay soil is 12% of the dry soil mass. Then, BLAsh content was varied in 0%, 25%, 50%, 75%, and 100% of the total content of stabilizer material. The result depicted that 25% of cement substitution by BLAsh proved the improvement of CBR value both in dry and critical condition. In addition, improvement of expansive soil was proven by the decreasing of swelling percentage in the mixture with 25% of BLAsh content. Also, the longer curing time is important in providing perfect reaction of the chemical contents in the mixture.

Keyword: soft clay, improvement treatment, bamboo leaf ash, CBR value

1. Introduction

Clay is a type of soil widely spread in Indonesia. Unfortunately, mostly, it has several adverse characteristics. One of them is expansive clay characteristic, which has a relatively low bearing capacity in saturated condition, high plasticity and potential for shrinkage [1]. This characteristic may cause damage to building structures, especially in light buildings, e.g. road pavement structures.

Soil stabilization is a method to improve the characteristic of soil, especially for soft soil problem. By mixing the soil with stabilizer material, the typical properties of soft soil improves. Cement is a stabilizer material that is widely applied in soft clay soil improvement. The advantage of cement is easy to apply and does not depend on the type of minerals in the soil. It has high content of CaO which if it reacts with water will provide bonding, hardening and strengthening in soil stabilization [2]. However, unfortunately, the utilization of large amount of cement has disadvantages in economic and environmental aspects. As an important material in construction activity, cement is relatively expensive, especially in developing country. In addition, the pollution induced by cement manufacturing process and the high heavy metal content in cement prove that it has negative effect to the environment. Therefore, alternative materials as the cement substitution are required in order to reduce the
disadvantages. Bamboo leaf ash (BLAsh) is an alternative material of cement substitution. It has a high silica content that may have high potential as the soil stabilization material [3].

Bamboo tree is a type of plant that is mostly found in subtropical and tropical countries, e.g. in Indonesia. However, bamboo leaves material has not been well utilized, so it is included in natural waste material. In the form of ash, bamboo leaves have a very high silica content. One of the references mentioned that silica content of BLAsh reaches 75.90 - 82.86% [4]. Based on this result, BLAsh is one of the pozzolanic materials with the second highest silica content after rice husk ash.

Previous study [5] proved that BLAsh is able to be utilized as a cement substitution in the concrete mixture in about 20% of BLAsh addition. Moreover, [6] stated that 75% of BLAsh content was capable of substituting cement utilization in order to improve the liquefaction resistance. Other research [7] also investigated the effect of mixture between BLAsh and lime in increasing the CBR (California Bearing Ratio) value on the silt clay soil stabilization for road construction. There are researchers ([8] and [9]) also conducted a study utilizing BLAsh in the mixture of cement and lime as a material stabilization of highway construction. However, investigation of the BLAsh addition as the cement substitution in the soft and expansive soil improvement especially to the CBR value has never been conducted. So, the aims of this research was to determine how the influence of BLAsh on changes in the soil density parameters, CBR value and swelling potential. Furthermore, the optimum value of BLAsh addition as the cement substitution material was expected to be generated.

2. Material and Methods

2.1. Materials

A series of experimental testing was conducted in laboratory. Materials investigated were mixtures consist of stabilized clay soil using cement and BLAsh. The soft clay soil material was taken in Wates, Kulonprogo, Yogyakarta. The cement material was Portland cement type 1 (figure 1). Based on [10], the optimum cement addition on the high plasticity of silt and clay soil is about 11-12 % of soil dry mass as shown in table 1. This research followed the suggestion as the reference percentage of stabilizing material total content in mixture, i.e. 12%. The bamboo leaf material was taken from Delanggu, Klaten, Central Java. Type of bamboo is Bambusa arundinacea. In the form of ash, bamboo leaf substituted cement content in the variation of 0%, 25%, 50%, 75% and 100% of cement dry mass.

2.2. Preparation of bamboo leaf ash

Following [6], bamboo leaf requires some steps in making process of BLAsh material. The steps of process are shown in figure 3. Firstly, bamboo leaf waste was collected and dried under the sun (figure 3(a)). The dry bamboo leaf was burnt in an open area (Figure 3(b)) and stopped after it become bamboo leaf charcoal in black color (Figure 3(c)). The bamboo leaf charcoal was heated in furnace at 600°C for 3 hours (Figure 3(d)). Figure 3(e) shows the results of closed combustion in furnace. The color changed to be grey color. It was cooled and grinded using mortar and pestle, then sieved using sieve no. 200. The result of BLAsh making process is seen in Figure 3(f).

![Figure 1. Portland Cement Type I.](image-url)
Table 1. Suggested Cement Content in Soil Improvement [10].

| Type of soil                                      | Cement content based on soil dry mass (%) |
|--------------------------------------------------|------------------------------------------|
| Granular, well-graded, GW, SW                     | 4 – 5                                    |
| Granular, poor graded or silty soil, GP, GM, SP, SM| 5 – 6                                    |
| Granular, fined-grained, GC, SC                   | 7 – 8                                    |
| Fine uniform sand, SP, SM                         | 9 – 10                                   |
| Clay and silt, low plasticity, CL, ML             | 9 – 10                                   |
| Clay and silt, high plasticity, CH, MH            | 11 – 12                                  |
| Organis soil, OL, OH                              | 13 – 14                                  |

Figure 2. (a) *Bamboosa Arundinacea* and (b) Bamboo Leaf Material

Figure 3. Making Process of Bamboo Leaf Ash

2.3. Research stages
The stage of this research were the investigating of the soft clay soil properties, the making mixture variation as the test specimen and the testing of standard proctor compaction based on ASTM D698-12
[11] in obtaining the value of Optimum Moisture Content (OMC) and Maximum Dry Density (MDD). The result of soil properties investigation and the mixture variation were shown in Table 2 and Table 3, respectively. Based on the Unified Soil Classification System (USCS), the soil was classified as CH soil. This means that the soil is high plasticity clay soil. Based on the value of OMC, the CBR testing was conducted in soaked and un-soaked condition based on ASTM D1883-16 [12]. In the investigation of the time function, variation of curing time was conducted to the specimen, i.e. 3 and 7 days before CBR testing. This results were compared to the CBR value requirement of subgrade material [13]. Also, swelling investigation was conducted based on ASTM D4546-14 [14] in discussing the effect of cement and BLAsh addition as the improvement of soft and expansive clay soil.

Table 2. Soft Clay Soil Properties.

| Parameters               | Value |
|--------------------------|-------|
| Water content (w)        | 10.98%|
| Specific gravity (G_s)   | 2.61  |
| Liquid limit (LL)        | 75%   |
| Plastic limit (PL)       | 33.96%|
| Plasticity index (PI)    | 41.05%|

Table 3. The Mixture Variation.

| Mixture Variation (%)     | Code      |
|---------------------------|-----------|
| Original soil             | S         |
| Soil+Cement100%+BLAsh0%   | SC100B0   |
| Soil+Cement75%+BLAsh25%   | SC75B25   |
| Soil+Cement50%+BLAsh50%   | SC50B50   |
| Soil+Cement25%+BLAsh75%   | SC25B75   |
| Soil+Cement0%+BLAsh100%   | SC0B100   |

3. Experiment result and discussion

3.1. MDD and OMC values

Based on the standard proctor or compaction test result, values of MDD and OMC were obtained. The results are shown in Figure 4. The curve of MDD value (Figure 4(a)) shows that the addition of 12% cement provided the highest improvement to the soft clay soil. This result indicates the conformity to the suggestion [10]. However, the trend of the MDD result in the BLAsh substitution was investigated in order to reach the aim of this research in reducing cement addition by BLAsh. Based on the result, substitution of BLAsh indicated negative trend to the density of the mixture. The more content of BLAsh in substituting cement material provided the lower value of MDD. Furthermore, the addition of the 12% BLAsh to the soft clay soil showed similar value to the MDD value of soft clay soil only. It indicated that there is no improvement to the MDD value in the 100% BLAsh addition in the mixture (mixture SC0B100). This results may in accordance with the chemical equation of cementation and pozzolanic reaction. Cementation process is occurred on the reaction between CaO in cement and water. It produces cement paste and Ca(OH)\textsubscript{2} as byproduct of reaction. Whereas, pozzolanic process is reaction between Ca(OH)\textsubscript{2} and silica or alumina content in pozzolan material to produce cement paste more. Based on [4], BLAsh has high silica content. It is expected to increase cement paste production after cementation process. Thus, if there is no cement content in the mixture, silica is not capable to produce cement paste. It could be concluded that BLAsh material is unable to be a totally cement replacement material.

The summary of OMC value was depicted in Figure 4(b). The addition of the stabilizer material to the soft clay soil, whether addition cement only, cement and BLAsh or BLAsh only, provided effect to
the OMC value. The value decreased along stabilizer material addition except the anomalous result seen in totally cement substitution by BLAsh (the mixture SC0B100). This is related to the characteristic of the stabilizer material. Both cement and BLAsh possess high water absorbability. Also, water was required in the process of cementation and pozzolanic reaction. As discussed above, the mixture SC0B100 does not undergo a perfect reaction due to the absence of CaO content.

![Effect of Mixture Variation to (a) The MDD Value and (b) The OMC Value.](image)

3.2. CBR values

The CBR test was conducted in laboratory to all mixture variations. Water addition in the mixture followed the OMC value as the result of compaction test in order to obtain maximum density. The OMC value was applied in the making process of CBR test specimens. Specimens were cured in 3 and 7 days to provide the time to set the chemical reaction in the mixture. Then, the specimen treated in two conditions, i.e. soaked and un-soaked condition. The result series of CBR tests of mixture variation under un-soaked and soaked condition were summarized in Figure 5 and Figure 6, respectively. The CBR value under un-soaked condition shows relatively consistent trend that is about 20-50% for all mixture variation (Figure 5). Also, all mixture variation are above the CBR value requirement that is equals to 6% of the CBR value as suggested by [13]. The highest value of CBR was achieved by mixture SC100B0 both after 3 and 7 days curing time. Based on the variation of curing time, 7 days curing time shows higher result than 3 days except mixture SC25B75.

This anomalous result might be caused by making process of specimen in laboratory improperly. On the other hand, under soaked condition shows significant result (Figure 6). Soft clay soil has lower CBR value than CBR value requirement under soaked condition. Consistent with un-soaked conditions, the highest value of soaked condition was also achieved by mixture SC100B0. Unfortunately, the higher content of BLAsh substitution provides the lower CBR value. However, rapidly decreasing CBR value was occurred in the more than 50% BLAsh substitution and even the 100% cement substitution by BLAsh produced the similar value as the soft clay soil. These results are consistent with the compaction test result previously discussed. This is due to the inability of BLAsh material to completely replace the function of cement. In addition, comparison between un-soaked and soaked condition is quite clear where the soaked condition is the critical condition in the field, e.g. after heavy rain. The bond produced by chemical reaction in the mixture are released again due to excess water content.

3.3. Optimum content

In determining the optimum content of BLAsh material as the cement substitution, comparison was conducted based on the CBR tests results. Both under un-soaked and soaked condition show that the
substitution of BLAsh content to the total stabilizer material content decreases the CBR value. However, in satisfying the aim of reducing the cement utilization in soft clay soil improvement, 25% of cement substitution by BLAsh material provides not extremely poor result. Also, the result of CBR test of mixture SC75B25 is above the CBR value requirement both under un-soaked and soaked condition. This means that although the CBR value achieved is not the highest value, it has satisfied the applicable requirement.

In addition, the consistent conclusion was also shown by other test, namely swelling percentage test. Swelling percentage indicates the characteristic of expansive soil. The lower swelling percentage depicts the more improvement of soft and expansive clay soil. As mentioned in Table 2, the PI of soft clay soil is high. This means that the soil has high plasticity and high swelling potential. Result of swelling percentage test after 3 days curing time was shown in Figure 7. The decreasing of swelling percentage are shown in mixture SC100B0 and SC75B25. Again, consistent result to the trend of CBR test, more than 50% of cement substitution by BLAsh material provides negative effect to the mixture even close to the swelling percentage of expansive soil. Thus, the optimum content of BLAsh in reducing cement utilization was determined equals 25%.

![Figure 5. The CBR Test Result under Un-soaked Condition in Variation of Curing Time.](image1)

![Figure 6. The CBR Test Result under Soaked Condition in Variation of Curing Time.](image2)
4. Conclusions

The conclusion that could be drawn from this research is that BLAsh is able to be utilized as a cement substitution material for stabilizing soft and expansive soil by its high silica content. This is evidenced by the results of the compaction and CBR tests. Moreover, BLAsh material is capable of reducing the OMC value of soil thereby reducing the swelling potential. Although BLAsh is unable exceed the strength of the improvement by cement only, 25% of cement substitution by BLAsh proved the improvement of CBR value both in dry and critical condition. In addition, improvement of expansive soil was proven by the decreasing of swelling percentage in the mixture with 25% of BLAsh content. Besides the content of stabilizer material, the longer curing time is also important in providing periods, so that the chemical contents in the mixture react perfectly. Based on these conclusions, BLAsh material is expected to be utilized by combining with other pozzolanic materials for more improving soil stabilization. Otherwise, BLAsh is suitable as a stabilizer material for applications with low strength requirement or non-structural applications.

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