

## Bamboo leaf ash as the stabilizer for soft soil treatment

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**Abstract.** Soft soil is a type of soil that have the size of particle less than 0.063mm. The strength of the soft soil does not fulfil the requirement for construction. The present of soft soil at the construction site always give a lot of problems and issues to geotechnical sector. Soil settlement is one of the problems that related to soft soil. The determination of the soft soil physical characteristics will provide a detail description on its characteristic. Soft soil need to be treated in order to gain the standard strength for construction. One of the method to strengthen the soft soil is by using pozzolanic material as a treatment method for soft soil. Furthermore bamboo leaf ash is one of the newly founded materials that contain pozzolanic material. Any material that consist of Silicon Dioxide ( $\text{SiO}_2$ ) as the main component and followed by Aluminium Oxide ( $\text{Al}_2\text{O}_3$ ) and Iron Oxide ( $\text{Fe}_2\text{O}_3$ ) are consider as pozzolanic material. Bamboo leaf ash is mix with the cement as the treatment material. Bamboo leaf ash will react with the cement to produce additional cement binder. Thus, it will increase the soil strength and will ease the geotechnical sector to achieve high quality of construction product.

### 1. Introduction

Soil is defined as a natural body that contain solid, liquid and gas. The origin of soil is from the process of disintegration of rocks. It has been discovered that there are many type of soil in the world. Mainly, it can be divided into three types of groups which are coarse, fine or soft and organic. Soil can be classify as coarse soil when the particle size is greater than 0.063mm while the particle size finer than 0.063mm is classify as fine soil. The term organic refer to the soil which is originate from plants or animals remain and also known humus. Soil settlement and structure crack always occur in a construction during or after the structure have completed. The main problem is the present of soft soil under the structure. Soft soil strength does not fulfil the requirement for construction. Every soil types will have their own standard specification of soil strength for example, the bearing capacity, the compression and the shear strength.

Currently construction is one of the major factors in the development of a country where the construction will consist of constructing infrastructure and buildings. Therefore, with the construction sector is increasingly and developing, problem may occur regarding to the structure or the construction itself. The problem that may occur from the construction is excessive soil settlement. Nowadays, lime, silica fume and fly ash are normally being used as a stabilizer to treat the soil settlement. The option of the stabilizer will increase with the addition of the bamboo leaf ash. Engineers will have more option in choosing their stabilizer for the soil settlement treatment. Moreover this will help to reduce the percentage of soil settlement cases as the engineering sectors know bamboo leaf ash can be used as a stabilizer.



In addition, this study will show that the bamboo leaf will not be treated as solid waste but as a stabilizer. Besides, the use of bamboo solid waste as a stabilizer will reduce the treatment cost. Lastly, the environment will benefit from this study where less solid waste from bamboo will be incinerated and reduce the rate of air pollution. In order to solve the soil settlement problem, preventive measures have to carry out by strengthening the soft soil. Bamboo leaf ash will act as a stabilizer to improve the strength of the soft soil. A mixture of bamboo leaf ash, ordinary Portland cement and soft soil can be applied as the treatment method to the soft soil. Bamboo leaf ash and ordinary Portland cement will acts as a cementitious material which will improve the shear strength of the soft soil. The increase of shear strength will make the soil capable of resisting load that act on it. Thus, the problem related to soil settlement can be prevent. Therefore a stabilizer is needed to be fused with the soft soil in order to stabilize the soft soil and help to achieve the standard strength for the construction of structures.

Stabilizer is a substance that can change the properties of the soft soil in order to meet the standard requirement for engineering purpose. Bamboo is a type of plant and natural resource that have high rate of growth and high yield strength [1]. Recent study shows that Bamboo leaf ash can act as a stabilizer to the soil. Bamboo leaf ash contains a pozzolanic material that is the main component that will produce the cementitious component when reacts with the ordinary Portland cement. The process of this action is called pozzolanic reaction [2]. Pozzolanic reaction is a reaction that will produce additional calcium silicate hydrate in the mixture of bamboo leaf ash, ordinary Portland cement and soil. Result from the reaction will make the soil denser which is more suitable for the construction and fulfil the standard requirement soil strength.

Soft soil is a type of soil that is found on the bed and onshore of ocean. Recent study shows that there is a lot of deposited soft soil especially marine clay at the Malaysian costal. Marine soil can be classified as the soft soil and has characteristics of high void ratio, poor consistency, very high compressibility and low value of shear strength [3]. As for the physical characteristic, marine clay has high value of moisture content. Marine clay is considered as uneconomical. The presence of this clay is very problematic. There are many cases where the major contribution of soil settlement is from the soft clay. Clay needs to treated in order to strengthen the soil.

Bamboo is a type of plant that categorized in grass group called Poaceae (Gramineae) family [4]. There is a lot of bamboo species in the world. The amount of bamboo species found in the world is 1250 species [5]. In Malaysia, there are 50 species of bamboo. Common types of bamboo in Malaysia are *Bambusa Vulgaris*, *Gigantochloa Levis* and *Gigantochloa Scortechinii* [4]. Futher study has been conducted on *Bambusa Vulgaris* to use in soil treatment as soil stabilizer.

Bamboo leaf ash is a waste product from bamboo industry as shown in Figure 1. Bamboo leaf needs to be process in order to produce bamboo leaf ash. Bamboo leaf can be divided into two groups which are mesophyll cell and parallel vein. Study from Singh et al. [6] shows that bamboo leaf ash is a natural amorphous and the presence of Silicon Dioxide ( $\text{SiO}_2$ ) is a sign of pozzolanic material. Bamboo leaf ash has its own physical characteristics which are normal consistency, settling time and specific gravity. The physical characteristic of bamboo is important in order to compare with the characteristics of ordinary Portland cement which will be used in the mixture. Bamboo leaf ash also has its own chemical properties. The main chemical composition of bamboo leaf ash is  $\text{SiO}_2$ .



**Figure 1.** The bamboo leaf ash [7]

The presence of  $\text{SiO}_2$  shows that bamboo leaf ash is a pozzolanic material [7]. The chemical composition is important in order to identify whether the specimens has pozzolanic material or not. Nowadays, the usage of pozzolan as a cement binder is increasing. Pozzolan can be used as the partial replacement in concrete to strengthen the soil. The function of bamboo leaf ash as pozzolanic material reduces the usage of cement in the mixture. However the strength of these mixing will be in acceptable range. According to Villar-Cociña et al. [8], the compressive strength of mortar is increasing when mixes with bamboo leaf ash and the value is quite similar to ordinary Portland cement. Bamboo leaf ash will contribute to strengthen the soil condition. Pozzolanic reaction will take place during the mixing of bamboo leaf ash and ordinary Portland cement.  $\text{SiO}_2$  presence in bamboo leaf ash will react with Calcium Hydroxide ( $\text{CaOH}_2$ ) in cement to produce Calcium Silicate Hydrate (CS-H) material which is the main cementitious material [2].

## 2. Research methodology

This research is an experimental study to determine the improvement of the soft clay adding with bamboo leaf ash and ordinary Portland cement. Data of the laboratory work were divided into physical characteristic and engineering properties. The physical characteristics of the soft soil were determined by conducting wet sieving, hydrometer, moisture content and Atterberg limit test. After that, the unconfined compressive test (UCT) was conducted to determine the deviator stress and the shear strength of bamboo leaf ash-clay-cement specimens. The samples were divided into 0%, 5% and 10% of bamboo leaf ash mix. All of the samples were curing on the period of 0, 7 and 28 days.

The samples were taken at Pengkalan Nelayan Sementa, Klang, Selangor with coordinates of  $3^{\circ}40'57.92''\text{N}$ ;  $76^{\circ}22'73.75''\text{E}$ . The disturbed sample was taken and placed in polyethylene bags. To avoid the loss of moisture content, the bags containing the sample must be carefully tied and brought back to the soil laboratory as soon as possible. Laboratory tests were then conducted with the use of appropriate quantities of the soil sample collected. Important physical and engineering properties were determined using appropriate equipments in the laboratory. The bamboo species that will be used is *Bambusa Vulgaris*.

About nine (9) remoulded specimens were used in the test with the dimensions of 50mm diameter and 100mm in height. Each of the specimens was prepared using 0, 5 and 10% of bamboo leaf ash mixing with constant ordinary Portland cement and water. Besides that, the specimens also will be subjected to curing time of 0, 7 and 28 days. The purpose of this method is to evaluate the reaction with respect to shear strength when the bamboo leaf ash blended with the soil and also the time that can influence the strength with respect to curing time.

In order to prepare for the bamboo leaf ash, about one (1) kilogram bamboo leaves was collected from the wild bamboo plant and was dries under the sun for seven (7) days. Then the dried bamboo leaves were burned at open atmosphere. After the burning process is completed, then the bamboo leaves were transferred into a furnace and continued with the heating process. The burned bamboo

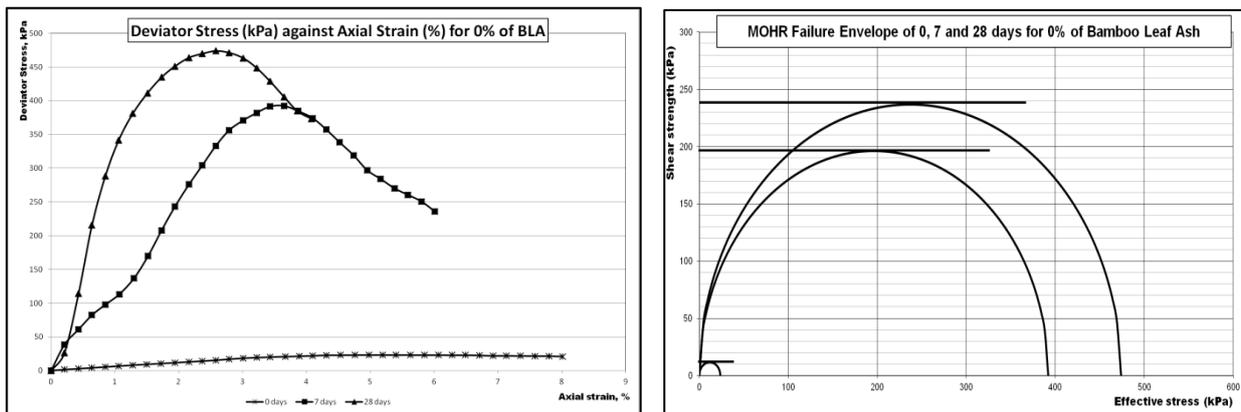
leaves were heated into a furnace for two (2) hours at 600°C in order to produce the bamboo leaf ash. Then the bamboo leaf ash was cooled down under atmospheric temperature.

Then the specimens are being prepared for the mixture between bamboo leaf ash and ordinary Portland cement. The soil and cement ratio used for this procedure is 5:1. The mixture of soil, bamboo leaf ash and cement were mixed in a mixing bowl. The mixture was added according to the ratio that will be tested and the amount of bamboo leaf ash also will be increased for each of the mixture. The percentage of bamboo leaf ash mixing was 0%, 5% and 10% of the ordinary Portland cement.

### 3. Experimental results and discussion

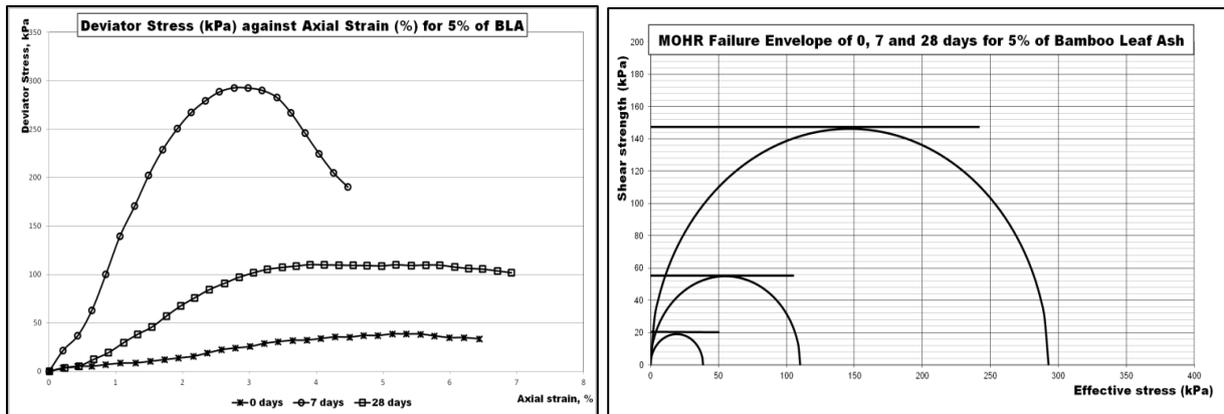
This soil taken from Pengkalan Nelayan, Sementa, Klang is classified as SILT of very high plasticity based on the physical properties test that has been done. Results reveal that for wet sieving test, the soil that passing through the sieve of 0.063mm is about 84.8% while about 15.2% were retained on the sieve. The water content of the specimens is 99.1% while for the specific gravity is 2.68. Furthermore liquid limit of the specimens is 75.8% with plastic limit is 40.7% and the plasticity index is 35.1%.

Figure 2(a) shows the deviator stress against axial strain for 0% of mixing bamboo leaf ash with 0, 7 and 28 days of curing. Results reveal that the highest value of deviator stress is 473.8kPa when the specimens mixing with 0% of bamboo leaf ash with the curing time of 28 days compare to others. The lowest value of deviator stress was at 23.4kPa for curing time of 0 day while in Figure 2(b) shows the shear strength of Mohr envelope which the highest value of shear strength is at 240kPa and the lowest shear strength is at 11kPa.



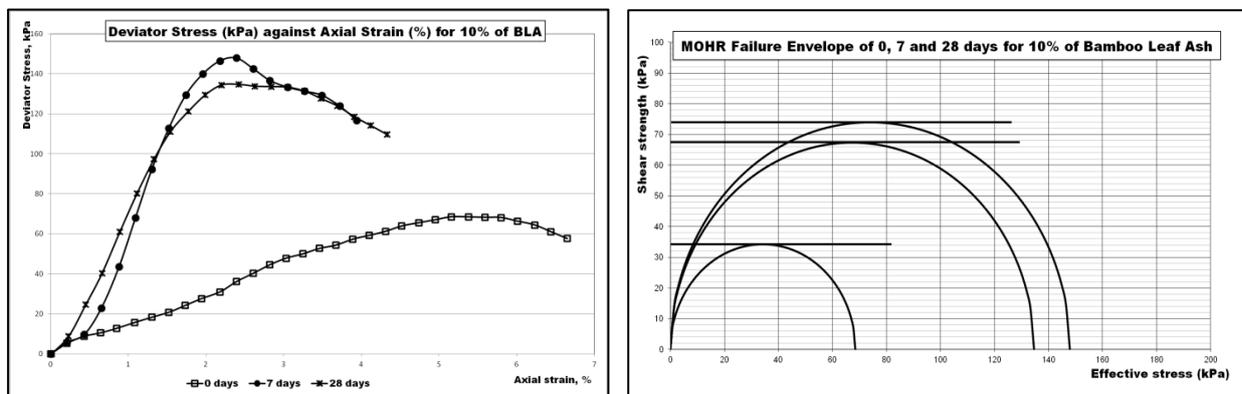
**Figure 2.** (a)Deviator stress against axial strain for 0% of bamboo leaf ash with curing time of 0, 7 and 28 days while in (b) shows the shear strength Mohr envelope at failure

Figure 3(a) shows the deviator stress against axial strain for 5% of mixing bamboo leaf ash with 0, 7 and 28 days of curing. Results show that the highest value of deviator stress is 292.7kPa when the specimens mixing with 5% of bamboo leaf ash with the curing time of 7 days compare to others. The lowest deviator stress was at 38.5kPa for curing time of 0 day while in Figure 3(b) shows the shear strength of Mohr envelope which the highest value of shear strength is at 148kPa and the lowest shear strength is at 20kPa.



**Figure 3.** (a) Deviator stress against axial strain for 5% of bamboo leaf ash with curing time of 0, 7 and 28 days while in (b) shows the shear strength Mohr envelope at failure.

While in Figure 4(a) shows the deviator stress against axial strain for 10% of mixing bamboo leaf ash with 0, 7 and 28 days of curing. Results show that the highest value of deviator stress is 147.9kPa when the specimens mixing with 10% of bamboo leaf ash with the curing time of 7 days compare to others. The lowest deviator stress was at 68.5kPa for curing time of 0 day while in Figure 4(b) shows the shear strength of Mohr envelope which the highest value of shear strength is at 74kPa and the lowest shear strength is at 34kPa.



**Figure 4.** (a) Deviator stress against axial strain for 10% of bamboo leaf ash with curing time of 0, 7 and 28 days while in (b) shows the shear strength Mohr envelope at failure.

Table 1 shows the tabulated results of all the mixing bamboo leaf ash of 0, 5 and 10% with respect to curing time required of 0, 7 and 28 days.

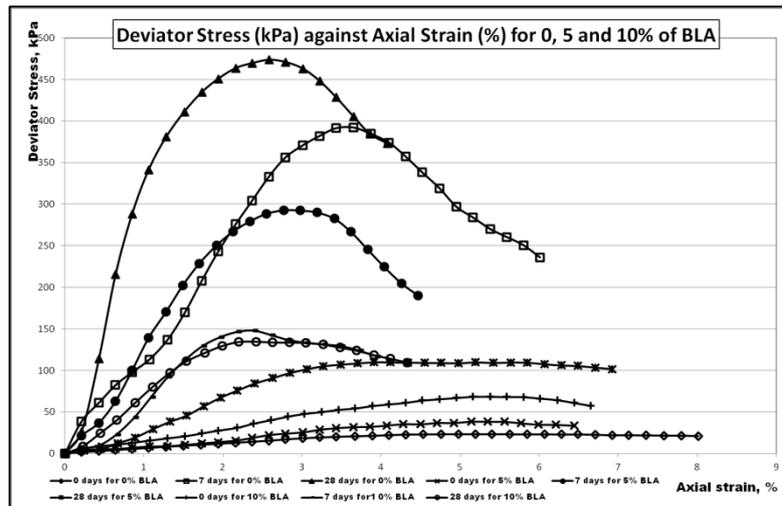
**Table 1.** Summaries of results for percentage of 0, 5 and 10% bamboo leaf ash with respect to 0, 7 and 28 days curing period

Percentage bamboo leaf ash, %	Deviator stress (kPa)		
	0 day	7 days	28 days
0	23.4	392.2	473.8
5	38.5	292.7	110.1
10	68.5	147.9	134.7

Results from Table 1 reveal that the highest value of deviator stress when mixing with bamboo leaf ash was at 473.8kPa with 0% of mixing in 28 days of curing while the lowest deviator stress value is 23.4kPa with 0% of mixing in 0 day of curing. It shows that when the specimens in natural condition i.e. without mixing with bamboo ash and without curing, the result is in the lowest value. However when the specimen is being curing for 7 and 28 days, the shear strength start to increase tremendously from 23.4kPa to 392.2 and 473.8kPa respectively. It means that the shear strength of the specimen without mixing with bamboo ash will start to increase drastically with time.

However for percentage of bamboo leaf ash at 5 and 10%, result shows that the highest deviator stress was in 7 days of curing and not for 28 days. This is because the pozzolanic reaction will not contribute to increase in the shear strength of the specimen when mixing too much of the bamboo ash. Apart from that result shows in 7 days of curing for 5% bamboo ash, the deviator stress was 292.7kPa and for 10% was 147.9kPa. Finding shows that an increase in the percentage of bamboo leaf ash would results in decrease of deviator stress for more than 7 days. In other words, the optimum percentage of the bamboo ash is at 5% and at 7 days of curing only. Apart from that, the results would be not significant in order to strengthen the shear strength of soft soil mixing with bamboo leaf ash.

Figure 5 shows the combination of deviator stress against axial strain for 0, 5 and 10% of mixing bamboo leaf ash with 0, 7 and 28 days of curing. Results show that the highest value of deviator stress is 473.8kPa when the specimens mixing with 0% of bamboo leaf ash with the curing time of 28 days while the lowest deviator stress value was at 23.4kPa with 0% of mixing bamboo leaf ash with 0 day of curing time. Apart from that the second highest value of deviator stress is at 392.2kPa with 0% of bamboo leaf ash and 7 days of curing time. Follow by deviator stress at 292.7kPa with 10% of bamboo leaf ash and 7 days of curing. After that the deviator stress reduces to 147.9kPa with 10% of bamboo leaf ash and 7 days of curing.



**Figure 5.** Combination of deviator stress against axial strain for 0, 5 and 10% of bamboo leaf ash with curing time of 0, 7 and 28 days.

**Table 2.** Summaries of results for shear strength of 0, 5 and 10% bamboo leaf ash with respect to 0, 7 and 28 days curing period

Percentage bamboo leaf ash, %	Shear Strength, $\tau$ (kPa)		
	0 day	7 days	28 days
0	11	195	240
5	20	148	56
10	34	74	68

Table 2 shows the tabulated results for shear strength using Mohr failure envelope of all the mixing bamboo leaf ash of 0, 5 and 10% with respect to curing time required of 0, 7 and 28 days.

**4. Conclusion and recommendation**

Based on the results presented the best curing time for bamboo leaf ash, ordinary Portland cement and soil mixtures was on the period of 7 days of curing where the highest stress is about 292.7kPa. Furthermore, the shear strength of the soil determine by Mohr failure envelope shows that the highest value is at 7 days of curing with 5% bamboo leaf ash mixing with cement. The value is 148kPa. As for the recommendation, there are many rooms for improvement regarding to improve the results on the test. First, the determination of the soft soil characteristics should be widening not only considering the physical characteristics but also chemical characteristics. The determination of the soft soil chemical characteristics might affect the pozzolanic reaction between the cement and pozzolanic material that being used on the study. Second, the chemical content of BLA should be analyse before proceeding the test. Different species of bamboo might have different percentage of the pozzolanic material that can affect the chemical reaction in the pozzolanic reaction. The determination of the CaO percentage also importance as the CaO can act as binder content. Lastly, the list of percentages of BLA used in the study should be increase or widen up so that we can further improve or stumble upon something which is new that can contribute to the advancement of this study.

### Acknowledgment

The authors would like to express their sincere gratitude to Ministry of Higher Education (MOHE) and Institute Research Management Institute (IRMI, UiTM) for providing financial support for this research. It was funded under Fundamental Research Grant Scheme (FRGS), UiTM (600-RMI/FRGS 5/3 (40/2015)).

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