# Effect of Bamboo Flakes on Stress-Strain Behavior of Cement Stabilized Loose and Poorly Graded Sand

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## 1. INTRODUCTION

Bamboo is a kind of natural resource that has ability to grow in varying conditions, especially in tropical and sub-tropical countries. In the form of bamboo chips combined with cement, Huang et.al. (2011) and Saki et.al. (2013) investigated bamboo utilization to improve soft ground with low bearing capacity and to increase erosion resistance, respectively. Moreover, Sato et.al. (2014) studied bamboo chips and flakes utilization in high water content of excavated mud. However, bamboo flakes utilization in the poorly graded sand under saturated condition has not been investigated yet. It is highly susceptible to liquefaction phenomenon by earthquake or other rapid loading. Soil improvement of road structure foundation called as subgrade improvement against liquefaction is a kind of the post-disaster mitigations. Safe road structure after earthquake is an important facility in the accommodation and logistic distribution after disaster. In this study, combination between pozzolanic content of cement and high water absorbability of bamboo flakes in the poorly graded sand was examined under static loading as a preliminary study for further investigation against liquefaction.

## 2. PROPERTIES OF BAMBOO FLAKES

Bamboo flakes is made from bamboo rod that is produced by using rubbing machine. The water absorbability is the important characteristic of bamboo flakes. The test was conducted to obtain absorbed water in a constant volume, 6 cm of diameter and 1.5 cm of height. The initial water content was kept less than 5%. Based on the test result, absorbed water is about 68-90% of constant volume of bamboo flakes in 90 minutes. This characteristic is expected to decrease the excess pore water pressure of soil mixture in undrained condition during loading.

Physical characterization of bamboo flakes was performed by elongation and flatness ratio. Elongation ratio is ratio between intermediate and shortest length of bamboo flakes particle, whereas flatness ratio is ratio between shortest and longest length. Cubical is the best shape of material in relation to fill the void in mixture. Based on these ratios, the dominant shapes of bamboo flakes are blade and rod. It can be concluded that property of bamboo flakes expected in mixture is high water absorbability instead of physical characteristic as a densification material.

## 3. BAMBOO FLAKES ADDITION

Toyoura sand (Dr = 35%) was used to perform loose and poorly graded sand. Variations of bamboo flakes content ($f_s$) are 0%, 1%, and 2% combined with 4% of cement. As a preliminary stage, static loading was conducted in the consolidated-undrained (CU) triaxial test ($\sigma_r$ = 50, 100, and 150 kPa).

Preparation of specimen was conducted by calculating required bamboo flakes and cement referenced to the dry soil weight, mixing materials in dry condition, pouring 20% of water, then compacting in mold with 5 cm diameter and 10 cm of height. The percentage of water is a result of preliminary trial in order to workability reason. 7 days and 14 days of curing time was performed to obtain mechanical behavior regarding time dependency.

Fig. 1 Bamboo flakes

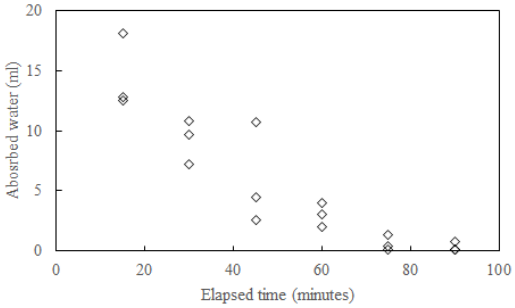


Fig. 2 Water absorbability test result

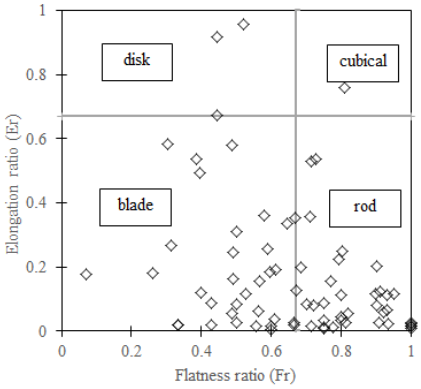


Fig. 3 Elongation and flatness ratio

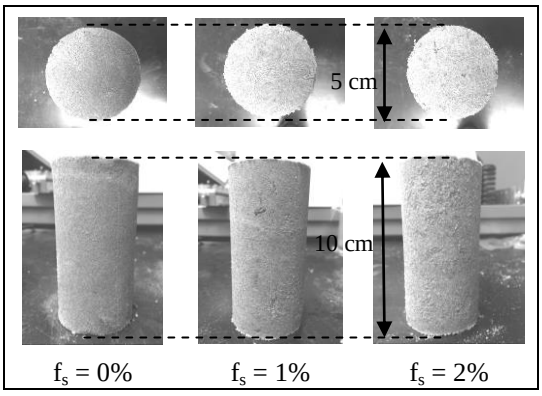


Fig. 4 Test specimens

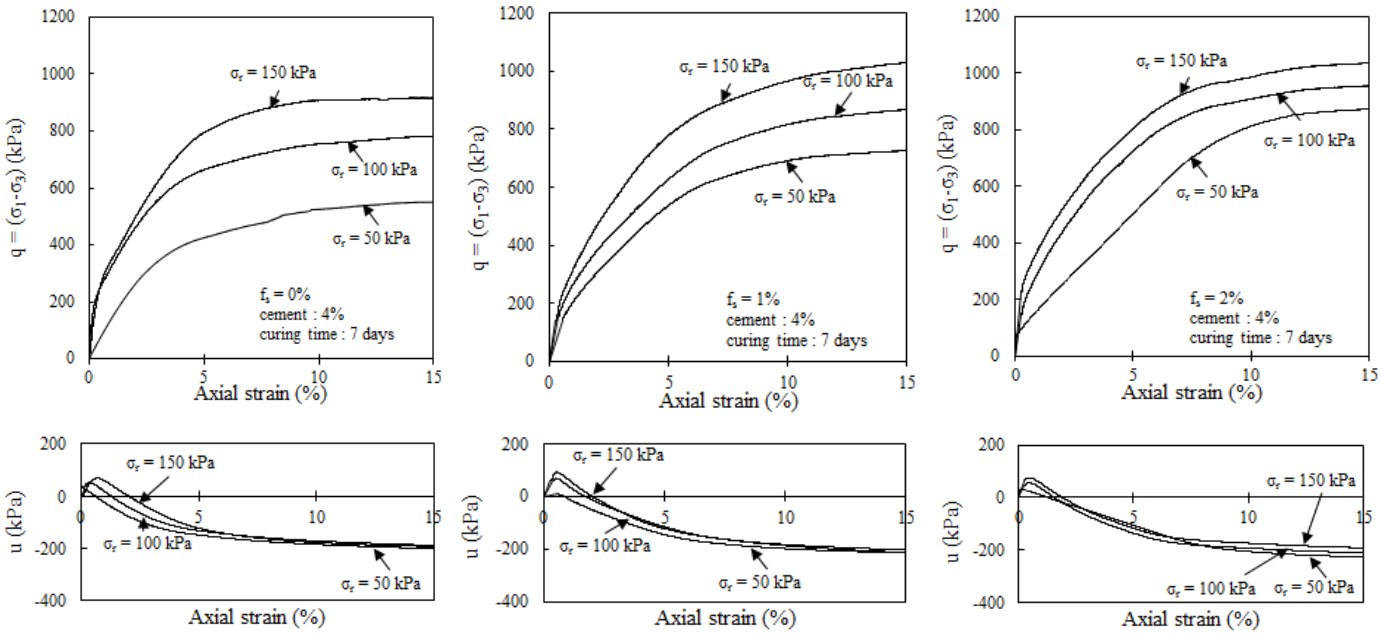


Fig. 5 Consolidated-undrained triaxial test results

Based on CU triaxial test results, addition of bamboo flakes in cemented soil mixture provides tendency of deviatoric stress behavior that proves the improvement of loose and poorly graded sand. Increasing of deviatoric stress and decreasing of excess pore water pressure in undrained condition during loading by addition of bamboo flakes content can be seen in Figure 5. In addition, increment of maximum deviatoric stress referenced by maximum deviatoric stress at 0% of bamboo flakes content and 7 days of curing time are shown in Figure 6 and Figure 7, respectively. Addition of bamboo flakes in 4% of cement content has significant influence to maximum deviatoric stress. Also, compared to 7 days curing time, the higher deviatoric stress after 14 days shows presence of time dependency in mixture. These properties are important in liquefaction resistance of soil. Wider variation and further study are necessary to obtain optimum mixture in order to utilization of natural material in ground improvement. Also, cyclic triaxial test is required as a further investigation regarding improvement of loose and poorly graded sand against liquefaction.

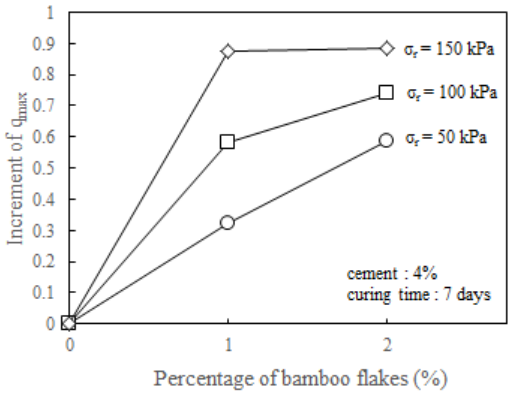


Fig. 6 Relationship between increment of maximum deviatoric stress and bamboo flakes content

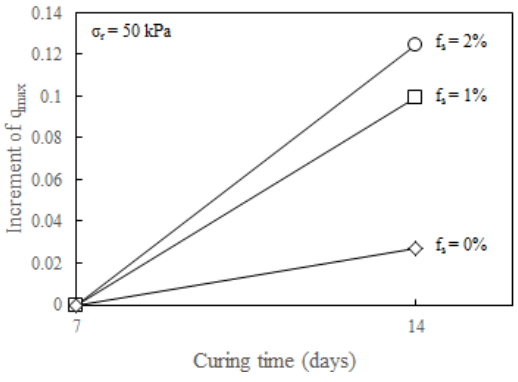


Fig. 7 Relationship between increment of maximum deviatoric stress and curing time

## 4. CONCLUSIONS

In this preliminary experiment, it can be concluded that the addition of bamboo flakes improves stress behavior of cemented sand. Thus, combination between bamboo flakes and cement can be utilized as a loose and poorly graded sand improvement. This result can be used as a foundation for wider investigation and further study under cyclic loading regarding the utilization of natural material in ground improvement to increase liquefaction resistance.

## REFERENCE

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