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EFFECT OF RICE STRAW LENGTH ON MECHANICAL PROPERTIES OF QUICK LIME AND RICE HUSK ASH STABILIZED SOIL

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ABSTRACT: Riverbank collapse often occurs along the Saigon River which flows through Ho Chi Minh City (HCMC). One of the influencing factors is the soft ground which is the riverbank composed of. Our research about the ground improvement method using quicklime, rice husks ash so far. Rice straw is newly added to the improved soil in this paper. The Rice straw is expected to improve the failure strain property that is to restrain brittle failure. These mixing materials can be obtained easily and cheaply in Vietnam. A series of unconfined compression tests are carried out to improve the mechanical properties of improved soil. Moreover pH tests are conducted to validate the chemical action of the improved soil and evaluate the effect of improved soil on surrounding environment.

Keywords: Ground improvement, Quick lime, Rice husk ash, Rice straw, pH test

INTRODUCTION

Major cities in South East Asia have been developed on river plain. Its soft ground often causes problems such as settlement. Particularly, Riverbank failure occurs along Saigon River, which flows in the center of Ho Chi Minh City. Fig.1 shows the riverbank failure along Saigon River. Saigon River is main water resource of HCMC, and has Saigon Port, which plays an important role of trading. One of the main factors of riverbank failure is assumed to be soft ground composing riverbank [1]. It causes serious damage to buildings and agricultural land in HCMC. Fig.2 shows that the building is leaned by the riverbank failure. Such damages can be seen on many points on Saigon riverbank. However, enough countermeasures to deal with the riverbank destruction have not been fully employed because of the restraint of budget and enormous length of target riverbank. Therefore it is necessary to propose effective and economical countermeasure for reinforcing riverbank in order to contribute further development of HCMC.

To solve this problem, our research group pays attention to improved soil with quicklime and rice husks ash to stabilize the Saingon Riverbank. These materials can be obtained easily and cheaply in Vietnam. The improved soil with quicklime and rice hulk ash has been proposed and its shear strength and durability to erosion by rainfall are estimated [2], but the relationships between material mix proportion and strength properties etc. are not fully investigated. Then, we have been investigated the mechanical properties of improved soil based on a series of unconfined compression tests [3]. As the results of this study, we could experimentally make clear that appropriate quantities of quick lime and rice hulk ash improve unconfined compression strength of the soft clay soil. However, some problems remains, that is, the failure strain of the improved soil is decreased as the curing days increase, and the brittle fracture occurs in some cases.

In this paper, to overcome the problem above, rice straw is more applied to improved soil in addition to quicklime and rice hulk ash. The rice straw is assumed that it improves failure strain and restrains the occurrence of brittle failure. A series of unconfined compression tests are carried out in order to investigate the strength characteristics of the improved soil. Moreover pH tests are performed for validation of the chemical action of the improved soil and considering the effect on surrounding environment.

Fig. 1. The riverbank failure along Saigon River

Fig. 2. The Building affected by riverbank failure

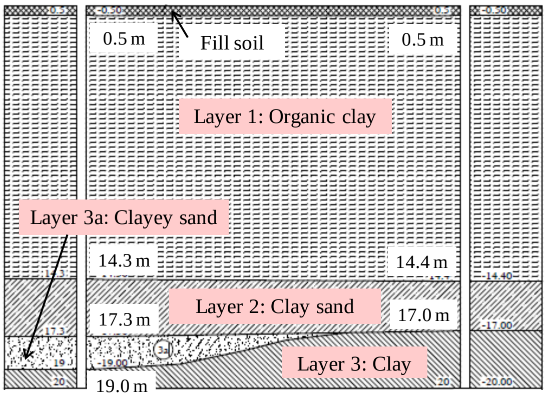


Fig. 3. The cross sectional profile of the riverbank

Fig. 4. Quicklime

Fig. 5. Rice hulk ash

Fig. 6. Rice straw

GEOTECHNICAL CHARACITERISTICS OF SAIGON RIVERBANK

Fig.3 show the cross sectional profile of the Saigon riverbank. SPT (Standard Penetration Test) s were carried out at two points at this observation site and record fill soil above either three or four compositionally distinct layers [1]. The surface of the ground is covered with a 0.5 m thickness of fill soil, which is carried from outside of the sample site. Layer 1 is organic clay with a SPT-N value of 1–2 and a thickness of 13.8–13.9 m. Layer 2 is clay sand with a SPT-N value of 12–13 and a thickness of2.6–3.0 m. Layer 3 is clay and has a SPT-N value of 7–11. Layer 3a, as shown in Fig.4, is clayey sand and has a SPT-N value of 8 and a maximum thickness of 2.7 m. In the presence, and considerable thickness of this very soft soil, is of particular importance for slope stability assessment of the Saigon riverbank. This research focuses on the soft clay soil on layer 1.

INPROVED SOIL USING THE QUICKLIME, RICE HUSKS ASH AND RICE STRAW

Quicklime, rice husks ash and rice straws are applied to stabilize the soft clay soil. The characteristics of the materials and hardening mechanism are explained in this chapter.

Characteristic of the materials

Quicklime (Fig.4) is used for soil stabilization in practical work for long time, and shows dehydration action and pozzolanic reaction. Rice hulk ash (Fig.5) includes silicon dioxide about 90 present of its weight, and this value is higher than that of fly ash, which used as pozzolanic material. Rice straw is dry stem of gramineous plant. The rice straw (Fig.6) is expected to increase the failure strain and to prevent the brittle fracture of improved material.

Hardening mechanism of the improved soil

The improved soil is hardened by dehydration action of quicklime, which is short term reaction, and pozzolanic reaction of silica, which is long term reaction.

Firstly, water in the soil vaporized by calcium oxide (CaO) which is the main component of quick lime. Then, the water content of the soil approaches optimum water content and compaction strength increases. In this process, water (H_2O) reacts with CaO and hydrated lime ($Ca(OH)_2$) is produced (Formula (1)) .

$$H_2O + CaO \rightarrow Ca(OH)_2 \quad (1)$$

Next, $Ca(OH)_2$ gently reacts with silicon dioxide (SiO_2) which is included in both rice hulk ash and soil and calcium silicate hydrate (nCaO・SiO$_2$・mH$_2$O) is produced (Formula (2)).

$$Ca(OH)_2 + [SiO_2] \rightarrow nCaO \cdot SiO_2 \cdot mH_2O \qquad (2)$$

where n and m are integer. Improved soil is hardened in this stage. This reaction is called “pozzolanic reaction”. Silicate hydrate (nCaO・SiO$_2$・mH$_2$O) is similar to cement and enhances durability and water-tightness and strength of the soil increases.

In addition, it is assumed that rice straws mixed into improved soil increase the failure strain of the material because tensile force and superficial cohesion of the soil are increased by fibers of the rice straw.

UNCONFINED COMPRESSION TEST OF IMPROVED SOIL

In order to validate the effect of the length of rice straws and understand mechanical properties of the improved soil, unconfined compression is carried out. In this study, unconfined compression strength, failure strain and modulus of deformation are estimated from the unconfined compression test to evaluate the mechanical properties. In this research, the target values of unconfined compression test are unconfined compression strength: 200 kN/m^2 and failure strain: 5 % [4][5].

Test method

First of all, specimens for the test are prepared. Fujinomori clay which is similar to soft ground material of the field is applied to the tests. Fujinomori clay and water are mixed and then the quicklime, rice husks ash and rice straw is mixed with soil in the mixer sufficiently. After that, improved soil is packed in a mold, which is 10 centimeter in height and 5 centimeter in diameter. Improved soil is packed dividing into 3 parts. The weight of packed soil in the mold is 300 g in each mold. Mix proportion of the materials for specimens is indicated in Table 1. 3 testing specimens are prepared for each testing condition.

Then, the specimens are cured. The specimens are cured in the air until 3 day, after that under the water, because when improved soil is practically used in the fields, most of them are assumed to be put under the water.

After curing, unconfined compression test is conducted. Test method in this study is based on the standard of The Japanese Geotechnical Society [JGS 0511 Method for unconfined compression test of soils]. During a test, the test specimen is compressed in a standard compression rate that a compression strain produces of 1% per a minute continually.

Table 1. Mix proportion of the materials
(The weight ratio to the weight of Fujinomori clay)

Fuzinomori clay	100 %
Water	About 50 %
Quicklime	5 %
Rice husks ash	10 %

Test condition

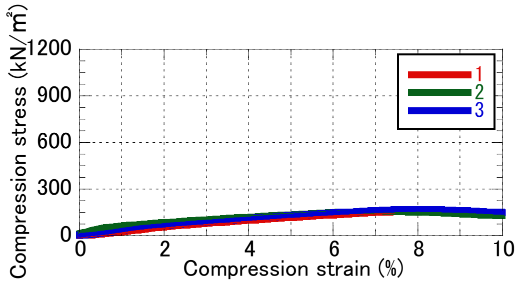
We used 3 types of wet rice straw to validate the effect of its length, that is, the length of the rice straw for the tests are 0.3-1.0 cm, 1.0-3.0 cm and 3.0-7.0 cm respectively. The curing periods of test specimens are 1, 3, 7, 14, 28 and 56 days. The specimens are cured in the air until 3 day, after that they are put under the water, because when improved soil is practically used in the fields, most of them are assumed to be put under the water.

Test results and discussion

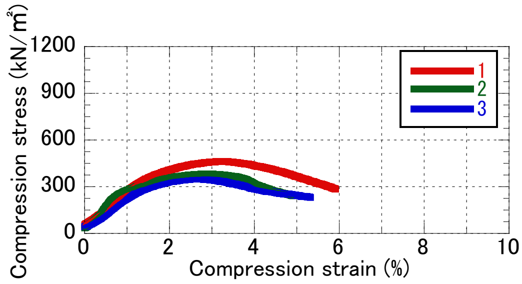
The stress-strain curves of the improved soil, using 0.3-1.0 cm of wet rice straw are shown in Fig. 7. Unconfined compression strength increases as the curing days. The stress-strain relationships are strongly influenced by the curing period. After curing period of 14 days, the value of failure strain is decreased. The Compression stress is dropped rapidly after yield. And, although the materials are mixed sufficiently, testing results vary more widely as the curing days. This is because the testing results highly depend on chemical reaction of the materials used in the improved soil. Validation of the strength of the improved soil should be estimated to expect deterioration of strength, which should be left for future works.

The stress-strain curves of the improved soil, using 3.0-7.0 cm of wet rice straw are shown in Fig. 8. Unconfined compression strength increases as the curing days as well as 0.3-1.0 cm rice straw specimens. The unconfined strength increases more early than that of 0.3-1.0 cm rice straw improved soil. The unconfined strength is dropped at the curing period 56 days. It is assumed that rice straws disturb the specimen, because the length of rice straws is large toward the size of specimen (5.0 cm ×10.0 cm). The tests with other size of specimens should be done to consider the effect of the length of rice straws.

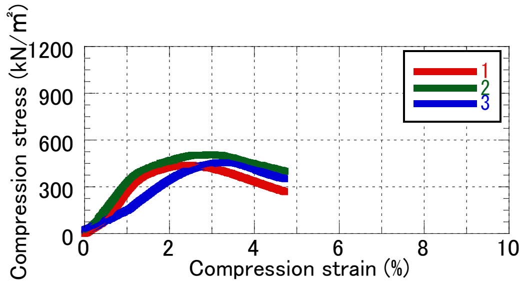
The relationships between unconfined compression strength and curing period are shown in Fig. 9. The results of the improved soil with no rice straw [3] are shown in the graph for the comparison. The unconfined strength exceeds the target value (200 kN/m^2) in all cases.



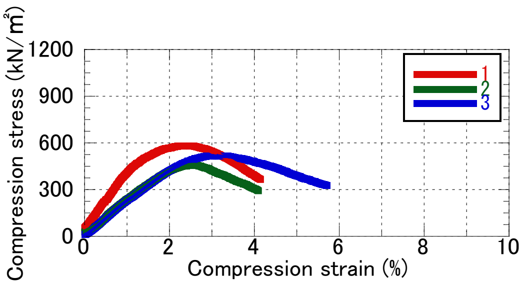
(a) Curing period 1 day



(b) Curing period 7 days

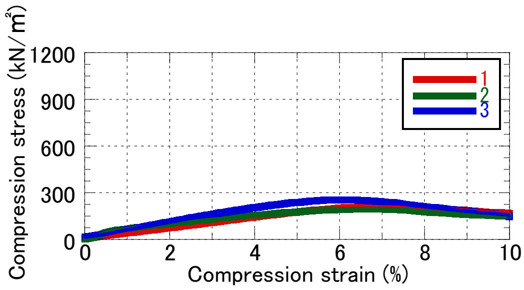


(c) Curing period 14 days

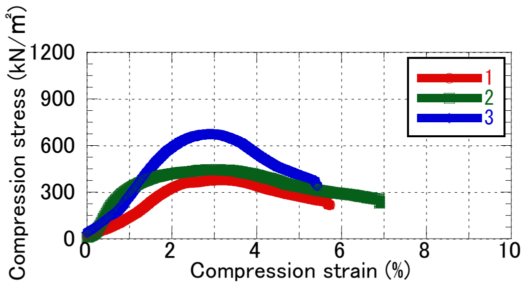


(d) Curing period 56 days

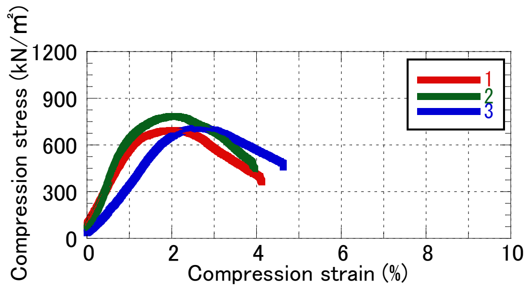
Fig. 7. The stress-strain curves of the improved soil with 0.3-1.0 cm of wet rice straw



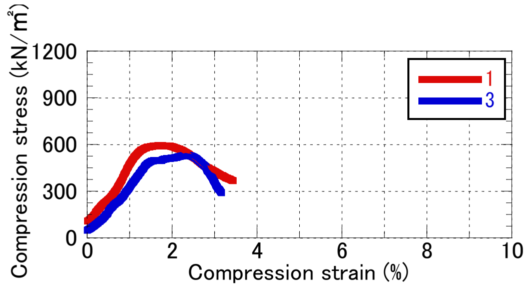
(a) Curing period 1 day



(b) Curing period 7 days



(c) Curing period 14 days



(d) Curing period 56 days

Fig. 8. The stress-strain curves of the improved soil with 3.0-7.0 cm of wet rice straw

In terms of the strength at curing period 56 days, 0.3 cm-1.0 cm rice straw is most suitable among the condition in this paper.

Fig.9 shows that the failure strains of the specimens mixing rice straw are higher than specimens without rice straw, so that we suppose that improved soil added rice straw can improve the failure strain property to some extent. Moreover among low failure strain, specimens corresponding to 0.3-1.0 cm rice straw are the most high failure strain comparing with other specimens although the failure strain does not reach the target value (5 %). This reason is assumed that rice straw is not long, but is much number because rice straws are broken up into small pieces, and they are mixed in entire soil. The improved soil with 0.3-1.0 cm rice straw is the best suited in the conditions which are validated in this time in terms of both the strength and the failure strain.

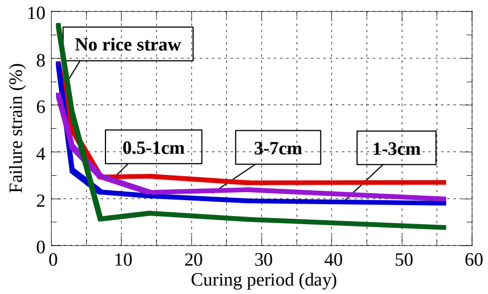


Fig. 9. The relationships between unconfined compression strength and curing period

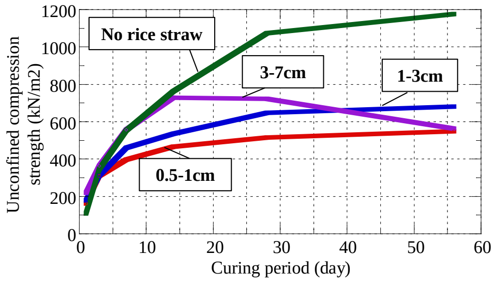
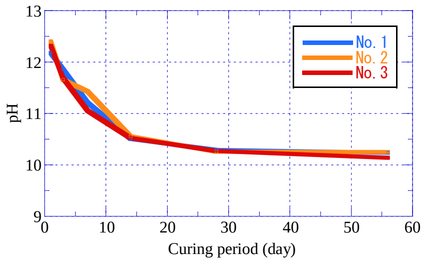
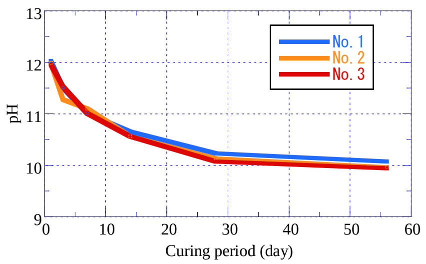


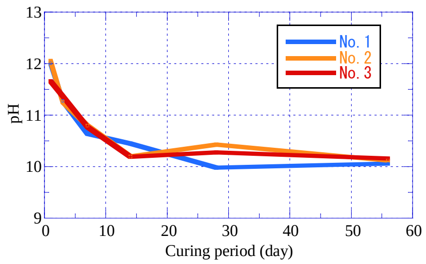
Fig. 10. The relationships between failure strain and curing period



(a) Rice straw 0.3 cm-1.0 cm



(b) Rice straw 1.0-3.0 cm



(c) Rice straw 3.0-7.0 cm

Fig. 11 The relationships between pH and curing period (Rice straw 0.3-1.0 cm)

UNCONFINED COMPRESSION TEST OF IMPROVED SOIL

pH tests are performed for validation of the soil and considering the effect on surrounding environment.

Test method

The method for PH test is based on the standard of the Japanese Geotechnical Society [JGS 211 Test method for pH of suspended soils]. A pH meter was calibrated at first by Neutral phosphate, Phthalate and Borate standard solution. Then, soil sample used for unconfined compression tests is mixed with water, and the suspension for the test is prepared. After the suspension is left for 30 minutes at least, pH is measured by pH meter (HORIBA D-51).

Test condition

The difference of test conditions is the same as the cases of unconfined compression tests. A specimen was used for unconfined compression test at first, and then the specimen was broken by hammer and next used for pH test as testing samples.

Test results and discussion

The results of pH tests corresponding to every curing period are shown in Fig. 11. The pH values distribute from about 12 to about 10 during 56 curing period at all condition. These shows that improved soil is changing reaction of alkali from neutrality. Moreover, the pH is decreasing largely not later than 7 days of curing period. It is due to dehydration action which is short term reaction. The amount of strong alkali which is in CaO reacts with water (H_2O), and weak alkali ($Ca(OH)_2$) is produced. As a result of this reaction, the pH is rapidly decreased until the period of 7 days. From the results of the pH tests, it is assumed that the dehydration action end by 7 days, and Pozzolanic reaction occurs after curing period of 7 days. Since there is not big difference between the testing conditions of rice straw length, the difference of rice straw length does not much effect on overall tendency.

CONCLUSION

This paper presented research results on the hardening mechanism of improved soil using materials of quicklime, rice husks ash and rice straw. The research was carried out based on the unconfined compression tests and the pH tests. In this paper, the improved soil with rice straw can improve failure strain property, but the failure strains are less than the target value. Among low failure strain, specimenwith 0.3-1.0 cm rice straw showed highest failure strain as compared to other specimens. This reason is assumed that rice straw is not long, but is much number and is mixed in entire soil. Unconfined compression strength is higher than the target value. The pH value of the soil are 12 at curing period 1 day and about 10 at curing period 56 day. pH test can make sure reaction of alkali from neutrality.

For future works, improved soil with larger amount of straw should be tested, because there is a possibility that failure strain by increasing the compound ratios of rice straw. Tests with other mix proportions should be conducted to clarify the suitable mix proportions. In addition, it is important to keep highly alkali to maintain the strength of the improved soil, so we should investigate validation of pH values of the improved soil.

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