# Static and dynamical properties of lime-stabilized Ariake clay with fly ash

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## INTROCDUION

Ariake clay is a very soft clay. It has been treated traditionally by lime and cement. Fly ash was proved to be an effective secondary additive in light of unconfined compressive strength of lime-treated Ariake clay with fly ash (LAF). In order to utilize the LAF mixtures as pavement materials, it is necessary to understand the properties under repeated loading condition. In the study, the dynamic properties of LAF mixtures were investigated by repeated load test. The influence of adding fly ash on the dynamic properties and unconfined compressive strength of the LAF mixtures is presented in the paper.

## MATERIALS AND EXPERIMENT METHOD

The physical properties of Ariake clay were listed in Table 1. Fly ash used in the study is coal fly ash. This is a normal kind of fly ash. The physical properties were listed in Table 2 and chemical properties listed in Table 3.

Mixtures were made with various contents of fly ash but a fixed lime content. The adequate content of lime used in the study is 10% expressed as a percentage by dry mass of the clay after referring to previous study. The contents of fly ash used in the study are 10, 20, 30%. LAF (1:8:1) stands for the mixture with 10% lime, 80% Ariake clay and 10% fly ash. In order to compare the properties of LAF mixtures with those of LA mixtures, LA mixtures with lime contents of 10 and 20% were discussed.

A soil mixer was used to mix all the materials uniformly. The LA mixtures were blended by mixing Ariake clay with lime for 10 minutes. Mixtures of the LAF were made by mixing LA with fly ash for another 10 minutes. All the samples were compacted by hand vibrating in three layers into cylindrical molds immediately. Samples are 5 cm in diameter and 10 cm in height, with being sealed completely in the molds, the samples were cured for 180 days in a curing room with temperature 20°C ± 3 and humidity 90% before the tests were carried out.

A fixed axial stress level, 0.45 MPa, is determined to apply for all the samples in order to make the results comparable. The axial load is in a sine shape. The repeating frequency is 1 Hz. That is to say one cycle of loading takes one second. The number of cycles applied on the samples equals the time spent in second. The axial load and the corresponding vertical deformation were recorded in each cycle.

## RESULTS AND DISCUSSIONS

### 1) Unconfined compression test

The results of unconfined compression test were listed in Table 4. It can be found that the addition of fly ash in the stabilized Ariake clay increased significantly the $q_u$. This was partly resulted from water reduction by increasing the content of fly ash, see also Table 4 and a series of reactions such as pozzolanic which will continue a long time to finish.

Table 1 Physical properties of Ariake clay

| | | |
|---|---|---|
| Natural water content (%) | | 153.5 |
| Density of soil particle (g/cm$^3$) | | 2.62 |
| Grade (%) | Gravel | 0.0 |
| | Sand | 21.0 |
| | Silt | 50.0 |
| | Clay | 29.0 |
| Liquid limit | (%) | 132.4 |
| Plasticity limit | (%) | 58.5 |
| Plastic index | | 73.9 |
| Ig. loss | (%) | 7.4 |
| Salinity | (%) | 1.4 |

Table 2 Physical properties of fly ash

| | | |
|---|---|---|
| Natural water content (%) | | 0.13 |
| Density of the particle (g/cm$^3$) | | 2.38 |
| Grade (%) | Gravel | 0.0 |
| | Sand | 11.1 |
| | Silt | 54.9 |
| | Clay | 34.0 |
| Liquid limit | (%) | NP |
| Plastic limit | (%) | NP |

Table 3 Chemical properties of fly ash

| | | |
|---|---|---|
| Ig. loss (%) | | 3.02 |
| Chemical compositions (%) | $Si_2O_3$ | 61.21 |
| | $Al_2O_3$ | 21.85 |
| | $Fe_2O_3$ | 5.15 |
| | $TiO_2$ | 1.06 |
| | CaO | 4.65 |
| | MgO | 1.32 |
| | $Na_2O$ | 0.70 |
| | $K_2O$ | 0.93 |

Table 4 Mechanical properties of LAF and LA mixtures

| Compositions | | $q_u$ (MPa) | w (%) | $\gamma$ (kg/cm$^3$) | $E_{50}$ (MPa) |
|---|---|---|---|---|---|
| LAF | 1:8:1 | 3.67 | 120 | 1.32 | 380 |
| | 1:7:2 | 4.62 | 98 | 1.46 | 500 |
| | 1:6:3 | 5.95 | 87 | 1.49 | 560 |
| LA | 1:9 | 2.24 | 131 | 1.34 | 200 |
| | 2:8 | 3.60 | 108 | 1.40 | 350 |

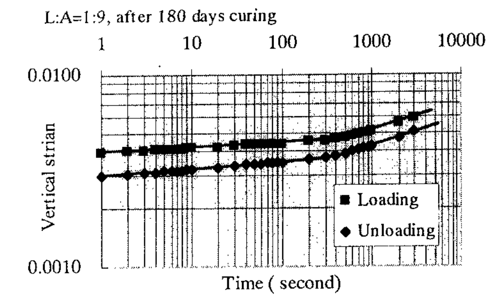


Fig.1 Vertical strain versus time of LA mixture

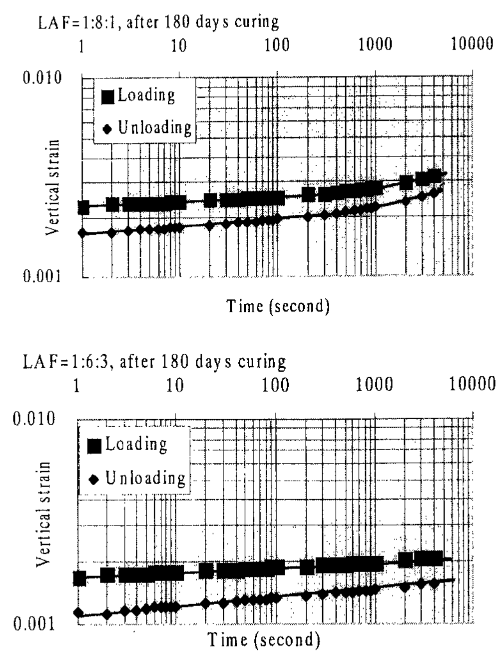


Fig.2 Vertical strain versus time of LAF mixture

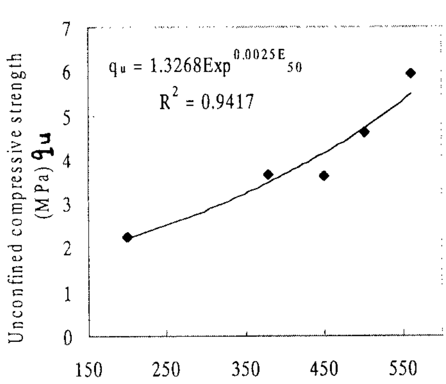


Fig.3 Unconfined compressive strength $q_u$ and $E_{50}$

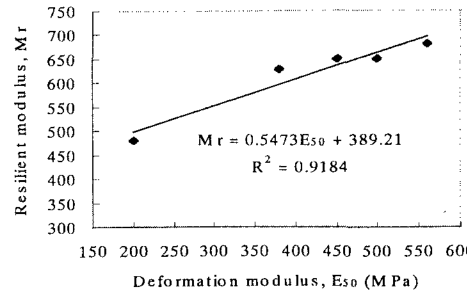


Fig.4 Relationship between *Mr* and $E_{50}$

**2) Repeated load test**

It can be found from Fig.1 that the vertical strain, both the total strain under loading and the plastic strain under unloading increased with the time within 4000 seconds linearly. In addition, the strain curves from the samples with 10% lime appeared "two-stage" increase phenomenon. In later stage, plastic strain developed faster than early stage when the time passed 300 seconds. The "two-stage" phenomenon indicated the mixtures produced more plastic strain in later stage.

Fig.2 presented the dynamic properties of LAF mixtures with various contents of fly ash. The influence of addition of fly ash thus can be easily obtained and compared with. It is obvious that an increase in content of fly ash can decrease both the total strain under loading and the plastic strain under unloading of the stabilized mixtures. And just as the results obtained from LA mixtures, the development of plastic strains after first loading and a number of repeated loading has been decreased with the addition of fly ash. The "two-stage" phenomenon of the development of stain with the time passed also disappeared gradually with the addition of fly ash.

Figs.3 and 4 presented the relationship between the unconfined compressive strength $q_u$ and the secant deformation modulus $E_{50}$, the relationship between the $E_{50}$ and *Mr,* resilient modulus from repeated test of the lime stabilized Ariake clay. It is realized that $E_{50}$ and *Mr* are related well by a line. The values of *Mr* are bigger than those of $E_{50}$, and are suitable for pavement base or subbase materials.

## CONCLUSIONS

Addition of fly ash increased significantly the unconfined compressive strength $q_u$ of the LAF mixture after long time curing

The total and plastic strains after first and 4000 numbers of loading of the LAF mixtures decreased with the content of fly ash indicating an improvement of rigidity of the mixtures.

A gradual disappearing of the "two-stage" phenomenon indicated the rigidity after repeated loading of the LAF mixtures also was improved by the addition of fly ash.

The values of *Mr* are bigger than those of $E_{50}$, and are suitable for pavement base or subbase materials.