# Improvement effect of FSP and lime on volume change for clay slurry observed by X-ray CT and XRF tests

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## 1. INTRODUCTION

Due the high plasticity and susceptibility for soft soils such as higher water content mud (clay slurry), enormous damage occurs on foundations. Development of improving methods for the soil is a challenging task as infrastructure engineers and researchers. In our research group, a fine shredded paper (FSP) has been investigated as an improving material for the higher water content mud[1)], and a hydrated lime is known as an additive for its early strength development on soft soil. The present study investigates the effect of these additives on volume change characteristics of the soft clay with high water content using X-ray florescence (XRF) and X ray CT scan tests.

## 2. EXPERIMENTAL SETUP

### 2.1 MATERIALS

The soil used for this study is Kasaoka clay manufactured in Okayama Prefecture. The clay powder is air dried before the experiment. The specific gravity of soil ($G_s$) was 2.72. The physical properties of this clay powder the 61% liquid limit (LL) and 22% plastic limit (PL), which gives the Plasticity index (PI) of 39%. One of additive materials used in this study is hydrated lime which composed of mainly CaO (63.4%). FSP is another additive that 97% ranges from 0.075mm to 2.0mm sieve size.

### 2.2 METHODS AND SAMPLE PREPARATION

Two types of specimens were prepared. The first type of the specimen is for X-ray CT scan. Beforehand, the unconfined compressive stress tests were conducted using the samples with mixing additives with different ratios and 2:1 considered due to its optimum values and resemblance to the recommended lime content [2)] for clay soil. The combined ratios of the mass for the additive to that for the dry clay include 0%, 10% and 20%. Each specimen was prepared by mixing airdried soil, FSP, and hydrated lime thoroughly with adding 1.5 times water content by the dry mass of the mix with proportion 0%,10% and 20% additive as shown in Table 1 (mix.no 1, 3 and 5). After mixing, the slurry poured and compacted in 50mm diameter and 100mm height transparent mold then allowed to cure for 14 days. The cured specimen was scanned as initial conditions (66.8%, 47.1% and 30.4% moisture content respectively for 0,10 and 20% additive), then after the oven dry specimen for 5 hours in 60°C was scanned. 5 hours was enough time to see the apparent difference in crack and shrinkage

Table 1: Mix proportions used for the study

| Mix No. | FSP (%) by dry weight of soil | Hydrated Lime (%) by dry weight of soil |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 3.33 | 1.67 |
| 3 | 6.67 | 3.33 |
| 4 | 10.0 | 5.0 |
| 5 | 13.33 | 6.67 |

patterns. The moisture content after drying was (40.3%, 39.2% and 27.8% respectively which shows 39.7%,16.8% and 8.7% decrement. This test continues to evaluate the effect of sample dimension and container with increasing drying time.

The second type of specimen is for the XRF test. The test mixing ratio is similar to X ray CT test and additives amount used for this test were 5%, 10%, 15% and 20% were its summarized in Table 1. The specimen is prepared by dry mixing the additives with optimum moisture content (22.6%) of water and statically compacted into equal three layers to the desired density. Then specimens were then allowed for curing for 3 days, 7days and 14 days in the controlled room temperature 25°C and 95% relative humidity. The cured sample was dried in oven at 110°C for 24 hours and crushed which pass 0.075mm sieve size.

## 3. RESULT AND DISCUSSIONS

### 3.1. XRF ANAYISIS OF STABILIZED SOIL

After mixing the clay with FSP, hydrated lime and water, the calcium ion ($Ca^{2+}$) dissociated from hydrated lime and migrate to the surface of clay particles, where it reacted with silica ($SiO_2$) and alumina ($Al_2O_3$) from the clay and new pozzolanic material calcium-silicate-hydrates (CSH) and calcium-aluminate-hydrates (CAH) formed as the following chemical reactions. Production of this pozzolanic substance creates the clay inter particle flocculation and agglomeration[3), 4)] that reinforced by FSP fibers where geotechnical properties changes. XRF analysis evaluates the elemental changes during chemical reaction of the stabilized soil at different curing period. Figures 1(a) and 1(b) show elemental composition at different amounts of additives and at different curing days, respectively. It is found from these figures that the increment of combined FSP and hydrated lime leads to reductions of the alumina and silica, where large calcium ion existence in the mixtures might contribute for these reductions.

Keywords: Clay, FSP, Hydrated lime, X-ray CT, XRF
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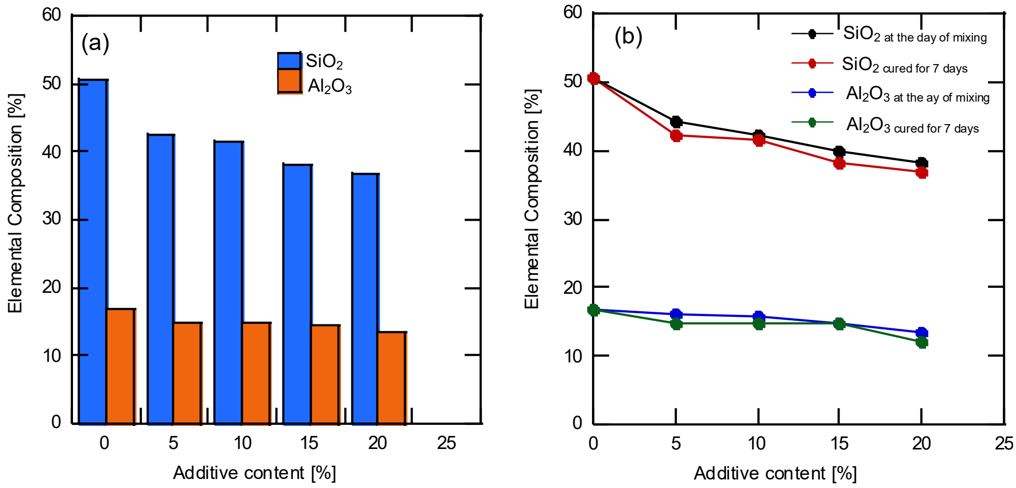


Figure 1: XRF test: a) during day of mix b) at different day of curing

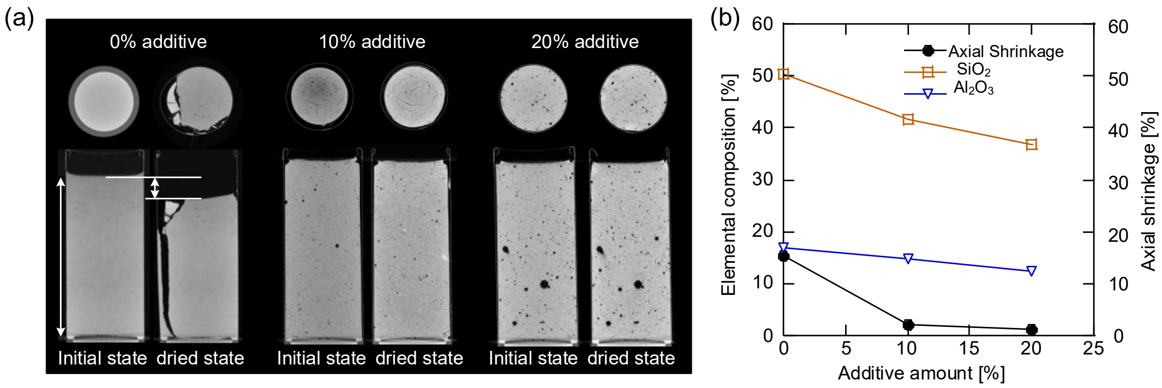


Figure 2: (a) X-ray CT image (b) Major Elemental composition and axial shrinkage reduction of treated soil

## 3.2. X-RAY CT SCAN TEST

The structural changes such as cracking, void formation and volumetric shrinkages are observed using X-ray CT. The CT images obtained at initial and drying states are shown in Fig. 2 (a). The specimen with no FSP shows large cracks inside the clay specimen after drying, namely, the cracks extend up to bottom section of the specimen. When the 10% FSP and hydrated lime used, those cracks reduced that only exist at the top of the sample, but small voids are visible across the sample. After drying at 60°C for 5 hours, cracks are seen up to 1.96 mm below the surface of the specimen with 10% additives, while those are seen up to 18.27 mm below for the specimen with 0% additives. Furthermore, no visible cracks are observed when 20% additive used. Larger size voids are observed with larger additives, and this reason will be studied more in the future.

The axial shrinkage percentage is calculated from the axial height difference at the center of each specimen between initial and dry state, as shown in Fig. 2 (a). Figure 2 (b) shows the variations in elemental composition and the axial shrinkage percentage. A reduction in the axial shrinkage percentage with an increase additive amount is consistent with that in elemental composition for $SiO_2$ and $Al_2O_3$, and the effect of the cementation by the silica in additive may be more significant on the shrinkage reduction due to the larger dissociation of the silica.

## CONCLUSIONS

When FSP and hydrated lime addition, silica and alumina involvement is highly visible which contribute to formation of pozzolanic materials. The treated soil using FSP and hydrated lime creates more stable soil mass when exposed to heating, which has shown with less cracks and shrinkage due to cementitious properties during the reaction.

## ACKNOWLEDGEMENT

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