LABORATORY TESTS ON LONG TERM PERFORMANCE OF TREATED SOILS

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1. INTRODUCTION AND OBJECTIVE OF STUDY

Ground improvement methods by adding cement or its derivatives to soft clayey or sandy soils have been highly developed and utilized in many projects in the world, to improve performance of earth structures and to mitigate liquefaction-induced damage. Many studies on the mechanical and physical properties of treated soils in comparison to untreated soils have been undertaken, for example, Koseki et al. (2008).

Kitazume et al. (2003), Mikami (2010) and many other researchers, have undertaken extensive laboratory studies on long term behavior of cement and lime treated soils observing that by contact with water, a leaching phenomenon occurs where Ca^{2+} dissolve and migrate to the outside. Similarly, Hayashi et al. (2003), undertook field observation on 1m diameter 8m long cement treated soil columns that were 17years old and observed that the unconfined compression strength increased within sound parts of the treated soil columns (core of soil column) and somewhat decreased on the deteriorated parts of the soil column(periphery of soil column). It is generally expected that the strength of the treated soils would increase linearly with log of time: see fig. 1. (Hayashi et al (2003)), but the data to confirm this phenomenon is limited.

In this study, treated soil samples that had previously been prepared by Mikami (2010) were utilized with the aim to observe the long term change in stiffness and strength of three types of laboratory prepared soil samples treated with cement, Quick Hardening Cement (QHC) and lime.

2. METHODOLOGY OF STUDY

Mikami (2010), prepared test samples by adding 1.9% (by wet weight of the soil) of the treatment material(cement, quick hardening cement and lime) to Inagi sand and made cylindrical specimens of a height of 100mm and diameter of 50mm, by tamping to a target compaction degree of 80%. Samples treated with lime were allowed to stand for 7 days and those treated with cement were subjected to 3-days of sealed water curing. Afterwards, all the samples were subjected to water immersion curing using tap water. The goal of the study by Mikami (2010), had been to investigate the applicability of construction generated soils as backfill materials of underground pipes so that the strength was high enough as a measure against liquefaction but at the same time maintain ease of re-excavatability for future replacement. Hence low amount of treatment materials were added and low unconfined compression strengths were obtained.

Due to the long period (8 years), the curing condition of the samples changed as is shown in Fig. 2 below. The lime treated samples were completely dry, QHC treated samples were half wet while the cement treated samples were still in the original curing condition (submerged in water).

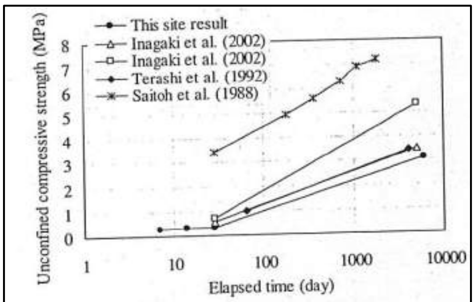

Fig.1: Strength increase with time (Source: Hayashi et. al, 2003)

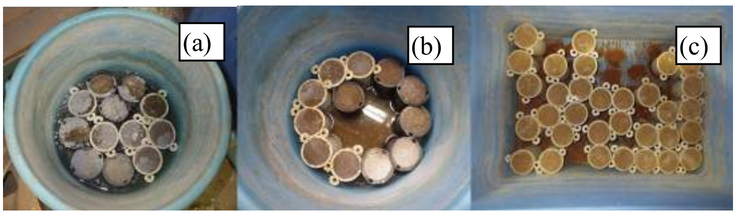

Fig.2: Test Sample condition: (a) Cement, (b) Quick Hardening cement, (c) Lime treated samples.

Local Deformation Transducer's (LDTs) were used to obtain local and small strain deformations and the External Displacement Transducer (EDT) was used to obtain the global deformation. The samples were carefully demolded and LDTs were fixed to the surface using gypsum before the unconfined compression tests were conducted. 6 cement treated samples, 3 QHC treated samples and 6 lime treated samples were tested. 3 of the lime treated samples had been re-soaked for 5 days so as to observe the effect of water content.

3. RESULTS AND DISCUSSIONS

3.1 Unconfined Compression Strength (UCS) and Elastic Modulus (E_{50})

As can be observed in fig. 3, apart from the cement treated samples where the UCS was almost constant, an increase in UCS values were observed in the lime and QHC treated samples.

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In the case of the re-soaked lime samples, a drop in the UCS was observed. Similar behavior is observed in the case of Elastic Modulus (E_{50}): See Fig. 4. The Elastic Modulus was obtained from strain calculated from EDT measurements. A dependency of strength to the water content can be seen in Fig. 4. As discussed by Hayashi et al. (2003), the strength of treated samples is expected to increase over time, as shown in Fig. 1 based on data obtained by other researchers. However, in this research as is seen in Fig. 5, the UC strength varies with the water content. Due to the low amount of the treatment material added (1.9% of wet weight) the soil structure could be over-riding the influence of the treatment material on the strength and stiffness of the treated soils, therefore the dependency on water content. For samples submerged in water (cement treated), the absence of increase in strength over time can be attributed to leaching of Ca^{2+} (bonding agent) by dissolving into water or erosion by water movement. In Fig. 2(a) above, a white film on the submerged samples can be seen which could be the eroded particles of the bonding material (i.e., cement in this case).

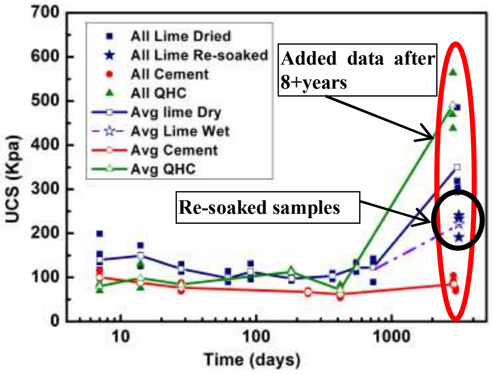

Fig. 3 UCS vs Elapsed Time.

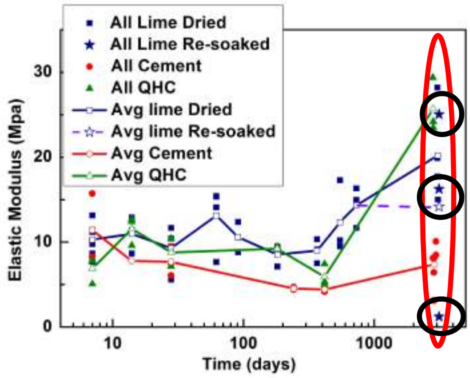

Fig. 4 Elastic Modulus vs Elapsed Time. (Ref to Fig. 3)

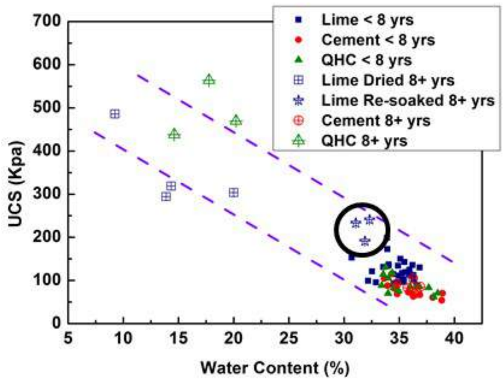

Fig. 5 UCS vs Water Content

3.2 Small Strain Stiffness

Fig. 6 below is a plot of secant Elastic Modulus at strains -0.001%, 0.01% and 0.1% and E_{50} calculated using LDT strain measurements. Previously, for test on samples at a younger age, LDTs were not utilized; hence comparison on effect of aging could not be done. A slight decrease in the stiffness is observed for all kind of samples as strain increases. In the case of the Lime samples, small strain stiffness of dried and re-soaked conditions were equivalent, despite the average of UCS values in re-soaked samples being smaller than those of dried samples. This would imply that the effect of drying and wetting due to the change of water level would not be significant in small strain stiffness, when the lime treated soil is used as back-fill for underground pipes.

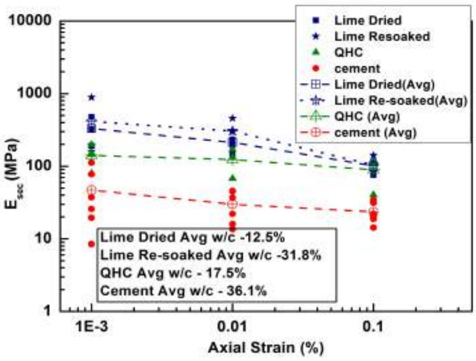

Fig. 6 E_{sec} vs Axial Strain

4. CONCLUSION

Both the strength and the stiffness are observed to increase with age for QHC and lime treated samples. But the strength of cement treated samples is observed to almost be constant. The increase in strength is observed to be dependent on water content with a higher strength and stiffness observed for lower water content. This can be attributed to effect of leaching of Ca^{2+}. Preliminary results of small strain stiffness indicate no effect on stiffness with change in water content in the case of lime treated samples.

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