STUDY ON THE PROGRESSION OF DETERIORATION IN CEMENT TREATED SOIL

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1. INTRODUCTION

Cement stabilization is widely used for improving engineering properties of the problematic construction generated soils. Miyashita et al. (2018) conducted a series of unconfined compression tests on cement treated construction generated soils under two different curing conditions. A reduction in unconfined compressive strength was observed on the cement treated soils cured under soaked condition. Ota et al. (2018) suggested that leaching of calcium and sulfate ions due to soaking may have influenced on the strength. However, the progressions of deterioration in the cement treated soil specimens are not well understood yet. In this study, the effect of soaking on the deterioration depth and the localized strengths were studied by conducting needle penetration tests.

2. MATERIAL AND EXPERIMENTAL PROCEDURE

An actual construction generated soil called Miho sand was used in this study. Physical and mechanical properties of natural Miho sand is shown in Table 1. The amount of cement was set to 3.5 % by dry weight of natural soil. The water content of the Miho sand was set to 31 %. Cement and Miho sand were mixed uniformly by a soil mixer around 5 minutes. The specimens 50 mm in diameter and 100 mm in height were prepared by applying static compaction. The degree of compaction of each sample was set to 90 % of Miho sand's maximum dry density.

Table 1. Physical and mechanical properties of Miho sand

Soil classification (JGS 0051)	SF *(sandy soil)*
Soil particle density, ρ_s (g/cm^3)	2.693
Optimum water content, w_{opt} (%)	21.6
Maximum dry density, ρ_{dmax} (g/cm^3)	1.624
Gravel (%)	0.8
Sand (%)	52.9
Silt (%)	21.6
Clay (%)	24.7

All specimens were cured under two different curing conditions and tested in three different conditions as schematically shown in Fig. 1. In case 1 which is called sealed-saturated hereafter, specimens were wrapped with plastic wrapping and cured under constant temperature. They were saturated under pure water by applying vacuum pressure 1 day priority to the corresponding curing date. In case 2 (a), second sets of specimens were soaked under pure water. To evaluate the effect of acidity of soaking water on the deterioration, the third set of specimens were cured under artificially made acidic water in case 2 (b) which is called hereafter as soaked-acid. The pH value of the acidic water was set to 4.5. For further details of the soaking water and the soaking method, see the previous paper (Miyashita et al., 2018).

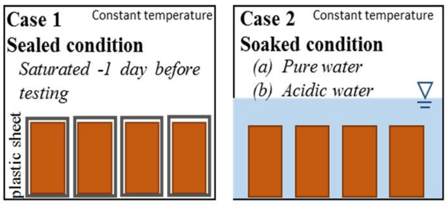

Fig. 1 Curing conditions

In order to investigate the progression of deterioration, needle penetration tests (JGS 3431) were conducted on all three sets of specimens after 7, 28 and 168 days from their preperation. The needle size was 0.84 mm in diameter and 30 mm in length. The needle was penetrated vertically from the top of the specimen and horizontally from three directions at the middle height of the specimen with a penetration speed of 0.18 mm/s for each specimen. Resistance force with penetration depth was recorded.

3. TEST RESULTS

The relationships between needle penetration resistance and the penetration length in vertical direction under each curing conditions were summarized according to the curing period as shown in Fig. 2. In all the cases, the needle penetration resistance becomes large when increasing the curing period. In the cases of soaked-pure and acid, needle penetration resistances were lower than sealed-saturated condition at the curing periods of 28 and 168 days. The largest difference was observed in 168 days curing while the needle penetration resistance at the deeper range reduces remarkably compared to the sealed-saturated condition. Similar observations were obtained in all three horizontal curves also. These results proved that deterioration of cement treated soil occurred due to soaking and it depends on the soaking period.

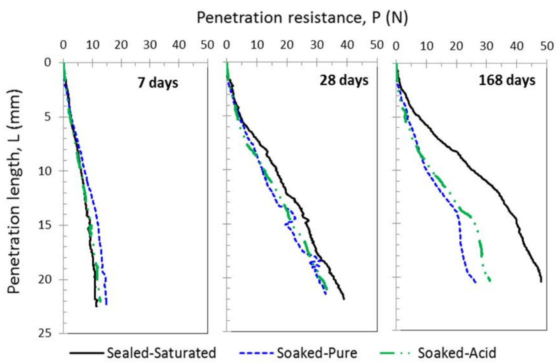

Fig. 2 Needle penetration test results in vertical direction

The deteriorated depths of the soaked specimens were evaluated by following the method introduced by Hara et al. (2014) (Fig. 6) and summarized as shown in Fig. 3 (a) and (b) for vertical and horizontal directions, respectively. The variations of the three data obtained in horizontal directions at particular curing period were also shown in Fig. 3(b). In

Keywords: Cement treated soil, deterioration, soaked curing, needle penetration test, strength ratio
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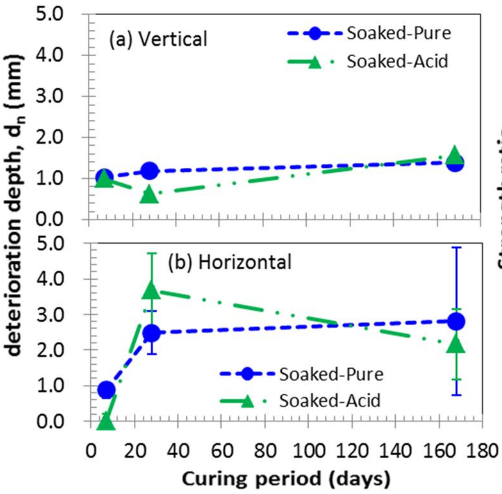

Fig. 3 Relationships between curing period and deterioration depth

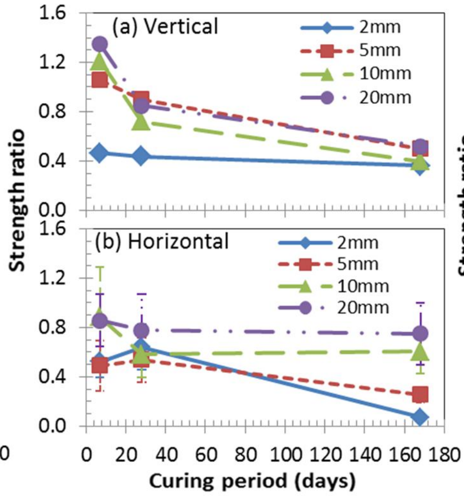

Fig. 4 Relationships between curing period and strength ratio in soaked-pure condition

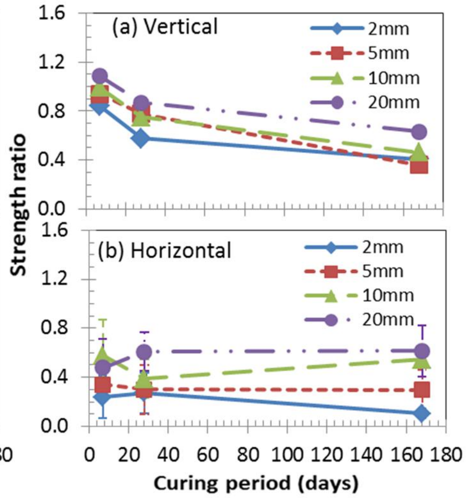

Fig. 5 Relationships between curing period and strength ratio in soaked-acid condition

here the deterioration depths were evaluated relative to sealed-saturated condition. Both vertical and horizontal deterioration depths have been increased when increasing the curing period except for the soaked-acid case in horizontal direction. The vertical deterioration depths were always lower than horizontal depths in both soaking cases at the curing period of 28 and 168 days. This might be due to the differences of densities on top and the middle height of the specimens resulted by the used specimen preparation method.

To understand the effect of deterioration on the localized strength, the needle penetration resistance values obtained at depths of 2, 5, 10 and 20 mm from the surface of the soaked specimens were analyzed. The deterioration was expressed by the strength ratio, which is defined as the ratio of the strength at each depth of soaked specimens to the strength of sealed saturated specimen at corresponding depths (Ngoc et al., 2016). The obtained results are shown in Fig. 4 and Fig.5 for soaked-pure and soaked-acid cases, respectively. Initially, the strength ratios of the vertical direction at depths of 5, 10 and 20 mm were around 1 and reduced with the increase in curing period in both pure and acid soaking. On the other hand, strength ratios of the horizontal direction were always less than 1 irrespectively to the depths until curing period of 28 days and only the strength ratios related to the depths of 2 and 5 mm shown a trend against the depth at the curing period of 168 days. The effect of acidity on the deterioration was not still distinguished until curing period of 168 days.

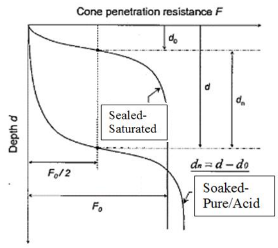

Fig. 6 Determination method of the deterioration depth (Hara et al. 2014)

An effort was taken to find a relationship between the evaluated deterioration depth and the strength ratios obtained at particular depths. It was difficult to come to a conclusion possibly due to the difference in local structures of soil particles composed of sand particles. Electron probe micro analyzer (EPMA) will be used to obtain ions distributions of the cross section of the specimen as shown in Fig. 7 and will try to find a relationship between the amount of leached Ca/other ions and the local strength at deteriorated depths. Additionally, under same curing conditions, more specimens with larger curing periods will be tested and analyzed.

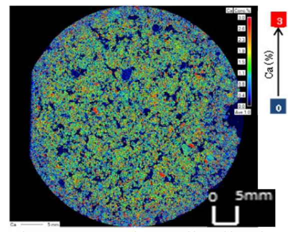

Fig. 7 Ca ion distribution soaked-acid 28days curing

4. SUMMARY

In this study, the progression of deterioration in cement treated surplus soils under two soaking conditions "pure" and "acid", was investigated by conducting needle penetration test in vertically and three directions in horizontally. Horizontal deterioration depths were the largest in both soaked conditions. In addition to that, the strength ratios in the vertical and horizontal directions became lower proving progression of deterioration with the curing period. The effect of acidity on the deterioration was not still distinguished until curing period of 168 days.

ACKNOWLEDGEMENT

The authors would like to thank to the members of the collaborative research which have been conducted by the Public Works Research Institute and 12 industry and academia.

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