EFFECT OF FREEZING AND THAWING ON THE DURABILITY OF AGGREGATED SOIL AND CEMENT TREATED SOIL

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1. INTRODUCTION

Cement-based stabilization is widely used for improving the engineering properties of problematic soils. Aggregated soil method is one of the cement-based stabilization methods which is recently developed to increase the permeability characteristic and water retention capacity of natural soil (Ue et al, 2005). The durability of the aggregated soil which is subjected to freezing and thawing is not yet properly understood to be used as a major construction material in cold regions. In this study, the behavior of unconfined compressive strength (UCS) of aggregated soil and cement treated soil which are subjected to 12 freezing thawing cycles were studied and compared with the UCS of unexposed soil samples. The intension was to distinguish the behavior of aggregated soil compared to cement treated soil because higher amount of water is retained in aggregated soil (Sugi et al, 2011).

2. EXPERIMENTAL PROCEDURE

2.1 Test Material

As shown in Figure 1, Masado sand samples which were taken from Fukuoka prefecture was used to prepare cement treated soil and aggregated soil samples. The particle size distribution of the Masado sand is shown in Figure 2 and categorized it as poorly graded non - plastic soil with e_{min}=0.380, e_{max}=1.224,w_{opt}=12.5% and $\rho_{dmax=}$1.825g/m^3. A liquid polymeric compound called crumb agent was used for the preparation of the aggregated soil. The used cement type was hexavalent chromium soluble cement.

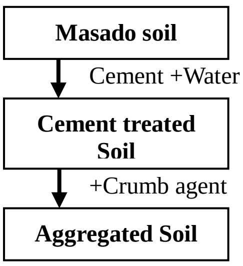

Figure 1: Components of soils

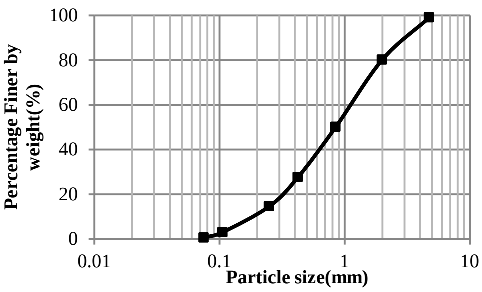

Figure 2:Particle size distribution

Table 1 Mixing proportions

Mix designation		**Cement** (by volume)	**Crumb agent** (by volume)	**Water** (by weight)
Aggregated soil		80kg/m^3	1.5l/m^3	16.5%
		20kg/m^3	1.5l/m^3	14.5%
Cement treated soil		80kg/m^3	-	16.5%
		20kg/m^3	-	14.5%

2.2 Testing Method

A total of four mix designs were used in this research. Aggregated soil and cement treated soil were prepared as two sets with different mixing proportions as shown in Table 1. Standard proctor compaction tests were conducted only for aggregated soils and obtained optimum water contents were used to prepare cement treated samples also. For testing UCS, two soil samples for each type of soils were prepared. They were compacted to larger than 90% of their maximum dry density in cylindrical PVC molds (ϕ5cm×10cm) by applying different compaction energy in accordance with the cement content.

The test was conducted according to the ASTM –D560 (2003) (withdrawn in 2012) standard test methods for freezing and thawing compacted soil -cement mixtures. As described in Figure 3, samples were cured for 7 days and exposed to 12 cycles of freezing at -23^{o}C for 24 hours and subsequent thawing at 21^{o}C for 23 hours. Specimens were placed on 6 mm thick water saturated felt pads and the water saturated felt pads were placed between the specimens and the carriers to allow absorption of water during the test (i.e. open system conditions). UCS test for exposed samples were conducted on day 33. It is known that the hydration of cement occurs at a very slow rate at sub-zero temperatures (Jamshidi et al, 2014). By assuming a minimal curing in each freezing period the unexposed (control) samples were cured only for 19 days. Those were unmolded on day 20 and kept in a vacuumed water bath for saturation. The UCS tests for unexposed control specimens were conducted on day 21. In the ASTM- D560 (2003), it has instructed to do a brushing test for the samples to measure the durability of the material. (Shihata et al, 2001) had found that the durability prediction by brushing operation can be omitted from the durability test and the results of UCS test can be used to predict the durability of soil-cement mixtures. So in this study brushing test was not conducted.

Keywords: Aggregated soil, Cement treated soil, Freezing-thawing, Unconfined compressive strength
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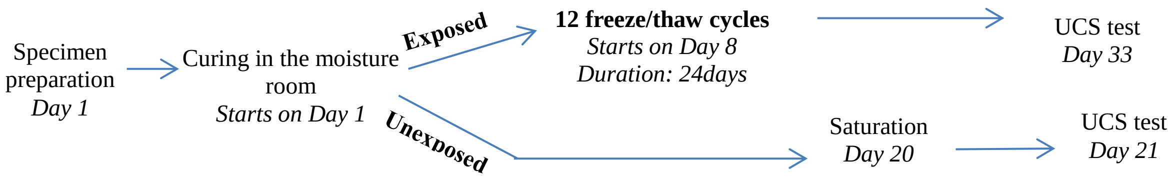

Figure 3: Summary of testing procedure

3 TEST RESULTS

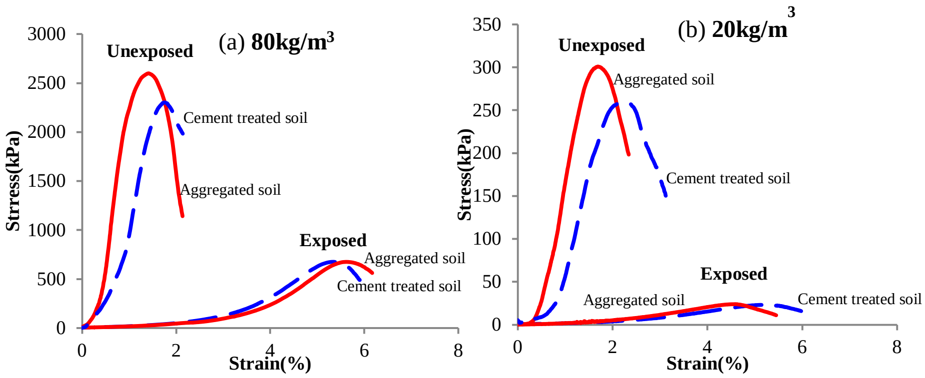

Figure 4: Stress strain behavior of f/t exposed and unexposed samples for the cement contents of (a) 80kg/m^3 (b) 20kg/m^3

Table 2: Summary of reduction of q_{max} and E_{50}

Cement content (kg/m^3)	Soil type	Reduction (%)	
		q_{max}(kPa)	E_{50}(MPa)
80	Aggregated soil	72	92
	Cement treated soil	72	87
20	Aggregated soil	92	98
	Cement treated soil	91	97

3 TEST RESULTS

Stress strain behavior of 12cycles f/t exposed and unexposed samples of the aggregate soil and cement treated soil are presented in Figure 4 in accordance with the cement contents. It can be observed that the maximum strength (q_{max}) of the both materials has been reduced due to the freeze and thaw exposure. The reason for this reduction in UCS is that when soil freezes ice lenses are created in the pores expanding water, inducing a more dispersed packing and segregation of the soil particles.

Variation of q_{max} and deformation modulus, E_{50} of cement treated soil and aggregated soil was evaluated and the reduction of each property is tabulated in Table 2 .It can be observed that the reduction of q_{max} for both soil types shown same value in each cement contents while the reduction of E_{50} was a little bit higher in aggregated soil. One of the objectives of this test was to compare the behavior of aggregated soil and the cement treated soil in f/t exposure, and it was expected more deterioration in the aggregated soil than cement treated soil due to its ability to retain more water. This behavior might be due to the water retentivity of the aggregated soil is dependable on the cement content (Sugi et al, 2011) . The cement contents 80kg/m^{3}and 20kg/m^3 might not be enough to predominant water retentivity of the aggregated soil than cement treated soil.

4 CONCLUSIONS

An effort was made to understand the effect of the freezing and thawing on the durability of aggregated soil and cement treated soil with cement contents of 80kg/m^3 and 20kg/m^3. A reduction of 72% and 92% in UCS is observed in respectively. As a conclusion the durability of both these cement contents are not enough to withstand extreme weather conditions of freezing and thawing and suitable cement content should be found prior to the application in major construction. More studies are required to understand the relationship between soil freezing and soil water retention characteristics of aggregated soil.

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REFERENCES

Jamshidi, Reza Jolous, Craig B. Lake, and Christopher L. Barnes. :Examining Freeze/thaw Cycling and Its Impact on the Hydraulic Performance of Cement-Treated Silty Sand. Journal of Cold Regions Engineering 29 (3), 2014, pp.4014014.

Shihata, Sabry A., and Zaki A. Baghdadi. : Long-Term Strength and Durability of Soil Cement. Journal of Materials in Civil Engineering 13 (3), 2001, pp.161–165.

Sugi Toshio, Fang Fang.: Study on hydraulic properties of aggregated soil In 46th Geotechnical research workshop(Kobe),2011,pp. 1025–26.

Ue,S., Fujiwara,H.,Kuwajima,K. and Takebayashi,T.: Ground improvement method using grain-sized agent and cement type solidifier(Japanese),Proccedings of symposium on cement treated soil,JGS,2005,pp.327-330.