Shear strength of remains soils and artificially cemented soils

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1. Introduction

Researches on soils sampled from some ancient remains, Yoshinogari Fun-kyu tomb in Japan and Tu-dun tomb in China, have been carried out by Onitsuka[1] (2002), and laboratory tests results show that remains soils, compared with remolded soils, exhibit bigger consolidation yield stress and bigger shear strength. Consequently, Onitsuka[1] (2002) attributed the strength increase in remains soils to occurrence of aging effects. Bjerrrum[2] (1967) proposed that cementing agents occurring in soils will improve soils strength by the way of producing a strengthening of the links of the soils structure, but the soil particle itself not otherwise being affected. Since adding cementing agents into soils could improve soil strength, it is important to compare the difference of strength increase in artificially cemented soils and remains soils.

2. Materials and tests program

In this research, one platy clay mineral, Kaolin (ρ_s=2.80g/cm^3, w_L=53.2%, w_P=23.3%, Silt=24.0%, Clay=76.0%), was used. Harvard compaction test result is shown in Figure 1. Based on the compaction curve, water content 30% was chosen, then three sets of specimens were prepared: 1. Kaolin moistened to 30%. 2. Kaolin moistened to 30%, then mixed with 3% Portland cement (Corresponding to total mass). 3. Kaolin moistened to 30%, then mixed with 5% Portland cement (Corresponding to total mass too). After mixing, soil was poured into a mold, then static compacted to specimens, 6 cm in diameter and 2 cm in height. After extruded from the mold, specimens were covered with saran wrap, then cured for 1day, 7days and 28days. Oedometer and direct shear tests were carried out on cured specimens.

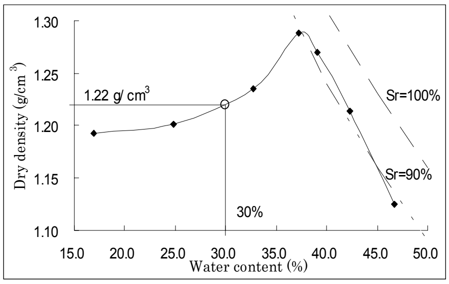

Figure 1 Harvard compaction curve

3. Results and discussion

Almost all investigated remains soils were unsaturated soils. Due to the limitation of equipments in laboratory, suction mobilization in the tests process could not be measured and recorded. Therefore soil stress states in tests are expressed by the pattern of total stress[1]. Here we assume that both of cemented soils and remains soils fulfill Coulomb shear stress failure criterion by the pattern of total stress.

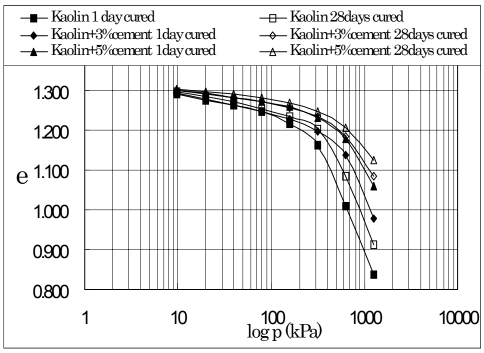

Figure 2 Oedometer test results

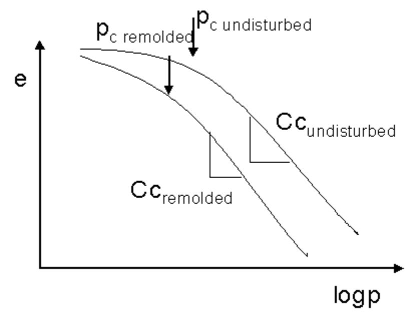

Figure 3 Definition of CDR_{Pc} and CDR_{Cc}

Figure 2 shows results of oedometer test on cured specimens. It is clearly shown that after 28days curing, all sets of specimen consolidation yield strength increased, and the more cementing agents were added into specimens, the more specimens consolidation yield stress increased. Meanwhile, adding cementing agents increased the stiffness in specimens. The results indicate that adding cementing agents into soils reinforces inter-particle contacts and results in occurrence of cementation bonds.

Since cementation effects could increase soils consolidation yield stress p_c and decrease coefficient

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of consolidation C_c in oedometer tests. Therefore cementation degree ratio for consolidation yield stress, $CDR_{pc} = p_{c\ undistirbed}/p_{c\ remolded}$ and coefficient of consolidation $CDR_{Cc} = Cc_{undisturbed}/Cc_{remolded}$, visualized in Figure 3, are defined to describe the soils strength varieties due to cementation effects. Figure 4 shows ratio of $CDRp_c$ to $1/CDR_{Cc}$. Figure 5 shows $CDRp_c$ for cemented Kaolin in this research and some remains soils. In Figure 6, 7, cohesion mobilization, $c_{undisturbed}/c_{remoldeded}$, and internal frictional angle mobilization, $\tan\phi_{undisturbed}/\tan\phi_{remolded}$, due to cementation effects are plotted with corresponding values of $CDRp_c$. In these figures, M means Mojianshan, Y means Yoshinogari Fun-kyu tomb and T means Tu-dun tomb.

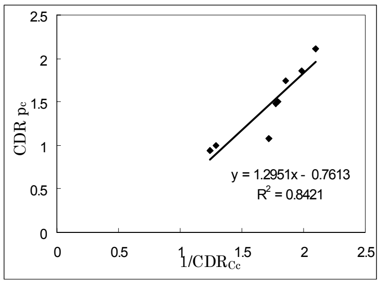

Figure 4 $CDRp_c$ versus $1/CDR_{Cc}$

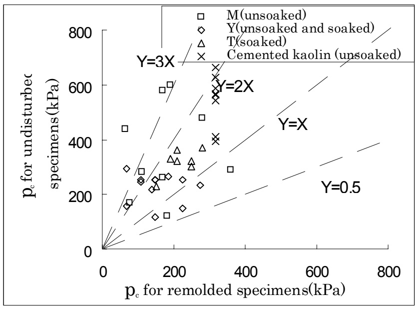

Fig.5. $CDRp_c$ for remains soils and cemented Kaolin

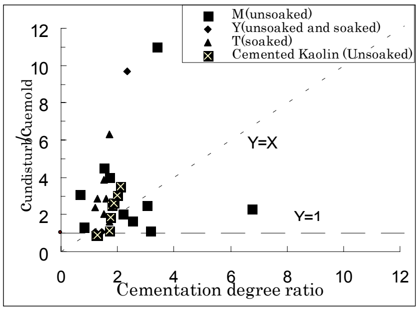

Fig.6. Cohesion mobilization versus $CDRp_c$

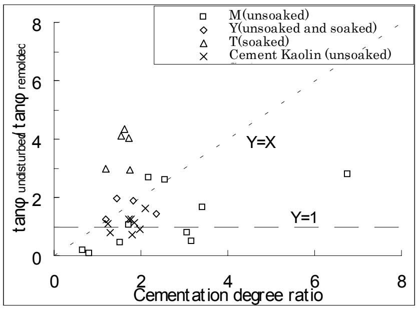

Fig.7. Internal frictional angle mobilization versus $CDRp_c$

Next the shear strength components, c and ϕ, will be reviewed. In this research, direct shear tests were carried out under five normal stresses, 58.8, 78.4, 98.0, 117.6 and 137.2kPa, therefore shear strength components can be traced with different displacement, if regardless influence of dilitancy. Figure 8 shows shear strength components mobilization with displacement increasing. Figure 9 shows shear strength component mobilization with displacements in soil sampled from Tu-dun tomb [1]. It is clearly shown that remains soil from Tu-dun tomb [1] has an almost similar c to the remolded specimens. It does not appear to have gained cohesive bond strength. But the ϕ component mobilization shown in Figure 9 increased to twice. These results suggest that the increased stiffness and strength in one remains soil, Tu-dun tomb [1], have resulted entirely from an increased friction capacity. In the case of cemented Kaolin, Figure 8 shows increase in stiffness and strength in cemented Kaolin are entirely due to increase in cohesion capacity.

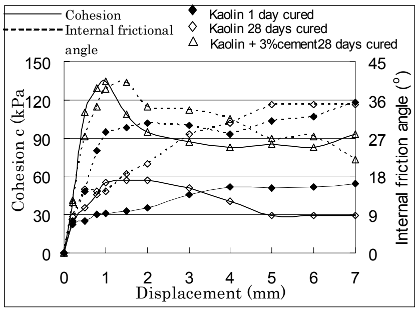

Fig.8. c and ϕ plotted as a function of displacement

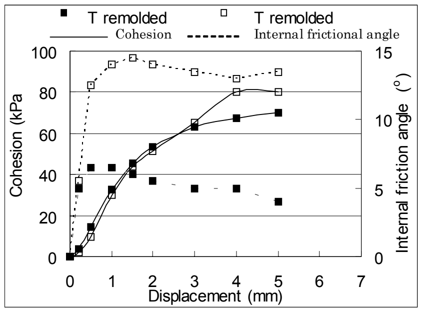

Fig.9. c and ϕ in one remains soil

4. Conclusion

1. From oedometer tests results, it is shown that adding cementing agents into compacted Kaolin increased its stiffness and strength. 2. Using a concept of $CDRp_c$ to analyze strength varieties in cemented Kaolin and remains soils shows that strength increase in remains is similar to strength increase in cemented Kaolin. 3. By plotting displacement dependent cohesions and internal frictional angles, it is clearly shown that stiffness and shear strength increase in cemented Kaolin is due to occurrence of cohesive bonds, which will fail within a range of small displacement, conversely, in the case of Tu-dun tomb, increase in friction capacity leads to its stiffness and shear strength increase.

Reference: (1) Onitsuka, K. et al.(2003): "Geotechnical characteristics and construction methods of Yoshinogari Fun-kyu tomb in Japan and Tu-dun tombs in China," Journal of JSCE, III-63，No.736. (2) Bjerrum.L (1967): "Engineering geology of Norwegian normally-consolidated marine clays as related to settlements of building," Geotechnique 17: 81-118.