SHEAR STRENGTH EVALUATION FOR CEMENT-MIXED SOIL CONSIDERING THE MIXING QUALITY

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1. INTRODUCTION

Cement-mixing technique in ground improvement has been widely used for stabilizing soft soils in applications ranging from the strengthening of weak soils foundation to the mitigation of liquefaction. Although there have been significant advances in the equipment and methods used for cement-mixing, there remains a high degree of spatial variability in the physical and mechanical properties of the treated ground (i.e., soil unit weight, shear strength, etc.). This spatial variability introduces uncertainties in the design of foundations on cement-mixed ground.

The purpose of this study is to make cement-mixed soil specimen with different mixing quality and to evaluate a strength variation in terms of mixing quality such as water cement ratio.

2. MATERIAL AND METHOD

In this study, 100 specimens of cement-mixed kaolin clay with the initial water content of 150% and the cement content of 10% were prepared with different mixing quality. The mix quality was controlled by changing mixing time from 30 s, 45 s, 1 min 2 min and 15 min. The specimen is 5 cm in diameter and 10 cm in high. After curing 7 (50 specimens) and 28 days (50 specimens), a series of unconfined compression test were conducted to measure the mean and standard deviation of unconfined compressive strength.

3. RESULTS AND DISCUSSION

Figure 1 shows the relationship between water cement ratio *W/C* and mixing time for cured specimen 7 and 28 days. It can be seen that *W/C* decreases with increasing mixing time, however *W/C* ranges from 13 to 15, which is not a large variation.

Figure 2 shows the relationship between the coefficient of variation $COV_{W/C}$ of water cement ratio *W/C* and mixing time. It can be seen that $COV_{W/C}$ has linear relationship with mixing time, $COV_{W/C}$ decreases with increasing mixing time, and the coefficient of determination R^2 are 99.6% for 7 days and 53.1 % for 28 days. Therefore, it can be confirmed that mixing quality is higher with increasing mixing time.

Figure 3 shows the relationship between unconfined compressive strength q_u and mixing time. Figures 3 (a) and (b) are for specimens cured for 7 days and 28 days respectively. It can be seen that mean strength increases, while standard deviation SD decreases with increasing mixing time. The relationship between strength q_u and mixing time can be summarized as equations (1) and (2). Equations (1) and (2) are for specimens cured for 7 days and 28 days respectively. It is noted that the coefficients of determination R^2 are 51.5 % for 7 days and 67.8 % for 28 days. It can be suggested that the accuracy of Equations (1) and (2) is not high because the mixing quality is not considered in those equations.

$$q_u = 3.7953 \ln t + 65.803 \ (R^2 = 0.5154) \quad (1)$$

$$q_u = 30.452 \ln t + 98.015 \ (R^2 = 0.6779) \quad (2)$$

where: q_u-Unconfined compressive strength, MPa; *t*-Mixing time, min; R^2-Coefficient of determination.

Figure 4 shows the relationship between the coefficient of variation COV_{q_u} of unconfined compressive strength q_u and mixing time for 7 and 28 days cured specimens. It can be seen that COV_{q_u} decreases with increasing mixing time, since cement-

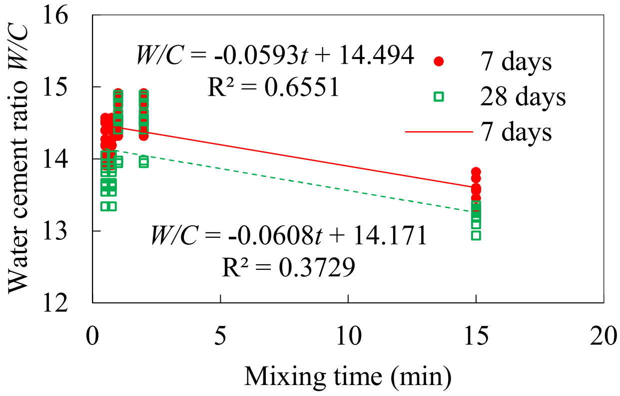

Figure 1. Relationship between water cement ratio and mixing time

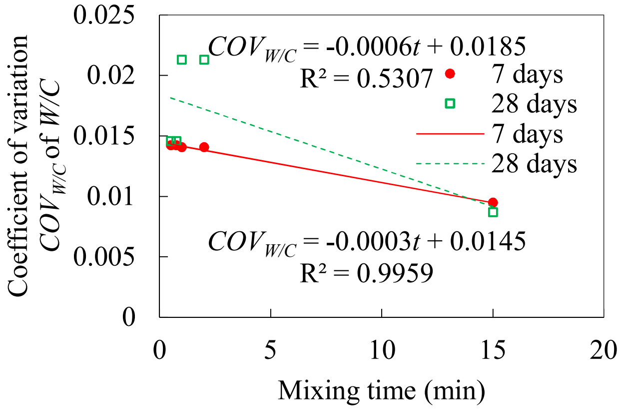

Figure 2. Relationship between the coefficient of variation $COV_{W/C}$ of water cement ratio *W/C* and Mixing time

Keywords: Cement-mixed; Mixing quality; Mixing time; Unconfined compressive strength
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mixed soil become uniform as mixing time increases. Equations (3) and (4) are formulas to estimate COV_{q_u} by mixing time. Equations (3) and (4) are for 7 days and days cured specimens respectively. It is noted that the coefficients of determination R^2 of COV_{q_u} are 25.3 % for 7 days cured specimen and 82.9 % for 28 days cured specimen.

$$COV_{q_u} = 0{,}1971t^{0.142} \ (R^2 = 0.2527) \qquad (3)$$

$$COV_{q_u} = 0{,}1935t^{0.142} \ (R^2 = 0.8289) \qquad (4)$$

where: COV_{q_u}- The coefficient of variation of unconfined compressive strength q_u; t-Mixing time, min; R^2-Coefficient of determination.

Figure 5 shows the relationship between the coefficient of variation COV_{q_u} of unconfined compressive strength q_u and the coefficient of variation $COV_{W/C}$ of water cement ratio W/C. It can be seen that COV_{q_u} of strength relatively increases with $COV_{W/C}$ of W/C.

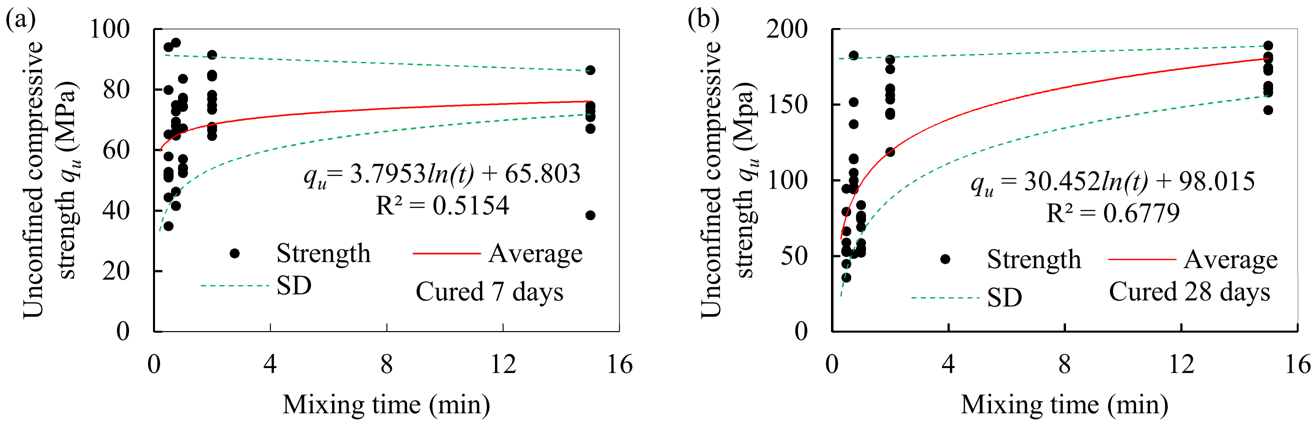

Figure 3. Relationship between unconfined compressive strength q_u and mixing time

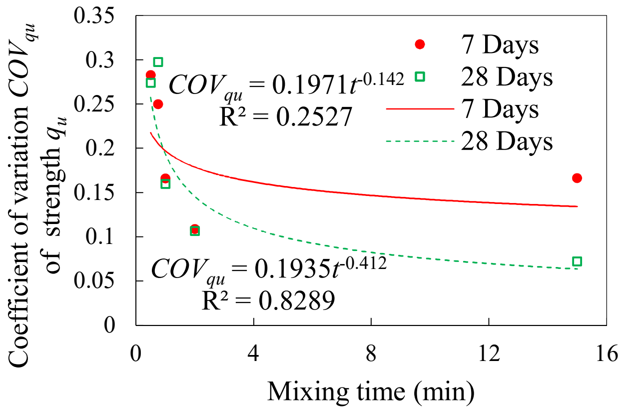

Figure 4. Relationship between the coefficient of variation COV_{q_u} of strength q_u and mixing time

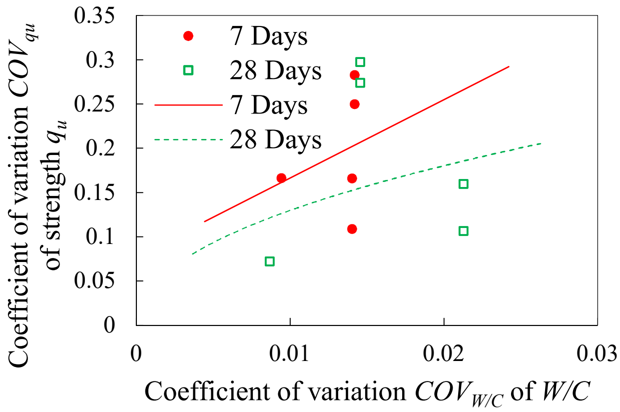

Figure 5. Relationship between the coefficient of variation COV_{q_u} of strength q_u and $COV_{W/C}$ of W/C

4. CONCLUSION

The unconfined compressive strength of cement-mixed kaolin clay has a function of water cement ratio and mixing quality. Namely, the unconfined compressive strength increases with increasing mixing time and decreasing water cement ratio.

In order to evaluate the strength reduction due to the non-uniformity of cement-mixed specimen resulted from the mixing quality, it would be needed to quantify the spatial variability of mixing quality in each specimen such as the average, standard deviation SD, coefficient of variation COV of water cement ratio.

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