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Laboratory study of the effect of temperature on strength and strain-stress curve of lime- stabilized soil

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ABSTRACT

Clay is one of the problematic soils in construction of development projects. It is common to use lime to improve the properties of these kinds of soils. Recently, many studies have been done on the effect of temperature on the strength of lime mortars. In this paper after determining the optimum percent of lime, some samples for uniaxial experiments were prepared. The samples were uniaxially tested in different conditions, i.e. 7 and 28 days in the laboratory environmental conditions, 3 and 7 days in an oven at a temperature of 42ºc, and 7 days in the temperature of 65º c. the experimental results illustrate that temperature greatly influences the curing speed, and the strength of 3-day samples in temperature of 42º c, is approximately equal to that of the 28-day samples in laboratory temperature.
Keywords: *Uniaxial Strength, Clay, Lime, Temperature, Curing period*

INTRODUCTION

In civil projects, it is highly probable that engineers face problematic soils including clay. If removing or replacing these soils with a higher quality soil imposes costs, the inevitable solution will be soil improvement and stabilization. Lime is one of available soil stabilizer improving soils mechanical properties. Mitchell, in 1981, studied required lime (in percent) to enhance fine-grained soils properties [1]. Consoli et al (2010) extensively investigated critical, effective variables of lime mortars' stiffness and strengths [2]. Cebeci et al (1989) studied the effect of temperature and humidity on resistance and shrinkage of cement and cement-lime mortars (Batard mortar) in terms of different lime percentages [3]. Paiva et al (2010) performed some researches on the impact of processing on softness and hardness of lime mortars with different lime percents. According to experiments, it revealed that processing causes decreased capillary, and increased and improved lime mortars' resistance properties [4]. The present research also studies the effect of processing temperature on lime mortars' uniaxial strength.

MATERIALS PROPERTIES

The clay soil with low plasticity property was extracted from a place located in Kerman, Iran, by a speculation device in 0-8 depths. Required experiments to determined soil properties were conducted in various depths and the results will be presented as follows:

Grading and hydrometric tests

Grading and hydrometric tests were performed according to Standard ASTM D422-63 [5] on soil sample. Figure 1 represents the test diagram.

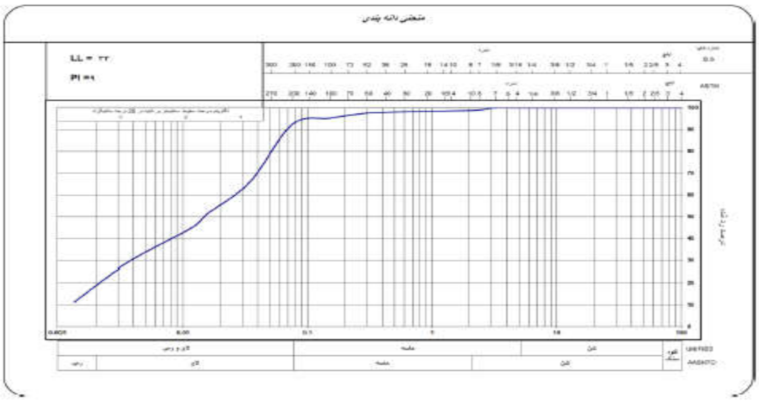

Figure 1. The study soil grading curve

Atterberg limits

Atterberg limits make possible determining the required amount of water to transit soil from one form to another. Atterberg limits test was carried out according to Standards ASTM D 423 [6] and ASTMD 424 [7]. The obtained properties are shown in Table 1.

Determining soil specific weight

Specific weight was measured according to ASTMD 854-02 [8] and the results are represented in Table 1.

Determining typical clay minerals

The type of clay mineral can be relatively determined according to the amount of clay activity in soil [9]. Thus,

$$A = \frac{PI}{\text{clay in percent}} = \frac{8}{17} = 0.47 \qquad 1.$$

Regarding the amount of activity, it concludes that the existed clay is mostly made of Kaolinite.

Determining maximum dry-specific weight and optimal moisture

Improved density test was conducted according to Standard AASHTO T18 [10], and C-standard method was implemented as fine-grain soil. Table 2 represents this test results.

Table 1. Soil summarized properties

Soil type			CL
Clay mineral type			Kaolinite clay
Soil activity	A		0.47
Fluidity limit	LL	%	33
Plasticity limit	PL	%	24
Plasticity index	PI	%	9
Soil specific weight	G_s		2.643
Maximum dry-specific weight	γ_d	kN/m³	19
Optimum moisture	ω	%	15

Table 2. Material optimum moisture and dry-specific weight

Typical	$\gamma_{d\,max}$(kN/m3)	ω_{opt}(%)
8% lime + clay	15.6	22

Lime optimum percent experiments

According to using lime in soil improvement, ASTMD 6276 [11] suggests pH value of combining lime various amounts (in %) with the desired soil is one of critical and determining criteria of soils' stabilization and improvement by lime. According to this regulation, the best lime percent for soil stabilization is the amount of lime with lime mortar pH equals 12.4. Figure 2 shows test results.

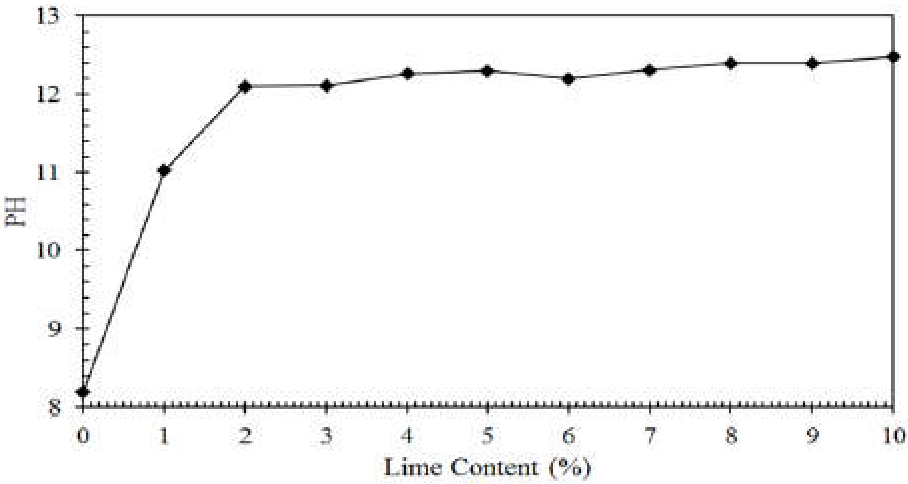

Figure 2. pH value of lime mortars

According to obtained results, 8% of lime is considered as the optimum percent for clay improvement. All samples consisted this amount of lime in uniaxial experiments.

Lime mortar uniaxial experiments

The samples were made based on a cylindrical shape with 70 mm diameter and 140mm height (figure 3). A circular-section hammer with equal diameter was made for samples' uniform density (similar to Marshal hammer, which is similar to protector hammer in term of weight and fall height). Samples were casted in five layers following dry materials were completely combined to water; then, were agglomerated with certain strikes. The sample removed from cast and weighted; then, kept in nylon in order to prevent processing reduced moisture. Finally, the sample transported to processing site.

Figure 3. Samples' cast and hammer

Samples processing

This research uniaxially studied some samples following 7 and 28 days processing in vitro [12]. The samples were kept in nylon at 23 C and environmental humidity of 27%. The other group of samples were kept in nylon once removing from cast; then, were processed at 42 C in an oven for 3-7 days. Remaining samples were processed at 65 C within 7 days.

Uniaxial experiments

ASTM D 5102 [12] presented some criteria for conducting uniaxial experiments on lime mortars. This standard recommends that axial strain not to exceed 5% of sample height. In addition, loading rate is suggested within 0.5-2 mm/min which loading rate here is determined 1 mm/min. It is worth mentioning that 3 samples were made per experiments in similar processing condition; next, mean of 3 responses was measured which is shown in figures 4-7. All samples were produced with optimum humidity and maximum dry matter weight (100 fold density percent).

Uniaxial experiment results

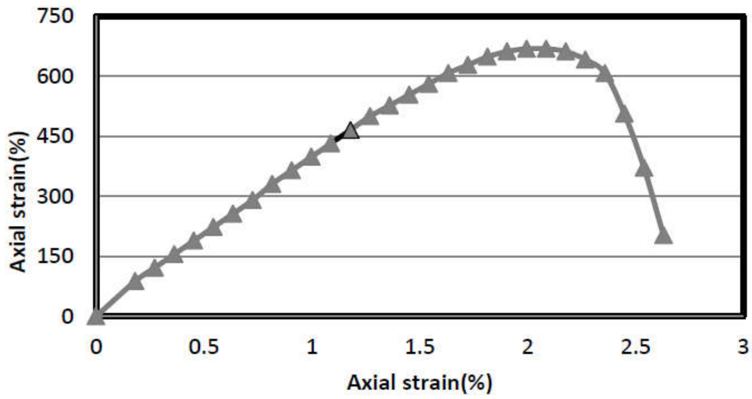

Figure 4. 7-day samples' strain-stress curve at laboratory temperature

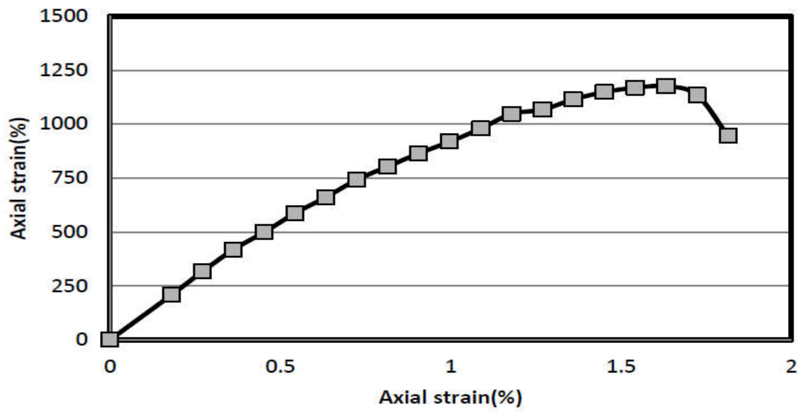

Figure 5. 28-day samples' strain-stress curve at laboratory temperature

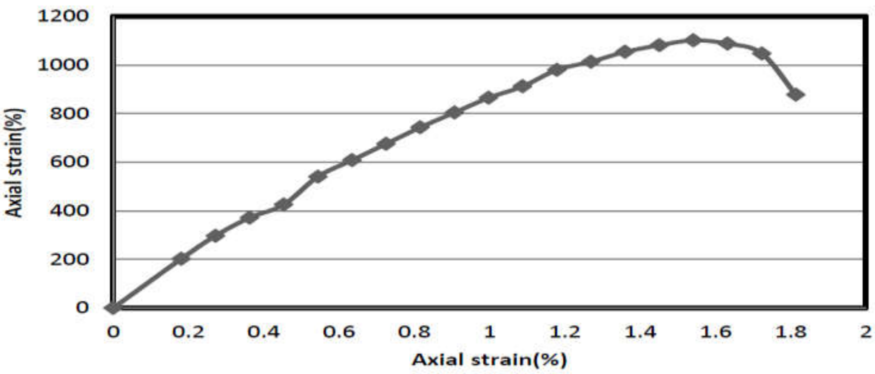

Figure 6. 3-day samples' strain-stress curve at 42° C

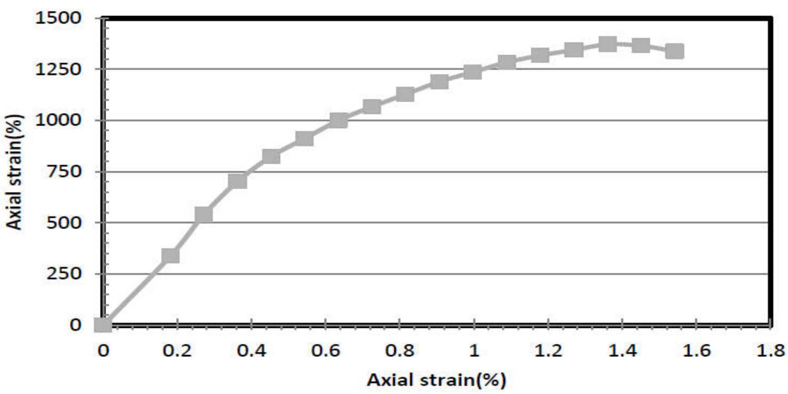

Figure 7. 7-day samples' strain-stress curve at 42° C

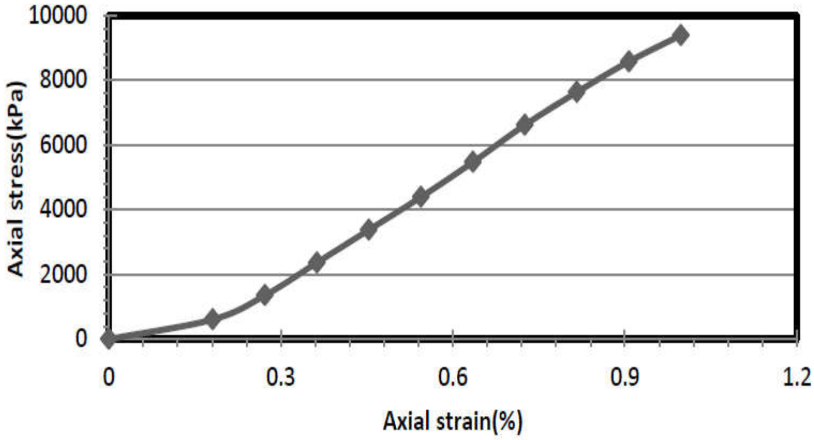

Figure 8. 7-day samples' strain-stress curve at 65°C

Analyzing experimental results

According to Figure 2, which is pH results, it can be stated that in different mixtures of lime with soil, 3% of more chemical reactions of lime percent influence soil. Moreover, it is clear that lime optimal percentage for Kaolinite clay fixation in Kerman equals 8%. Figures 5 and 6 demonstrate that resistance of samples processed for 3 days at 42° C is almost similar to resistance of samples, which were processed for 28 days in vitro temperature (23° C). it is concluded from figures 5 and 7 that resistance of samples processed for 7 days at 42° C is almost 1.2 times more than resistance of samples processed 28 days in vitro (23° C).

Moreover, it is concluded from figures 5 and 8 that resistance of samples processed 7 days at 65°C is 7.5 times of samples processed for 28 days in vitro at 23° C. Strain-stress curves in figures 4-8 reveal that samples' brittleness will strongly increases with increased temperature and longer processing time.

CONCLUSION

1. According curves it is seen that up to 3% lime, soil and lime reaction influence mortar behavior, and optimal lime percent to improve Kaolinite clay in Kerman is 8%.
2. Temperature causes faster processing of lime mortars such that lime mortars' resistance processed three days at 42° C equals to that of samples processed at 23° C for 28 days in vitro.
3. Resistance of samples processed for 7 days at 65° C is almost 7.5 times more than that of samples with 28 days of processing at 23° C.
4. 7-day processed samples at 65° C similarly behave, as stones such that strain-stress curve slope is low at first, then increases.
5. Samples' brittleness increases by increased temperature and higher processing time.

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