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Evaluation of the Lime and Cement Effect on the Mechanical and Physical Characteristics of the Collapsible Soils

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ABSTRACT

The physical properties of most soils change when they are exposed to saturation and increasing water content. One of the most important Problematic Soils is Collapsible Soils. The volume change in these soils is intensified when they become saturated. These phenomena especially in dams and channels that get easily saturated have a great value to be investigated. Hitherto, different methods such as saturating, dynamic compaction, grouting and stabilizing have been presented to reduce the collapsibility in these soils. Due to the existence of great number of such soils in nature and the importance of civil projects, this study tries to present an appropriate method to stabilize the collapsible soils. In addition to using cement and lime to stabilize these soils and studying the effect of using these materials on the instability of the soils, the present method tries to monitor and control physical and mechanical behaviors in different time periods of treatment. The results show that by adding cement and lime to collapsible soil and increasing curing time, the collapsibility phenomenon can be properly controlled. In addition, the unconfined compressive strength was increased and their plasticity index decreases.

KEYWORDS**:** collapsible soil, improving and stabilizing, cement, lime, instability potential, physical and mechanical properties.

INTRODUCTION

In most civil projects such as channels, roads, foundations and dams, the designer encounters a great variety of soils with different technical properties. Many of these soils are not suitable to build. The collapsible soils belong to this type of soils.

Collapsible soils which have dry conditions can tolerate considerable loads, but if the bed of channels, foundations or dams get saturated and overflowed, the structure of the soil breaks down, and then it leads to differential settlement in the structure of the building. There are a great number of such unstable soils in different areas, but few surveys have been conducted to investigate the collapsible soils in comparison with other types of problematic soils, and it is necessary to delve into the properties of these soils. Many methods have been developed to improve collapsible soils including saturating, dynamic compaction, controlling the surface water, using piles, grouting and stabilizing the soils (Marian 1999).

If collapsible soils are not taken into account in designing and constructing the civil structures, the projects may face great failures. Hence, presetting such a method for stabilizing the collapsible soils and investigating the ways to reduce the impact of effective factors on itcan be the some reasons for the importance of this study. In this paper, after detecting the collapsibility of the soil and determining the potential collapsibility, the soil under test will be stabilized for different mixtures of cement and lime during different times curing of the treatment; then, soil properties including the potential collapsibility will be studied in more details.

SOILS USED IN THE TESTS

The soil used in this experiment is a homogenous soil that has been provided from Sivand that is a region located in the north of Shiraz; the soils have been taken from the earth around the Sibuye dam. The experiment conducted on soil revealed that the soil was potentially collapsible. This verified the previous reports which had been already established by the company in charge of designing the dam. Because of considerable amount of passing soil over sieve No.10, only the soils passed the sieve were intended in the experiments and the reminder left over on the sieve were put away.

Results showed that, the soil is fine-grained and has the great mass of finer than #200 sieve. In

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addition, according to the unified classification, its type is CL. Generally, it consists of silty-clay with a low plasticity index, about 10.2.

SAMPLE PREPARATION

In order to obtain the samples, the soil should have specific conditions. In this regard, first, a rubber hammer was used to grinder the soil lumps. The soil was kept in a warm place for 48 hours so that it completely dried. Next, the standard compaction test soil was used. The sample had the optimum moisture content of 17.5% and the maximum dry density of 1.77 gr/cm^3. Finally, the samples were kept inside the bags. Moreover, the temperature was kept constant.

MEASUREMENT OF COLLAPSIBILITY

There are several methods to measure the collapsibility of the soils including:

- Measurement by plate load test in the field
- Measurement by triaxial and consolidation experiments in lab

In this survey, a consolidation device was used to determine the collapsibility of the soil before and after the stabilization. This was done according to the ASTM D5333 standard. In this standard, the one dimentional collapsibility of the soil is measured after saturating. this value was calculated by Eq. 1 for all samples Before and after the stabilization:

$$I_C = \frac{d_f - d_i}{h_0} \times 100 \tag{1}$$

$I_{C:}$ collapse potential of soil in target presser of 200 kPa.
d_f: The displacement gauge readout in the specified stress after water absorption (mm)
d_i: The displacement gauge readout in the specified stress before water absorption (mm)
h_o: The initial sample height (mm)

After calculating the collapsibility of the soil, the collapsibility index classification was performed according to the values shown in Table 1 and thus, the collapsibility degrees of samples were determined.

Table 1. Collapsibility index classification (ASTM D5333)

Degree of collapsibility	Collapsibility index
Non collapsible	0-.1
Low	0.1-2
Intermediate	2-6
Moderately rapid	6-10
Rapid	>10

First, a sample was made from the collapsibility soil with the moisture content a little fewer than the optimum moisture content (that is, w=14.5% and ρ= 1.5 gr/cm^3) and its collapsibility was measured under standard test. In fact, observing the mentioned conditions for samples was intended to facilitate the test and provide a suitable situation for the experiment. Fig. 1 illustrates the diagram of deformation-time for specimen.

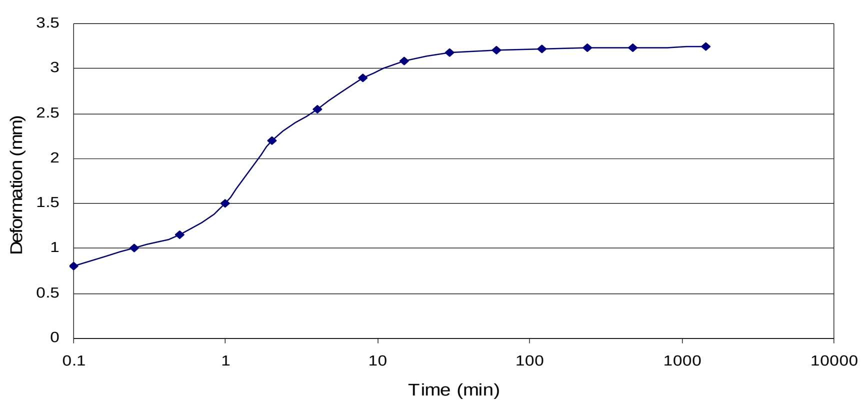

FIG. 1. Diagram of deformation-time for the soil of Sivand region with w=14.5 % and ρ= 1.5 gr/cm^3.

By Fig. 1 and Eq. 1 it can be concluded that collapsibility of the soil in the mentioned conditions is 12.9 and hence, the soil falls into the highly collapsible group.

Regarding the most civil projects such as dams and roads, the soil is compacted in optimum moisture conditions so that it can reach its maximum dry density. The Fig. 2 shows the deformation-time diagram in this condition.

The collapsibility of this sample was 1.1, so the soil in the efficient condition falls into low instability degree soil group.

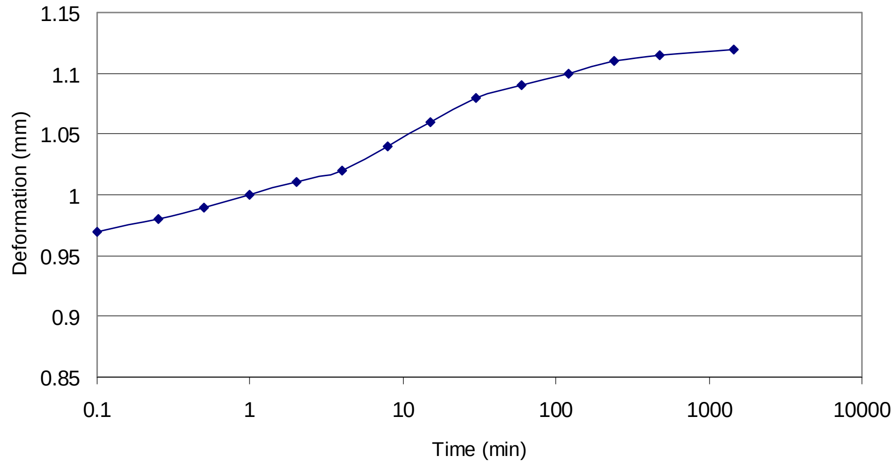

FIG. 2. Diagram of deformation-time for the soils of Sivand region with ρ_{max} and w_{opt}.

Adding chemical materials to the soil can cause reactions such as cation exchange, flocculating-dispersing reaction, hydration reaction and pozzolanic reaction. Eq. 2,shows the general order of the cation exchange in the soil.

$$Na^{+} < K^{+} < Mg^{2+} < Ca^{2+} < Al^{3+} < Fe^{3+} \tag{2}$$

In this series, ions tend to replace the ones in the left side. The cation exchange inside the soils begins after adding sufficient chemical materials to it. In the chemical materials used in this research, such as lime and cement, calcium ion (Ca^{2+}) and in the pozzolan, aluminum ion (Al^{3+}) replace other ions (Anand et al 2004).

If all the exchangeable action has been already replaced with aluminum and calcium ions, the ion exchange inside the soil completely stops or is limited largely.

The clay grains were flocculated by the flocculating reactions and became larger and changed the structure of the soil greatly. Based on previous research, the flocculating reactions are caused by the increase of the electrolyze power of the water penetrated in the soil. Moreover, the production of the hydrated aluminates calcium has a significant effect on the spark of flocculating reactions.

The exothermic reactions in which quicklime and cement are mixed with water are called hydration in which the solid components in the cement react with water that results in the production of silicate calcium hydrate, hydrate calcium alumina and hydrate lime. This reaction is performed in short time treatment and reduced the moisture content of the mixture. The released calcium ions in cement and quicklime hydration cause the ion-exchange reactions to begin (Petry and Das 2001).

The reaction that involve lime, water, silica and alumina can produce different types of cohesive jells called pozzolanic reactions. The mentioned materials that contain silica and alumina can be produced when stabilizer materials are added. Also, the soils containing the clay minerals include these components.

RESULTS AND DISCUSSION

The results were obtained by using the collapsibility potential determination test for the cement-lime stabilized samples. Fig. 3 and Fig. 4 illustrate the results of the collapsibility potential test on the stabilized samples with cements of 1.5% and 3% for different ingredients values of lime during different treatment times.

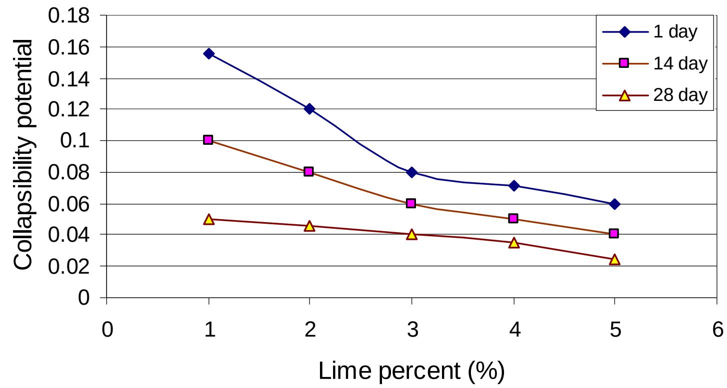

FIG. 3. Diagram of the lime effect on the collapsibility potential of the stabilized samples with constant amount of cement 1.5% for different treatment times with ρ_{dmax} and w_{opt}.

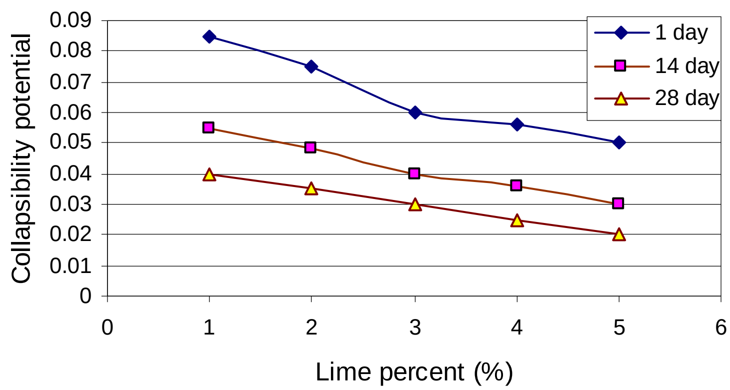

FIG. 4. Diagram of the lime effect on the collapsibility potential of the stabilized samples with constant amount of cement 3% for different treatment times with ρ_{dmax} and w_{opt}.

The results revealed the significant effect of the cement-lime mixture on limiting the collapsibility phenomenon. For instance, except in the case that there was a mixture of 1.5% of cement and 1% of lime in treatment times of 1 and 14 days, in all other cases the collapsibility phenomenon has been controlled desirably; However, these diagrams indicate that after 28 days the reduction of collapsibility potential continues at a slower rate. In addition, for the stabilized samples with 3% and 5% of lime and different amounts of cements during all treatment times, the reduction of collapsibility potential followed a similar pattern.

The effect of cement and lime on the Atterberg limits of the collapsible soil was investigated. The importance of Atterberg limits in determining the behavior and properties of the soil justifies the relevant studies done in this paper.

In several surveys, it has been pointed out that although the liquid limit in soils containing the kaolinite and elite minerals decreases when chemical materials are added to the soil, liquid limit increases with treatment time. Moreover, it is noted that ion-exchange reactions are the most profound factor in decreasing the plastic properties of the fine-grained soils (Shrwood 1996).

Fig. 5 and Fig. 6 show the changes of plasticity index in the samples stabilized by cements of 1.5% and 3% for different ingredients values of lime during different time treatments.

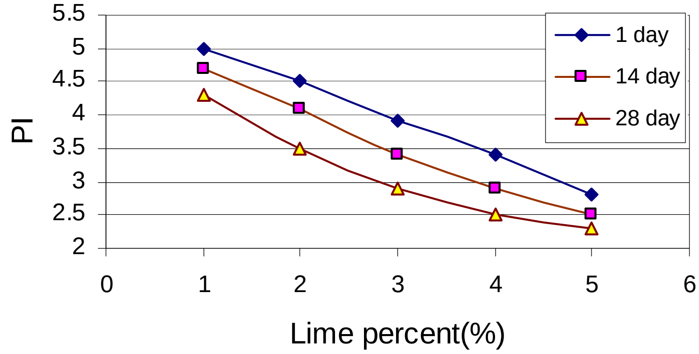

FIG. 5.Diagram of the lime effect on the plasticity index n the samples stabilized with constant amount of cement 1.5% for different curing times

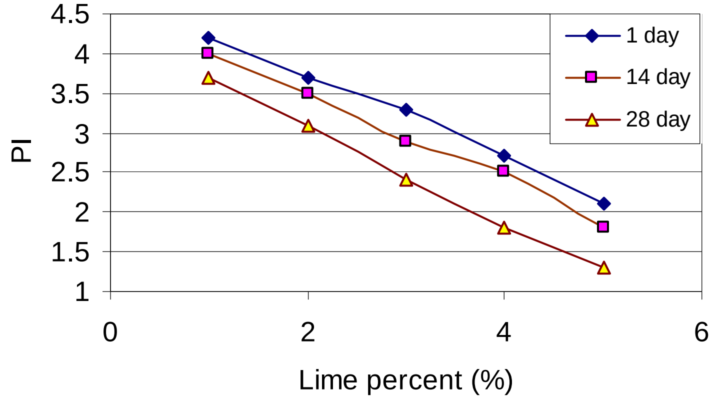

FIG. 6.Diagram of the lime effect on the plasticity index in the samples stabilized with constant amount of cement 3% for different curing times

Although the plasticity index is reduced as curing time increases, the results testify that there is only a weak correlation between plasticity index and time.

The effect of cement and lime on the unconfined compressive strength of the collapsible soil is investigated. Fig. 7 and Fig. 8 show the unconfined compressive strength of the stabilized samples with 1.5% and 3% of cement and different amounts of lime in different curing time.

The unconfined compressive shear strength of the stabilized samples increases with treatment time. Moreover, comparing Fig. 7 and 8, it can be concluded that, the cement has more influential effect than the lime. In fixed percentage of cement (e.g. 1.5%) and at the end of 1 day curing, by increasing lime percentage from 1 to 5 percent, the unconfined compressive strength increases about 250 kPa. While in fixed percentage of lime (e.g. 2%) and at the end of 1 day curing, by increasing cement percentage from 1.5 to 3 percent, the unconfined compressive strength increases about 400 kPa.

The diagrams of the unconfined compressive shear strength indicate that most of changes of this value occur in thefirst 14 days after correction.

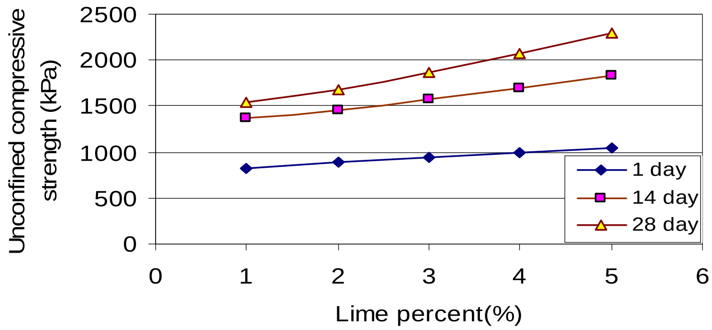

FIG. 7.Diagram of the lime effect on the unconfined compressive strength in the samples stabilized with constant amount of cement 1.5% for different curing times with ρ_{dmax} and w_{opt}.

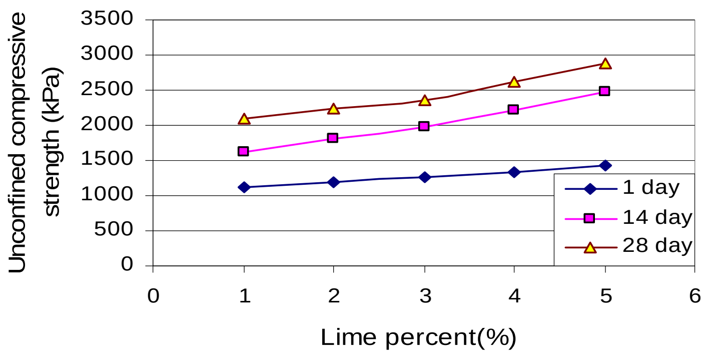

FIG. 8. Diagram of the lime effect on the unconfined compressive strength in the samples stabilized with constant amount of cement 3% for different curing times with ρ_{dmax} and w_{opt}.

CONCLUSIONS

- The cement-lime mixture has a great effect on controlling the collapsibility phenomenon.
- In our experiment, almost all the cases resulted in an acceptable controllability of the instability phenomenon except in the case of 1.5% cement and 1% lime mixture within 1 and 14 days of treatment.
- Stabilized samples with cement and lime with more curing time can cause higher liquid limit, and lower the plasticity index came down.
- By increasing the amount of cement and lime, and curing time, the unconfined compressive strength of stabilized samples increases.

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