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Studying collapse potential of gypseous soil treated by grouting

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Abstract

Gypseous soil is a collapsible soil, which causes large deformations in the buildings which are constructed on it. Therefore, several methods have been used to minimize this effect, such as replacing the gypseous soil or stabilizing it (grouting or soil improvement).

This study presents the results of tests carried out on four types of gypseous soil with different properties and various gypsum contents. The testing was conducted on undisturbed samples to evaluate the compressibility of the gypseous soil under different conditions. The samples were grouted with acrylate liquid. The treated samples showed that the acrylate liquid was able to reduce the compressibility of the gypseous soil by more than 60–70%. This is attributed to the acrylate liquid film coating the gypsum particles, and thus, isolating them from being subjected to the effect of water. The treated gypseous samples exhibited a low collapse potential in which the acrylate liquid reduced the collapsibility of the gypseous soil by more than 50–60%. The acrylate liquid affected the shear strength parameters of the gypseous soil by increasing the cohesion and decreasing the angle of internal friction.

For unsoaked samples, it was observed that the cohesion increased and the angle of internal friction relatively decreased. This behaviour may be attributed to the cohesion effect, caused by the presence of the acrylate liquid, and because contact between particles was prevented which caused a reduction in friction. As long as the specimens were saturated, the strength of the sand appeared to increase at the same rate as for an increase in total stress. Once the sand became unsaturated, the rate of increase in strength decreased, and in fact, the strength decreased when the suction was increased beyond some limiting value.

Keywords: Collapse; Gypseous soil; Grouting; Soaking

1. Introduction

Many soils can prove problematic in geotechnical engineering, because they expand, collapse, disperse, undergo excessive settlement, have a distinct lack of strength or are soluble. Such characteristics may be attributable to their composition, the nature of their pore fluids, their mineralogy or their fabric (Briscoll and Chown, 2001).

There are many types of problematic soils, some of the most noteworthy being swelling clay, dispersive soils, and collapsible soils that will be discussed subsequently. The present study focuses mainly on collapsible soils.

Collapsible soils are unsaturated soils which present the potential for large deformations and a complete change to the whole particle structure after wetting, with or without loading. These soils are characterized by loose structures composed of silt to fine-sand-size particles. Collapsible soils are deposited in arid and semi-arid regions. Due to the expansion of human

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activities, these regions are being aggressively occupied. This is leading to the use of large quantities of water, which creates favorable conditions for soil collapses. These soil failures lead to severe damage and large distress to man-made structures. Abbeche et al. (2010) made an experimental study to illustrate that the mechanical resistance of collapsible soils can be improved. The study demonstrated that it is possible to minimize the collapse potential, C_p, to an acceptable level after chemically treating the soils with salts (ammonium sulfates $(NH_4)_2SO_4$ and potassium chlorides KC1) at different concentrations (i.e., 0.5, 1.0, 1.5, and 2.0 mol/l) and under different compaction energies. The method used in their study was based on oedometric tests with variable levels of normal stress.

To overcome collapse problems, Mohamed and El-Gamalin (2012) used sulfur cement as a treatment method and evaluated the microstructure, the mineralogical composition, and the physical, thermal, mechanical, hydraulic, and chemical properties of specimens. After treatment, the specimens were tested for their compressive strength. The results indicated that the strength of the treated soil was about three times higher than that stabilized by normal Portland cement.

2. Gypseous collapsible soil

Gypseous soil is found in arid and semi-arid regions on gypseous rocks and sediments of different origins. There are different origins and different definitions for gypseous soil, among which is the definition by Barazanji (1973), who divided gypseous soil into sub-groups, namely, soil containing more than 50% gypsum and soil containing less than 50% gypsum. For soil containing more than 50% gypsum, the textures of non-gypsiferous materials are used as adjectives, such as loamy gypsiferous materials. For soil containing less than 50% gypsum, five subdivisions are proposed according to the percentage of gypsum, as shown in Table 1.

The presence of gypsum in soil represents one of most complex engineering problems due to its detrimental behaviour, especially when accompanied by environmental changes in moisture content (Nashat, 1990). The leaching of gypsum from soil changes the physical–chemical and the mechanical properties of the soil with the development of large settlement (Mikheev et al., 1973).

Several methods have been used to minimize the collapse potential of gypseous soil, such as replacing the gypseous soil or stabilizing it (grouting or soil improvement). For grouting, several materials have been used, such as cement, bentonite, asphalt emulsion, and sodium silicate. Grouting is one of several methods used to improve the strength of soil. The main function of the grout is to provide a cohesive bond between soil particles and to provide a waterproofing coat around the gypseous soil particles. The success of the grouting material depends on several factors among which are grouting pressure, soil properties, grout type, viscosity, temperature, and time. The grouting of soil with these materials may be recognized as a solution for some gypseous soil at various depths in situ; the grouting acts as a binder and provides stability to the soil mass and isolates the soil particles from being in contact with water (Mori et al., 1989).

Table 1
Classification of gypseous soil (after Barazanji, 1973).

Gypsum content (%)	*Classification*
0.0–0.3	*Non-gypsiferous*
0.3–3.0	*Very slightly gypsiferous*
3.0–10	*Slightly gypsiferous*
10–25	*Moderately gypsiferous*
25–50	*Highly gypsiferous*

The objective of the present study is to investigate the collapsibility and the strength of gypseous soil treated by grouting with acrylate liquid.

3. Experimental work

This study was carried out on four types of gypseous soil which have different properties and various gypsum contents. The work considered in this study can be divided into two main categories. The first includes identification and conventional tests, while the second includes model tests. The testing was carried out on undisturbed samples to evaluate the compressibility of gypseous soil under different conditions. The soil samples were taken from different sites in Iraq, namely, the areas of Kerbala City and al-Najaf City west of Baghdad.

A detailed laboratory testing program was planned for the samples from four sites. The program included two major series of tests in addition to the classification tests.

3.1. Classification tests

I. Physical tests: grain size analysis, specific gravity, consistency limits (liquid and plastic limits). The grain size distribution of the gypseous soil was determined by a dry sieve analysis, which was conducted according to B.S. 1377 (1990), Test No. 7 B (Head, 2006).

   The grain size distribution of all the soil samples tested is shown in Fig. 1.

II. Chemical analysis: gypsum content (Gc), total soluble salts (T.S.S.), sulphate content (SO_3), and pH value.

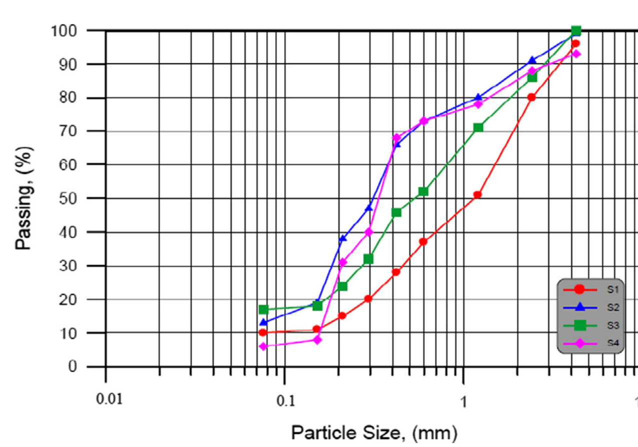

Fig. 1. Grain size distribution of all soils.