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Impact of soaking–drying cycles on gypsum sand roadbed soil

Sabah Said Razouki [a,*], Bushra M. Salem [b]

[a] Nahrain University, Baghdad, Iraq
[b] Columbus State Community College, OH, USA

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ABSTRACT

A thorough laboratory investigation is carried out to study the effects on strength and deformation of cyclic soaking and drying tests on gypsum rich sand used for the construction of roadbeds. The changes in the properties were assessed by the use of California Bearing Ratio (CBR) tests. Each cycle consisted of 90 days of soaking followed by 90 days of drying at room temperature giving a cycle length of 180 days.

The soil tested was poorly graded sand with gravel, (SP) soil according to the Unified Soil Classification System and A-1-b soil according to American Association of State Highway and Transportation Officials (AASHTO) Soil Classification System. It had a gypsum content of about 39%.

Eleven pairs of CBR samples were prepared at the optimum moisture content and at 95% of the maximum dry density for modified AASHTO compaction, and subjected to a surcharge load of 45 lb (200 N) during soaking and drying. The CBR load penetration test was carried out at the end of each soaking and each drying phase of each cycle of the five cycles studied.

The paper reveals that the CBR increased during drying and decreased during soaking. The CBR value decreased with increasing number of cycles reaching equilibrium at the end of the fifth cycle indicating that the soaked equilibrium CBR is about 83% of that for the commonly used four days soaking. During the first soaking phase, the soil swelled for the first three days and then underwent settlement that continued at a slower rate during the next drying phase. Thereafter, swelling during soaking and settlement during drying took place for the second and third cycle but led to an equilibrium condition after the third cycle.

Introduction

The widespread use of gypsiferous sands as roadbed soils and as embankment fill in the Middle East, especially, Iraq (Razouki et al., 2008, 2011; Razouki and El-Janabi, 1999; Tomlinson and Boorman, 1996; Fookes, 1978) necessitated research into gypsiferous soils. Recent research on gypsum sand has focused attention on the development of experimental techniques to provide more accurate characterization of such compacted soils as construction materials (Razouki et al., 2008, 2011). However, geotechnical engineers should be aware of the importance of saturation state in governing the strength and deformation properties of compacted gypsiferous fills and gypsiferous roadbed soils both immediately after construction as well as during its service life.

The important effect of moisture content on both the strength and stiffness of gypsum-rich roadbed soil was reported by Razouki and Al-Azawi (2003). Their laboratory tests were carried out on well graded sand with silt

* Corresponding author.
E-mail address: nspsf2004@yahoo.com (S.S. Razouki).

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Notation

AASHTO	American Association of State Highway and Transportation Officials	CBR_t	California bearing ratio at any time t
ASTM	American Society for Testing and Materials	CBR_{un}	California bearing ratio for unsoaked condition
CBR	California bearing ratio	M_R	Resilient modulus

(SW-SM), according to ASTM D2487-93, having a gypsum content of about 34%.

Razouki and Al-Azawi (2003) pointed out that the laboratory long-term soaking tests for CBR soil specimens revealed a marked drop in both CBR and M_R (resilient modulus) with soaking period. This decrease in strength and stiffness took place at a high rate within the first week and at a decreased rate thereafter so that the soil strength and stiffness became almost constant after about six months of continuous soaking in fresh water.

In addition, the tests revealed that the soil swelled initially then it started to settle and the settlement process continued at a slow rate even after 180 days soaking.

Unfortunately, the majority of previous studies on gypsiferous soils (Razouki and El-Janabi, 1999; Razouki and Kuttah, 2004a, 2006) were concerned with continuous soaking without drying cycles. However, roadbed soils in both cut and fill sections of roads are subject to changing environmental conditions during their service life. Such seasonal variations are reflected primarily by moisture content and temperature changes. Accordingly, in this study, samples are to be subjected to cyclic soaking and drying.

This research is a part of a wider research aiming at a thorough understanding of the behavior of gypsiferous soils of wide occurrence in the Middle East especially Iraq, where the routes of various transportation systems pass through gypsiferous terrains.

In addition, this paper aims at focusing attention on the evaluation of moisture sensitivity, risk of settlement, the proper CBR-value for pavement design and the need for introducing special specifications for such soils.

The test methodology of this research program can be summarized as follows:

From a region in Iraq with gypsum rich sand, sufficient amount of the soil is to be obtained for testing in the laboratory. For studying the strength and deformation behavior of this gypsum rich roadbed sand in the laboratory, the CBR (California Bearing Ratio) test was adopted. To study the effect of cyclic soaking and drying, a cycle length of 180 days was considered suitable for a Ph.D. research for about 2–3 years. Such a cycle length will allow sufficient cycles to be obtained for the study within the available research period.

Although the CBR method is not a mechanistic method to estimate strength/stiffness characteristics of soils, but it has local/regional importance as reported by Razouki and Salem (2014), Razouki et al. (2014, 2008), Razouki and Kuttah (2006) and Huang (2003). The CBR soil specimen is sufficiently large to represent the gypsum-rich sand of this study. In addition, the repeated load triaxial testing machine for soil stiffness, which is both expensive and complex, was not available at the University of Technology in Baghdad at the time of this study. Therefore, the CBR testing method was considered suitable especially for Iraq and all developing countries of the Middle East.

Properties of soil tested

The soil under study is a gypsum sand obtained from a region near Baghdad, Iraq. In accordance with the Earth Manual of US Department of Interior (1980), the total soluble salt (TSS) content in the soil tested was determined as 42.6% at a soil:water ratio of 1:300. The gypsum content in the soil tested was 38.8% according to BSI (1990). Thus, the gypsum content is about 91% of TSS indicating that nearly all of the total soluble salts in the soil tested are mainly gypsum.

In addition, X-ray diffraction analysis was carried out on the soil tested indicating that the components of the soil under study are quartz, gypsum, calcite, dolomite and feldspar.

The particle size distribution for the soil tested, according to AASHTO (1993), was determined by Razouki and Salem (2014) indicating that the percentage passing no. 200 sieve is 3.65%. The liquid limit of the soil could not be determined and the soil is accordingly non-plastic. Using the British Standard density bottle method (BSI, 1990), with white spirit instead of water, the specific gravity of the gypsum sand studied was 2.47.

According to the Unified Soil Classification System (ASTM, 1993, D 2487-93), the soil tested was found to be poorly graded sand with gravel (SP) and according to American Association of State Highway and Transportation Officials (AASHTO, 1986) soil classification system, the soil belongs to A-1-b soil group.

The compaction curve of the soil, for each of standard and modified AASHTO compaction test (AASHTO, 1986), was obtained using six pairs of soil samples as shown in Fig. 1. Note that the maximum dry unit weight of the modified AASHTO compaction was 18.27 kN/m^3 taking place at the optimum moisture content of 10.8%.

It is necessary to note that regarding the moisture content determination, Horta (1989) reported that soil specimens containing gypsum should be dried to a constant weight at a temperature lower than 60 °C and preferably 40 °C. Razouki et al. (2008) recommended strongly this method of Horta (1989) and, therefore, it was adopted in this work.

Preparation and testing of soil samples

To study the effect of changing environmental conditions on the strength and deformation characteristics of gypsum sand subgrade soil, 11 pairs of California Bearing